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FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 5 - VOLUME 2 - APPENDICES D THROUGH G ****DRAFT FINAL**** - MARCH 1995

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FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 5

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 2

Appendices D through G

MARCH 1995

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

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Appendix D

APPENDIX D

SOIL WASHING TREATABILITY STUDY

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LIST OF ACRONYMS AND ABBREVIATIONS

ASL	analytical support level
ASTM	American Society for Testing and Materials
BrPADAP	2-(5-bromo-2-pyridylazo)-5-diethylaminophenol
$Ca(OH)_2$	calcium hydroxide
CBD	sodium citrate/bicarbonate/dithionite
CDR	conceptual design report
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	contract laboratory program
cm	centimeter
COC	constituents of concern
CRU5	CERCLA/RCRA Unit 5
DECO	Denver Equipment Company
EDTA	ethylene diamine triacetic acid
EPA	United States Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FRP	fiberglass reinforced plastic
FS	feasibility study
g	gravity
g	gram
H_2O	water
H_2SO_4	sulfuric acid
H_3PO_4	phosphoric acid
HNO_3	nitric acid
HPLC	high performance liquid chromatography
HSL	hazardous substances list
IC	ion chromatography
in.	inch
ISA	initial screening of alternatives
ISP	interim stabilization project
IT	International Technology Corporation
kg	kilogram
LESAT	Lockheed Environmental Systems and Technology
M	molar
meq	milliequivalents
mg	milligram
MgO	magnesium oxide
mL	milliliter
mm	millimeter
mM	millimolar
N	normal
Na_2CO_3	sodium carbonate
$Na_4P_2O_1$	sodium pyrophosphate
$NaHCO_3$	sodium bicarbonate

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

$(NH_4)_2CO_3$	ammonium carbonate
$(NH_4)HCO_3$	ammonium bicarbonate
NaOH	sodium hydroxide
nm	nanometers
NSI	IT proprietary chemical extractant
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
pCi	picocurie
PCP	pentachlorophenols
PFD	process flow diagram
PS	process stream
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
ROD	record of decision
rpm	revolutions per minute
SD	standard deviation
SVOCs	semivolatile organic compounds
TCE	trichloroethylene
TCLP	toxicity characteristic leaching procedure
THC	Toronto Harbor Commissioners
tph	tons per hour
TSWP	Treatability Study Work Plan
USDA	United States Department of Agriculture
USID	Uranium in Soils Integration Demonstration
VOCs	volatile organic compounds
WSTC	Westinghouse Science and Technology Center
WSWP	Westinghouse Soil Washing Process
μm	micrometer

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D.1.0 INTRODUCTION

D.1.1 PURPOSE OF THE SOIL WASHING TREATABILITY STUDY

Soil washing was identified as a viable treatment process option for remediating soil at the FEMP Environmental Management Project (FEMP). Little information relative to the specific application and potential effectiveness of the soil washing process exists that applies to the types of soil at the FEMP. To properly evaluate this process option in conjunction with the ongoing FEMP Remedial Investigation/Feasibility Study (RI/FS), a treatability testing program was necessary to provide a foundation for a detailed technical evaluation of the viability of the process. In August 1991, efforts were initiated to develop a work plan and experimental design for investigating the effectiveness of soil washing on FEMP soil. In August 1992, the final Treatability Study Work Plan for Operable Unit 5: Soil Washing (DOE 1992) was issued. This document shall be referenced throughout the remainder of this report as the Treatability Study Work Plan (TSWP).

The purpose of this treatability study was to generate data to support initial screening and the detailed analysis of alternatives for the Operable Unit 5 FS. All units of measure are presented in a modernized metric system, the Systéme International d'Unités or SI. Based on characterization data (see Section D.1.2), relatively large quantities of FEMP surface and subsurface soils contain above-background concentrations of radioactive constituents. To a lesser degree, nonradioactive contaminants may exist in conjunction with the radioactive contaminants. To address the cases where these contaminants are present at levels exceeding preestablished preliminary risk-based action levels, a number of process options, including soil washing, were considered. This process option review and evaluation process is described in the Operable Unit 5 Initial Screening of Alternatives (ISA) (DOE 1993). After careful review of these process options, soil washing was selected as a promising technology warranting more rigorous technical consideration through the conduct of site-specific treatability studies. A primary consideration was to integrate the soil washing treatability technology being evaluated in this study with other similar technology evaluations being conducted for the remediation of Operable Unit 5 soil.

The TSWP outlines the objectives, procedures, and techniques for conducting screening of soil washing processes and conditions. Work objectives were defined in the TSWP in the context of FS considerations as follows:

- Proof of principle for the soil washing technology's applicability to the FEMP soil
- Compliance of process option with applicable or relevant and appropriate requirements
- Projected mass and leachability data to support fate and transport modeling

- Residual concentrations of contaminants in the process streams

- Development of a pre-design process flow diagram and preliminary mass balance for a production-scale soil washing facility to facilitate detailed technical analysis and establishment of a sound basis for cost estimation

- Projected chemical, radiological, and physical characteristics of aqueous and solid process streams.

Soil washing, if successful, produces large volumes of remediated soil which potentially can be returned to the site from which it was excavated while significantly reducing the final volume of material requiring greater confinement and disposal. The success of the process option will be assessed based on the final volume of treated soil and the level to which specific contaminants are removed. This volume reduction level will account for all processed soil, spent washing solutions, extracting chemicals, and the residues retaining significant levels of contaminants. Residues from this process may require selective treatment (e.g., vitrification or stabilization), storage, and/or disposal practices. In essence, the final volume of material requiring selective treatment, storage, and/or disposal practices must be significantly less than the initial volume of contaminated soil.

D.1.1.1 Initial Screening of Alternatives

An initial phase of the FS involves the development and screening of remediation alternatives, otherwise known as the ISA. Three of the primary steps in the ISA for Operable Unit 5 (DOE 1993) are (1) identifying and screening the technologies applicable to each general response action to eliminate those that cannot be technically implemented at the site; (2) identifying and evaluating technology process options on the basis of effectiveness, implementability, and relative cost to select a representative process for each technology type retained for further consideration; and (3) assembling the selected representative technologies into alternatives representing a range of treatment and containment combinations as appropriate.

The first step is identifying and screening the technologies applicable to each general response action. The general response action pertinent to treatability testing is the treatment response action. This includes physical, chemical, and biological measures which reduce the toxicity, mobility, or volume of a contaminant or waste by altering the physical or chemical properties of the contaminant and/or media. The treatment process options identified and evaluated relative to effectiveness, implementability, and cost include biological, physical, physicochemical, solidification/stabilization, and thermal measures.

Assembling and selecting representative technologies into alternatives representing a range of treatment and containment combinations were presented in Section 4.0 of the ISA for Operable

Unit 5. The following were the only technologies retained for further evaluation for each of the five treatment process options noted above:

- Biological - soil aeration
- Physical - soil vapor extraction
- Physicochemical - soil washing
- Solidification/stabilization
  - Cement-based/pozzolanic-based fixation
  - Microencapsulation
  - Batch vitrification/glassification
  - In situ vitrification
- Thermal - plasma centrifugal furnace.

The technologies for each treatment process option were then further evaluated in Section 5.0 of the ISA for Operable Unit 5, rating each according to: (1) effectiveness, (2) implementability, (3) capital cost, and (4) operation and maintenance cost. Three of the eight technologies (microencapsulation, in situ vitrification, and plasma centrifugal furnace) were not retained for further consideration. Soil aeration and soil vapor extraction were retained as a support option for limited soil areas. Two of the remaining three technologies (batch vitrification/glassification and cement-based/pozzolanic-based fixation) were already being evaluated under existing treatability studies for other operable units. Soil washing, considered a potentially viable option with high implementability, was selected for further evaluation.

D.1.1.2 Soil Washing Description

Soil washing (generally referred to as soil decontamination) is an ex situ water-based treatment process that separates chemical contaminants from the soil matrix using a combination of physical and chemical treatments. The treatment technique basically mobilizes the contaminants physically by mass action, or chemically by complexing, chelating, reducing, oxidizing, or ion exchange mechanisms. Techniques like those used in solution mining and mineral extraction have been used in soil washing operations for the removal of contaminants from soil. The basis for this type of process is particle separation by size and/or density characteristics. Chemically amended aqueous solutions can then accelerate contaminant dissolution kinetics from individual soil size fractions.

There is a fundamental basis to soil that makes physical separation an important tool within the soil washing technology. Soil consists of organic and inorganic components. Organic components include vegetation (roots and shoots) and organic matter (partially decomposed vegetative material). Inorganic components consist of primary and secondary minerals. Particle-size separation is primarily

directed at these mineral categories. The categories for coarse fragments (greater than 2 millimeters [mm] in diameter) and soil separates (individual-size groups of mineral particles less than 2 mm in diameter) have been defined by the U.S. Department of Agriculture (USDA), Soil Conservation Service. Soil separates include clay (less than 0.002 mm), silt (0.002 - 0.05 mm), and five categories of sand (ranging between 0.05 - 2 mm). Coarse fragments include gravel (2mm - 3 inches) cobbles (3 - 10 inches), and stones (greater than 10 inches). There may also be materials within the soil, both natural and anthropogenic, that fall into the fragment categories that are termed debris.

Physical separation techniques have been the focal point of most soil washing processes and serve two objectives. The initial objective is to reduce soil aggregates to single-grain composition of clay, silt, sand, and gravel. This reduction is accomplished by either mechanical means (e.g., high pressure water or mixers) and/or chemical dispersing agents (e.g., sodium salts). This initial step in the operation is the basis for separating the coarse-size fraction of the soil (e.g., sand and gravel) from the finer particles of soil (e.g., silt and clay). The second objective of physical separation techniques is to dislodge chemical contaminants from the surface of soil particles by force and/or abrasive processes. High-pressure water washers (hydraulic shearing) and attrition scrubbers are two types of equipment to aid in these physical separation processes. Physical separation operations in soil washing may also include screening, centrifugation, froth flotation, hydrogravimetric separation (including hydrocyclones, mineral jigs, and spiral classifiers), and multigravity separation.

The concept of using these types of volume reduction processes for contaminated soil via physical separation techniques is based on the premise that the soil is primarily comprised of coarse particles and that most organic and inorganic contaminants tend to bind primarily to clay particles and, to some lesser degree, fine silt particles (see Section D.1.2). However, there are soil/chemical matrices in which the chemical contaminants are associated with coarse silt and sand as well as the fine silt and clay. In these matrices, simple water-based physical separation processes will not remove contaminants from any size fraction to an acceptable level and combination of physical separation and chemical extraction processes may be needed. This type of system would consist of first separating the soil into discrete-size fractions and then removing the chemical contaminants from each size fraction via physicochemical processes.

Although selected chemicals can be included in the physical separation part of the system, a separate part of the system may need to include a chemical extraction process. Chemical reagents (especially sodium salts) which can be employed in the physical separation part of the system to break down soil aggregates into discrete soil particles may also function as extraction reagents, removing chemical contaminants from the surface of individual soil particles. However, more aggressive conditions (e.g., type of chemicals, chemical concentration, extraction temperature, and reaction time) may need

to be incorporated into the chemical extraction part of the soil washing process to effectively remove contaminants from individual soil particles.

Water-soluble chemicals (e.g., surfactants, chelators, acids, and bases) can be used in specifically designed reactor vessels as part of the chemical extraction process. Water washing with extractive agents includes basic aqueous solutions (caustic, lime, slaked lime, or industrial alkali-based washing compounds); acidic aqueous solutions (sulfuric, hydrochloric, nitric, phosphoric, or carbonic acids); or solutions with surfactant or chelating agents. Hydrogen peroxide, sodium hypochlorite, and other strong oxidizing agents can chemically change the contaminants and enhance their removal from soil. The removal of organics from soil can be enhanced by strong basic or surfactant solutions, while the extraction of metals is best facilitated by chelating agents or strongly acid solutions.

Soil process streams resulting from the above-described physicochemical soil washing system must be analyzed to determine the residual level of selected contaminants. Based on the amount of contaminants still remaining in each soil process stream, the soil is either released as final treated soil or recycled back through the soil washing system. The remaining residue and the part of the soil not effectively treated are collected, containerized, and stored for disposal or subsequent treatment (e.g., vitrification, solidification, stabilization, etc.).

A final operation in the soil washing system is the regeneration of the spent washing solution. In many operations, the amount of spent wash water generated during the soil washing operation may equal anywhere from three to ten times the initial volume of soil being processed through the system. To prevent the system from generating more waste than the initial volume of contaminated soil, regeneration of spent wash water is mandatory. Although innovative technologies for treatment of spent wash solutions exist (e.g., electromagnetic and biphasic separation), two primary processes for wastewater treatment are ion exchange and precipitation. The resin or precipitate (now containing the chemical contaminants removed from the soil and subsequently from the wash water) is collected and stored for further treatment and/or disposal.

D.1.1.3 Soil Washing Literature Review

An initial review of the literature on the use of soil washing for removing radionuclides from soil was conducted in 1991 in support of the TSWP. This review indicated that the application of soil washing to radionuclide-contaminated soil was minimal. Since that initial review, the soil washing technology has evolved, resulting in a broader and better defined soil washing process, as described in Section D.1.1.2. The recent interest to make this technology successful has been the primary driver. In part, the development of the soil washing technology is needed to: develop a technology that reduces the volume of contaminated soil that would otherwise have to be excavated, containerized, and stored; provide a processed soil fraction that can be returned to an environment requiring a minimum of

institutional controls; and develop a soil washing technology that can be more universally applied to a variety of soil-contaminant matrices. Based on this understanding of soil washing, the recent literature review focused on three primary aspects of the technology: (1) physical separation processes relative to soil washing; (2) chemical extraction processes relative to the soil-contaminant matrices; and (3) existing soil washing systems or pilot-scale tests.

D.1.1.3.1 Physical Separation

Physical separation processes have been the focal point of the soil washing technology. Physical separation processes serve to: separate the soil into various particle size fractions; separate loosely bound contaminants from the soil; and separate particulate contaminants from soil particles. The concept of reducing soil contamination through the use of particle-size separation is based on the understanding that many organic and inorganic contaminants tend to bind primarily to clay and fine silt soil particles. The attraction of chemicals to this soil-size fraction (especially in ionic form) is primarily a function of the negative exchange sites associated with the surfaces of clay. Separating this soil-size fraction from the rest of the soil will in turn separate chemicals associated with the clay from the rest of the soil. In essence, this is called volume reduction, where a large mass of contaminant-free coarse soil particles is separated from the contaminant-laden finer fraction. There are occurrences where coating of clays, metal oxides, and carbonates on the surface of coarse soil separates and fragments results in the larger size particles also containing significant levels of contaminants.

Some contaminants, especially metals, may reside in the soil in particulate form. Discrete particles of metals (e.g., uranium, lead, iron, etc.) may exist as either metallic products from manufacturing processes or have complexed into metal oxides, hydroxides, and carbonates. These particulates may exist in the soil as: free particulates that disassociated from individual soil particles; particulates that are bound to the surface of coarse separates and fragments; or particulates that are occluded within soil aggregates or soil particles. Liberating these particulates so that they are disassociated from soil particles is a primary function of physical separation processes.

Much of the technology and equipment used during the physical separation stage in soil washing comes directly from the mining industry. Pretreatment processes are initial steps in the soil washing operation and are designed to reduce soil aggregates to single grain composition (i.e., clay, silt, sand, gravel, cobble, rock, debris, and particulates). This is accomplished by a number of mechanical processes (e.g., grizzlies, trommel screens, and drum washers). High pressure water and/or mixers can also be employed at this stage to aid in particle liberation. Various screening mechanisms and sizes are used during these initial operations to perform particle sizing and separation. Generally, soil fragments and debris are removed at this point from the excavated soil because they constitute a small amount of the total soil mass, their size is not conducive to being processed through the subsequent

steps of the operation without prior size reduction (crushing), and the level of contamination is not as high relative to the total mass in these oversized materials.

Once the excavated soil mass has gone through an aggregate dispersion process and initial fragment and debris sizing and separation, the actual "boiler room" part of the physical separation process can begin treating the soil. Attrition scrubbers and mixing tanks are used to aid in particle and contaminant liberation. Additional particle-size and density separation processes are used to further physically separate soil particles. Selected mining equipment (e.g., froth flotation cells, clarifiers, hydrocyclones, mineral jigs, and spiral classifiers), centrifuges, and multigravity separators are used to perform various particle-size cuts of the soil separates. The resulting individual process streams, each containing a selected size of soil particle, can individually be addressed relative to further treatment or processing.

Certain particle-sizing equipment noted previously also serve as dewatering devices (e.g., centrifuges, hydrocyclones, and clarifiers). Dewatering processes are necessary to remove soluble contaminants from the soil solids and aid in further process operations requiring higher solids loading such as attrition scrubbing. Although filter presses and belt filters are sometimes employed for dewatering soil, the resulting filter cake (usually highly concentrated with contaminants) is considered a final process stream of the soil washing operation.

D.1.1.3.2 Chemical Extraction

The use of chemical reagents to displace ions or compounds associated with the soil's solid phase has been a subject of research since the inception of cation exchange. The incorporation of chemicals in an aqueous solution is used to physicochemically enhance the removal of ions and compounds (collectively referred to as chemicals) from soil particles. Physicochemical separation of chemicals may be via mass action, substitution, or complexation. The basic bonding mechanisms (e.g., ionic, covalent, nonspecific, and polar bonding) and Van der Waal forces will in part dictate the mechanisms by which these chemicals are disassociated from the solid matrix into the extracting solution. The chemical reagents used in the extracting solution will also in part be responsible for the selective disassociation of chemicals into the solution. The use of these water-soluble chemicals (e.g., surfactants, chelators, acids, and bases) can be incorporated into physical separation operations common to soil washing techniques, or they can be used in specifically designed reactor vessels as part of the chemical extraction process.

A review of soil washing technologies that use chemical extractants and their applicability to Superfund sites (EPA 1989a) concluded that water washing with extractant reagents is applicable for cleaning nonvolatile hydrophilic and hydrophobic organics and heavy metals from soil. The report concluded that, although extraction of organics and toxic metal contaminants from excavated

sandy/silty soil that is low in clay and humus content has been successfully demonstrated at several pilot-plant test facilities, extraction from clay and humus soil fractions is more complicated.

Kunze and Gee (1989) demonstrated greater than 90 percent removal of a large number of contaminants from the soil at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site using various surfactant, organic solvent, and acid-washing solutions. They determined that both aqueous surfactant and aqueous citrate-based solutions are effective for high percentage removals of all classes of the organic compounds tested. Their bench-scale soil washing study also showed that with high levels of contamination at a site, several washings may be required and used solutions would have to be treated before reuse.

Soil washing is not a new technology, but its application to mixed waste (organics, inorganics, and radionuclides) contamination problems, such as exist at the FEMP site, extend the application of such a technology to a relatively new dimension. Soil washing has been successfully used on soil contaminated with radionuclides. Richardson, et al. (1989), conducted soil washing studies on the removal of radium-226 and thorium-230 from two soil. The results of their wet-sieving and water-washing studies indicated that the combination of the two processes can significantly reduce the radionuclide levels in soil.

D.1.1.3.3 Existing Soil Washing Systems

Soil washing has been practiced in Europe since the mid-1980s and has received considerable attention in the United States during the 1990s. A review of soil washing vendors presented at the WASTECH™ Symposium indicated that there were 19 vendors in the United States and 14 in Europe. Although 14 United States vendors have conducted pilot-scale studies, only six vendors were noted as having full-scale soil washing systems. It has been noted that although pilot-plant demonstrations are designed to provide detailed cost, design, and performance data on a field-scale system, in some cases the system may become the actual plant used in site remediation.

Soil washing has shown up as the selected remedy in 17 records of decision (RODs) as of mid-1992. No full-scale systems were in operation in support of these RODs before 1992 (Mann 1992). A more recent literature search in support of the Operable Unit 5 FS has indicated that a number of full-scale demonstrations have been documented either through internal or referenced publications and news releases.

U.S. Environmental Protection Agency's (EPA's) Mobil Soil Washing System

The mobil soil washing system developed during the 1980s separates contaminants from soil by high-energy mixing of soil with solvents, additives, surfactants, acids, and bases (Scholz and Milanowski 1983; Skinner and Bassin 1988; 1991). The soil washer consists of three components: a drum

washer, a counter-current extraction chamber, and a dewatering unit. Soil is initially rough-screened to remove large stones and debris and then passed through a rotating drum equipped with high-pressure water sprays and a 2-mm screen. The countercurrent extraction chambers incorporate turbine mixers, air agitators, and hydrocyclones during the chemical extraction process. With a throughput capacity of approximately 2 tons per hour (tph), the system has been demonstrated at an Alabama site to treat lead-contaminated soil. Most recently, the system was demonstrated on soil at the Montclair/Glen Ridge Superfund site, initially characterized as containing radium-226 (Richardson, et al. 1990; EPA 1989a). Final results indicated that the system could treat over 50 percent of the soil mass to less than the targeted 15 picocurie per gram (pCi g^{-1}) activity level (Eagle, et al. 1993).

Alternative Remedial Technologies, Inc.

A joint venture in 1992 between Geraghty & Miller, Inc. and Heidemij Reststoffendiensten has brought the Heidemij soil washing system to the United States. The system incorporates a combination of physical/chemical processes which first separate the oversize materials by a series of vibrating screens. Wet screening combined with particle-size separation using hydrocyclones creates a coarse fraction and a fine fraction. The coarse-grain fraction is directed to froth flotation cells where it is washed with chemicals before dewatering. The fine fraction is directed to a sludge basin where solids are allowed to settle and the resulting sludge is dewatered using a belt filter press. With a processing rate of 25 tph, the system has treated over 20,000 tons of soil contaminated with chromium, copper, and nickel at the King of Prussia Superfund site in New Jersey.

Bergmann USA

The primary projects for Bergmann USA are a 10 tph demonstration plant for the Toronto Harbor Commissioners and a 10 tph barge-mounted plant for removal of polychlorinated biphenyl (PCB) contaminants from dredged sediment for the U.S. Army Corps of Engineers. The Toronto Harbor system incorporated a high-pressure trommel washer, attrition scrubbers, bioslurry reactors, and hydrocyclones for dewatering (EPA 1993). The treatment train was comprised of a trommel to remove oversize material, an attrition scrubber to segregate the soil into uncontaminated coarse material and highly contaminated fines, metals removal process by chelation, chemical and biological treatment for reduction of organic contaminants, and hydrocyclonic dewatering. The system achieved cleanup criteria for the gravel and sand products, representing about 80 percent of the product (treated soil), while concentrating 74 percent of the organic contaminants into 19 percent of the product output. The system was not effectively evaluated on metal removal due to low initial concentrations.

Lockheed Corporation

The Lockheed System incorporates a TRU clean™ patented modular process which includes soil size fractionation and gravimetric separation. The process has been demonstrated at the

government-owned China Lake site in California, where particulate uranium was separated from a sandy soil. A combination of hydrocyclones and shaker screens was used to fractionate the soil into selected size groups (e.g., sand, silt, and clay). Modified mineral jigs were used to separate particulate uranium from the coarse soil fraction. Chemical extractants were subsequently used to remove residual nonparticulate uranium. Centrifuges are used for dewatering. Currently, a system incorporating hydrocyclonic/shaker-screen size fractionation is located at the FEMP. This system also incorporates the use of attrition scrubbers, chemical extraction tanks, and dewatering centrifuges.

Westinghouse Soil Washing Process (WSWP)

The WSWP was used in 1992 for treating 16,000 cubic yards of metals-contaminated soil at a site near Bruni, Texas. Currently, the process is being tested at the Feather River Superfund site in northern California (ENR 1994). Contaminants at this site include pentachlorophenols (PCPs), polycyclical aromatic hydrocarbons (PAHs), dioxins, and heavy metals (arsenic, chromium, and copper). The full-scale units are integrated process trains which use equipment originally developed for the mining industry. The process is arranged to form three functional units: (1) an initial screening and washing of coarse materials, (2) breakup of the remaining solids followed by a thorough wash, and (3) a high intensity leaching and separation of the contaminated fines from the clean soil. The system is capable of treating soil contaminated with organics, heavy metals, and radionuclides.

D.1.1.4 Study Justification

The literature review conducted in 1991 for the TSWP resulted in few references on the removal of radionuclides from soil using a combination of physical separation and chemical extraction techniques. The review revealed that water washing with extractive agents is applicable for cleaning nonvolatile hydrophilic and hydrophobic organics and heavy metals from soil (EPA 1989a) and had been successfully used on soil contaminated with radionuclides. Information was not found on its application to soil containing the radionuclides, inorganics, and organics that characterize the Operable Unit 5 soil at the FEMP. Therefore, due to the lack of information available to adequately address the overall effectiveness of the soil washing process on removing contaminants from the FEMP soil, as well as the other EPA remedy evaluation criteria necessary during the detailed analysis of alternatives, a decision was made to proceed with treatability testing. In August 1992, the final TSWP was issued and a treatability study was designed to evaluate the effectiveness of soil washing in removing contaminants, primarily uranium, from FEMP soil.

D.1.1.5 EPA Treatability Guidance

The EPA's Guide for Conducting Treatability Studies Under CERCLA (1989b) outlines a three-tiered approach to conducting treatability studies for a Superfund site. The revised approach and terminology (dePercin, et al. 1991) illustrated in Figure D.1-1 is as follows:

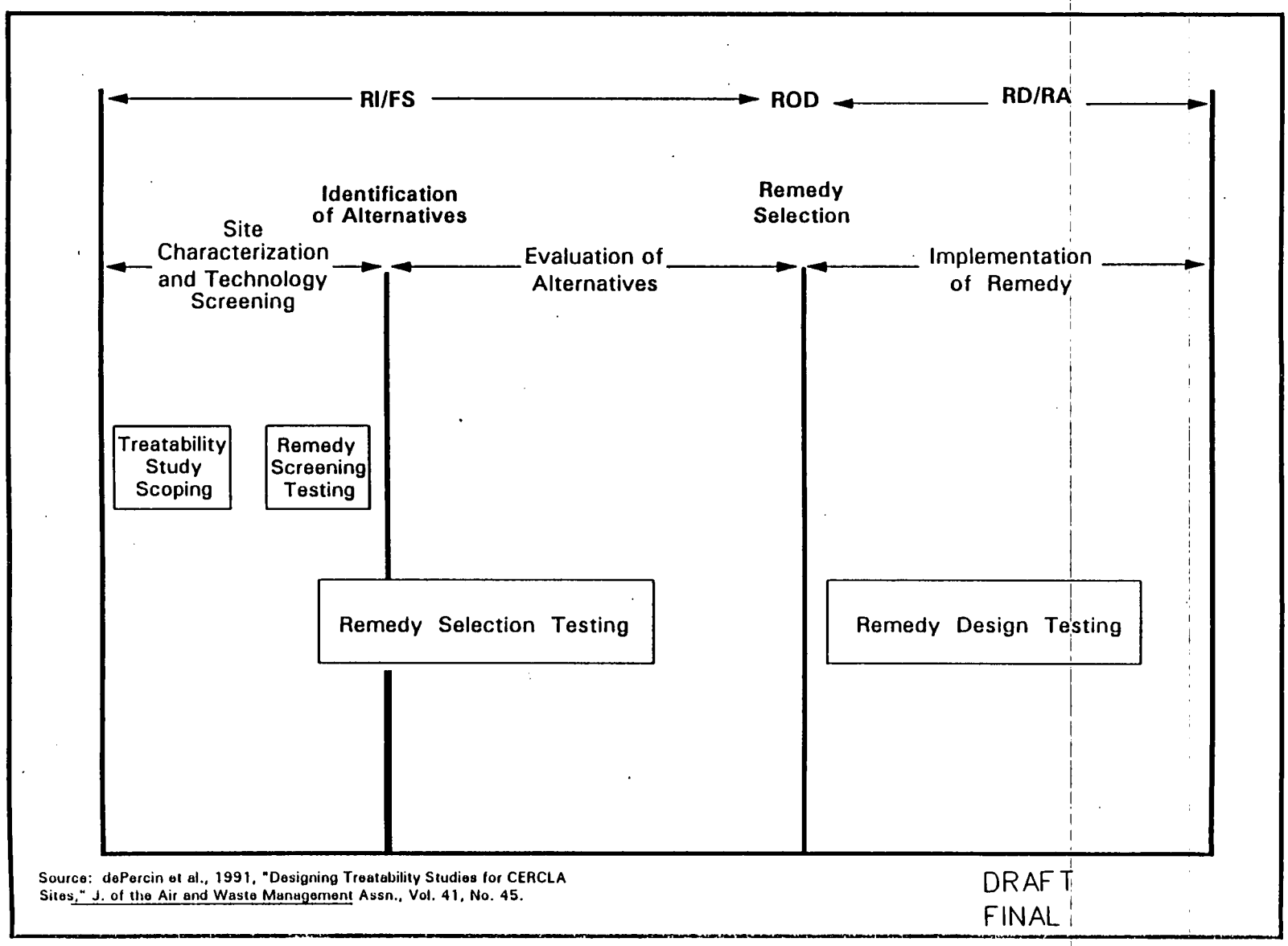
- Remedy screening
- Remedy selection
- Remedy design

The three tiers of treatability testing are divided into pre-ROD and post-ROD studies. The remedy screening and remedy selection testing are generally pre-ROD studies, and the remedy design studies are generally post-ROD. However, the appropriateness and levels of treatability testing required are flexible, and remedy design studies, on a site-specific basis, may be conducted before issuance of the ROD.

The remedy screening and remedy selection treatability studies provide the performance and cost data needed to evaluate all potentially applicable treatment alternatives and select an alternative for remedial action based on the nine RI/FS evaluation criteria. The detailed analysis of the alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD.

Remedy screening is the first step in the tiered approach. The purpose of this step is to determine the feasibility of a treatment alternative for the contaminants/matrix of interest. These tests are typically conducted under conditions that are favorable to the technology. These small-scale studies are designed to provide a qualitative evaluation of the technology and are conducted with minimal levels of quality assurance/quality control (QA/QC). Tests conducted under this tier are generic in nature (not vendor specific). If the feasibility of the treatment cannot be demonstrated, the alternative should generally be screened out at this time.

The purpose of the remedy selection tier is to generate the performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives phase of the FS. The cost data developed in this tier should support cost estimates of +50 percent to -30 percent accuracy. The performance data will be used to determine whether this technology will meet remedial action objectives. Remedy selection studies are typically small scale, incorporating generic tests using bench- or pilot-scale equipment in either the laboratory or the field. The study costs are higher than those encountered in the remedy screening tier and the tests require longer durations to complete. The levels of QA/QC are generally moderate to high.



Source: dePercin et al., 1991, "Designing Treatability Studies for CERCLA Sites," J. of the Air and Waste Management Assn., Vol. 41, No. 45.

FIGURE D.1-1. RELATIONSHIP BETWEEN OPERABLE UNIT 5 TREATABILITY STUDIES TO THE RI/FS PROCESS

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In the remedy design tier, detailed scale-up design, performance, and cost data are generated to implement and optimize the selected remedy (Figure D.1-1). Remedy design studies are usually performed as part of remedy implementation on full-scale or near-full-scale equipment. These studies focus on optimizing process parameters, which are not a part of this treatability study.

D.1.2 NATURE AND EXTENT OF SOIL AND SOIL CONTAMINATION

D.1.2.1 Soil

Soil in the region was formed by parent materials that were deposited by the action of Wisconsin and Illinoisan glaciers. These materials consist mainly of glacial till but include sand, gravel, glacial lake clay, and silt.

Three major soil associations have been mapped in the vicinity of the FEMP by the USDA (USDA et al. 1980, 1982): Russell-Xenia-Wynn, Fincastle-Xenia-Wynn, and Fox-Genesee. The soil are usually light colored, acidic, and well drained. Many have developed on wind-blown material (loess), except along present and old river basins where the Fox-Genesee soil is glacial till origin. The soil are moderately high in agricultural productivity and are frequently used for growing cash crops and producing livestock.

Soil at the FEMP site are primarily categorized as Fincastle-Xenia silt loams. These soil are light colored, medium acid, and moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as are fertility and organic content. The soil have formed in 18 to 40 inches of wind-blown silt (loess) over limy loam till. In areas where Fincastle soil are predominant, artificial drainage is required for moderate crop productivity. If artificial drainage is not used, the water table remains high for extended periods in winter and spring. Fincastle-Xenia soil also cover large areas west of the FEMP.

Before development of the FEMP, soil in the former production area consisted primarily of Fincastle silt loams. The Fincastle series consists of deep, somewhat poorly drained soil that formed in loess and in the underlying loam till. Fincastle soil are characterized by low permeability, moderate productivity, seasonal wetness, and low soil strength. During the construction of the production area, native soil were covered by introduced gravels, paving materials, and facilities. Areas that are currently planted with grasses and maintained as lawns or buffer zones tend to represent native Fincastle soil.

D.1.2.2 Soil Contamination

The nature and extent of chemical contaminants within FEMP soil has been investigated through two programs. The sampling and analyses conducted in support of the Operable Unit 5 RI/FS was extensive in describing the type of contaminants existing at the FEMP and the three-dimensional

distribution of these contaminants throughout the soil profile. The Uranium in Soil Integration Demonstration (USID) program, established by the U.S. Department of Energy Office of Technology Development, is the second characterization program at the FEMP. The USID Characterization Task group was given the responsibility to conduct a study to obtain basic information relating to soil properties and the nature of uranium contamination for the site's soil.

Current characterization information indicates that a minimal amount of soil at the FEMP contains hazardous chemicals. However, constituents of concern (COCs) for contaminated soil at the FEMP, which have been noted in the Site-Wide Characterization Report (DOE 1993), are listed below:

Chemicals	Radionuclides
• Antimony	• Lead-210
• Arsenic	• Radium 226
• Beryllium	• Radium-228
• Lead	• Thorium-228
• Mercury	• Thorium-230
• Aroclor-1254	• Thorium-232
• Aroclor-1260	• Uranium (depleted)
• Benzene	• Benzo(a)pyrene
• DDT	
• Tetrachloroethene	

D.1.2.2.1 Operable Unit 5 Remedial Investigation

Uranium is the indicator parameter for contamination at the FEMP. Uranium has also been present in samples containing concentrations above background levels for other inorganic constituents including radionuclides and metals, and concentrations above detection limits for organics. The level of contamination in surface soil is generally less than the level of contamination of soil under or near certain process buildings. The highest levels of uranium have been detected near Plant 6 and Plant 2/3. Acids were used to digest or pickle material in these locations. Organic contamination occurs near plants where chemicals were used for process development or in conjunction with machining and maintenance operations, except in the case of the fire training area, the graphite furnace and oil burner, and the coal pile.

Surface soil in the vicinity of the FEMP has become contaminated from a variety of sources. Overall, the site has received a dusting of airborne uranium from the stacks in the former production area. Additional airborne material has been released in the waste storage area by dust blown from the disposal pits and tracking of contamination by vehicles. The incinerator in the sewage treatment plant area was also a source of airborne contamination. Additionally, leaks and spills from processing activities within the former production area have resulted in soil contamination.

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The data used to characterize the nature and extent of soil contamination at the FEMP were collected and analyzed from the spring of 1988 through 1990. In general, concentrations of total uranium in soil samples from outside the former production area and waste storage area are below 50 milligram per kilogram (mg kg)$^{-1}$. The exceptions to this are in suspect areas, such as the fire training area, the sewage treatment plant area, and the rubble mound west of the K-65 silos. Each of these areas has surface contamination in excess of 50 mg kg^{-1} of total uranium. The maximum total uranium value found in soil from throughout the former production area was detected in a sample collected just below the concrete floor of the Plant 6 wastewater treatment area.

Large portions of the former production area have total uranium concentrations in soil from 0.0 to 1.5 feet at greater than 50 mg kg^{-1}. Actually, a large part of the uranium contamination is a surface contamination problem. A comparison of the 50 mg kg^{-1} contours indicates that below 1.5 feet total uranium values greater than 50 mg kg^{-1} are restricted to the northern end of Plant 6, scattered points around the garage and heavy equipment building, the Plant 2/3 area, the southwest corner of the pilot plant, the northwest corner of the maintenance building, and the southeast corner of Plant 9. Within the former production area, leaks and spills from process equipment have resulted in deeper migration of contaminants at higher concentrations than is due to airborne deposition. Although uranium is the indicator parameter at the FEMP, many samples have been analyzed for other radionuclides. To better focus the investigation of this complex production network into a manageable technical framework, the former production area was separated into four distinct quadrants.

D.1.2.2.2 Uranium in Soil Integrated Demonstration Characterization Study

The primary objective of the USID program was to evaluate and demonstrate remedial alternatives for uranium-contaminated soil. An initial phase in this program was to obtain basic information relating to soil properties and the nature of uranium contamination. The USID selected five areas within the FEMP property and conducted an extensive characterization of selected soil samples from these areas (Lee and Marsh 1992).

The basis for this characterization was to investigate the nature of soil contamination by examining:

- Uranium distribution with soil depth
- Soil particle-size distributions and their uranium contribution
- Soil chemical and physical properties
- Particle density of soil and contaminant
- Mineralogical and microscopic properties of soil and contaminant
- Chemical leaching characteristics
- Background soil uranium content and soil properties.

The following results are taken directly from Lee and Marsh's report:

- Except in an area contaminated by acidic solution spills, the contamination depth of most areas was shallow (usually less than 10 centimeters [cm] containing from 10 to 2800 pCi g^{-1})
- Background uranium concentration of off-site soil was less than 4 pCi g^{-1}
- The sand and silt-size fractions contained from 48 to 79 percent of the uranium in soil.
- The dominant form of uranium was sand and silt-sized particulates often associated with calcium, phosphorous, iron, and silicon
- Most of the uranium particulates had a density greater than 2.9 g milliliter $(mL)^{-1}$
- Considerable amounts of soil uranium, 10 to 40 percent and 20 to 75 percent, could be extracted using 2 percent solutions of ammonium carbonate and citric acid, respectively.

D.1.2.3 Description of Treatability Study Soil

D.1.2.3.1 Incinerator Area (ID-A)

This area is located outside of the production area to the east, and the underlying soil should be Fincastle series. The soil has a well-developed surface horizon with fine granular structure and the occurrence of small limestone gravel. The source of uranium contamination in this area was incinerator emissions from burning low-level contaminated trash.

D.1.2.3.2 Plant 1 Drum Storage Area (ID-B)

This area is located in the northwestern part of the production area and the underlying soil should be Fincastle series if they have not been too deeply disturbed. The soil had a weakly developed structure and about 30 to 60 percent limestone gravel. The presence of the angular limestone gravel indicated that the area had been highly disturbed from past activities. The source of uranium contamination in this area was runoff from the drum storage pad coupled with air deposition from stack emissions.

D.1.3 DESCRIPTION OF TREATABILITY STUDY APPROACH

The approach used for the Operable Unit 5 soil washing treatability study is illustrated in Figure D.1-1. This approach was consistent with the EPA's tiered system for conducting treatability studies. The two-tiered treatability approach was designed to evaluate the soil washing process for Operable Unit 5 by conducting both bench-scale testing (remedy screening) and pilot-scale testing (remedy selection). A unique aspect to this standard CERCLA approach for conducting treatability studies is that the study was designed to support a cooperative testing effort between the USID program and the FEMP RI/FS project.

Parallel bench-scale tests were conducted during Stage I testing of the remedy screening process. Because soil washing is a physicochemical treatment process, separate physical separation and chemical extraction tests were conducted in a parallel effort. The physical separation tests were targeted as describing the particle-size distribution and the resulting uranium associated with each size fraction. The chemical extraction tests were used to identify the most effective chemical for separating uranium from the soil. Stage II incorporated the findings from Stage I testing into a combination of physical separation and chemical extraction treatments. The findings from these Stage I and II bench-scale studies were incorporated into a pilot-scale version of a soil washing treatment system during the remedy selection part of the CERCLA process.

The Guidance for Conducting Treatability Studies Under CERCLA (EPA 1988) recommends that target compounds be used during remedy screening tests. Because uranium is the primary contaminant at the FEMP, total uranium was selected as the target compound to evaluate the effectiveness of the various treatments tested. Although other contaminants were monitored during selected stages of testing, uranium was the primary analyte used to evaluate a treatment's effectiveness.

D.1.3.1 Remedy Screening - Bench-Scale Testing

The physical separation component of Remedy Screening-Stage I was designed to test the effect of different dispersants on removing uranium from different soil-size fractions and characterize the soil particle-size distribution and the respective uranium concentration among individual soil-size fractions. Each soil was dispersed in a number of sodium salt solutions and mechanically separated into specific soil-size fractions using a wet-sieving technique. Each soil-size fraction and spent dispersing solution was collected and analyzed for total uranium.

In a parallel effort during Remedy Screening-Stage I testing, chemical extraction experiments were designed to test a wide range of chemicals under very aggressive conditions that were selected to give each chemical the best probability for effectively removing uranium from the soil. The conditions chosen were high temperature (80° C), relatively high reagent concentrations (e.g., 1:1), and relatively high dose rate (10:1). The high temperature and high reagent concentration may adversely increase the rate of other metal compound dissolution; therefore, the high dose rate will minimize the effect that common ion dissolution has on ionic strength of the extracting solution. The most effective extractants were determined by evaluating the residual uranium in the soil following extraction. These results would provide the baseline conditions to further define chemical selection and process optimization.

Stage II of the remedy screening process combined the results of Stage I physical separation and chemical extraction experiments. The soil-size fractions that were shown to retain significant levels

of uranium were selected for use in a series of chemical extraction tests. The number of extractants tested during Stage I testing were reduced to only the most effective extractants in removing uranium from soil. During Stage II testing, the effects of extractant concentration, temperature, and dose rate were investigated. Also during Stage II testing, spent extractant treatment via precipitation and ion exchange were investigated. The uranium-loaded extractant solutions and rinse solutions contained material leached from the soil. Preliminary precipitation tests were performed to determine which type(s) of precipitating and flocculating reagents were necessary to remove the majority of the hazardous and radioactive metals. Ion exchange tests were also performed to evaluate the effectiveness of specific resins in selectively and/or quantitatively removing uranium from the spent extractant and rinse solutions.

D.1.3.2 Remedy Selection - Pilot-Scale Testing

Pilot-scale testing of the soil washing process was conducted as part of the remedy selection component of the CERCLA guidance for treatability testing. The pilot-scale tests incorporated specific equipment (e.g., trommel, vibrating screen deck, attrition scrubber, centrifuge, and extraction vessels) as part of the soil washing system. Only the most successful chemical extracting solutions from Stage II bench-scale testing were incorporated into this system. It was expected that a combination of chemical extractants, combined with physical separation techniques, might be necessary to effectively remove uranium from the soil. The overall effectiveness of an empirically derived soil washing system for treating FEMP soil was evaluated by conducting a complete analysis of the soil before and following the treatment process.

D.1.3.3 Relationship of Treatability Data to FS Evaluation Criteria

The following information was obtained or can be calculated as a result of the treatability study testing:

- Volume of soil in which uranium content was reduced to defined concentrations for uranium and other COCs
- Volume of residues requiring disposal
- Wash water volume for treatment and/or disposal relative to the initial untreated waste volume
- Volume of extracting reagents for disposal relative to the initial volume of untreated waste
- Amount of contaminants removed from soil by extractants and process water
- Cost of implementing the technology
- Conceptual process flow diagram for a full-scale production system

- Conceptual mass balance across a process flow diagram (PFD) for full-scale production system

- Mobility of contaminants in untreated and treated soil.

D.1.4 DESCRIPTION OF OTHER SOIL WASHING LABORATORY STUDIES

D.1.4.1 Oak Ridge National Laboratory (ORNL)

Two soils were used in bench-scale testing at ORNL to determine the effectiveness of sodium carbonate and citric acid leaching (extraction) to decontaminate or remove uranium to acceptable regulatory levels. The objective of the work by Francis, et. al. (1993) was to selectively extract uranium using a soil washing/extraction process without seriously degrading the soil's physicochemical characteristics or generating a secondary waste form that would be difficult to manage and/or dispose of. The two soil used in the treatability testing were the same ID-A and ID-B soil from the incinerator area and Plant 1 storage pad area, respectively. These two soil were also used in an interlaboratory treatability study sponsored by the FEMP USID program. Uranium concentrations in these soil, as determined by ORNL, ranged from 450 to 550 mg kg^{-1} total uranium.

Carbonate extractions generally removed from 70 to 90 percent of the uranium from the ID-B soil. Uranium was slightly more difficult to extract from the ID-A soil. Increasing the extraction temperature from 22 to 40° C for the ID-A soil increased the fraction of uranium extracted from approximately 40 to 80 percent. However, the increased extraction temperature did not appear to increase extraction effectiveness for the ID-B soil. Extraction with carbonate at high solution-to-soil ratios were as effective as extractions at low solution-to-soil ratios, indicating attrition by the paddle mixer was not significantly different than that provided in a rotary extractor. Pretreatment such as milling or pulverizing the soil sample also did not appear to increase extraction efficiency when carbonate extractions were carried out at elevated temperatures (60°C) or long extraction times (23 hours). Adding $KMnO_4$ to the carbonate extractions appeared to be more effective in removing uranium from the silt- and sand-size fractions (greater than 0.002 mm) of soil than from the clay-size fractions (less than 0.002 mm).

The most effective extraction rates (greater than 90 percent from both soil) were obtained using a citrate/dithionite extraction procedure designed to remove amorphous (noncrystalline) iron/aluminum sesquioxides from surfaces of clay minerals. Citric acid also proved to be a very good extractant for uranium. At pH values less than 5, approximately 50 and 90 percent of the uranium could be extracted from the ID-A and ID-B soil, respectively. A citric acid extraction (0.1 M) of the ID-A soil followed with two carbonate extractions containing $KMnO_4$ removed greater than 80 percent of the uranium, indicating that a combination of citric acid and carbonate extracting procedures may be the best approach for soil containing residual forms of uranium. ORNL's efforts to date have shown that significant quantities of uranium can be extracted from these two soil without seriously degrading the

soil's physicochemical characteristics or generating a secondary uranium waste form that is difficult to manage and/or to dispose of.

D.1.4.2 Lockheed Environmental Systems and Technology (LESAT)

The bench-scale treatability testing conducted by LESAT was in support of the Minimum Additive Waste Stabilization program with the specific objective of demonstrating the feasibility of integrating vitrification of the Operable Unit 1 waste pit material with soil washing and water treatment. The initial objective of the soil washing system was to use physical separation processes to provide a silica feed for the vitrification process. A subsequent objective was to use physicochemical processes with the soil washing system to treat that fraction of the soil not serving as the silica feed to an acceptable cleanup level. The experimental design and results are contained in an internal report issued by LESAT.

The soil used by LESAT during their bench-scale treatability testing was from the Plant 1 pad area. The soil was not the same soil that was screened and homogenized by the USID program and used in subsequent bench-scale testing by ORNL and International Technology (IT) Corporation. The soil received by LESAT contained surface vegetation (grass) and roots. Therefore, specific characteristics, e.g., organic matter content, particle-size distribution, and uranium concentration, may significantly vary from those characteristic described for the ID-B soil (Plant 1 pad area soil). The following are the primary conclusions resulting from LESAT bench-scale soil washing treatability testing:

- Uranium contamination is distributed throughout the soil matrix in levels above 35 pCi g^{-1} and the majority of soil particles are less than 0.1 mm in size. Consequently it was concluded that physical separation techniques alone will not achieve the 35 pCi g^{-1} criteria and achieve a significant volume reduction.

- The 100 mesh (0.149 mm) to 0.03 mm fraction has the highest silica content of the soil matrix as determined by concentration of SiO_2. It was therefore selected as a feed stream for the vitrification process. Because of its high SiO_2 content it is beneficial to vitrification and reduces the need for additives.

- There is a significant amount of organic matter in the soil matrix. The organic matter has the highest activity levels relative to other soil fractions. Because processing the organic matter through the leach process will reduce leach performance and/or increase chemical usage and cost, it will be screened out of the soil matrix and fed to the melter. Initial vitrification tests have shown that this soil fraction is processable for vitrification.

- Carbonate leaching of the minus-0.03 mm fraction is effective in achieving the 35 pCi g^{-1} criteria.

- The ion-exchange resins to be used in field tests are acceptable in removing uranium from the leach concentrate, allowing the water to be recycled for use in the soil washing system.

D.1.4.3 Westinghouse Science and Technology Center (WSTC)

The soil used in bench-scale soil washing treatability testing by WSTC were the two soil collected under the USID program, the incinerator area soil (ID-A) and the Plant 1 pad area soil (ID-B). Results of this testing are contained in an internal report issued by WSTC. WSTC tested the use of 0.2 molar (M) ammonium bicarbonate (NH_4HCO_3) solution alone and in conjunction with a oxidation pretreatment using two percent sodium hypochlorite (NaOCl) solution. Based on these test parameters, the following conclusions were reached:

- Removal of the uranium from both soil appears to be technically feasible by using a combination of ammonium bicarbonate and sodium hypochlorite solution and physical separation.

- The contamination in the ID-A soil was divided between a highly soluble form and a relatively insoluble form in soil fractions between 0.075 to 0.3 mm.

- The contamination in the ID-B soil was highly soluble and readily mobilized by the leachate.

D.2.0 CONCLUSION AND RECOMMENDATIONS

D.2.1 CONCLUSIONS

An extensive investigation into the application of soil washing as an effective remedial alternative for soil at the Fernald Environmental Management Program (FEMP) was conducted over the past three years. The investigation was initiated with a characterization study by Oak Ridge National Laboratory (ORNL) of uranium contamination at the FEMP. This characterization study concluded, based on the five areas sampled (Plant 2/3, plant 1 drum storage pad, drum baling area, incinerator area, and Plant 6), that uranium was distributed throughout all soil size fractions (gravel, sand, silt and clay). In addition, uranium in the soil was noted to exist as individual discrete particles or as smaller particles cemented to silt, sand, and gravel fractions rather than as a preferentially adsorbed form on clay minerals. Although particulate uranium was a dominant form in FEMP soil, the delta specific gravity was not great enough for multigravitational separation techniques to work effectively. Because of the ubiquitous distribution of uranium among all soil particles, physical separation techniques alone were considered to be ineffective in achieving a volume reduction in the soil mass or a significant volume reduction in the uranium mass. Therefore, an emphasis was placed on investigating the potential effectiveness of using physicochemical soil washing processes for treating FEMP soil.

Following the initial characterization effort by ORNL, the scope of the subsequent treatability studies was a two-year investigation which focused on removing uranium from FEMP soil using a physicochemical soil washing approach. This investigation was funded by two DOE programs: A remedial investigation/feasibility study (RI/FS) -funded series of treatability tests by IT Corporation on both a bench- and pilot-scale; and an Office of Technological Development-funded integrated approach by Lockheed, Westinghouse, as well as an array of national laboratories including ORNL, Los Alamos National Laboratory and Argonne National Laboratory. Although these two Department of Energy-funded programs adhered to different missions, the integration of their activities and the sharing of data and ideas generated during the extensive treatability testing created an interactive exchange that focused on the ultimate objective of removing uranium from FEMP soil to an acceptable residual level in terms of both mass and mobility.

This report has focused on the results obtained during the treatability testing by IT Corporation and the Fernald Environmental Restoration Management Corporation (FERMCO). The study was conducted as part of remedy screening and remedy selection testing in support of the Operable Unit 5 FS to evaluate remedial alternatives for cleaning soil at the FEMP site. The testing was conducted in accordance with CERCLA guidelines for conducting treatability studies. Although, reference has been made frequently to support studies, in particular ORNL's test results, data presented here relative to constituent concentrations and removal efficiencies, are solely a product of these tests.

Comparison to other test data for the same soil, must be with the understanding of the inherent variability associated with any soil-contaminant matrices, regardless of how homogeneous. In most cases, tests were run without replication, which negates the association of any statistical reliability with the results. In the few cases where duplicate or more replications were conducted, statistical interpretations with respect to the data were presented.

During the two-year duration of treatability testing in support of the Operable Unit 5 FS, 12 soils were characterized and to some degree used in subsequent treatability testing. Initially, soil from two of the five areas investigated by ORNL, incinerator area (ID-A) and Plant 1 drum storage pad (ID-B), considered to be representative of the soil-contaminant matrices at the FEMP, were selected and used in the treatability studies. These two soil contained no constituents of concern (COCs) other than uranium. Because the Treatability Study Work Plan (TSWP) was directed at testing a remedial technology that would address a range in soil-contaminant matrices, a third soil (from the maintenance building area [OU5-A]) containing other COCs besides uranium was also used in the initial bench-scale treatability studies. However, due to certain site constraints, only the ID-A and ID-B soil were used in remedy selection pilot-scale testing at the FEMP soil washing pilot plant. The nine remaining soil (not initially referenced in the TSWP) were collected and used in bench-scale testing at the FEMP during the final stages of the treatability study to determine if the proposed hybrid soil washing process (Appendix L) used as the foundation for the Operable Unit 5 FS would be effective over a wider range of soil-contaminant matrices.

The two soil studied during initial bench-scale testing were the ID-A and the ID-B soil. Geotechnical characterization of the two soil (initially prescreened at 19 mm) showed that 77.4 and 74.6 percent, respectively, of the ID-A and ID-B soil were in the less than 0.05 mm-size fraction and of this percentage, approximately 15 percent was clay (less than 0.002 mm). It was also determined that uranium was distributed among all particle-size fractions (consistent with ORNL results). Soil quantities used during bench-scale testing contained approximately 497 and 450 mg kg^{-1} total uranium for the ID-A and ID-B soil, respectively. Uranium concentrations in the sand and silt fractions were 1028 and 317 mg kg^{-1}, respectively, for the ID-A soil and 189 and 223 mg kg^{-1}, respectively, for the ID-B soil. Although the ID-A and ID-B clay fractions contained 1475 and 2710 mg kg^{-1}, respectively, part of this was uranium that was brought into solution during the soil dispersion process and adsorbed back onto the clays.

During Stage I of the bench-scale treatability studies, physical separation techniques and chemical dispersants/extractants were used in combination to treat the ID-A and ID-B soil. Four 1 mm sodium reagent solutions (sodium hydroxide, sodium carbonate, sodium bicarbonate, and a sodium citrate-bicarbonate-dithionite mixture) and potable water were evaluated for effectiveness in dispersing each soil into single-grain separates and extracting total uranium from each of the resulting

particle-size fractions. Dilute sodium solutions were more effective than water in dispersing the soil. No solutions were effective in removing uranium from any soil-size fraction. The use of dispersants, as compared to water, on the less than 2-mm-size fraction seemed to causes a shift in the distribution of uranium out of the sand fraction and into the silt and clay fractions for ID-A soil and onto the clay fraction for the ID-B soil.

More rigorous treatment conditions were applied during the ensuing physical separation bench-scale testing. Attrition scrubbing was combined with higher strength sodium compound solutions and used to treat the less than 2 mm soil fraction for the ID-A and ID-B soil. The three alkaline extraction solutions tested were sodium pyrophosphate, sodium carbonate/sodium bicarbonate, and ammonium carbonate/ammonium bicarbonate. The independent variables tested were solution strength (0.1, 0.25 and 0.5 M) and attrition scrubbing time (5, 15, and 30 minutes), The uranium concentration was determined in the sand fraction (greater than 0.053 mm) and the silt-clay fraction (less than 0.053 mm). There was little difference among the chemical extractants on their effectiveness in removing uranium from either soil fraction. Higher concentrations of each chemical extractant (0.5 M) were more effective in removing uranium from each of the two size fractions. Increasing the attrition scrubbing time from 5 to 30 minutes also increased the amount of uranium removed from each size fraction. Even though there was less than a linear response with increasing extractant concentration or attrition scrubbing time, a point of diminishing returns had to be selected. This point for Stage II testing would be a 0.25 M concentration for sodium carbonate/sodium bicarbonate and an attrition scrubbing time of 15 minutes. Sodium carbonate/bicarbonate was also selected due to its use in the uranium mining industry.

While the physical separation testing was being conducted, a parallel effort was being pursued with respect to the use of chemical extractants. Due to the ubiquitous distribution of contamination among all soil particles, 12 chemical reagents comprised of inorganic acids, salts, bases, and chelants were evaluated for their effectiveness in removing total uranium from the less than 2-mm-size fraction of the ID-A and ID-B soil. This remedy screening part of the study was designed in stages to selectively and sequentially investigate certain aspects of chemical extraction. Successful results from each stage were transferred to subsequent stages to further refine the use of chemicals for extraction of total uranium from both soil.

Stage I chemical extraction testing used very aggressive conditions. Very concentrated reagents were tested at a high extractant:soil ratio (10:1), high temperature (80°C) and a 4 hour reaction time. Results indicated that the most effective chemical extractants in removing total uranium from both soil were the inorganic acids (nitric, hydrochloric, phosphoric, and sulfuric); they reduced total uranium concentration by over 95 percent. Although sodium carbonate, ammonium carbonate, and sodium hydroxide were more effective on the ID-B soil, all three extractants reduced total uranium

concentration in the solids to less than 50 mg kg^{-1}, representing a more than 90 percent reduction in total uranium.

Based on findings from Stage I testing, three inorganic acids (sulfuric, hydrochloric, and nitric) were carried into Stage II testing for further investigation. Stage II testing was directed at reducing the half-concentrated acids used in Stage I testing to the lowest acid strength without reducing their effectiveness in uranium extraction. Stage II results showed that all concentrations of acids greater than or equal to 1 N were able to achieve less than 50 mg kg^{-1} total uranium in the extracted soil solids, equating to a more than 90 percent reduction in uranium.

In Stage III testing, extractant, extractant concentration (1 and 2 N), temperature (ambient and 40°C), dose rate (4:1 and 7:1 extractant:soil), and extraction time (0.5 and 2 hours) were evaluated. Although nitric and sulfuric acid extractants were effective on both soil in removing uranium, sulfuric acid was selected for use in pilot-scale testing. Results from bench-scale testing showed that a 1 N sulfuric acid solution (4:1 dose rate) at 40°C and 0.5 hour extraction time was able to reduce total uranium concentration in the ID-A extracted soil to 38 mg kg^{-1}. Sulfuric acid was also very effective on ID-B soil, regardless of extraction conditions. A 1 N sulfuric acid solution, 0.5 hour extraction time, 40°C temperature, and 7:1 dose rate reduced total uranium concentration in the extracted solids to 19 mg kg^{-1}.

Based on the findings from the bench-scale physical separation and chemical extraction testing, a combined approach was developed for final bench-scale testing before taking the process to pilot-scale. The ID-A and ID-B soil were subjected to an initial physical process followed by a chemical extraction process. Both soil were attrition scrubbed for 15 minutes using a 0.1 M sodium carbonate/sodium bicarbonate solution at a 2:1 dose rate (33 percent solids). At the end of this first part of the combined treatment process, the uranium concentration in the ID-A and ID-B soil were reduced to 341 and 241 mg kg^{-1}, respectively. This equated to a 31 and 46 percent reduction in the ID-A and ID-B soil respectively. These soil were then extracted for 30 minutes at 40°C with a 2 N sulfuric acid solution at a 7:1 dose rate (12.5 percent solids). The final concentration of uranium in the ID-A and ID-B treated soil solids following this sequential treatment process was 49 and 71 mg kg^{-1}, respectively. This equated to a 90 and 84 percent total reduction in the ID-A and ID-B soils, respectively. These operational parameters were then used to construct the processing conditions for operation of the soil washing pilot plant tests.

The initial configuration of the soil washing pilot plant was based on the fundamental designs of current soil washing systems within the United States. However, modifications to the design were implemented during construction of the pilot plant, resulting in a process configuration of the system specifically targeting FEMP soil. A 3000-square-foot, bi-level skid-mounted system was constructed

to separate the soil into discrete-size fractions to facilitate separate treatment of each size fraction. Soil size cuts of the less than 19 millimeter (mm) feed soil were made at the trommel (4.75 mm), the screen deck (2 and 0.3 mm), and the centrifuge (approximately 0.02 mm).

The operation of the soil washing pilot plant was structured around a hybrid system incorporating physical separation processes with selected chemical extraction processes. The physical separation part of the system was directed at producing a selected soil size fraction from the feed soil that provided sufficient mass to warrant the use of an attrition scrubbing process. The attrition scrubbing part of the physical separation process incorporated a bisequential chemical extraction process which used multiple 0.1 M carbonate/ bicarbonate sequential extractions in the attrition scrubber followed by a 1 N sulfuric acid extraction process at 40°C to treat all soil solids greater than 0.02 mm. The less than 0.02 mm soil solids were solely extracted with 1 N H_2SO_4 at 40°C for 1 hour.

The soil washing pilot plant was operated in batch mode for a period of three months. Two batch runs (one 55-gallon drum of soil per batch run) of both the ID-A and ID-B soil were conducted during this pilot-scale testing. The two runs per soil were used to evaluate reproducibility of process operations and to provide some statistical reliability to the resulting data. Potentially, six basic process streams could have been generated during the operation of the soil washing system. Those streams included: (1) treated soil solids greater than 4.75 mm; (2) treated soil solids 0.3 to 4.75 mm (3) treated soil solids 0.02 to 0.3 mm; (4) treated soil solids less than 0.02 mm; (5) a filter cake (residue); and (6) spent carbonate extraction solution. Due to the operation of the soil washing system these primary process streams were slightly changed. The 0.3 to 4.75 mm soil solids coming off of the screen deck were combined with the 0.02 to 0.3 mm soil solids coming off of the centrifuge to form a single process stream. A centrifuge heel was created during system operations. The centrifuge heel was partially treated soil retained by the centrifuge during the batch-mode operation of the system. Although this soil was not originally considered to be part of any primary process stream, it constituted such a significant amount of the initial soil mass and total uranium mass that it was used in the mass balancing of process operations. It should also be noted that although the centrifuge functioned very well as a dewatering device, it did not provide a particle-size separation at 0.02 mm.

Laboratory analysis by FERMCO, used to support mass balancing calculation for operation of the soil washing system, showed the initial average uranium concentration for the ID-A soil was 459 (SD=39.6) mg kg^{-1} total uranium. The total uranium concentrations in the greater-than-0.02-mm and less-than-0.02 mm treated soil solids were 27 mg kg^{-1} (SD=1.4) and 62.5 mg kg^{-1} (SD=26.2), respectively. These two primary process streams, plus the greater-than-4.75 mm gravel, accounted for an average of 74.3 percent (SD=4.4) of the initial total mass for the ID-A treated soil solids. This total mass of treated soil averaged 27 mg kg^{-1} (SD=1.4). Residual total uranium mass

remaining in the treated soil was approximately 10.3 percent (SD=0.4) of that contained in the feed soil. This equated to nearly a 90 percent reduction in total uranium mass for nearly 75 percent of the ID-A soil processed. Most of the uranium mass was either concentrated in the filter cake or remained in the spent carbonate extractant. The filter cake having a final total uranium concentration of approximately 637 mg kg^{-1} (SD=209) contained 11.2 percent (SD=3.5) of the total uranium mass. Most of the uranium remained in the spent carbonate solution. This solution contained 71.5 percent (SD=16) of the total uranium mass. This solution also contained a significant amount of the initial soil mass, although an exact value could not be calculated. Much of this soil mass was the fine fraction of the soil separates that did not partition into the solid phase during centrifugation.

The initial average uranium concentration for the ID-B soil was 422 (SD=46.7) mg kg^{-1} total uranium. The total uranium concentrations in the greater-than-0.02-mm and less-than-0.02 mm treated soil solids were 17 mg kg^{-1} (SD=4.2) and 35.5 mg kg^{-1} (SD=2.1), respectively. An additional quantity of effectively treated soil generated during the processing of the ID-B was the centrifuge heel. The centrifuge heel constituted nearly 31 percent of the initial soil mass with a final total uranium concentration of 60 mg kg^{-1} (SD=19.1). These three primary process streams, plus the greater-than-4.75 mm gravel, accounted for an average of 78 percent (SD=10.7) of the initial total mass for the ID-B treated soil solids. This total mass of treated soil averaged 37 mg kg^{-1} (SD=12.7). Residual total uranium mass remaining in the treated soil was approximately 6.7 percent (SD=2.5) of that contained in the feed soil. This equated to over a 90 percent reduction in total uranium mass for nearly 78 percent of the ID-B soil processed. Most of the uranium mass was either concentrated in the filter cake or remained in the spent carbonate extractant. The filter cake having a final total uranium concentration of approximately 3455 mg kg^{-1} (SD=1281) contained 47.5 percent (SD=10.7) of the total uranium mass. A major portion of the uranium remained in the spent carbonate solution. This solution contained 23.5 percent (SD=11.8) of the total uranium mass. This solution also contained a significant amount of the initial soil mass, although an exact value could not be calculated. Much of this soil mass was the fine fraction of the soil separates that did not partition into the solid phase during centrifugation.

Off-site analyses by a contracted laboratory were also conducted in support of toxicity characteristic leaching procedure (TCLP) evaluation on the primary process streams generated during the operation of the soil washing system. Total uranium concentration values for the initial soil and the primary process streams were consistently higher by off-site analysis as compared to on-site analysis. The average total uranium concentrations for the 0.02- to 4.75-mm process stream are 59 mg kg^{-1} (SD=4.2) and 75 mg kg^{-1} (SD=1.4) by the contracted laboratory, respectively, for the ID-A and ID-B soil. The average total uranium concentrations for the less-than-0.02-mm process stream were 158 mg kg^{-1} (SD=23.3) and 112 mg kg^{-1} (SD=2.1) by the contracted laboratory, respectively, for the ID-A and ID-B soil.

The TCLP results indicated that there is a reduction in the leachable quantity of uranium for the 0.02- to 4.75-mm and the less-than-0.02-mm process streams, as compared to the initial soil. The initial feed soil showed TCLP values of 1206 and 11,398 pCi L^{-1} for the ID-A and ID-B soils, respectively. The 0.02- to 4.75-mm process stream was reduced to average TCLP values of 98 pCi L^{-1} (SD=50.9) and 267 pCi L^{-1} (SD=11.3) for the ID-A and ID-B soil, respectively. The less-than-0.02-mm process stream was reduced to average TCLP values of 377 pCi L^{-1} (SD=358.5) and 712 pCi L^{-1} (SD=219.2) for the ID-A and ID-B soil, respectively.

D.2.2 RECOMMENDATIONS

A summary of the findings of this extensive testing has established a baseline understanding of the FEMP soil-contaminant matrix, as well as the potential effectiveness of soil washing on FEMP soil. The primary considerations when determining the effectiveness of soil washing for decontaminating FEMP soil must be premised with an understanding of the diversity of soil types, contaminant concentrations, and the resulting soil/contaminant matrices. The effectiveness of soil washing with respect to a reduction in residual uranium mass and mobility, and this extrapolation to the concept of volume reduction, were evaluated based on the results from these extensive bench- and pilot-scale studies.

A hybrid soil washing system has evolved which emphases a sequential extraction process that incorporates a carbonate based reagent as a primary extractant followed by a sulfuric acid based secondary extraction process used on an as-need basis. Using a conservative estimate for the potential effectiveness of a hybrid soil washing system, the data indicates that greater than 90 percent of the soil can be treated to a residual total uranium concentration of 100 mg kg^{-1} or less with a mobility of less than 1 mg L^{-1} total uranium established through TCLP testing.

D.3.0 TREATABILITY STUDY APPROACH

D.3.1 STUDY OBJECTIVES AND EXPERIMENTAL DESIGN

D.3.1.1 Study Objectives

Study objectives were established so that the performance of soil washing techniques could be evaluated on the basis of volume reduction, contaminant removal from individual soil fractions, and contaminant removal from the wash solutions. These performance objectives were used to determine if a particular series of physical/chemical processes could effectively and efficiently remove contaminants from soil. Only selected constituents found during the initial soil characterization in this study were targeted and followed through the treatability study.

The physical separation and chemical extraction tests were the focus of the bench-scale soil washing study. Results from these bench-scale tests are contained in Attachment I. The test conditions which optimize the efficiency with which a radionuclide was extracted from the soil during these bench-scale studies were used to define the operational parameters for a pilot-scale soil washing system. The findings from the soil washing pilot-scale demonstration were used to evaluate the potential for soil washing to serve as a successful remedial technology for FEMP soil.

D.3.1.2 Soil Washing Experimental Design

Figure D.3-1 shows the series of treatment stages that comprise the experimental design. This design for soil washing incorporated a tiered approach in determining (1) the binding association of radionuclides and other inorganic and organic chemical constituents within the soil matrix and (2) the physical separation and chemical extraction processes necessary for soil washing and wash solution (spent extractant) recovery. This design incorporated the two parallel testing phases of physical separation and chemical extraction as part of the Stage I study, selectively separating soil into five individual soil size fractions (19.5 to 9.5 mm, 9.5 to 2 mm, 2 to 0.053 mm, 0.053 to 0.002 mm, and less than 0.002 mm).

The Remedy Screening-Stage I chemical extraction experiments were designed to examine gross effects on the less than 2 mm soil size fraction. The conditions were selected to yield favorable results (i.e., reagents that have a reasonable probability for success). The conditions chosen were high temperature (80°C), high reagent concentrations, and high dose rate (10:1 extraction solution to soil). The aggressive temperature and reagent conditions were selected to accelerate the rate of metal compound dissolution. The high dose (low percent solids) rate was used to minimize the effects of common ion effect and ionic strength on the dissolution of the desired material.

Initial screening tests conducted during Stage I studies were used to refine the Stage II approach for soil washing. The physical separation tests were used to identify the soil size fractions with which

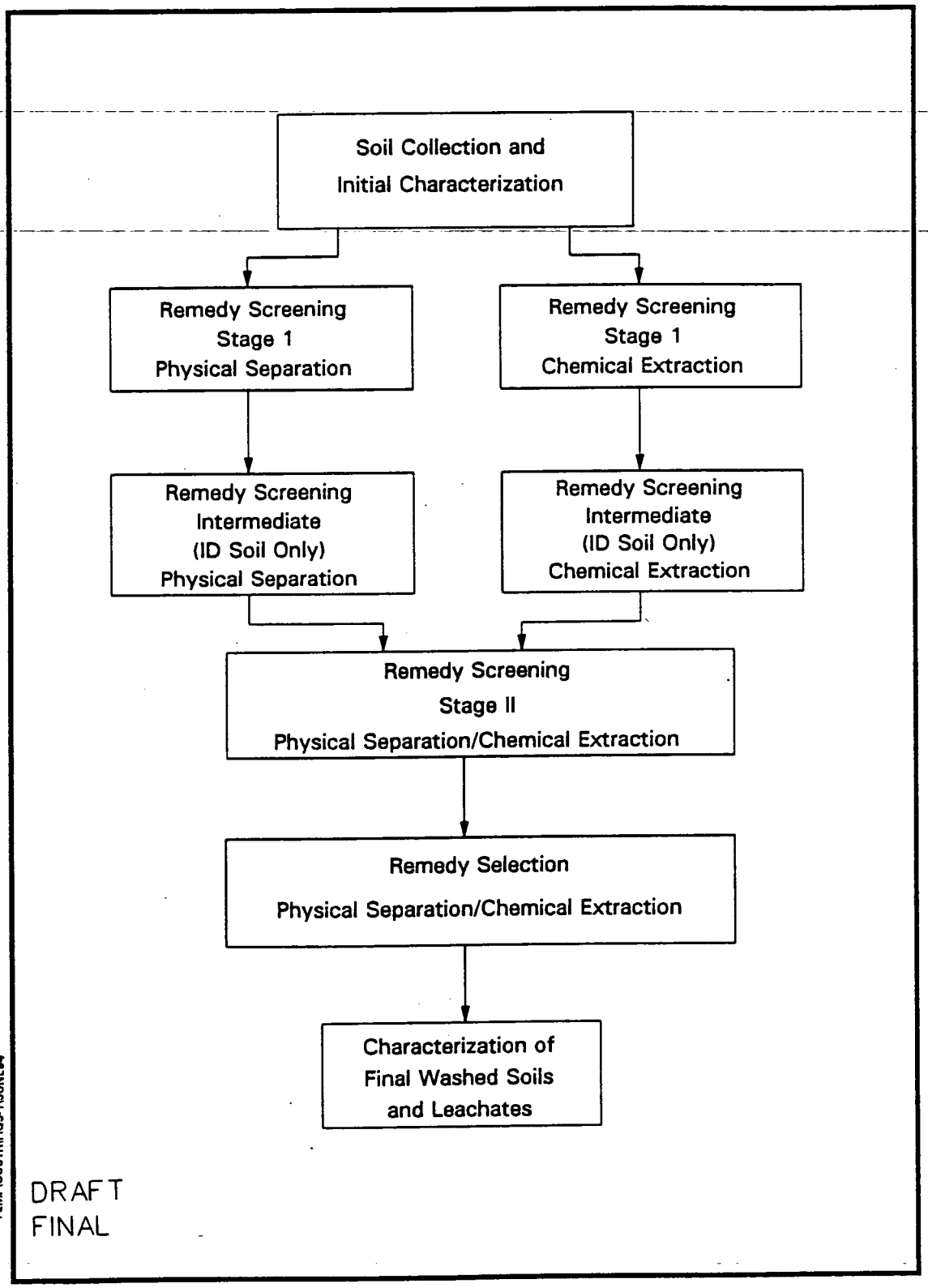

FIGURE D.3-1 - TREATMENT PHASES OF SOIL WASHING EXPERIMENTAL DESIGN FOR OPERABLE UNIT 5 SOIL

each type of contaminant (e.g., radionuclides and organic and inorganic compounds) was associated. Stage II Remedy Screening focused on these individual soil size fractions as part of the test matrix. The most effective washing solutions, determined during Stage I chemical extraction testing, were used for washing selected soil size fractions. The effect of extractant concentration and dose rate were to be determined.

Results from Stage II studies demonstrated the extraction reagents and concentrations that were most effective in removing radionuclides and other chemical constituents from selected soil size fractions. These results help establish the series of steps during physical separation and chemical extraction that are necessary to achieve a particular action level for contaminant removal. Also, the results from chemical extraction tests help determine the effectiveness of iterative chemical extractions in removing additional contaminants from soil and wash solutions or leachates. The Remedy Screening results were incorporated into the Remedy Selection advance phase testing and the pilot-scaled version of the soil washing treatment system.

D.3.2 SOILS USED IN THE SOIL WASHING TREATABILITY STUDY

D.3.2.1 Initial Selection of Soil

The Operable Unit 5 soil washing study requirements included the initial collection and characterization of soil used for treatability testing. Soil chosen for soil washing were initially selected from three locations that are considered to be representative of the contamination problem at the FEMP. The basic criteria for the type of soil selected, described in Section 6.0 of the TSWP, focuses on three soil with moderate to high uranium contamination. The selection of soil from one of these locations that also contain other inorganic and organic constituents allowed for soil washing treatability testing to address other specific contamination problems of soil at the FEMP.

Soil contaminated primarily with radionuclides (specifically uranium) were noted as "ID" soil. These soil were collected as part of the Uranium in Soil Integrated Demonstration (USID) program. Soil contaminated with radionuclides as well as other inorganic and organic chemicals were noted as "OU5" soil because they are unique to the Operable Unit 5 TSWP program. Specific reference to the three soil selected for use in this treatability study were given the following soil identifications: ID-A, ID-B, and OU5-A.

The ID-A soil was collected from the incinerator area. The source of uranium contamination in the surface soil in this area was incinerator emissions from burning low-level contaminated trash. The second soil was collected from the Plant 1 drum storage area and was identified as the ID-B soil. Contaminants in the surface soil of this area were thought to be introduced primarily by runoff from the drum storage pad. A complete characterization of the ID-A and ID-B soil is provided in the report by Lee and Marsh (1992) and corresponds to the SP9/SP10 and SP3/SP4 soil, respectively.

The locations of the two ID soil (ID-A and ID-B) selected for soil washing are illustrated in the TSWP.

The Operable Unit 5 (OU5-A) soil's uniqueness is due to the presence of COCs other than radionuclides. The source of contamination in Operable Unit 5-A soil is due to operations conducted at the maintenance building during production operation. The location of this soil is also given in the TSWP. Since much of the bench-scale testing conducted on the ID-A and ID-B soil had were performed before initiating testing on the OU5-A soil, the test program for the OU5-A soil was modified to test only the most effective extraction conditions. A description of the experimental design for the bench-scale testing of the OU5-A soil is contained in Section D.3.3.4.

D.3.2.2 Initial Analysis and Characterization of Soil

Soil from each of the three locations were initially screened, homogenized, and placed into separate 55-gallon metal drums in accordance with Section 6.0 of the TSWP. Each area (approximately 6.2 by 7.7 m), was first prepared by removing all surface vegetation and the upper few centimeters of surface soil. The remaining upper 15 to 20 cm of soil was excavated and passed through a 19 mm screen to remove any cobbles, large gravel, and debris. The minus 19 mm soil was homogenized either in a large concrete mixer (ID-A and ID-B) or by shovel (OU5-A) and placed into 55 gallon plastic-lined metal drums. These resulting 15 and 16 drums for ID-A and ID-B soil were determined to be homogeneous with respect to particle size distribution and total uranium concentration (Kneff, et. al., 1992). The five drums of OU5-A soil collected were determined to have uniform distribution of total uranium and soil particle distribution.

After the set of drums for each soil were determined to be homogeneous, a representative sample of soil from each drum was collected and composited and further homogenized using a stainless steel hand trowel. Physical and chemical characterization of all three soil (ID-A, ID-B, and Operable Unit 5-A) were conducted following collection and preceding treatability testing. A list of the parameters tested in this initial baseline characterization is presented in Table D.3-1. This characterization was conducted in accordance with guidelines established in Section D.3.0 and Section 6.0 of the TSWP. These analyses provided the initial baseline characterization of the soil for each location to be used in all subsequent treatability studies. The results of this initial characterization are provided in Section 4.1.

The concentration of other inorganic and organic COCs in the soil (termed HSL analytes in the TSWP) and the TCLP extract were determined for soil during the initial characterization and for the resulting treated soil following the Remedy Selection testing. This was considered necessary to address the criteria for targeted action cleanup levels as well as the potential applicable Resource Conservation and Recovery Act (RCRA) guidelines for returning treated soil to the site.

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TABLE D.3-1

PARAMETERS FOR INITIAL BASELINE CHARACTERIZATION

Pesticides/PCBs

4,4'-DDD
4,4'-DDE
4,4'-DDT
Aldrin
alpha-BHC
alpha-Chlordane
Aroclor 1016
Aroclor 1221
Aroclor 1232
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260
beta-BHC
delta-BHC
Dieldrin
Endosulfan sulfate
Endosulfan-I
Endosulfan-II
Endrin
Endrin aldehyde
Endrin ketone
gamma-Chlordane
Heptachlor
Heptachlor epoxide
Methoxychlor
Toxaphene

Volatile Organics

1,1-Dichloroethane
1,1-Dichloroethene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
1,2-Dichloroethane
1,2-Dichloroethene (total)
1,2-Dichloroethylene
1,2-Dichloropropane
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
cis-1,3-Dichloropropene
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
trans-1,3-Dichloropropene

Semivolatile Organics

1,2-Dichlorobenzene
1,2,4-Trichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,6-Dinitrotoluene
3-Nitroaniline
3,3'-Dichlorobenzidine
4-Bromophenyl phenylether
4-Chloro-3-methylphenol
4-Chloraniline
4-Chlorophenyl-phenylether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
4,6-Dinitro-2-methylphenol
Acenaphthene
Acenaphthylene
Anthracene
Benzoic acid
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h)perylene
Benzo(k)fluoranthene
Benzyl alcohol
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chloroisopropyl)ether
bis(2-Ethylhexyl)phthalate
Butyl benzyl phthalate
Carbazole
Chrysene
Dibenzofuran
Dibenzo(a,h)anthracene
Diethylphthalate
Dimethylphthalate
Di-n-butyl phthalate
Di-n-octyl phthalate
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Napthalene
Nitrobenzene
N-Nitroso-di-n-propylamine
N-Nitrosodiphenylamine
Pentachlorophenol
Phenanthrene
Phenol
Pyerene

TABLE D.3-1 (Continued)

Inorganics	Radionuclides
Aluminum (Al)	Cesium-137
Antimony (Sb)	Neptunium-237
Arsenic (As)	Plutonium-238
Barium (Ba)	Plutonium-239/240
Beryllium (Be)	Radium-224
Boron (B)	Radium-226
Calcium (Ca)	Radium-228
Cadmium (Cd)	Ruthenium-106
Chromium (Cr)	Strontium-90
Cobalt (Co)	Technetium-90
Copper (Cu)	Thorium-228
Cyanide (Cn)	Thorium-230
Lead (Pb)	Thorium-232
Magnesium (Mg)	Uranium-234
Manganese (Mn)	Uranium-235/236
Mercury (Hg)	Uranium-238
Molybdenum (Mo)	Gross alpha
Potassium (K)	Gross beta
Nickel (Ni)	
Selenium (Se)	
Silicon (Si)	
Silver (Ag)	
Sodium (Na)	
Thallium (TI)	
Vanadium (V)	
Zinc (Zn)	

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Soil to be used in bench-scale tests were removed from drums and transferred to five 5-gallon metal containers (approximately 23 kg of soil per container) and shipped to an IT Corporation laboratory in Oak Ridge, Tennessee for treatability testing. Because the soil contained in these drums was prepared in a manner representative of the bulk preparation of soil quantities in excess of 1000 kg, there was a need to further prepare the small quantities of soil sent to the laboratory before use in bench-scale tests.

D.3.2.3 Laboratory Preparation and Initial Analysis of Soil

The initial procedure for preparing soil received at the laboratory is illustrated in Figure D.3-2. Approximately 50 kg (two 5-gallon containers each) of ID-A and ID-B soil were air dried for 48 hours and periodically stirred to ensure even drying. The soil was physically attenuated to break up large aggregates. Approximately 125 g batches of each soil were dry sieved through a stack of 9.5 and 2 mm Tyler stainless steel sieves for 30 minutes on a Ro-Tap shaker. The resulting three sample fractions (19 - 9.5 mm, 9.5 - 2 mm, and less than 2 mm) were then placed in separate plastic containers. Each container was then placed on a rotating jar mixer for 30 minutes and emptied into a 4.75 mm sample splitter. Each sample was split, recombined, and placed back into the plastic container to ensure that each fraction was homogeneous. This procedure ensured that the total amount of each soil to be used for the initial analyses and during the various stages of testing had relatively the same textural composition and total uranium concentration. The remaining three 5-gallon containers (approximately 100 kg) of soil were retained as "whole soil."

The whole soil and the less than 2 mm size fraction were analyzed for homogeneity. Six aliquots from each soil were analyzed for total uranium by ion chromatography (IC). The less than 2 mm soil size fraction was used for the Stages I and II bench-scale tests. The whole soil (less than 19 mm) was used in Stage III testing. A grain size distribution analysis was conducted on the less than 2mm size fraction according to American Society for Testing and Materials (ASTM) D422-63 (ASTM 1991). The percentages of sand, silt, and clay were 23, 62 and 15 percent for ID-A soil and 27, 57 and 16 percent, respectively, for ID-B soil.

D.3.2.3.1 Total Uranium Analysis by Ion Chromatography (IC)

Uranium analysis for solid and liquid samples were performed using a nitric acid digestion procedure followed by IC analysis using high performance liquid chromatography (HPLC). The HPLC incorporated a Perkin Elmer 204-S fluorescence detector [set at 515 nanometers (nm) emission wavelength) preceded by a Dionex HPLC-CG2 exchange resin. A 0.1 molar (M) phosphoric acid solution was used as the eluant. Soil to be analyzed were oven dried at 105°C for 12 hours before digestion. Soil digestion was performed on approximately 0.1 grams samples using 1 mL of concentrated nitric acid (HNO_3). Liquid digestion was performed on 1 mL aliquots of sample. Each sample was heated on a hot plate at 160°C until all moisture was gone, and then heated in a muffle

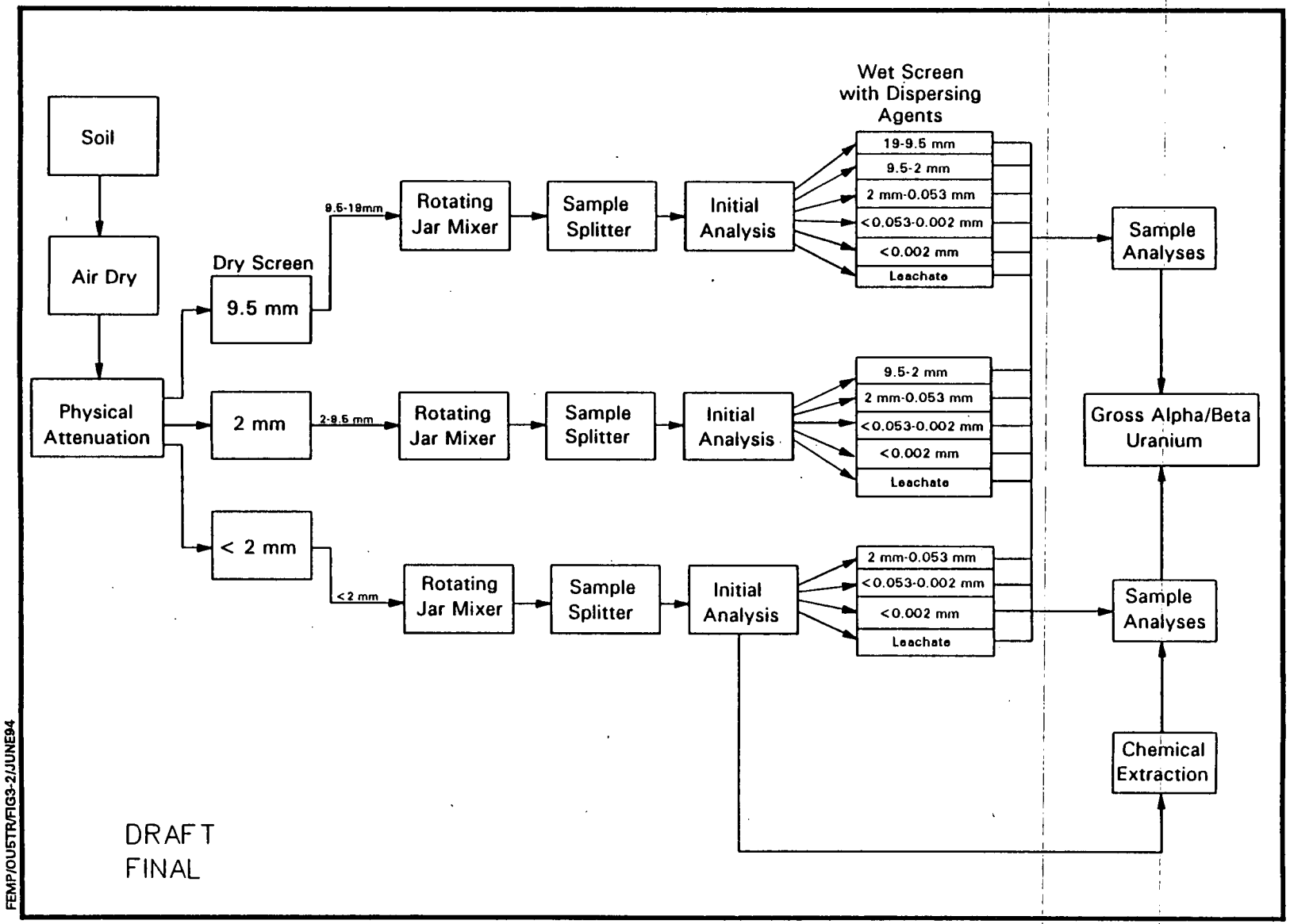

FIGURE D.3-2 - INITIAL PROCEDURE FOR PREPARING SOILS RECEIVED AT THE LABORATORY PRIOR TO INITIATING BENCH-SCALE TESTING

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furnace at 550°C for 15 minutes to remove nitrates or organics. This process was repeated until all residue was gone or no longer changed color. Digested samples were cooled and brought into solution with 1 mL of 25 percent HNO_3 and 19 mL of 0.2 percent phosphoric acid (H_3PO_4). Each solution was sonicated for 30 minutes at 59°C before analysis.

D.3.3 BENCH-SCALE TESTING

~~D.3.3.1 Physical Separation Tests~~

D.3.3.1.1 Test Objectives

The initial objective of physical separation testing was to characterize the soil/contaminant matrix relative to particle size distribution and the level of uranium (the radiological contaminant) associated with individual soil size fractions. As part of this initial stage in the soil washing bench-scale treatability study, basic physical separation techniques were tested to derive the level and tenacity of the soil/contaminant association. A second objective was to evaluate chemical dispersants and their effectiveness in aggregate dispersion and uranium extraction. The third and final objective was to test a combination of physical and chemical treatments in order to define the best dispersant and physical separation parameters for removing uranium from the two test soil.

D.3.3.1.2 Chemical Dispersant/Extractant Tests

ID-A and ID-B Soil

Four dispersing reagents and potable water were tested to determine their effectiveness in: (1) deflocculating soil aggregates into single grain separates and (2) removing uranium from the resulting soil fractions. The dispersants were 1 millimolar (mM) solutions of sodium carbonate (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), sodium hydroxide (NaOH) and a sodium citrate/bicarbonate/dithionite (CBD) mixture (Lee and Marsh 1992). Potable water was used for making all dispersant solutions.

The less than 2 mm size fraction of ID-A and ID-B soil (250-g samples) were reacted in a 2 liter (L) flask with 500 mL of a 1 mM solution of each dispersant. Each sample was agitated at low speed on a shaker table for 30 minutes before sieving. The slurry was transferred to a stack of Tyler stainless steel sieves (9.5 mm, 2 mm, and 53 μm). The sieves were completely sealed and the slurry was Ro-Taped for 1 hour. The soil on each sieve was collected and dried at 105°C and analyzed for total uranium.

The dispersing solution and the less than 53 μm soil slurry were collected. This slurry was subjected to a modified version of the M.L. Jackson procedure (Jackson 1975) using centrifugation for separating silt (2 - 53 μm) from clay (less than 2 μm) and clay from the solution. Sufficient dispersing solution was initially added to the less than 53 μm slurry to make a final 1800-mL volume for each dispersant/soil slurry. While being agitated on a stir plate, 100-mL aliquots of the slurry and 100-mL of dispersing solution were placed into 250-mL centrifuge tubes, shaken, and centrifuged at

800 revolutions per minute (rpm) for seven minutes. The time and speed were calculated from Stokes law in integrated form, which yields time needed for sedimentation under centrifugal acceleration for a given particle diameter.

The supernatant, dispersant solution, and less than 2 μm soil were decanted into a 2-L beaker following centrifugation. The solids were resuspended by adding more dispersing solution, shaken, and centrifuged. This process continued until the supernatant appeared clear (approximately 5-6 times). The final 2-53 μm soil fraction remaining in the centrifuge tube following this procedure was slurried with potable water and dried at 105°C. The combined supernatants (less than 2 μm soil slurry) were centrifuged at 3000 rpm for 60 minutes to separate the final soil size fraction from the dispersing solution. The resulting two soil size fractions (less than 2 μm and 2-53 μm) were analyzed for total uranium.

D.3.3.1.3 Attrition Scrubbing Tests

The ID-A and ID-B soil were subject to attrition scrubbing testing using a modified Hamilton Beach mixer (Figure D.3-3). The 13,000 rpm mixer was modified by replacing the single agitator propeller with two oppositely pitched propellers placed approximately 5 to 7 cm apart on the mixer shaft. During operation, the top blade forces sample down and the bottom blade forces sample up, causing an attriting action of the soil particles with each other.

Three dispersant solution and potable water were tested on both soil to determine their effectiveness in removing uranium from the less than 2-mm soil size fraction. A $Na_2CO_3/NaHCO_3$ solution, an ammonium carbonate/ammonium bicarbonate solution $(NH_4)_2CO_3/(NH_4)HCO_3$, a sodium pyrophosphate ($Na_4P_2O_7$), and potable water were used in the attrition scrubbing tests. The ammonium and sodium carbonate solutions were tested at a 3:1 ratio of carbonate to bicarbonate.

All three dispersant solutions were tested on both soil at three concentrations (0.1 M, 0.25 M, and 0.5 M) and three attrition scrubbing times (5, 15, and 30 minutes). A 1:2 ratio of air-dry soil to dispersant solution was used. The pH of the slurry was measured at the completion of the attrition scrubbing time. The soil slurry was transferred onto a 53 μm sieve with lid and collection pan, completely sealed, and shaken for 30 minutes on the Ro-Tap shaker. The greater than 53 μm fraction was then washed on the sieve with potable water and dried at 90°C. The less than 53 μm soil slurry was transferred to 200 ml centrifuge tubes and centrifuged for 1 hour at 2500 rpm. This centrifugation separated all the solids greater than 0.12 μm from the liquid. The solids were weighed and analyzed for total uranium.

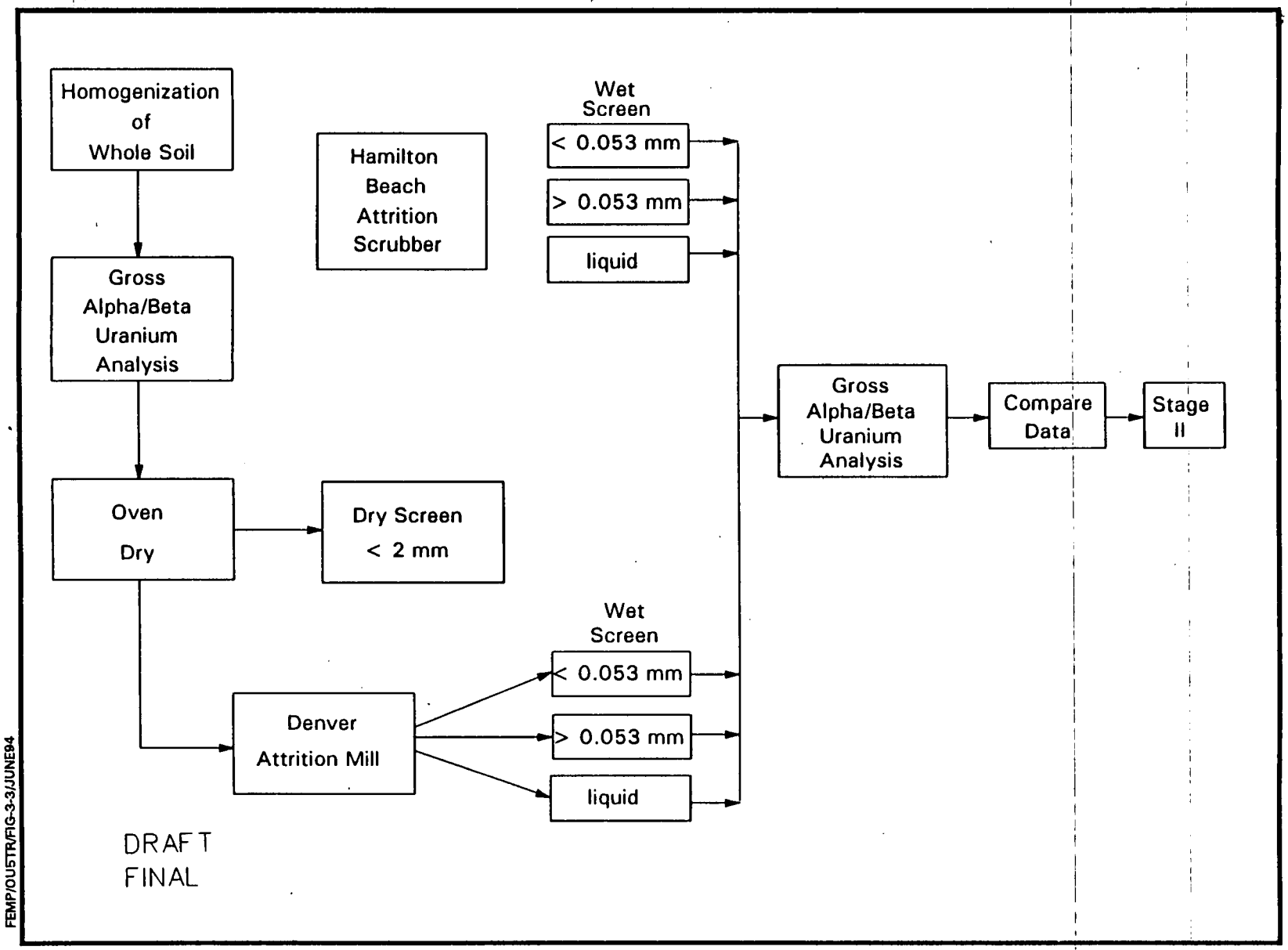

FIGURE D.3-3 - THE PROCEDURE FOR ATTRITION SCRUBBING TESTS

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D.3.3.2 Chemical Extraction Tests

D.3.3.2.1 Test Objectives

The chemical extraction tests were designed in stages to selectively and sequentially investigate certain aspects of chemical extraction. Successful results from each stage of testing were transferred to subsequent stages of testing to further refine the use of chemicals for extraction of uranium from the soil. The initial objective of the first stage of the chemical extraction tests was to evaluate the effectiveness of various types of acids, bases, chelants, and salts in removing uranium from each soil. The second objective, Stage II testing, was to select the most successful chemical reagents from Stage I and evaluate the effect of reagent concentration on chemical extraction. The final objective, Stage III testing, was to evaluate the effects of temperature, reaction time, and dose rate (extracting solution to soil ratio), using the lowest successful concentrations of extraction reagents from Stage II.

D.3.3.2.2 Stage I: Initial Screening of Chemical Extractants

Twelve chemical reagents were tested on the ID-A and ID-B soil in this stage of the study. This stage of testing is illustrated in Figure D.3-4. The chemicals tested (shown in Table D.3-2) ranged from concentrated inorganic acids to salt solutions. The chemical extractants and corresponding extracting solution concentrations included: 1:1 aqueous concentrations of concentrated sulfuric, hydrochloric, nitric, and phosphoric acids; 60 g/20 g per liter concentrations of sodium carbonate/sodium bicarbonate and ammonium carbonate/ammonium bicarbonate; 4.0 N sodium hydroxide; 15 percent sodium chloride and 15 percent potassium chloride; 0.5 M ethylene diamine triacetic acid (EDTA) at three pH values (6, 8, and 10); 10 percent NS1 (a proprietary extractant); and 10 percent Citrikleen™. The extraction equipment used in the study consisted of six 1000 mL Pyrex reaction kettles with mechanical stirring (approximately 150 rpm) provided by a modified Phipps & Bird six-paddle stirrer (Figure D.3-5). All stirrers had rods and Teflon™ paddles. The kettles were heated by a heating mantle which was electrically regulated by a thermocouple and controller. Vapor losses from the kettles were minimized by placing a condenser and a Teflon gasket between the top and bottom sections of the kettles. Vacuum filtration was performed using a Spectrum Mesh Filtration unit with a 20 to 25 micron glass fiber filter.

Approximately 50-g aliquots of homogenized soil were reacted with each extractant in a 10:1 (wt:wt) ratio of extracting solution to soil. The soil and extractant solution were reacted in the heated kettles for 4 hours at 80°C. At the conclusion of the reaction time, each soil slurry was filtered to separate the spent extracting solution from the soil solids. The spent extractant was collected for analysis. The soil solids on the filter (filter cake) were reslurried with 200 mL of deionized water and filtered. This was to reduce the residual extractant concentration and remove additional uranium remaining in the filter cake. The rinsate solution and extracted soil solids were collected separately for analysis. The extracted solids, extractant solution, and rinse water were analyzed for uranium by IC. The efficacy of each extractant was evaluated based on the final concentration of uranium in the

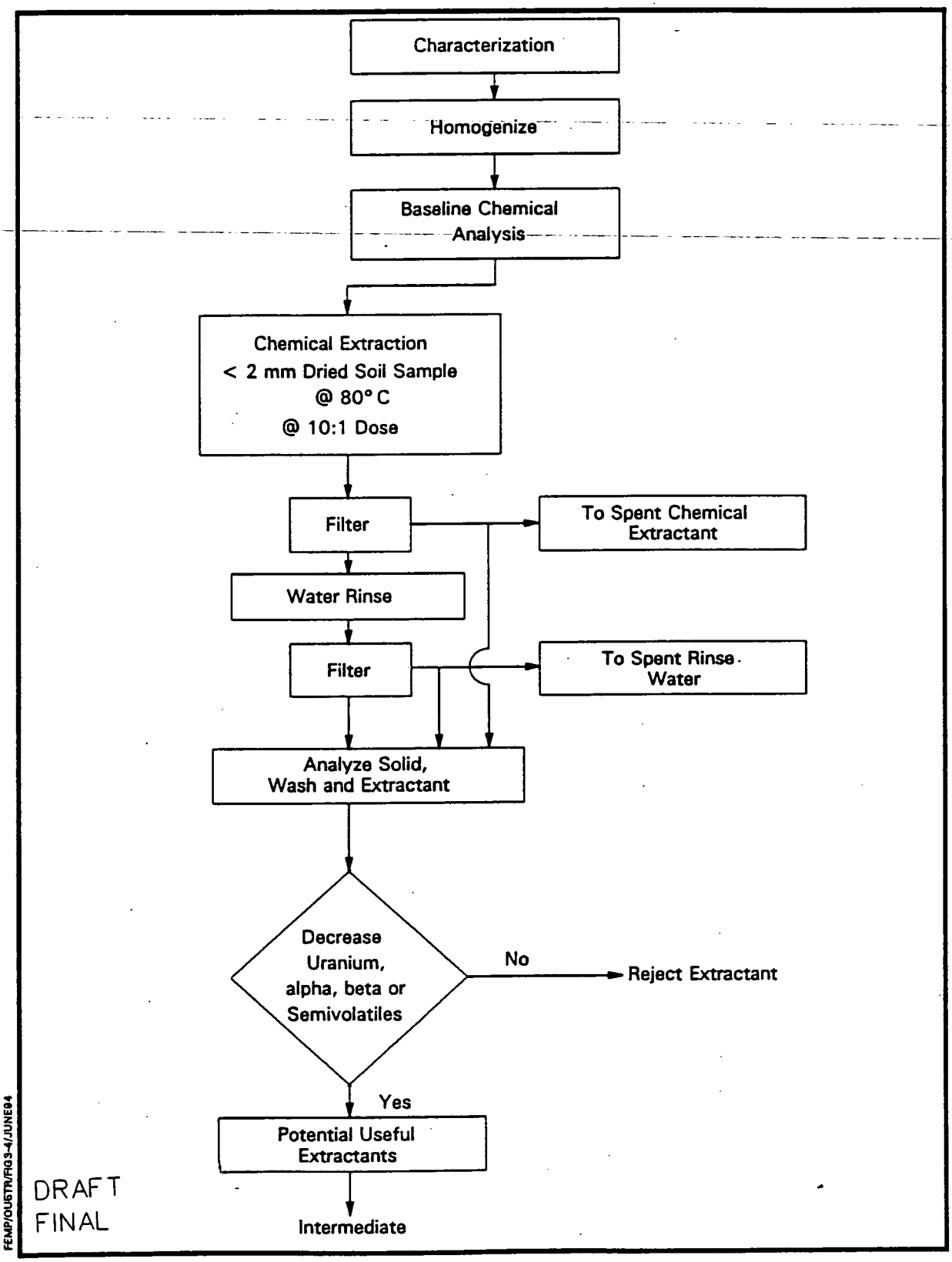

FIGURE D.3-4 - STAGE I OF REMEDY SCREENING TESTS FOR CHEMICAL EXTRACTION OF ID SOILS

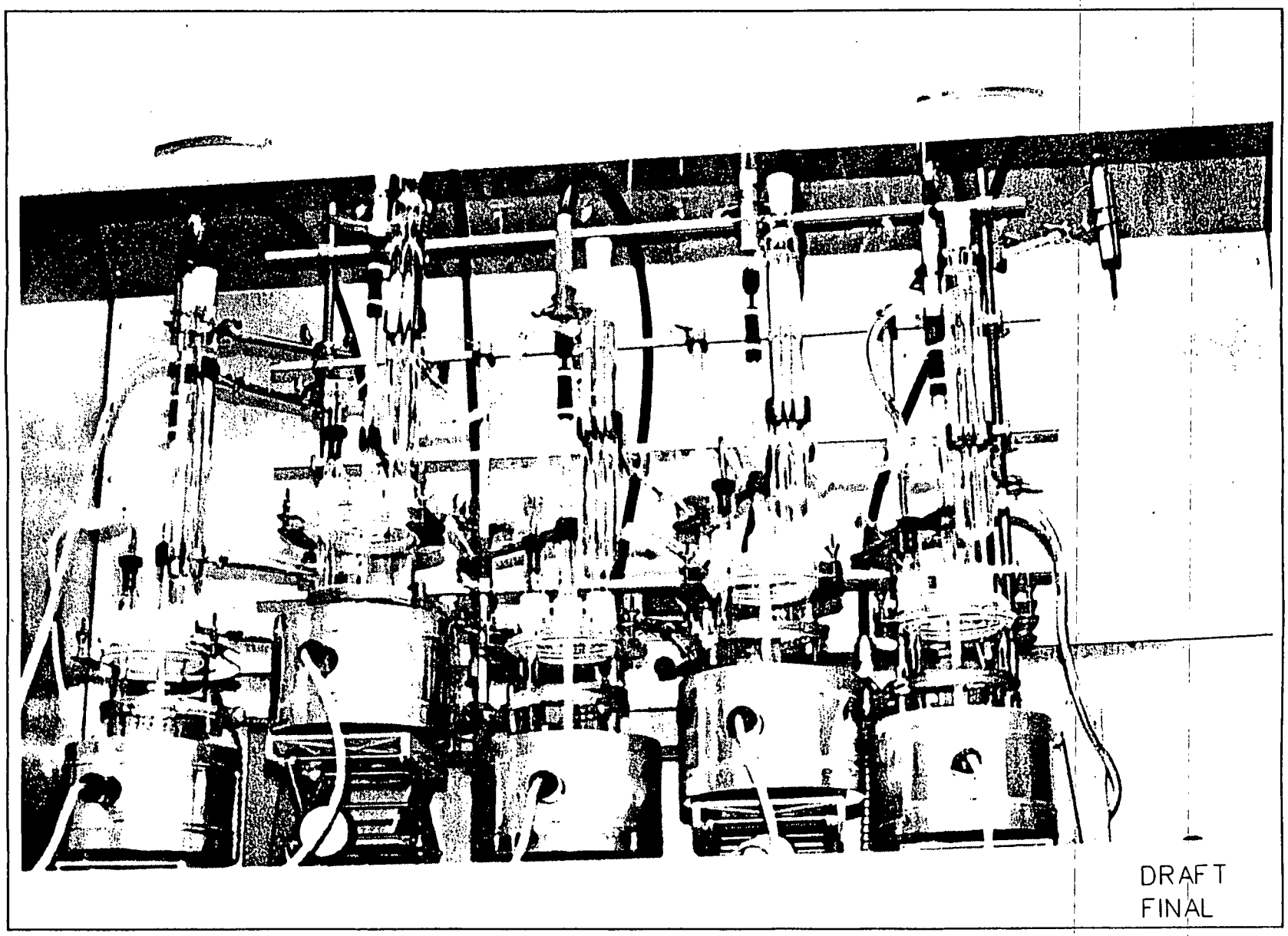

FIGURE D.3-5 - MODIFIED PHIPPS AND BIRD STIR REACTOR

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TABLE D.3-2

TEST PROGRAM FOR ID SOILS EXTRACTANT SCREENING

Extractants	Concentration	Dose (wt extractant /wt init sample)	Temperature (°C)
Acids/Bases/Salts			
$H_{2SO}4$	1:1	10:1	80
HCl	1:1	10:1	80
HNO_3	1:1	10:1	80
H_3PO_4	1:1	10:1	80
Na_2CO_3	60/20 (g/L)	10:1	80
NaOH	4.0 N	10:1	80
$(NH_4)_2$ CO_3/(NH_4) HCO_3	60/20 (g/L)	10:1	80
NaCl	15%	10:1	80
KCl	15%	10:1	80
Chelants			
EDTA			
pH 6.00	0.5 M	10:1	80
pH 8.00	0.5 M	10:1	80
pH 10.00	0.5 M	10:1	80
NS1	1:10	10:1	80
Citrikleen	1:10	10:1	80

extracted soil solids, and the calculated percent removal of uranium during the extraction process. The percentage of uranium removed was calculated by summation of solids, spent extractant, and rinse water. All tests were run as single replications and no statistical analysis was performed.

D.3.3.2.3 Stage II: Screening of Selected Extractants

Stage II testing incorporated the most effective chemical extractants from Stage I testing. Three inorganic acids, sulfuric, nitric, and hydrochloric, were selected to further evaluate their effectiveness in removing total uranium from the ID-A and ID-B soil. Each extractant was tested at five concentrations to determine the lowest concentration of extractant that could be used without significantly diminishing the amount of total uranium removed from the extracted solids.

Sulfuric acid was tested at 0.2, 1, 2, 12 and 18 (1:1) normal (N); nitric acid at 0.1, 0.5, 1, 5.3, and 8 (1:1) N; and hydrochloric acid at 0.1, 0.5, 1, 4, 6 (1:1) N. The extraction time (4 hours), temperature (80°C), and dose rate (10:1 wt/wt)) were kept the same as in Stage I testing. The extraction apparatus and methodology were the same as used in Stage I testing (see Figure D.3-6). All tests were run as
single replications and no statistical analysis was performed.

D.3.3.2.4 Stage III: Time, Temperature, and Concentration Study

Two of the inorganic acids tested in Stage II were carried over to Stage III and tested on both the ID-A and the ID-B soil. Stage III testing was designed to evaluate the effects of extractant concentration, temperature, dose rate, and extraction time on the amount of total uranium removed from the extracted solids. Sulfuric acid and nitric acid were tested at 1 and 2 N concentrations. Each concentration of acid was tested at 4:1 and 7:1 dose rates (20 and 12.5 percent solids respectively), two extraction times (0.5 and 2 hours) and two temperatures [ambient (approximately 20°C) and 40°C]. The test design consisted of a four by four matrix incorporating the two levels of each of the four variables. All tests were run as single replications and no statistical analysis was performed.

D.3.3.3 Stage II: Physical Separation and Chemical Extraction Tests

D.3.3.3.1 Test Objectives

The objective of this stage of testing was to combine the most favorable conditions from physical separation and chemical extraction testing into a sequential process and test its efficacy in removing uranium from soil. The testing of the combined process (physical separation and chemical extraction) was performed on dried "as received" soil. Since this stage of testing incorporated the use of a Denver Equipment Company (DECO) attrition mill (see Figure D.3-7), an initial test was conducted

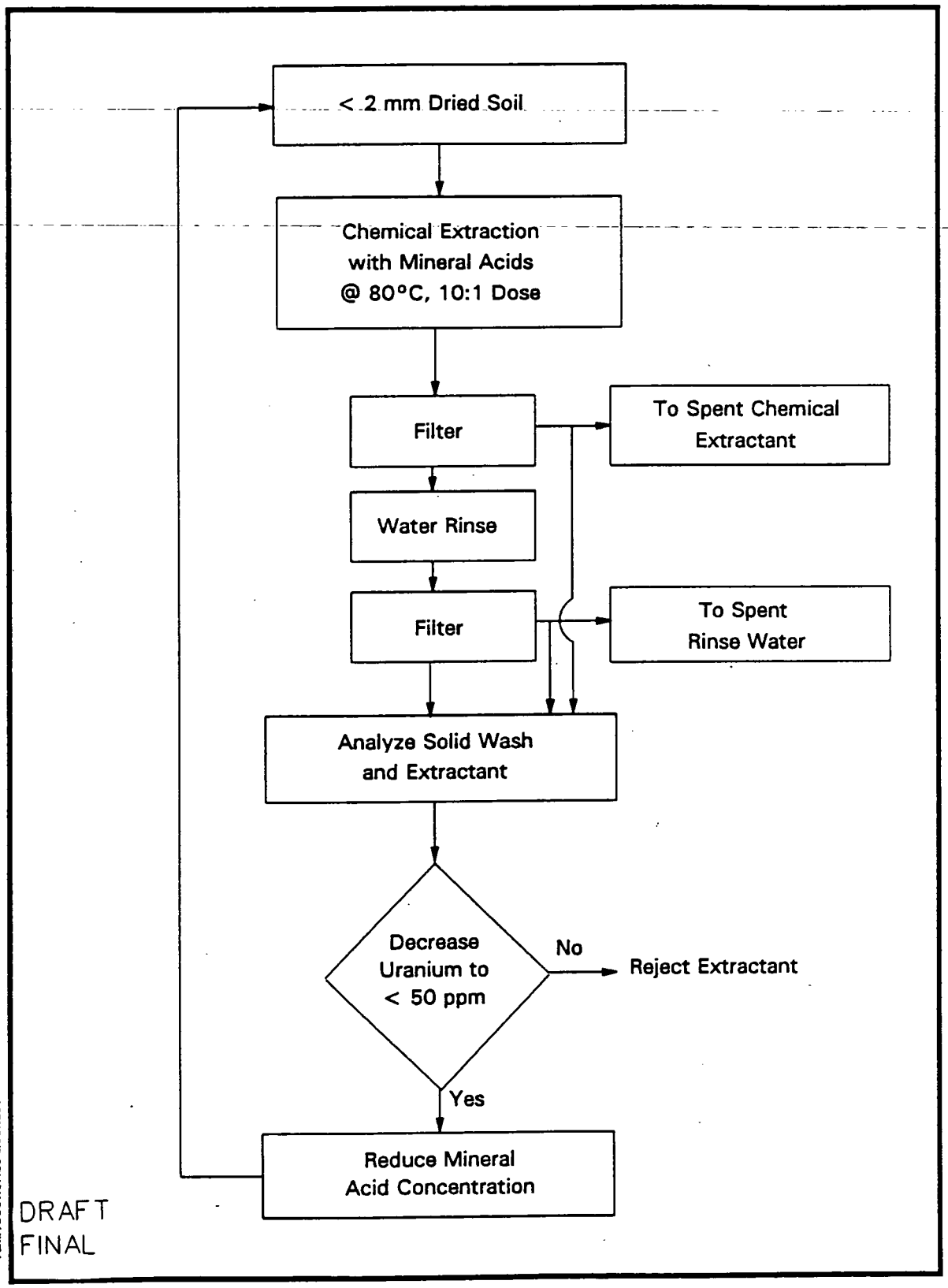

FIGURE D.3-6 - STAGE II OF REMEDY SCREENING TESTS FOR CHEMICAL EXTRACTION OF ID SOILS

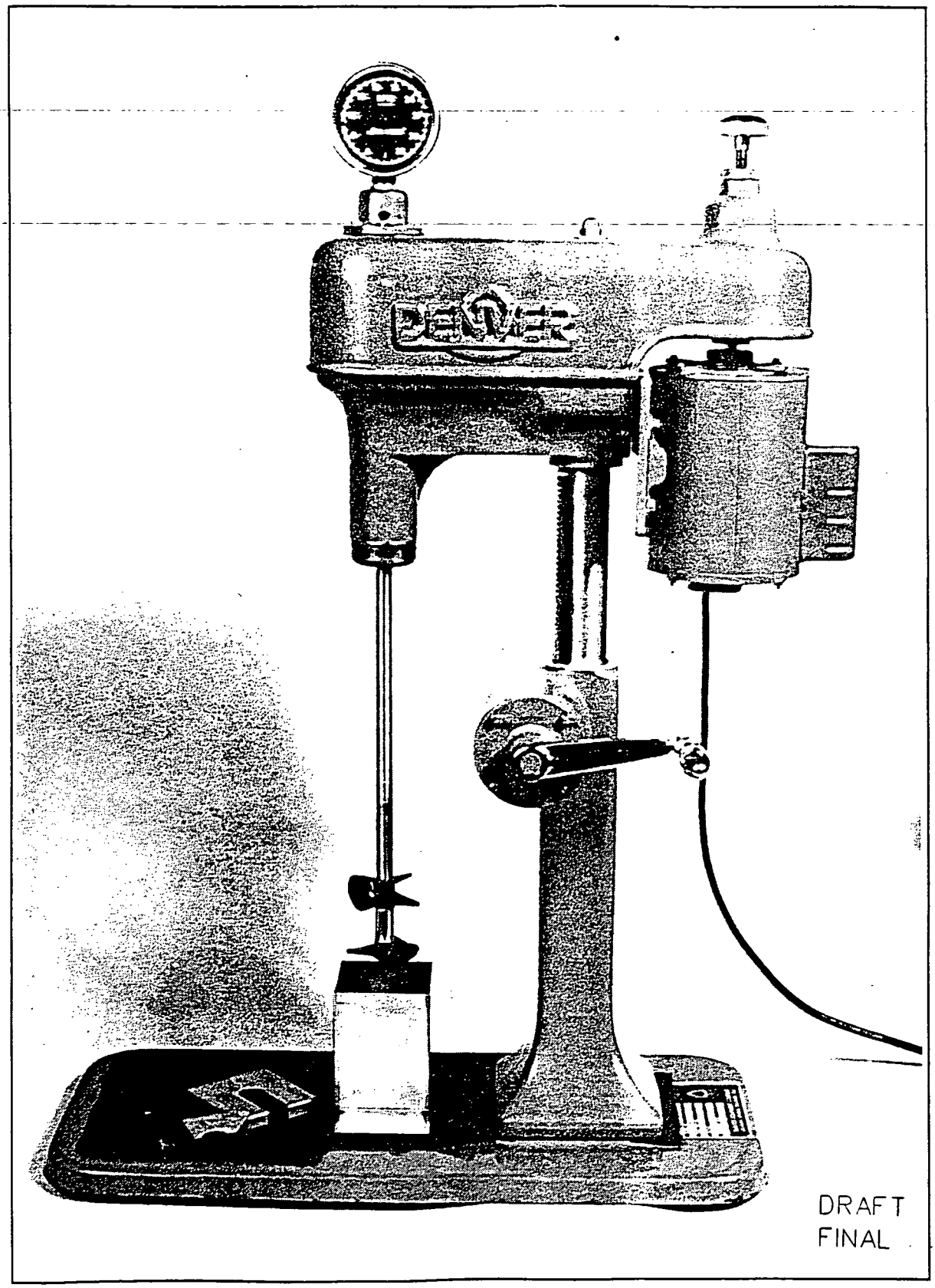

FIGURE D.3-7 - DENVER EQUIPMENT COMPANY ATTRITION MILL

to compare the use of a Hamilton Beach mixer with a DECO attrition mill and the effects of the two different mixing speeds on uranium concentration of both the ID-A and ID-B soil.

D.3.3.3.2 Experimental Design

Comparison Test

ID-A and ID-B soil were attrition scrubbed in both a Hamilton Beach mixer and a DECO attrition mill. The Hamilton Beach and the DECO mixers operate at 13,000 and 900 rpm, respectively. A 2:1 slurry was made by adding 200 g of dry less than 2 mm soil to 400 g 0.25 M Na_2CO_3/ $NaHCO_3$ solution.

Each soil slurry was mixed for 5, 15, and 30 minutes. The slurry was transferred to a Ro-Tap shaker to separate out the greater than 53 μm soil fraction. The less than 53 μm soil slurry was transferred to centrifuge tubes for phase separation. The greater than and less than 53 μm size fractions and the spent carbonate extractant were analyzed for total uranium.

Combined Test

The combined physical separation and chemical extraction test is illustrated in Figure D.3-8. Approximately 200 grams of "as received" ID-A and ID-B soil were attrition scrubbed with 400 grams of 0.1 M Na_2CO_3/$NaHCO_3$ for 15 minutes using the DECO attrition mill. The soil slurry was dewatered by centrifugation at 2500 rpm for 88 minutes. The liquid was decanted and the soil sampled and analyzed for total percent water, uranium by IC, and metals by ICP. The liquid and soil were analyzed for total uranium and metals. The remaining soil solids were divided into two approximately equal soil masses and subjected to chemical extraction. All attrition scrubbing tests were conducted in duplicate.

Each soil sample was extracted at a 4:1 and 7:1 extractant-to-soil ratio dose rate with 1 N sulfuric acid at 40°C for 30 minutes. Following extraction, the samples were centrifuged at 2500 rpm for 88 minutes. The resulting liquid was decanted off and the soil was dried at 100°C. The liquid and soil were analyzed for total uranium and ICP metals (Table D.3-3).

D.3.4 PILOT-SCALE TESTING

D.3.4.1 Phase I: CRU5 Soil Washing Demonstration Tests

D.3.4.1.1 Test Objectives

The intent of this Remedy Selection stage of testing was to demonstrate and evaluate the effectiveness of a soil washing process on two FEMP soil. The soil washing pilot plant's design and operation was based on findings from initial soil characterization efforts as well as extensive bench-scale testing. By demonstrating bench-scale findings on a pilot-scale system, this CERCLA/RCRA Unit 5 (CRU5) coordinated demonstration could be used to evaluate the performance effectiveness and cost effectiveness of a pilot-scale soil washing system for remediating FEMP soil.

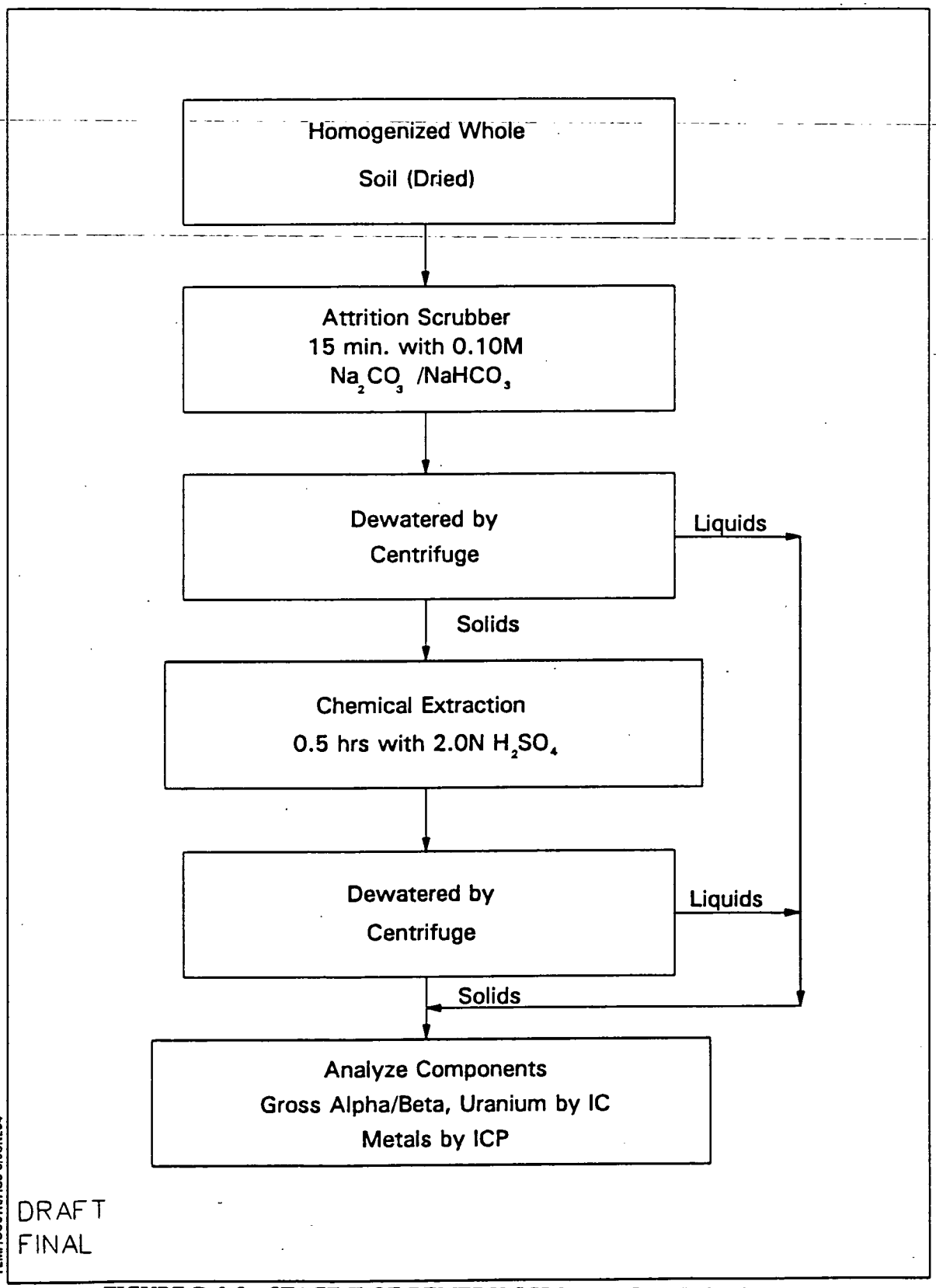

FIGURE D.3-8 - STAGE II OF REMEDY SCREENING TESTS FOR COMBINED PHYSICAL SEPARATION AND CHEMICAL EXTRACTION OF ID SOILS

TABLE D.3-3

ICP METALS ANALYZED FOR DURING COMBINED PHYSICAL SEPARATION AND CHEMICAL EXTRACTION TESTING

Silver (Ag)	Molybdenum (Mo)
Aluminum (Al)	Sodium (Na)
Arsenic (As)	Nickel (Ni)
Boron (B)	Lead (Pb)
Barium (Ba)	Antimony (Sb)
Beryllium (Be)	Thorium (Th)
Calcium (Ca)	Thallium (Tl)
Cadmium (Cd)	Uranium (U)
Copper (Cu)	Vanadium (V)
Iron (Fe)	Zinc (Zn)
Potassium (K)	
Magnesium (Mg)	
Manganese (Mn)	

D.3.4.1.2 Equipment Used in the Soil Washing Pilot Plant

The soil washing pilot plant was designed and constructed of standard processing equipment common to the mining industry. Equipment used in the soil washing system consisted of a conveyor, trommel, vibrating screen deck, attrition scrubber, centrifuge, filter press, holding tanks, and reactor vessels. The following is a brief description of each piece of equipment. A more detailed description of this equipment is provided in an internal report by the FERMCO Treatability Group, "Operational Procedure Report for the Fernald Soil Washing Pilot Plant Demonstration: Phase I."

Drum Handling Station and Conveyor - The drum handling station consisted of a drum handler and hoist to raise, lower, and move drums. Calibrated scales were used to record the weight of each drum, before and after the soil was loaded onto the conveyor. The conveyor transported contaminated soil from the drum emptying area to the trommel screen. The conveyor was rated at a maximum capacity of 160 tons per hour (tph) with an incline of approximately 15 degrees.

Trommel Screen with High Pressure Sprayer - The trommel screen was a rotating drum screen with 4.75 mm screen openings. Lifter bars were used to assist in breaking down soil aggregates. A spray bar was oriented along the inside top of the trommel to distribute the high pressure water [1,000 pounds per square inch (psi)] along the entire horizonal length of the rotating drum.

Vibrating Screen Deck - The modified Best duel screen deck used vibrational and oscillating forces to separate soil by particle size. The bi-level deck consisted of a top 2 mm (10 mesh) stainless steel screen and a bottom 0.3 mm (50 mesh) stainless steel screen. The deck was tilted 0.25 inches from front to back along the 60-in length.

Centrifuge - The Hysep Decanter MD43 horizonal duel-scroll centrifuge generated a maximum of 3000 gravity (g) force. The centrifuge, consisting primarily of a bowl and scroll, used differential speeds between the bowl and scroll to separate liquids from solids.

Attrition Scrubber - The attrition scrubber unit consisted of two 0.5 cubic foot cells in series. Each cell was equipped with opposed axial flow impellers (one at 100 percent pitch and the other at 150 percent pitch), which ran at low rpm. This differential in pitch resulted in a high impact zone between the propellers, creating an intense multiple grain-to-grain contact. The low rpm minimized any shearing action by the impellers on the soil particles.

Filter Press - The *SP* JWI plate and frame filter press had 6 cubic feet total volume capacity with a 3000 psi hydraulic closing mechanism. The unit consisted of twenty 0.3 cubic-foot chambers with polypropylene filter cloth-lined plates.

Processing Tanks - Most processing tanks were polyvinyl chloride (PVC) cone-bottom tanks with 0.25 inch thick fiberglass reinforced plastic (FRP) encasement. Tanks ranged in capacity from 50 to 500 gallons.

Chemical Extraction Reactor Vessel - The chemical extraction vessel was a glass-lined, closed-top, jacketed reactor. The working capacity was 500 gallons with a gross capacity of 578 gallons. The jacket capacity was 110 gallons with a heating area of 80 square feet. The reactor was equipped with a three retreat agitator.

Process Pumps

The majority of transfer operations used Wilden air driven diaphragm pumps. Aluminum pumps with Buna N diaphragms were used for the physical treatment; Kynar® pumps with Teflon® diaphragms were used for the chemical treatment. Three different models, the M-4, the M-8, and the M-15, were available in aluminum, while only the M-4 and M-8 were manufactured from Kynar®. Additional pumps used in the system were the Goulds model NPE centrifugal pump, a Pacer centrifugal pump, and a Masterflex B/T peristaltic pump.

Agitators/Mixers

Nettco mixers were used for all of the 500-gallon tanks except for the reactor vessel. The mixers were equipped with 1/2-hp motors, 1 inch diameter shafts, and three-blade propellers (10.5 inches in diameter). Propeller speed was 350 rpm. All tanks smaller than 500 gallons were equipped with portable Ligthnin mixers. These mixers are gear-driven models having impeller diameters of 11.2 inches.

D.3.4.1.3 Chemicals Used in the Soil Washing Pilot Plant

Aqueous reagent formulations of sulfuric acid and sodium carbonate/sodium bicarbonate were used in the washing solutions for the extraction of uranium from the different soil size fractions. Concentrated sulfuric acid was metered into the extraction vessel containing a soil-water slurry to achieve a 1 N acid extraction solution. Sodium carbonate/sodium bicarbonate was added in powder form to the processing tank during the attrition scrubbing part of the soil washing process. Twenty percent sodium hydroxide was added to spent sulfuric acid solutions to precipitate metals from the spent extraction solution. A Betz 1147L polymer was used at a 0.5 percent concentration to aid phase separation during the centrifugation of the soil/acid solution following the chemical extraction process.

D.3.4.1.4 Soil Washing System Design and Operation

The soil washing system design, a collaborative effort between IT Corporation and FERMCO, is illustrated in Figures D.3-9 through D.3-12. The system incorporated a combination of physical separation and chemical extraction processes for removing contaminants (primarily uranium) from

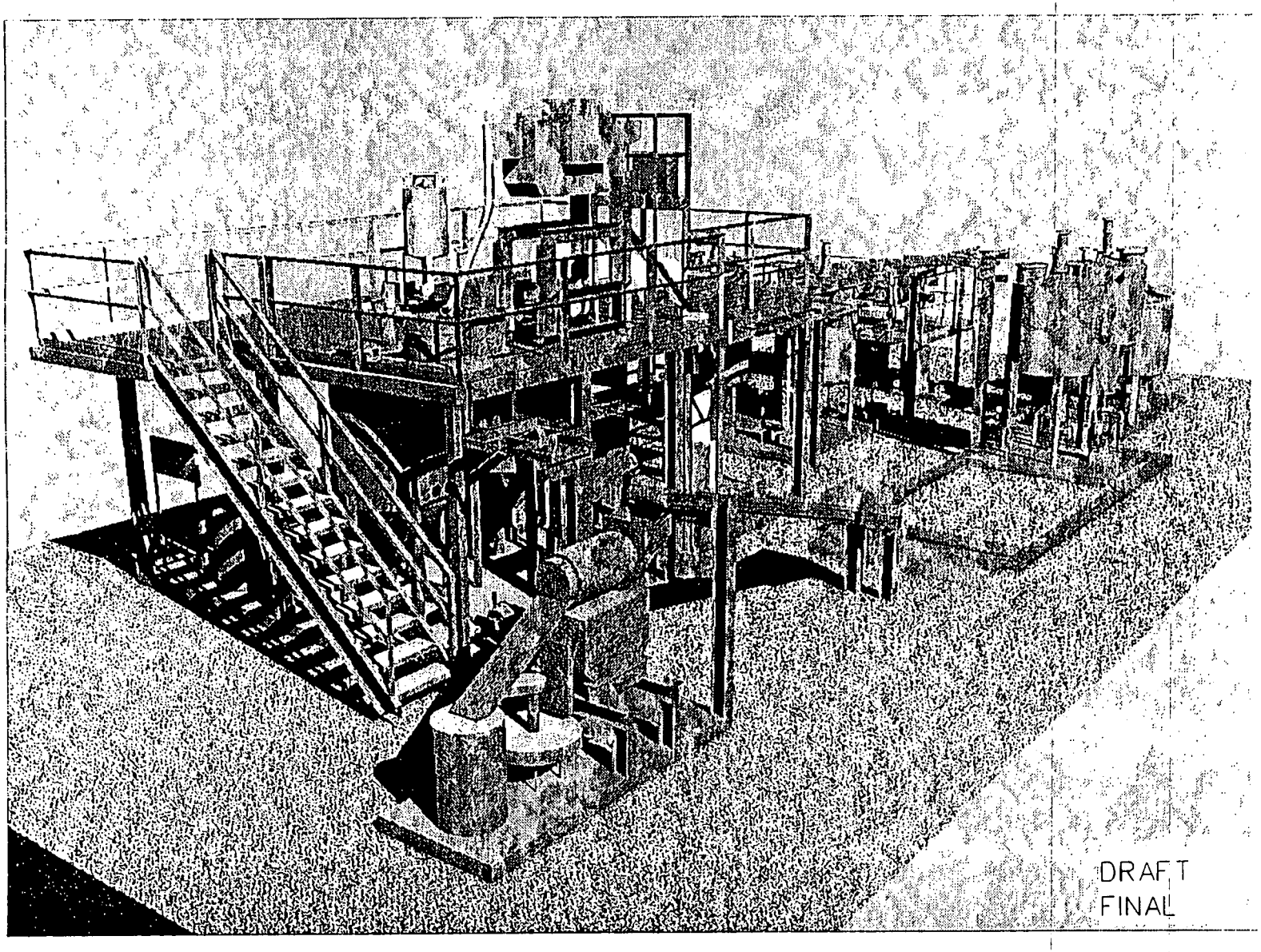

FIGURE D.3-9 - 3-DIMENSIONAL COMPUTER MODEL OF THE SOIL WASHING PILOT PLANT - VIEW 1

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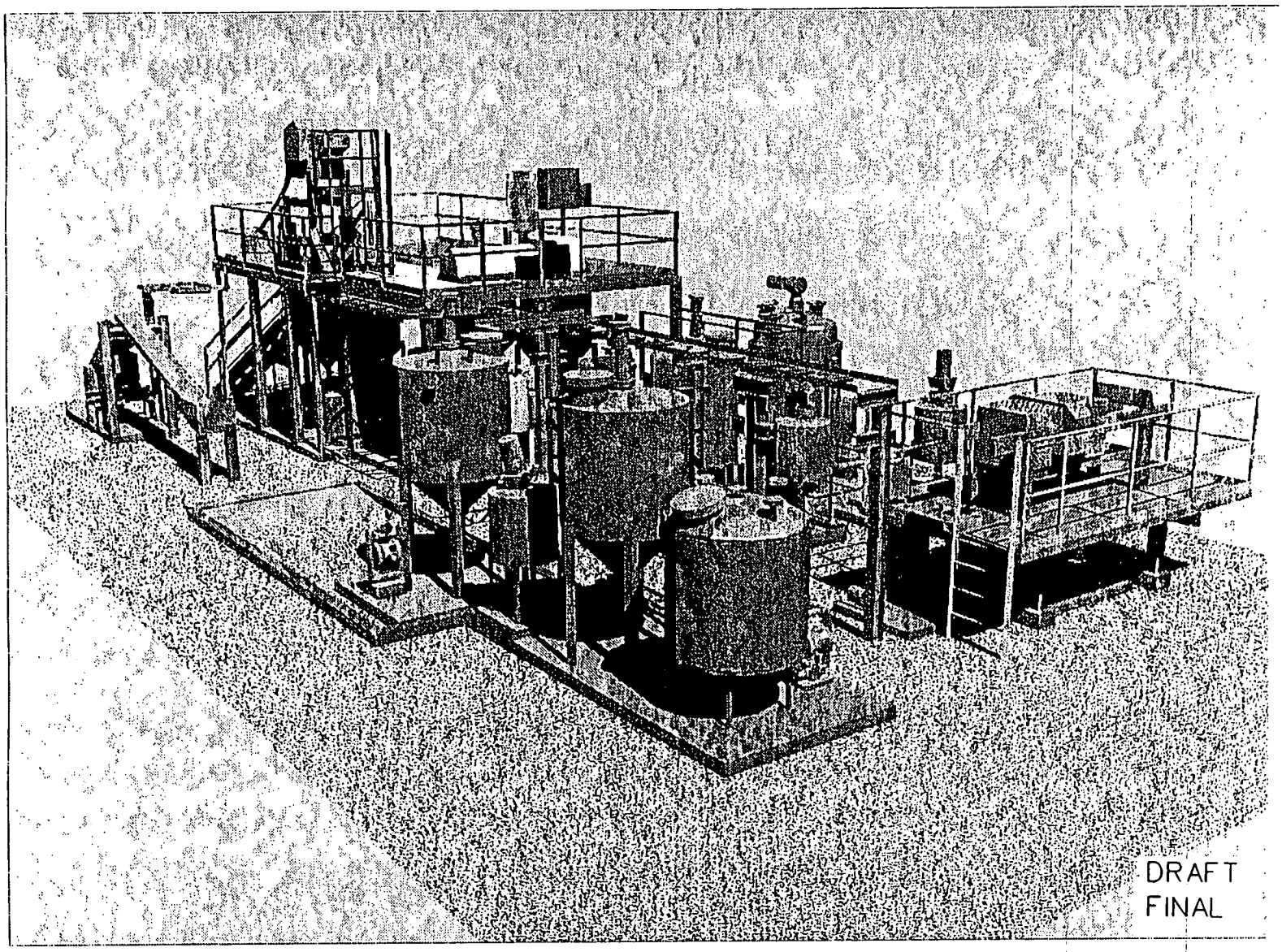

FIGURE D.3-10 - 3-DIMENSIONAL COMPUTER MODEL OF
THE SOIL WASHING PILOT PLANT - VIEW 2

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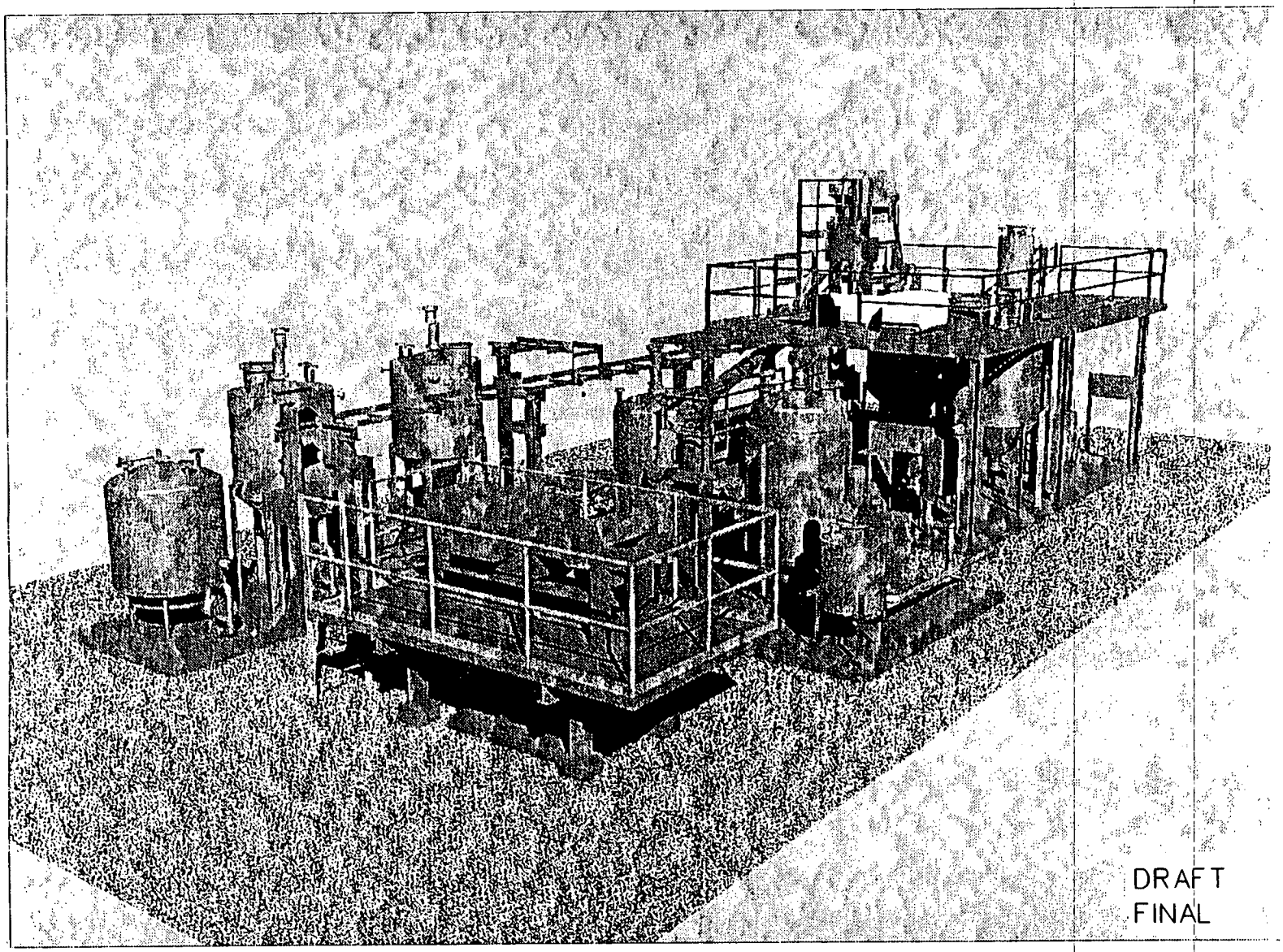

FIGURE D.3-11 - 3-DIMENSIONAL COMPUTER MODEL OF THE SOIL WASHING PILOT PLANT - VIEW 3

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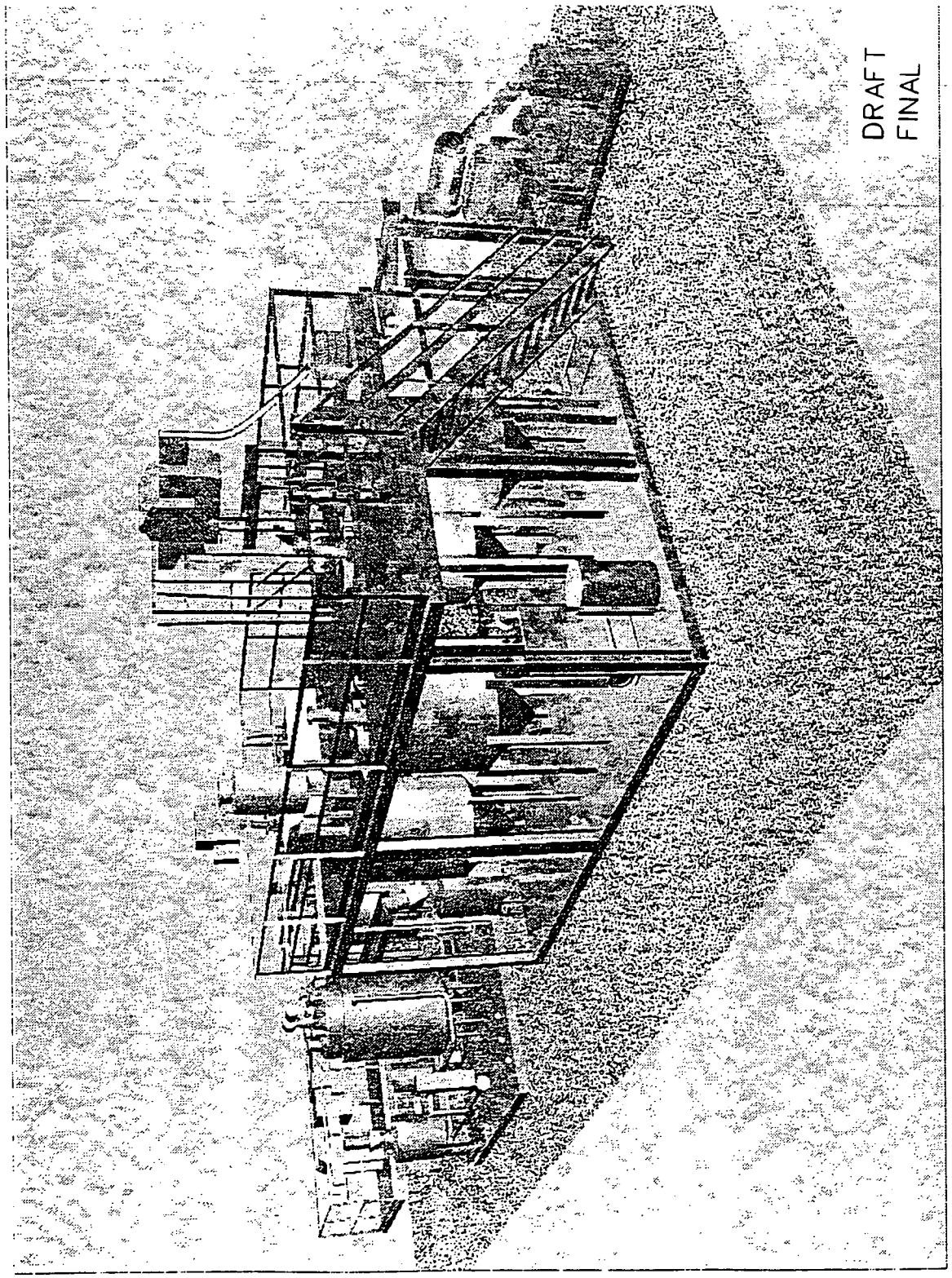


FIGURE D.3-12 - 3-DIMENSIONAL COMPUTER MODEL OF THE SOIL WASHING PILOT PLANT - VIEW 4

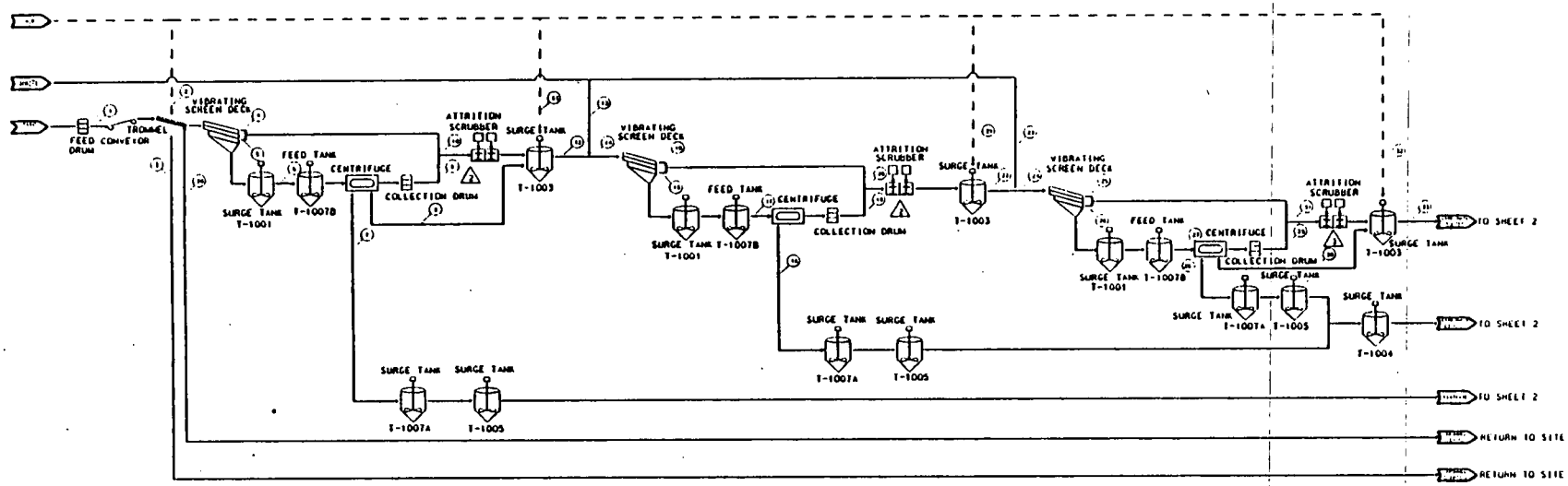
FEMP soil. The physical/chemical treatment processes initially separated the soil into different particle-size fractions and then used physicochemical extraction techniques to remove contaminants from each size fraction.

The process flow for the system was designed to treat soil that had been prescreened through a 19 mm screen. A representative process flow diagram (PFD) for the soil washing pilot plant is shown in Figures D.3-13 and D.3-14. The system was operated in batch mode during pilot-scale testing. A single 55-gallon drum of soil was processed through the system for each run of the entire process. Specific PFDs for each run are given in an internal report by the FERMCO Treatability Group, "Operational Procedure Report for the Fernald Soil Washing Pilot Plant Demonstration."

Soil was introduced into the system by transferring soil by hand from the drum onto the conveyor. This soil was conveyed to a trommel where high pressure water was used to break down soil aggregates in individual discrete gravel and soil particles and to remove clay particles from the surface of larger particles. The high pressure sprayer was maintained at a maximum pressure of 1,000 psi and 4 gallons per minute (gpm) flow rate. The retention time in the trommel, considered critical for proper aggregate dispersion and clay removal from the larger particles, was controlled by the rotational speed and angle of the trommel. Optimum conditions were 4 rpm at an angle between 1 and 2 degrees decline. High pressure water injected into the trommel was directed at the soil as it rolled up on the inner rotating screen and out of the slurry on the bottom of the trommel. This maximized direct contact of the spray with soil aggregates and minimized any buffering effect due to the pooling of water on the bottom of the trommel. The oversize gravel fraction (greater than 4.75 mm), predetermined to constitute less than 5 percent of the initial soil mass, was discharged as the first process stream (PS-1).

The undersize fraction passed through the trommel screen and was collected in a modified covered bowl pump, where it was transferred via a Wilden Kynar® M-8 diaphragm pump and 2 inch polypropylene SuperVac vacuum hoses as a slurry to the vibrating screen deck. Since the vibrating screen deck was not completely covered, the slurry was pumped to the screen deck at the slowest rate possible to avoid any splashes or spills. The air supplied (120 psi regulated) to the diaphragm pump was maintained below 20 psi.

The vibrating screen deck was designed with two decks of screens to produce three size fractions. The first 2 mm screen (10 mesh) retained the 4.75 to 2 mm soil size fraction. The second 0.3 mm screen (50 mesh) retained the 2 to 0.3 mm soil size fraction. The less than 300 μm slurry was collected below in a 500 gallon tank. Although the screens were removable and a different set of cuts could have been made, the selected cuts were considered optimum to enhance process operations. The 2 mm screen kept the lower 0.3 mm screen from blinding during the screening process, while the



NOTES:

1. ALL MATERIAL FROM THIS OPERATION CONSUMED BY SAMPLE
2. APPROXIMATELY ONE CUBIC FOOT OF MATERIAL ACCUMULATES IN ATTRITION SCRUBBER AT THIS OPERATION. NOT REFLECTED IN TOTAL MASS FOR SUBSEQUENT STREAM.
3. ATTRITION SCRUBBER EMPTIED AFTER THIS OPERATION.

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FIGURE D.3-13 - A PROCESS FLOW DIAGRAM FOR THE PHYSICAL SEPARATION OPERATIONS IN THE SOIL WASHING PILOT PLANT

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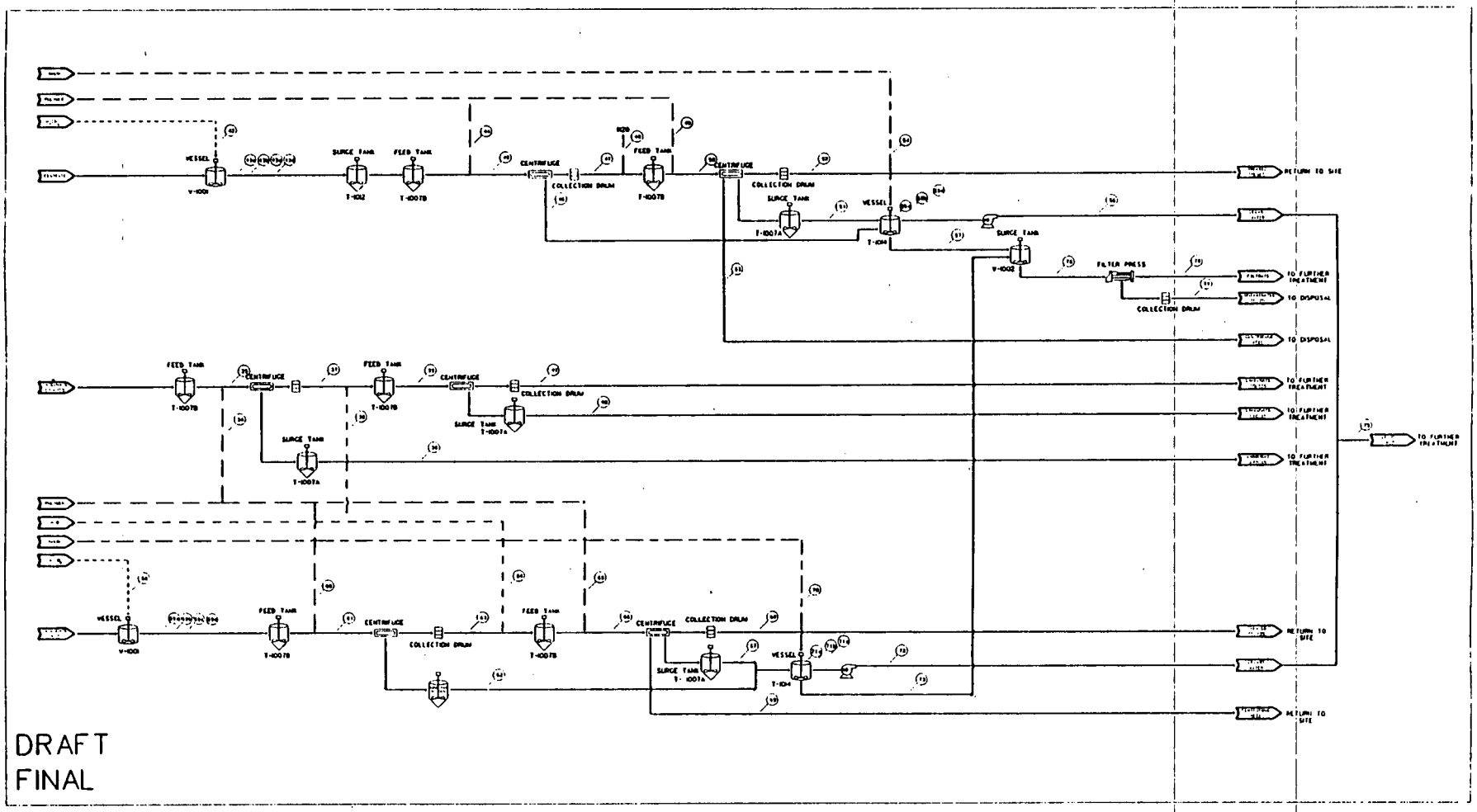

FIGURE D.3-14 - A PROCESS FLOW DIAGRAM FOR THE CHEMICAL EXTRACTION OPERATIONS IN THE SOIL WASHING PILOT PLANT

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0.3 mm cut was determined to be the maximum particle size obtainable during operation and also provided ware protection to the centrifuge from coarse particles. The deck was tilted 0.25 inches from front to back to allow the material to flow gravimetrically off the screen. This angle also provided enough retention time for effective separation of the material. This resulting soil fraction (4.75 to 0.3 mm) was collected and later combined with the solids from the centrifuge process before processing through the attrition scrubber.

The less than 0.3 mm soil slurry was pumped to the Hysep Decanter MD43 centrifuge at an about 5 gpm flow rate where the soil-water slurry was subjected to phase separation. The centrifuge provided continuous separation in a horizontal bowl which contained a double decanter system. From the center feed-pipe, the slurry was fed into the inner decanter where the initial separation and thickening of the slurry took place. Thickened slurry was then passed to the outer decanter where liquid and solids were separated. Solids scrolled out through the dry solids outlet and the overflow flowed back to its own outlet. During pilot plant operation, the centrifuge was configured to provide a bowl speed of 2041 rpm and a scroll speed of 2056 rpm at a differential of 15 rpm with 1100g force.

The objective of this design was to operate the centrifuge to obtain a 20 μm soil particle size cut. Two process streams were generated during this part of the process. The solids (estimated to be approximately 65 percent solids) from the centrifuge were estimated to contain soil particles in the 0.02 to 0.3 mm size range, were transferred to the attrition scrubbing part of the process. The centrate [soil-water slurry (ca. 5 to 10 percent solids)] resulting from the centrifugation process was estimated to contain the less than 0.02 mm soil particles and was pumped directly to the chemical extraction reaction vessel for acid extraction.

A 20-μm particle size separation using the centrifuge was a critical part of the design. First, soil separates greater than 20 μm are silt and sand particles. The attrition scrubber operates optimally on particles in the sand fraction (greater than 50 μm), while clay particles (less than 2 μm) have a tendency to buffer the attriting action. The silt particles (2 to 50 μm) which fall between the clay and sand particles in size but physically resemble the sand particles since they don't have a lattice structure like clays, were thought to behave like sand particles with respect to attrition scrubbing. Second, since uranium contamination was characterized to partially exist as oxide coatings on the coarser particles, attrition scrubbing with carbonate additives was considered to be the optimum method for surface removal. Third, since less than 15 percent of the soil solids were greater than 300 μm and in order to justify an attrition scrubbing step in the soil washing process, a more significant mass of soil needed to be directed to the attrition scrubber. By producing a particle size faction greater than 20 μm, approximately 50 percent of the soil could be directed to the attrition scrubber. Fourth, since the attrition scrubber operates optimally in the range of 60 to 70 percent

solids, the greater than 20 μm soil size fraction produced by the centrifuge was dewatered to approximately this range during phase separation.

The 0.02 to 0.3 mm soil from the centrifuge was combined with the 0.3 to 4.75 mm soil from the screen deck. This 0.02 to 4.75 mm size fraction, consisting of about 50 to 70 percent solids, was fed to the attrition scrubber. The solids were loaded into a feed box at the top of the first cell, flowed from the bottom of the first cell to the second cell, and exited at the top of the second cell through a flanged opening. Soil was fed in batches to allow a 15 minute retention time per cell. The solids overflowed into a 500-gallon tank. This first attrition scrubbing cycle did not contain sodium carbonate/bicarbonate. Once through the attrition scrubber, the solids were repulped in the 500-gallon collection tank using a 0.1 M sodium carbonate/bicarbonate solution. This repulping process with water facilitated slurry pumping and sodium carbonate/bicarbonate addition. This slurry was dewatered using the combined screen deck and centrifuge. This soil processing combination utilizing the screen deck, centrifuging, and attrition scrubber was repeated three times during each run. Sodium carbonate/sodium bicarbonate was added during the first and second repulping cycles. These solids were repulped with water following the third attrition scrubbing. This final soil slurry was transferred to the extraction vessel and reacted with concentrated sulfuric acid in a 1 N solution for one hour at 40°C. Although some residual sodium carbonate/bicarbonate remained in the soil slurry before acid extraction, sufficient concentrated sulfuric acid was metered into the extraction vessel (based on an estimate of the total volume of slurry in the extraction vessel) to achieve a 1 N solution.

Following the final extraction process step for this 0.02 to 4.75 mm size fraction, the slurry was transferred to the centrifuge for a final dewatering step. Polymer was added as the soil slurry entered the centrifuge to enhance flocculation of the suspended particles and aid in phase (solid-liquid) separation. Polymer flow rates varied from approximately 0.1 to 0.5 gpm during the 5 gpm extracted soil slurry flow rate.

The centrate (containing the less than 0.02 mm soil size fraction) initially coming off the centrifuge was pumped directly to the reactor vessel. Concentrated sulfuric acid was metered into the reactor vessel to achieve a 1 N H_2SO_4 solution. The slurry was reacted for one hour at 40°C. This process stream was estimated to contain approximately 30 percent of the initial soil mass. Following the extraction step, the slurry was pumped though the centrifuge for phase separation. Polymer was metered into the slurry as it entered the centrifuge to promote flocculation and aid solids separation. The solids generated during this phase separation were repulped with water as a rinse cycle and processed through the centrifuge again for phase separation. These solids (less than 0.02 mm soil particles) were collected as a final treated soil process stream. The centrate resulting from both centrifugation steps was collected and pumped to a precipitation reaction vessel.

The spent acid extractant and spent rinse water were precipitated with a 20 percent NaOH solution. The NaOH solution was metered into the precipitation vessel so that the precipitation process was performed in three stages: at pH values of 4.5, 7.5, and 9.5. Continuous agitation was conducted during the NaOH addition. The final solution was allow to stand for 24 hours. The supernatant was pumped from the tank and collected, while the solids were pumped to the filter press and dewatered. The filtrate and filter cake were collected.

D.3.4.1.5 Analytical Support

Analytical support was carried out on two levels during the operation of the soil washing pilot plant. In-house analyses were conducted by the FERMCO laboratory and outside analyses were conducted by contracted laboratories.

In-house analyses were directed at tracking soil mass and total uranium (the target analyte) throughout the soil washing process operation. This soil mass and uranium mass tracking supported the detailed description of process operations by mass balancing each run of soil through the soil washing pilot plant. Total uranium was determined by the BrPADAP method. In addition to total uranium, pH, percent solids, and percent moisture were determined during many of the process operations.

Each run of soil through the soil washing system generated six primary process streams. These process streams included four processed (treated) soil, solids, a residue, and spent extractant solution. These primary process streams were analyzed by a Contract Laboratory Program laboratory to provide specified analytical support level (ASL) analyses of final process streams for all COCs (Table D.3-1). Since no VOCs or SVOCs were determined in the initial characterization (Attachment II), only radionuclides, inorganic analytes and PCBs were analyzed for in each of the final process streams.

D.3.5 ADDITIONAL SOIL WASHING PROCESS TESTING FOR OTHER COCs

D.3.5.1 Test Objectives

The intent of this additional remedy selection stage of testing was to demonstrate and evaluate the effectiveness of a bench-scale simulated soil washing process on additional FEMP soil. The OU5-A soil had been the only soil of the three soil initially characterized to contain other COCs besides uranium. However, the OU5-A soil contained minimal quantities of a limited number of COCs; Therefore, an additional nine soil were collected to test in bench-scale soil washing process.

A simulated soil washing process was designed to provide a combination of residence time and reactor conditions that would be expected in the actual soil washing process as described in the Conceptual Design Report for CRU5. The three original soil and the nine additional soil (AS) tested

were selected to test the soil washing process on a variety of soil containing a range in contaminants of concern (COCs) at the FEMP.

D.3.5.2 Experimental Design and Procedures

D.3.5.2.1 Location of Additional Soil (AS) for Testing

Nine additional locations within the FEMP were determined, based to RI data, to have soil containing other COCs. The following is a list of the soil and the areas within the FEMP from which the soil were collected:

- AS-1 - Plant 9 (archive sample)
- AS-2 - Plant 2/3 (archive sample)
- AS-3 - Plant 6 (archive sample)
- AS-4 - Pilot Plant
- AS-5 - Graphite Furnace
- AS-6 - Paddy's Run
- AS-7 - KC-2 Warehouse
- AS-8 - Decontamination and Demolition (D&D) Facility
- AS-9 - Building 77/79

D.3.5.2.2 Preparation and Initial Characterization of Additional Nine Soil

The AS-1, AS-2, and AS-3 soil were soil that had been collected during RI sampling and archived in glass jars sealed with Teflon™ lined caps. Soil for each of the AS samples were combined by location and air dried for approximately 24 h. The soil were passed through a 2 mm screen. The greater than 2 mm aggregates were broken down using a mortar and pestle and passed through a 2 mm screen. All less than 2 mm soil was combined and homogenized by the quartering method. A single aliquot of the homogenized less than 2 mm soil was sent to a contracted laboratory for initial characterization which included analysis for radionuclides, inorganics (metals), SVOCs, VOCs, PCBs, and pesticides. Analytical results are contained in Attachment III.

The AS-4, AS-5, AS-6, AS-7, AS-8, and AS-9 soil were specifically collected from their respective location (Section 3.5.2.1) for this additional bench-scale treatability testing. Exact areas within the defined locations were determined according to the procedure described in Section 6.0 of the TSWP. Two-foot square areas were excavated to a depth of six inches. The soil was passed through a 4.75 mm screen and placed into 5 gallon metal buckets. These soil were transferred to the laboratory, air dried, passed through a 2 mm screen, and homogenized. The greater than 2 mm aggregates were broken down using a mortar and pestle and passed through a 2 mm screen. A single aliquot of the homogenized less than 2 mm soil was sent to a contracted laboratory for initial characterization which included analysis for radionuclides, inorganics (metals), SVOCs, VOCs, PCBs, and pesticides. Analytical results are contained in Attachment III.

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Based on the initial characterization, certain soil were selected for additional testing. These soil were selected based on two characteristics. Soil that had total uranium concentrations different than the ID-A, ID-B and OU5-A soil were selected to increase of range in uranium concentrations over which the soil washing process could be evaluated as to its effectiveness in removing uranium. Soil were also selected if additional COCs were detected so as to evaluate the effectiveness of the soil washing process on soil contaminated with other constituents besides uranium. The three additional soil were selected were AS-3, AS-4 and AS-7. The Plant 6 soil (AS-3) was selected because of the high levels of total uranium. The pilot plant soil (AS-4) was selected due to the presence of other COC, including radionuclides and metals. The KC-2 Warehouse soil (AS-7) was selected because of the low concentration of total uranium.

D.3.5.2.3 Simulated Soil Washing System Test

The bench-scale soil washing test incorporated a test procedure that was modeled after the preliminary CRU5 CDR flow diagram of the proposed soil washing system. This mock-run of the soil washing process was designed around selected operational parameters that simulated processing condition, e.g., temperature, soil to extractant ratio, staging time during processing operations, and rinse cycles.

Sodium Carbonate/Sodium Bicarbonate System

During the testing of the carbonate simulated soil washing system, 600 g of each soil was combined with 1200 mL of a 0.5 M sodium carbonate/sodium bicarbonate solution in a 2.2 L Teflon bottle. The soil-extractant slurry was shaken for approximately 1 min, and placed into a constant-temperature water bath at 40°C for 2 h. The bottle was removed from the bath and the slurry mixed using a Yamato mixer at low rpm or an attrition scrubber for 1 h at ambient temperature (approximately 25° C). The bottle was placed back into the water bath at 40°C for 2 h. The slurry was transferred to 1 L polyethylene bottles and centrifuged at 2500 rpm for 15 min. The supernatant was decanted and the solids repulped with 600 mL of potable water. The slurry was centrifuged at 2500 rpm for 15 minutes and the supernatant decanted. This rinsing (repulping) procedure was repeated for a total of two rinse cycles.

Sulfuric Acid System

During the testing of the acid simulated soil washing system, extraction, 1200 mL of potable water was added to 600 g of soil in a 2.2 L Teflon bottle. The soil-extractant slurry was shaken for approximately 1 min, and placed into a constant-temperature water bath at 40°C for 2 h. The bottle was removed from the bath and the slurry mixed using a Yamato mixer at low rpm for 1 h at ambient temperature (approximately 25°C). During this stage of mixing, concentrated sulfuric acid was added to the slurry to achieve a pH of 1.5 to 2.0. The bottle was placed back into the water bath at 40°C for 2 h. The slurry was transferred to 1 L polyethylene bottles and centrifuged at 2500 rpm for 15 min. The supernatant was decanted and the solids repulped with 600 mL of potable water. The

slurry was centrifuged at 2500 rpm for 15 minutes and the supernatant decanted. This rinsing (repulping) procedure was repeated for a total of two rinse cycles.

D.3.5.3 Equipment and Materials

The simulated soil washing system set up in the FERMCO treatability laboratory, was designed to simulate operational parameters proposed in the PFD for a full-scale soil washing system. The simulation focused mostly on reaction time, soil:extract or soil:rinse water ratios, extraction temperature, chemical extractant concentration, and rinse cycles. The equipment used in the laboratory testing consisted of 2.2 L Teflon reactor bottles, constant-temperature water bath, and an International Equipment Company (IEC) Model K centrifuge for solid-liquid phase separation.

D.3.5.4 Sampling and Analysis

All analyses were conducted by a contracted laboratory for a full radiological, inorganic and organic Yanalytes. Soil samples collected for initial characterization were aliquoted from the 5-gallon buckets containing the homogenized soil from each location. Only one sample was analyzed for the AS-1 through AS-3 soil. The AS-4 through AS-9 soil were analyzed in duplicate. A single replication was analyzed for all extracted soil.

D.3.5.5 Data Management

All data from contracted laboratory analyses, received by FERMCO, was entered directly into the FACTS system following data validation. Validated data was electronically transferred from the FACTS to the Sitewide Environmental Database (SED). Total data reports and summary data reports, contained in the attachments, are generated directly from the SED.

D.4.0 RESULTS AND DISCUSSION

D.4.1 INITIAL CHARACTERIZATION

Attachments II and IV contain the initial characterization results for the twelve soil used in soil-washing treatability testing. Table D.4-1 lists the 12 soil, acronym identifier, initial total uranium concentration, and whether other COCs were present. Figure D.4-1 shows the location of the 12 soil within the FEMP. Total uranium values were calculated from isotopic U-238 using a conversion constant for activity to concentration of 2.98. Total uranium concentrations for the ID-A, ID-B, and Operable Unit 5-A soil are for composite samples taken from the 55-gallon drums. Selected quantities of these three soil were taken from these prepared drummed soil and further homogenized and characterized before use in bench-scale testing. The ID-A, ID-B, and Operable Unit 5-A soil were used in bench-scale testing conducted at an IT laboratory. ID-A and ID-B soil were used in pilot-scale testing at the FEMP. The remaining nine soil (AS-1 through AS-9) were used solely for additional bench-scale testing in support of an investigation of a wider range of FEMP soil with a wider range of COCs and total uranium concentrations. All twelve soil were used in additional bench-scale testing conducted at the FEMP during the final stages of treatability testing.

D.4.2 BENCH-SCALE TESTS

D.4.2.1 Physical Separation Tests

D.4.2.1.1 Initial Analysis and Characterization Soil

Soil from two of the five sites investigated in the characterization report by Lee and Marsh (1992) were selected for use in bench-scale tests. These soil were initially considered to be representative of the soil/contaminant matrix found on the FEMP site. Geotechnical characteristics of the two soil are presented in Table D.4-2. The most interesting aspect to these soil, considering that physical separation treatment is being investigated as the primary mechanism for soil/contaminant separation and ultimately volume reduction, is the high silt (0.053 - 0.002 mm) and clay (less than 0.002 mm) content. Both soil are comprised of approximately 60 percent silt and 15 percent clay.

Initial average total uranium concentrations were determined by analyzing six aliquots each of the final homogenized whole soil. The ID-A and ID-B soil were determined to have 497.6 [standard deviation (SD) equals 60.3] and 450.8 (SD equals 36.6) mg kg^{-1} total uranium, respectively. This compared favorably to the 538 and 446 mg kg^{-1} total uranium values for the ID-A and ID-B whole soil analyzed in a parallel treatability study conducted by the ORNL (Francis et al., 1993).

Different methods for digestion and analysis of uranium in soil can contain a certain amount of inherent variability. The ORNL noted three analytical methods for determining total uranium in FEMP soil samples. The three methods, neutron activation, wet digestion, and radiocounting, produced values of 538, 470, and 543 mg kg^{-1}, respectively, for the ID-A soil and 446, 387, and

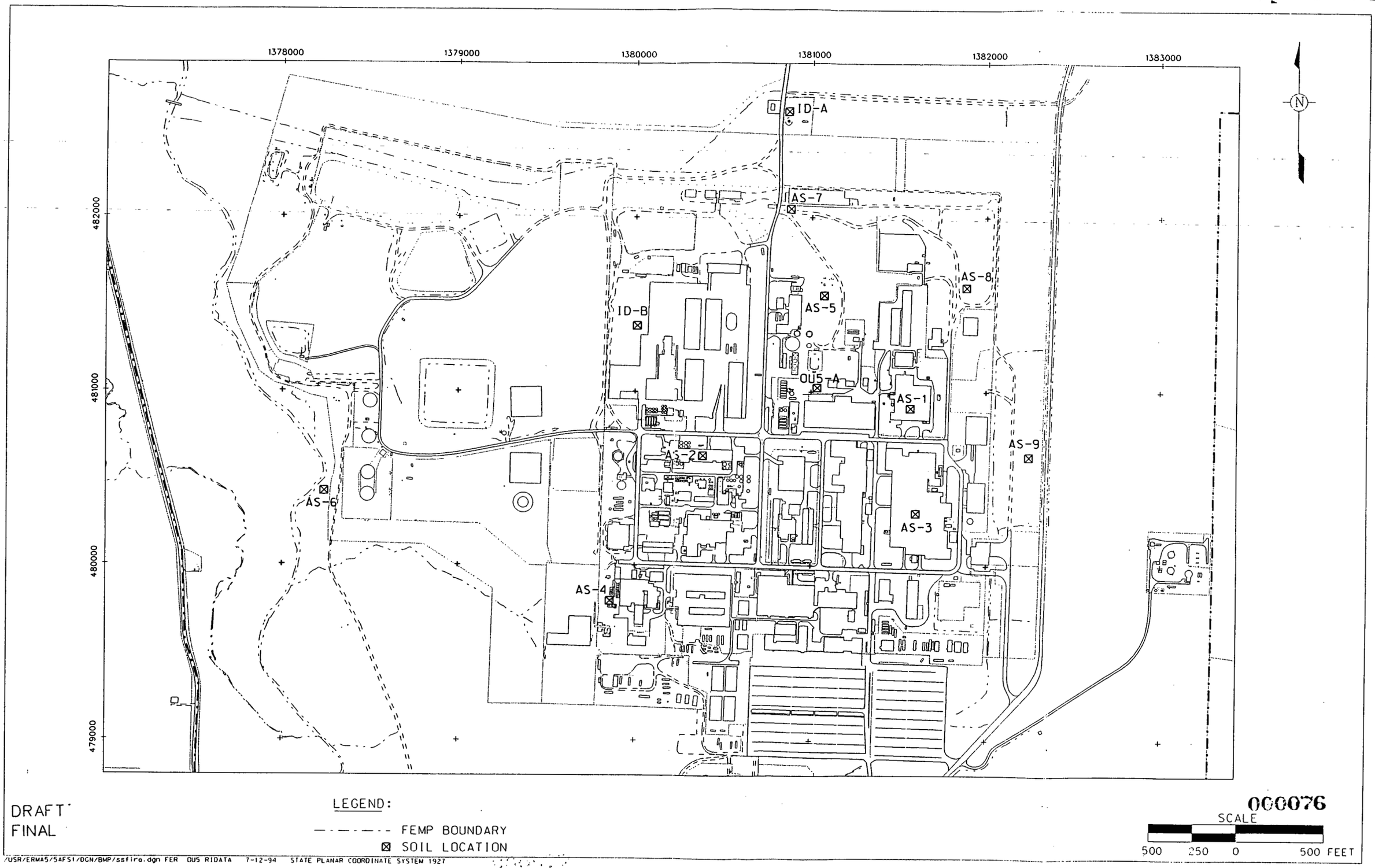

FIGURE D.4-1 MAP OF THE FEMP SHOWING LOCATION OF TWELVE SOILS USED IN TREATABILITY TESTING

TABLE D.4-1

LIST OF TWELVE SOILS SHOWING LOCATION WITHIN THE FEMP, ACRONYM IDENTIFIER, INITIAL TOTAL URANIUM CONCENTRATION, AND WHETHER OTHER COCs WERE PRESENT

Soil Acronym	Soil Location	Total Uranium (mg/kg^{-1})	Other COCs Present?
ID-A[a]	Incinerator	499	No
ID-B[a]	Plant 1 Storage Pad	536	No
OU5-A[a]	Maintenance Building	199	Yes
AS-1	Plant 9	190	No
AS-2	Plant 2/3	254	No
AS-3	Plant 6	1490	No
AS-4	Pilot Plant	85	Yes
AS-5	Graphite Furnace	98	No
AS-6	Paddys Run	27	No
AS-7	KC-2 Warehouse	52	Yes
AS-8	D&D Facility	52	Yes
AS-9	Building 77/79	54	No

[a] Initial total uranium values for drum soil; values will vary from initial values determined for individual amounts used in selected treatability testing

TABLE D.4-2

GEOTECHNICAL PARAMETERS FOR ID-A AND ID-B SOIL RECEIVED BY THE LABORATORY FROM THE FEMP SITE

Soil Separates	Parameter	Analytical Methods	Soil Location: ID-A Incinerator Soil	Soil Location: ID-B Plant 1 Pad Soil
Gravel	>2 mm (%)	ASTM[c] D 422	4.6	2.1
Sand	2 mm - 0.05 mm (%)	ASTM D 422	18.0	23.3
Silt	0.05mm - 0.002 mm (%)	ASTM D 422	62.4	58.6
Clay	<0.002mm (%)	ASTM D 422	15.0	16.0
	Specific gravity	ASTM D 854	2.67	2.74
	Liquid Limit	ASTM D 4318	26.0	34.0
	Plasticity Index	ASTM D 4318	8.0	18.0
	CEC[a] (meq[b]/100 g)	SW-846[d] (9081)	19.3	19.2
	Water Content (%)	ASTM D 2216	21.8	14.1

[a] CEC - Cation Exchange Capacity
[b] meq - milliequivalents
[c] ASTM - American Society of Testing Materials
[d] EPA SW-846 - Test Methods for Evaluating Solid Waste

421 mg kg^{-1}, respectively, for the ID-B soil (Francis, et al. 1993). Initial total uranium concentration values of 497 and 451 mg kg^{-1} determined in this bench-scale work, using wet digestion with IC detection, compares favorably to the values for whole soil from the parallel treatability study conducted by ORNL.

The concentration and distribution of uranium within the various size fractions for the ID-A and ID-B soil are given in Table D.4-3. Soil were shaken for 30 minutes in a 4:1 potable water to soil slurry. Low particle size load values for total uranium in the 19 to 9.5 mm and 9.5 to 2 mm particle size fractions were noted for ID-A (3.2 and 6.3 mg kg^{-1}, respectively) and ID-B (0 and 2.1 mg kg^{-1}, respectively) soil. Since the percentage of total uranium contributed by these two size fractions for both soil was relatively insignificant, subsequent tests involving the effectiveness of various dispersants as extracting reagents were focused only on the less than 2mm soil size fractions. Particle size load values for total uranium among the sand, silt, and clay size fractions ranged from 64.9 to 195 mg kg^{-1} for ID-A and 54.4 to 171 mg kg^{-1} for ID-B.

D.4.2.1.2 Chemical Dispersant/Extractant Study

Four sodium reagents used as dispersants were compared to potable water on their effectiveness in deflocculating aggregates and removing uranium from each of the resulting soil size fractions. The ID-A and ID-B soil used in the study had initially been dry screened through a 2-mm sieve. Table D.4-3 shows the percentage of soil in each size fraction resulting from potable water and the 1 M dispersing solutions. Comparison of the particle distribution in this table with those values derived from the ASTM standard analytical method (see Table D.4-1) indicates some discrepancy for individual textural classes, particularly the sand and clay fractions. Since the data in Table D.4-1 is considered to be the baseline geotechnical data for the two whole soil, the low percentage of sand for the ID-A soil is considered an anomaly and probably results from of the initial drying and sieving procedures (Section 2.2). The low clay content for all solutions except CBD is considered to result from the inability for those solutions or the 30-minute shake procedure to provide complete dispersion of the aggregates.

The distribution of uranium among the size fractions for both soil indicate that simple physical separation, even with a dilute chemical dispersing solution, does not result in any size fraction that has an acceptably low concentration of uranium. The uranium concentration is highest in the sand and clay fractions for the ID-A soil and the clay fraction for the ID-B soil. One of the most important factors relative to uranium distribution in these two soil is that the silt fraction, which constitutes nearly two-thirds of the soil mass, contains uranium concentrations between 250 and 300 mg kg^{-1}, regardless of the dispersing solution. This is well above an acceptable uranium level for treated soil.

Table D.4-4 contrasts the effects of potable water and dispersing solutions (the values are averaged across the four dispersants tested) on the concentration and distribution of uranium in the three size fractions for the less than 2 mm ID-A and the ID-B soil. The use of dispersants increased the percent of the siltfraction while decreasing the percent sand fraction, indicating an enhanced effect on aggregate dispersion. The loading factor for uranium also seems to have shifted from the sand and silt fractions in both soil to the clay fraction as a result of the dispersing solutions. In the case of the ID-A soil, the uranium load value for the sand fraction decreased from 460 to 182 mg kg^{-1} by using dispersing solutions. The uranium load values in the clay fraction of the ID-B soil increased from 79 to 192 mg kg^{-1} with the addition of dispersing reagents.

The effect of using a sodium reagent on the distribution of uranium among the three size fractions is shown in Table D.4-5. The shift in uranium contribution by size fraction from sands to the clays indicates a redistribution of uranium or uranium-bearing particles (e.g., clay films). After using water, 61.9 percent of the uranium remained with the ID-A soil sand fraction while only 4.8 percent was associated with the ID-A soil clay fraction. However, with the use of dispersants, only 36.9 percent of the uranium was associated with the sand fraction while 18.5 percent was now associated with the clay fraction. This is also evident in the ID-B soil, where the amount of uranium associated with the clay fraction increased from 25 percent to 45.1 percent.

D.4.2.1.3 Attrition Scrubbing Tests

The results of the dispersant/extractant tests provided distribution characteristics for uranium relative to individual particle size fractions; however, these tests did not identify any soil fraction for either the ID-A or ID-B soil that reduced uranium to acceptable residual levels. In an effort to simulate physical separation processes common to the soil washing technology, alkaline reagents were combined with mechanical mixing and tested for their effectiveness in removing uranium from the soil.

Attrition scrubbing tests were conducted on the less than 2 mm size fraction for ID-A and ID-B soil using water and three alkaline extraction solutions common to the uranium mining and processing industry: sodium carbonate/sodium bicarbonate, ammonium carbonate/ammonium bicarbonate, and sodium pyrophosphate. The test design was structured to target extractant, extraction solution concentration, and attrition scrubbing time effects on uranium and activity removal from two soil size fractions (less than 0.053 mm and greater than 0.053 mm).

ID-A Soil

Figures D.4-2 through D.4-4 illustrate the effect of alkaline extractants on removing uranium from two size fractions of the ID-A soil. Figure D.4-2 shows the effect of the sodium pyrophosphate

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TABLE D.4-3

CONCENTRATION AND DISTRIBUTION OF TOTAL URANIUM IN SELECTED PARTICLE SIZE FRACTIONS USING A SOIL/WATER SLURRY[a] FOR ID-A AND ID-B HOMOGENIZED WHOLE SOILS FROM THE FEMP SITE

Soil Location	Particle Size Distribution	% Fraction in Size Distribution	Uranium Concentration (mg/kg^{-1})	Particle Size Load (mg/kg^{-1})	% Uranium Contribution by Size Fraction
ID-A Incinerator Area	Whole Soil	NA[b]	497	NA	NA
	19 - 9.5 mm	20.1	16	3.2	0.8
	9.5 - 2 mm	1.5	420	6.3	1.6
	2 mm - 0.053 mm	12.5	1028	128	32.2
	0.053 mm - 0.002 mm	61.5	317	195	49.1
	<0.002mm	4.4	1475	64.9	16.3
ID-B Plant 1 Pad Area	Whole Soil	NA	450	NA	NA
	19 - 9.5 mm	0.0	0	0	0.0
	9.5 - 2 mm	3.1	66	2.1	0.6
	2 mm - 0.053 mm	28.8	189	54.4	14.9
	0.053 mm - 0.002 mm	61.8	223	138	37.8
	<0.002mm	6.3	2710	171	46.7

[a] 4:1 potable water to soil slurry shaken for 30 minutes.

[b] NA - Not applicable.

TABLE D.4-4

PARTICLE SIZE DISTRIBUTIONS AND URANIUM CONCENTRATIONS FOR THE LESS THAN 2-MM ID-A AND ID-B SOILS RESULTING FROM WATER AND FOUR 1MM DISPERSING REAGENT SOLUTIONS[a]

		Soil Size Fraction (mm)					
		2 - 0.053		0.053 - 0.002		<0.002	
Soil Location	Dispersing Reagent	Soil Fraction (%)	Uranium Concentration (mg/kg^{-1})	Soil Fraction (%)	Uranium Concentration (mg/kg^{-1})	Soil Fraction (%)	Uranium Concentration (mg/kg^{-1})
ID-A Incinerator Area	H_2O	23.3	1970	72.6	340	4.1	883
	NaOH	11.6	1566	83.0	265	5.4	1303
	Na_2CO_3	9.4	1610	85.8	267	4.8	2017
	$NaHCO_3$	9.3	2202	85.6	300	5.1	1295
	CBD	10.7	1713	78.3	227	11.0	913
ID-B Incinerator Area	H_2O	38.4	228	55.1	273	6.5	1219
	NaOH	27.6	231	66.4	270	6.0	2293
	Na_2CO_3	28.3	214	67.3	247	4.4	3577
	$NaHCO_3$	27.1	248	68.6	279	4.3	3244
	CBD	28.1	186	56.3	281	15.6	999

[a] Solutions were 1:4 soil/dispersing solution ratios shaken for 30 minutes.

TABLE D.4-5

CONCENTRATION AND DISTRIBUTION OF URANIUM IN THE THREE SIZE FRACTIONS OF THE LESS THAN 2MM ID-A AND ID-B SOILS USING WATER AND DISPERSANTS

Soil Location	Particle Size Distribution	% Fraction in Size Distribution	Uranium Concentration (mg/kg^{-1})	Particle Size Load (mg/kg^{-1})	Uranium Contribution by Size Fraction
		Water			
ID-A Incinerator Area	2 mm - 0.053 mm	23.3	1970	460	61.9
	0.053 mm - 0.002 mm	72.6	340	237	33.3
	<0.002 mm	4.1	883	35	4.8
ID-B Plant 1 Pad	2 mm - 0.053 mm	38.4	228	87	27.6
	0.053 mm - 0.002 mm	55.1	273	150	47.4
	<0.002 mm	6.5	1219	79	25.0
		Dispersing Solutions (Averaged)			
ID-A Incinerator Area	2 mm - 0.053 mm	10.3	1773	182	36.9
	0.053 mm - 0.002 mm	83.1	264	220	44.6
	<0.002 mm	6.6	1382	91	18.5
ID-B Plant 1 Area Pad	2 mm - 0.053 mm	27.8	219	61	14.3
	0.053 mm - 0.002 mm	64.6	269	173	40.6
	<0.002 mm	7.6	2528	193	45.1

concentration and attrition scrubbing time on uranium concentration for the less than 0.053 mm and greater than 0.053 mm soil.

The most striking feature about Figure D.4-2 is the large difference in uranium concentration between the two size fractions. The greater than 0.053 mm (sand) fraction contains roughly four to six times the concentration of uranium than the less than 0.053 mm (silt and clay) size fraction. However, only 18 percent of the ID-A soil falls within the sand fraction (Table D.4-3).

Increasing the concentration of dispersant generally resulted in a decreasing concentration of uranium within all attrition scrubbing times. The effect was most pronounced for the greater than 0.053 mm soil fraction during the 5 minute attrition scrubbing test. The graph illustrates an overall similar effect within all attrition scrubbing times for both soil fractions. Holding the extractant concentration constant, a similar pattern exists for attrition scrubbing time, where increasing the attrition scrubbing time increases the amount of uranium removed.

One can evaluate an optimum set of conditions for removing uranium while minimizing concentration and scrubbing time by proceeding from the far back corner of the graph (least aggressive conditions) diagonally forward towards the front corner of the graph (most aggressive conditions). Sands seem to reach optimum operation conditions at about 15 minute extraction time for the 0.25 M concentration. This means that little uranium is further removed by increasing scrubbing time to 30 minutes or extractant concentration to 0.5 M. Although less pronounced, the same scenario exist for the silt and clay fractions.

Figure D.4-3 illustrates the effect of ammonium carbonate/bicarbonate concentration and attrition scrubbing time on uranium concentration of the two soil fractions for the ID-A soil. Five minutes of scrubbing in a 33 percent solids slurry and water resulted in the sand fraction at approximately 1500 mg kg^{-1} uranium and the silt and clay fraction at 250 mg kg^{-1}. Increasing scrubbing time to 15 minutes and carbonate concentration to 0.25 M decreased uranium concentration in the sand fraction to 571 mg kg^{-1}. Increasing scrubbing time to 30 minutes and extractant concentration to 0.5 M only reduced uranium concentration from 571 to 526 mg kg^{-1} (8 percent). The effect of ammonium carbonate/bicarbonate on the less than 0.053 mm soil fraction was once again less pronounced. The best effect was achieved by simply increasing the extractant concentration to 0.25 M. This reduced uranium concentration in the silt and clay fractions from approximately 250 to 145 mg kg^{-1}, approximately 40 percent.

The pattern for uranium extraction from the sand fraction using sodium carbonate/bicarbonate (Figure D.4-4) is not as defined as for the other extractants. Still, the 0.25 M concentration was one of the most effective; however, it required 30 minutes of attrition scrubbing. The results for the less than

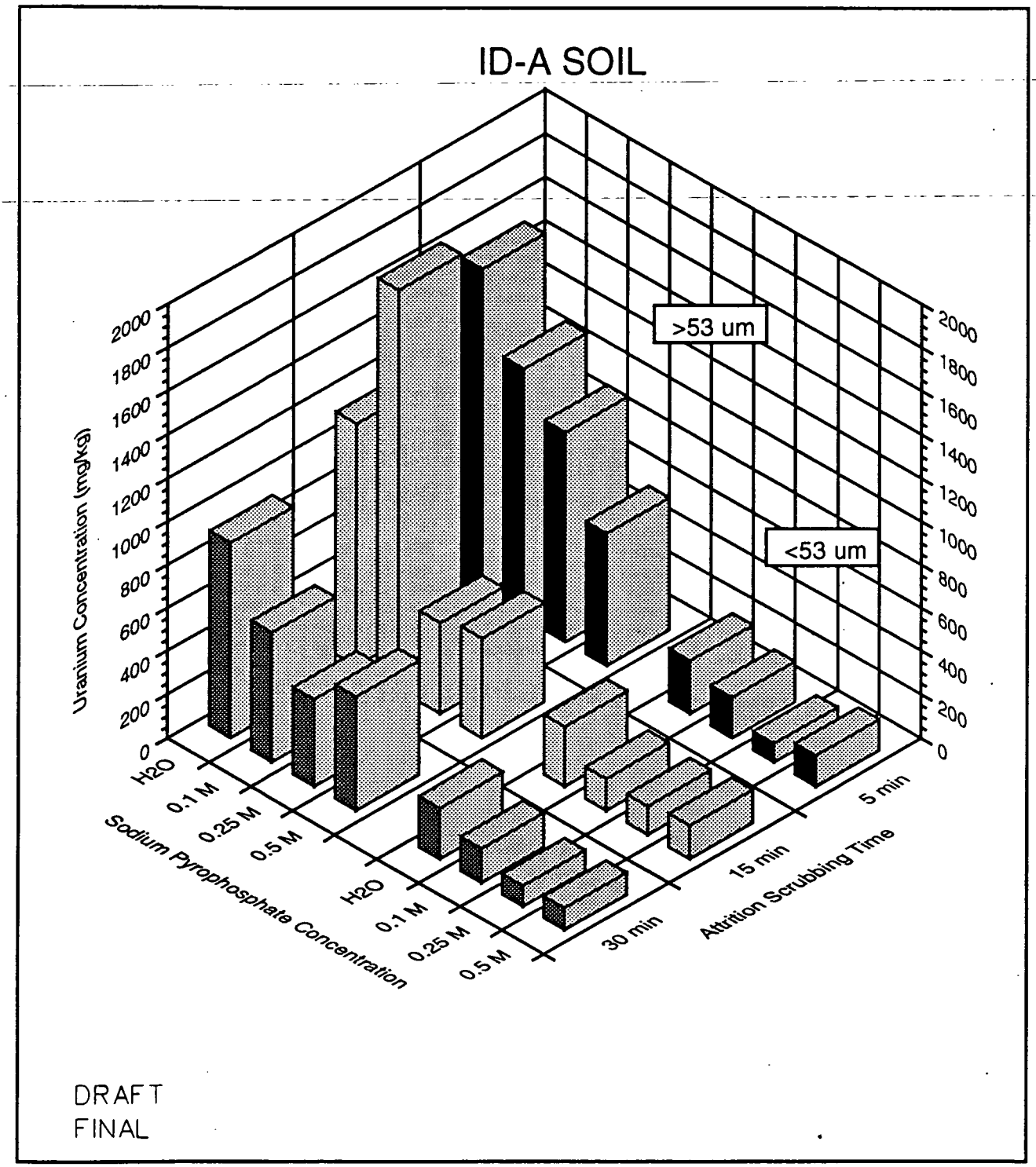

FIGURE D.4-2. THE EFFECT OF SODIUM PYROPOSPHATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-A SOIL.

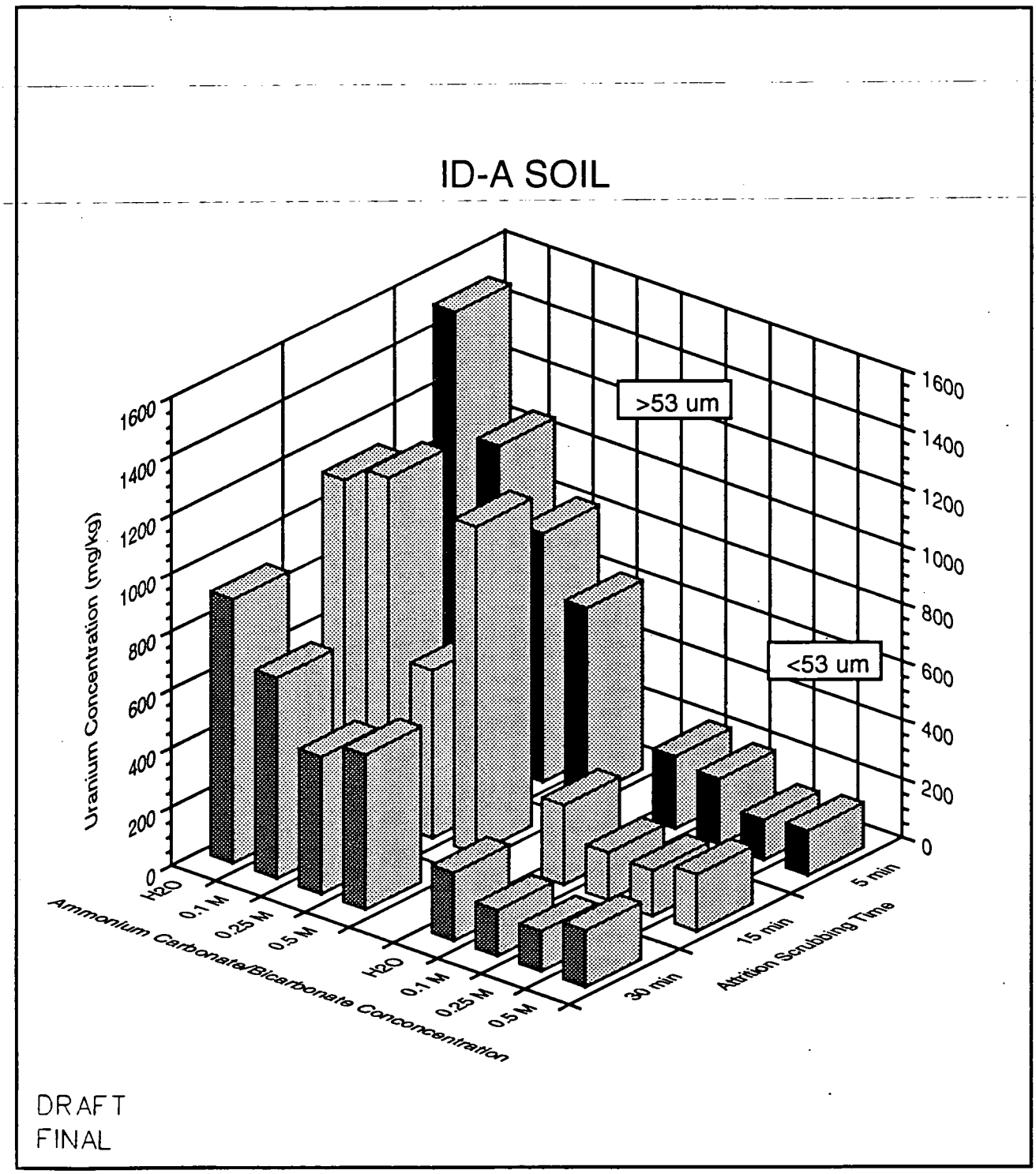

FIGURE D.4-3. THE EFFECT OF AMMONIUM CARBONATE/BICARBONATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-A SOIL.

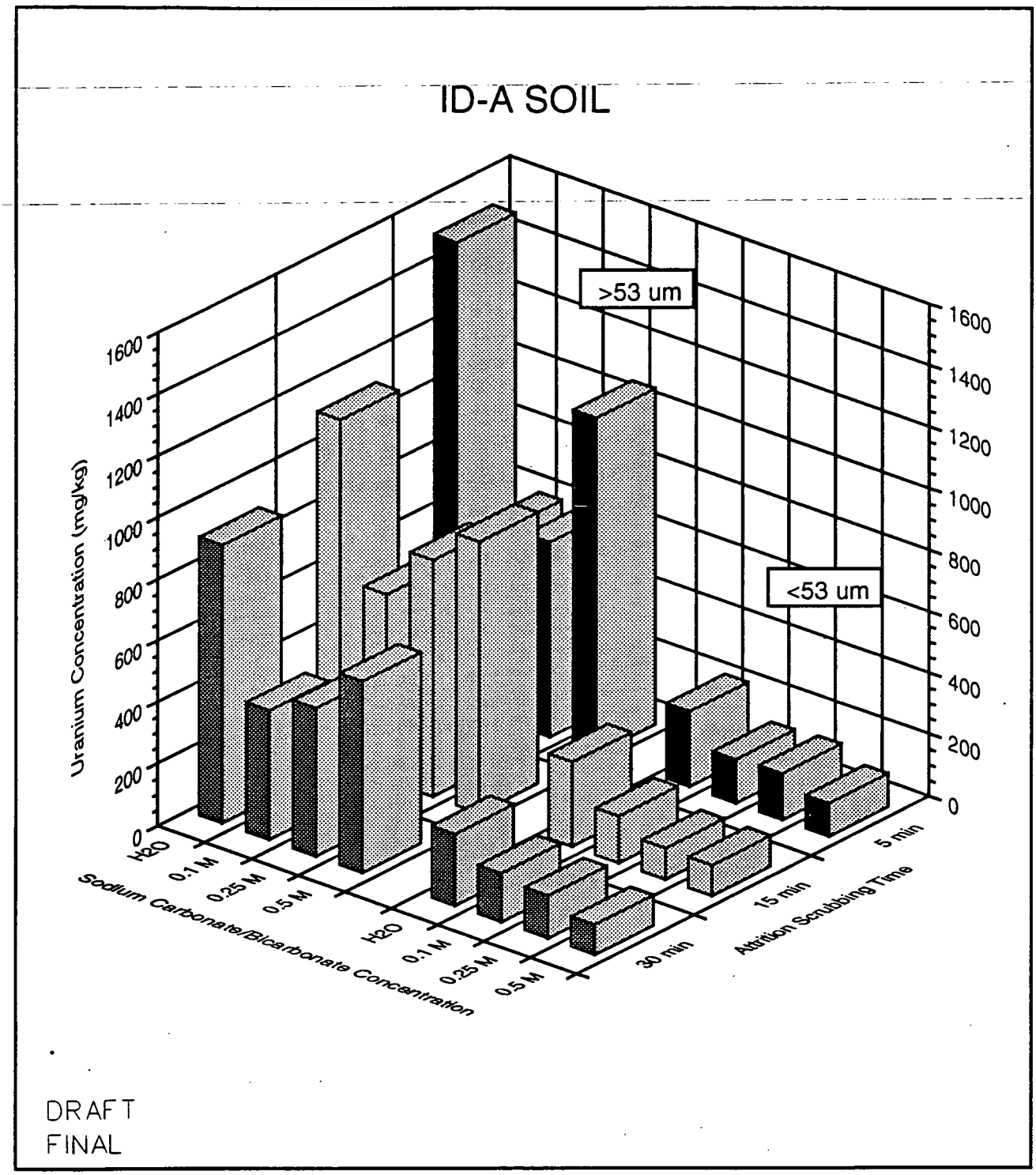

FIGURE D.4-4. THE EFFECT OF SODIUM CARBONATE/BICARBONATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-A SOIL.

0.053 mm soil fraction were similar in pattern to the previous two extractants. Nearly 60 percent of the uranium was removed by a 0.25 M solution during 15 minutes of scrubbing.

ID-B Soil

Figures D.4-5 through D.4-7 illustrate the effect of alkaline extractants on removing uranium from two size fractions of the ID-B soil. The ID-B soil, much like the ID-A soil, has a low amount of sand (23 percent) and a high amount of silt (58 percent) and clay (16 percent). Comparison of the data for the ID-B soil with the ID-A soil brings out one very prominent feature; the high levels of uranium are associated with the less than 0.053 mm soil fraction, rather than the greater than 0.053 mm soil. The uranium concentration in the silt and clay fraction is on an average approximately two to three time the uranium level on the sand fraction. Also, the levels of uranium concentration within any size fraction does not exceed 500 mg kg^{-1}. These two features clearly illustrate the differences between the two soil relative to the effectiveness that physical separation and chemical extraction treatments might have.

Figure D.4-5 shows the effect of sodium pyrophosphate concentration and attrition scrubbing time on uranium concentration for the less than 0.053 mm and greater than 0.053 mm size fraction for the ID-B soil. Attrition scrubbing time had no effect on either soil fraction with water. Increasing the concentration of dispersant generally resulted in a decreasing concentration of uranium within all attrition scrubbing times for both soil size fractions. The effect was most pronounced for the less than 0.053 mm soil fraction during the 5 minute attrition scrubbing test, where the uranium concentration was reduced from 330 to 65 mg kg^{-1}, a reduction of almost 80 percent. The graph illustrates an overall similar effect within all attrition scrubbing times for both soil fractions.

Once again, one can evaluate an optimum set of conditions for removing uranium while minimizing concentration and scrubbing time by proceeding from the far back corner of the graph (least aggressive conditions) diagonally forward towards the front corner of the graph (most aggressive conditions). Both soil fractions seem to reach optimum operation conditions at about 15 minutes extraction time for the 0.25 M concentration.

Figure D.4-6 illustrates the effect of ammonium carbonate/bicarbonate concentration and attrition scrubbing time on uranium concentration of the two soil fractions for the ID-A soil. Little difference was noted for 5 minute attrition scrubbing, regardless of extractant concentration. However, when the scrubbing time was increased to 15 minutes, a 0.1 M solution was very effective, removing almost 78 percent of the uranium. The effect of ammonium carbonate/bicarbonate on the greater than 0.053 mm soil fraction was less pronounced, with an overall average reduction of only about 20 to 30 percent, regardless of attrition scrubbing time or extractant concentration The pattern for uranium extraction from the silt and clay fractions using sodium carbonate/bicarbonate (Figure D.4-7) is

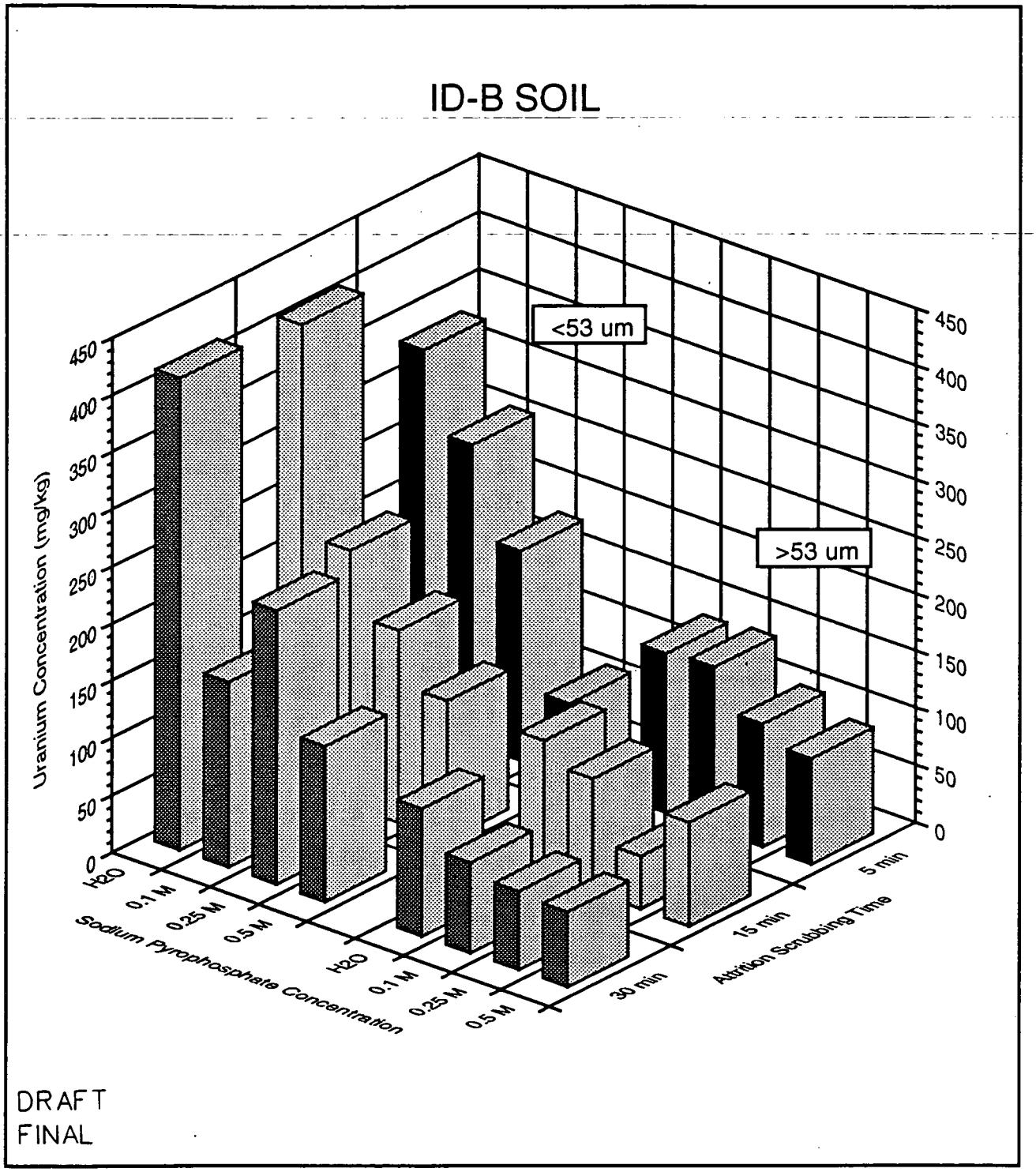

FIGURE D.4-5. THE EFFECT OF SODIUM PYROPOSPHATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-B SOIL.

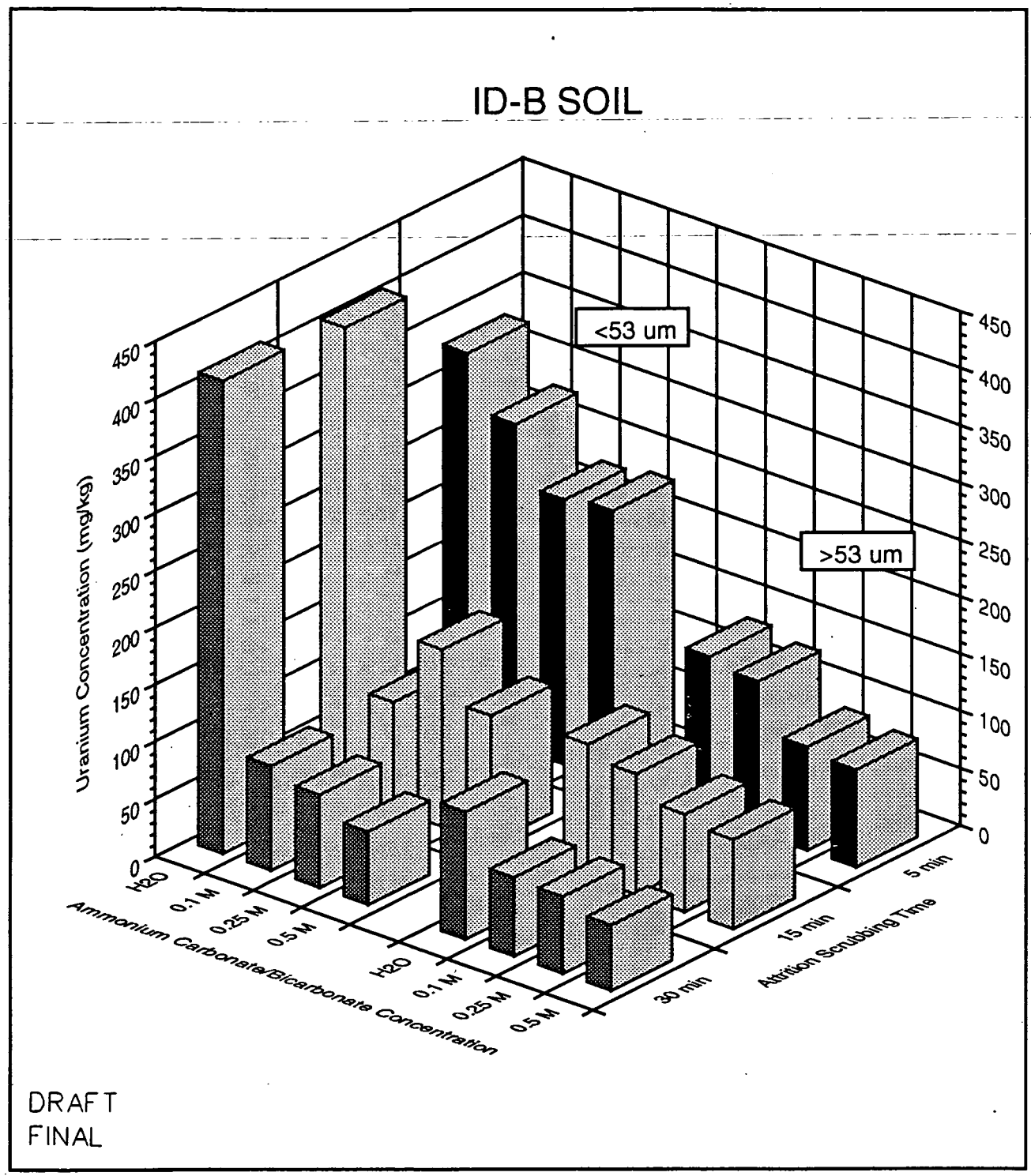

FIGURE D.4-6. THE EFFECT OF AMMONIUM CARBONATE/BICARBONATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-B SOIL.

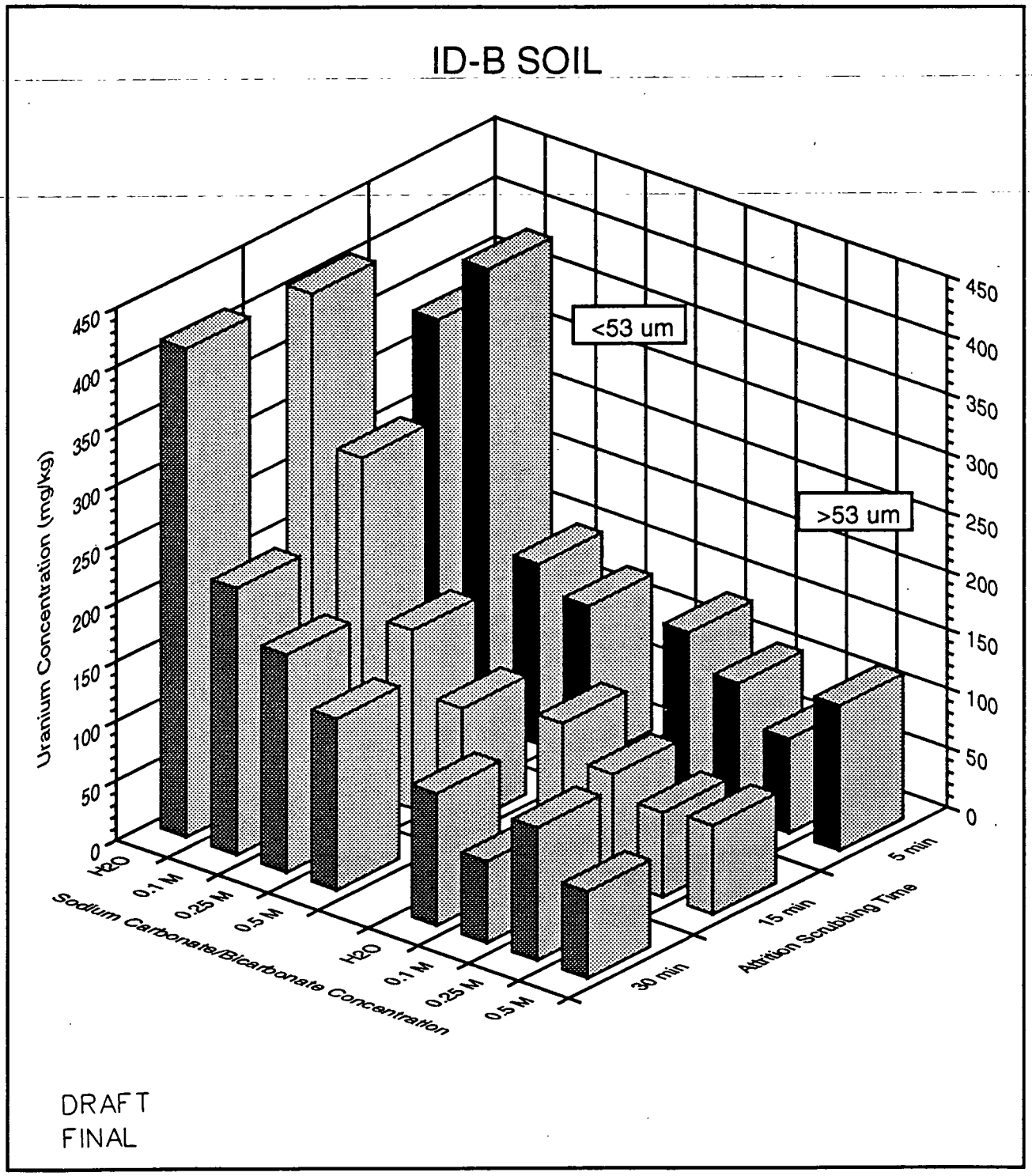

FIGURE D.4-7. THE EFFECT OF SODIUM CARBONATE/BICARBONATE CONCENTRATION AND ATTRITION SCRUBBING TIME ON URANIUM CONCENTRATION OF TWO PARTICLE-SIZE FRACTIONS FOR ID-B SOIL.

similar to the other extractants. Still, the 0.25 M concentration and 15 minute scrubbing time was one of the most effective for the both soil fractions.

D.4.2.2 Chemical Extraction Tests

D.4.2.2.1 Initial Analyses and Characterization of Soil

An initial analysis and characterization of two soil considered to be representative of the soil/contaminant matrix found at the FEMP site was conducted before their use in bench-scale chemical extraction tests. Initial total uranium concentrations for ID-A and ID-B soil described in Section D.4.2.1.1 were 497 and 451 kg^{-1}, respectively. Total uranium did not preferentially reside with any single size fraction but was distributed throughout the sand, silt, and clay for both soil. Due to the distribution of total uranium among all particle size fractions and the corresponding particle size loads, the less than 2 mm soil was used in chemical extraction tests.

D.4.2.2.2 Stage I: Initial Screening of Chemical Extractants

Twelve chemical extractants were tested on their effectiveness in removing uranium from the less than 2 mm size fraction for ID-A and ID-B soil. Relatively aggressive conditions were selected to first evaluate each chemicals effectiveness. Figure D.4-8 illustrates the concentration of uranium in ID-A and ID-B soil solids following chemical extraction at 80°C, 1:10 dose rate (10 percent solids), 4-hour extraction time, and highly concentrated extractants. The chemical extractants that were most effective at removing total uranium from the less than 2mm size fraction for both soil were the inorganic acids.

Nitric, hydrochloric, phosphoric, and sulfuric acids reduced uranium concentration in the soil solids from 497 mg kg^{-1} to 4.9, 23.4, 13.1 and 14.0 mg kg^{-1}, respectively, for ID-A soil. The inorganic acids were also the most effective chemical extractants for the ID-B soil and reduced uranium concentration in the soil from 451 mg kg^{-1} to 2.3, 3.2, 4.8 and 13.4 mg kg^{-1} for the respective acids. The only other extractant that was effective on ID-A soil was EDTA at pH 10, which reduced uranium to less than 50 mg kg^{-1}. Sodium carbonate, ammonium carbonate, and sodium hydroxide were more effective on the ID-B soil than on the ID-A soil. These extractants reduced total uranium concentration in ID-B soil to 25.5, 29.1 and 29.1 mg kg^{-1}, respectively. EDTA was more effective at the high pH range (pH 10 and pH 8), reducing uranium concentration to 24.3 and 34.6 mg kg^{-1}, respectively.

Figures D.4-9 and D.4-10 illustrate the percent of total uranium in extracted soil solids, spent extract, and rinsate for each of the extractants for ID-A and ID-B soil, respectively. The inorganic acids resulted in over 95 percent reduction in uranium concentration in the solid phase of both soil. EDTA (pH 10) was also able to achieve a greater than 90 percent reduction in uranium concentration in both soil. The carbonate compounds, sodium hydroxide and EDTA were the next most effective

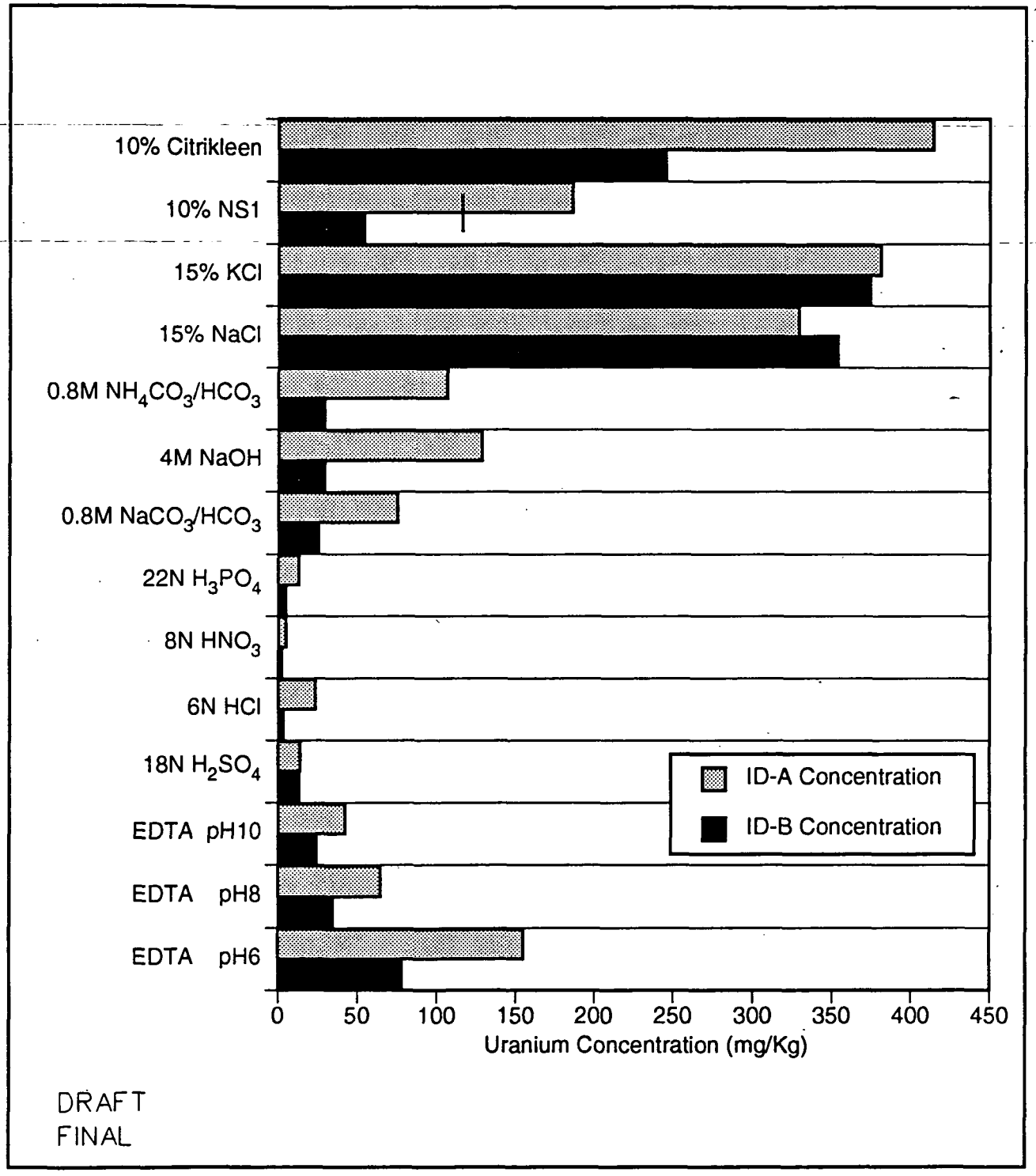

FIGURE D.4-8.
URANIUM CONCENTRATION IN ID-A AND ID-B EXTRACTED SOILS
FOR TWELVE EXTRACTANTS

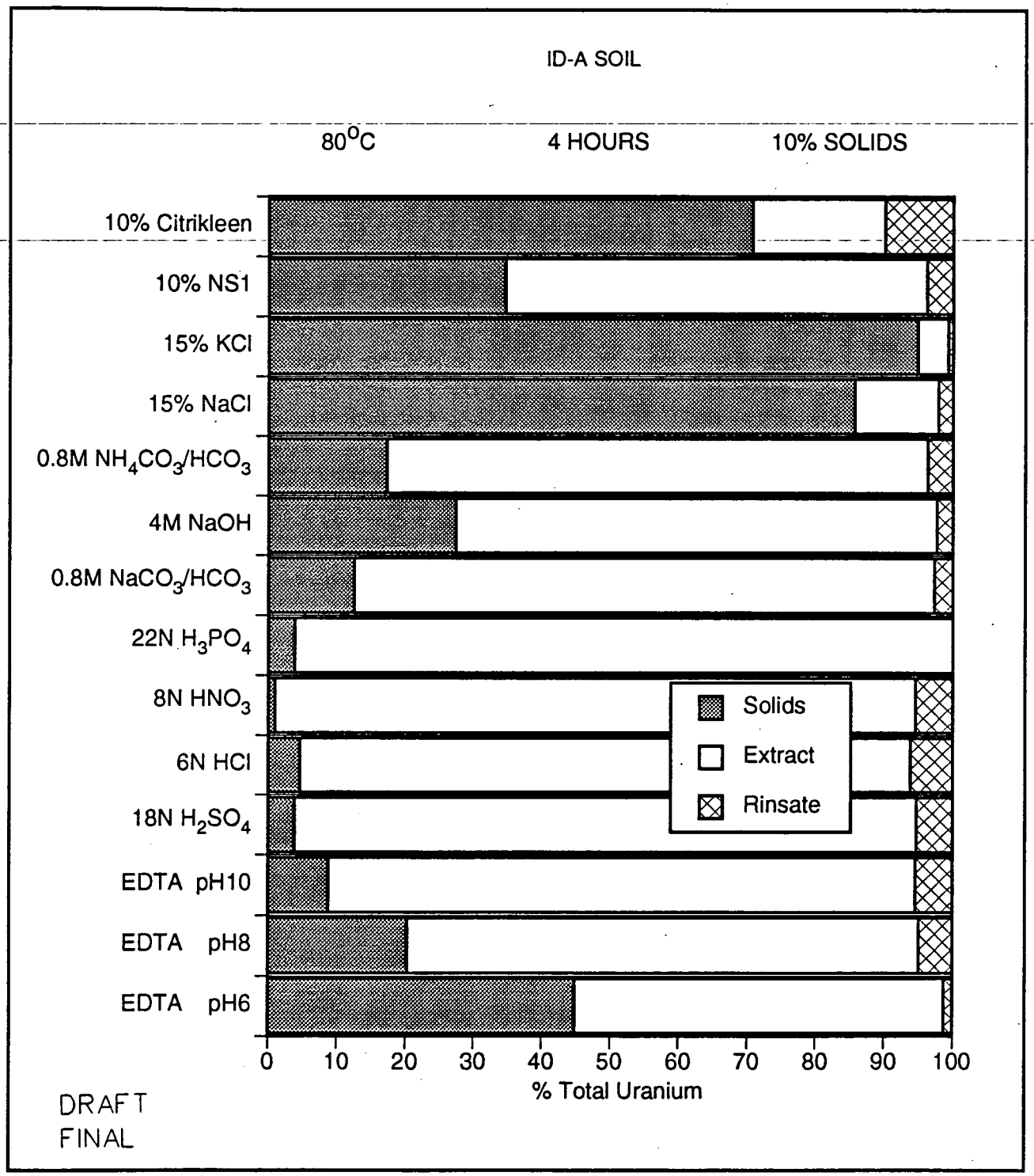

FIGURE D.4-9
THE PERCENT OF TOTAL URANIUM IN EXTRACTED SOIL SOLIDS, SPENT EXTRACTANT, AND RINSATE FOR ID-A SOILS FOLLOWING EXTRACTION, FOR TWELVE EXTRACTANTS.

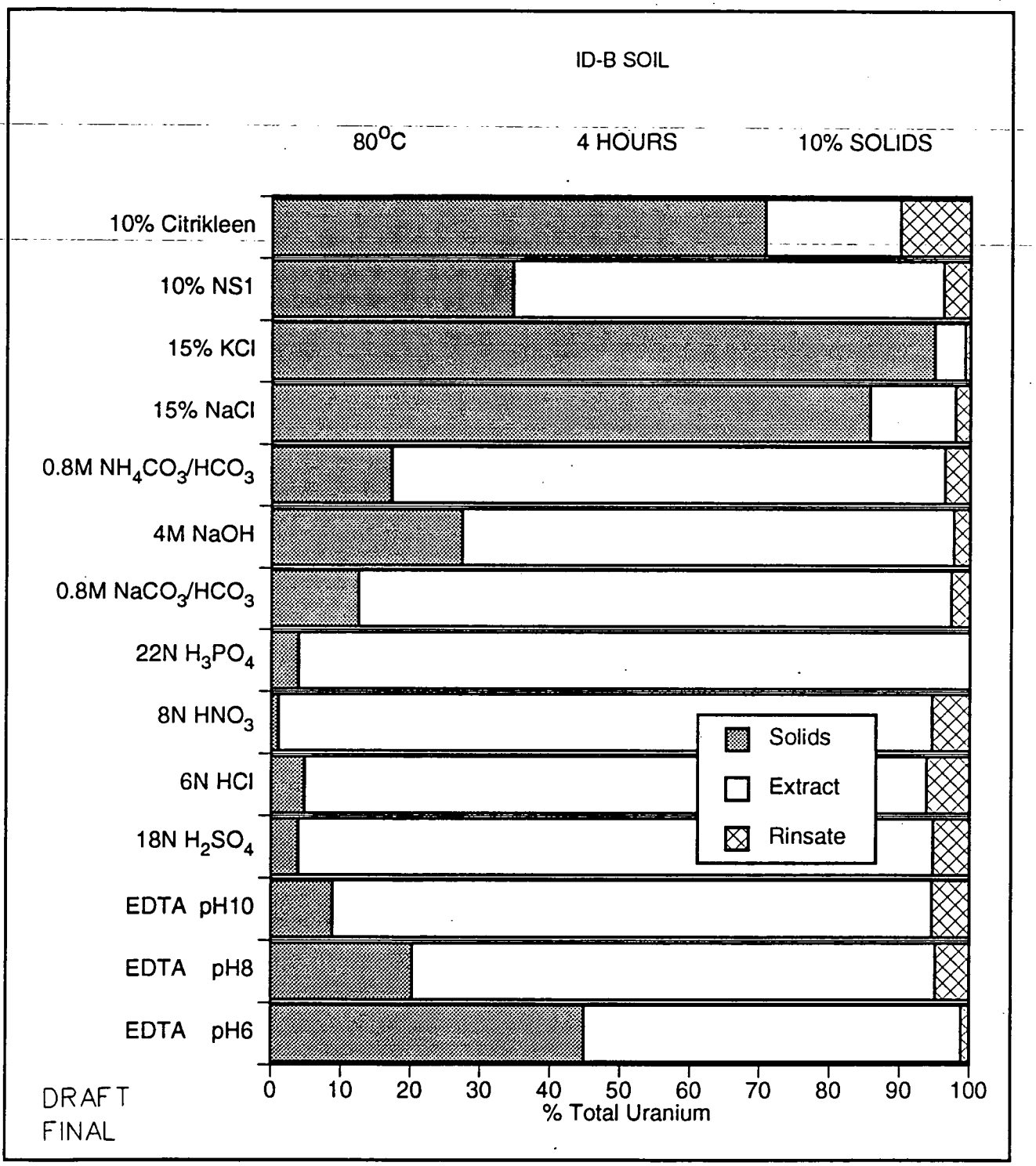

FIGURE D.4-10
THE PERCENT OF TOTAL URANIUM IN EXTRACTED SOIL SOLIDS, SPENT EXTRACTANT, AND RINSATE FOR ID-B SOILS FOLLOWING EXTRACTION, FOR TWELVE EXTRACTANTS.

chemical extractants for ID-A soil, removing better than 70 percent of the total uranium. However, sodium carbonate, ammonium carbonate, sodium hydroxide, and EDTA (pH 8 and pH 10) were very effective in ID-B soil, reducing total uranium concentration in the solids to less than 50 mg kg^{-1}, equating to more than a 90 percent reduction in total uranium. ETDA's effectiveness seemed to be pH dependent. Figures D.4-9 and D.4-10 illustrate that the rinsate accounts for less than 10 percent of the total uranium removed during the extraction process. However, an additional 10 percent would remove 50 and 45 mg kg-1 from ID-A and ID-B soil, respectively.

D.4.2.2.3 Stage II: Screening of Selected Extractants

The inorganic acids were the most effective extractants of the reagents tested. Therefore, three inorganic acids (sulfuric, nitric, and hydrochloric) were selected from Stage I testing for further evaluation in Stage II testing on their effectiveness in removing total uranium from the two soil. Each extractant was tested at five concentrations to determine the lowest concentration of extractant that could be used without significantly diminishing the amount of total uranium removed from the extracted solids. The extraction time (4 hours), temperature (80°C), and dose rate (10 percent solids) were kept the same as in Stage I testing. Figure D.4-11 shows the effect of five concentrations of sulfuric acid on uranium concentration in ID-A and ID-B soil following chemical extraction. All sulfuric acid concentrations, except for 0.2 N, were able to achieve less than 50 mg kg^{-1} total uranium in the extracted solids (greater than 90 percent reduction in total uranium).

The ineffectiveness of the 0.2 N solution may be a result of the buffer capacity of the ID-A soil and the resulting neutralization of the added acid. Increasing the concentration beyond 1 N did not reduce total residual uranium concentration in the soil beyond the 14 mg kg^{-1}. The ID-B soil was responsive to all concentrations of sulfuric acid. Increasing acid concentration from 1 N to 2 N reduced total uranium concentration in the extracted solids from 18 to 8 mg kg^{-1}. Overall, sulfuric acid concentration in excess of 1.0 N resulted in little additional uranium being removed from either the ID-A or ID-B soil.

The concentration of total uranium in extracted ID-A and ID-B soil following chemical extraction for five concentrations of nitric acid is illustrated in Figure D.4-12. Much like the results for sulfuric acid extraction, a 1.0 N nitric acid concentration was necessary to achieve less than 50 mg kg^{-1} total uranium concentration in both soil. A 1 N acid strength reduced total uranium concentration in extracted solids to 9 mg kg^{-1} for both soil. Increasing the concentration of nitric acid to 5.3 and 8.0 N resulted in less than 1 percent additional uranium removal from either soil.

Figure D.4-13 shows the concentration of total uranium in extracted ID-A and ID-B soil following chemical extraction for five concentrations of hydrochloric acid. A 1 N hydrochloric acid solution, much like sulfuric and nitric acids, was slightly more effective on ID-B soil than ID-A soil, reducing

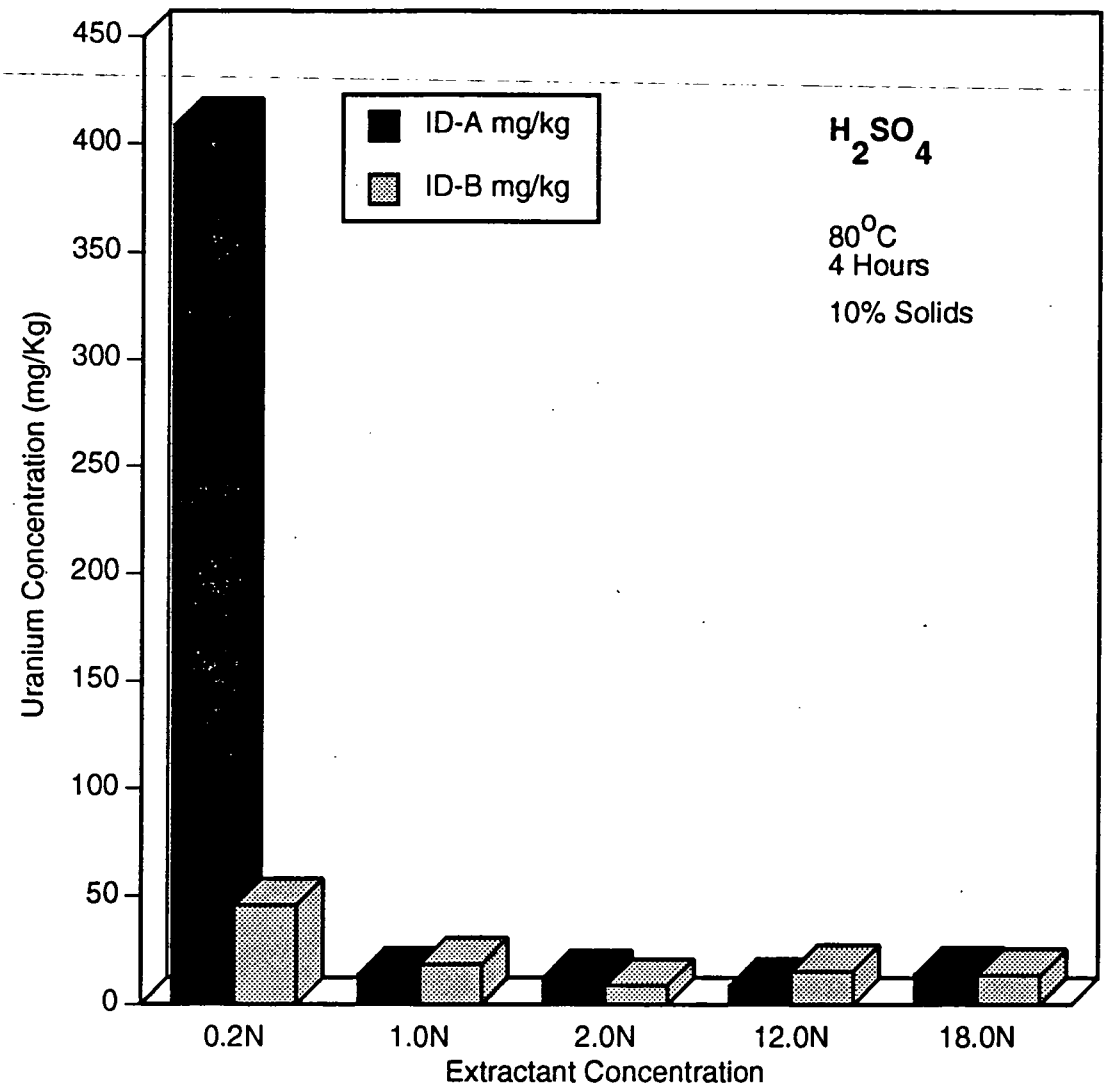

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FIGURE D.4-11.
THE CONCENTRATION OF TOTAL URANIUM IN EXTRACTED ID-A AND ID-B SOILS FOLLOWING CHEMICAL EXTRACTION FOR FIVE CONCENTRATIONS OF SULFURIC ACID.

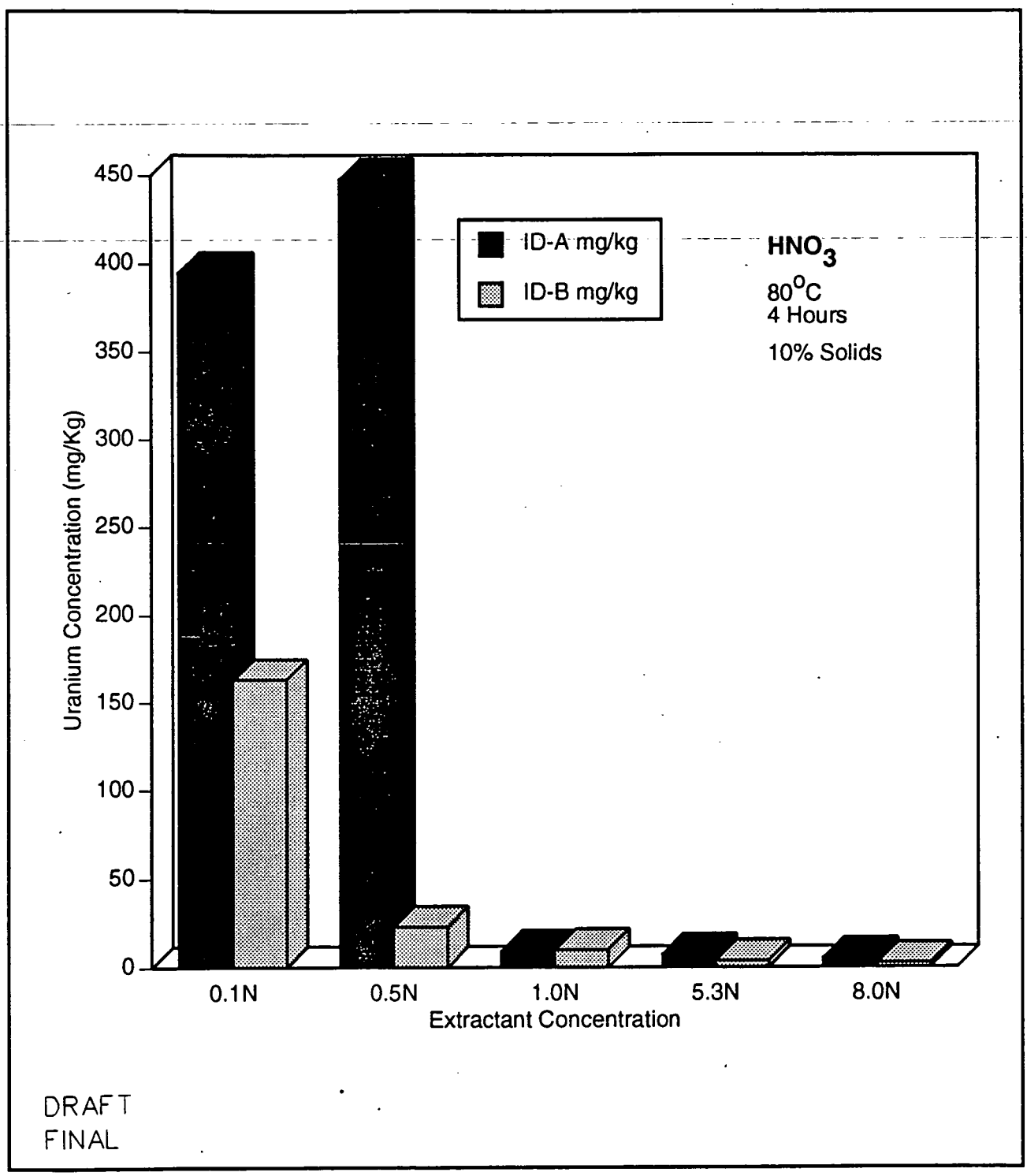

FIGURE D.4-12.
THE CONCENTRATION OF TOTAL URANIUM IN EXTRACTED ID-A AND ID-B SOILS FOLLOWING CHEMICAL EXTRACTION FOR FIVE CONCENTRATIONS OF NITRIC ACID.

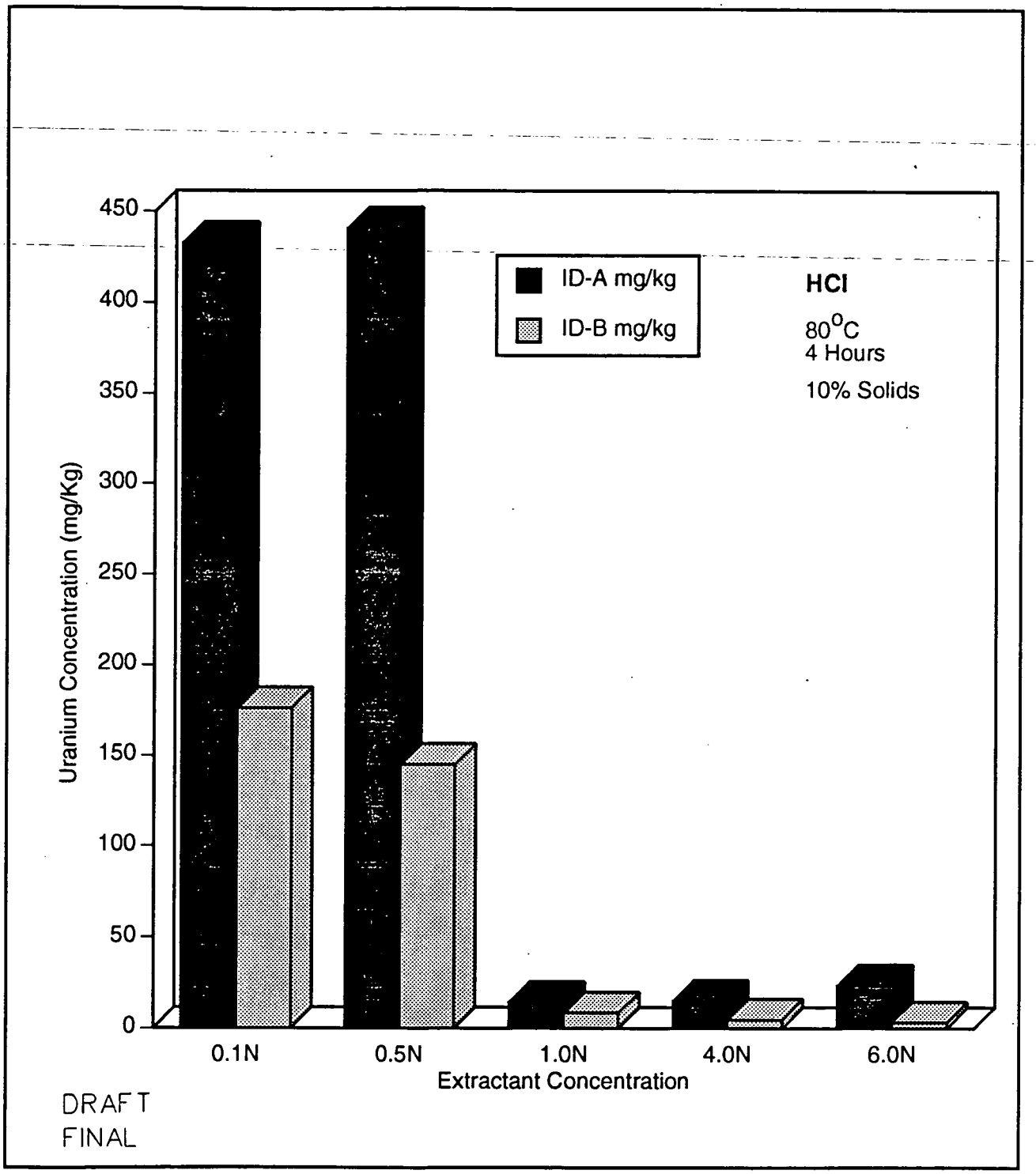

FIGURE D.4-13.
THE CONCENTRATION OF TOTAL URANIUM IN EXTRACTED ID-A AND ID-B SOILS FOLLOWING CHEMICAL EXTRACTION FOR FIVE CONCENTRATIONS OF HYDROCHLORIC ACID.

total uranium concentrations to 8 and 14 mg kg^{-1}, respectively. Additional acid strengths beyond 1.0 N resulted in little additional removal of total uranium from the extracted solids.

The distribution of total uranium among the extracted soil, spent extractant, and rinse water for ID-A and ID-B soil following extraction, with five concentrations of sulfuric acid, nitric acid, and hydrochloric acid is shown in Figures D.4-14 and D.4-15. Figure D.4-14 illustrates that at lower acid concentrations, over 90 percent of the uranium remained in the extracted solids for the ID-A soil. This ineffectiveness in total uranium extraction at lower concentrations is not evident in the ID-B soil (Figure D.4-15). The amount of uranium removed in the rinsate for all three acids and both soil never exceeded 10 percent of the total uranium. However, as noted previously, a 10 percent reduction in the amount of additional uranium can potentially remove as much as 50 mg kg^{-1}.

D.4.2.2.4 Stage III: Time, Temperature, and Concentration Study

Two of the inorganic acids tested in Stage II were carried over to Stage III testing. The effects of sulfuric and nitric acids at two dose rates, two extraction times, and two temperatures are illustrated in Figure D.4-16 for the ID-A soil. The optimum interactive effects of time, temperature, and dose rate for each acid can be evaluated from this figure. The least aggressive condition (e.g., 4:1 dose rate, 0.5 hour extraction time, ambient temperature, and 1 N concentration) are near the back corner of the graph. By proceeding from the far back corner of the graph diagonally forward towards the front corner, the extraction conditions become more aggressive. Figure D.4-16 shows that nitric acid had a pronounced effect on total uranium removal when the extraction temperature was increased from ambient to 40°C. On the average, an additional 50 mg kg^{-1} of total uranium was removed from the ID-A soil by increasing the temperature. Although increasing the acid concentration from 1 N to 2 N at ambient temperature did not influence uranium extraction, it did seem to enhance total uranium extraction at 40°C. Increasing the reaction time from 0.5 to 2 hours and/or increasing the dose rate from 4:1 (20 percent solids) to 7:1 (12.5 solids) did not show a similar effect on reducing the total uranium concentration in the extracted solids. A 1 N nitric acid solution at 40°C and a 7:1 dose rate and 0.5 hour extraction time was able to reduce total uranium concentration in the ID-A extracted soil to 26 mg kg^{-1}.

Increasing the temperature from ambient to 40°C during sulfuric acid extraction reduced the total uranium concentration in the extracted solids an additional 30 mg kg^{-1} (Figure D.4-16). Increasing acid strength from 1 N to 2 N for either temperature did not seem to have much effect on the final concentration of total uranium in extracted soil solids. Overall, dose rate and extraction time did not seem to influence total uranium extraction for sulfuric acid in ID-A soil. Based on this data, 1 N and 2 N sulfuric acid solutions at 40°C and a 4:1 dose rate and 0.5 hour reaction time were able to reduce total uranium concentration in the extracted soil to 38 and 36 mg kg^{-1}, respectively.

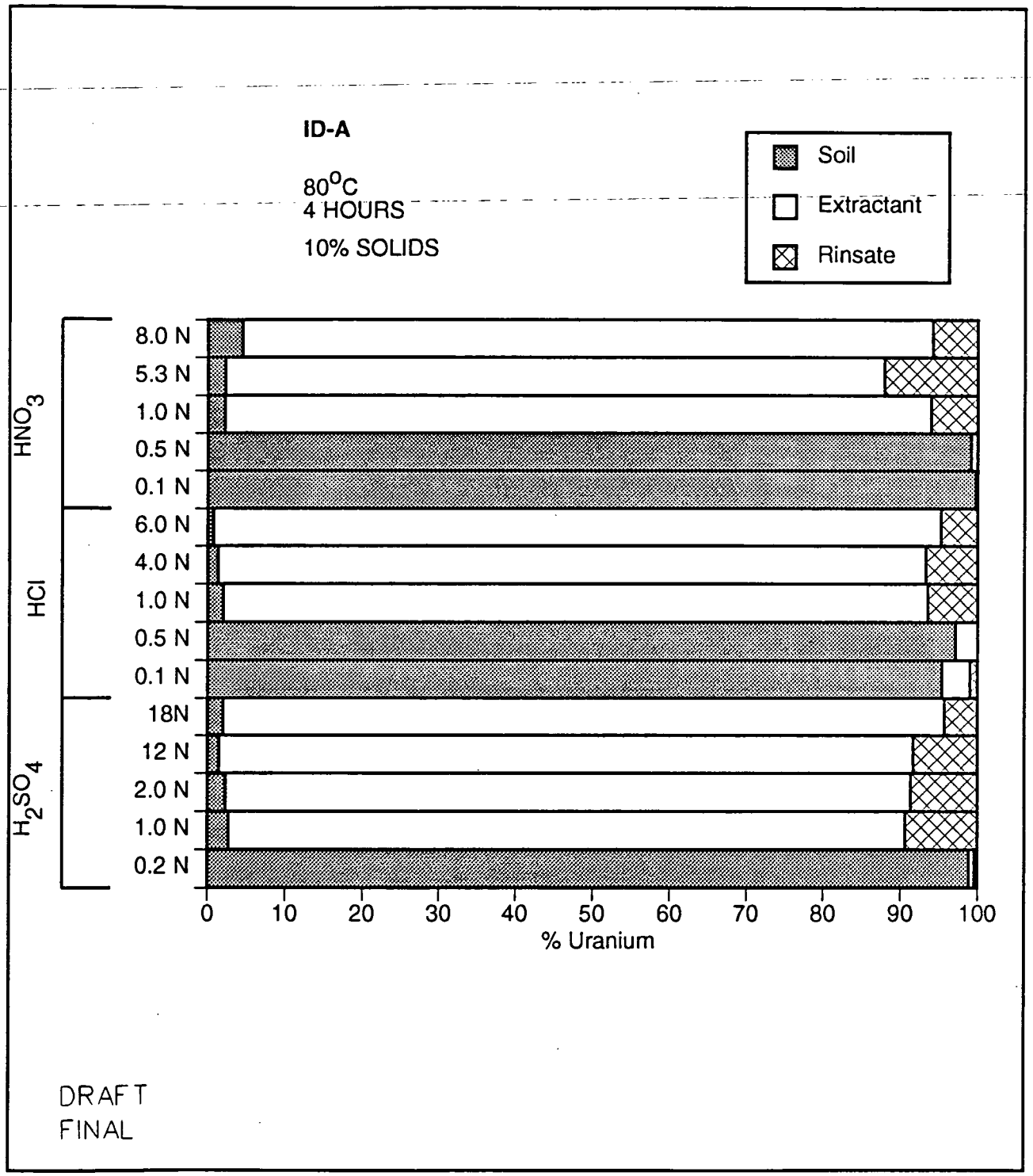

FIGURE D.4-14.
THE PERCENT URANIUM CONCENTRATION IN EXTRACTED SOIL, SPENT EXTRACTANT, AND RINSE WATER FOR ID-A SOIL FOLLOWING EXTRACTION WITH FIVE CONCENTRATIONS OF SULFURIC, NITRIC, AND HYDROCHLORIC ACIDS.

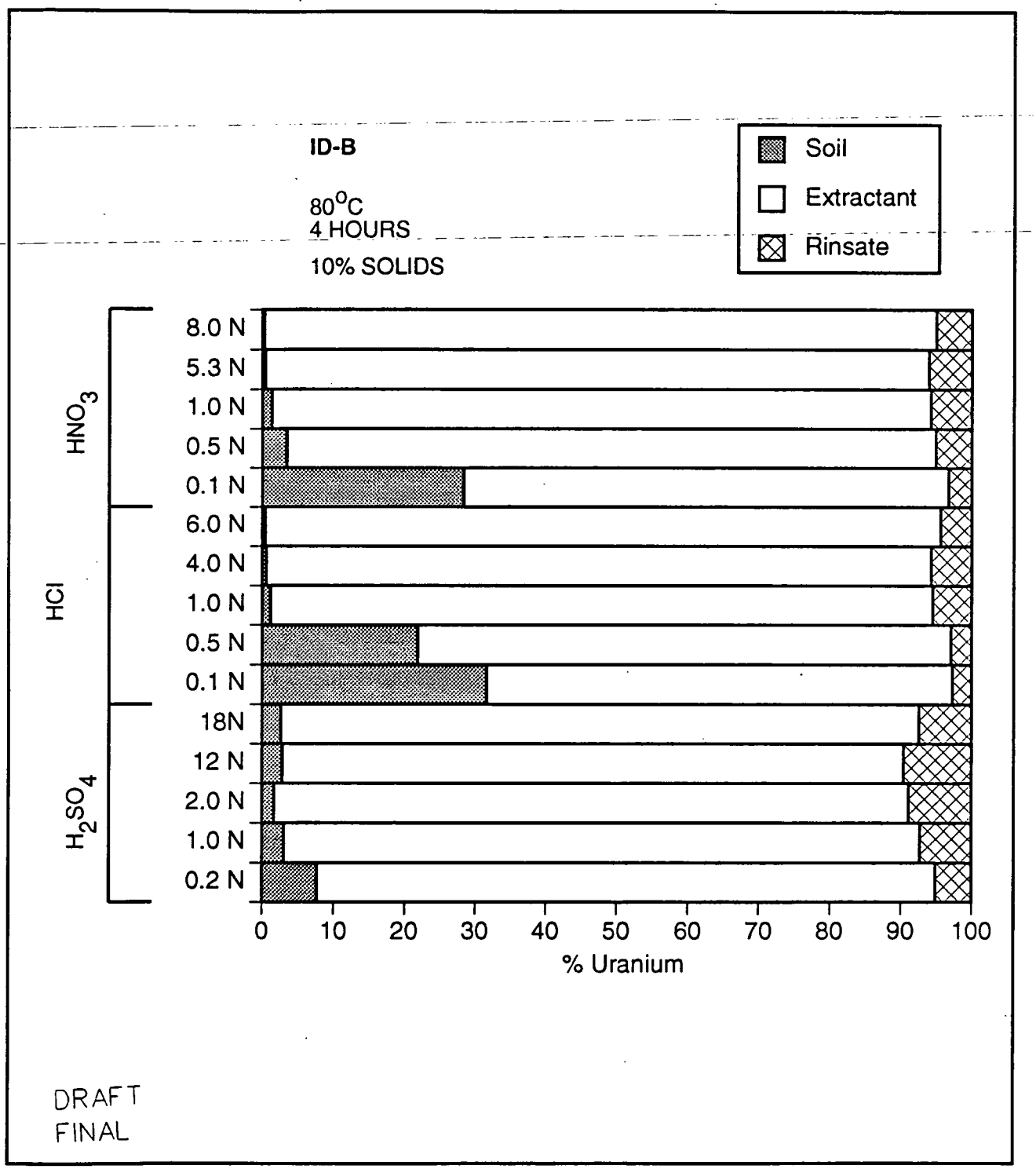

FIGURE D.4-15.
THE PERCENT URANIUM CONCENTRATION IN EXTRACTED SOIL, SPENT EXTRACTANT, AND RINSE WATER FOR ID-B SOIL FOLLOWING EXTRACTION WITH FIVE CONCENTRATIONS OF SULFURIC, NITRIC, AND HYDROCHLORIC ACIDS.

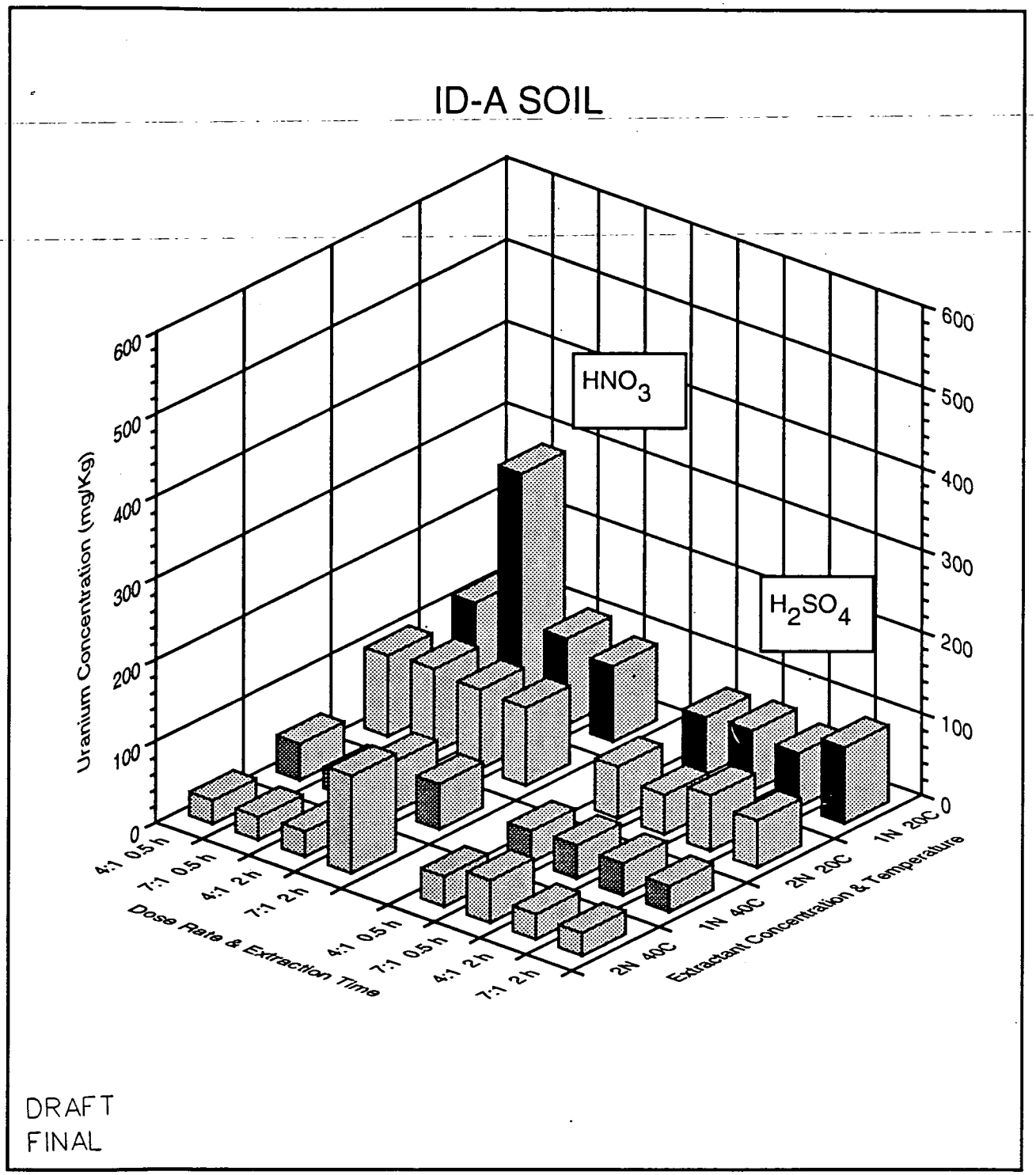

FIGURE D.4-16.
THE EFFECT OF NITRIC ACID AND SULFURIC ACID CONCENTRATIONS, TEMPERATURE, EXTRACTION TIME AND DOSE RATE ON URANIUM CONCENTRATION IN EXTRACTED ID-A SOIL.

Figure D.4-17 illustrates the effect of nitric acid and sulfuric acid concentrations, temperature, extraction time, and dose rate on total uranium concentration in extracted ID-B soil. It is obvious that 1 N nitric acid solutions at a 4:1 dose rate, regardless of temperature or extraction time, did not affect total uranium concentration in extracted solids. A 2 N nitric acid solution at 40°C was extremely effective, regardless of dose rate or extraction time. The most aggressive and effective extraction conditions were a 2 N nitric acid solution at 40°C, 7:1 dose rate, and 2 hour extraction time. This treatment lowered the concentration of total uranium in the extracted soil to 17 mg kg^{-1}. However, decreasing acid concentration to 1 N and extraction time to 0.5 hour still resulted in a final concentration of total uranium in the extracted soil of 41 mg kg^{-1}.

Sulfuric acid was very effective on ID-B soil, regardless of extraction conditions. Only the least aggressive conditions for the 1 N and 2N sulfuric acid solutions (e.g., ambient, 4:1 dose rate, and 0.5 hour extraction time) resulted in a total uranium concentration in the extracted soil in excess of 50 mg kg^{-1}. The most aggressive conditions reduced total uranium concentration in the extracted soil solids to 17 mg kg^{-1}. By reducing acid strength to 1 N and extraction time to 0.5 hour and maintaining 40°C temperature and a 7:1 dose rate, total uranium concentration in the extracted solids was only 19 mg kg^{-1}.

D.4.2.3 Physical Separation and Chemical Extraction Tests

Based on the findings from initial physical separation and chemical extracting bench-scale testing, a final set of bench-scale tests were conducted to evaluate the selected soil washing treatment process before initiating pilot-scale testing. These tests were designed to evaluate a sequential treatment process that incorporated attrition scrubbing with sodium carbonate/sodium bicarbonate solution followed by a dilute sulfuric acid extraction.

All earlier bench-scale physical separation testing was conducted using a modified Hamilton Beach mixer. The experimental design incorporated the use of a DECO attrition mill in the combined physical separation and chemical extraction test since the mill was considered to provide results comparable to the attrition scrubber designed into the soil washing pilot plant. Figure D.4-18 illustrates the results from a comparative study conducted with a DECO attrition mill and a Hamilton Beach mixer. Although no replications were conducted to allow for a statistical analysis, visual comparison of the results indicate that uranium concentration for the two soil size fractions in treated ID-A and ID-B soil as a function of attrition scrubbing time are similar between the two pseudo-attrition scrubbers.

The DECO attrition mill was used in the combined process test to evaluate the effectiveness of a sequential physical separation and chemical extraction treatment process on removing uranium from the two soil. A 0.1 M sodium carbonate/sodium bicarbonate solution, 15 minutes attrition scrubbing

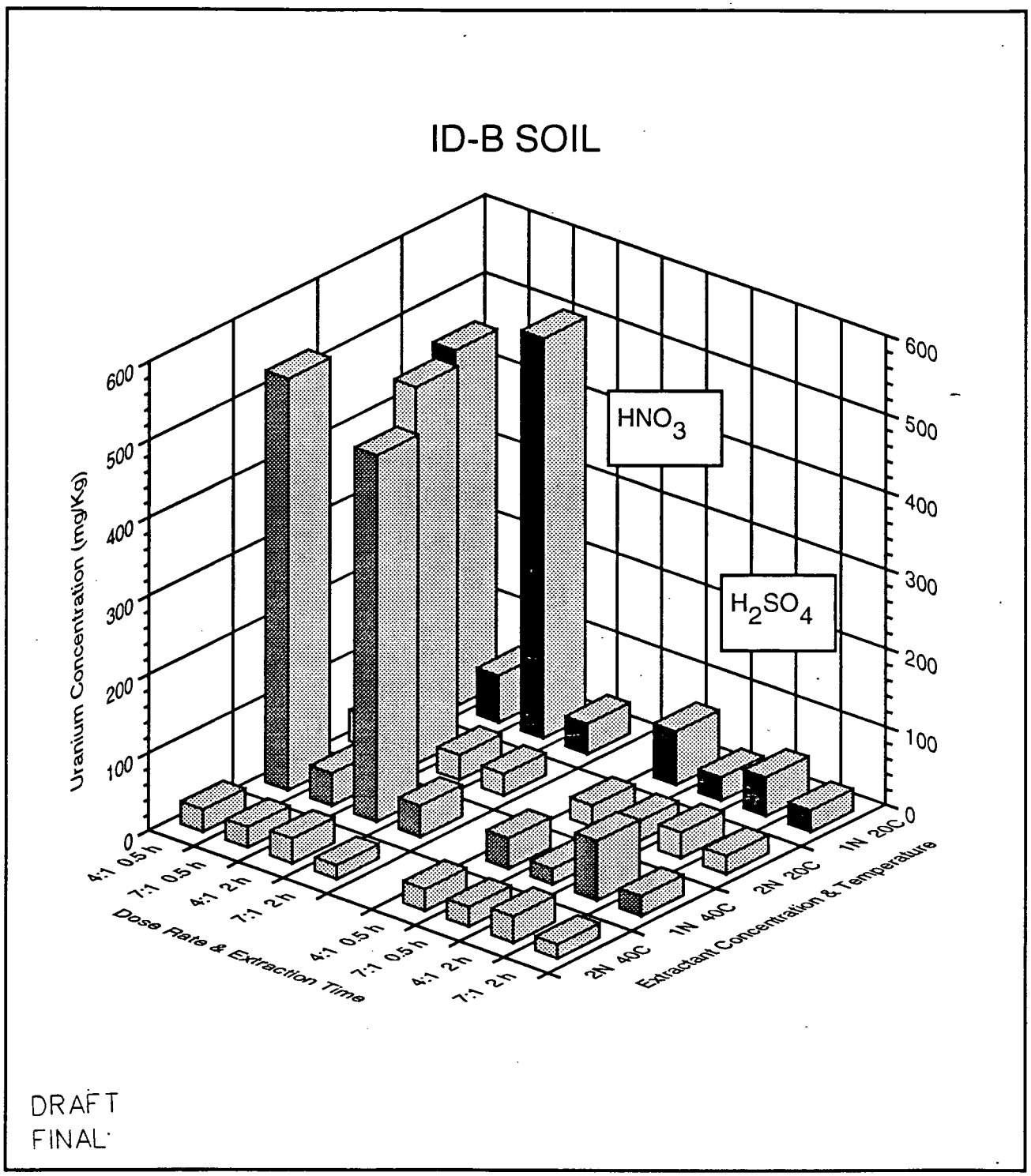

FIGURE D.4-17.
THE EFFECT OF NITRIC ACID AND SULFURIC ACID CONCENTRATIONS, TEMPERATURE, EXTRACTION TIME AND DOSE RATE ON URANIUM CONCENTRATION IN EXTRACTED ID-B SOIL.

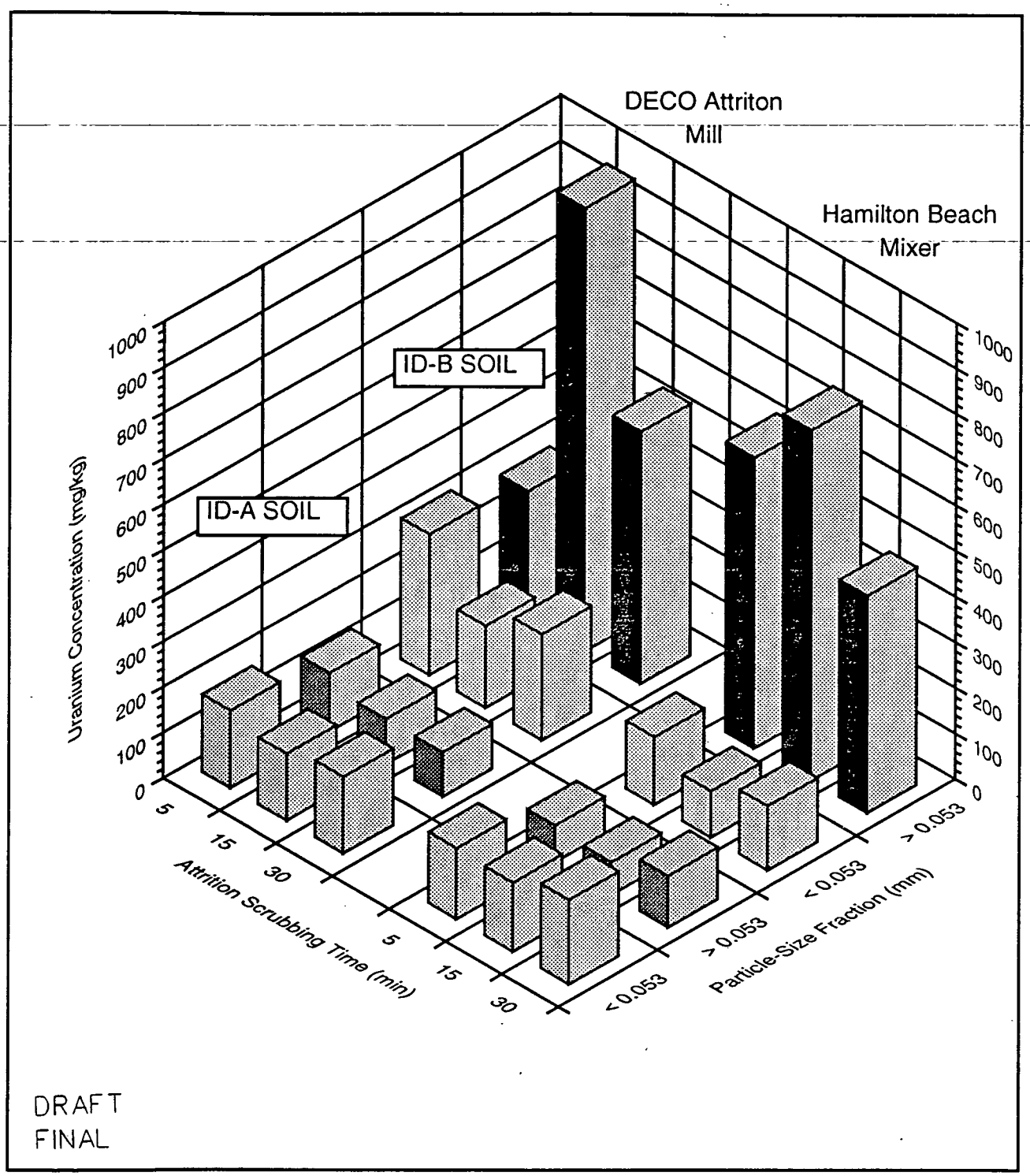

FIGURE D.4-18
A COMPARISON OF RESIDUAL CONCENTREATION OF URANIUM IN TWO SIZE FRACTIONS OF ID-A AND ID-B SOILS FOLLOWING ATTRITION SCRUBBING WITHA DECO ATTRITION MILL AND A HAMILTON BEACH MIXER.

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time and 33 percent solids, reduced uranium concentration in the ID-A soil from 497 to 341 mg kg^{-1} and in the ID-B soil and from 450 to 241 mg kg^{-1}. This equates to a 31 and 46 percent reduction in total uranium concentration.

These carbonate-attrition-scrubbed soil were centrifuged to separate the soil solids which were subsequently treated with a 2 N sulfuric acid solution at 40°C for 30 min. When a 4:1 dose rate (20 percent solids) was used, uranium concentrated in the treated solids was reduced to 52 and 92 mg kg-1 for ID-A and ID-B soil, respectively. This equated to a 90 and 80 percent reduction in the initial uranium concentration for the ID-A and ID-B soil respectively. When a 7:1 does rate (12.5 percent solids) was used, uranium concentration in the treated solids was reduced to 49 and 71 mg kg-1 for ID-A and ID-B soil, respectively. This equated to a 90 and 85 percent reduction in the initial uranium concentration for the ID-A and ID-B soil respectively.

D.4.3 PILOT-SCALE TESTS

D.4.3.1 Phase I: CRU5 Soil Washing Demonstration Tests

The soil washing pilot plant, located in Plant 8, was operated in a batch mode during the summer of 1993 for a period of three months. Figure D.4-19 illustrates a simplified version of the soil washing process, previously given in detail in the PFDs provided in Section D.3 and Attachment D.V. This figure shows the primary process streams generated during the operation of the soil washing system. Potentially, six basic process streams could have been generated from operation of the pilot plant. Those streams included: (1) treated soil solids greater than 4.75 mm; (2) treated soil solids 0.3 to 4.75 mm; (3) treated soil solids 0.02 to 0.3 mm; (4) treated soil solids less than 0.02 mm; (5) a filter cake (residue); and (6) spent carbonate extraction solution. Due to the operation of the soil washing system these primary process streams were slightly changed. The 0.3 to 4.75 mm soil solids coming off of the screen deck was combined with the 0.02 to 0.3 mm soil solids coming off of the centrifuge to form a single process stream. A centrifuge heel was created during system operations. The centrifuge heel was partially treated soil retained by the centrifuge during the batch-mode operation of the system. Although this soil was not considered part of any primary process stream, it constituted a significant amount of the initial soil mass and uranium and therefore was used in mass balancing.

As noted in Section D.3.4.1.5, analytical support was provided by both the FERMCO laboratory and the contracted laboratory. The soil and uranium mass balancing for pilot plant operations was derived solely from FERMCO analytical data. Analyses performed by the contracted laboratory for the primary process streams included all radiological and inorganic (metals) analytes in addition to total uranium, as listed in Table D.3-1. Therefore, final total uranium analyses presented in the following sections for soil processed through the soil washing system will be discussed on two levels:
(1) on-site analyses used to described process operations for soil and uranium mass tracking and

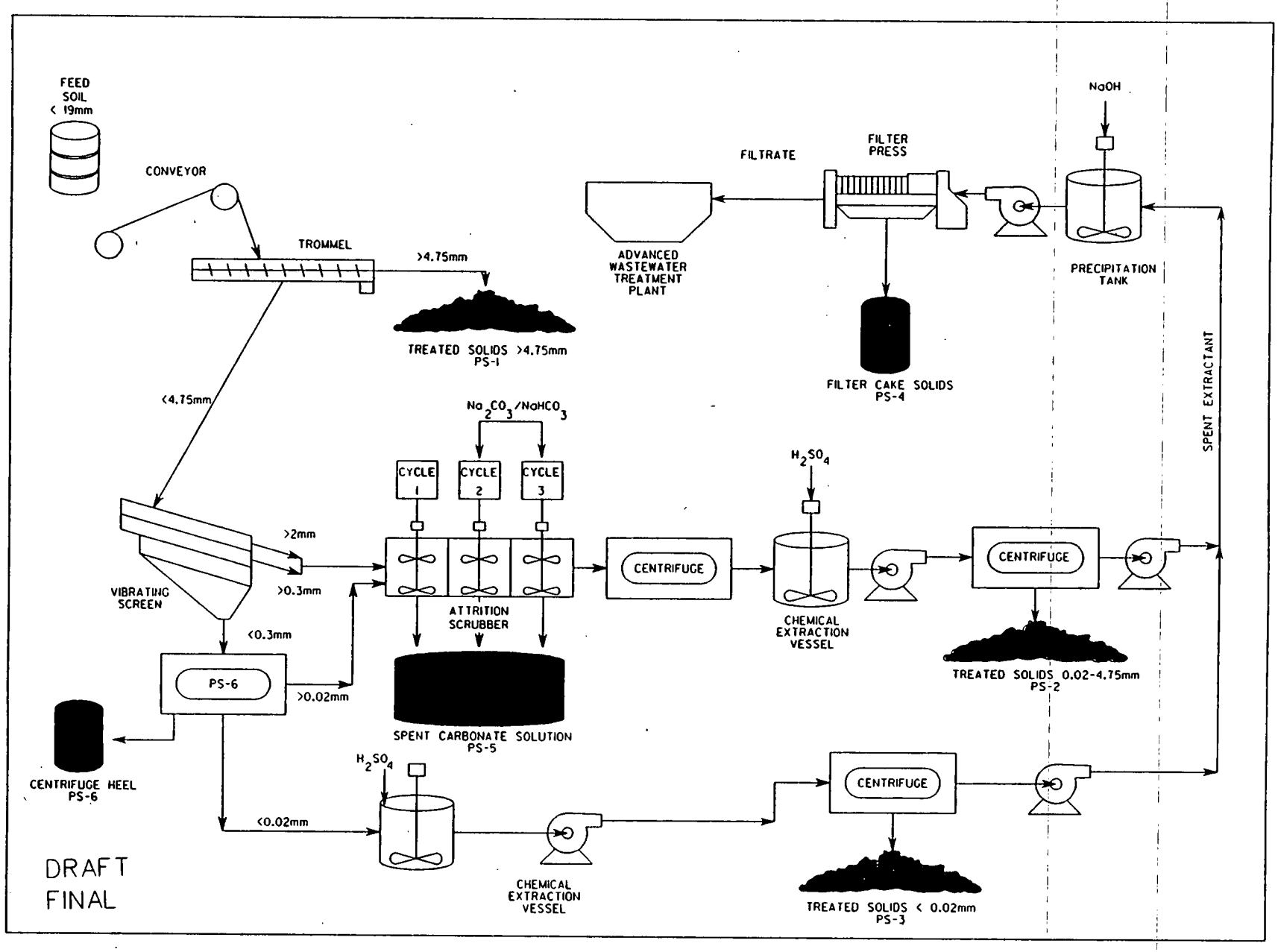

FIGURE D.4-19 - SOIL WASHING PROCESS FLOW DIAGRAM

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(2) off-site contracted laboratory analyses used to provide final concentrations for all radiological and inorganic analytes.

Initial concentrations of analytes for the two feed soil is provided in Attachment II. Total uranium (the target analyte) concentration was determined by off-site analysis to be 499 and 536 mg kg^{-1} for ID-A and ID-B, respectively (Table D.4-1). This was a composite analysis for all the fifteen 55-gallon drums of each soil prepared by the ID program. Specific total uranium analysis of each 55-gallon drum processed through the soil washing system was determined by on-site analysis to be 431 and 487 mg kg^{-1} for the two drums of ID-A soil and 389 and 455 mg kg^{-1} for the two drums of ID-B soil.

D.4.3.1.1 Physical Separation

The physical separation side of the soil washing pilot plant was designed with three principle components (trommel, screen deck, and centrifuge) to provide selected soil size fractions during processing operations. The trommel provided the first process stream by separating gravel greater than 4.75 mm from the soil. Only 3.7 (SD=0.6) and 0.7 (SD=0.3) percent of the initial soil mass fell into this size fraction for ID-A and ID-B, respectively. Although not analyzed for total uranium, this process stream was considered to be relatively low in total uranium concentration.

The centrifuge and screen deck were used to provide a feed to the attrition scrubber. The centrifuge provided a soil particle size fraction of approximately 0.02 mm. The screen deck was used as a protective step within the operation to remove a coarser fraction of the soil (greater than 0.3 mm) before centrifugation. The 0.3 to 4.75 mm soil solids from the screen deck averaged greater than 75 percent solids for both ID-A and ID-B soil. The centrifuge produced both a high solids stream and a high water stream (centrate). While the centrate was averaging approximately one percent solids, the 0.02 to 0.3 mm soil solids from the centrifuge averaged greater than 70 percent solids for both soil. These 0.02 to 0.3 mm soil solids from the centrifuge were combined with the 0.3 to 4.75 mm soil solids from the screen deck and processed through the attrition scrubber. This 0.02 to 4.75 mm soil solids was considered the second primary process stream. The centrate from the centrifuge, which also contained a significant amount of the soil mass (considered to primarily consist of the fine less than 0.02 mm soil fraction of the soil), was transferred directly to the chemical extraction vessel and represented the third primary process stream.

The centrifuge was designed to provide a coarse soil size fraction with significant mass to warrant the use of an attrition scrubber. In general, attrition scrubbing is recommended for particles greater than 0.075 mm (sand particles). However, grain size distribution for these two soil (Attachment V) showed that only approximately 18 and 22 percent, respectively, of the ID-A and ID-B soil particles were greater than 0.075 mm. By directing the soil fraction greater than 0.02 mm to the attrition

scrubber, approximately 40 to 45 percent of the total soil mass could be processed through attrition scrubbing. The attrition scrubbing of the finer sand fraction (0.05 to 0.075 mm) and the coarser silt fraction (0.02 to 0.05 mm) in conjunction with the 0.075 mm to 4.75 mm soil fraction was considered potentially effective since individual particles in these size fractions exhibited similar physical characteristics (e.g., the lack of elasticity, plasticity, and cohesive qualities).

Grain size distribution was determined for all batch runs of the centrifuge solids (as compared to the centrate) coming off of the centrifuge for each of the three cycles through the centrifuge (Attachment D.XI). All the soil solids coming off the centrifuge were less than 75 μm. However, approximately 70 percent and more of this soil mass was less than 0.02 mm. In most cases, over 10 percent of the soil solids coming off the centrifuge was in the clay size fraction (less than 0.002 mm). Although the centrifuge functioned well as a dewatering device, it did not provide the specific particle size fraction of 0.02 mm. Therefore, the soil processed through the attrition scrubber was probably more representative of the whole soil. All reference to this primary process stream will continue to be referred to as the greater than 0.02 mm soil fraction. All reference to the soil separates contained in the centrate will be referred to as the less than 0.02 mm soil fraction.

D.4.3.1.2 Soil Washing of the ID-A Soil

Tables D.4-6 and D.4-7 show the results and mass balances for soil and total uranium for individual soil washing process streams for the first and second drums respectively of the incinerator area soil. Each drum was processed separately and represented a single replication of the process operation. The two replications for each soil were used to evaluate reproducibility of process operations. The following is a discussion of the effectiveness of the soil washing process on the ID-A soil using average values and standard deviations (SD) calculated from data contained in Tables D.4-6 and D.4-7.

The total uranium concentrations in the greater than 0.02 mm and less than 0.02 mm treated soil solids were 27 mg kg^{-1} (SD=1.4) and 62.5 mg kg^{-1} (SD=26.2), respectively. These two primary process streams and the greater than 4.75 mm gravel accounted for an average of 74.3 percent (SD=4.4) of the initial total mass for the ID-A treated soil solids. This total mass of treated soil averaged 27 mg kg^{-1} (SD=1.4). Residual total uranium mass remaining in the treated soil was approximately 10.3 percent (SD=0.4) of the total uranium mass contained in the feed soil. This equates to nearly a 90 percent reduction in total uranium mass for nearly 75 percent of the processed ID-A soil.

Most of the uranium mass which was either concentrated in the filter cake or remained in the spent carbonate extractant. The filter cake, which was the precipitate product from the spent sulfuric acid extractant, had a final total uranium concentration of approximately 637 mg kg^{-1} (SD=209) and

contained 11.2 percent (SD=3.5) of the total uranium mass. The final total uranium concentration in the treated spent sulfuric acid solution was approximately 5 $\mu g\ L^{-1}$. Most of the uranium remained in the spent carbonate solution. This solution contained 71.5 percent (SD=16) of the total uranium mass. This solution also contained a significant amount of the initial soil mass, although an exact value could not be calculated. Much of this soil mass contained the fine fraction of the soil separates that did not partition into the solid phase during centrifugation.

Figures D.4-20 and D.4-21 show the average reduction in total uranium concentration in the 0.02 to 4.75 and less than 0.02 mm soil solids, respectively, during Runs one and two of the ID-A soil treatment processes. Attrition scrubbing with carbonates reduced total uranium concentration in the 0.02 to 4.75 mm soil solids from 475 mg kg^{-1} to less than 110 mg kg^{-1}. Total uranium concentration in this fraction was further reduced to 27 mg kg^{-1} following 1 N sulfuric acid extraction. This sequential process resulted in a 95 percent reduction in total uranium for this size fraction of soil solids.

The centrate from the initial centrifuging of the undersize soil slurry from the screen deck was transferred directly to the reaction vessel for chemical extraction. The average total uranium concentration in these less than 0.02 mm soil solids was 1186 mg kg^{-1}. Following a 1 N sulfuric acid extraction, the total uranium in this soil fraction was reduced to 995 mg kg^{-1}, equating to a 92 percent reduction in uranium concentration (Figure D.4-21).

D.4.3.1.3 Soil Washing of the ID-B Soil

Tables D.4-8 and D.4-9 show the results and mass balances for soil and total uranium for individual soil washing process streams for the first and second drums respectively of the plant one pad area soil. Each drum of ID-B soil was processed separately and represented a single replication of the process operation. The two replications for each soil were once again used to evaluate reproducibility of process operations. The following is a discussion of the effectiveness of the soil washing process on the ID-B soil using average values and standard deviations calculated from data contained in Tables D.4-8 and D.4-9.

The total uranium concentrations in the greater than 0.02 mm and less than 0.02 mm treated soil solids were 17 mg kg^{-1} (SD=4.2) and 35.5 mg kg^{-1} (SD=2.1), respectively. The centrifuge had provided an addition quantity of effectively treated soil constituting nearly 31 percent of the initial soil mass with a final total uranium concentration of 60 mg kg^{-1} (SD=19.1). These three primary process streams and the greater than 4.75 mm gravel accounted for an average of 78 percent (SD=10.7) of the initial total mass for the ID-B treated soil solids. This total mass of treated soil averaged 37 mg kg^{-1} (SD=12.7). Residual total uranium mass remaining in the treated soil was approximately 6.7 percent (SD=2.5) of the total uranium mass contained in the feed soil. This

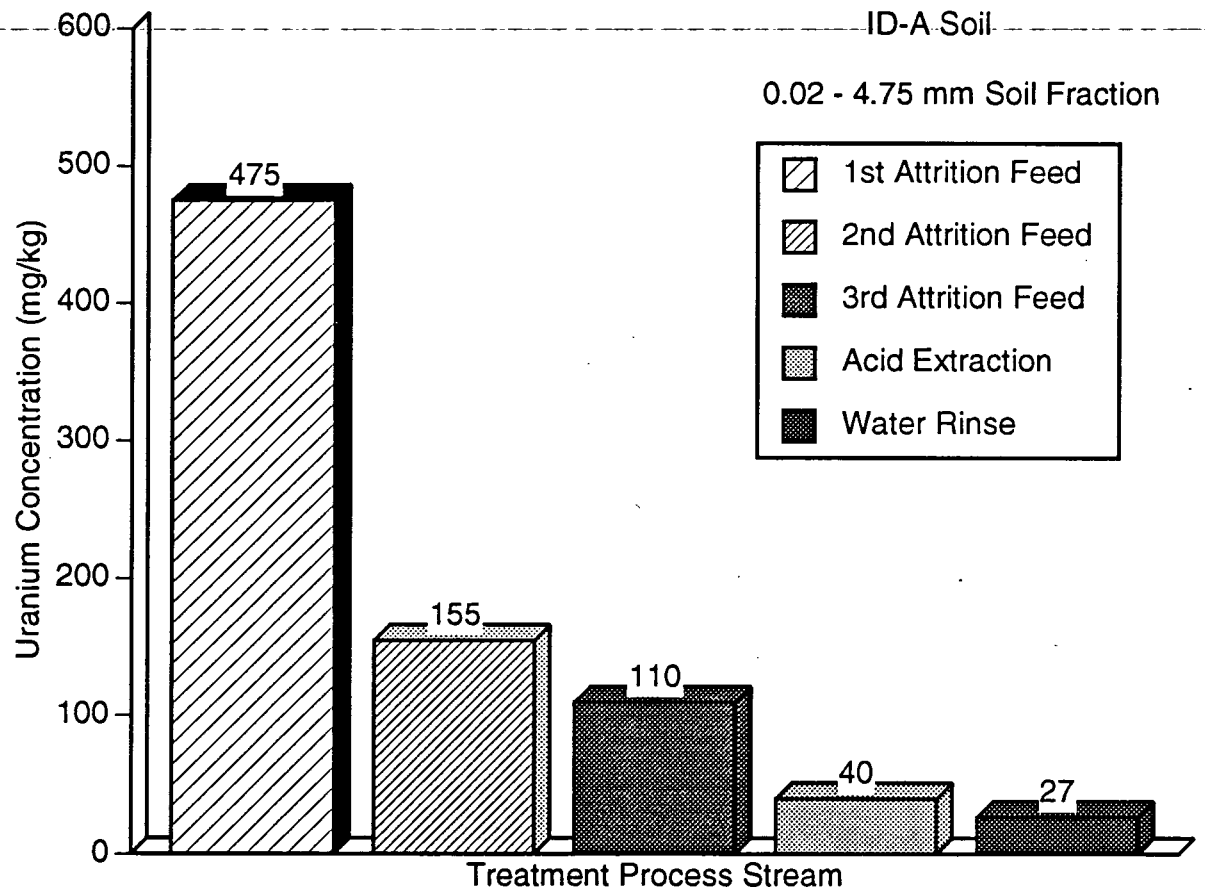

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FIGURE D.4-20.
THE SEQUENTIAL REDUCTION IN TOTAL URANIUM CONCENTRATION IN THE 0.02 TO 4.75 mm ID-A SOIL SOLIDS DURING TREATMENT PROCESSES.

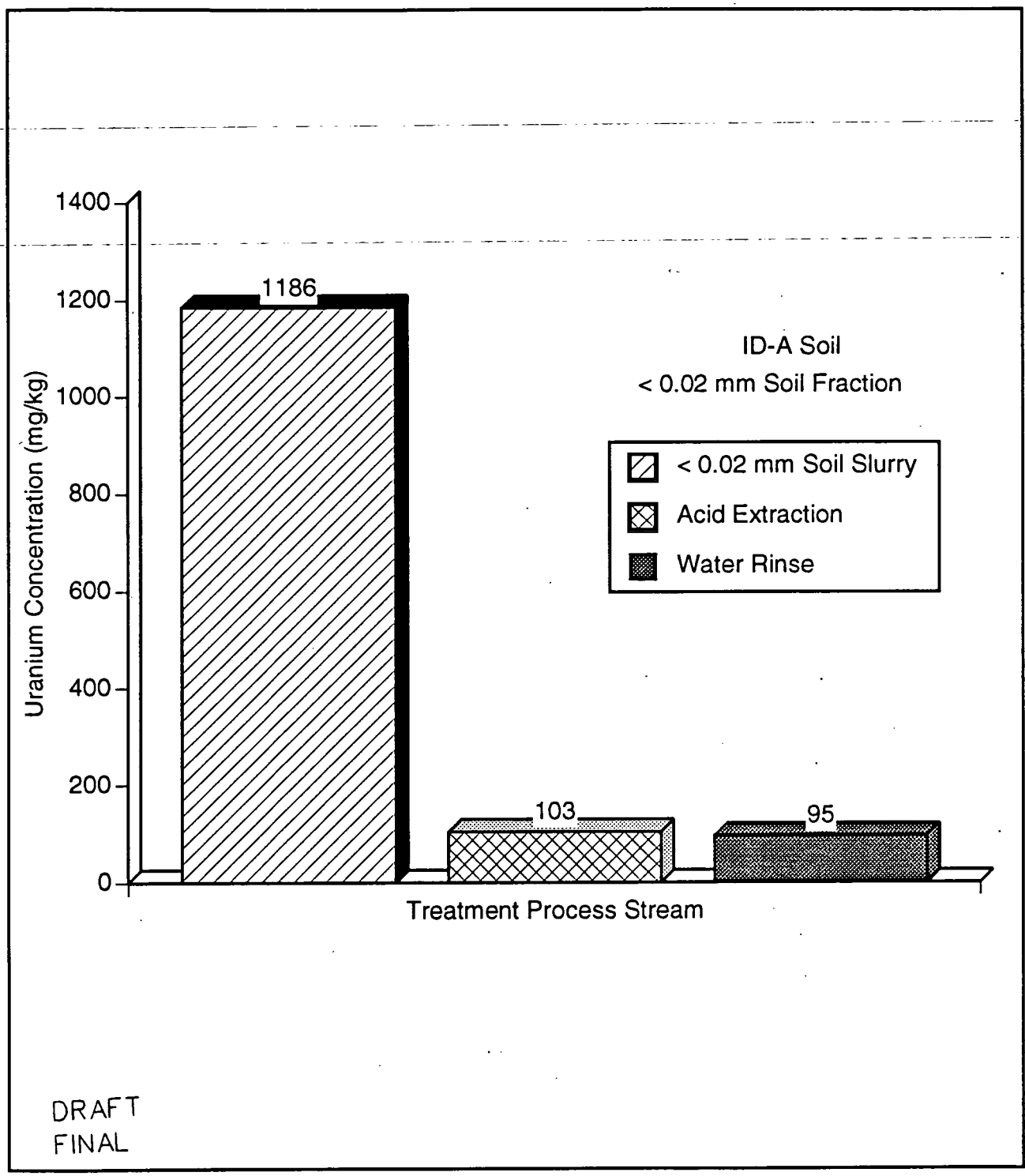

FIGURE D.4-21.
THE SEQUENTIAL REDUCTION IN TOTAL URANIUM CONCENTRATION IN THE LESS THAN 0.02 mm ID-A SOIL SOLIDS DURING TREATMENT PROCESSES.

TABLE D.4-6

SOIL WASHING PILOT PLANT PROCESS STREAMS FOR INCINERATOR AREA SOIL (ID-A, RUN 1), SINGLE BATCH (DRUM) PROCESS

Process Streams	Total Mass (kg)	Uranium (%)	Uranium (mg kg^{-1})	Uranium (mg)	(%)
Feed Soil	178.00	100.00	431	76,728	100.0
Treated Solids (> 4.75 mm)	5.78	3.25	NA[a]	NA	NA
Treated Solids (0.02 - 4.75 mm)	99.13	55.69	26	2,577	3.4
Treated Solids (< 0.02 mm)	32.95	18.51	44	1,453	1.9
Totals	137.86	77.45	29	4,030	5.3
Centrifuge Heel (avg.)	10.82	6.08	235	2,544	3.3
Filter Cake	13.02	7.31	489	6,367	8.7
Spent Carbonate Solution	44.03	NA	NA	63,546	82.8

[a] NA - Not Applicable

TABLE D.4-7

SOIL WASHING PILOT PLANT PROCESS STREAMS FOR INCINERATOR AREA SOIL (ID-A, RUN 2), SINGLE BATCH (DRUM) PROCESS

Process Streams	Total Mass (kg)	Total Mass (%)	Uranium (mg kg^{-1})	Uranium (mg)	Uranium (%)
Feed Soil	181.28	100.00	487	88,222	100.0
Treated Solids (> 4.75 mm) mm)	7.50	4.14	NA[a]	NA	NA
Treated Solids (0.02 - 4.75 mm) 4.75	102.04	56.29	28	2,857	3.2
Treated Solids (< 0.02 mm) mm)	19.48	10.75	81	1,578	1.8
Totals	129.02	71.17	34	4,435	5.0
Centrifuge Heel (avg.)	13.57	7.49	219	2,969	3.3
Filter Cake	15.42	8.51	785	12,104	13.7
Spent Carbonate Solution	39.52	NA	NA	53,102	60.2

[a] NA - Not Applicable

equates to over a 90 percent reduction in total uranium mass for nearly 78 percent of the processed ID-B soil.

Most of the uranium mass was either concentrated in the filter cake or remained in the spent carbonate extractant. The filter cake, which was the precipitate product from the spent sulfuric acid extractant, had a final total uranium concentration of approximately 3455 mg kg^{-1} (SD=1281) and contained 47.5 percent (SD=10.7) of the total uranium mass. The final total uranium concentration in the treated spent sulfuric acid solution was approximately 5 mg L^{-1}. A major portion of the uranium remained in the spent carbonate solution. This solution contained 23.5 percent (SD=11.8) of the total uranium mass. This solution also contained a significant amount of the initial soil mass, although an exact value could not be calculated. Much of this soil mass contained the fine fraction of the soil separates that did not partition into the solid phase during centrifugation.

Figures D.4-22 and D.4-23 show the sequential reduction in total uranium concentration in the 0.02 to 4.75 and less than 0.02 mm soil solids, respectively, during these treatment processes. These values are an average for Runs one and two of the ID-B soil. Attrition scrubbing with carbonates reduced total uranium concentration in the 0.02 to 4.75 mm soil solids from 198 mg kg^{-1} to less than 41 mg kg^{-1}. Total uranium concentration in this fraction was further reduced to 28 mg kg^{-1} following 1 N sulfuric acid extraction. This sequential process resulted in a 85 percent reduction in total uranium for this size fraction of soil solids.

The centrate from the initial centrifuging of the undersize soil slurry from the screen deck was transferred directly to the reaction vessel for chemical extraction. The average total uranium concentration in these less than 0.02 mm soil solids was 237 mg kg^{-1}. Following a 1 N sulfuric acid extraction, the total uranium in this soil fraction was reduced to 35 mg kg^{-1}, equating to an 85 percent reduction in uranium concentration (Figure D.4-23).

D.4.3.1.4 <u>TCLP and Comparative HSL Analyses for Primary Process Streams</u>

Table D-4-10 shows the total uranium values for ID-A and ID-B soil processed through the soil washing pilot plant for samples analyzed by the contracted laboratory and the FERMCO laboratory. The on-site analysis provided by the FERMCO laboratory supported the mass balancing of the process runs. The off-site analysis provided by the contracted laboratory supported TCLP analysis and tracking of other COCs. Table D-4-10 compares total uranium analyses by the two laboratories and provides the TCLP analysis by the off-site laboratory for the primary process streams.

Total uranium concentration values for the initial soil and the primary process streams were consistently higher by off-site analysis as compared to on-site analysis. Table D-4-10 shows that the average total uranium concentrations for the 0.02 to 4.75 mm process stream are 59 mg kg^{-1} (SD=42)

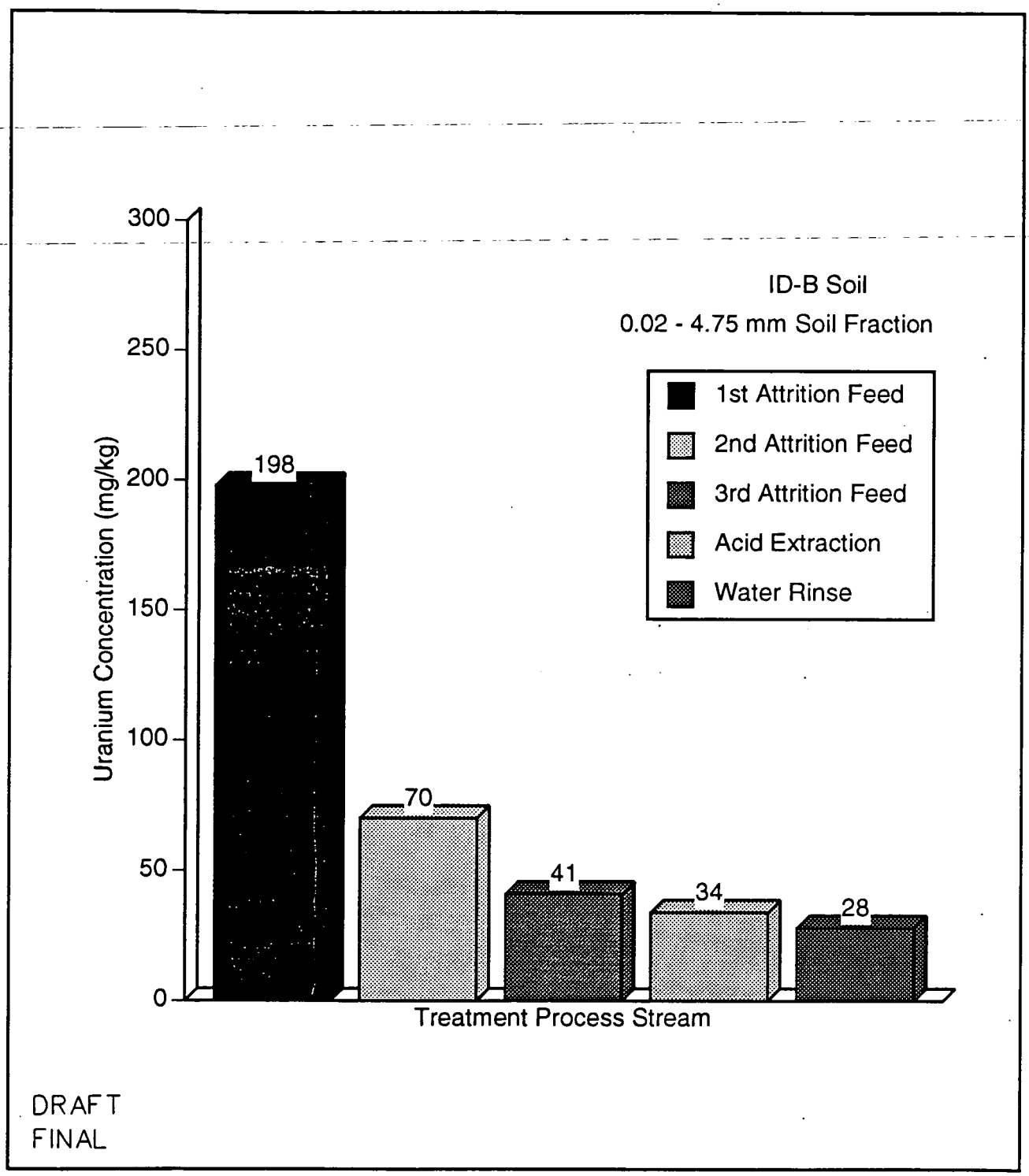

FIGURE D.4-22.
THE SEQUENTIAL REDUCTION IN TOTAL URANIUM CONCENTRATION IN THE 0.02 TO 4.75 mm ID-B SOIL SOLIDS DURING TREATMENT PROCESSES.

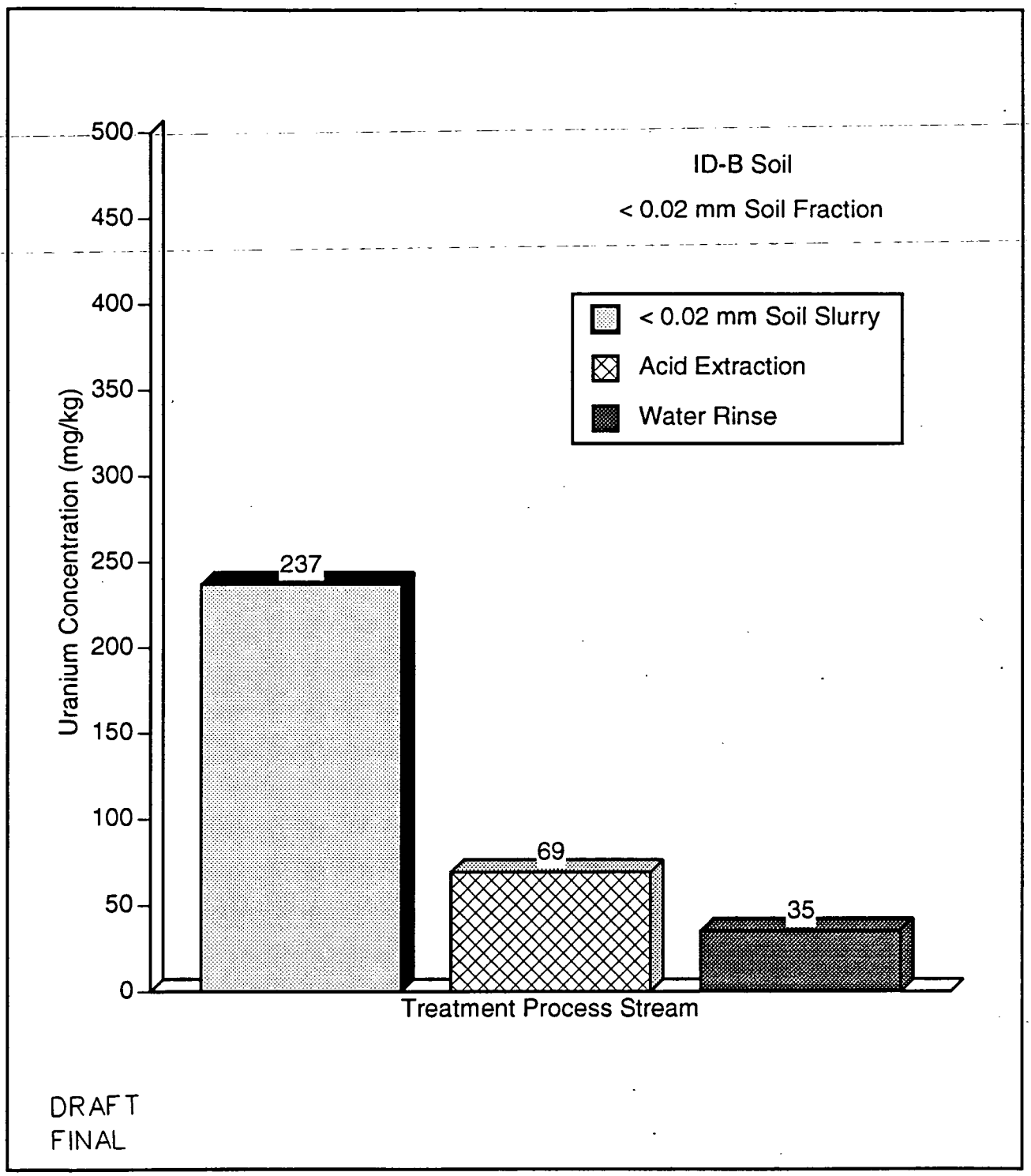

FIGURE D.4-23.
THE SEQUENTIAL REDUCTION IN TOTAL URANIUM CONCENTRATION IN THE LESS THAN 0.02 mm ID-B SOIL SOLIDS DURING TREATMENT PROCESSES.

TABLE D.4-8

SOIL WASHING PILOT PLANT PROCESS STREAMS FOR INCINERATOR AREA SOIL (ID-B, RUN 1), SINGLE BATCH (DRUM) PROCESS

Process Streams	Total Mass (kg)	Total Mass (%)	Uranium (mg kg^{-1})	Uranium (mg)	Uranium (%)
Feed Soil	169.53	100.00	389	65,958	100.0
Treated Solids (> 4.74 mm)	1.14	0.67	0	0	0.0
Treated Solids (> 20 μm)	61.43	36.24	14	860	1.3
Treated Solids (> 20 μm)	16.36	9.65	37	605	0.9
Centrifuge Heel (avg.)	40.59	23.94	46	1,849	2.8
Totals	119.52	70.50	28	3,314	5.0
Filter Cake	10.35	6.10	2,549	26,381	40.0

[a] NA - Not Applicable

TABLE D.4-9

SOIL WASHING PILOT PLANT PROCESS STREAMS FOR INCINERATOR AREA SOIL (ID-A, RUN 1), SINGLE BATCH (DRUM) PROCESS

Process Streams	Total Mass (kg)	Total Mass (%)	Uranium (mg kg^{-1})	Uranium (mg)	Uranium (%)
Feed Soil	99.73	100.00	455	45,377	100.0
Treated Solids (> 4.74 mm)	1.60	1.60	0	0	0.0
Treated Solids (> 20 μm)	30.05	30.13	20	601	1.3
Treated Solids (> 20 μm)	16.38	16.42	34	557	1.2
Centrifuge Heel (avg.)	37.36	37.46	73	2,729	6.0
Totals	85.39	85.62	46	3,887	8.5
Filter Cake	5.73	5.75	4,361	24,990	55.1
Spent Carbonate Solution	10.32	NA[a]	NA	6,916	15.2

[a] NA - Not Applicable

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and 75 mg kg^{-2} (SD=1.4) by the contracted laboratory, respectively, for the ID-A and ID-B soil. The average total uranium concentrations for the less than 0.02 mm process stream are 158 mg kg^{-1} (SD=23.3) and 112 mg kg^{-1} (SD=2.1) by the contracted laboratory, respectively, for the ID-A and ID-B soil, and 62 mg kg^{-1} (SD=26.1) and 35 mg kg^{-1} (SD=2.1) by the FERMCO laboratory, respectively, for the ID-A and ID-B soil.

The TCLP results indicate that there is a reduction in the leachable quantity of uranium for the 0.02 to 4.75 mm and the less than 0.02 mm process streams, as compared to the initial soil. The initial feed soil showed TCLP values of 3.6 and 33.9 mg L^{-1} for the ID-A and ID-B soil, respectively. The 0.02 to 4.75 mm process stream was reduced to average TCLP values of 0.3 mg L^{-1} (SD=0.15) and 0.8 mg L^{-1} (SD=0.03) for the ID-A and ID-B soil, respectively. The less than 0.02 mm process stream was reduced to average TCLP values of 1.1 mg L^{-1} (SD=1.1) and 2.1 mg L^{-1} (SD=0.65) for the ID-A and ID-B soil, respectively.

D.4.4 COC TESTS

The bench-scale soil washing test for COCs incorporated a test procedure that was modeled after the preliminary CRU5 CDR flow diagram for the proposed soil washing system. The six soil initially characterized and processed through a sulfuric acid process and a sodium carbonate/sodium bicarbonate process were ID-A, ID-B, OU5-A, AS-3, AS-4, and AS-7. The uranium concentrations for the soil before treatment and following an acid and a carbonate extraction process is given in Table D.4-11.

All soil, except for soil the pilot plant area, resulted in residual uranium concentrations less than 113 mg kg^{-1} following treatment with either sulfuric acid or sodium carbonate/sodium bicarbonate. All but one soil had initial TCLP values greater than 1.2 mg L^{-1}. The TCLP values for treated soil ranged from 8.6 mg L^{-1} for carbonate-extracted Plant 6 soil (AS-3) to 0.15 mg L^{-1} for KC-2 Warehouse soil (AS-7). However, there seems to be no relationship between TCLP values for treated soil and uranium concentration in soil solids before or following treatment.

The effectiveness of each chemical extraction process for soil with high uranium concentration (AS-3) and a soil with low uranium concentration (AS-7) is shown in Table D.4-11. Sulfuric acid extraction reduced uranium in the AS-3 treated soil solids to 277 mg kg^{-1} (81 percent reduction), while carbonate extraction reduced uranium concentration to 357 mg kg^{-1} (76 percent reduction). The KC-2 Warehouse area soil, having an initial uranium concentration of 52 mg kg^{-1}, was treated to test the effectiveness of extractant process on soil with low uranium concentrations. Although carbonate extraction had no effect on removing uranium from this soil, sulfuric acid extraction removed 56 percent of the uranium to a final concentration of 23 mg kg^{-1} in the treated solids. Attachment IV contains the characterization data for soil used in COC testing. Only two soils contained significant

levels of other COCs, the Maintenance Building area soil (OU5-A) and the Pilot Plant area soil (AS-4). Only certain constituents are of potential concern in the groundwater pathway via vertical migration. The Maintenance Building area soil had elevated levels of certain inorganics (e.g., beryllium, chromium, and lead). The Pilot Plant area soils had elevated levels of chromium and lead. Lead concentration in both soils was unaffected by either a sulfuric acid or carbonate extraction process. Chromium levels were reduced in the AS-4 soil treated with sulfuric acid but were unaffected in the OU5-A soil.

TABLE D.4-10

URANIUM VALUES BY TWO LABORATORIES FOR BOTH THE ID-A AND ID-B SOILS PROCESSED THROUGH THE SOIL WASHING PILOT PLANT

	Init Soil		> 4.75 mm		0.02 - 4.75 mm		< 0.02 mm		Filter Cake	
	HSL mg kg^{-1}	TCLP μg/L^{-1}	HSL mg kg^{-1}	TCLP μg/L^{-1}	HSL mg kg^{-1}	TCLP μg/L^{-1}	HSL mg kg^{-1}	TCLP μg/L^{-1}	HSL mg kg^{-1}	TCLP μg/L^{-1}
ID-A Run 1										
Contracted Lab	499[a]	1206[a]	NA	441	56	134	175	124	2083	855
FERMCO	431	NA	NA	NA	26	NA	44	NA	489	NA
ID-A Run 2										
Contracted Lab	499[a]	1206[a]	NA	441	62	62	142	631	3516	3218
FERMCO	487	NA	NA	NA	28	NA	81	NA	785	NA
ID-B Run 1										
Contracted Lab	536[b]	11398[b]	NA	NA	76	275	111	557	4350	117
FERMCO	389	NA	NA	NA	14	NA	37	NA	2549	NA
ID-B Run 1										
Contracted Lab	536[b]	11398[b]	NA	NA	74	259	114	867	4738	21187
FERMCO	455	NA	NA	NA	20	NA	34	NA	4361	NA

[a] One initial value was determined during initial characterization for ID-A soil.

[b] One initial value was determined during initial characterization for ID-B soil.

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TABLE D.4-11

URANIUM CONCENTRATIONS IN THE SOIL SOLIDS AND THE TCLP EXTRACT FOR SIX FEMP SOIL BEFORE TREATMENT AND FOLLOWING AN ACID AND A CARBONATE EXTRACTION PROCESS

Soil Process Locations	Initial Soil		Sulfuric Acid Process		Carbonate Extraction	
	HSL mg kg^{-1}	TCLP mg L^{-1}	HSL mg kg^{-1}	TCLP mg L^{-1}	HSL mg kg^{-1}	TCLP mg L^{-1}
ID-A	499	1.2	113	1.6	86	0.38
ID-B	536	11.4	28	0.51	44	2.2
OU5-A	199	2.1	113	5.6	113	0.68
AS-3	1490	---	277	---	357	8.6
AS-4	85	4.1	---	---	50	1.1
AS-7	52	0.38	23	0.15	51	0.44

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ATTACHMENT I
IT BENCH-SCALE DATA

STAGE 1
PHYSICAL SEPARATION
ID SOILS

FERNALD CRU5 - ID SOILS INITIAL HOMOGENIZATION OF DRIED SIEVE FRACTIONS

ID-A < 2mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-01	307.85	404.00	263.00	667.00
1055/06-02	304.91	318.00	234.00	552.00
1055/06-03	304.32	298.00	252.00	550.00
1055/06-04	298.31	478.00	299.00	777.00
1055/06-05	289.80	427.00	223.00	650.00
1055/06-06	305.18	320.00	235.00	555.00
AVERAGE	301.73	374.17	251.00	625.17
% RSD	2.01%	17.71%	10.00%	13.28%

ID-B < 2mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-19	429.51	213.00	206.00	419.00
1055/06-20	423.51	255.00	201.00	456.00
1055/06-21	409.52	228.00	179.00	407.00
1055/06-22	413.15	258.00	192.00	450.00
1055/06-23	380.16	319.00	246.00	565.00
1055/06-24	410.32	311.00	217.00	528.00
AVERAGE	411.03	264.00	206.83	470.83
% RSD	3.79%	14.87%	10.19%	12.12%

ID-A 9.5-2mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-07	367.48	542.00	332.00	874.00
1055/06-08	284.01	455.00	275.00	730.00
1055/06-09	338.02	535.00	340.00	875.00
1055/06-10	337.32	519.00	312.00	831.00
1055/06-11	358.79	521.00	314.00	835.00
1055/06-12	332.57	458.00	284.00	742.00
AVERAGE	336.37	505.00	309.50	814.50
% RSD	7.89%	6.97%	7.58%	7.14%

ID-B 9.5-2mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-25	404.51	331.00	257.00	588.00
1055/06-26	429.29	382.00	281.00	663.00
1055/06-27	393.62	410.00	258.00	668.00
1055/06-28	397.18	420.00	327.00	747.00
1055/06-29	381.18	379.00	275.00	654.00
1055/06-30	392.45	270.00	199.00	469.00
AVERAGE	399.71	365.33	266.17	631.5
% RSD	3.74%	14.01%	14.27%	13.6

ID-A 19-9.5mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-13	375.92	401.00	232.00	633.00
1055/06-14	361.19	518.00	275.00	793.00
1055/06-15	355.99	502.00	259.00	761.00
1055/06-16	399.61	390.00	249.00	639.00
1055/06-17	355.75	431.00	286.00	717.00
1055/06-18	397.58	484.00	246.00	730.00
AVERAGE	374.34	454.33	257.83	712.17
% RSD	4.92%	10.91%	7.04%	8.28%

ID-B 19-9.5mm	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/06-31	416.84	308.00	205.00	513.00
1055/06-32	410.68	370.00	290.00	660.00
1055/06-33	392.65	328.00	247.00	575.00
1055/06-34	417.84	305.00	215.00	520.00
1055/06-35	398.11	371.00	261.00	632.00
1055/06-36	399.15	345.00	309.00	654.00
AVERAGE	405.88	337.83	254.50	592.33
% RSD	2.39%	7.88%	14.65%	10.17%

FERNALD CRU5 - INITIAL HOMOGENIZATION OF WHOLE SOIL

ID-A As Received Whole Soil	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/29-05	526.00	245.00	198.00	444.00
1055/29-06	506.00	338.00	229.00	567.00
1055/29-07	400.00	348.00	242.00	590.00
1055/29-08	491.00	349.00	280.00	629.00
1055/29-09	464.00	382.00	248.00	630.00
1055/29-10	599.00	417.00	292.00	708.00
AVERAGE	497.67	346.50	248.17	594.67
% RSD	13.29%	16.64%	13.79%	14.81%

ID-B As Received Whole Soil	Total Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055/29-11	423.00	238.00	199.00	438.00
1055/29-12	428.00	211.00	217.00	428.00
1055/29-13	413.00	304.00	249.00	554.00
1055/29-14	447.00	376.00	261.00	637.00
1055/29-15	474.00	332.00	262.00	593.00
1055/29-16	520.00	416.00	260.00	677.00
AVERAGE	450.83	312.83	241.33	554.50
% RSD	8.91%	25.19%	11.13%	18.54%

ID-A Soil

19 - 9.5 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	19 - 9.5 mm	56.53	22.65	16.42	<72.8	80.10	152.90
	9.5 - 2 mm	5.21	2.09	145.26	249.00	166.00	415.00
	2 mm - 53μ	17.67	7.08	633.76	615.00	308.00	923.00
	53μ - 2μ	136.64	54.76	279.80	1000.00	553.00	1560.00
	<2μ	10.26	4.11	1200.78	365.00	259.00	624.00
NaOH	19 - 9.5 mm	50.17	20.07	25.03	<76.3	83.30	159.60
	9.5 - 2 mm	15.38	6.15	67.83	102.00	68.50	170.00
	2 mm - 53μ	13.13	5.25	1266.32	1220.00	722.00	1940.00
	53μ - 2μ	139.04	55.61	210.12	485.00	319.00	804.00
	<2μ	11.28	4.51	1429.40	1110.00	385.00	1500.00
Na2CO3	19 - 9.5 mm	58.14	23.25	613.41	839.00	692.00	1530.00
	9.5 - 2 mm	8.21	3.28	187.05	281.00	145.00	426.00
	2 mm - 53μ	16.84	6.74	897.69	800.00	443.00	1240.00
	53μ - 2μ	136.38	54.55	232.63	280.00	227.00	506.00
	<2μ	10.46	4.18	1987.06	1670.00	854.00	2530.00
NaHCO3	19 - 9.5 mm	48.47	19.39	47.23	<69.4	70.60	140.00
	9.5 - 2 mm	11.13	4.45	100.32	198.00	98.10	296.00
	2 mm - 53μ	11.67	4.67	1386.95	1470.00	833.00	2300.00
	53μ - 2μ	152.55	61.02	287.06	332.00	266.00	598.00
	<2μ	9.88	3.95	1529.49	1360.00	635.00	1990.00
CBD	19 - 9.5 mm	76.05	30.42	25.02	88.00	70.60	159.00
	9.5 - 2 mm	8.97	3.59	165.88	371.00	190.00	561.00
	2 mm - 53μ	10.30	4.12	1103.14	1070.00	612.00	1680.00
	53μ - 2μ	125.72	50.28	244.05	294.00	209.00	502.00
	<2μ	13.34	5.34	701.14	494.00	354.00	849.00

ID-A Soil

9.5 - 2 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	9.5 - 2 mm	3.48	1.39	696.58	850.00	482.00	1330.00
	2 mm - 53μ	23.46	9.38	482.85	483.00	343.00	826.00
	53μ - 2μ	184.13	73.65	330.65	335.00	239.00	573.00
	<2μ	15.94	6.38	2343.10	1520.00	725.00	2240.00
NaOH	9.5 - 2 mm	3.44	1.38	226.43	331.00	180.00	511.00
	2 mm - 53μ	26.36	10.54	486.95	506.00	299.00	805.00
	53μ - 2μ	192.24	76.90	230.96	225.00	177.00	402.00
	<2μ	14.80	5.92	1452.03	1100.00	636.00	1740.00
Na2CO3	9.5 - 2 mm	4.86	1.94	255.42	339.00	219.00	558.00
	2 mm - 53μ	27.37	10.95	414.60	584.00	285.00	869.00
	53μ - 2μ	188.62	75.43	214.98	323.00	185.00	507.00
	<2μ	7.90	3.16	2109.20	1270.00	514.00	1780.00
NaHCO3	9.5 - 2 mm	3.84	1.54	1184.55	1930.00	1100.00	3030.00
	2 mm - 53μ	25.01	10.00	653.17	750.00	423.00	1173.00
	53μ - 2μ	195.48	78.18	270.38	331.00	162.00	493.00
	<2μ	5.69	2.28	1948.56	1300.00	637.00	1930.00
CBD	9.5 - 2 mm	4.01	1.60	687.23	898.00	482.00	1380.00
	2 mm - 53μ	25.11	10.04	458.25	387.00	270.00	657.00
	53μ - 2μ	186.95	74.75	197.48	179.00	108.00	287.00
	<2μ	12.95	5.18	1464.97	1010.00	546.00	1560.00

ID-A Soil

< 2 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	2 mm - 53μ	74.53	29.86	558.12	1240.00	715.00	1955.00
	53μ - 2μ	196.69	78.80	435.69	565.00	351.00	916.00
	<2μ	4.66	1.87	1500.20	1340.00	751.00	2090.00
NaOH	2 mm - 53μ	39.58	15.82	366.42	781.00	453.00	1230.00
	53μ - 2μ	199.28	79.65	335.19	345.00	256.00	601.00
	<2μ	3.59	1.43	1406.20	947.00	775.00	1720.00
Na2CO3	2 mm - 53μ	33.78	13.51	446.69	670.00	393.00	1060.00
	53μ - 2μ	192.08	76.80	358.04	318.00	255.00	573.00
	<2μ	3.83	1.53	1404.20	1770.00	1060.00	2830.00
NaHCO3	2 mm - 53μ	38.42	15.32	337.66	617.00	438.00	1060.00
	53μ - 2μ	181.52	72.39	417.31	314.00	355.00	696.00
	<2μ	7.17	2.86	1670.21	1110.00	797.00	1910.00
CBD	2 mm - 53μ	36.37	14.53	404.27	550.00	370.00	920.00
	53μ - 2μ	186.55	74.54	347.86	613.00	270.00	883.00
	<2μ	11.19	4.47	3905.32	3850.00	1670.00	5520.00

ID-A Soil

<2mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	2mm-53μ	64.40	23.36	1970.02	1550	1190	2730
	53μ-2μ	200.04	72.57	340.73	311	279	589
	<2μ	11.21	4.07	883.02	492	429	921
NaOH	2mm-53μ	27.86	11.59	1566.42	1040	843	1880
	53μ-2μ	199.45	83.00	265.69	209	198	407
	<2μ	13.00	5.41	1303.51	716	449	1170
Na2CO3	2mm-53μ	22.30	9.41	1610.59	1310	1020	2330
	53μ-2μ	203.19	85.78	267.02	169	191	361
	<2μ	11.37	4.80	2017.07	912	557	1470
NaHCO3	2mm-53μ	22.08	9.32	2202.26	1770	1390	3160
	53μ-2μ	202.62	85.54	300.09	245	189	435
	<2μ	12.18	5.14	1295.90	478	361	839
CBD	2mm-53μ	26.05	10.74	1713.03	1390	1090	2470
	53μ-2μ	189.83	78.28	227.15	153	141	294
	<2μ	26.61	10.97	913.19	529	434	963

Modified Procedure From Previous Initial Characterization of < 2mm Soil

ID-B Soil

19 - 9.5 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	19 - 9.5 mm	----------	----------	----------	--------	--------	--------
	9.5 - 2 mm	----------	----------	----------	--------	--------	--------
	2 mm - 53μ	----------	----------	----------	--------	--------	--------
	53μ - 2μ	----------	----------	----------	--------	--------	--------
	<2μ	----------	----------	----------	--------	--------	--------
NaOH	19 - 9.5 mm	----------	----------	----------	--------	--------	--------
	9.5 - 2 mm	----------	----------	----------	--------	--------	--------
	2 mm - 53μ	----------	----------	----------	--------	--------	--------
	53μ - 2μ	----------	----------	----------	--------	--------	--------
	<2μ	----------	----------	----------	--------	--------	--------
Na2CO3	19 - 9.5 mm	----------	----------	----------	--------	--------	--------
	9.5 - 2 mm	----------	----------	----------	--------	--------	--------
	2 mm - 53μ	----------	----------	----------	--------	--------	--------
	53μ - 2μ	----------	----------	----------	--------	--------	--------
	<2μ	----------	----------	----------	--------	--------	--------
NaHCO3	19 - 9.5 mm	----------	----------	----------	--------	--------	--------
	9.5 - 2 mm	----------	----------	----------	--------	--------	--------
	2 mm - 53μ	----------	----------	----------	--------	--------	--------
	53μ - 2μ	----------	----------	----------	--------	--------	--------
	<2μ	----------	----------	----------	--------	--------	--------
CBD	19 - 9.5 mm	----------	----------	----------	--------	--------	--------
	9.5 - 2 mm	----------	----------	----------	--------	--------	--------
	2 mm - 53μ	----------	----------	----------	--------	--------	--------
	53μ - 2μ	----------	----------	----------	--------	--------	--------
	<2μ	----------	----------	----------	--------	--------	--------

ID - B Soil Contained No 19 - 9.5 mm Size Fraction after Addition of Dispersant

ID-B Soil

9.5 - 2 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	9.5 - 2 mm	8.12	3.25	66.04	109.00	<51.3	160.00
	2 mm - 53μ	43.95	17.59	151.38	181.00	139.00	320.00
	53μ - 2μ	170.47	68.22	174.70	141.00	140.00	281.00
	<2μ	14.71	5.89	4201.93	2860.00	1310.00	4170.00
NaOH	9.5 - 2 mm	13.12	5.25	97.51	135.00	77.80	213.00
	2 mm - 53μ	39.10	15.64	129.71	182.00	124.00	306.00
	53μ - 2μ	137.16	54.86	132.69	169.00	200.00	370.00
	<2μ	20.73	8.29	2880.12	888.00	576.00	1460.00
Na2CO3	9.5 - 2 mm	6.68	2.67	60.42	92.60	<56.1	149.00
	2 mm - 53μ	43.49	17.40	231.10	271.00	208.00	479.00
	53μ - 2μ	148.56	59.44	104.90	118.00	141.00	259.00
	<2μ	35.78	14.32	2994.93	1560.00	669.00	2220.00
NaHCO3	9.5 - 2 mm	8.31	3.33	86.09	123.00	54.00	177.00
	2 mm - 53μ	41.21	16.5	159.81	205.00	125.00	330.00
	53μ - 2μ	171.05	68.50	118.00	166.00	157.00	323.00
	<2μ	17.52	7.02	4014.64	2350.00	1120.00	3470.00
CBD	9.5 - 2 mm	8.01	3.21	92.18	138.00	109.00	247.00
	2 mm - 53μ	37.81	15.14	165.71	182.00	149.00	331.00
	53μ - 2μ	133.60	53.51	66.17	117.00	147.00	264.00
	<2μ	53.91	21.59	1725.02	1080.00	647.00	1730.00

ID-B Soil

< 2 mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	2 mm - 53μ	24.99	9.96	194.41	151.00	91.80	243.00
	53μ - 2μ	153.16	61.07	354.25	301.00	227.00	528.00
	<2μ	1.36	0.54	6042.70	5720.00	2000.00	7720.00
NaOH	2 mm - 53μ	69.14	27.64	154.00	74.30	73.60	148.00
	53μ - 2μ	144.67	57.84	398.73	303.00	236.00	539.00
	<2μ	2.10	0.84	4620.00	4890.00	1390.00	6280.00
Na2CO3	2 mm - 53μ	70.64	28.22	_	171.00	123.00	294.00
	53μ - 2μ	146.38	58.49	350.64	294.00	307.00	601.00
	<2μ	4.33	1.73	4335.21	3680.00	1250.00	4930.00
NaHCO3	2 mm - 53μ	67.83	27.06	154.19	74.50	73.80	148.00
	53μ - 2μ	134.07	53.48	349.68	361.00	259.00	620.00
	<2μ	22.58	9.01	15352.40	8920.00	2880.00	11800.00
CBD	2 mm - 53μ	80.12	31.94	151.91	177.00	170.00	347.00
	53μ - 2μ	136.76	54.52	384.23	186.00	202.00	388.00
	<2μ	15.97	6.37	8516.19	4830.00	1840.00	6670.00

ID-B Soil

< 2mm Dry Sieve Fraction

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	2mm-53μ	106.15	42.42	228	77.3	111	188
	53μ-2μ	152.27	60.85	273	110	235	345
	<2μ	17.97	7.18	1219	398	396	795
NaOH	2mm-53μ	65.72	26.29	231	129	119	248
	53μ-2μ	157.87	63.14	270	120	249	370
	<2μ	14.29	5.72	2293	958	681	1640
Na2CO3	2mm-53μ	64.64	25.85	214	67.4	60.4	128
	53μ-2μ	153.54	61.40	247	240	204	444
	<2μ	10.01	4.00	3577	154	147	301
NaHCO3	2mm-53μ	63.06	25.21	248	149	124	274
	53μ-2μ	159.90	63.93	279	118	258	376
	<2μ	10.12	4.05	3244	1310	590	1900
CBD	2mm-53μ	66.20	26.47	186	95	106	201
	53μ-2μ	132.58	53.00	281	154	145	299
	<2μ	36.94	14.77	999	141	224	364

Modified Procedure From Previous Initial Characterization of < 2mm Soil

STAGE 1
PHYSICAL SEPARATION
OU5-A SOIL

FERNALD CRU5-OU5A SOIL INITIAL HOMOGENIZATION

Description	Sample ID	Total U (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
Bucket 1 Grab Sample	10642301	289.86	284	221	505
replicate	10642302	297.52	231	224	455
replicate	10642303	263.34	215	195	410
Bucket 2 Grab Sample	10642304	256.13	206	156	362
replicate	10642305	267.91	288	192	479
replicate	10642306	270.04	331	174	504
Bucket 3 Grab Sample	10642307	258.34	189	130	319
replicate	10642308	254.81	326	218	544
replicate	10642309	261.39	231	179	410
Average		268.82	255.67	187.67	443.11
% RSD		5%	19%	16%	16%
Soil Composite	10642310	220.09	265	184	448
Soil Composite	10642311	269.84	202	199	401
Soil Composite	10642312	327.93	299	255	554
Soil Composite	10642313	248.11	212	155	368
Soil Composite	10642314	239.56	289	155	444
Soil Composite	10642315	309.15	268	180	449
Average		269.11	255.83	188.00	444.00
% RSD		14%	14%	18%	13%

OU5-A INITIAL HOMOGENIZATION ORGANIC CONCENTRATIONS

Description	Sample ID	TCE (PPM)	NAP (PPM)	ACEY (PPM)	ACEN (PPM)	FLU (PPM)	PHEN (PPM)	ANTH (PPM)	FLUA (PPM)	PYR (PPM)
Bucket 1 Grab Sample	10642301	13	0.11	<0.1	0.1	0.18	1	0.19	1.3	1.3
replicate	10642302	19	0.11	<0.1	<0.1	0.11	0.53	<0.1	0.82	1.2
replicate	10642303	17	0.1	<0.1	<0.1	0.1	0.59	<0.1	0.85	0.93
Bucket 2 Grab Sample	10642304	9.7	0.09	0.11	<0.1	0.1	0.61	<0.1	0.97	1.2
replicate	10642305	9.6	<0.1	<0.1	<0.1	<0.1	0.5	<0.1	0.88	1
replicate	10642306	8.6	0.09	<0.1	<0.1	0.09	0.8	0.12	1.8	1.8
Bucket 3 Grab Sample	10642307	11	0.12	<0.1	<0.1	0.13	0.66	<0.1	1.1	1.3
replicate	10642308	13	0.11	<0.1	<0.1	0.15	0.74	<0.1	1.1	1.3
replicate	10642309	12	0.1	<0.1	<0.1	0.16	0.8	0.11	1.2	1.5
Soil Composite	10642310	22	0.11	0.12	0.14	0.09	0.52	<0.1	0.83	1.1
Soil Composite	10642311	20	0.12	<0.1	0.12	0.17	1.4	0.13	1.8	2
Soil Composite	10642312	17	0.09	<0.1	0.14	0.09	0.54	<0.1	0.84	0.96
Soil Composite	10642313	14	0.13	<0.1	<0.1	0.18	0.92	0.12	1.3	1.6
Soil Composite	10642314	15	0.11	<0.1	<0.1	0.11	0.44	<0.1	0.84	1
Soil Composite	10642315	17	0.11	<0.1	<0.1	<0.1	0.42	<0.1	0.67	0.96

ABBREVIATION KEY

TCE=Trichloroethylene
NAP=Naphthalene
ACEY=Acenaphthylene
ACEN=Acenaphthene
FLU=Fluorene
PHEN=Phenanthrene
ANTH=Anthracene
FLUA=Fluoranthene
PYR=Pyrene
BAA=Benzo (a) anthracene
CHRY=Chrysene
BBF=Benzo (b) fluoranthene
BKF=Benzo (k) fluoranthene
BAP = Benzo (a) pyrene
INDP - Indeno (1,2,3-cd) pyrene
DBA=Dibenzo (a,h) anthracene
BGP=Benzo (g,h,i) perylene

OU5-A Soil

<19 mm

Size Fraction Distribution After Wet Seiving

Dispersant at 1 mM Concentration	Size Fraction	Soil Mass in Size Fraction (g)	% Total of Initial Soil Wt.	Total U in Size Fraction (ppm)	Gross Alpha (pCi/g)		Gross Beta (pCi/g)	Total Activity (pCi/g)
H20	19-2mm	45.64	18.24	20.73	20.64		15.58	36.22
	2mm-53μ	74.87	29.92	110.16	125	<	64.6	190
	53-2μ	106.09	42.39	180.68	234		149	238
	<2μ	24.21	9.67	279.20	125		113	238
Na2CO3/HCO3	19-2mm	47.54	18.99	1.44	1.32	<	1.63	2.96
	2mm-53μ	100.34	40.09	113.92	96.1		52	148
	53-2μ	102.72	41.04	192.40	169		151	320
	<2μ	22.82	9.12	315.25	150		89.2	239
(NH4)2CO3/HCO3	19-2mm	39.32	15.71	2.33	1.37	<	1.63	3.00
	2mm-53μ	93.01	37.16	115.94	96.2		74.7	171
	53-2μ	86.67	34.63	192.30	181		117	298
	<2μ	19.74	7.89	269.80	199	<	124	323

OU6-A

INITIAL CHARACTERIZATION ORGANIC CONCENTRATIONS

Dispersing/ Extraction Agent	Size Fraction	Wt. of Size Fraction	TCE (ppm)	NAP (ppm)	ACEY (ppm)	ACEN (ppm)	FLU (ppm)	PHEN (ppm)	ANTH (ppm)	FLUA (ppm)	PYR (ppm)	BAA (ppm)	CHRY (ppm)	BBF (ppm)	BKF (ppm)	BAP (ppm)	INDP (ppm)	DBA (ppm)	BGP (ppm)
water	19-2mm	46.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
water	2mm-53μ	74.87	19	<0.5	<0.1	<0.1	0.16	1.1	0.12	1.6	<2.0	<1.0	0.78	<0.1	1.3	0.42	0.35	0.12	0.49
water	53-2μ	106.09	18	<0.5	<0.1	0.2	0.21	0.42	<0.1	0.68	<2.0	<1.0	0.37	<0.1	0.8	0.094	0.12	<0.1	0.38
water	<2μ	24.21	N/A	<0.5	0.14	<0.1	0.14	0.15	<0.1	<0.1	<2.0	<1.0	0.16	<0.1	0.76	0.47	<0.1	<0.1	0.66
water	liquid	13651.50	0.04	0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
sod. carb/bicarb	19-2mm	47.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
sod. carb/bicarb	2mm-53μ	100.34	29	<0.5	<0.1	<0.1	0.15	0.8	0.1	1.1	<2.0	<1.0	0.56	0.68	<0.1	0.33	0.28	0.11	0.19
sod. carb/bicarb	53-2μ	102.72	21	<0.5	<0.1	0.18	0.25	0.52	<0.1	0.89	<2.0	<1.0	0.44	<0.1	1.1	0.17	0.25	0.091	0.25
sod. carb/bicarb	<2μ	22.82	0.66	<0.5	<0.1	<0.1	0.09	0.12	<0.1	0.91	<2.0	<1.0	0.15	<0.1	0.66	0.32	<0.1	<0.1	0.48
sod. carb/bicarb	liquid	13807.66	0.01	0.003	1	<0.001	0.002	0.001	<0.001	<0.001	0.005	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002
amm. carb/bicarb	19-2mm	39.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
amm. carb/bicarb	2mm-53μ	93.01	16	<0.5	0.19	0.1	0.54	1.6	0.24	2.1	<2.0	<1.0	0.98	<0.1	1.5	0.87	0.53	0.2	0.38
amm. carb/bicarb	53-2μ	88.67	24	<0.5	<0.1	<0.1	0.21	0.45	<0.1	0.82	<2.0	<1.0	0.4	<0.1	0.98	0.18	0.19	0.09	0.18
amm. carb/bicarb	<2μ	19.74	1.1	<0.5	<0.1	<0.1	0.18	0.12	<0.1	0.93	<2.0	<1.0	0.18	<0.1	0.43	0.23	<0.1	<0.1	0.5
amm. carb/bicarb	liquid	15034.95	0.03	0.002	<.001	<0.001	0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001

ABBREVIATION KEY

TCE=Trichloroethylene
NAP=Naphthalene
ACEY=Acenaphthylene
ACEN=Acenaphthene
FLU=Fluorene
PHEN=Phenanthrene
ANTH=Anthracene
FLUA=Fluoranthene
PYR=Pyrene
BAA=Benzo (a) anthracene
CHRY=Chrysene
BBF=Benzo (b) fluoranthene
BKF=Benzo (k) fluoranthene
BAP = Benzo (a) pyrene
INDP - Indeno (1,2,3-cd) pyrene
DBA=Dibenzo (a,h) anthracene
BGP=Benzo (g,h,i) perylene

OU5 - A ATTRITION SCRUBBING DATA

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	mg U in Size Fraction	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1064	34	3	water	n/a	0.08	2mm-53μ	70.00	116.34	8.14	177.00	87.20	264.00
1064	34	4	water	n/a	0.08	<53μ	86.95	164.37	14.29	124.00	108.00	232.00
1064	34	5	water	n/a	0.08	liquid	884.84	2.03	1.80	< 0.01	< 1.48	2.48
1064	34	8	water	n/a	0.25	2mm-53μ	55.17	101.82	5.62	< 87.10	83.40	170.00
1064	34	9	water	n/a	0.25	<53μ	88.36	170.43	15.06	< 120.00	105.00	225.00
1064	34	10	water	n/a	0.25	liquid	517.85	2.55	1.32	2.27	< 1.49	3.76
1064	34	13	water	n/a	0.50	2mm-53μ	61.67	80.26	4.95	< 93.80	< 71.30	165.00
1064	34	14	water	n/a	0.50	<53μ	103.43	193.56	20.02	188.00	< 122.00	311.00
1064	34	15	water	n/a	0.50	liquid	695.49	1.93	1.34	1.59	< 1.49	3.07
1064	34	18	sod.carb/bicarb	0.10M	0.08	2mm-53μ	74.52	85.30	6.36	112.00	< 72.60	184.00
1064	34	19	sod.carb/bicarb	0.10M	0.08	<53μ	84.00	153.02	12.85	126.00	83.10	209.00
1064	34	20	sod.carb/bicarb	0.10M	0.08	liquid	767.42	8.50	6.52	5.46	< 1.50	6.95
1064	34	23	sod.carb/bicarb	0.10M	0.25	2mm-53μ	78.88	106.69	8.42	104.00	< 77.20	182.00
1064	34	24	sod.carb/bicarb	0.10M	0.25	<53μ	87.88	159.35	14.00	177.00	115.00	292.00
1064	34	25	sod.carb/bicarb	0.10M	0.25	liquid	557.44	10.20	5.68	4.24	< 1.50	5.73
1064	34	28	sod.carb/bicarb	0.10M	0.50	2mm-53μ	70.54	84.36	5.95	< 84.50	< 61.40	146.00
1064	34	29	sod/carb/bicarb	0.10M	0.50	<53μ	91.76	141.66	13.00	123.00	93.30	216.00
1064	34	30	sod.carb/bicarb	0.10M	0.50	liquid	613.52	9.53	5.85	5.90	< 1.50	7.39
1064	34	33	sod.carb/bicarb	0.25 M	0.08	2mm-53μ	75.30	121.83	9.17	93.00	57.90	151.00
1064	34	34	sod.carb/bicarb	0.25 M	0.08	<53μ	84.42	140.43	11.86	89.80	89.30	179.00
1064	34	35	sod.carb/bicarb	0.25 M	0.08	liquid	639.67	10.63	6.80	< 1.61	< 1.50	3.11
1064	36	3	sod.carb/bicarb	0.25 M	0.25	2mm-53μ	64.98	96.97	6.30	< 90.40	< 67.60	158.00
1064	36	4	sod.carb/bicarb	0.25 M	0.25	<53μ	92.13	127.39	11.74	159.00	167.00	327.00
1064	36	5	sod.carb/bicarb	0.25 M	0.25	liquid	560.41	11.09	6.21	6.65	< 1.51	8.16
1064	36	8	sod.carb/bicarb	0.25 M	0.50	2mm-53μ	71.13	61.82	4.40	< 81.20	61.70	143.00
1064	36	9	sod.carb/bicarb	0.25 M	0.50	<53μ	88.92	128.25	11.40	< 119.00	153.00	272.00
1064	36	10	sod.carb/bicarb	0.25 M	0.50	liquid	590.90	10.16	6.00	2.86	< 1.49	4.35
1064	36	13	sod.carb/bicarb	0.50M	0.08	2mm-53μ	73.25	89.01	6.52	< 106.00	< 84.80	191.00
1064	36	14	sod.carb/bicarb	0.50M	0.08	<53μ	88.41	123.32	10.90	170.00	< 129.00	299.00
1064	36	15	sod.carb/bicarb	0.50M	0.08	liquid	594.90	11.81	7.02	4.85	< 1.52	6.37
1064	36	18	sod.carb/bicarb	0.50M	0.25	2mm-53μ	66.54	86.88	5.78	< 106.00	< 84.80	191.00
1064	36	19	sod.carb/bicarb	0.50M	0.25	<53μ	88.48	116.99	10.35	95.40	117.00	212.00
1064	36	20	sod.carb/bicarb	0.50M	0.25	liquid	612.34	11.27	6.90	4.21	1.86	6.07

OU5 - A ATTRITION SCRUBBING DATA

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	mg U in Size Fraction	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1064	36	28	amm carb/bicarb	0.10M	0.08	2mm-53μ	71.76	103.23	7.41	73.50	53.40	127.00
1064	36	29	amm carb/bicarb	0.10M	0.08	<53μ	88.19	165.41	14.59	120.00	115.00	235.00
1064	36	30	amm carb/bicarb	0.10M	0.08	liquid	565.47	6.30	3.56	3.17	< 1.36	4.53
1064	36	33	amm carb/bicarb	0.10M	0.25	2mm-53μ	73.58	100.22	7.37	101.00	84.20	185.00
1064	36	34	amm carb/bicarb	0.10M	0.25	<53μ	84.66	184.23	15.60	109.00	121.00	230.00
1064	36	35	amm carb/bicarb	0.10M	0.25	liquid	559.75	6.53	3.65	5.68	< 1.44	7.12
1064	38	3	amm carb/bicarb	0.10 M	0.50	2mm-53μ	68.13	88.70	6.04	102.00	71.30	173.00
1064	38	4	amm carb/bicarb	0.10 M	0.50	<53μ	89.03	210.95	18.78	138.00	143.00	281.00
1064	38	5	amm carb/bicarb	0.10 M	0.50	liquid	583.62	6.13	3.58	2.64	< 1.36	4.00
1064	38	8	amm carb/bicarb	0.25 M	0.08	2mm-53μ	72.03	89.25	6.43	95.70	63.50	159.00
1064	38	9	amm carb/bicarb	0.25 M	0.08	<53μ	84.98	194.82	16.56	112.00	96.80	209.00
1064	38	10	amm carb/bicarb	0.25 M	0.08	liquid	641.11	7.22	4.63	4.87	< 1.36	6.23
1064	38	13	amm carb/bicarb	0.25 M	0.25	2mm-53μ	64.85	70.17	4.55	73.40	55.00	128.00
1064	38	14	amm carb/bicarb	0.25 M	0.25	<53μ	93.43	163.07	15.24	90.00	118.00	208.00
1064	38	15	amm carb/bicarb	0.25 M	0.25	liquid	639.12	8.11	5.18	5.39	< 1.36	6.75
1064	38	18	amm carb/bicarb	0.25 M	0.50	2mm-53μ	66.81	56.44	3.77	81.20	47.80	129.00
1064	38	19	amm carb/bicarb	0.25 M	0.50	<53μ	95.07	163.11	15.51	75.30	113.00	188.00
1064	38	20	amm carb/bicarb	0.50 M	0.50	liquid	578.85	9.80	5.67	4.80	< 1.36	6.17
1064	38	23	amm carb/bicarb	0.50 M	0.08	2mm-53μ	72.25	107.52	7.77	63.40	58.70	122.00
1064	38	24	amm carb/bicarb	0.50 M	0.08	<53μ	88.84	174.45	15.50	86.90	102.00	189.00
1064	38	25	amm carb/bicarb	0.50 M	0.08	liquid	552.21	10.87	6.00	5.80	< 1.36	7.16
1064	38	28	amm carb/bicarb	0.50 M	0.25	2mm-53μ	67.70	80.24	5.43	126.00	74.20	200.00
1064	38	29	amm carb/bicarb	0.50 M	0.25	<53μ	82.14	171.20	14.06	64.80	83.00	148.00
1064	38	30	amm carb/bicarb	0.50 M	0.25	liquid	575.86	11.77	6.78	5.74	< 1.36	7.10
1064	38	33	amm carb/bicarb	0.50 M	0.50	2mm-53μ	65.07	65.73	4.28	< 36.00	45.40	81.40
1064	38	34	amm carb/bicarb	0.50 M	0.50	<53μ	96.35	145.37	14.01	79.70	79.40	159.00
1064	38	35	amm carb/bicarb	0.50 M	0.50	liquid	622.01	9.76	6.07	3.91	< 1.36	5.27

STAGE 1
CHEMICAL EXTRACTION
ID SOILS

OU5 CHEMICAL EXTRACTION: STAGE I

FERNALD OU5 ID - A SOIL - ON-SITE INCINERATOR AREA

EXTRACTION FLUID TYPE	CONC.	pH	DOSE	TEMP (°C)	TIME (HRS.)	ID	EXTRACTED SOLIDS GROSS ALPHA (pCi/g)	GROSS BETA (pCi/g)	TOTAL ACTIVITY (pCi/g)	EXTRACT U (ppm)	RINSATE U (ppm)	EXTRACTED SOLIDS U (ppm)	TOTAL EXTRACTED U (mg)	PERCENT URANIUM REMOVAL	PE UR REC
SULFURIC ACID	1:1 (18N)	N/A	10:1	80	4	O	139.00	187.00	326.00	32.61	4.70	14.04	23.36	97.48%	
HYDROCHLORIC ACID	1:1 (6N)	N/A	10:1	80	4	P	173.00	67.80	240.80	43.89	7.57	23.37	25.58	93.59%	
NITRIC ACID	1:1 (8N)	N/A	10:1	80	4	Q	79.00	<46.60	126.00	42.66	6.14	4.87	27.18	98.90%	
PHOSPHORIC ACID	1:1 (22N)	N/A	10:1	80	4	R	62.10	44.00	106.00	32.09	0.00	13.09	21.30	97.16%	
SODIUM CARBONATE/ BICARBONATE	60\20 (0.8M)	N/A	10:1	80	4	S	106.00	127.00	233.00	50.72	4.05	75.01	28.09	85.09%	
SODIUM HYDROXIDE	4.0N	N/A	10:1	80	4	T	256.00	192.00	448.00	32.89	2.67	128.31	20.27	61.53%	
AMMONIUM CARBONATE/ BICARBONATE	60/20 (0.8M)	N/A	10:;1	80	4	U	92.40	143.00	235.00	48.78	5.55	106.56	23.12	73.87%	
SODIUM CHLORIDE	15%	N/A	10:1	80	4	V	343.00	233.00	577.00	4.69	2.02	329.34	2.71	12.90%	
POTASSIUM CHLORIDE	15%	N/A	10:1	80	4	W	273.00	267.00	541.00	1.75	0.74	380.81	0.94	2.75%	
NS1	1:10	N/A	10:1	80	4	X	99.70	135.00	234.00	33.12	5.10	186.28	16.32	56.43%	
CITRIKLEEN	1:10	N/A	10:1	80	4	Y	582.00	286.00	868.00	11.30	14.57	414.04	7.45	4.16%	
EDTA	0.5M	6.36	10:1	80	4	Z	183.00	246.00	429.00	18.58	1.04	154.95	8.98	70.28%	
EDTA	0.5M	8.13	10:1	80	4	AA	52.10	99.90	152.00	23.78	3.88	64.60	11.17	86.97%	
EDTA	0.5M	10.00	10:1	80	4	AB	40.30	63.40	104.00	41.27	6.46	42.27	20.59	91.32%	

000150

OU5 CHEMICAL EXTRACTION: STAGE I

FERNALD OU5 ID - B SOIL - STORAGE PAD 1 AREA

EXTRACTION FLUID TYPE	CONC.	pH	DOSE	TEMP (°C)	TIME (HRS.)	ID	EXTRACTED SOLIDS GROSS ALPHA (pCi/g)	GROSS BETA (pCi/g)	TOTAL ACTIVITY (pCi/g)	EXTRACT U (ppm)	RINSATE U (ppm)	EXTRACTED SOLIDS U (ppm)	TOTAL EXTRACTED U (mg)	PERCENT URANIUM REMOVED	PERCENT URANIUM RECOVERY
SULFURIC ACID	1:1 (18N)	N/A	10:1	80	4	A	<74.10	86.00	160.10	43.55	9.24	13.41	31.84	97.26%	156.76%
HYDROCHLORIC ACID	1:1 (6N)	N/A	10:1	80	4	B	<85.00	117.00	202.00	39.44	4.97	3.18	22.61	99.57%	109.56%
NITRIC ACID	1:1 (8N)	N/A	10:1	80	4	C	102.00	103.00	205.00	41.76	7.73	2.34	26.97	99.66%	130.52%
PHOSPHORIC ACID	1:1 (22N)	N/A	10:1	80	4	D	<118.00	<116.00	234.00	——**	5.32	4.85	——**	——**	——**
SODIUM CARBONATE/ BICARBONATE	60\20 (0.8M)	N/A	10:1	80	4	E	<54.20	147.00	201.20	43.94	7.55	25.50	25.30	94.45%	128.16%
SODIUM HYDROXIDE	4.0N	N/A	10:1	80	4	F	117.00	205.00	322.00	30.70	3.03	29.07	19.03	93.54%	97.42%
AMMONIUM CARBONATE/ BICARBONATE	60/20 (0.8M)	N/A	10:1	80	4	G	<51.40	221.00	272.40	39.73	4.90	29.07	18.90	93.45%	93.28%
SODIUM CHLORIDE	15%	N/A	10:1	80	4	H	307.00	243.00	550.00	5.14	3.28	353.51	3.11	-13.10%	127.60%
POTASSIUM CHLORIDE	15%	N/A	10:1	80	4	I	357.00	219.00	576.00	3.84	0.83	374.16	1.95	15.79%	93.23%
NS1	1:10	N/A	10:1	80	4	J	85.10	205.00	290.10	34.52	4.48	54.32	17.13	87.60%	93.78%
CITRIKLEEN	1:10	N/A	10:1	80	4	K	172.00	146.00	318.00	17.76	9.04	245.14	9.07	——*	——*
EDTA	0.5M	6.36	10:1	80	4	L	138.00	279.00	417.00	20.95	1.12	78.13	10.12	87.82%	61.04%
EDTA	0.5M	8.13	10:1	80	4	M	91.00	198.00	289.00	20.35	1.60	34.62	9.80	94.36%	53.04%
EDTA	0.5M	10.00	10:1	80	4	N	74.40	124.00	198.40	24.65	5.00	24.26	12.28	95.98%	63.43%

* Extracted material could not be dewatered by vacuum filtration. After reviewing the Gross Alpha/Beta data it was decided not to complete the testing with Citrikleen.

** The Phosphoric Acid extract and rinsate samples were not able to be analyzed by Ion Chromatography because the mobile phase for the uranium method is also phosphoric acid. Therefore the efficency of the acid was determine by the Gross Alpha/Beta results.

Rev 3.0 04/06/93

OU5CESUXLS

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1229

STAGE 1
CHEMICAL EXTRACTION
OU5-A SOIL

FERNALD OU5 - A SOIL

EXTRACTION FLUID			DOSE	TEMP	TIME	EXTRACT	RINSATE	EXTRACTED	TOTAL	PERCENT	PERCENT
TYPE	CONC.	pH		(°C)	(HRS.)	U (ppm)	U (ppm)	SOLIDS U (ppm)	EXTRACTED U (mg)	URANIUM REMOVED	URANIUM RECOVERED
SULFURIC ACID	2.0N	N/A	7:1	40	2	20.82	6.00	17.59	6.95	93.26%	58.43%
HYDROCHLORIC ACID	1.0N	N/A	7:1	40	2	0.22	0.02	203.19	0.06	26.49%	73.96%
NITRIC ACID	1.0N	N/A	7:1	40	2	18.74	4.14	26.78	6.57	94.38%	54.43%
SODIUM CARBONATE/ BICARBONATE	1.0M	N/A	7:1	40	2	9.23	1.19	61.36	2.68	76.81%	43.13%
AMMONIUM CARBONATE/ BICARBONATE	1.0M	N/A	7:1	40	2	8.90	3.08	55.73	2.55	74.73%	44.22%
Tiron	0.6M	5.00	7:1	40	2	10.42	2.38	103.08	2.71	66.30%	60.76%
EDTA	0.5M	10.00	7:1	40	2	12.24	4.32	82.43	4.30	31.92%	57.21%

1229

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Residual Uranium (ppm) in OU5-A Sulfuric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	pH of Solids	ppm U in Solids OU5-A	DUP	% U Removed	% U Recovered
1087	30	9	40° C	2.0 N	2.0 Hrs.	7:1		17.59		93.26%	58.43%
	38	9							20.40	94.36%	55.11%
1087	38	6	40° C	2.0 N	2.0 Hrs.	4:1		178.71		34.73%	68.57%
	38	12							140.17	43.05%	60.93%
	38	18							165.46	35.64%	66.34%
1087	42	3	40° C	2.0 N	0.5 Hr.	7:1		13.85		95.07%	55.76%
1087	38	27	40° C	2.0 N	0.5 Hr.	4:1		56.31		77.69%	71.06%
1087	46	3	40° C	1.0 N	2.0 Hrs.	7:1		60.70		75.92%	66.73%
1087	46	6	40° C	1.0 N	2.0 Hrs.	4:1		110.69		57.06%	45.29%
1087	42	6	40° C	1.0 N	0.5 Hr.	7:1		64.06		73.33%	68.82%
1087	42	9	40° C	1.0 N	0.5 Hr.	4:1		125.74		49.04%	51.85%
1087	38	21	Ambient	2.0 N	2.0 Hrs.	7:1		55.13		78.76%	58.42%
1087	38	24	Ambient	2.0 N	2.0 Hrs.	4:1		18.18		92.85%	39.26%
1087	42	12	Ambient	2.0 N	0.5 Hr.	7:1		38.78		85.39%	50.80%
1087	42	15	Ambient	2.0 N	0.5 Hr.	4:1		55.35		75.48%	54.80%
	46	15							62.15	73.31%	67.89%
1087	46	9	Ambient	1.0 N	2.0 Hrs.	7:1		64.41		75.15%	105.98%
1087	46	12	Ambient	1.0 N	2.0 Hrs.	4:1		133.50		49.68%	50.71%
1087	46	18	Ambient	1.0 N	0.5 Hr.	7:1		65.30		74.63%	61.18%
1087	42	18	Ambient	1.0 N	0.5 Hr.	4:1		117.68		55.18%	59.12%

Residual Uranium (ppm) in OU5-A Nitric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	pH of Solids	ppm U in Solids OU5-A	ppm U in Solids DUP	% U Removed	% U Recovered
1087	30	6	40° C	2.0 N	2.0 Hrs.	7:1		26.78		94.38%	54.43%
	54	15							14.30	97.23%	46.01%
1087	54	18	40° C	2.0 N	2.0 Hrs.	4:1		211.57		50.78%	49.86%
1087	50	15	40° C	2.0 N	0.5 Hr.	7:1		32.91		93.04%	73.50%
1087	50	18	40° C	2.0 N	0.5 Hr.	4:1		188.52		52.39%	50.05%
1087	54	3	40° C	1.0 N	2.0 Hrs.	7:1		175.10		57.90%	42.62%
1087	54	6	40° C	1.0 N	2.0 Hrs.	4:1		148.55		56.30%	43.79%
1087	50	3	40° C	1.0 N	0.5 Hr.	7:1		153.61		63.15%	37.29%
1087	50	6	40° C	1.0 N	0.5 Hr.	4:1		251.49		22.64%	77.50%
1087	58	3	Ambient	2.0 N	2.0 Hrs.	7:1		82.11		82.51%	56.16%
1087	58	6	Ambient	2.0 N	2.0 Hrs.	4:1		252.05		37.74%	62.50%
1087	58	9	Ambient	2.0 N	0.5 Hr.	7:1		82.89		81.74%	36.87%
1087	58	12	Ambient	2.0 N	0.5 Hr.	4:1		185.26		53.16%	48.87%
1087	54	9	Ambient	1.0 N	2.0 Hrs.	7:1		234.82		47.68%	53.04%
1087	54	12	Ambient	1.0 N	2.0 Hrs.	4:1		164.41		47.79%	52.31%
1087	50	9	Ambient	1.0 N	0.5 Hr.	7:1		201.64		52.51%	48.80%
1087	50	12	Ambient	1.0 N	0.5 Hr.	4:1		182.25		47.82%	52.76%

000455

INTERMEDIATE STAGE PHYSICAL SEPARATION ID SOILS

Fernald OU5 ID-A Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	mg U in Size Fraction	Gross Alpha, (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	52	1	water	n/a	0.08	>53 μm	8.85	1502.46	13.30	731	714	1440
1055	52	2	water	n/a	0.08	<53 μm	87.13	244.19	21.28	278	177	455
1055	52	3	water	n/a	0.08	Liquid	553.74	1.99	1.10	<0.659	<1.25	1.91
1055	52	4	water	n/a	0.25	>53 μm	7.08	1117.00	7.91	863	712	1570
1055	52	5	water	n/a	0.25	<53 μm	91.82	271.27	24.91	283	160	443
1055	52	6	water	n/a	0.25	Liquid	509.15	1.18	0.60	0.684	1.25	1.93
1055	52	7	water	n/a	0.50	>53 μm	6.45	902.16	5.82	701	522	1220
1055	52	8	water	n/a	0.50	<53 μm	89.38	232.00	20.74	251	107	358
1055	52	9	water	n/a	0.50	Liquid	705.34	2.48	1.75	0.73	1.25	1.98
1055	52	10	Pyrophosphate	0.1 M	0.08	>53 μm	7.57	1151.77	8.72	669	603	1270
1055	52	11	Pyrophosphate	0.1 M	0.08	<53 μm	88.06	185.21	16.31	166	120	286
1055	52	12	Pyrophosphate	0.1 M	0.08	Liquid	551.82	36.67	20.24	20.5	9.68	30.2
1055	52	13	Pyrophosphate	0.1 M	0.25	>53 μm	6.29	1844.08	11.60	741	557	1300
1055	52	14	Pyrophosphate	0.1 M	0.25	<53 μm	87.79	145.65	12.79	197	103	300
1055	52	15	Pyrophosphate	0.1 M	0.25	Liquid	670.99	34.60	23.22	20.7	12.5	33.2
1055	52	16	Pyrophosphate	0.1 M	0.50	>53 μm	6.39	594.82	3.80	479	409	888
1055	52	17	Pyrophosphate	0.1 M	0.50	<53 μm	88.57	157.26	13.93	126	122	248
1055	52	18	Pyrophosphate	0.1 M	0.50	Liquid	551.19	44.06	24.29	17.1	12.5	29.5
1055	52	19	Pyrophosphate	0.25 M	0.08	>53 μm	6.77	968.08	6.55	536	416	953
1055	52	20	Pyrophosphate	0.25 M	0.08	<53 μm	87.81	86.39	7.59	167	74.9	242
1055	52	21	Pyrophosphate	0.25 M	0.08	Liquid	553.10	55.23	30.55	15.8	19.2	35
1055	52	22	Pyrophosphate	0.25 M	0.25	>53 μm	6.08	419.47	2.55	287	282	569
1055	52	23	Pyrophosphate	0.25 M	0.25	<53 μm	89.23	131.19	11.71	113	93.9	207
1055	52	24	Pyrophosphate	0.25 M	0.25	Liquid	615.94	44.54	27.43	18.9	17.4	36.3
1055	52	25	Pyrophosphate	0.25 M	0.50	>53 μm	5.74	397.83	2.28	223	248	471
1055	52	26	Pyrophosphate	0.25 M	0.50	<53 μm	90.83	95.15	8.64	142	101	243
1055	52	27	Pyrophosphate	0.25 M	0.50	Liquid	605.01	55.78	33.75	24.5	21.2	45.7
1055	54	22	Pyrophosphate	0.50 M	0.08	>53 μm	6.76	615.69	4.16	423	383	806
1055	54	23	Pyrophosphate	0.50 M	0.08	<53 μm	87.04	141.28	12.30	112	102	214
1055	54	24	Pyrophosphate	0.50 M	0.08	Liquid	668.48	49.47	33.07	11.2	16.4	27.6
1055	54	25	Pyrophosphate	0.50 M	0.25	>53 μm	8.10	457.44	3.71	407	346	753
1055	54	26	Pyrophosphate	0.50 M	0.25	<53 μm	41.61	151.75	6.31	152	104	256
1055	54	27	Pyrophosphate	0.50 M	0.25	Liquid	541.60	50.54	27.37	24.2	9.09	33.2
1055	56	7	Pyrophosphate	0.50 M	0.50	>53 μm	9.21	519.38	4.78	507	484	991
1055	56	8	Pyrophosphate	0.50 M	0.50	<53 μm	87.82	103.65	9.10	102	146	248
1055	56	9	Pyrophosphate	0.50 M	0.50	Liquid	648.14	46.12	29.89	34.3	18.6	53

Fernald OU5 ID-A Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	mg U in Size Fraction	Gross Alpha, (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	52	28	Amm. Carbonate	0.10 M	0.08	>53 μm	8.21	1095.98	9.00	725	700	1420
1055	52	29	Amm. Carbonate	0.10 M	0.08	<53 μm	91.71	221.49	20.31	203	142	345
1055	52	30	Amm. Carbonate	0.10 M	0.08	Liquid	524.32	31.26	16.39	15.5	6.51	22
1055	52	31	Amm. Carbonate	0.10 M	0.25	>53 μm	6.70	1177.41	7.89	637	487	1120
1055	52	32	Amm. Carbonate	0.10 M	0.25	<53 μm	91.13	162.96	14.85	193	163	355
1055	52	33	Amm. Carbonate	0.10 M	0.25	Liquid	675.39	29.75	20.09	16.7	6.21	22.9
1055	54	1	Amm. Carbonate	0.10 M	0.50	>53 μm	6.59	684.18	4.51	770	570	1340
1055	54	2	Amm. Carbonate	0.10 M	0.50	<53 μm	90.61	157.21	14.24	178	161	339
1055	54	3	Amm. Carbonate	0.10 M	0.50	Liquid	609.82	38.00	23.17	22.6	9.89	32.5
1055	54	4	Amm. Carbonate	0.25 M	0.08	>53 μm	7.33	852.56	6.25	683	492	1180
1055	54	5	Amm. Carbonate	0.25 M	0.08	<53 μm	48.11	136.84	6.58	174	91	265
1055	54	6	Amm. Carbonate	0.25 M	0.08	Liquid	610.71	32.35	19.76	16.1	6.97	23.1
1055	54	7	Amm. Carbonate	0.25 M	0.25	>53 μm	6.10	571.21	3.48	527	494	1020
1055	54	8	Amm. Carbonate	0.25 M	0.25	<53 μm	82.17	155.19	12.75	138	118	256
1055	54	9	Amm. Carbonate	0.25 M	0.25	Liquid	564.16	46.66	26.33	30.2	11.7	41.9
1055	54	10	Amm. Carbonate	0.25 M	0.50	>53 μm	6.39	466.61	2.98	743	481	1220
1055	54	11	Amm. Carbonate	0.25 M	0.50	<53 μm	77.90	138.19	10.77	227	223	450
1055	54	12	Amm. Carbonate	0.25 M	0.50	Liquid	595.13	48.59	28.92	26.2	10.3	36.5
1055	54	13	Amm. Carbonate	0.50 M	0.08	>53 μm	7.40	648.26	4.80	752	569	1320
1055	54	14	Amm. Carbonate	0.50 M	0.08	<53 μm	48.25	152.99	7.38	145	166	311
1055	54	15	Amm. Carbonate	0.50 M	0.08	Liquid	787.04	46.93	36.93	20.5	11	31.5
1055	54	16	Amm. Carbonate	0.50 M	0.25	>53 μm	6.32	1118.38	7.07	580	447	1030
1055	54	17	Amm. Carbonate	0.50 M	0.25	<53 μm	71.36	194.47	13.88	189	175	364
1055	54	18	Amm. Carbonate	0.50 M	0.25	Liquid	567.58	48.02	27.26	21.5	11.4	32.9
1055	54	19	Amm. Carbonate	0.50 M	0.50	>53 μm	5.85	526.95	3.08	753	513	1270
1055	54	20	Amm. Carbonate	0.50 M	0.50	<53 μm	89.12	194.66	17.35	206	235	442
1055	54	21	Amm. Carbonate	0.50 M	0.50	Liquid	627.10	49.08	30.78	22.7	11.9	34.6
1055	54	28	Na Carbonate	0.10 M	0.08	>53 μm	8.09	623.73	5.05	565	502	1070
1055	54	29	Na Carbonate	0.10 M	0.08	<53 μm	87.47	141.13	12.34	188	157	344
1055	54	30	Na Carbonate	0.10 M	0.08	Liquid	680.13	38.88	26.44	17.2	9	26.2
1055	56	1	Na Carbonate	0.10 M	0.25	>53 μm	6.44	604.67	3.89	456	342	798
1055	56	2	Na Carbonate	0.10 M	0.25	<53 μm	88.03	150.05	13.21	150	154	304
1055	56	3	Na Carbonate	0.10 M	0.25	Liquid	540.95	48.22	26.09	24.4	12.8	37.2
1055	56	4	Na Carbonate	0.10 M	0.50	>53 μm	5.70	416.91	2.38	449	449	898
1055	56	5	Na Carbonate	0.10 M	0.50	<53 μm	86.93	158.49	13.78	219	196	414
1055	56	6	Na Carbonate	0.10 M	0.50	Liquid	676.06	39.12	26.45	30.5	11.6	42.1

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Fernald OU5 ID-A Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	mg U in Size Fraction	Gross Alpha, (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	56	10	Na Carbonate	0.25 M	0.08	>53 μm	5.74	637.72	3.66	519	462	982
1055	56	11	Na Carbonate	0.25 M	0.08	<53 μm	90.51	149.19	13.50	129	113	242
1055	56	12	Na Carbonate	0.25 M	0.08	Liquid	596.66	67.91	40.52	24.5	7.49	32
1055	56	13	Na Carbonate	0.25 M	0.25	>53 μm	6.56	768.51	5.04	579	461	1040
1055	56	14	Na Carbonate	0.25 M	0.25	<53 μm	60.49	101.63	6.15	125	101	226
1055	56	15	Na Carbonate	0.25 M	0.25	Liquid	668.81	33.01	22.07	15.5	7.49	23
1055	56	16	Na Carbonate	0.25 M	0.50	>53 μm	6.20	477.27	2.96	246	268	514
1055	56	17	Na Carbonate	0.25 M	0.50	<53 μm	80.53	139.03	11.20	221	168	389
1055	56	18	Na Carbonate	0.25 M	0.50	Liquid	656.46	51.85	34.04	24	9.2	33.2
1055	56	19	Na Carbonate	0.50 M	0.08	>53 μm	11.48	1092.75	12.54	397	477	874
1055	56	20	Na Carbonate	0.50 M	0.08	<53 μm	86.17	107.36	9.25	131	130	262
1055	56	21	Na Carbonate	0.50 M	0.08	Liquid	694.87	51.56	35.83	21.7	6.62	28.4
1055	56	22	Na Carbonate	0.50 M	0.25	>53 μm	10.29	881.73	9.07	479	455	935
1055	56	23	Na Carbonate	0.50 M	0.25	<53 μm	85.81	99.31	8.52	148	156	304
1055	56	24	Na Carbonate	0.50 M	0.25	Liquid	615.12	42.98	26.44	29.8	10.1	39.9
1055	56	25	Na Carbonate	0.50 M	0.50	>53 μm	8.39	617.29	5.18	856	456	1310
1055	56	26	Na Carbonate	0.50 M	0.50	<53 μm	46.07	98.61	4.54	62.7	145	207
1055	56	27	Na Carbonate	0.50 M	0.50	Liquid	535.90	50.46	27.04	25.7	10.4	36.1

Fernald OU5 ID-B Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	58	1	water	n/a	0.08	>53 µm	25.09	139.87	124	72	196
1055	58	2	water	n/a	0.08	<53 µm	72.41	330.20	177	253	429
1055	58	3	water	n/a	0.08	Liquid	495.55	13.77	4.35	2.96	7.31
1055	58	4	water	n/a	0.25	>53 µm	27.13	116.96	212	76.6	289
1055	58	5	water	n/a	0.25	<53 µm	72.32	406.08	213	256	468
1055	58	6	water	n/a	0.25	Liquid	571.55	15.53	4.7	2.39	7.09
1055	58	7	water	n/a	0.50	>53 µm	22.14	111.01	137	62.4	199
1055	58	8	water	n/a	0.50	<53 µm	75.10	413.58	232	275	506
1055	58	9	water	n/a	0.50	Liquid	524.43	16.17	5.76	2.43	8.19
1055	60	1	Pyrophosphate	0.1 M	0.08	>53 µm	17.27	142.71	100	83.6	184
1055	60	2	Pyrophosphate	0.1 M	0.08	<53 µm	73.66	262.63	110	133	244
1055	60	3	Pyrophosphate	0.1 M	0.08	Liquid	484.15	47.18	27.6	9.1	36.7
1055	60	4	Pyrophosphate	0.1 M	0.25	>53 µm	19.82	98.66	48.5	55.8	104
1055	60	5	Pyrophosphate	0.1 M	0.25	<53 µm	69.94	223.77	116	129	244
1055	60	6	Pyrophosphate	0.1 M	0.25	Liquid	536.47	47.34	22.3	11	33.4
1055	60	7	Pyrophosphate	0.1 M	0.50	>53 µm	19.72	79.52	63.4	36.6	100
1055	60	8	Pyrophosphate	0.1 M	0.50	<53 µm	70.39	161.05	127	88.6	216
1055	60	9	Pyrophosphate	0.1 M	0.50	Liquid	460.54	56.12	28	8.77	36.8
1055	60	10	Pyrophosphate	0.25 M	0.08	>53 µm	20.24	107.98	57.4	53.6	111
1055	60	11	Pyrophosphate	0.25 M	0.08	<53 µm	69.20	184.60	75.9	77.1	153
1055	60	12	Pyrophosphate	0.25 M	0.08	Liquid	512.07	43.20	20.6	8.48	29.1
1055	60	13	Pyrophosphate	0.25 M	0.25	>53 µm	19.74	46.08	39.2	52.5	91.7
1055	60	14	Pyrophosphate	0.25 M	0.25	<53 µm	78.29	168.20	69.7	76.8	147
1055	60	15	Pyrophosphate	0.25 M	0.25	Liquid	562.48	41.43	20.6	9.02	29.6
1055	60	16	Pyrophosphate	0.25 M	0.50	>53 µm	16.90	69.30	<36.9	45.2	82.1
1055	60	17	Pyrophosphate	0.25 M	0.50	<53 µm	79.19	239.70	100	111	211
1055	60	18	Pyrophosphate	0.25 M	0.50	Liquid	514.67	44.60	31.1	8.74	39.9
1055	60	31	Pyrophosphate	0.50 M	0.08	>53 µm	16.23	92.10	82.8	73.4	156
1055	60	32	Pyrophosphate	0.50 M	0.08	<53 µm	81.71	65.10	83.6	129	212
1055	60	33	Pyrophosphate	0.50 M	0.08	Liquid	494.94	49.81	15.8	7.3	23.1
1055	62	1	Pyrophosphate	0.50 M	0.25	>53 µm	16.55	90.50	77.7	50.9	129
1055	62	2	Pyrophosphate	0.50 M	0.25	<53 µm	78.65	121.30	99.4	107	207
1055	62	3	Pyrophosphate	0.50 M	0.25	Liquid	532.49	48.15	16.2	8.3	24.5

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Fernald OU5 ID-B Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	62	4	Pyrophosphate	0.50 M	0.50	>53 µm	15.65	66.37	69.7	33.2	103
1055	62	5	Pyrophosphate	0.50 M	0.50	<53 µm	81.46	135.80	114	87.1	201
1055	62	6	Pyrophosphate	0.50 M	0.50	Liquid	513.84	45.91	20.7	8.14	28.8
1055	62	7	Amm. Carbonate	0.10 M	0.08	>53 µm	17.25	132.70	144	80	224
1055	62	8	Amm. Carbonate	0.10 M	0.08	<53 µm	58.36	283.40	151	88.2	239
1055	62	9	Amm. Carbonate	0.10 M	0.08	Liquid	351.48	36.93	14.6	6.2	20.8
1055	62	10	Amm. Carbonate	0.10 M	0.25	>53 µm	17.76	105.21	120	157	277
1055	62	11	Amm. Carbonate	0.10 M	0.25	<53 µm	78.17	93.90	212	194	407
1055	62	12	Amm. Carbonate	0.10 M	0.25	Liquid	483.73	38.39	19.6	5.62	25.2
1055	62	13	Amm. Carbonate	0.10 M	0.50	>53 µm	17.89	69.10	64.2	74.4	139
1055	62	14	Amm. Carbonate	0.10 M	0.50	<53 µm	75.62	91.00	97.3	114	212
1055	62	15	Amm. Carbonate	0.10 M	0.50	Liquid	529.68	38.89	17.1	4.77	21.8
1055	60	19	Amm. Carbonate	0.25 M	0.08	>53 µm	17.17	90.00	48.5	75.5	124
1055	60	20	Amm. Carbonate	0.25 M	0.08	<53 µm	78.71	232.00	116	136	252
1055	60	21	Amm. Carbonate	0.25 M	0.08	Liquid	489.08	45.53	17.2	7.12	24.4
1055	60	22	Amm. Carbonate	0.25 M	0.25	>53 µm	15.90	85.80	40.5	45.1	85.6
1055	60	23	Amm. Carbonate	0.25 M	0.25	<53 µm	79.00	154.60	137	144	281
1055	60	24	Amm. Carbonate	0.25 M	0.25	Liquid	487.97	46.84	21	6.55	27.5
1055	62	16	Amm. Carbonate	0.25 M	0.50	>53 µm	17.45	67.60	98.6	103	202
1055	62	17	Amm. Carbonate	0.25 M	0.50	<53 µm	79.46	81.60	94.5	117	212
1055	62	18	Amm. Carbonate	0.25 M	0.50	Liquid	513.05	47.29	24.8	7.62	32.4
1055	60	25	Amm. Carbonate	0.50 M	0.08	>53 µm	16.16	85.80	69.1	67.2	136
1055	60	26	Amm. Carbonate	0.50 M	0.08	<53 µm	79.40	237.60	141	140	281
1055	60	27	Amm. Carbonate	0.50 M	0.08	Liquid	492.82	47.07	22.5	7.39	29.9
1055	60	28	Amm. Carbonate	0.50 M	0.25	>53 µm	15.45	78.70	76.7	59.4	136
1055	60	29	Amm. Carbonate	0.50 M	0.25	<53 µm	72.07	111.00	127	116	243
1055	60	30	Amm. Carbonate	0.50 M	0.25	Liquid	495.98	45.12	13	6.55	19.5
1055	62	19	Amm. Carbonate	0.50 M	0.50	>53 µm	16.15	57.00	81.4	80.9	162
1055	62	20	Amm. Carbonate	0.50 M	0.50	<53 µm	72.91	64.20	63.8	117	181
1055	62	21	Amm. Carbonate	0.50 M	0.50	Liquid	532.23	46.60	21.4	6.31	27.8
1055	58	10	Na Carbonate	0.10 M	0.08	>53 µm	24.98	111.54	157	100	257
1055	58	11	Na Carbonate	0.10 M	0.08	<53 µm	71.33	388.24	107	114	221
1055	58	12	Na Carbonate	0.10 M	0.08	Liquid	492.34	48.44	21.9	12.4	34.3

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Fernald OU5 ID-B Hamilton Beach Mixer Data

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
1055	58	13	Na Carbonate	0.10 M	0.25	>53 µm	22.87	88.92	158	77.3	235
1055	58	14	Na Carbonate	0.10 M	0.25	<53 µm	73.80	282.19	87.8	83.7	171
1055	58	15	Na Carbonate	0.10 M	0.25	Liquid	544.41	48.57	23.3	14.8	38.1
1055	58	34	Na Carbonate	0.10 M	0.50	>53 µm	24.06	69.02	226	67	293
1055	58	35	Na Carbonate	0.10 M	0.50	<53 µm	69.22	225.26	68.7	78.4	147
1055	58	36	Na Carbonate	0.10 M	0.50	Liquid	631.99	46.03	21.9	14.6	36.4
1055	58	16	Na Carbonate	0.25 M	0.08	>53 µm	24.46	79.12	96.8	64.7	161
1055	58	17	Na Carbonate	0.25 M	0.08	<53 µm	73.28	153.57	102	90	192
1055	58	18	Na Carbonate	0.25 M	0.08	Liquid	509.49	48.00	18.7	6.18	24.8
1055	58	19	Na Carbonate	0.25 M	0.25	>53 µm	23.42	71.90	85.1	60.4	145
1055	58	20	Na Carbonate	0.25 M	0.25	<53 µm	72.98	150.30	84.4	135	220
1055	58	21	Na Carbonate	0.25 M	0.25	Liquid	602.19	47.81	18	6.71	24.7
1055	58	31	Na Carbonate	0.25 M	0.50	>53 µm	23.49	112.18	61.5	64.9	126
1055	58	32	Na Carbonate	0.25 M	0.50	<53 µm	73.09	183.36	69.2	118	188
1055	58	33	Na Carbonate	0.25 M	0.50	Liquid	498.54	48.28	13.9	7.58	21.5
1055	58	22	Na Carbonate	0.50 M	0.08	>53 µm	21.13	122.16	83.4	58.4	142
1055	58	23	Na Carbonate	0.50 M	0.08	<53 µm	74.62	132.50	54.5	135	190
1055	58	24	Na Carbonate	0.50 M	0.08	Liquid	624.52	46.06	19.7	8.57	28.2
1055	58	25	Na Carbonate	0.50 M	0.25	>53 µm	19.86	75.88	49.4	61.3	111
1055	58	26	Na Carbonate	0.50 M	0.25	<53 µm	79.15	99.83	59.4	135	194
1055	58	27	Na Carbonate	0.50 M	0.25	Liquid	672.30	51.08	28.5	9.65	38.1
1055	58	28	Na Carbonate	0.50 M	0.50	>53 µm	18.52	73.77	127	63.2	190
1055	58	29	Na Carbonate	0.50 M	0.50	<53 µm	59.29	144.55	81.7	116	197
1055	58	30	Na Carbonate	0.50 M	0.50	Liquid	452.10	46.04	16.2	7.03	23.2

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Comparison of DECO Attrition Scrubber to Hamilton Beach Mixer

Fernald OU5-ID-A soil DECO Attrition Scrubbing

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Percent of Total U
1055	70	7	Na CO3/HCO3	0.25 M	0.08	>53 μm	19.38	280.11	5.25
1055	70	8	Na CO3/HCO3	0.25 M	0.08	<53 μm	164.86	309.13	49.29
1055	70	9	Na CO3/HCO3	0.25 M	0.08	Liquid	881.07	53.35	45.46
1055	70	10	Na CO3/HCO3	0.25 M	0.25	>53 μm	21.23	970.57	23.67
1055	70	11	Na CO3/HCO3	0.25 M	0.25	<53 μm	135.04	180.44	28.00
1055	70	12	Na CO3/HCO3	0.25 M	0.25	Liquid	815.33	51.59	48.33
1055	70	13	Na CO3/HCO3	0.25 M	0.50	>53 μm	17.96	552.50	12.58
1055	70	14	Na CO3/HCO3	0.25 M	0.50	<53 μm	119.06	232.79	35.15
1055	70	15	Na CO3/HCO3	0.25 M	0.50	Liquid	903.40	45.63	52.27

Fernald OU5-ID-A soil Hamilton Beach Mixer

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Percent of Total U
1055	56	10	Na CO3/HCO3	0.25 M	0.08	>53 μm	5.74	637.72	6.35
1055	56	11	Na CO3/HCO3	0.25 M	0.08	<53 μm	90.51	149.19	23.41
1055	56	12	Na CO3/HCO3	0.25 M	0.08	Liquid	596.66	67.91	70.24
1055	56	13	Na CO3/HCO3	0.25 M	0.25	>53 μm	6.56	768.51	22.69
1055	56	14	Na CO3/HCO3	0.25 M	0.25	<53 μm	60.49	101.63	27.66
1055	56	15	Na CO3/HCO3	0.25 M	0.25	Liquid	333.74	33.06	49.65
1055	56	16	Na CO3/HCO3	0.25 M	0.50	>53 μm	6.20	477.27	6.14
1055	56	17	Na CO3/HCO3	0.25 M	0.50	<53 μm	80.53	139.03	23.23
1055	56	18	Na CO3/HCO3	0.25 M	0.50	Liquid	656.46	51.85	70.63

All DECO samples were "whole" soil and all Hamilton samples were <2mm soil.

Comparison of DECO Attrition Scrubber to Hamilton Beach Mixer

Fernald OU5-ID-B soil DECO Attrition Scrubbing

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Percent of Total U
1055	76	1	Na CO3/HCO3	0.25 M	0.08	>53 μm	49.08	129.38	8.77
1055	76	2	Na CO3/HCO3	0.25 M	0.08	<53 μm	144.68	170.64	34.08
1055	76	3	Na CO3/HCO3	0.25 M	0.08	Liquid	809.40	51.15	57.15
1055	76	4	Na CO3/HCO3	0.25 M	0.25	>53 μm	48.31	99.13	8.21
1055	76	5	Na CO3/HCO3	0.25 M	0.25	<53 μm	122.82	147.38	31.05
1055	76	6	Na CO3/HCO3	0.25 M	0.25	Liquid	637.19	55.58	60.74
1055	74	13	Na CO3/HCO3	0.25 M	0.50	>53 μm	53.12	97.11	6.44
1055	74	14	Na CO3/HCO3	0.25 M	0.50	<53 μm	157.21	167.04	32.77
1055	74	15	Na CO3/HCO3	0.25 M	0.50	Liquid	943.53	51.63	60.79

Fernald OU5-ID-B soil Hamilton Beach Mixer

Note-Book #	Page #	Sample #	Dispersing/ Extraction Agent	Conc.	Contact Time	Size Fraction	Wt. of Size Fraction	ppm U in Size Fraction	Percent of Total U
1055	58	16	Na CO3/HCO3	0.25 M	0.08	>53 μm	24.46	79.12	5.14
1055	58	17	Na CO3/HCO3	0.25 M	0.08	<53 μm	73.28	153.57	29.89
1055	58	18	Na CO3/HCO3	0.25 M	0.08	Liquid	509.49	48.00	64.96
1055	58	19	Na CO3/HCO3	0.25 M	0.25	>53 μm	23.42	71.90	4.06
1055	58	20	Na CO3/HCO3	0.25 M	0.25	<53 μm	72.98	150.30	26.47
1055	58	21	Na CO3/HCO3	0.25 M	0.25	Liquid	602.19	47.81	69.47
1055	58	31	Na CO3/HCO3	0.25 M	0.50	>53 μm	23.49	112.18	6.57
1055	58	32	Na CO3/HCO3	0.25 M	0.50	<53 μm	73.09	183.36	33.42
1055	58	33	Na CO3/HCO3	0.25 M	0.50	Liquid	498.54	48.28	60.01

All DECO samples were "whole [illegible]l and all Hamilton samples were <2mm soil.

000164

INTERMEDIATE STAGE CHEMICAL EXTRACTION ID SOILS

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID			ID	SOIL	EXTRACTANT				
TYPE	CONC.	pH		TYPE	GROSS ALPHA (pCi/ml)	GROSS BETA (pCi/ml)	TOTAL ACTIVITY (pCi/ml)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	AU	ID-A	< 0.96	2.29	3.26	0.38	0.16
SULFURIC ACID	1.0 N	N/A	AV	ID-A	17.40	15.30	32.70	46.00	19.79
SULFURIC ACID	2.0N	N/A	AI	ID-A	20.90	21.30	42.20	44.40	20.49
SULFURIC ACID	2:1 (12N)	N/A	AJ	ID-A	42.90	29.80	72.70	47.80	22.06
SULFURIC ACID	1:1 (18N)	N/A	O	ID-A	35.30	29.90	65.10	32.61	22.35
HYDROCHLORIC ACID	0.1N	N/A	AW	ID-A	< 1.22	< 1.37	2.59	0.00	0.00
HYDROCHLORIC ACID	0.5N	N/A	AX	ID-A	< 2.21	< 1.45	3.67	0.29	0.13
HYDROCHLORIC ACID	1.0N	N/A	AK	ID-A	33.00	11.30	44.30	52.00	23.99
HYDROCHLORIC ACID	2:1 (4N)	N/A	AL	ID-A	23.50	12.30	35.70	54.70	25.68
HYDROCHLORIC ACID	1:1 (6N)	N/A	P	ID-A	59.80	25.10	84.90	43.89	24.01
NITRIC ACID	0.1N	N/A	AY	ID-A	1.53	1.47	3.00	1.47	0.66
NITRIC ACID	0.5N	N/A	AZ	ID-A	< 2.24	< 1.46	3.70	0.93	0.43
NITRIC ACID	1.0N	N/A	AM	ID-A	22.50	15.30	37.80	37.00	17.19
NITRIC ACID	2:1 (5.3N)	N/A	AN	ID-A	30.20	26.90	57.10	44.80	20.83
NITRIC ACID	1:1 (8N)	N/A	Q	ID-A	42.70	27.90	70.60	42.66	25.89

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OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	RINSATE GROSS ALPHA (pCi/ml)	GROSS BETA (pCi/ml)	TOTAL ACTIVITY (pCi/ml)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	AU	ID-A	< 0.90	< 1.36	2.26	0.73	0.08
SULFURIC ACID	1.0 N	N/A	AV	ID-A	1.83	4.19	6.02	15.00	2.11
SULFURIC ACID	2.0N	N/A	AI	ID-A	5.00	5.00	10.00	12.00	1.98
SULFURIC ACID	2:1 (12N)	N/A	AJ	ID-A	4.55	6.94	11.50	12.50	2.03
SULFURIC ACID	1:1 (18N)	N/A	O	ID-A	3.13	3.58	6.71	4.70	1.02
HYDROCHLORIC ACID	0.1N	N/A	AW	ID-A	< 0.88	< 1.36	2.24	0.23	0.04
HYDROCHLORIC ACID	0.5N	N/A	AX	ID-A	< 1.28	< 1.37	2.65	0.00	0.00
HYDROCHLORIC ACID	1.0N	N/A	AK	ID-A	5.03	1.86	6.89	8.59	1.57
HYDROCHLORIC ACID	2:1 (4N)	N/A	AL	ID-A	7.86	2.96	10.80	21.50	3.63
HYDROCHLORIC ACID	1:1 (6N)	N/A	P	ID-A	60.60	6.88	67.50	7.57	1.57
NITRIC ACID	0.1N	N/A	AY	ID-A	1.03	1.45	2.48	1.09	0.18
NITRIC ACID	0.5N	N/A	AZ	ID-A	1.18	< 1.37	2.55	0.00	0.00
NITRIC ACID	1.0N	N/A	AM	ID-A	3.91	1.56	5.47	7.18	1.21
NITRIC ACID	2:1 (5.3N)	N/A	AN	ID-A	2.61	2.66	5.28	8.82	1.51
NITRIC ACID	1:1 (8N)	N/A	Q	ID-A	5.17	3.08	8.24	6.14	1.29

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	EXTRACTED SOLIDS GROSS ALPHA (pCi/g)	GROSS BETA (pCi/g)	TOTAL ACTIVITY (pCi/g)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	AU	ID-A	753.00	277.00	1030.00	409.00	22.06
SULFURIC ACID	1.0 N	N/A	AV	ID-A	< 129.00	< 110.00	239.00	13.80	0.61
SULFURIC ACID	2.0N	N/A	AI	ID-A	151.00	102.00	253.00	12.60	0.53
SULFURIC ACID	2:1 (12N)	N/A	AJ	ID-A	149.00	82.70	232.00	8.79	0.36
SULFURIC ACID	1:1 (18N)	N/A	O	ID-A	139.00	187.00	326.00	14.04	0.47
HYDROCHLORIC ACID	0.1N	N/A	AW	ID-A	466.00	252.00	717.00	433.00	18.49
HYDROCHLORIC ACID	0.5N	N/A	AX	ID-A	410.00	299.00	709.00	441.00	16.09
HYDROCHLORIC ACID	1.0N	N/A	AK	ID-A	245.00	280.00	525.00	14.20	0.57
HYDROCHLORIC ACID	2:1 (4N)	N/A	AL	ID-A	181.00	207.00	388.00	15.00	0.67
HYDROCHLORIC ACID	1:1 (6N)	N/A	P	ID-A	173.00	67.80	240.80	23.37	1.19
NITRIC ACID	0.1N	N/A	AY	ID-A	392.00	295.00	687.00	395.00	17.50
NITRIC ACID	0.5N	N/A	AZ	ID-A	429.00	324.00	753.00	448.00	14.75
NITRIC ACID	1.0N	N/A	AM	ID-A	94.80	158.00	253.00	9.04	0.37
NITRIC ACID	2:1 (5.3N)	N/A	AN	ID-A	103.00	104.00	207.00	7.16	0.30
NITRIC ACID	1:1 (8N)	N/A	Q	ID-A	79.00	< 46.60	126.00	4.87	0.20

000168

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	TOTAL EXTRACTED U (mg)	PERCENT URANIUM REMOVED	PERCENT URANIUM RECOVERY
SULFURIC ACID	0.2N	N/A	AU	ID-A	0.25	-19.35%	120.68%
SULFURIC ACID	1.0 N	N/A	AV	ID-A	21.90	96.72%	121.73%
SULFURIC ACID	2.0N	N/A	AI	ID-A	22.47	97.13%	124.40%
SULFURIC ACID	2:1 (12N)	N/A	AJ	ID-A	24.09	98.05%	132.29%
SULFURIC ACID	1:1 (18N)	N/A	O	ID-A	23.36	97.48%	128.68%
HYDROCHLORIC ACID	0.1N	N/A	AW	ID-A	0.04	-0.04%	100.26%
HYDROCHLORIC ACID	0.5N	N/A	AX	ID-A	0.13	12.96%	87.75%
HYDROCHLORIC ACID	1.0N	N/A	AK	ID-A	25.56	96.94%	141.34%
HYDROCHLORIC ACID	2:1 (4N)	N/A	AL	ID-A	29.32	96.39%	162.24%
HYDROCHLORIC ACID	1:1 (6N)	N/A	P	ID-A	25.58	93.58%	144.82%
NITRIC ACID	0.1N	N/A	AY	ID-A	0.85	5.32%	99.26%
NITRIC ACID	0.5N	N/A	AZ	ID-A	0.43	20.19%	82.13%
NITRIC ACID	1.0N	N/A	AM	ID-A	18.40	97.99%	101.54%
NITRIC ACID	2:1 (5.3N)	N/A	AN	ID-A	22.34	98.38%	122.44%
NITRIC ACID	1:1 (8N)	N/A	Q	ID-A	27.18	98.90%	147.95%

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID			ID	SOIL TYPE	EXTRACTANT				
TYPE	CONC.	pH			GROSS ALPHA (pCi/ml)	GROSS BETA (pCi/ml)	TOTAL ACTIVITY (pCi/ml)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	BA	ID-B	17.40	15.20	32.50	51.80	23.42
SULFURIC ACID	1.0 N	N/A	BB	ID-B	22.10	21.70	43.80	51.10	22.83
SULFURIC ACID	2.0N	N/A	AO	ID-B	16.40	18.00	34.40	45.90	20.48
SULFURIC ACID	2:1 (12N)	N/A	AP	ID-B	22.90	25.30	48.20	43.50	19.70
SULFURIC ACID	1:1 (18N)	N/A	A	ID-B	91.10	25.50	116.60	43.55	19.03
HYDROCHLORIC ACID	0.1N	N/A	BC	ID-B	27.10	7.70	34.80	36.70	16.52
HYDROCHLORIC ACID	0.5N	N/A	BD	ID-B	8.40	6.47	14.90	37.40	17.04
HYDROCHLORIC ACID	1.0N	N/A	AQ	ID-B	11.20	13.40	24.60	44.80	21.12
HYDROCHLORIC ACID	2:1 (4N)	N/A	AR	ID-B	16.40	20.10	36.50	44.90	21.49
HYDROCHLORIC ACID	1:1 (6N)	N/A	B	ID-B	38.70	20.40	59.10	39.44	18.92
NITRIC ACID	0.1N	N/A	BE	ID-B	2.22	7.08	2.93	38.00	17.09
NITRIC ACID	0.5N	N/A	BF	ID-B	25.70	14.30	40.00	56.70	25.94
NITRIC ACID	1.0N	N/A	AS	ID-B	8.16	17.20	25.30	47.30	22.01
NITRIC ACID	2:1 (5.3N)	N/A	AT	ID-B	18.90	17.80	36.70	45.30	21.58
NITRIC ACID	1:1 (8N)	N/A	C	ID-B	28.60	22.90	51.50	41.76	19.65

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	RINSATE GROSS ALPHA (pCi/ml)	GROSS BETA (pCi/ml)	TOTAL ACTIVITY (pCi/ml)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	BA	ID-B	1.46	1.87	3.33	6.38	1.36
SULFURIC ACID	1.0 N	N/A	BB	ID-B	5.75	4.51	1.03	10.60	1.85
SULFURIC ACID	2.0N	N/A	AO	ID-B	5.91	4.17	10.10	14.10	2.03
SULFURIC ACID	2:1 (12N)	N/A	AP	ID-B	5.11	4.95	10.10	13.00	2.15
SULFURIC ACID	1:1 (18N)	N/A	A	ID-B	4.23	3.30	7.53	9.24	1.56
HYDROCHLORIC ACID	0.1N	N/A	BC	ID-B	2.49	< 1.36	3.85	3.58	0.69
HYDROCHLORIC ACID	0.5N	N/A	BD	ID-B	2.82	2.15	4.97	3.18	0.66
HYDROCHLORIC ACID	1.0N	N/A	AQ	ID-B	4.08	2.09	6.17	7.55	1.25
HYDROCHLORIC ACID	2:1 (4N)	N/A	AR	ID-B	4.39	3.19	7.58	8.30	1.31
HYDROCHLORIC ACID	1:1 (6N)	N/A	B	ID-B	1.86	2.40	4.26	4.97	0.87
NITRIC ACID	0.1N	N/A	BE	ID-B	2.72	1.71	4.43	5.32	0.81
NITRIC ACID	0.5N	N/A	BF	ID-B	4.50	2.34	6.84	9.44	1.45
NITRIC ACID	1.0N	N/A	AS	ID-B	3.35	2.24	5.59	8.09	1.37
NITRIC ACID	2:1 (5.3N)	N/A	AT	ID-B	2.59	2.61	5.20	8.53	1.41
NITRIC ACID	1:1 (8N)	N/A	C	ID-B	3.93	2.86	6.79	7.73	1.05

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	EXTRACTED SOLIDS GROSS ALPHA (pCi/g)	GROSS BETA (pCi/g)	TOTAL ACTIVITY (pCi/g)	TOTAL U (ppm)	TOTAL U (mg)
SULFURIC ACID	0.2N	N/A	BA	ID-B	99.80	145.00	245.00	45.70	2.08
SULFURIC ACID	1.0 N	N/A	BB	ID-B	64.70	76.90	142.00	18.40	0.79
SULFURIC ACID	2.0N	N/A	AO	ID-B	386.00	226.00	612.00	8.59	0.39
SULFURIC ACID	2:1 (12N)	N/A	AP	ID-B	232.00	227.00	460.00	15.20	0.65
SULFURIC ACID	1:1 (18N)	N/A	A	ID-B	< 74.10	86.00	160.10	13.41	0.57
HYDROCHLORIC ACID	0.1N	N/A	BC	ID-B	244.00	207.00	451.00	176.00	7.97
HYDROCHLORIC ACID	0.5N	N/A	BD	ID-B	194.00	205.00	399.00	145.00	4.96
HYDROCHLORIC ACID	1.0N	N/A	AQ	ID-B	376.00	204.00	580.00	8.41	0.27
HYDROCHLORIC ACID	2:1 (4N)	N/A	AR	ID-B	329.00	344.00	673.00	4.70	0.14
HYDROCHLORIC ACID	1:1 (6N)	N/A	B	ID-B	< 85.00	117.00	202.00	3.18	0.09
NITRIC ACID	0.1N	N/A	BE	ID-B	224.00	238.00	462.00	163.00	7.09
NITRIC ACID	0.5N	N/A	BF	ID-B	112.00	160.00	272.00	22.80	0.98
NITRIC ACID	1.0N	N/A	AS	ID-B	401.00	195.00	596.00	9.81	0.32
NITRIC ACID	2:1 (5.3N)	N/A	AT	ID-B	352.00	136.00	488.00	3.56	0.11
NITRIC ACID	1:1 (8N)	N/A	C	ID-B	102.00	103.00	205.00	2.34	0.07

000172

OU5 CHEMICAL EXTRACTION: STAGE I and INTERMEDIATE

EXTRACTION FLUID TYPE	CONC.	pH	ID	SOIL TYPE	TOTAL EXTRACTED U (mg)	PERCENT URANIUM REMOVED	PERCENT URANIUM RECOVERY
SULFURIC ACID	0.2N	N/A	BA	ID-B	24.79	89.90%	130.69%
SULFURIC ACID	1.0 N	N/A	BB	ID-B	24.68	96.16%	123.92%
SULFURIC ACID	2.0N	N/A	AO	ID-B	22.50	98.12%	111.35%
SULFURIC ACID	2:1 (12N)	N/A	AP	ID-B	21.85	96.84%	109.46%
SULFURIC ACID	1:1 (18N)	N/A	A	ID-B	20.59	97.24%	102.88%
HYDROCHLORIC ACID	0.1N	N/A	BC	ID-B	17.21	61.24%	122.48%
HYDROCHLORIC ACID	0.5N	N/A	BD	ID-B	17.69	75.89%	110.19%
HYDROCHLORIC ACID	1.0N	N/A	AQ	ID-B	22.36	98.69%	110.10%
HYDROCHLORIC ACID	2:1 (4N)	N/A	AR	ID-B	22.80	99.32%	111.64%
HYDROCHLORIC ACID	1:1 (6N)	N/A	B	ID-B	19.79	99.56%	96.65%
NITRIC ACID	0.1N	N/A	BE	ID-B	17.90	65.52%	121.57%
NITRIC ACID	0.5N	N/A	BF	ID-B	27.39	95.22%	138.05%
NITRIC ACID	1.0N	N/A	AS	ID-B	23.38	98.43%	115.35%
NITRIC ACID	2:1 (5.3N)	N/A	AT	ID-B	22.99	99.47%	112.36%
NITRIC ACID	1:1 (8N)	N/A	C	ID-B	20.70	99.66%	100.98%

STAGE 2
CHEMICAL EXTRACTION
ID SOILS

Fernald OU5 - Stage 2 Time and Temperature Tests with Sulfuric Acid

Residual Uranium (ppm) in OU5 ID-A Sulfuric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	Filtration Time(min.)	pH of Solids after Water Rinse	ppm U in solids ID-A	ppm U in solids Dup	% U Removed	% U Recovered
1063	4	3	80° C	18.0 N	4.0 Hrs.	10:1	NR	NR	14.04		97.48%	128.68%
1063	14	6	80° C	12.0 N	4.0 Hrs.	10:1	NR	NR	8.79		98.05%	132.29%
1063	14	3	80° C	2.0 N	4.0 Hrs.	10:1	NR	NR	12.60		97.13%	124.40%
1063	22	6	80° C	1.0 N	4.0 Hrs.	10:1	NR	NR	13.80		96.72%	121.73%
1063	22	3	80° C	0.2 N	4.0 Hrs.	10:1	NR	NR	409.00		-19.35%	120.68%
1063	38	3	40° C	2.0 N	2.0 Hrs.	7:1	25	2.28	27.85		94.56%	121.83%
1063	50	3					>120	2.41		36.51	92.47%	118.03%
1063	38	6	40° C	2.0 N	2.0 Hrs.	4:1	5	2.49	30.67		94.00%	121.47%
1063	50	6					11	2.22		66.48	87.32%	105.22%
1063	38	9	40° C	2.0 N	0.5 Hr.	7:1	35	2.67	51.66		89.86%	116.88%
1063	46	3					44	2.44		39.15	92.21%	115.32%
1063	46	6	40° C	2.0 N	0.5 Hr.	4:1	12	2.51	36.07		92.41%	119.23%
1063	50	9	40° C	1.0 N	2.0 Hrs.	7:1	>120	2.51	31.28		93.96%	106.58%
1063	50	12	40° C	1.0 N	2.0 Hrs.	4:1	18	2.50	38.36		92.73%	123.54%
1063	46	9	40° C	1.0 N	0.5 Hr.	7:1	52	2.41	40.59		92.51%	118.41%
1063	46	12	40° C	1.0 N	0.5 Hr.	4:1	15	2.33	38.14		92.33%	116.37%
1063	50	15	Ambient	2.0 N	2.0 Hrs.	7:1	>120	2.67	57.03		88.30%	120.15%
1063	50	18	Ambient	2.0 N	2.0 Hrs.	4:1	47	2.41	67.61		85.97%	111.04%
1063	46	15	Ambient	2.0 N	0.5 Hr.	7:1	95	2.55	48.70		90.06%	107.32%
1063	46	18	Ambient	2.0 N	0.5 Hr.	4:1	58	2.46	62.94		87.29%	118.02%
1063	62	3	Ambient	1.0 N	2.0 Hrs.	7:1	>150	2.49	93.59		81.04%	117.64%
1063	62	6	Ambient	1.0 N	2.0 Hrs.	4:1	85	2.54	66.09		86.34%	104.27%
1063	38	15	Ambient	1.0 N	0.5 Hr.	7:1	120	3.02	73.70		85.47%	115.92%
1063	38	18	Ambient	1.0 N	0.5 Hr.	4:1	65	3.57	69.86		86.07%	110.49%
1063	38	12	30° C	1.50 N	1.25 Hrs.	5.5:1	30	2.51	111.13		76.47%	124.22%

NR - Not Recorded

Fernald OU5 - Stage 2 Time and Temperature Tests with Nitric Acid

Residual Uranium (ppm) in OU5 ID-A Nitric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	Filtration Time(min.)	pH of Solids after Water Rinse	ppm U in solids ID-A	% U Removed	% U Recovered
1063	4	9	80° C	8.0 N	4.0 Hrs.	10:1	NR	NR	4.87	98.90%	147.95%
1063	14	18	80° C	5.3 N	4.0 Hrs.	10:1	NR	NR	7.16	98.38%	122.44%
1063	14	15	80° C	1.0 N	4.0 Hrs.	10:1	NR	NR	9.04	97.99%	101.54%
1063	22	18	80° C	0.5 N	4.0 Hrs.	10:1	NR	NR	448.00	20.19%	82.13%
1063	22	15	80° C	0.1 N	4.0 Hrs.	10:1	NR	NR	395.00	5.32%	99.26%
1063	66	3	40° C	2.0 N	2.0 Hrs.	7:1	5	1.88	119.00	77.26%	137.66%
1063	66	6	40° C	2.0 N	2.0 Hrs.	4:1	20	2.09	30.59	93.86%	119.02%
1063	70	3	40° C	2.0 N	0.5 Hr.	7:1	20	2.51	28.45	94.56%	117.58%
1063	70	6	40° C	2.0 N	0.5 Hr.	4:1	13	2.42	28.54	94.27%	114.93%
1063	66	9	40° C	1.0 N	2.0 Hrs.	7:1	70	2.56	55.49	89.31%	118.51%
1063	66	12	40° C	1.0 N	2.0 Hrs.	4:1	35	2.48	61.53	88.38%	93.71%
1063	70	9	40° C	1.0 N	0.5 Hr.	7:1	18	2.65	26.05	95.12%	102.66%
1063	70	12	40° C	1.0 N	0.5 Hr.	4:1	11	2.62	44.50	91.49%	108.17%
1063	66	15	Ambient	2.0 N	2.0 Hrs.	7:1	70	2.18	95.36	79.67%	119.40%
1063	66	18	Ambient	2.0 N	2.0 Hrs.	4:1	50	2.23	97.22	80.49%	114.09%
1063	70	15	Ambient	2.0 N	0.5 Hr.	7:1	>34	3.16	102.90	81.30%	115.96%
1063	70	18	Ambient	2.0 N	0.5 Hr.	4:1	34	2.88	98.91	81.27%	102.19%
1063	82	3	Ambient	1.0 N	2.0 Hrs.	7:1	17	2.83	92.50	82.39%	115.29%
1063	82	6	Ambient	1.0 N	2.0 Hrs.	4:1	56	2.91	106.40	79.77%	107.96%
1063	82	9	Ambient	1.0 N	0.5 Hr.	7:1	62	2.95	287.50	41.09%	160.18%
1063	82	12	Ambient	1.0 N	0.5 Hr.	4:1	46	3.80	110.12	80.03%	109.61%

NR - Not Recorded

000176

Fernald OU5 - Stage 2 Time and Temperature Tests with Sulfuric Acid

Residual Uranium (ppm) in OU5 ID-B Sulfuric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	Filtration Time(min)	pH	ppm U in solids ID-B	ppm U in solids Dup	% U Removed	% U Recovered
1055	11	1	80° C	18.0 N	4.0 Hrs.	10:1	NR	NR	13.41		97.24%	102.88%
1063	18	6	80° C	12.0 N	4.0 Hrs.	10:1	NR	NR	15.20		96.84%	109.46%
1063	18	3	80° C	2.0 N	4.0 Hrs.	10:1	NR	NR	8.59		98.12%	111.35%
1063	26	6	80° C	1.0 N	4.0 Hrs.	10:1	NR	NR	18.40		96.16%	123.92%
1063	26	3	80° C	0.2 N	4.0 Hrs.	10:1	NR	NR	45.70		89.90%	130.69%
1063	58	3	40° C	2.0 N	2.0 Hrs.	7:1	22	6.28	17.79		96.82%	88.99%
1063	58	6	40° C	2.0 N	2.0 Hrs.	4:1	15	6.69	32.98		93.72%	81.48%
1063	54	3	40° C	2.0 N	0.5 Hr.	7:1	59	6.23	24.82		95.10%	90.00%
1063	54	6	40° C	2.0 N	0.5 Hr.	4:1	23	6.18	27.46		94.34%	87.00%
1063	42	3	40° C	1.0 N	2.0 Hrs.	7:1	40	6.63	25.20		95.14%	97.30%
1063	58	9					38	6.41		22.83	95.73%	91.55%
1063	42	6	40° C	1.0 N	2.0 Hrs.	4:1	12	6.58	75.64		84.38%	98.43%
1063	58	12					20	6.62		33.86	93.93%	84.29%
1063	42	9	40° C	1.0 N	0.5 Hr.	7:1	40	6.64	19.85		96.06%	97.16%
1063	54	9	40° C	1.0 N	0.5Hr.	7:1	44	6.74		23.24	95.45%	85.80%
1063	54	12	40° C	1.0 N	0.5 Hr.	4:1	20	6.67	38.82		91.81%	83.47%
1063	58	15	Ambient	2.0 N	2.0 Hrs.	7:1	70	6.54	22.89		95.94%	97.31%
1063	58	18	Ambient	2.0 N	2.0 Hrs.	4:1	93	6.53	32.59		93.84%	87.39%
1063	54	15	Ambient	2.0 N	0.5 Hr.	7:1	>120	6.09	25.70		95.10%	87.65%
1063	54	18	Ambient	2.0 N	0.5 Hr.	4:1	125	6.95	27.04		94.71%	75.98%
1063	62	9	Ambient	1.0 N	2.0 Hrs.	7:1	88	4.88	28.04		94.16%	86.06%
1063	62	12	Ambient	1.0 N	2.0 Hrs.	4:1	72	6.30	50.12		88.93%	86.83%
1063	62	15	Ambient	1.0 N	0.5 Hr.	7:1	154	4.79	30.71		93.37%	77.92%
1063	62	18	Ambient	1.0 N	0.5 Hr.	4:1	50<x<75	5.65	68.94		85.09%	84.25%
1063	42	12	30° C	0.6 N	1.25 Hrs.	5.5:1	18	6.56	278.54		44.47%	87.98%
1063	42	15	Ambient	0.2 N	0.5 Hr.	7:1	56	6.61	443.26		12.38%	91.41%
1063	42	18	Ambient	0.2 N	0.5 Hr.	4:1	62	6.54	278.29		47.12%	81.95%

NR - Not Recorded

Fernald OU5 - Stage 2 Time and Temperature Tests with Nitric Acid

Residual Uranium (ppm) in OU5 ID-B Nitric Acid Extracted Soils

Note-Book #	Page #	Sample ID #	Temp	Conc	Time	Dose	Filtration Time(min)	pH of Solids after Water Rinse	ppm U in solids ID-B	% U Removed	% U Recovered
1055	11	3	80° C	8.0 N	4.0 Hrs.	10:1	NR	NR	2.34	99.66%	100.98%
1063	18	18	80° C	5.3 N	4.0 Hrs.	10:1	NR	NR	3.56	99.47%	112.36%
1063	18	15	80° C	1.0 N	4.0 Hrs.	10:1	NR	NR	9.81	98.43%	115.35%
1063	26	18	80° C	0.5 N	4.0 Hrs.	10:1	NR	NR	22.80	95.22%	138.05%
1063	26	15	80° C	0.1 N	4.0 Hrs.	10:1	NR	NR	163.00	65.52%	121.57%
1063	86	3	40° C	2.0 N	2.0 Hrs.	7:1	19	2.57	17.63	97.27%	96.25%
1063	86	6	40° C	2.0 N	2.0 Hrs.	4:1	19	2.65	31.39	94.93%	92.29%
1063	78	3	40° C	2.0 N	0.5 Hr.	7:1	20	2.63	26.08	96.16%	95.82%
1063	78	6	40° C	2.0 N	0.5 Hr.	4:1	11	3.06	28.76	95.77%	91.53%
1063	86	9	40° C	1.0 N	2.0 Hrs.	7:1	32	2.77	40.22	94.38%	93.61%
1063	86	12	40° C	1.0 N	2.0 Hrs.	4:1	19	6.33	468.60	22.84%	77.75%
1063	78	9	40° C	1.0 N	0.5 Hr.	7:1	23	3.56	41.84	93.95%	92.37%
1063	78	12	40° C	1.0 N	0.5 Hr.	4:1	19	6.13	526.63	11.53%	88.91%
1063	74	15	Ambient	2.0 N	2.0 Hrs.	7:1	50	3.00	27.99	95.92%	91.45%
1063	74	18	Ambient	2.0 N	2.0 Hrs.	4:1	61	2.61	32.37	95.23%	88.73%
1063	78	15	Ambient	2.0 N	0.5 Hr.	7:1	28	3.04	482.17	26.47%	159.55%
1063	78	18	Ambient	2.0 N	0.5 Hr.	4:1	27	3.34	39.78	93.92%	90.79%
1063	86	15	Ambient	1.0 N	2.0 Hrs.	7:1	>40	3.24	38.48	93.98%	94.24%
1063	86	18	Ambient	1.0 N	2.0 Hrs.	4:1	40	6.18	510.35	13.22%	86.92%
1063	82	15	Ambient	1.0 N	0.5 Hr.	7:1	60	3.55	59.63	91.22%	95.94%
1063	82	18	Ambient	1.0 N	0.5 Hr.	4:1	19	6.45	455.03	24.20%	76.20%
1063	74	3	30° C	2.0 N	2.0 Hrs.	7:1	35	2.49	18.19	97.81%	76.05%
1063	74	6	30° C	2.0 N	2.0 Hrs.	4:1	24	3.32	28.87	96.01%	57.44%
1063	74	9	30° C	1.0 N	2.0 Hrs.	7:1	54	3.20	49.68	92.63%	93.78%
1063	74	12	30° C	1.0 N	2.0 Hrs.	4:1	40	3.33	82.97	87.50%	88.05%

NR - Not Recorded

STAGE 2
PHYSICAL SEPARATION/
CHEMICAL EXTRACTION
ID SOILS

FERNALD OU5 ID SOILS STAGE 2 - COMBINED PROCESS

Test #1- Attrition Scrubbing with Sodium Carbonate/ Bicarbonate followed by Chemical Extraction with Sulfuric Acid

Results from Attrition Scrubbing

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	2 : 1	0.1 M	0.25	solid	310.23	308.00	270.00	577.00
				liquid	66.45	19.90	15.70	35.50
ID - B	2 : 1	0.1 M	0.25	solid	235.82	140.00	255.00	395.00
				liquid	68.50	34.00	10.30	44.30
ID - A	2 : 1	0.1 M	0.25	solid	372.59	359.00	304.00	663.00
				liquid	66.87	26.00	9.06	35.10
ID - B	2 : 1	0.1 M	0.25	solid	248.18	139.00	225.00	365.00
				liquid	64.82	40.80	9.05	49.80

Results from Chemical Extraction

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Temp (°C)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	4 : 1	2.0 N	0.5	40	extract	71.28	40.60	39.40	80.00
					solid	42.04	77.10	71.40	149.00
ID - A	7 : 1	2.0 N	0.5	40	extract	37.75	15.80	23.50	39.20
					solid	31.28	<63.20	62.20	125.00
ID - A	4 : 1	2.0 N	0.5	40	extract	103.65	58.50	54.00	112.00
					solid	63.32	60.80	92.30	153.00
ID - A	7 : 1	2.0 N	0.5	40	extract	50.74	<14.40	30.90	45.30
					solid	68.97	<52.80	87.60	140.00
ID - B	4 : 1	2.0 N	0.5	40	extract	60.85	26.10	34.10	60.10
					solid	25.57	<85.90	65.50	151.00
ID - B	7 : 1	2.0 N	0.5	40	extract	33.85	<11.90	19.30	31.20
					solid	22.96	<55.50	78.00	133.00
ID - B	4 : 1	2.0 N	0.5	40	extract	67.50	<11.80	34.40	46.30
					solid	30.82	<99.60	<70.50	170.00
ID - B	7 : 1	2.0 N	0.5	40	extract	37.01	<13.20	22.80	36.00
					solid	25.68	<88.60	91.90	180.00

000180

Fernald CRU5 - Stage 2 Testing

Test #1- Attrition Scrubbing with 0.25 M Sodium Carbonate/Bicarbonate followed by Chemical Extraction with 2.0 N Sulfuric Acid

Metals ppm	ID - A Attr. Scr.- 15 mins Chem.Xtrt.- 7:1, 40 °C, 0.5 hr.		ID - A DUP Attr. Scr.- 15 mins Chem.Xtrt.- 7:1, 40 °C, 0.5 hr.		ID - A Average Concentration		ID - A Attr. Scr.- 15 mins Chem.Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A DUP Attr. Scr.- 15 mins Chem.Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A Average Concentration	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	371	8054	406	8111	388.5	8082.5	856	8365	339	9386	597.5	8875.5
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	<0.009	12.7	<0.009	<0.45	<0.009	6.58	<0.009	3.18	<0.009	11.2	<0.009	7.19
Ba	0.147	67.9	0.12	63.4	0.1335	65.65	0.108	91.3	0.116	71.2	0.112	81.25
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	881	769	918	885	899.5	827	857	2454	878	1575	867.5	2014.5
Cd	0.217	<0.25	0.214	<0.25	0.2155	<0.25	0.429	<0.25	0.567	<0.25	0.498	<0.25
Co	0.616	2.22	0.621	3.01	0.6185	2.615	1.60	2.07	1.67	2.33	1.635	2.2
Cr	0.987	14.8	1.41	14.3	1.1985	14.55	2.29	14.3	3.52	15.7	2.905	15
Cu	1.29	7.37	1.41	5.65	1.35	6.51	2.61	7.51	2.75	6.79	2.68	7.15
Fe	981	8150	1057	8200	1019	8175	2547	7701	2896	6978	2721.5	7339.5
K	16.2	835	16.2	920	16.2	877.5	41.6	934	41.6	1313	41.6	1123.5
Mg	242	1269	248	1266	245	1267.5	514	1382	575	1289	544.5	1335.5
Mn	70.8	114	71.9	166	71.35	140	216	161	55	148	135.5	154.5
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	397	216	528	181	462.5	198.5	719	322	272	340	495.5	331
Ni	0.987	9.41	2.63	9.36	1.8085	9.385	2.10	7.54	2.86	7.19	2.48	7.365
Pb	0.818	18.7	0.974	18.4	0.896	18.55	0.958	23.6	1.30	16.4	1.129	20
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	180	38.2	187	54.2	183.5	46.2	266	39.9	312	66.6	289	53.25
Th	2.46	6.61	3.23	8.81	2.845	7.71	5.45	6.66	6.64	8.31	6.045	7.485
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	34.3	29.1	43.2	63.8	38.75	46.45	64.5	39.6	85.6	66.9	75.05	53.25
V	1.65	11.8	1.74	11.6	1.695	11.7	3.24	12.6	4.28	14.5	3.76	13.55
Zn	3.88	28.2	3.99	28.6	3.935	28.4	7.19	26.3	8.88	25.2	8.035	25.75

Fernald CRU5 - Stage 2 Testing

Test #1- Attrition Scrubbing with 0.25 M Sodium Carbonate/Bicarbonate followed by Chemical Extraction with 2.0 N Sulfuric Acid

Metals ppm	ID - B Attr. Scr.- 15 mins Chem.Xtrt.- 7:1, 40 °C, 0.5 hr.		ID - B DUP Attr. Scr.- 15 mins Chem.Xtrt.- 7:1, 40 °C, 0.5 hr.		ID - B Average Concentration		ID - B Attr. Scr.- 15 mins Chem.Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B DUP Attr. Scr.- 15 mins Chem.Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B Average Concentration	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	553	10620	510	15780	531.5	13200	1257	7045	1232	11070	1244.5	9057.5
As	<0.05	<2.5	2.68	<2.5	<0.05	<2.5	<0.05	<2.5	2.68	<2.5	1.365	<2.5
B	<0.009	21.7	<0.009	25.7	<0.009	23.7	<0.009	16.2	<0.009	19.6	<0.009	17.9
Ba	0.103	72.2	0.092	90.6	0.0975	81.4	0.114	66.2	0.103	78	0.1085	72.1
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	888	34000	917	33240	902.5	33620	790	31500	817	28680	803.5	30090
Cd	0.242	4.02	0.23	3.32	0.236	3.67	0.593	<0.25	0.569	4.06	0.581	2.155
Co	0.851	2.19	0.784	1.33	0.8175	1.76	1.73	1.63	1.74	2.33	1.735	1.98
Cr	1.34	15.1	1.16	4.89	1.25	9.995	3.22	11.4	3.08	16.1	3.15	13.75
Cu	2.27	12	1.99	13.4	2.13	12.7	4.94	9.36	4.23	10.5	4.585	9.93
Fe	1142	14810	1007	17080	1074.5	15945	3050	10850	2902	12910	2976	11880
K	29.6	2313	24.1	3815	26.85	3064	67.3	1436	52.4	2775	59.85	2105.5
Mg	2125	4457	2062	4606	2093.5	4531.5	3604	3288	3543	4056	3573.5	3672
Mn	70.9	113	69.4	30.4	70.15	71.7	141	83.7	143	113	142	98.35
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	601	360	637	453	619	406.5	1091	434	1123	542	1107	488
Ni	1.65	8.24	1.51	<0.55	1.58	<0.55	3.76	6.40	3.76	8.21	3.76	7.305
Pb	0.189	6.23	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55	0.249	8.07	0.14	4.81
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<2.10	<0.042
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	342	42.9	326	67.8	334	55.35	643	50.3	667	65.9	655	58.1
Th	2.15	4.86	2.02	<2.00	2.085	3.43	4.18	5.92	4.20	6.72	4.19	6.32
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	26.9	22.1	28.5	<7.00	27.7	14.55	51.1	23	53.4	29	52.25	26
V	1.49	11.5	1.42	22.1	1.455	16.8	3.31	8.23	3.20	14.6	3.255	11.415
Zn	3.64	26.7	3.59	29.5	3.615	28.1	7.78	19.9	6.10	23.8	6.94	21.85

000182

FERNALD OU5 ID SOILS STAGE 2 - COMBINED PROCESS

Test #2 - Chemical Extraction with Sulfuric Acid followed by Attrition Scrubbing with Sodium Carbonate\ Bicarbonate

Results from Chemical Extraction

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Temp (°C)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	4 : 1	2.0 N	0.5	40	extract	100.44			
					solid	101.57	141.00	118.00	259.00
ID - B	4 : 1	2.0 N	0.5	40	extract	99.82			
					solid	77.56	<36.90	109.00	145.00
ID - A	4 : 1	2.0 N	0.5	40	extract	102.10			
					solid	76.15	96.30	115.00	211.00
ID - B	4 : 1	2.0 N	0.5	40	extract	99.64			
					solid	77.66	43.20	107.00	150.00

Results from Attrition Scrubbing

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	2 : 1	0.1 M	0.25	solid	39.15	<135.00	94.00	229.00
				liquid	12.40	6.86	4.92	11.80
ID - B	2 : 1	0.1 M	0.25	solid	56.18	<143.00	<78.80	222.00
				liquid	12.75	2.84	3.74	6.58
ID - A	2 : 1	0.1 M	0.25	solid	50.49	<116.00	101.00	217.00
				liquid	19.36	5.79	7.19	13.00
ID - B	2 : 1	0.1 M	0.25	solid	55.71	<143.00	<78.80	222.00
				liquid	16.28	8.21	3.63	11.80

Fernald CRU5 - Stage 2 Testing

Test #2- Chemical Extraction with 2.0 N Sulfuric Acid followed by Attrition Scrubbing with 0 25 M Sodium Carbonate / Bicarbonate

ICP Results After Attrition Scrubbing Only

Metals ppm	ID - A Attr. Scr - 15 mins		ID - A DUP Attr. Scr - 15 mins		ID - A Average Concentration		ID - B Attr. Scr.- 15 mins		ID - B DUP Attr. Scr.- 15 mins		ID - B Average Concentration	
	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0 003	<0.15	<0.003	<0.15	<0 003	<0.15
Al	2 06	>8927	0.66	>8927	1.36	>8927	<0 004	>8927	<0.004	>8927	>0 004	>8927
As	<0 05	<2.5	<0.05	<2 5	<0.05	<2.5	<0.05	<2 5	<0.05	<2.5	<0.05	<2 5
B	0.04	24.8	0.02	26.6	<0.009	6.58	0.01	38.4	<0.009	41.5	<0.009	39.95
Ba	0.053	91 9	0.050	83.9	0.0515	87.9	0.014	83	0.019	90.1	0.0165	86.55
Be	<0.002	<0.10	<0 002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	7.72	>1266	17 1	>1266	12.41	>1266	>28 0	>1266	>28.0	>1266	>28 0	>1266
Cd	<0 005	2 94	<0 005	3 4	<0 005	<0.25	<0 005	4.62	<0.005	4.88	<0.005	<0 25
Co	<0.003	5 61	<0 003	5.68	<0.003	5.645	<0.003	5.07	<0.003	5.55	<0 003	5.31
Cr	<0.007	42 8	<0 007	32 8	<0 007	37.8	<0 007	35	<0.007	49.8	<0 007	42 4
Cu	0 192	8.62	0 146	9	0.169	8 81	0 052	25 6	0.058	18 9	0 055	22 25
Fe	1.34	>3061	0.367	>3061	0.8535	>3061	<0.003	>3061	<0.003	>3061	<0.003	>3061
K	4.20	745	4.94	639	4.57	692	7.74	1301	8.50	1492	8.12	1396.5
Mg	8.26	>1350	>30 0	>1350	na	>1350	>30 0	>1350	>30 0	>1350	>30 0	>1350
Mn	0 056	312	0.041	342	0 0485	327	0 056	205	0.144	226	0.1	215 5
Mo	<0.007	<0.35	<0 007	<0 35	<0.007	<0.35	<0 007	<0.35	<0.007	<0 35	<0.007	<0.35
Na	>197	>1600	>197	>1600	>197	>1600	>197	>1600	>197	>1600	>197	>1600
Ni	0.051	20.9	<0.011	19 6	<0.011	20 25	<0 011	20.1	<0.011	28.4	<0.011	24 25
Pb	<0.031	32 3	<0.031	29.4	<0.031	30.85	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55
Sb	<0.042	<2.10	<0.042	<2 10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2 10
Se	<0.067	<3.35	<0.067	<3 35	<0 067	<3.35	<0.067	<3 35	<0.067	<3.35	<0.067	<0.067
Si	5.38	56.4	1 61	69 7	3 50	63.05	3 85	88.4	2.22	71.5	3 035	79 95
Th	0.469	12 4	0.690	<2 00	0.2545	7.2	<0 040	<2 00	<0.40	<2.00	<0.040	<2 00
Tl	<0.12	<6 00	<0 12	<6 00	<0.12	<6.00	<0 12	<6.00	<0.12	<6.00	<0.12	<6.00
U	9.90	30.3	14 8	<7.00	12.35	18.65	10.1	<7 00	12.2	<7.00	11.15	<7.00
V	0.139	17.1	0 126	15 6	0.1325	16.35	0 076	17.4	0.092	19.2	0.084	18 3
Zn	<0.003	50.3	<0.003	56 2	<0 003	53.25	<0 003	52.3	<0.003	55.1	<0.003	53 7

Fernald CRU5 - Stage 2 Testing

Test #2- Chemical Extraction with 2.0 N Sulfuric Acid followed by Attrition Scrubbing with 0.10M Sodium Carbonate/Bicarbonate

ICP results after Chemical Extraction Only

Metals mg/L	ID - A Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A DUP Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A Average Concentration		ID - B Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B DUP Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B Average Concentration	
	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	731	12870	510	14270	620.5	13570	698	16010	701	14920	699.5	15465
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	<0.009	<0.45	<0.009	<0.45	<0.009	<0.45	<0.009	<0.45	<0.009	<0.45	<0.009	<0.45
Ba	0.139	107	0.107	107	0.123	107	0.132	105	0.129	100	0.1305	102.5
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	848	1896	758	1445	803	1670.5	785	45070	805	50440	795	47755
Cd	0.427	2.24	0.321	2.53	0.374	2.385	0.286	3.67	0.298	3.5	0.292	3.585
Co	1.13	3.71	0.973	4.97	1.05	4.34	1.18	4.39	1.21	4.7	1.195	4.545
Cr	2.02	25.1	1.62	25.8	1.82	25.45	1.49	26.5	1.44	26.1	1.465	26.3
Cu	1.98	8.32	1.51	9.19	1.745	8.755	2.93	17.5	2.84	16.1	2.885	16.8
Fe	1963	11060	1239	13070	1601	12065	1201	20470	1255	19020	1228	19745
K	40.9	1980	29.4	1776	35.15	1878	56.2	3784	54.6	3162	55.4	3473
Mg	446	1910	353	2122	399.5	2016	3214	6102	3239	8160	3226.5	7131
Mn	121	201	92.8	293	106.9	247	104	180	105	214	104.5	197
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	11.3	87.3	4.43	80.9	7.865	84.1	19.2	133	16	138	17.6	135.5
Ni	2.04	11.8	1.72	77.1	1.88	44.45	2.11	78.6	1.95	78.4	2.03	78.5
Pb	1.35	29.1	1.6	24.2	1.475	26.65	0.333	<1.55	0.344	11.6	0.3385	6.575
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<3.35	<0.067
Si	304	114	202	153	253	133.5	411	150	370	142	390.5	146
Th	5.94	13.9	5.12	13.7	2.99	13.8	4.22	14.1	4.2	14.5	2.13	14.3
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	99.2	101	85.8	13.6	92.5	57.3	83.9	15.9	78.4	16.3	81.15	16.1
V	3.05	21	2.29	23	2.67	22	1.86	21.6	1.86	20.1	1.86	20.85
Zn	7.25	42.2	6.55	49.7	<0.003	45.95	5.04	43	5.28	41.8	5.16	42.4

FERNALD OU5 ID SOILS STAGE 2 - COMBINED PROCESS

Test #3- Attrition Scrubbing with Potable Water followed by Chemical Extraction with Sulfuric Acid

Results from Attrition Scrubbing

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	2 : 1	N / A	0.25	solid	363.14	590.00	389.00	979.00
				liquid	1.76	9.66	<1.56	2.53
ID - A	2 : 1	N / A	0.25	solid	425.14	558.00	362.00	920.00
				liquid	1.44	<1.01	<1.56	2.57
ID - B	2 : 1	N / A	0.25	solid	347.89	195.00	204.00	399.00
				liquid	13.51	8.94	5.73	14.70
ID - B	2 : 1	N / A	0.25	solid	363.63	485.00	313.00	798.00
				liquid	12.74	6.48	5.12	11.60

Results from Chemical Extraction

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Temp (°C)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	4 : 1	2.0 N	0.5	40	extract	124.70	48.00	46.20	94.30
					solid	79.49	88.10	131.00	220.00
ID - A	7 : 1	2.0 N	0.5	40	extract	69.35	32.60	34.40	67.00
					solid	64.46	67.90	115.00	183.00
ID - A	4 : 1	2.0 N	0.5	40	extract	121.64	25.00	24.70	49.70
					solid	79.25	78.90	125.00	204.00
ID - A	7 : 1	2.0 N	0.5	40	extract	61.68	22.40	20.30	42.80
					solid	56.99	<44.80	99.00	144.00
ID - B	4 : 1	2.0 N	0.5	40	extract	96.54	31.60	28.80	60.40
					solid	76.76	67.90	106.00	174.00
ID - B	7 : 1	2.0 N	0.5	40	extract	59.64	19.20	21.70	40.90
					solid	42.37	<42.10	90.40	133.00
ID - B	4 : 1	2.0 N	0.5	40	extract	100.96	31.60	30.70	62.30
					solid	80.62	<51.30	93.90	145.00
ID - B	7 : 1	2.0 N	0.5	40	extract	58.55	17.40	17.70	35.10
					solid	70.19	<44.70	103.00	147.00

000186

Fernald CRU5 - Stage 2 Testing

Test #3- Attrition Scrubbing with Potable Water followed by Chemical Extraction with 2 0 N Sulfuric Acid

ICP Results After Attrition Scrubbing Only

Metals ppm	ID - A Attr Scr - 15 mins		ID - A DUP Attr. Scr.- 15 mins		ID - A Average Concentration		ID - B Attr. Scr.- 15 mins		ID - B DUP Attr. Scr.- 15 mins		ID - B Average Concentration	
	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids	Dispersant	Solids
Ag	<0.003	<0.15	<0.003	<0 15	<0 003	<0 15	<0.003	<0.15	<0.003	<0 15	<0.003	<0 15
Al	0 366	18760	0.624	21170	0 495	19965	0 461	22040	0.645	23120	0.553	22580
As	<0.05	<2 5	<0.05	<2 5	<0.05	<2.5	<0.05	<2 5	<0.05	<2 5	<0.05	<2 5
B	<0.009	39.8	<0.009	37.2	<0 009	6 58	<0 009	44.2	<0.009	44.2	<0.009	44 2
Ba	0.046	128	0.049	139	0.0475	133.5	0 042	120	0 038	121	0.04	120 5
Be	<0 002	<0 10	<0.002	<0 10	<0 002	<0 10	<0.002	<0 10	<0.002	<0.10	<0.002	<0.10
Ca	68 3	10280	67 8	9294	68 05	9787	78 8	67850	73 3	58240	76 05	63045
Cd	<0 005	4 71	<0.005	4 36	<0 005	<0 25	<0 005	4.99	<0 005	5 15	<0 005	<0 25
Co	<0.003	11 6	<0.003	10 1	<0.003	10 85	<0 003	8 16	<0 003	8.35	<0 003	8 255
Cr	<0 007	38 5	<0.007	35 6	<0 007	37.05	<0 007	32	0.018	34.4	0.01	33 2
Cu	0 061	18 6	0.062	17 2	0 0615	17 9	0 058	28 9	0.078	29.4	0.068	29 15
Fe	0.666	23990	0.928	21280	0 797	22635	0 694	25440	0.888	25020	0.791	25230
K	5.17	2639	2.93	3318	4 05	2978 5	16 3	5503	4.20	5607	10 25	5555
Mg	13.4	4411	12.9	4380	13.15	4395 5	4 24	19850	4 52	17140	4.38	18495
Mn	0.212	856	0.233	779	0 2225	817.5	0 034	489	0.077	490	0.0555	489 5
Mo	<0.007	<0.35	<0.007	<0 35	<0.007	<0.35	<0 007	<0 35	<0.007	<0.35	<0.007	<0 35
Na	7.04	219	7.02	197	7.03	208	11 8	266	11.2	246	11.5	256
Ni	<0 011	35 6	<0.011	19 3	<0 011	27 45	<0 011	19.7	<0.011	20.7	<0.011	20 2
Pb	<0.031	41 4	<0.031	28 7	<0 031	35 05	<0 031	<1 55	<0.031	<1.55	<0.031	<1 55
Sb	<0.042	<2.10	<0 042	<2.10	<0 042	<2.10	<0 042	<2 10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3 35	<0.067	<3 35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<3.35	<0 067
Si	3.38	169	3.89	225	3.635	197	3 64	154	3.86	152	3.75	153
Th	0.062	44.4	<0.040	39.7	0.051	42 05	0 607	30.8	<0 040	27.5	0.32	29 15
Tl	<0.12	<6 00	<0.12	<6.00	<0 12	<6 00	<0 12	<6 00	<0.12	<6.00	<0.12	<6 00
U	2.00	540	1.55	456	1 775	498	14 40	336	13.1	340	13.75	338
V	0.012	45 1	0.01	43 4	0.011	44 25	0 10	39 5	0.09	40 7	0.095	40 1
Zn	<0.003	72.4	<0.003	73 2	<0.003	72 8	<0 003	59	<0.003	57 5	<0.003	58 25

Fernald CRU5 - Stage 2 Testing

Test #3- Attrition Scrubbing with Potable Water followed by Chemical Extraction with 2.0 N Sulfuric Acid

Metals ppm	ID - A Attr. Scr.- 15 mins Chem. Xtrt.-7:1, 40 °C, 0.5 hr.		ID - A DUP Attr. Scr.- 15 mins Chem. Xtrt.- 7:1, 40 °C, 0.5 hr.		ID - A Average Concentration		ID -A Attr. Scr.- 15 mins Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A DUP Attr. Scr.- 15 mins Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - A Average Concentration	
	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	>199	>8927	>199	>8927	>199	>8927	>199	>8927	>199	>8927	>199	>8927
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	1.84	20	1.78	22.7	1.81	21.35	3.51	20.4	3.04	22.4	3.275	21.4
Ba	0.129	95	0.082	96.7	0.1055	95.85	0.127	97.3	0.114	82.4	0.1205	89.85
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>28.00	>1266	>28	>1266	>28.00	>1266	>28	>1266	>28	>1266	>28	>1266
Cd	0.295	2.57	0.28	2.82	0.2875	2.695	0.561	2.73	0.399	2.63	0.48	2.68
Co	0.976	3.92	0.588	4.84	0.782	4.38	1.45	3.71	1.25	4.34	1.35	4.025
Cr	1.34	22.7	0.91	20.6	1.125	21.65	2.14	26.2	1.73	19.9	1.935	23.05
Cu	1.49	8.56	1.18	9.59	1.335	9.075	2.54	9.25	2.22	9.76	2.38	9.505
Fe	>66	>3061	>66	>3061	>66	>3061	>66	>3061	>66.0	>3061	>66.0	>3061
K	47.8	912	15.5	848	31.65	880	75.9	1432	24.5	875	50.2	1153.5
Mg	>30	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350
Mn	>23	202	>23.0	330	>23.0	>23.0	>23.0	188	>23.0	252	>23.0	220
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	7.34	49.8	2.81	56.2	5.075	53	11.5	87.2	5.02	57.1	8.26	72.15
Ni	3.06	15.2	0.876	13.3	1.968	14.25	3.32	15.1	1.73	11.7	2.525	13.4
Pb	1.16	29.5	0.946	28.7	1.053	29.1	1.24	29.6	1.53	27.7	1.385	28.65
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.[illegible]
Si	>113	72.1	>113	87.5	>113	79.8	<0.02	111	>113	89.2	56.51	83.755
Th	4.03	9.86	4.05	9.71	4.04	9.785	6.94	<2.00	<0.040	10.7	3.49	6.35
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	0.12	<6.00
U	63.10	51.8	52.0	49.1	57.55	50.45	111	71.2	98.2	71	104.6	71.1
V	1.99	13.30	1.66	13.4	1.825	13.35	3.51	18.0	2.93	14.3	3.22	16.15
Zn	4.42	43.3	4.45	45.6	4.435	44.45	8.41	43.3	8.2	44.9	8.305	44.1

000188

Fernald CRU5 - Stage 2 Testing

Test #3- Attrition Scrubbing with Potable Water followed by Chemical Extraction with 2.0 N Sulfuric Acid

Metals ppm	ID -B Attr. Scr.- 15 mins Chem. Xtrt.-7:1, 40 °C, 0.5 hr.		ID - B DUP Attr. Scr.- 15 mins Chem. Xtrt.- 7:1, 40 °C, 0.5 hr.		ID -B Average Concentration		ID -B Attr. Scr.- 15 mins Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B DUP Attr. Scr.- 15 mins Chem. Xtrt.- 4:1, 40 °C, 0.5 hr.		ID - B Average Concentration	
	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids	Extractant	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.15	<0.003
Al	>199	>8927	>199	>8927	>199	>8927	>199	>8927	>199	>8927	>199	>8927
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<2.5	<0.05
B	2.56	<0.45	<0.009	31	1.2845	15.725	3.44	27	2.72	32.7	3.08	29.85
Ba	0.051	94.4	0.044	88.4	0.0475	91.4	0.062	85.3	0.053	103	0.0575	94.15
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.002	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>28.0	>1266	>28.0	>1266	>28.0	>1266	>28.0	>1266	>28.0	>1266	>28.0	>1266
Cd	0.37	3.37	0.208	4.06	0.289	3.715	0.55	3.62	0.451	4.26	0.5005	3.94
Co	0.941	3.31	0.725	4.84	0.833	4.075	1.27	4.2	1.23	4.19	1.25	4.195
Cr	1.62	19.4	0.966	37.7	1.293	28.55	2.15	19.8	1.83	32.7	1.99	26.25
Cu	2.88	11.8	2.48	38.8	2.68	25.3	4.73	31.5	4.54	53.7	4.635	42.6
Fe	>66.0	>3061	>66.0	>3061	>66.0	>3061	>66.0	>3061	>66.0	>3061	>40	>3061
K	69.6	2672	49.7	2415	59.65	2543.5	92.8	2174	84.3	2859	88.55	2516.5
Mg	>30.0	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350	>30.0	>1350
Mn	>23.0	136	>23.0	225	>25	180.5	>23.0	195	>23.0	228	>23.0	211.5
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	14.3	112	14.2	191	14.25	151.5	25	127	25.6	159	25.3	143
Ni	2.01	9.99	1.3	23.6	1.655	16.795	2.68	12	2.49	18.6	2.585	15.3
Pb	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55	<0.031	<1.55
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	>113	106	>113	109	>113	107.5	>113	93.8	>113	114	>50	103.9
Th	3.18	<2.00	2.61	<2.00	2.895	<2.00	4.67	9.94	4.76	<2.00	4.715	5.97
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	50.5	<7.00	52.6	59.1	51.55	33.05	80.7	66.1	84.8	68.2	82.75	67.15
V	1.63	14.8	1.25	16.4	1.44	15.6	2.48	12.9	2.25	17.7	2.365	15.3
Zn	4.96	30	3.37	47.8	4.165	38.9	7.36	37.3	6.87	50.9	7.115	44.1

T229

FERNALD OU5 ID SOILS STAGE 2 - COMBINED PROCESS

Test #4 - Attrition Scrubbing with Sand and Sodium Carbonate/ Bicarbonate Only

Results from Attrition Scrubbing

Soil	Dose Sand : Soil : Fluid :	Conc.	Time (hrs)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	5 : 1 : 2	0.25 M	0.25	> 53 μm	11.84	43.00	18.00	61.10
				< 53 μm	88.13	107.00	78.50	186.00
				Extractant	17.53	9.30	3.94	13.20
ID - B	5 : 1 : 2	0.25 M	0.25	> 53 μm	11.18	< 41.00	7.45	48.40
				< 53 μm	130.35	103.00	160.00	263.00
				Extractant	15.25	9.12	3.06	12.20

000130

FERNALD OU5 ID SOILS STAGE 2 - COMBINED PROCESS

Test #5 - Chemical Extraction with Hydrochloric Acid (HCl) followed with Sodium Carbonate/ Bicarbonate (SCB)

Results from Chemical Extraction

Soil	Dose Fluid : Soil	Fluid	Conc.	Time (hrs)	Temp (°C)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
ID - A	7 : 1	HCl	1.0 N	1	40	extract	56.47	20.70	10.00	30.70
						solid	67.98	204.00	244.00	448.00
	7 : 1	SCB	0.8 M	1	40	extract	4.75	5.24	14.10	19.30
						solid	38.98	<87.50	164.00	252.00
ID - A	4 : 1	HCl	1.0 N	1	40	extract	114.15	70.60	21.80	92.40
						solid	77.03	282.00	402.00	684.00
	4 : 1	SCB	0.8 M	1	40	extract	13.81	7.12	22.90	30.00
						solid	27.11	<80.90	156.00	237.00
ID - A	7 : 1	HCl	1.0 N	1	Ambient	extract	47.13	18.00	8.88	26.80
						solid	82.92	149.00	263.00	412.00
	7 : 1	SCB	0.8 M	1	Ambient	extract	3.57	<5.59	16.20	21.80
						solid	61.77	<80.20	170.00	251.00
ID - A	4 : 1	HCl	1.0 N	1	Ambient	extract	73.57	32.90	10.40	43.30
						solid	94.08	155.00	279.00	434.00
	4 : 1	SCB	0.8 M	1	Ambient	extract	5.77	7.54	21.30	28.80
						solid	68.32	65.60	138.00	204.00
ID - B	7 : 1	HCl	1.0 N	1	40	extract	56.89	25.30	16.10	41.40
						solid	20.06	<79.20	291.00	370.00
	7 : 1	SCB	0.8 M	1	40	extract	1.56	<3.33	10.10	13.40
						solid	6.71	<74.50	171.00	246.00
ID - B	4 : 1	HCl	1.0 N	1	40	extract	87.50	21.90	10.20	32.00
						solid	28.37	<110.00	380.00	490.00
	4 : 1	SCB	0.8 M	1	40	extract	3.99	<5.43	12.50	17.90
						solid	7.70	<93.00	250.00	343.00
ID - B	7 : 1	HCl	1.0 N	1	Ambient	extract	53.23	22.20	12.80	35.00
						solid	33.22	<78.50	332.00	411.00
	7 : 1	SCB	0.8 M	1	Ambient	extract	2.29	<5.03	15.10	20.20
						solid	13.55	<51.50	130.00	181.00
ID - B	4 : 1	HCl	1.0 N	1	Ambient	extract	92.88	30.60	10.30	40.90
						solid	69.64	<81.20	301.00	382.00
	4 : 1	SCB	0.8 M	1	Ambient	extract	5.93	6.84	21.00	27.80
						solid	15.70	<121.00	277.00	398.00

Fernald CRU5 - Stage 2 Testing

Test #5-Chemical Extraction with 1.0 N Hydrochloric Acid followed by 0.8 M Sodium Carbonate/Bicarbonate

Metals ppm	ID - A Chem.Xtrt.- 7:1, 1.0 hr. Ambient HCl		ID - A Chem.Xtrt.- 7:1, , 1.0 hr. Ambient Na(CO3/HCO3)		ID - A Chem.Xtrt.- 4:1, 1.0 hr. Ambient HCl		ID - A Chem.Xtrt.- 4:1, 1.0 hr. Ambient Na(CO3/HCO3)	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	240	14670	<0.004	13470	345	12500	0.691	12460
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	1.31	19.9	0.66	<0.45	<0.009	<0.45	0.716	<0.45
Ba	8.22	46.1	0.014	48.3	11.6	39.0	0.029	44.1
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>2907	2489	11.4	1544	>2907	6358	34	2983
Cd	<0.005	2.82	<0.005	2.85	0.49	2.65	<0.005	3.06
Co	0.63	3.67	<0.003	3.92	0.69	3.43	<0.003	<0.15
Cr	0.97	46.4	0.06	59.2	1.22	36.9	<0.007	47.9
Cu	0.99	8.28	0.06	8.48	1.58	7.78	0.07	8.41
Fe	1029	12080	8.11	12240	1465	11840	13.70	12520
K	46.8	2602	5.16	2287	81.2	2188	5.33	2203
Mg	907	2509	12.4	2224	688	2244	6.62	2120
Mn	73.8	94.6	0.08	116	103	104	0.22	137
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	19	115	128	16180	29	94.6	129	15680
Ni	0.76	26.8	0.08	35.2	0.95	21.3	<0.011	28.8
Pb	3.4	<1.55	<0.031	<1.55	5.00	<1.55	<0.031	<1.55
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	66.6	132	30	102	14.1	59.5	34.2	91.9
Th	2.01	20.3	<0.040	12	2.74	17.7	0.39	13.1
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	35.9	75.5	2.49	61.9	49.9	73.9	4.21	49.8
V	1.43	20.9	0.07	17.2	1.8	17.5	0.11	16.6
Zn	2.46	43.4	0.03	43.3	4.19	40.9	0.05	42.4

Fernald CRU5 - Stage 2 Testing

Test #5-Chemical Extraction with 1.0 N Hydrochloric Acid followed by 0.8 M Sodium Carbonate/Bicarbonate

Metals ppm	ID - A Chem.Xtrt.- 7:1, 1.0 hr. 40 C HCl		ID - A Chem.Xtrt.- 7:1, , 1.0 hr. 40 C Na(CO3/HCO3)		ID - A Chem.Xtrt.- 4:1, 1.0 hr. 40 C HCl		ID - A Chem.Xtrt.- 4:1, 1.0 hr. 40 C Na(CO3/HCO3)	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	364	10160	<0.004	13250	585	12240	<0.004	12970
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	1.7	39.9	0.599	23.4	<0.009	<0.45	0.624	21.1
Ba	10.1	69.3	0.003	51.3	16.2	51.9	0.14	52.0
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>2907	1989	9.32	2418	>2907	1504	9.41	1570
Cd	0.32	5.98	<0.005	3.8	0.51	3.44	<0.005	3.18
Co	0.58	13.2	<0.003	6.9	1.02	7.80	<0.003	6.18
Cr	0.98	60.9	<0.007	69.8	1.69	50.2	0.08	62.6
Cu	1.52	9.36	0.07	9.51	2.24	8.77	0.2	8.45
Fe	852	27480	3.14	15380	1511	14270	7.81	13660
K	55.6	1836	6.13	2572	84.5	1917	14.1	2371
Mg	1533	1894	15.4	2414	1199	2200	14.2	2196
Mn	66.1	11.3	0.31	385	108	520	0.96	423
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	22.1	1422	270	14290	22.1	202	120	12110
Ni	1.06	32.9	<0.011	40.8	1.89	29.8	<0.011	36.7
Pb	4.49	<1.55	<0.031	<1.55	7.38	<1.55	<0.031	<1.55
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	138	90.6	41.6	58.3	83.8	87.2	51.8	77.7
Th	2.95	23	<0.040	<2.00	4.9	<2.00	0.5	<2.00
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	61.5	69.4	3.4	<7.00	95.8	69.6	8.59	<7.00
V	1.64	26.6	0.09	19.4	2.69	19.2	0.25	18.7
Zn	6.13	59.7	0.03	46.6	8.44	39.2	0.19	40.3

Fernald CRU5 - Stage 2 Testing

Test #5-Chemical Extraction with 1.0 N Hydrochloric Acid followed by 0.8 M Sodium Carbonate/Bicarbonate

Metals ppm	ID - B Chem.Xtrt.- 7:1, 1.0 hr. Ambient HCl		ID - B Chem.Xtrt.- 7:1, , 1.0 hr. Ambient Na(CO3/HCO3)		ID - B Chem.Xtrt.- 4:1, 1.0 hr. Ambient HCl		ID - B Chem.Xtrt.- 4:1, 1.0 hr. Ambient Na(CO3/HCO3)	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	347	18000	<0.004	16350	571	19760	<0.004	17270
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	1.45	<0.45	0.648	<0.45	<0.009	<0.45	0.601	31.4
Ba	8.66	55.5	0.014	56.1	14.3	64.9	<0.001	61.1
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>2907	3218	9.59	3062	>2709	7066	11	4843
Cd	0.33	4.17	<0.005	4.61	0.57	5.32	<0.005	4.72
Co	0.49	5.08	<0.003	5.26	0.77	5.74	<0.003	5.27
Cr	0.86	53.1	<0.007	73.7	1.28	50.1	<0.007	70.8
Cu	2.25	15.4	0.08	16.8	3.74	17.5	0.12	15.4
Fe	1097	19690	13.5	18960	1714	24140	18.90	20070
K	101	4801	11.2	4781	128	5266	17.7	4969
Mg	2190	4781	46.3	4199	>2464	6301	122	4548
Mn	61.5	126	0.09	124	104	167	0.1	143
Mo	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	35.7	151	124	19100	45.8	169	162	19120
Ni	0.82	34	<0.011	48.8	1.22	30.8	0.06	45
Pb	1.18	<1.55	<0.031	<1.55	1.9	<1.55	<0.031	<1.55
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35
Si	83.8	76.4	39.3	52	74.3	102	14	59.6
Th	2.03	<2.00	<0.040	<2.00	3.3	<2.00	<0.040	<2.00
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	42	<7.00	1.73	<7.00	64.3	43.9	3.92	<7.00
V	1.05	21.7	0.05	18.9	1.6	24.6	0.01	19.6
Zn	2.49	42.6	<0.003	41.9	4.12	48.3	0.06	42.9

0001194

Fernald CRU5 - Stage 2 Testing

Test #5-Chemical Extraction with 1.0 N Hydrochloric Acid followed by 0.8 M Sodium Carbonate/Bicarbonate

Metals ppm	ID - B Chem.Xtrt.- 7:1, 1.0 hr. 40 C HCl		ID - B Chem.Xtrt.- 7:1, , 1.0 hr. 40 C Na(CO3/HCO3)		ID - B Chem.Xtrt.- 4:1, 1.0 hr. 40 C HCl		ID - B Chem.Xtrt.- 4:1, 1.0 hr. 40 C Na(CO3/HCO3)	
	Extract	Solids	Extract	Solids	Extract	Solids	Extract	Solids
Ag	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15	<0.003	<0.15
Al	724	14430	<0.004	7455	1202	19050	3.94	6233
As	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5	<0.05	<2.5
B	2.72	0.45	0.641	<0.45	<0.009	26.4	0.725	<0.45
Ba	10.1	43.7	0.009	32.0	17.7	54.4	0.056	22.4
Be	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10	<0.002	<0.10
Ca	>2907	2139	11.7	2039	>2907	4243	48.7	4008
Cd	0.8	1.96	<0.005	1.47	1.43	2.10	<0.005	<0.25
Co	0.72	2.29	<0.003	2.12	1.04	2.42	<0.003	<0.15
Cr	1.84	33.9	<0.007	34.4	2.84	62.6	<0.007	23.7
Cu	3.89	4.93	0.09	4.83	5.9	5.29	0.16	14.9
Fe	2594	8414	0.59	5964	4510	8139	12.4	4753
K	221	3517	16.3	2058	361	6590	20.4	2076
Mg	>2464	2904	16.3	1978	>2464	3358	40.3	1803
Mn	69.1	57.4	0.06	51.1	115	75.1	0.31	44.9
Mo	0.14	<0.35	<0.007	<0.35	<0.007	<0.35	<0.007	<0.35
Na	44.3	123	118	22880	61.6	277	119	22260
Ni	1.63	18.3	0.011	22.9	2.44	33.9	<0.011	13.9
Pb	1.31	<1.55	<0.031	<1.55	1.83	<1.55	<0.031	39.7
Sb	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10	<0.042	<2.10
Se	<0.067	<3.35	<0.067	<3.35	<0.067	<3.35	<0.067	<3..35
Si	11.6	99.5	106	70.1	8.42	80.6	84.2	60.8
Th	2.28	<2.00	<.040	<2.00	3.5	<2.00	0.23	<2.00
Tl	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00	<0.12	<6.00
U	41.1	<7.00	1.09	<7.00	55	<7.00	3.21	<7.00
V	1.72	13.5	0.06	4.32	2.65	23.4	0.16	3.69
Zn	5.18	18.5	<0.003	14.6	8.38	15.9	0.06	11.4

STAGE 2
PHYSICAL SEPARATION/
CHEMICAL EXTRACTION
OU5-A SOIL

FERNALD OU5-A STAGE 2 - COMBINED PROCESS

Test #1- Attrition Scrubbing with Sodium Carbonate/ Bicarbonate followed by Chemical Extraction with Sulfuric Acid

Results from Attrition Scrubbing

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
OU5-A	2 : 1	0.1 M	0.25	>2mm	41.12	0.06	29.78	29.84
				solid	179.43	112.00	122.00	235.00
				liquid	14.10	11.00	2.27	13.30
OU5-A	2 : 1	0.1 M	0.25	>2mm	41.90	19.17	45.20	64.37
				solid	155.89	145.00	90.90	236.00
				liquid	14.77	10.50	2.46	12.90

Results from Chemical Extraction

Soil	Dose Fluid : Soil	Conc.	Time (hrs)	Temp (°C)	Fraction	Uranium (ppm)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total Activity (pCi/g)
OU5 - A	7 : 1	2.0 N	0.5	40	extract	17.37	3.47	8.68	12.10
					solid	34.67	69.80	57.30	127.00
					rinse	6.16	2.88	1.70	4.59
OU5 - A	4 : 1	2.0 N	0.5	40	extract	24.33	7.13	11.30	18.40
					solid	57.79	85.20	60.40	146.00
					rinse	4.61	1.40	1.49	2.89
OU5 - A	7 : 1	2.0 N	0.5	40	extract	17.14	4.01	9.10	13.10
					solid	60.91	70.00	57.50	127.00
					rinse	6.37	2.17	1.90	4.07
OU5 - A	4 : 1	2.0 N	0.5	40	extract	24.85	4.11	12.10	16.20
					solid	47.16	104.00	54.90	159.00
					rinse	6.14	1.74	1.49	3.23

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Fernald CRU5 - Stage 2 Testing OU5-A

Test #1- Attrition Scrubbing with 0,25 M Sodium Carbonate/Bicarbonate followed by Chemical Extraction with 2.0 N Sulfuric Acid

Metals ppm	> 2mm - OU5-A UNEXTRACTED	> 2mm - OU5-A UNEXTRACTED	> 2mm - OU5-A AVERAGE CONCENTRATION	OU5-A Attr. Scr.- 15 mins Chem.Xtrt.- 7:1, 40 °C, 0.5 hr.		OU5-A Attr. Scr.- 15 mins Chem.Xtrt.- 4:1, 40 °C, 0.5 hr.	
	Solids	Solids	Solids	Extract	Solids	Extract	Solids
Ag	<0.019	<0.022	<0.021	<0.003	<0.15	<0.003	<0.15
Al	6139	7399	6769	235	10120	275	9670
As	<0.323	<0.371	<0.347	0.18	<2.5	0.08	<2.5
B	12.02	14.78	13.4	1.65	55	1.95	44.1
Ba	31.08	25.26	28.17	0.19	75.4	0.04	68.6
Be	<0.013	<0.015	<0.014	<0.002	<0.10	<0.002	<0.10
Ca	313000	342000	327500	815	99850	535	106200
Cd	3.23	6.39	4.81	0.28	3.21	0.35	3.92
Co	3.04	4.75	3.895	0.78	3.38	1.09	3.68
Cr	19	28.45	23.725	2.44	30.4	4.03	35.3
Cu	10.02	24.89	17.455	2.94	15.7	<0.004	17.6
Fe	12800	19700	16250	1121	19010	1204	12640
K	1740	4880	3310	21.8	4802	23	4940
Mg	61300	93400	77350	3032	7270	4470	12640
Mn	604.2	554.2	579.2	46.6	146	68.1	194
Mo	<0.045	1.19	0.62	<0.007	<0.35	<0.007	<0.35
Na	290.8	658.2	474.5	380	413	540	495
Ni	10.79	19.02	14.905	3.10	16.3	4.45	14.6
Pb	98.22	20.43	59.325	4.06	144	3.97	168
Sb	<0.271	<0.312	<0.292	<0.042	<2.10	<0.042	<2.10
Se	<0.433	<0.498	<0.466	<0.067	<3.35	<0.067	<3.35
Si	21.26	12.11	16.685	283	104	283	86.8
Th	<0.258	<0.297	<0.278	0.9	9.57	1.15	8.72
Tl	<0.775	<0.891	<0.833	<0.12	<6.00	<0.12	<6.00
U	28.37	26.15	27.26	14.8	34.7	20.5	47.6
V	6.14	14.49	10.315	0.48	13.9	0.51	14.0
Zn	147	92.9	119.95	61.2	76.0	90.9	99.9

OU5-A Stage 2 Organic Concentrations

OU5-A Attr. Scr. 15min. Chem. Xtrt. 40 °C 0.5 hr

SOLID/LIQUID			TCE (PPM)	NAP (PPM)	ACEY (PPM)	ACEN (PPM)	FLU (PPM)	PHEN (PPM)	ANTH (PPM)	FLUA (PPM)	PYR (PPM)	BAA (PPM)	CHRY (PPM)	BBF (PPM)	BKF (PPM)	BAP (PPM)	INDP (PPM)	DBA (PPM)	BGP (PPM)
1087/66-13	7 : 1	LIQUID	0.091	0.001	<0.002	<0.002	<0.002	<0.002	0.007	<0.003	0.002	<0.002	0.004	<0.005	<0.005	<0.002	<0.001	<0.001	<0.001
1087/66-15	7 : 1	SOLID	4.1	0.11	<0.1	<0.1	0.12	0.68	0.25	1	1.5	0.31	0.46	0.74**	**	0.23	0.2	<0.2	0.27
1087/66-16	4 : 1	LIQUID	0.066	0.001	<0.002	<0.002	<0.002	<0.002	0.013	<0.003	<0.002	<0.002	0.001	<0.005	<0.005	<0.002	<0.001	<0.001	<0.001
1087/66-18	4 : 1	SOLID	4.2	0.1	<0.1	<0.1	0.13	0.58	0.2	0.92	1.2	0.27	0.39	0.65**	**	0.2	0.41	<0.2	0.22

** Benzo(b) and (k) Fluoranthene cannot be fully resolved. The total is qualified as Benzo(b)Fluoranthene.

ABBREVIATION KEY

TCE=Trichloroethylene
NAP=Naphthalene
ACEY=Acenaphthylene
ACEN=Acenaphthene
FLU=Fluorene
PHEN=Phenanthrene
ANTH=Anthracene
FLUA=Fluoranthene
PYR=Pyrene
BAA=Benzo (a) anthracene
CHRY=Chrysene
BBF=Benzo (b) fluoranthene
BKF=Benzo (k) fluoranthene
BAP = Benzo (a) pyrene
INDP - Indeno (1,2,3-cd) pyrene
DBA=Dibenzo (a,h) anthracene
BGP=Benzo (g,h,i) perylene

WASTEWATER TREATMENT ID SOILS

FERNALD OU5 - TREATMENT OF SPENT ACIDS FROM CHEMICAL EXTRACTION OF ID SOILS

PRECIPITATION - 2.0 HOURS REACTION TIME

SAMPLE ID	SOIL ID	FEED ID	FEED LIQUID U (ppm)	FEED ACID CONC. (N)	FEED ACID TYPE	FEED DOSE RATE	FEED pH	LIQUID WT. (g)	REAGENT 1				REAGENT 2				FINAL LIQUID U CONC. (ppm)
									TYPE	CONC. (%)	AMT. (g)	FINAL pH	TYPE	CONC. (%)	AMT. (g)	FINAL pH	
10821001	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.01	NaOH	25	6.20	9.75	----------	------	------	------	0.30
10821002	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.03	Ca(OH)2	20	1.14	0.45	NaOH	25	5.17	9.75	0.13
10821003	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.96	MgO	20	1.18	0.53	NaOH	25	4.81	9.05	0.09
10821004	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.35	NaOH	25	3.86	9.66	----------	------	------	------	0.10
10821005	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.38	Ca(OH)2	20	1.14	1.13	NaOH	25	2.86	9.75	0.06
10821006	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.36	MgO	20	1.18	1.37	NaOH	25	2.76	9.50	0.03
10821501	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.36	NaOH	25	2.28	9.85	----------	------	------	------	0.09
10821502	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.30	Ca(OH)2	20	1.14	1.36	NaOH	25	1.20	9.42	0.03
10821503	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.38	MgO	20	1.18	4.10	NaOH	25	0.87	9.40	0.05
10821504	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.87	NaOH	25	5.13	9.32	----------	------	------	------	0.00
10821505	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.88	Ca(OH)2	20	1.14	0.56	NaOH	25	4.16	9.55	0.18
10821506	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.93	MgO	20	1.18	0.68	NaOH	25	4.08	9.35	NA
10821507	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.88	NaOH	25	5.86	3.80	NALMET	1.00	1.01	3.85	38.62
10821508	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.32	NaOH	25	2.40	3.80	NALMET	1.00	1.01	3.85	40.38
10821509	A	10632204	45.24	2.0	H2SO4	10:1	0.72	20.31	NaOH	25	1.50	3.85	NALMET	1.00	1.01	3.90	35.03
10821510	B	10631801	44.75	1.0	H2SO4	10:1	0.36	20.86	NaOH	25	4.21	3.80	NALMET	1.00	1.01	3.85	33.76

FERNALD OU5 - TREATMENT OF SPENT ACIDS FROM CHEMICAL EXTRACTION OF ID SOILS

PRECIPITATION - 4.0 HOURS REACTION TIME

SAMPLE ID	SOIL ID	FEED ID	FEED LIQUID U CONC. (ppm)	FEED ACID CONC. (%)	FEED ACID TYPE	FEED DOSAGE	FEED pH	LIQUID WT. (g)	REAGENT 1				REAGENT 2				FINAL LIQUID U CONC. (ppm)
									TYPE	CONC. (%)	AMT. (g)	FINAL pH	TYPE	CONC. (%)	AMT. (g)	FINAL pH	
10821101	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.01	NaOH	25	6.20	9.75	----------	------	------	------	0.33
10821102	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.03	Ca(OH)2	20	1.14	0.45	NaOH	25	5.17	9.75	0.18
10821103	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.96	MgO	20	1.18	0.53	NaOH	25	4.81	9.05	0.13
10821104	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.35	NaOH	25	3.86	9.66	----------	------	------	------	0.11
10821105	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.38	Ca(OH)2	20	1.14	1.13	NaOH	25	2.86	9.75	0.09
10821106	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.36	MgO	20	1.18	1.37	NaOH	25	2.76	9.50	0.04
10821601	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.36	NaOH	25	2.28	9.85	----------	------	------	------	0.09
10821602	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.30	Ca(OH)2	20	1.14	1.36	NaOH	25	1.20	9.42	0.04
10821603	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.38	MgO	20	1.18	4.10	NaOH	25	0.87	9.40	0.05
10821604	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.87	NaOH	25	5.13	9.32	----------	------	------	------	0.09
10821605	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.88	Ca(OH)2	20	1.14	0.66	NaOH	25	4.16	9.55	0.86
10821606	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.93	MgO	20	1.18	0.68	NaOH	25	4.08	9.35	0.31
10821607	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.88	NaOH	25	5.86	3.80	NALMET	1.00	1.01	3.85	37.70
10821608	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.32	NaOH	25	2.40	3.80	NALMET	1.00	1.01	3.85	40.01
10821609	A	10632204	45.24	2.0	H2SO4	10:1	0.72	20.31	NaOH	25	1.50	3.85	NALMET	1.00	1.01	3.90	35.31
10821610	B	10631801	44.75	1.0	H2SO4	10:1	0.36	20.86	NaOH	25	4.21	3.80	NALMET	1.00	1.01	3.85	32.96

FERNALD OU5 - TREATMENT OF SPENT ACIDS FROM CHEMICAL EXTRACTION OF ID SOILS

PRECIPITATION - 24.0 HOURS REACTION TIME

SAMPLE ID	SOIL ID	FEED ID	FEED LIQUID U CONC. (ppm)	FEED ACID CONC. (N)	FEED ACID TYPE	FEED DOSAGE	FEED pH	LIQUID WT. (g)	REAGENT 1				REAGENT 2				FINAL LIQUID U CONC. (ppm)	DRY CAKE WT. (g)	CAKE: SOIL RATIO
									TYPE	CONC. (%)	AMT. (g)	FINAL pH	TYPE	CONC. (%)	AMT. (g)	FINAL pH			
10821201	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.01	NaOH	25	6.20	9.60	----------	-------	------	------	0.60	0.55	0.26
10821202	A	10631401	50.94	2.0	H2SO4	10:1	0.30	21.03	Ca(OH)2	20	1.14	0.45	NaOH	25	5.17	9.55	0.22	0.97	0.46
10821203	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.96	MgO	20	1.18	0.53	NaOH	25	4.81	9.00	0.36	0.73	0.35
10821204	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.35	NaOH	25	3.86	9.51	----------	-------	------	------	0.20	0.98	0.48
10821205	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.38	Ca(OH)2	20	1.14	1.13	NaOH	25	2.86	9.58	0.17	0.77	0.38
10821206	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.36	MgO	20	1.18	1.37	NaOH	25	2.76	9.43	0.10	0.56	0.27
10821701	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.36	NaOH	25	2.28	9.60	----------	-------	------	------	0.08	0.31	0.15
10821702	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.30	Ca(OH)2	20	1.14	1.36	NaOH	25	1.20	9.32	0.09	0.86	0.42
10821703	A	10632204	45.24	1.0	H2SO4	10:1	0.72	20.38	MgO	20	1.18	4.10	NaOH	25	0.87	9.31	0.11	0.46	0 23
10821704	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.87	NaOH	25	5.13	9.32	----------	-------	------	------	0.27	0.81	0.39
10821705	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.88	Ca(OH)2	20	1.14	0.56	NaOH	25	4.16	9.20	1.52	1.10	0.52
10821706	B	10631801	44.75	2.0	H2SO4	10:1	0.36	20.93	MgO	20	1.18	0.68	NaOH	25	4.08	9.25	0.34	0.95	0.45
10821707	A	10631401	50.94	2.0	H2SO4	10:1	0.30	20.88	NaOH	25	5.86	3.80	NALMET	1.00	1.01	3.85	38.03	0.11	0 05
10821708	B	10632604	51.39	1.0	H2SO4	10:1	0.50	20.32	NaOH	25	2.40	3.80	NALMET	1.00	1.01	3.85	41.12	0.12	0.06
10821709	A	10632204	45.24	2.0	H2SO4	10:1	0.72	20.31	NaOH	25	1.50	3.85	NALMET	1.00	1.01	3.95	35.40	0.07	0 03
10821710	B	10631801	44.75	1.0	H2SO4	10:1	0.36	20.86	NaOH	25	4.21	3.80	NALMET	1.00	1.01	3.80	33.69	0 20	0 10

OU5 ION EXCHANGE
TREATMENT OF SPENT ACIDS
FROM TREATMENT OF ID SOILS

Fernald #	Sample ID	Soil Type	Feed	Resin ID	Resin Wgt. (g)	Liquid Wgt. (g)	Dosage (L/H)	pH	Dilute (Y)	Treated Liquid	
										Total Uranium (ppm)	Total Iron (ppm)
75410	10822501	A	10822403	IRA 400	0.0103	10.12	L	N	Y	22.32	650.6
75410	10822502	A	10822403	IRA 400	0.1003	10.09	H	N	Y	12.53	648.0
75410	10822503	A	10822404	IRA 400	0.0106	10.19	L	1	Y	16.93	601.3
75410	10822504	A	10822404	IRA 400	0.1007	10.15	H	1	Y	4.65	595.6
75410	10822505	A	10822405	IRA 400	0.0102	10.20	L	2	Y	7.11	554.7
75410	10822506	A	10822405	IRA 400	0.1006	10.25	H	2	Y	0.73	528.2
75411	10822507	B	10822406	IRA 400	0.0108	10.15	L	N	Y	18.72	843.6
75411	10822508	B	10822406	IRA 400	0.1017	10.10	H	N	Y	7.97	859.8
75411	10822509	B	10822407	IRA 400	0.0103	10.07	L	1	Y	14.81	815.0
75411	10822510	B	10822407	IRA 400	0.1026	10.13	H	1	Y	3.79	812.7
75411	10822511	B	10822408	IRA 400	0.0104	10.19	L	2	Y	5.45	783.4
75411	10822512	B	10822408	IRA 400	0.1019	10.21	H	2	Y	0.58	710.5
75410	10822513	A	10822403	IONAC A-642	0.0104	10.12	L	N	Y	24.35	646.2
75410	10822514	A	10822403	IONAC A-642	0.101	10.13	H	N	Y	18.69	577.1
75410	10822515	A	10822404	IONAC A-642	0.0101	10.16	L	1	Y	20.85	594.0
75410	10822516	A	10822404	IONAC A-642	0.1006	10.15	H	1	Y	9.21	576.6
75410	10822517	A	10822405	IONAC A-642	0.0107	10.26	L	2	Y	12.94	570.3
75410	10822518	A	10822405	IONAC A-642	0.1037	10.21	H	2	Y	2.68	533.3
75411	10822519	B	10822406	IONAC A-642	0.0103	10.12	L	N	Y	20.86	856.6
75411	10822520	B	10822406	IONAC A-642	0.1001	10.10	H	N	Y	10.04	881.9
75411	10822521	B	10822407	IONAC A-642	0.01	10.06	L	1	Y	18.35	827.6
75411	10822522	B	10822407	IONAC A-642	0.1003	10.08	H	1	Y	8.06	798.5
75411	10822523	B	10822408	IONAC A-642	0.0102	10.20	L	2	Y	11.77	773.4
75411	10822524	B	10822408	IONAC A-642	0.1009	10.21	H	2	Y	2.38	723.5
75410	10822525	A	10822403	21 K	0.0101	10.11	L	N	Y	25.43	613.7
75410	10822526	A	10822403	21 K	0.1033	10.07	H	N	Y	14.52	640.0
75410	10822527	A	10822404	21 K	0.0107	10.20	L	1	Y	19.53	589.0
75410	10822528	A	10822404	21 K	0.1045	10.23	H	1	Y	6.88	594.8
75410	10822529	A	10822405	21 K	0.0102	10.21	L	2	Y	10.78	565.4
75410	10822530	A	10822405	21 K	0.1015	10.22	H	2	Y	1.72	529.8
75411	10822531	B	10822406	21 K	0.0103	10.06	L	N	Y	20.25	870.7
75411	10822532	B	10822406	21 K	0.1003	10.14	H	N	Y	10.93	863.4
75411	10822533	B	10822407	21 K	0.0101	10.15	L	1	Y	17.67	832.1
75411	10822534	B	10822407	21 K	0.1031	10.12	H	1	Y	6.00	822.1
75411	10822535	B	10822408	21 K	0.0103	10.27	L	2	Y	8.99	774.8
75411	10822536	B	10822408	21 K	0.1027	10.21	H	2	Y	1.39	729.4
75410	10822537	A	10822403	G-55	0.0109	10.10	L	N	Y	23.95	648.6
75410	10822538	A	10822403	G-55	0.1001	10.15	H	N	Y	14.22	657.0
75410	10822539	A	10822404	G-55	0.0105	10.14	L	1	Y	17.82	585.7
75410	10822540	A	10822404	G-55	0.1036	10.12	H	1	Y	5.56	603.3
75410	10822541	A	10822405	G-55	0.0104	10.23	L	2	Y	7.94	592.3
75410	10822542	A	10822405	G-55	0.1019	10.28	H	2	Y	1.08	532.4
75411	10822543	B	10822406	G-55	0.0108	10.05	L	N	Y	19.83	864.2
75411	10822544	B	10822406	G-55	0.1015	10.09	H	N	Y	9.04	856.7
75411	10822545	B	10822407	G-55	0.0103	10.14	L	1	Y	16.16	819.1
75411	10822546	B	10822407	G-55	0.1017	10.12	H	1	Y	4.58	806.4
75411	10822547	B	10822408	G-55	0.0107	10.23	L	2	Y	6.17	779.6
75411	10822548	B	10822408	G-55	0.1002	10.21	H	2	Y	0.86	721.0
75410	10822549	A	10822403	IRC 718	0.0108	10.12	L	N	Y	26.14	644.5
75410	10822550	A	10822403	IRC 718	0.1027	10.13	H	N	Y	20.18	624.0

OU5 ION EXCHANGE
TREATMENT OF SPENT ACIDS
FROM TREATMENT OF ID SOILS

Fernald #	Sample ID	Soil Type	Feed	Resin ID	Resin Wgt. (g)	Liquid Wgt. (g)	Dosage (L/H)	pH	Dilute (Y)	Treated Liquid Total Uranium (ppm)	Treated Liquid Total Iron (ppm)
75410	10822551	A	10822404	IRC 718	0.0105	10.25	L	1	Y	24.23	589.7
75410	10822552	A	10822404	IRC 718	0.1024	10.21	H	1	Y	15.45	478.7
75410	10822553	A	10822405	IRC 718	0.0108	10.24	L	2	Y	24.24	493.1
75410	10822554	A	10822405	IRC 718	0.1021	10.18	H	2	Y	8.63	126.7
75411	10822555	B	10822406	IRC 718	0.0102	10.13	L	N	Y	23.57	844.6
75411	10822556	B	10822406	IRC 718	0.1038	10.11	H	N	Y	16.13	812.7
75411	10822557	B	10822407	IRC 718	0.0102	10.14	L	1	Y	22.01	812.2
75411	10822558	B	10822407	IRC 718	0.1027	10.13	H	1	Y	14.06	673.6
75411	10822559	B	10822408	IRC 718	0.0101	10.20	L	2	Y	21.28	704.6
75411	10822560	B	10822408	IRC 718	0.1035	10.21	H	2	Y	8.70	220.3
75410	10822561	A	10822403	S-930	0.0107	10.15	L	N	Y	25.41	661.1
75410	10822562	A	10822403	S-930	0.1028	10.15	H	N	Y	19.30	626.1
75410	10822563	A	10822404	S-930	0.01	10.27	L	1	Y	23.37	599.2
75410	10822564	A	10822404	S-930	0.102	10.28	H	1	Y	15.97	471.2
75410	10822565	A	10822405	S-930	0.0102	10.40	L	2	Y	21.17	513.8
75410	10822566	A	10822405	S-930	0.1026	10.42	H	2	Y	7.88	148.4
75411	10822567	B	10822406	S-930	0.0101	10.18	L	N	Y	22.54	849.6
75411	10822568	B	10822406	S-930	0.1025	10.18	H	N	Y	16.20	798.6
75411	10822569	B	10822407	S-930	0.0103	10.28	L	1	Y	21.29	821.8
75411	10822570	B	10822407	S-930	0.1028	10.27	H	1	Y	14.70	659.8
75411	10822571	B	10822408	S-930	0.01	10.37	L	2	Y	20.10	739.8
75411	10822572	B	10822408	S-930	0.1015	10.38	H	2	Y	7.74	283.6
75410	10822573	A	10822403	IONAC SR3	0.0107	10.14	L	N	Y	25.19	646.6
75410	10822574	A	10822403	IONAC SR3	0.103	10.16	H	N	Y	19.61	658.5
75410	10822575	A	10822404	IONAC SR3	0.0105	10.27	L	1	Y	24.38	608.4
75410	10822576	A	10822404	IONAC SR3	0.1008	10.28	H	1	Y	17.12	614.3
75410	10822577	A	10822405	IONAC SR3	0.0102	10.41	L	2	Y	23.37	591.5
75410	10822578	A	10822405	IONAC SR3	0.1016	10.41	H	2	Y	14.91	597.1
75411	10822579	B	10822406	IONAC SR3	0.0102	10.17	L	N	Y	21.89	11.7
75411	10822580	B	10822406	IONAC SR3	0.103	10.18	H	N	Y	17.51	894.6
75411	10822581	B	10822407	IONAC SR3	0.0104	10.28	L	1	Y	23.43	772.4
75411	10822582	B	10822407	IONAC SR3	0.1017	10.29	H	1	Y	24.51	744.6
75411	10822583	B	10822408	IONAC SR3	0.0107	10.38	L	2	Y	22.08	711.5
75411	10822584	B	10822408	IONAC SR3	0.102	10.39	H	2	Y	19.47	732.6
75410	10822585	A	10822403	IONAC SR5	0.0109	10.14	L	N	Y	26.33	653.0
75410	10822586	A	10822403	IONAC SR5	0.1022	10.15	H	N	Y	25.54	629.3
75410	10822587	A	10822404	IONAC SR5	0.0109	10.29	L	1	Y	21.82	600.0
75410	10822588	A	10822404	IONAC SR5	0.1039	10.29	H	1	Y	18.29	514.5
75410	10822589	A	10822405	IONAC SR5	0.0109	10.41	L	2	Y	23.82	539.1
75410	10822590	A	10822405	IONAC SR5	0.1006	10.40	H	2	Y	11.37	215.3
75411	10823101	B	10822406	IONAC SR5	0.1	10.18	L	N	Y	22.82	874.7
75411	10823102	B	10822406	IONAC SR5	0.102	10.19	H	N	Y	17.97	820.2
75411	10823103	B	10822407	IONAC SR5	0.0107	10.27	L	1	Y	22.02	813.0
75411	10823104	B	10822407	IONAC SR5	0.1021	10.29	H	1	Y	15.35	692.6
75411	10823105	B	10822408	IONAC SR5	0.0109	10.38	L	2	Y	21.38	729.6
75411	10823106	B	10822408	IONAC SR5	0.1039	10.38	H	2	Y	9.39	312.7
75410	10823107	A	10822403	XFS 4195.02	0.0103	10.15	L	N	Y	21.22	655.2
75410	10823108	A	10822403	XFS 4195.02	0.1028	10.15	H	N	Y	5.65	658.5
75410	10823109	A	10822404	XFS 4195.02	0.0101	10.28	L	1	Y	17.52	589.3
75410	10823110	A	10822404	XFS 4195.02	0.1019	10.29	H	1	Y	3.60	589.9

000206

6771

OU5 ION EXCHANGE
TREATMENT OF SPENT ACIDS
FROM TREATMENT OF ID SOILS

Fernald #	Sample ID	Soil Type	Feed	Resin ID	Resin Wgt. (g)	Liquid Wgt. (g)	Dosage (L/H)	pH	Dilute (Y)	Treated Liquid Total Uranium (ppm)	Treated Liquid Total Iron (ppm)	QA INFORMATION
75410	10823111	A	10822404.5	XFS 4195.02	0.0105	10.41	L	2	Y	14.72	571.0	———
75410	10823112	A	10822404.9	XFS 4195.02	0.1017	10.41	H	2	Y	1.91	489.7	———
75411	10823113	B	10822405.7	XFS 4195.02	0.0102	10.18	L	N	Y	17.72	869.8	———
75411	10823114	B	10822406.26	XFS 4195.02	0.1006	10.17	H	N	Y	4.41	862.7	———
75411	10823115	B	10822406.68	XFS 4195.02	0.0101	10.28	L	1	Y	15.29	822.4	———
75411	10823116	B	10822407.1	XFS 4195.02	0.1017	10.28	H	1	Y	3.61	804.2	———
75411	10823117	B	10822407.53	XFS 4195.02	0.0101	10.38	L	2	Y	16.87	754.1	———
75411	10823118	B	10822407.53	XFS 4195.02	0.1002	10.39	H	2	Y	1.79	616.9	———
75410	10823119	A	10822403	XFS 43084	0.0101	10.13	L	N	Y	22.64	648.8	———
75410	10823120	A	10822403	XFS 43084	0.1005	10.15	H	N	Y	11.01	665.1	———
75410	10823121	A	10822404	XFS 43084	0.0105	10.28	L	1	Y	20.36	620.8	———
75410	10823122	A	10822404	XFS 43084	0.1012	10.30	H	1	Y	6.69	607.7	———
75410	10823123	A	10822404.5	XFS 43084	0.0102	10.40	L	2	Y	16.36	580.8	———
75410	10823124	A	10822404.9	XFS 43084	0.1033	10.41	H	2	Y	2.86	555.1	———
75411	10823125	B	10822405.7	XFS 43084	0.0105	10.18	L	N	Y	19.28	850.5	———
75411	10823126	B	10822406.26	XFS 43084	0.1025	10.16	H	N	Y	15.26	734.3	———
75411	10823127	B	10822406.68	XFS 43084	0.0102	10.28	L	1	Y	18.72	825.4	———
75411	10823128	B	10822407.1	XFS 43084	0.1004	10.27	H	1	Y	5.47	814.9	———
75411	10823129	B	10822407.53	XFS 43084	0.0101	10.37	L	2	Y	14.14	791.6	———
75411	10823130	B	10822407.53	XFS 43084	0.1005	10.39	H	2	Y	2.10	760.2	———
75410	10823131	A	10822403	IRA 400	0.0101	10.18	L	N	Y	23.32	638.6	10822501dup
75411	10823132	B	10822407.1	IONAC A-642	0.1003	10.06	H	1	Y	8.71	798.5	10822522dup
75410	10822403	A	———	Feed	———	———	———	—	Y	28.46	698.5	———
75410	10822404	A	———	Feed	———	———	———	—	Y	26.42	625.9	———
75410	10822405	A	———	Feed	———	———	———	—	Y	25.28	608.8	———
75411	10822406	B	———	Feed	———	———	———	—	Y	25.40	881.6	———
75411	10822407	B	———	Feed	———	———	———	—	Y	24.30	869.4	———
75411	10822408	B	———	Feed	———	———	———	—	Y	23.18	827.8	———

000207

4/10/93 2:03 PM
108226.XLS

OU5 ION EXCHANGE
TREATMENT OF SPENT ACIDS
FROM TREATMENT OF ID SOILS

Fernald #	Sample ID	Soil Type	Feed	Resin ID	Resin Wgt. (g)	Liquid Wgt. (g)	Dosage (L/H)	pH	Dilute (Y)	Reduce (Y)	Treated Liquid Total Uranium (ppm)	Treated Liquid Total Iron (ppm)	Treated Liquid Total Thorium (ppm)
75410	10823601	A	10823601	G-55	0.0107	10.20	L	2	—	—	18.40	1068.0	1.59
75410	10823602	A	10823605	G-55	0.0107	10.28	L	3	—	—	13.60	645.3	1.17
75410	10823603	A	10823607	G-55	0.0101	10.17	L	3	Y	—	4.10	258.1	0.50
75410	10823604	A	10823603	G-55	0.0102	10.29	L	3	Y	Y	5.00	405.6	0.55
75411	10823605	B	10823602	G-55	0.0104	10.30	L	2	—	—	16.00	1482.0	1.48
75411	10823606	B	10823606	G-55	0.0101	10.18	L	3	—	—	14.10	1290.0	1.11
75411	10823607	B	10823608	G-55	0.0105	10.32	L	3	Y	—	4.54	611.3	0.41
75411	10823608	B	10823604	G-55	0.01	10.20	L	3	Y	Y	3.72	652.4	0.44
75410	10823609	A	10823601	G-55	0.1017	10.15	H	2	—	—	2.60	939.2	0.91
75410	10823610	A	10823605	G-55	0.1007	10.17	H	3	—	—	1.16	443.5	0.48
75410	10823611	A	10823607	G-55	0.1018	10.21	H	3	Y	—	0.39	186.0	0.29
75410	10823612	A	10823603	G-55	0.0999	10.20	H	3	Y	Y	0.61	281.8	0.28
75411	10823613	B	10823602	G-55	0.102	10.24	H	2	—	—	2.32	1367.0	0.65
75411	10823614	B	10823606	G-55	0.1019	10.33	H	3	—	—	1.67	897.3	0.34
75411	10823615	B	10823608	G-55	0.1032	10.20	H	3	Y	—	0.56	396.4	0.13
75411	10823616	B	10823604	G-55	0.1009	10.17	H	3	Y	Y	0.44	509.3	0.28
75410	10824001	A	10823601	IRA-400	0.0107	10.20	L	2	—	—	15.50	1019.0	1.48
75410	10824002	A	10823605	IRA-400	0.01	10.43	L	3	—	—	11.00	597.8	1.11
75410	10824003	A	10823607	IRA-400	0.0104	10.35	L	3	Y	—	2.75	259.5	0.38
75410	10824004	A	10823603	IRA-400	0.0101	10.19	L	3	Y	Y	3.16	388.9	0.54
75411	10824005	B	10823602	IRA-400	0.0106	10.22	L	2	—	—	8.78	1494.0	1.24
75411	10824006	B	10823606	IRA-400	0.0102	10.41	L	3	—	—	11.50	1226.0	0.92
75411	10824007	B	10823608	IRA-400	0.0105	10.20	L	3	Y	—	2.96	618.7	0.32
75411	10824008	B	10823604	IRA-400	0.011	10.20	L	3	Y	Y	1.87	867.9	0.40
75410	10824009	A	10823601	IRA-400	0.1016	10.22	H	2	—	—	1.72	942.8	0.79
75410	10824010	A	10823605	IRA-400	0.1027	10.28	H	3	—	—	0.88	593.2	0.55
75410	10824011	A	10823607	IRA-400	0.1017	10.21	H	3	Y	—	0.28	NA	0.24
75410	10824012	A	10823603	IRA-400	0.1038	10.49	H	3	Y	Y	0.32	245.6	0.25
75411	10824013	B	10823602	IRA-400	0.1013	10.38	H	2	—	—	1.71	1341.0	0.67
75411	10824014	B	10823606	IRA-400	0.1052	10.31	H	3	—	—	1.04	893.0	0.50
75411	10824015	B	10823608	IRA-400	0.104	10.29	H	3	Y	—	0.27	377.3	0.16
75411	10824016	B	10823604	IRA-400	0.1012	10.22	H	3	Y	Y	0.31	488.4	0.24
75410	10823601	A	—	Feed	—	—	—	2	N	—	44.57	1017.0	2.43
75411	10823602	B	—	Feed	—	—	—	2	N	—	40.09	1499.0	2.15
75410	10823603	A	—	Feed	—	—	—	3	Y	Y	23.56	430.3	1.38
75411	10823604	B	—	Feed	—	—	—	3	Y	Y	15.71	697.8	1.30
75410	10823605	A	—	Feed	—	—	—	3	N	—	37.13	621.3	2.30
75411	10823606	B	—	Feed	—	—	—	3	N	—	36.31	1266.0	2.12
75410	10823607	A	—	Feed	—	—	—	3	Y	—	22.54	281.0	1.36
75411	10823608	B	—	Feed	—	—	—	3	Y	—	20.50	648.6	1.20

000608

OU5 ION EXCHANGE
TREATMENT OF SPENT ACIDS
FROM TREATMENT OF ID SOILS

Fernald #	Sample ID	Soil Type	Feed	Resin ID	Dosage (L/H)	pH	Dilute (Y)	Reduce (Y)	Treated Liquid Total Uranium (ppm)	Treated Liquid Total Iron (ppm)	Treated Liquid U (ppm)	Feed Conc U (ppm)	Total U Loaded on Resin (mg)	U Loading on Resin (g/g)
75410	10823601	A	10823601	G-55	L	2	—	—	18.40	1068.0	18.4	44.57	0.27	0.025
75410	10823602	A	10823605	G-55	L	3	—	—	13.60	645.3	13.6	37.13	0.24	0.023
75410	10823603	A	10823607	G-55	L	3	Y	—	4.10	258.1	4.1	22.54	0.19	0.019
75410	10823604	A	10823603	G-55	L	3	Y	Y	5.00	405.6	5	23.56	0.19	0.019
75411	10823605	B	10823602	G-55	L	2	—	—	16.00	1482.0	16	40.09	0.25	0.024
75411	10823606	B	10823606	G-55	L	3	—	—	14.10	1290.0	14.1	36.31	0.23	0.022
75411	10823607	B	10823606	G-55	L	3	Y	—	4.54	611.3	4.54	20.50	0.16	0.016
75411	10823608	B	10823604	G-55	L	3	Y	Y	3.72	652.4	3.72	15.71	0.12	0.012
75410	10823609	A	10823601	G-55	H	2	—	—	2.60	939.2	2.6	44.57	0.43	0.004
75410	10823610	A	10823605	G-55	H	3	—	—	1.16	443.5	1.16	37.13	0.37	0.004
75410	10823611	A	10823607	G-55	H	3	Y	—	0.39	186.0	0.386	22.54	0.23	0.002
75410	10823612	A	10823603	G-55	H	3	Y	Y	0.51	281.8	0.512	23.56	0.24	0.002
75411	10823613	B	10823602	G-55	H	2	—	—	2.32	1367.0	2.32	40.09	0.39	0.004
75411	10823614	B	10823606	G-55	H	3	—	—	1.67	897.3	1.67	36.31	0.36	0.004
75411	10823615	B	10823606	G-55	H	3	Y	—	0.56	396.4	0.561	20.50	0.20	0.002
75411	10823616	B	10823604	G-55	H	3	Y	Y	0.44	509.3	0.438	15.71	0.16	0.002
75410	10824001	A	10823601	IRA-400	L	2	—	—	15.50	1019.0	15.5	44.57	0.30	0.028
75410	10824002	A	10823605	IRA-400	L	3	—	—	11.00	597.8	11	37.13	0.27	0.027
75410	10824003	A	10823607	IRA-400	L	3	Y	—	2.75	259.5	2.75	22.54	0.20	0.020
75410	10824004	A	10823603	IRA-400	L	3	Y	Y	3.16	368.9	3.16	23.56	0.21	0.021
75411	10824005	B	10823602	IRA-400	L	2	—	—	8.78	1494.0	8.78	40.09	0.32	0.030
75411	10824006	B	10823606	IRA-400	L	3	—	—	11.50	1226.0	11.5	36.31	0.26	0.025
75411	10824007	B	10823606	IRA-400	L	3	Y	—	2.96	618.7	2.96	20.50	0.18	0.017
75411	10824008	B	10823604	IRA-400	L	3	Y	Y	1.87	667.9	1.87	15.71	0.14	0.013
75410	10824009	A	10823601	IRA-400	H	2	—	—	1.72	942.8	1.72	44.57	0.44	0.004
75410	10824010	A	10823605	IRA-400	H	3	—	—	0.88	593.2	0.875	37.13	0.37	0.004
75410	10824011	A	10823607	IRA-400	H	3	Y	—	0.26	NA	0.26	22.54	0.23	0.002
75410	10824012	A	10823603	IRA-400	H	3	Y	Y	0.32	245.6	0.318	23.56	0.24	0.002
75411	10824013	B	10823602	IRA-400	H	2	—	—	1.71	1341.0	1.71	40.09	0.40	0.004
75411	10824014	B	10823606	IRA-400	H	3	—	—	1.04	893.0	1.04	36.31	0.36	0.003
75411	10824015	B	10823606	IRA-400	H	3	Y	—	0.27	377.3	0.265	20.50	0.21	0.002
75411	10824016	B	10823604	IRA-400	H	3	Y	Y	0.31	488.4	0.314	15.71	0.16	0.002

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MODIFIED TOXICITY CHARACTERIZATION LEACH PROCEDURE (MTCLP) ID SOILS

FERNALD OU5 - MODIFIED TOXICITY CHARACTERIZATION LEACH PROCEDURE

Sample Description	RCRA Metals (ppm) Ag	As	Ba	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Th	U	Zn	Total Uranium (ppm)	Gross Alpha (pCi/ml)	Gross Beta (pCi/ml)	Total Activity (pCi/ml)
Fernald OU5 ID-A Soil As Is	<0.003	<0.05	0.36	<0.005	<0.003	<0.007	<0.004	<0.003	<0.011	<0.031	<0.067	<0.040	0.92	0.065	0.99	< 1.54	< 1.07	2.60
DUP	<0.003	<0.05	0.313	<0.005	<0.003	<0.007	<0.004	<0.003	<0.011	<0.031	<0.067	<0.040	0.81	0.065	0.97	< 1.51	< 1.06	2.57
Fernald OU5 ID-B Soil As Is	<0.003	<0.05	0.628	<0.005	<0.003	<0.007	0.027	<0.003	<0.011	<0.031	<0.067	0.423	9.91	<0.003	10.88	4.01	< 1.08	5.09
DUP	<0.003	<0.05	0.618	<0.005	<0.003	<0.007	<0.004	<0.003	<0.011	<0.031	<0.067	0.401	9.97	<0.003	10.85	2.44	1.23	3.67
Fernald OU5 ID-A Treated by Attrition Scrubbing/ Chemical Extraction	<0.003	<0.05	0.028	0.057	0.205	0.358	0.151	210	0.391	<0.031	<0.067	<0.040	2.19	1.48	2.41	< 1.65	< 1.08	2.73
DUP	<0.003	<0.05	0.027	<0.005	0.183	0.356	0.124	184	0.333	<0.031	<0.067	<0.040	1.94	1.29	2.09	< 1.59	< 1.07	2.66
Fernald OU5 ID-B Treated by Attrition Scrubbing/ Chemical Extraction	<0.003	<0.05	0.032	<0.005	0.11	0.117	0.105	58.6	0.272	<0.031	<0.067	<0.040	1.73	0.666	2.03	< 1.40	< 1.06	2.45
DUP	<0.003	<0.05	0.039	<0.005	0.11	0.07	0.07	43.4	0.253	<0.031	<0.067	<0.040	1.62	0.63	1.82	< 1.76	< 1.09	2.84

MODIFIED TOXICITY CHARACTERIZATION LEACH PROCEDURE (MTCLP) OU5-A SOIL

FERNALD OU5 - MODIFIED TOXICITY CHARACTERIZATION LEACH PROCEDURE

Sample Description	RCRA Metals Ag	As	Ba	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Th	U	Zn	Total Uranium	Gross Alpha	Gross Beta	Total Activity
	(ppm)														(ppm)	(pCi/ml)	(pCi/ml)	(pCi/ml)
Fernald OU5																		
OU5-A Soil As Is	<0.003	<0.05	0.814	<0.005	<0.003	<0.007	<0.004	0.095	<0.011	<0.031	<0.067	<0.040	1.54	1.20	1.70	< 1.53	< 1.07	2.60
DUP	<0.003	<0.05	0.568	<0.005	<0.003	0.283	<0.004	1.09	0.423	<0.031	<0.067	<0.040	1.10	0.879	1.21	< 1.55	< 1.07	2.62
Fernald OU5 OU5-A Treated by Attrition Scrubbing/ Chemical Extraction	<0.003	<0.05	0.14	<0.005	<0.003	<0.007	<0.004	0.095	<0.011	<0.031	<0.067	N/A	N/A	0.04	0.13	< 1.18	1.29	2.48
DUP	<0.003	<0.05	0.15	<0.005	<0.003	<0.007	<0.004	1.09	0.423	<0.031	<0.067	N/A	N/A	0.04	0.11	< 1.16	2.24	3.40

000213

12269

ATTACHMENT II
INITIAL CHARACTERIZATION DATA FOR ID-A AND ID-B SOILS

ID-A INITIAL CHARACTERIZATION

Soil:	IDA INITIAL CHARACTERIZATION 1				IDA INITIAL CHARACTERIZATION 2				IDA INITIAL CHARACTERIZATION 3				IDA INITIAL CHARACTERIZATION 4			
Sample Point:																
Sample Id:	100279				100280				100281				100282			
Analytes	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual
Cesium-137	0.21		20.00	U	0.19		20.00	U	0.19		20.00	U	0.21		20.00	U
Gross Alpha	570.00		270.00		480.00		360.00		960.00		230.00		730.00		56.00	
Gross Beta	250.00		120.00		240.00		130.00		300.00		130.00		260.00		20.00	
Neptunium-237	2.30		1.40		1.10		1.70		2.10		0.70		2.40		2.10	
Plutonium-238	0.34		1.00	U	0.53		1.00	U	0.25		1.00	U	0.60		1.00	U
Plutonium-239/240	0.11		1.00	U	0.09		1.00	U	0.10		1.00	U	0.05		1.00	U
Ruthenium-106	0.17	U	150.00	U	0.17	U	150.00	U	0.17	U	150.00	U	0.17	U	150.00	U
Strontium-90	5.00	U	4.20		5.00	U	3.70		5.00	U	3.60		5.00	U	5.00	U
Technetium-99	9.00		30.00	U	8.60		30.00	U	8.60		30.00	U	6.20		30.00	U
Thorium-228	2.20		1.00	U	2.20		1.00	U	2.20		0.50		2.40		1.00	U
Thorium-230	39.00		1.00	U	37.00		1.00	U	46.00		1.00	U	40.00		1.00	U
Thorium-232	2.10		1.00	U	2.40		1.00	U	2.10		1.00	U	2.20		1.00	U
Uranium, Total	360.00		770.00		360.00		1000.00		350.00		680.00		330.00		1300.00	
Uranium-234	190.00		320.00		150.00		425.00		150.00		220.00		140.00		550.00	
Uranium-235/236	6.80		9.00		7.00		12.00		5.80		3.50		7.00		13.00	
Uranium-238	200.00		340.00		150.00		460.00		160.00		230.00		160.00		590.00	
Aluminum	7940.00	-	2.40	J	10300.00	-	1.80	J	9510.00	-	0.16	UJ	9820.00	-	1.50	J
Antimony									3.10	UJ	0.02	U				
Arsenic	7.50	J	0.01	UJ	9.90	J	0.01	UJ	10.40	J	0.01	UJ	9.90	J	0.01	UJ
Barium	86.80	-	4.80	-	92.90	-	3.70	-	93.40	-	0.47	-	89.50	-	3.30	-
Beryllium	0.80	U	0.00	U	0.76	U	0.00	U	0.77	U	0.00	U	0.82	U	0.00	U
Boron	1.40	U	3.50	-	3.20	U	2.60	-	2.00	U	0.08	-	2.40	U	2.30	-
Cadmium	0.74	U	0.00	UJ	0.39	U	0.00	UJ	1.20	U	0.00	UJ	0.42	U	0.00	UJ
Calcium	5600.00	J	269.00	J	7450.00	J	249.00	J	8510.00	J	280.00	J	5080.00	J	370.00	J
Chromium	14.30	-	0.01	-	15.90	-	0.01	-	14.70	-	0.00	-	15.60	-	0.00	-
Cobalt	6.90	-	0.00	U	10.50	-	0.00	U	9.90	-	0.00	U	8.00	-	0.00	U
Copper	22.00	-	0.00	U	14.70	-	0.00	U	13.50	-	0.00	U	14.60	-	0.00	U
Cyanide	0.17	J	0.01	UJ	0.30	J	0.01	UJ	0.15	UJ	0.01	UJ	0.30	UJ	0.01	UJ

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

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Soil: / Sample Point: / Sample Id: / Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
Cesium-137	0.20	0.01	0.20	0.01
Gross Alpha	685.00	210.48	685.00	210.48
Gross Beta	262.50	26.30	262.50	26.30
Neptunium-237	1.98	0.60	1.98	0.60
Plutonium-238	0.30	0.24	0.30	0.24
Plutonium-239/240	0.07	0.04	0.07	0.04
Ruthenium-106	0.17	0.00	0.17	0.00
Strontium-90	5.00	0.00	5.00	0.00
Technetium-99	6.06	3.40	6.06	3.40
Thorium-228	1.70	0.86	1.70	0.86
Thorium-230	32.83	12.29	32.83	12.29
Thorium-232	1.68	0.81	1.68	0.81
Uranium, Total	350.00	14.14	350.00	14.14
Uranium-234	115.17	67.83	115.17	67.83
Uranium-235/236	6.65	0.57	6.65	0.57
Uranium-238	122.83	71.35	122.83	71.35
Aluminum	8036.67	2253.91	8036.67	2253.91
Antimony	5.27	1.89	5.27	1.89
Arsenic	8.80	1.44	8.80	1.44
Barium	88.45	9.13	88.45	9.13
Beryllium	0.91	0.39	0.91	0.39
Boron	2.25	0.75	2.25	0.75
Cadmium	0.55	0.37	0.55	0.37
Calcium	7736.67	2093.48	7736.67	2093.48
Chromium	13.75	2.21	13.75	2.21
Cobalt	10.00	2.68	10.00	2.68
Copper	14.58	3.97	14.58	3.97
Cyanide	0.23	0.08	0.23	0.08

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A INITIAL CHARACTERIZATION

Soil:	IDA				IDA				IDA				IDA			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100279				100280				100281				100282			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Iron	16000.00	-	0.18	J	16700.00	-	0.13	J	17600.00	-	0.07	UJ	18000.00	-	0.07	UJ
Lead	41.20	-	0.02	J	59.90	-	0.01	UJ	45.70	-	0.02	J	41.20	-	0.02	J
Magnesium	2540.00	-	38.80	-	3050.00	-	40.20	-	4330.00	-	43.20	-	2670.00	-	33.00	-
Manganese	516.00	-			621.00	-			748.00	-			551.00	-	0.55	J
Mercury	0.08	U	0.00	U	0.07	U	0.00	U	0.06	U	0.00	U	0.06	U	0.00	U
Molybdenum	1.80	U	0.00	U	1.60	U	0.00	U	1.60	U	0.00	U	1.30	U	0.00	U
Nickel	17.00	-	0.02	-	19.80	-	0.01	-	14.60	-	0.01	-	17.40	-	0.02	-
Potassium	586.00	-	4.70	-	759.00	-	3.90	-	705.00	-	0.97	-	729.00	-	3.40	-
Selenium	9.90	UJ	0.02	UJ	10.70	UJ	0.02	UJ	10.50	UJ	0.02	UJ	10.70	UJ	0.02	UJ
Silicon	724.00	-	3.40	J	1170.00	-	3.50	J	750.00	-	3.00	J	504.00	-	2.60	J
Silver	0.75	-	0.00	U	0.73	U	0.00	U	0.71	U	0.00	-	0.73	U	0.00	U
Sodium	51.10	U	1430.00	J	53.60	U	1370.00	J	62.30	U	1440.00	J	54.70	U	1580.00	J
Thallium	1.10	UJ	0.04	UJ	1.20	U	0.04	UJ	1.20	UJ	0.04	UJ	1.20	U	0.04	UJ
Vanadium	21.40	-	0.00	U	24.30	-	0.00	U	25.70	-	0.00	U	25.50	-	0.00	U
Zinc	77.70	U	3.60	J	69.40	U	2.90	J	68.40	U	0.14	UJ	66.90	U	2.70	J
1,1,1-Trichloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,1,2,2-Tetrachloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,1,2-Trichloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,1-Dichloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,1-Dichloroethene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,2-Dichloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,2-Dichloroethene (Total)	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,2-Dichloropropane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
2-Butanone	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
2-Hexanone	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
4-Methyl-2-pentanone	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Acetone	11.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ
Benzene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

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Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
Iron	17983.33	2319.84	17983.33	2319.84
Lead	45.48	7.59	45.48	7.59
Magnesium	2863.33	805.03	2863.33	805.03
Manganese	729.50	223.80	729.50	223.80
Mercury	0.07	0.01	0.07	0.01
Molybdenum	1.58	0.21	1.58	0.21
Nickel	18.48	2.79	18.48	2.79
Potassium	646.33	95.31	646.33	95.31
Selenium	7.09	5.22	7.09	5.22
Silicon	787.00	278.16	787.00	278.16
Silver	0.67	0.10	0.67	0.10
Sodium	333.35	664.76	333.35	664.76
Thallium	0.87	0.47	0.87	0.47
Vanadium	24.70	2.07	24.70	2.07
Zinc	64.45	11.92	64.45	11.92
1,1,1-Trichloroethane	11.75	0.50	11.75	0.50
1,1,2,2-Tetrachloroethane	11.75	0.50	11.75	0.50
1,1,2-Trichloroethane	11.75	0.50	11.75	0.50
1,1-Dichloroethane	11.75	0.50	11.75	0.50
1,1-Dichloroethene	11.75	0.50	11.75	0.50
1,2-Dichloroethane	11.75	0.50	11.75	0.50
1,2-Dichloroethene (Total)	11.75	0.50	11.75	0.50
1,2-Dichloropropane	11.75	0.50	11.75	0.50
2-Butanone	11.75	0.50	11.75	0.50
2-Hexanone	11.75	0.50	11.75	0.50
4-Methyl-2-pentanone	11.75	0.50	11.75	0.50
Acetone	11.75	0.50	11.75	0.50
Benzene	11.75	0.50	11.75	0.50

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A INITIAL CHARACTERIZATION

Soil:	IDA				IDA				IDA				IDA			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100279				100280				100281				100282			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Bromodichloromethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Bromoform	11.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ
Bromomethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Carbon Tetrachloride	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Carbon disulfide	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Chlorobenzene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Chloroethane	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Chloroform	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Chloromethane	11.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ	12.00	U	10.00	UJ
Dibromochloromethane					12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Ethylbenzene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Methylene chloride	11.00	U	19.00	UJ	12.00	U	28.00	UJ	12.00	U	18.00	UJ	12.00	U	24.00	UJ
Styrene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Tetrachloroethene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Toluene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Trichloroethene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Vinyl Acetate	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Vinyl chloride	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
Xylenes, Total	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
cis-1,3-Dichloropropene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
trans-1,3-Dichloropropene	11.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U	12.00	U	10.00	U
1,2,4-Trichlorobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
1,2-Dichlorobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
1,3-Dichlorobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
1,4-Dichlorobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
2,4,5-Trichlorophenol	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	U	1000.00	U		
2,4,6-Trichlorophenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
2,4-Dichlorophenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

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Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
Bromodichloromethane	11.75	0.50	11.75	0.50
Bromoform	11.75	0.50	11.75	0.50
Bromomethane	11.75	0.50	11.75	0.50
Carbon Tetrachloride	11.75	0.50	11.75	0.50
Carbon disulfide	11.75	0.50	11.75	0.50
Chlorobenzene	11.75	0.50	11.75	0.50
Chloroethane	11.75	0.50	11.75	0.50
Chloroform	11.75	0.50	11.75	0.50
Chloromethane	11.75	0.50	11.75	0.50
Dibromochloromethane	12.00	0.00	12.00	0.00
Ethylbenzene	11.75	0.50	11.75	0.50
Methylene chloride	11.75	0.50	11.75	0.50
Styrene	11.75	0.50	11.75	0.50
Tetrachloroethene	11.75	0.50	11.75	0.50
Toluene	11.75	0.50	11.75	0.50
Trichloroethene	11.75	0.50	11.75	0.50
Vinyl Acetate	11.75	0.50	11.75	0.50
Vinyl chloride	11.75	0.50	11.75	0.50
Xylenes, Total	11.75	0.50	11.75	0.50
cis-1,3-Dichloropropene	11.75	0.50	11.75	0.50
trans-1,3-Dichloropropene	11.75	0.50	11.75	0.50
1,2,4-Trichlorobenzene	400.00	14.14	400.00	14.14
1,2-Dichlorobenzene	400.00	14.14	400.00	14.14
1,3-Dichlorobenzene	400.00	14.14	400.00	14.14
1,4-Dichlorobenzene	400.00	14.14	400.00	14.14
2,4,5-Trichlorophenol	990.00	20.00	990.00	20.00
2,4,6-Trichlorophenol	400.00	14.14	400.00	14.14
2,4-Dichlorophenol	400.00	14.14	400.00	14.14

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Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
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Metals	mg/kg	mg/L

Soil:	IDA				IDA				IDA				IDA			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100279				100280				100281				100282			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
2,4-Dimethylphenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
2,4-Dinitrophenol	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	UJ	1000.00	U		
2,4-Dinitrotoluene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
2,6-Dinitrotoluene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
2-Chloronaphthalene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
2-Chlorophenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
2-Methylnaphthalene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
2-Methylphenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
2-Nitroaniline	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	U	1000.00	U	22.00	U
2-Nitrophenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
3,3'-Dichlorobenzidine	380.00	U	9.00	UJ	410.00	UJ	11.00	UJ	410.00	UJ	10.00	U	400.00	UJ	9.00	U
3-Nitroaniline	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	U	1000.00	U	22.00	U
4,6-Dinitro-2-methylphenol	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	UJ	1000.00	U		
4-Bromophenyl phenyl ether	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
4-Chloro-3-methylphenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
4-Chlorophenylphenyl ether	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
4-Methylphenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
4-Nitroaniline	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	U	1000.00	U	22.00	U
4-Nitrophenol	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	UJ	1000.00	U		
Acenaphthene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Acenaphthylene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Anthracene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzo(a)anthracene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzo(a)pyrene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzo(b)fluoranthene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzo(g,h,i)perylene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzo(k)fluoranthene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Benzoic acid	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	UJ	400.00	U		

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NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

1229

0002222

ID-A INITIAL CHARACTERIZATION

Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
2,4-Dimethylphenol	400.00	14.14	400.00	14.14
2,4-Dinitrophenol	990.00	20.00	990.00	20.00
2,4-Dinitrotoluene	400.00	14.14	400.00	14.14
2,6-Dinitrotoluene	400.00	14.14	400.00	14.14
2-Chloronaphthalene	400.00	14.14	400.00	14.14
2-Chlorophenol	400.00	14.14	400.00	14.14
2-Methylnaphthalene	400.00	14.14	400.00	14.14
2-Methylphenol	400.00	14.14	400.00	14.14
2-Nitroaniline	990.00	20.00	990.00	20.00
2-Nitrophenol	400.00	14.14	400.00	14.14
3,3'-Dichlorobenzidine	400.00	14.14	400.00	14.14
3-Nitroaniline	990.00	20.00	990.00	20.00
4,6-Dinitro-2-methylphenol	990.00	20.00	990.00	20.00
4-Bromophenyl phenyl ether	400.00	14.14	400.00	14.14
4-Chloro-3-methylphenol	400.00	14.14	400.00	14.14
4-Chlorophenylphenyl ether	400.00	14.14	400.00	14.14
4-Methylphenol	400.00	14.14	400.00	14.14
4-Nitroaniline	990.00	20.00	990.00	20.00
4-Nitrophenol	990.00	20.00	990.00	20.00
Acenaphthene	400.00	14.14	400.00	14.14
Acenaphthylene	400.00	14.14	400.00	14.14
Anthracene	400.00	14.14	400.00	14.14
Benzo(a)anthracene	400.00	14.14	400.00	14.14
Benzo(a)pyrene	400.00	14.14	400.00	14.14
Benzo(b)fluoranthene	400.00	14.14	400.00	14.14
Benzo(g,h,i)perylene	400.00	14.14	400.00	14.14
Benzo(k)fluoranthene	400.00	14.14	400.00	14.14
Benzoic acid	400.00	14.14	400.00	14.14

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E = ECR - Exceeds calibration range, diluted for lab analysis (for Organics).
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NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A INITIAL CHARACTERIZATION

Soil:	IDA				IDA				IDA				IDA			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100279				100280				100281				100282			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Butyl benzyl phthalate	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	UJ	400.00	U		
Carbazole	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Chrysene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Di-n-butyl phthalate	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Di-n-octyl phthalate	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	UJ	400.00	U		
Dibenzo(a,h)anthracene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Dibenzofuran	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Diethyl phthalate	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Dimethyl phthalate	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Fluoranthene	65.00	J	9.00	U	410.00	U	3.00	J	410.00	U	10.00	U	400.00	U	1.00	J
Fluorene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Hexachlorobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Hexachlorobutadiene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Hexachlorocyclopentadiene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Hexachloroethane	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Indeno(1,2,3-cd)pyrene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Isophorone	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
N-Nitroso-di-n-propylamine	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
N-Nitrosodiphenylamine	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Naphthalene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Nitrobenzene	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
Pentachlorophenol	960.00	U	23.00	U	1000.00	U	27.00	U	1000.00	U	26.00	U	1000.00	U		
Phenanthrene	380.00	U	9.00	U	410.00	U	4.00	J	410.00	U	10.00	U	400.00	U	9.00	U
Phenol	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U		
Pyrene	380.00	U	9.00	U	410.00	U	2.00	J	410.00	U	10.00	U	400.00	U	9.00	U
bis(2-Chloroethoxy)methane	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
bis(2-Chloroethyl)ether	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U
bis(2-Chloroisopropyl) ether	380.00	U	9.00	U	410.00	U	11.00	U	410.00	U	10.00	U	400.00	U	9.00	U

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E* = Estimated Duplicate Analysis (for Inorganics)
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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

000223

6221

Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
Butyl benzyl phthalate	400.00	14.14	400.00	14.14
Carbazole	400.00	14.14	400.00	14.14
Chrysene	400.00	14.14	400.00	14.14
Di-n-butyl phthalate	400.00	14.14	400.00	14.14
Di-n-octyl phthalate	400.00	14.14	400.00	14.14
Dibenzo(a,h)anthracene	400.00	14.14	400.00	14.14
Dibenzofuran	400.00	14.14	400.00	14.14
Diethyl phthalate	400.00	14.14	400.00	14.14
Dimethyl phthalate	400.00	14.14	400.00	14.14
Fluoranthene	321.25	170.90	321.25	170.90
Fluorene	400.00	14.14	400.00	14.14
Hexachlorobenzene	400.00	14.14	400.00	14.14
Hexachlorobutadiene	400.00	14.14	400.00	14.14
Hexachlorocyclopentadiene	400.00	14.14	400.00	14.14
Hexachloroethane	400.00	14.14	400.00	14.14
Indeno(1,2,3-cd)pyrene	400.00	14.14	400.00	14.14
Isophorone	400.00	14.14	400.00	14.14
N-Nitroso-di-n-propylamine	400.00	14.14	400.00	14.14
N-Nitrosodiphenylamine	400.00	14.14	400.00	14.14
Naphthalene	400.00	14.14	400.00	14.14
Nitrobenzene	400.00	14.14	400.00	14.14
Pentachlorophenol	990.00	20.00	990.00	20.00
Phenanthrene	400.00	14.14	400.00	14.14
Phenol	400.00	14.14	400.00	14.14
Pyrene	400.00	14.14	400.00	14.14
bis(2-Chloroethoxy)methane	400.00	14.14	400.00	14.14
bis(2-Chloroethyl)ether	400.00	14.14	400.00	14.14
bis(2-Chloroisopropyl) ether	400.00	14.14	400.00	14.14

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A INITIAL CHARACTERIZATION

Soil:	IDA		IDA		IDA		IDA	
Sample Point:	INITIAL CHARACTERIZATION 1		INITIAL CHARACTERIZATION 2		INITIAL CHARACTERIZATION 3		INITIAL CHARACTERIZATION 4	
Sample Id:	100279		100280		100281		100282	
	HSL	TCLP	HSL	TCLP	HSL	TCLP	HSL	TCLP
Analytes	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual
bis(2-Ethylhexyl)phthalate	380.00 U	1.00 UJ	410.00 UJ	11.00 UJ	410.00 UJ	10.00 UJ	400.00 UJ	
p-Chloroaniline	380.00 UJ	9.00 UJ	410.00 UJ	11.00 UJ	410.00 UJ	10.00 UJ	400.00 UJ	9.00 UJ
4,4'-DDDRE	3.70 UJ				4.10 UJ		4.00 UJ	
4,4'-DDERE	3.70 UJ				4.10 UJ		4.00 UJ	
4,4'-DDTRE	3.70 UJ				4.10 UJ		4.00 UJ	
AldrinRE	1.90 UJ				2.00 UJ		2.00 UJ	
Aroclor-1016	38.00 U	0.99 U						
Aroclor-1016RE					41.00 U		40.00 U	
Aroclor-1221	77.00 U	2.00 U						
Aroclor-1221RE					81.00 U		81.00 U	
Aroclor-1232	38.00 U	0.99 U						
Aroclor-1232RE					41.00 U		40.00 U	
Aroclor-1242	38.00 U	0.99 U						
Aroclor-1242RE					41.00 U		40.00 U	
Aroclor-1248	38.00 U	0.99 U						
Aroclor-1248RE					41.00 U		40.00 U	
Aroclor-1254	63.00 -	0.99 U						
Aroclor-1254RE					40.00 J		30.00 J	
Aroclor-1260	38.00 U	0.99 U						
Aroclor-1260RE					41.00 U		40.00 U	
DieldrinRE	3.70 UJ				4.10 UJ		4.00 UJ	
Endosulfan IIRE	3.70 UJ				4.10 UJ		4.00 UJ	
Endosulfan sulfateRE	3.70 UJ				4.10 UJ		4.00 UJ	
Endosulfan-IRE	1.90 UJ				2.00 UJ		2.00 UJ	
EndrinRE	3.70 UJ				4.10 UJ		4.00 UJ	
Endrin aldehydeRE	3.70 UJ				4.10 UJ		4.00 UJ	
Endrin ketoneRE	3.70 UJ				4.10 UJ		4.00 UJ	
HeptachlorRE	1.90 UJ				2.00 UJ		2.00 UJ	

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

000225

6221

Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
bis(2-Ethylhexyl)phthalate	400.00	14.14	400.00	14.14
p-Chloroaniline	400.00	14.14	400.00	14.14
4,4'-DDDRE	3.93	0.21	3.93	0.21
4,4'-DDERE	3.93	0.21	3.93	0.21
4,4'-DDTRE	3.93	0.21	3.93	0.21
AldrinRE	1.97	0.06	1.97	0.06
Aroclor-1016	38.00	0.00	38.00	0.00
Aroclor-1016RE	40.50	0.71	40.50	0.71
Aroclor-1221	77.00	0.00	77.00	0.00
Aroclor-1221RE	81.00	0.00	81.00	0.00
Aroclor-1232	38.00	0.00	38.00	0.00
Aroclor-1232RE	40.50	0.71	40.50	0.71
Aroclor-1242	38.00	0.00	38.00	0.00
Aroclor-1242RE	40.50	0.71	40.50	0.71
Aroclor-1248	38.00	0.00	38.00	0.00
Aroclor-1248RE	40.50	0.71	40.50	0.71
Aroclor-1254	63.00	0.00	63.00	0.00
Aroclor-1254RE	35.00	7.07	35.00	7.07
Aroclor-1260	38.00	0.00	38.00	0.00
Aroclor-1260RE	40.50	0.71	40.50	0.71
DieldrinRE	3.93	0.21	3.93	0.21
Endosulfan IIRE	3.93	0.21	3.93	0.21
Endosulfan sulfateRE	3.93	0.21	3.93	0.21
Endosulfan-IRE	1.97	0.06	1.97	0.06
EndrinRE	3.93	0.21	3.93	0.21
Endrin aldehydeRE	3.93	0.21	3.93	0.21
Endrin ketoneRE	3.93	0.21	3.93	0.21
HeptachlorRE	1.97	0.06	1.97	0.06

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A INITIAL CHARACTERIZATION

Soil:	IDA INITIAL CHARACTERIZATION 1				IDA INITIAL CHARACTERIZATION 2				IDA INITIAL CHARACTERIZATION 3				IDA INITIAL CHARACTERIZATION 4			
Sample Point:																
Sample Id:	100279				100280				100281				100282			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Heptachlor epoxideRE	1.90	UJ														
MethoxychlorRE	19.00	UJ							2.00	UJ			2.00	UJ		
Toxaphene	190.00	U	4.90	U					20.00	UJ			20.00	UJ		
ToxapheneRE													200.00	U	5.30	UJ
alpha-BHCRE	1.90	UJ							200.00	U						
alpha-ChlordaneRE	1.90	UJ							2.00	UJ			2.00	UJ		
beta-BHCRE	1.90	UJ							2.00	UJ			2.00	UJ		
delta-BHCRE	1.90	UJ							2.00	UJ			2.00	UJ		
gamma-BHC (Lindane)RE	1.90	UJ							2.00	UJ			2.00	UJ		
gamma-ChlordaneRE	1.90	UJ							2.00	UJ			2.00	UJ		
									2.00	UJ			2.00	UJ		

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E = Estimated Value (for Inorganics)
E = ECR - Exceeds calibration range, diluted for lab analysis (for Organics).
Null = No Qualifiers
E* = Estimated Duplicate Analysis (for Inorganics)
NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

00027300

6721

Soil:
Sample Point:
Sample Id:

Analytes	IDA Summary, HSL Average	IDA Summary, HSL Std Dev	IDA Summary, TCLP Average	IDA Summary, TCLP Std Dev
Heptachlor epoxideRE	1.97	0.06	1.97	0.06
MethoxychlorRE	19.67	0.58	19.67	0.58
Toxaphene	195.00	7.07	195.00	7.07
ToxapheneRE	200.00	0.00	200.00	0.00
alpha-BHCRE	1.97	0.06	1.97	0.06
alpha-ChlordaneRE	1.97	0.06	1.97	0.06
beta-BHCRE	1.97	0.06	1.97	0.06
delta-BHCRE	1.97	0.06	1.97	0.06
gamma-BHC (Lindane)RE	1.97	0.06	1.97	0.06
gamma-ChlordaneRE	1.97	0.06	1.97	0.06

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-8 Initial Characterization

Soil:	IDB				IDB				IDB				IDB			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100272				100274				100275				100276			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Gross Alpha	68.00		6000.00		60.00		5300.00		60.00		5300.00		60.00		5300.00	
Gross Beta	46.00		3300.00		50.00		2900.00		50.00		2900.00		50.00		2900.00	
Neptunium-237	1.40		31.00		1.80		33.00		1.80		33.00		1.80		33.00	
Plutonium-238	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U
Plutonium-239/240	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U	1.00	U
Radium-226	2.80		1.00	U	2.40		1.00	U	2.40		1.00	U	2.40		1.00	U
Radium-228	3.60		4.90		3.60		3.70		3.60		3.70		3.60		3.70	
Strontium-90	6.00		5.00	U	5.00	U	5.00	U	5.00	U	5.00	U	5.00	U	5.00	U
Technetium-99	11.00		41.00		17.00		30.00		17.00		30.00		17.00		30.00	
Thorium-228	1.20		1.00	U	1.40		1.00	U	1.40		1.00	U	1.40		1.00	U
Thorium-230	2.20		1.00	U	2.20		1.00	U	2.20		1.00	U	2.20		1.00	U
Thorium-232	1.20		1.00	U	1.00		1.00	U	1.00		1.00	U	1.00		1.00	U
Uranium, Total	360.00		9600.00		370.00		9500.00		370.00		9500.00		370.00		9500.00	
Uranium-234	170.00		3800.00		160.00		3300.00		160.00		3300.00		160.00		3300.00	
Uranium-235/236	7.60		330.00		7.70		180.00		7.70		180.00		7.70		180.00	
Uranium-238	180.00		4200.00		180.00		3700.00		180.00		3700.00		180.00		3700.00	
Aluminum	13500.00	J	0.48	-	13100.00	J	0.35	-	19600.00	J	0.54	-	18500.00	J	0.49	-
Arsenic	6.90	U	0.01	U	6.80	U	0.01	U	6.90	U	0.01	U	6.90	U	0.01	U
Barium	108.00	-	2.10	-	100.00	-	1.40	-	124.00	-	2.00	-	112.00	-	2.00	-
Beryllium	0.85	-	0.00	U	0.80	-	0.00	U	1.10	-	0.00	U	0.96	-	0.00	U
Cadmium	0.23	U	0.00	UJ	0.23	U	0.00	UJ	0.23	U	0.00	UJ	0.23	U	0.00	UJ
Calcium	50800.00	J	652.00	J	58200.00	J	576.00	J	56500.00	J	560.00	J	53800.00	J	559.00	J
Chromium	17.70	J	0.00	U	16.90	J	0.00	U	23.50	J	0.00	U	21.80	J	0.00	U
Cobalt	10.30	-	0.00	U	9.90	-	0.00	U	12.00	-	0.00	U	10.20	-	0.00	U
Copper	29.10	J	0.00	U	28.80	J	0.00	U	33.60	J	0.00	U	28.90	J	0.00	U
Cyanide	0.14	U			1.40	-			1.30	-			0.31	-		
Iron	22600.00	J	0.03	U	22400.00	J	0.04	U	26600.00	J	0.09	U	23000.00	J	0.05	U
Magnesium	16100.00	J	19.40	J	15800.00	J	18.80	J	16900.00	J	18.50	J	16400.00	J	18.40	J
Manganese	574.00	J	1.20	J	576.00	J	1.00	J	615.00	J	1.00	J	522.00	J	1.00	J
Mercury	0.03	-	0.00	U	0.02	-	0.00	U	0.04	-	0.00	U	0.04	-	0.00	U
Nickel	22.60	-	0.01	-	21.30	-	0.01	-	23.80	-	0.01	-	22.00	-	0.01	-
Potassium	1600.00	-	3.90	-	1420.00	-	3.40	-	2990.00	-	3.90	-	3010.00	-	3.90	-
Selenium	0.69	UJ	0.06	U	0.68	UJ	0.06	U	0.69	UJ	0.06	U	0.69	UJ	0.06	U

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NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

1229

00229

Soil:
Sample Point:
Sample Id:

Analytes	IDB Summary, HSL Average	IDB Summary, HSL Std Dev	IDB Summary, TCLP Average	IDB Summary, TCLP Std Dev
Gross Alpha	62.00	4.00	62.00	4.00
Gross Beta	49.00	2.00	49.00	2.00
Neptunium-237	1.70	0.20	1.70	0.20
Plutonium-238	0.67	0.51	0.67	0.51
Plutonium-239/240	0.81	0.43	0.81	0.43
Radium-226	2.07	0.98	2.07	0.98
Radium-228	2.59	1.56	2.59	1.56
Strontium-90	5.25	0.50	5.25	0.50
Technetium-99	11.13	7.18	11.13	7.18
Thorium-228	1.05	0.49	1.05	0.49
Thorium-230	1.69	0.80	1.69	0.80
Thorium-232	0.84	0.36	0.84	0.36
Uranium, Total	367.50	5.00	367.50	5.00
Uranium-234	112.20	78.04	112.20	78.04
Uranium-235/236	7.68	0.05	7.68	0.05
Uranium-238	124.17	86.51	124.17	86.51
Aluminum	13948.33	4364.95	13948.33	4364.95
Arsenic	6.35	0.85	6.35	0.85
Barium	107.77	14.02	107.77	14.02
Beryllium	0.82	0.20	0.82	0.20
Cadmium	1.01	1.90	1.01	1.90
Calcium	60433.33	10945.44	60433.33	10945.44
Chromium	17.95	4.09	17.95	4.09
Cobalt	10.07	2.70	10.07	2.70
Copper	28.38	4.90	28.38	4.90
Cyanide	0.79	0.65	0.79	0.65
Iron	22316.67	2754.21	22316.67	2754.21
Magnesium	41100.00	63682.53	41100.00	63682.53
Manganese	565.17	134.60	565.17	134.60
Mercury	0.04	0.01	0.04	0.01
Nickel	21.75	3.72	21.75	3.72
Potassium	1923.33	843.41	1923.33	843.41
Selenium	0.53	0.24	0.53	0.24

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil:	IDB				IDB				IDB				IDB			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100272				100274				100275				100276			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Silver	1.10	U	0.02	J	1.10	U	0.01	UJ	1.10	U	0.01	UJ	1.20	U	0.01	UJ
Sodium	142.00	J			149.00	J			181.00	J			169.00	J		
Thallium	0.46	U	0.04	U	0.45	U	0.04	U	0.46	U	0.04	U	0.46	U	0.04	U
Vanadium	25.90	J	0.00	U	23.90	J	0.00	U	37.40	J	0.00	U	34.30	J	0.00	U
Zinc	71.30	J	1.10	J	67.90	J	0.60	J	82.80	J	1.20	J	75.40	J	1.10	J
1,1,1-Trichloroethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,1,2,2-Tetrachloroethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,1,2-Trichloroethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,1-Dichloroethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,1-Dichloroethene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,2-Dichloroethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,2-Dichloroethene (Total)	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,2-Dichloropropane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Acetone	17.00	UJ	10.00	U	11.00	UJ	10.00	U	11.00	UJ	10.00	U	12.00	UJ	36.00	U
Benzene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Bromodichloromethane	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Bromoform	6.00	U	5.00	UJ	6.00	U	5.00	UJ	6.00	U	5.00	UJ	6.00	U	5.00	UJ
Bromomethane	11.00	U	10.00	U	11.00	U	10.00	U	11.00	U	10.00	U	12.00	U	10.00	U
Carbon Tetrachloride	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Carbon disulfide	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Chlorobenzene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Chloroethane	11.00	U	10.00	UJ	11.00	U	10.00	UJ	11.00	U	10.00	UJ	12.00	U	10.00	UJ
Chloroform	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Chloromethane	11.00	U	10.00	U	11.00	U	10.00	U	11.00	U	10.00	U	12.00	U	10.00	U
Dibromochloromethane	6.00	U	5.00	U	5.00	U	6.00	U	5.00	U	6.00	U	6.00	U	5.00	U
Ethylbenzene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Methylene chloride	6.00	U	11.00	U	6.00	U	13.00	U	6.00	U	16.00	U	6.00	U	14.00	U
Styrene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Tetrachloroethene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Toluene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Trichloroethene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
Vinyl Acetate	11.00	U	10.00	UJ	11.00	U	10.00	UJ	11.00	U	10.00	UJ	12.00	U	10.00	UJ
Vinyl chloride	11.00	U	10.00	U	11.00	U	10.00	U	11.00	U	10.00	U	12.00	U	10.00	U

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Print Date: 14-JUL-94

T229

Soil:
Sample Point:
Sample Id:

Analytes	IDB Summary, HSL Average	IDB Summary, HSL Std Dev	IDB Summary, TCLP Average	IDB Summary, TCLP Std Dev
Silver	0.94	0.29	0.94	0.29
Sodium	747.83	1471.05	747.83	1471.05
Thallium	0.39	0.10	0.39	0.10
Vanadium	29.08	5.56	29.08	5.56
Zinc	67.98	13.83	67.98	13.83
1,1,1-Trichloroethane	6.00	0.00	6.00	0.00
1,1,2,2-Tetrachloroethane	6.00	0.00	6.00	0.00
1,1,2-Trichloroethane	6.00	0.00	6.00	0.00
1,1-Dichloroethane	6.00	0.00	6.00	0.00
1,1-Dichloroethene	6.00	0.00	6.00	0.00
1,2-Dichloroethane	6.00	0.00	6.00	0.00
1,2-Dichloroethene (Total)	6.00	0.00	6.00	0.00
1,2-Dichloropropane	6.00	0.00	6.00	0.00
Acetone	12.75	2.87	12.75	2.87
Benzene	6.00	0.00	6.00	0.00
Bromodichloromethane	6.00	0.00	6.00	0.00
Bromoform	6.00	0.00	6.00	0.00
Bromomethane	11.25	0.50	11.25	0.50
Carbon Tetrachloride	6.00	0.00	6.00	0.00
Carbon disulfide	6.00	0.00	6.00	0.00
Chlorobenzene	6.00	0.00	6.00	0.00
Chloroethane	11.25	0.50	11.25	0.50
Chloroform	6.00	0.00	6.00	0.00
Chloromethane	11.25	0.50	11.25	0.50
Dibromochloromethane	5.50	0.58	5.50	0.58
Ethylbenzene	6.00	0.00	6.00	0.00
Methylene chloride	6.00	0.00	6.00	0.00
Styrene	6.00	0.00	6.00	0.00
Tetrachloroethene	6.00	0.00	6.00	0.00
Toluene	6.00	0.00	6.00	0.00
Trichloroethene	6.00	0.00	6.00	0.00
Vinyl Acetate	11.25	0.50	11.25	0.50
Vinyl chloride	11.25	0.50	11.25	0.50

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil:	IDB				IDB				IDB				IDB			
Sample Point:	INITIAL CHARACTERIZATION 1				INITIAL CHARACTERIZATION 2				INITIAL CHARACTERIZATION 3				INITIAL CHARACTERIZATION 4			
Sample Id:	100272				100274				100275				100276			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Xylenes, Total	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
cis-1,3-Dichloropropene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
trans-1,3-Dichloropropene	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U	6.00	U	5.00	U
1,2,4-Trichlorobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
1,2-Dichlorobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
1,3-Dichlorobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
1,4-Dichlorobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2,4,5-Trichlorophenol					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
2,4,6-Trichlorophenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2,4-Dichlorophenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2,4-Dimethylphenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2,4-Dinitrophenol					1800.00	UJ	43.00	UJ	1800.00	UJ	51.00	UJ	1800.00	UJ	43.00	UJ
2,4-Dinitrotoluene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2,6-Dinitrotoluene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2-Chloronaphthalene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2-Chlorophenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2-Methylnaphthalene					370.00	UJ	9.00	UJ	370.00	UJ	10.00	UJ	370.00	UJ	9.00	UJ
2-Methylphenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
2-Nitroaniline					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
2-Nitrophenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
3,3'-Dichlorobenzidine									730.00	U	21.00	U	740.00	U	18.00	U
3-Nitroaniline					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
4,6-Dinitro-2-methylphenol					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
4-Bromophenyl phenyl ether					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
4-Chloro-3-methylphenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
4-Chlorophenylphenyl ether					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
4-Methylphenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
4-Nitroaniline					1800.00	U	43.00	U	1800.00	UJ	51.00	UJ	1800.00	U	43.00	UJ
4-Nitrophenol					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
Acenaphthene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Acenaphthylene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Anthracene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Benzo(a)anthracene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U

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E = ECR - Exceeds calibration range, diluted for lab analysis (for Organics).
Null = No Qualifiers
E* = Estimated Duplicate Analysis (for Inorganics)
NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium, Total	mg/kg	ug/L
Volatiles, Semi Volatiles, Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

00033

6271

Soil:
Sample Point:
Sample Id:

Analytes	IDB Summary, HSL Average	IDB Summary, HSL Std Dev	IDB Summary, TCLP Average	IDB Summary, TCLP Std Dev
Xylenes, Total	6.00	0.00	6.00	0.00
cis-1,3-Dichloropropene	6.00	0.00	6.00	0.00
trans-1,3-Dichloropropene	6.00	0.00	6.00	0.00
1,2,4-Trichlorobenzene	370.00	0.00	370.00	0.00
1,2-Dichlorobenzene	370.00	0.00	370.00	0.00
1,3-Dichlorobenzene	370.00	0.00	370.00	0.00
1,4-Dichlorobenzene	370.00	0.00	370.00	0.00
2,4,5-Trichlorophenol	1800.00	0.00	1800.00	0.00
2,4,6-Trichlorophenol	370.00	0.00	370.00	0.00
2,4-Dichlorophenol	370.00	0.00	370.00	0.00
2,4-Dimethylphenol	370.00	0.00	370.00	0.00
2,4-Dinitrophenol	1800.00	0.00	1800.00	0.00
2,4-Dinitrotoluene	370.00	0.00	370.00	0.00
2,6-Dinitrotoluene	370.00	0.00	370.00	0.00
2-Chloronaphthalene	370.00	0.00	370.00	0.00
2-Chlorophenol	370.00	0.00	370.00	0.00
2-Methylnaphthalene	370.00	0.00	370.00	0.00
2-Methylphenol	370.00	0.00	370.00	0.00
2-Nitroaniline	1800.00	0.00	1800.00	0.00
2-Nitrophenol	370.00	0.00	370.00	0.00
3,3'-Dichlorobenzidine	735.00	7.07	735.00	7.07
3-Nitroaniline	1800.00	0.00	1800.00	0.00
4,6-Dinitro-2-methylphenol	1800.00	0.00	1800.00	0.00
4-Bromophenyl phenyl ether	370.00	0.00	370.00	0.00
4-Chloro-3-methylphenol	370.00	0.00	370.00	0.00
4-Chlorophenylphenyl ether	370.00	0.00	370.00	0.00
4-Methylphenol	370.00	0.00	370.00	0.00
4-Nitroaniline	1800.00	0.00	1800.00	0.00
4-Nitrophenol	1800.00	0.00	1800.00	0.00
Acenaphthene	370.00	0.00	370.00	0.00
Acenaphthylene	370.00	0.00	370.00	0.00
Anthracene	370.00	0.00	370.00	0.00
Benzo(a)anthracene	370.00	0.00	370.00	0.00

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil: / Sample Point: / Sample Id:	IDB INITIAL CHARACTERIZATION 1 100272				IDB INITIAL CHARACTERIZATION 2 100274				IDB INITIAL CHARACTERIZATION 3 100275				IDB INITIAL CHARACTERIZATION 4 100276			
	HSL		TCLP		HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Benzo(a)pyrene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Benzo(b)fluoranthene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Benzo(g,h,i)perylene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Benzo(k)fluoranthene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Benzoic acid					1800.00	U	43.00	UJ	1800.00	U	51.00	U	1800.00	U	43.00	U
Benzyl alcohol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Butyl benzyl phthalate					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Carbazole					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Chrysene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Di-n-butyl phthalate					100.00	J	9.00	U	37.00	J	10.00	U	370.00	U	9.00	U
Di-n-octyl phthalate					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Dibenzo(a,h)anthracene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Dibenzofuran					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Diethyl phthalate					370.00	U	9.00	U	370.00	U	78.00	-	140.00	J	9.00	U
Dimethyl phthalate					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Fluoranthene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Fluorene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Hexachlorobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Hexachlorobutadiene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Hexachlorocyclopentadiene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Hexachloroethane					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Indeno(1,2,3-cd)pyrene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Isophorone					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
N-Nitroso-di-n-propylamine					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
N-Nitrosodiphenylamine					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Naphthalene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Nitrobenzene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Pentachlorophenol					1800.00	U	43.00	U	1800.00	U	51.00	U	1800.00	U	43.00	U
Phenanthrene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Phenol					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
Pyrene					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
bis(2-Chloroethoxy)methane					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
bis(2-Chloroethyl)ether					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U

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E = ECR - Exceeds calibration range, diluted for lab analysis (for Organics).
Null = No Qualifiers
E* = Estimated Duplicate Analysis (for Inorganics)
NV = Data will not be validated

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

00035

1229

Soil:
Sample Point:
Sample Id:

Analytes	IDB Summary, HSL Average	IDB Summary, HSL Std Dev	IDB Summary, TCLP Average	IDB Summary, TCLP Std Dev
Benzo(a)pyrene	370.00	0.00	370.00	0.00
Benzo(b)fluoranthene	370.00	0.00	370.00	0.00
Benzo(g,h,i)perylene	370.00	0.00	370.00	0.00
Benzo(k)fluoranthene	370.00	0.00	370.00	0.00
Benzoic acid	1800.00	0.00	1800.00	0.00
Benzyl alcohol	370.00	0.00	370.00	0.00
Butyl benzyl phthalate	370.00	0.00	370.00	0.00
Carbazole	370.00	0.00	370.00	0.00
Chrysene	370.00	0.00	370.00	0.00
Di-n-butyl phthalate	169.00	176.90	169.00	176.90
Di-n-octyl phthalate	370.00	0.00	370.00	0.00
Dibenzo(a,h)anthracene	370.00	0.00	370.00	0.00
Dibenzofuran	370.00	0.00	370.00	0.00
Diethyl phthalate	293.33	132.79	293.33	132.79
Dimethyl phthalate	370.00	0.00	370.00	0.00
Fluoranthene	370.00	0.00	370.00	0.00
Fluorene	370.00	0.00	370.00	0.00
Hexachlorobenzene	370.00	0.00	370.00	0.00
Hexachlorobutadiene	370.00	0.00	370.00	0.00
Hexachlorocyclopentadiene	370.00	0.00	370.00	0.00
Hexachloroethane	370.00	0.00	370.00	0.00
Indeno(1,2,3-cd)pyrene	370.00	0.00	370.00	0.00
Isophorone	370.00	0.00	370.00	0.00
N-Nitroso-di-n-propylamine	370.00	0.00	370.00	0.00
N-Nitrosodiphenylamine	370.00	0.00	370.00	0.00
Naphthalene	370.00	0.00	370.00	0.00
Nitrobenzene	370.00	0.00	370.00	0.00
Pentachlorophenol	1800.00	0.00	1800.00	0.00
Phenanthrene	370.00	0.00	370.00	0.00
Phenol	370.00	0.00	370.00	0.00
Pyrene	370.00	0.00	370.00	0.00
bis(2-Chloroethoxy)methane	370.00	0.00	370.00	0.00
bis(2-Chloroethyl)ether	370.00	0.00	370.00	0.00

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil:	IDB INITIAL CHARACTERIZATION 1				IDB INITIAL CHARACTERIZATION 2				IDB INITIAL CHARACTERIZATION 3				IDB INITIAL CHARACTERIZATION 4			
Sample Point:																
Sample Id:	100272				100274				100275				100276			
Analytes	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual	HSL Result	HSL Qual	TCLP Result	TCLP Qual
bis(2-Chloroisopropyl) ether					370.00	U	9.00	U	370.00	UJ	10.00	UJ	370.00	U	9.00	UJ
bis(2-Ethylhexyl)phthalate					370.00	U	9.00	U	370.00	U	10.00	U	38.00	J	9.00	U
p-Chloroaniline					370.00	U	9.00	U	370.00	U	10.00	U	370.00	U	9.00	U
4,4'-DDD					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
4,4'-DDE					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
4,4'-DDT					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Aldrin					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
Aroclor-1016					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Aroclor-1221					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Aroclor-1232					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Aroclor-1242					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Aroclor-1248					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Aroclor-1254					180.00	U	1.00	U	180.00	U	1.00	U	180.00	U	1.00	U
Aroclor-1260					180.00	U	1.00	U	180.00	U	1.00	U	180.00	U	1.00	U
Dieldrin					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Endosulfan II					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Endosulfan sulfate					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Endosulfan-I					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
Endrin					18.00	U	0.10	U	18.00	UJ	0.10	U	18.00	UJ	0.10	U
Endrin aldehyde					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Endrin ketone					18.00	U	0.10	U	18.00	U	0.10	U	18.00	U	0.10	U
Heptachlor					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
Heptachlor epoxide					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
Methoxychlor					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Toxaphene					180.00	U	1.00	U	180.00	U	1.00	U	180.00	U	1.00	U
alpha-BHC					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
alpha-Chlordane					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
beta-BHC					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
delta-BHC					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
gamma-BHC (Lindane)					8.90	U	0.05	U	9.10	U	0.05	U	9.10	U	0.05	U
gamma-Chlordane					89.00	U	0.49	U	91.00	U	0.49	U	91.00	U	0.49	U
Total Organic Carbon	9640.00	-			10600.00	-			6550.00	-			9990.00	J		

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Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles,Semi Volatiles,Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

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FEMP-05FS-4 DRAFT
November 14, 1994

ATTACHMENT III
FINAL CHARACTERIZATION DATA FOR ID-A ND ID-B SOILS PROCESSED THROUGH THE SOIL WASHING PILOT PLANT: SUMMARY REPORT

ID-A RUN 3

Soil: Sample Point	ID-A Run 3 INITIAL CHARACTERIZATION		ID-A Run 3 C .02-.475mm		ID-A Run 3 D <.02mm		ID-A Run 3 E Filter Cake		ID-A Run 3 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Cesium-137	0.21	20.00	0.08	13.20	0.42	18.50	0.29	15.70	0.32	18.10
Gross Alpha	570.00	270.00	49.90	44.80	46.20	430.00	577.00	496.00	121.00	69.70
Gross Beta	250.00	120.00	51.60	16.20	153.00	192.00	688.00	261.00	194.00	49.40
Neptunium-237	2.30	1.40	0.74	0.32	0.21	0.76	1.10	0.79	0.21	0.48
Plutonium-238	0.34	1.00	0.11	0.17	0.17	0.14	0.90	0.14	0.22	0.27
Plutonium-239/240	0.11	1.00	0.13	0.04	0.20	0.08	0.37	0.07	0.19	0.10
Radium-226			1.30	1.40	3.40	0.42	2.40	0.54	2.40	1.20
Radium-228			1.80	1.70	3.30	2.00	2.90	2.90	2.60	2.70
Strontium-90			1.50	0.64	0.55	1.10	0.59	1.20		
Technetium-99	9.00	30.00			1.20	28.80	1.40	51.00	1.40	26.90
Thorium, Total			10.60	1.10	21.70	1.60	41.60	1.20	21.80	3.30
Thorium-228	2.20	1.00	1.10	0.26	2.60	0.32	4.60	0.28	2.70	0.38
Thorium-230	39.00	1.00	8.90	0.86	42.50	2.60	143.00	1.40	63.90	2.60
Thorium-232	2.10	1.00	1.20	0.12	2.40	0.17	4.60	0.13	2.40	0.36
Uranium, Total	360.00	770.00	79.40	363.00	302.00	676.00	2098.00	762.00	365.00	86.60
Uranium-234	190.00	320.00	18.40	40.00	55.00	40.80	688.00	277.00	80.00	54.30
Uranium-235/236	6.80	9.00	0.99	1.90	3.30	2.20	86.40	13.40	4.20	2.30
Uranium-238	200.00	340.00	18.90	45.00	58.90	41.90	699.00	286.00	85.00	58.40
Aluminum	7940.00	2.40	2430.00	1.30	21000.00	13.10	34500.00	0.53	17600.00	0.75
Arsenic	7.50	0.01					16.40	0.00	6.10	0.00
Barium	86.80	4.80	40.60	0.12	176.00	0.12	221.00	0.06	165.00	0.42
Beryllium							3.00	0.00		
Calcium	5600.00	269.00	575.00	26.40	2170.00	29.10	36700.00	288.00	9740.00	142.00
Chromium	14.30	0.01	6.90	0.01	32.00	0.08	206.00	0.01	26.40	0.01
Cobalt	6.90	0.00			5.30	0.06	57.20	0.01	14.30	0.07
Copper	22.00	0.00	3.50	0.01	22.60	0.02	78.70	0.01	28.50	0.01
Cyanide	0.17	0.01					0.61			
Iron	16000.00	0.18	4650.00	16.40	30000.00	104.00	105000.00	0.03	27300.00	0.27
Lead	41.20	0.02	14.40	0.08	53.20	0.02	138.00	0.00	57.60	0.01
Magnesium	2540.00	38.80	605.00	6.50	3440.00	26.00	28100.00	180.00	5040.00	29.40
Manganese	516.00		49.20	1.20	255.00	3.20	4720.00	2.30	1070.00	10.70
Nickel	17.00	0.02	12.60	0.25	42.30	0.44	430.00	0.03	57.80	0.21
Potassium	586.00	4.70	359.00	2.90	1680.00	5.90	1960.00	3.10	1240.00	4.90
Silicon	724.00	3.40	435.00	3.50	1300.00	7.10	3480.00	2.80	645.00	10.40
Silver	0.75	0.00			9.70	0.03	30.90	0.01	8.00	0.01

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

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T229

ID-A RUN 3

Soil: Sample Point	ID-A Run 3 INITIAL CHARACTERIZATION		ID-A Run 3 C .02-.475mm		ID-A Run 3 D <.02mm		ID-A Run 3 E Filter Cake		ID-A Run 3 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Sodium			335.00		1080.00		53300.00		8700.00	
Vanadium	21.40	0.00	7.70	0.01	53.60	0.03	141.00	0.01	43.00	0.01
Zinc			22.30	0.15	100.00	0.68	427.00	0.01	150.00	0.25
Fluoranthene	65.00	9.00								
Aroclor-1254	63.00	0.99								
Aroclor-1260							130.00	1.00	100.00	1.00
Total Organic Carbon			13867.00		6494.00		24399.00		22991.00	

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-A RUN 4 PILOT PLANT

Soil: Sample Point	ID-A Run 4 INITIAL CHARACTERIZATION		ID-A Run 4 C .02-.475mm		ID-A Run 4 D <.02mm		ID-A Run 4 E Filter Cake		ID-A Run 4 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Cesium-137	0.19	20.00			0.36	13.50	0.09	12.20	0.56	17.70
Gross Alpha	480.00	360.00	53.50	43.30	73.90	583.00	1350.00	1420.00	155.00	53.20
Gross Beta	240.00	130.00	54.70	29.60	110.00	133.00	1630.00	573.00	309.00	34.60
Neptunium-237	1.10	1.70	0.22	0.32	0.31	0.79	0.34	0.95	0.15	0.42
Plutonium-238	0.53	1.00	0.26	0.07	0.14	0.10	0.94	0.14	0.26	0.07
Plutonium-239/240	0.09	1.00	0.12	0.10	0.22	0.09	0.50	0.06	0.28	0.14
Radium-226			1.60	1.70	3.10	0.78	1.60	1.00	3.80	1.50
Radium-228			1.90	1.90	3.00	1.80	1.40	2.00	3.60	2.40
Strontium-90							0.67	1.20	0.78	2.70
Technetium-99	8.60	30.00	0.60	27.60	1.00	34.40	2.20	25.60	1.20	24.50
Thorium, Total			16.20	1.50	15.60	1.90	95.70	1.80	50.00	2.00
Thorium-228	2.20	1.00	1.40	0.26	2.00	0.26	8.40	0.37	5.00	0.38
Thorium-230	37.00	1.00	10.70	0.61	27.40	1.20	321.00	1.40	143.00	1.50
Thorium-232	2.40	1.00	1.80	0.16	1.70	0.21	10.50	0.20	5.50	0.22
Uranium, Total	360.00	1000.00	66.00	45.50	247.00	540.00	3859.00	1907.00	659.00	45.30
Uranium-234	150.00	425.00	20.40	20.70	45.60	197.00	1206.00	989.00	85.90	23.20
Uranium-235/236	7.00	12.00	1.10	1.20	2.00	10.80	85.00	54.70	4.50	1.60
Uranium-238	150.00	460.00	210.00	21.00	47.70	212.00	1184.00	1080.00	90.50	26.90
Aluminum	10300.00	1.80	3580.00	0.41	17500.00	1.40	29200.00	0.99	28500.00	0.50
Arsenic	9.90	0.01							10.40	0.00
Barium	92.90	3.70	50.60	0.22	147.00	0.06	99.70	0.11	231.00	0.37
Beryllium							3.80	0.00		
Cadmium							114.00	0.40		
Calcium	7450.00	249.00	496.00	8.90	1850.00	23.50	14100.00	117.00	10700.00	120.00
Chromium	15.90	0.01	17.10	0.01	25.20	0.01	126.00	0.01	38.90	0.01
Cobalt	10.50	0.00			5.20	0.03	73.00	0.25	21.10	0.05
Copper	14.70	0.00	5.10	0.01	18.40	0.01	105.00	0.01	44.10	0.01
Cyanide	0.30	0.01					1.50		0.25	
Iron	16700.00	0.13	6390.00	4.00	23100.00	23.30	142000.00	5.30	40300.00	0.11
Lead	59.90	0.01	20.90	0.04	42.80	0.01	112.00	0.00	99.40	0.01
Magnesium	3050.00	40.20	763.00	2.70	3130.00	12.60	27400.00	184.00	6680.00	28.30
Manganese	621.00		68.20	0.91	254.00	2.10	6830.00	47.50	1480.00	8.30
Nickel	19.80	0.01	22.10	0.14	38.30	0.20	523.00	1.40	80.00	0.17
Potassium	759.00	3.90	455.00	2.20	1420.00	2.60	594.00	1.90	1860.00	4.80
Silicon	1170.00	3.50	557.00	4.90	1240.00	8.10	3170.00	19.00	821.00	11.00

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

12229

ID-A RUN 4 PILOT PLANT

Soil: Sample Point	ID-A Run 4 INITIAL CHARACTERIZATION		ID-A Run 4 C .02-.475mm		ID-A Run 4 D <.02mm		ID-A Run 4 E Filter Cake		ID-A Run 4 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Silver					7.30	0.01	45.10	0.01	15.00	0.01
Sodium			178.00		1190.00		67900.00		9340.00	
Vanadium	24.30	0.00	11.10	0.01	42.80	0.01	181.00	0.01	66.40	0.01
Zinc			25.20	0.11	88.50	0.30	1020.00	0.84	211.00	0.16
4,4'-DDD	4.10	0.11								
4,4'-DDE	4.10	0.11								
4,4'-DDT	35.00	0.95								
Aldrin	9.20	0.25								
Aroclor-1016	41.00	1.10								
Aroclor-1221	81.00	2.10								
Aroclor-1232	41.00	1.10								
Aroclor-1242	41.00	1.10								
Aroclor-1248	41.00	1.10								
Aroclor-1254	36.00	1.10								
Aroclor-1260	41.00	1.10								
Dieldrin	29.00	0.99								
Endosulfan II	4.10	0.11								
Endosulfan sulfate	4.10	0.11								
Endosulfan-I	2.00	0.05								
Endrin	29.00	1.00								
Endrin aldehyde	4.10	0.11								
Endrin ketone	4.10	0.11								
Heptachlor	13.00	0.36								
Heptachlor epoxide	2.00	0.05								
Methoxychlor	20.00	0.53								
Toxaphene	200.00	5.30								
alpha-BHC	2.00	0.05								
alpha-Chlordane	2.00	0.05								
beta-BHC	2.00	0.05								
delta-BHC	2.00	0.05								
gamma-BHC (Lindane)	15.00	0.52								
gamma-Chlordane	2.00	0.05								
Total Organic Carbon			6609.00		13731.00		69853.00		37353.00	

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-B RUN 5 PILOT PLANT

Soil: Sample Point	ID-B Run 5 INITIAL CHARACTERIZATION		ID-B Run 5 C .02-.475mm		ID-B Run 5 D <.02mm		ID-B Run 5 E Filter Cake		ID-B Run 5 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Cesium-137			0.27	15.00	0.32	18.00			0.03	18.00
Gross Alpha	68.00	6000.00	24.10	82.90	30.90	368.00	1130.00	23.50	13.50	6.90
Gross Beta	46.00	3300.00	92.90	59.70	174.00	122.00	1450.00	54.10	40.20	2.00
Neptunium-237	1.40	31.00	0.52	0.16	0.25	0.18	0.39	0.16	0.57	0.26
Plutonium-238			0.12	0.32	0.10	0.13	0.26	0.68	0.10	0.16
Plutonium-239/240			0.08	0.02	0.13	0.07	0.31	0.11	0.11	0.00
Radium-226	2.80	1.00	1.70	0.32	1.50	0.98	0.53	0.09	1.20	0.24
Radium-228	3.60	4.90	1.70	0.43	1.80	0.52			0.94	0.18
Strontium-90	6.00	5.00	1.20	1.60	0.62	2.10			0.33	0.51
Technetium-99	11.00	41.00	2.50	27.10			2.70	59.00	1.50	19.10
Thorium, Total			7.80	3.90	12.80	0.33	33.00	0.00	6.80	0.36
Thorium-228	1.20	1.00	1.10	0.03	1.50	0.17	4.00	0.47	0.73	0.16
Thorium-230	2.20	1.00	3.70	1.60	6.60	0.57	17.80	1.60	2.50	0.44
Thorium-232	1.20	1.00	0.85	0.43	1.40	0.04	3.60	0.00	0.75	0.04
Uranium, Total	360.00	9600.00	159.00	260.00	289.00	521.00	3640.00	227.00	41.20	30.40
Uranium-234	170.00	3800.00	22.60	87.50	34.40	171.00	1340.00	36.00	6.00	10.10
Uranium-235/236	7.60	330.00	0.94	4.40	2.00	8.00	74.70	1.80	0.48	0.58
Uranium-238	180.00	4200.00	25.70	92.50	37.50	187.00	1460.00	39.30	7.00	10.80
Aluminum	13500.00	0.48	21500.00	0.56	25400.00	0.09	33700.00	0.07	5560.00	0.10
Arsenic			8.40	0.00	10.80	0.00	25.70	0.00	3.40	0.00
Barium	108.00	2.10	199.00	0.13	172.00	0.53	55.20	0.06	71.70	0.06
Beryllium	0.85	0.00	1.10	0.00	1.50	0.00	4.70	0.00		
Calcium	50800.00	652.00	23400.00	378.00	44200.00	107.00	15700.00	82.50	62500.00	819.00
Chromium	17.70	0.00	34.60	0.01	36.80	0.01	118.00	0.01	14.10	0.01
Cobalt	10.30	0.00	12.30	0.03	21.10	0.02	81.00	0.02		
Copper	29.10	0.00	31.40	0.01	55.20	0.01	155.00	0.01	12.20	0.01
Cyanide							1.60			
Iron	22600.00	0.03	41000.00	38.00	44900.00	0.09	127000.00	0.02	11200.00	0.90
Lead			20.80	0.01	7.40	0.00	34.90	0.00	11.70	0.01
Magnesium	16100.00	19.40	6230.00	39.50	10600.00	33.60	69700.00	297.00	2890.00	20.70
Manganese	574.00	1.20	211.00	1.80	869.00	3.00	4970.00	4.80	141.00	0.90
Mercury	0.03	0.00			0.43	0.00				
Nickel	22.60	0.01	35.80	0.24	75.30	0.09	368.00	0.02	17.80	0.09
Potassium	1600.00	3.90	3170.00	1.60	2520.00	3.60			937.00	1.00
Silicon			405.00	7.60	491.00	5.00	1100.00	2.60	259.00	2.30

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

00023

T229

Soil: Sample Point	ID-B Run 5 INITIAL CHARACTERIZATION		ID-B Run 5 C .02-.475mm		ID-B Run 5 D <.02mm		ID-B Run 5 E Filter Cake		ID-B Run 5 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Sodium	142.00		586.00	0.20	7730.00	0.20	73500.00	0.20	240.00	0.20
Vanadium	25.90	0.00	41.60	0.01	41.70	0.01	87.70	0.01	11.90	0.01
Zinc	71.30	1.10	60.70	0.23	121.00	0.07	634.00	0.06	24.60	0.07
1,2,4-Trichlorobenzene	3100.00	91.00								
1,2-Dichlorobenzene	380.00	12.00								
1,3-Dichlorobenzene	380.00	12.00								
1,4-Dichlorobenzene	3100.00	94.00								
2,4,5-Trichlorophenol	1800.00	58.00								
2,4,6-Trichlorophenol	380.00	12.00								
2,4-Dichlorophenol	380.00	12.00								
2,4-Dimethylphenol	380.00	12.00								
2,4-Dinitrophenol	1800.00	58.00								
2,4-Dinitrotoluene	2800.00	93.00								
2,6-Dinitrotoluene	380.00	12.00								
2-Chloronaphthalene	380.00	12.00								
2-Chlorophenol	6200.00	170.00								
2-Methylnaphthalene	380.00	12.00								
2-Methylphenol	380.00	12.00								
2-Nitroaniline	1800.00	58.00								
2-Nitrophenol	380.00	19.00								
3,3'-Dichlorobenzidine	750.00	24.00								
3-Nitroaniline	1800.00	58.00								
4,6-Dinitro-2-methylph	1800.00	58.00								
4-Bromophenyl phenyl e	380.00	12.00								
4-Chloro-3-methylpheno	7600.00	150.00								
4-Chlorophenylphenyl e	380.00	12.00								
4-Methylphenol	380.00	12.00								
4-Nitroaniline	1800.00	58.00								
4-Nitrophenol	6000.00	79.00								
Acenaphthene	3300.00	110.00								
Acenaphthylene	380.00	12.00								
Anthracene	380.00	12.00								
Benzo(a)anthracene	380.00	12.00								
Benzo(a)pyrene	380.00	12.00								
Benzo(b)fluoranthene	380.00	12.00								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil: Sample Point	ID-B Run 5 INITIAL CHARACTERIZATION		ID-B Run 5 C .02-.475mm		ID-B Run 5 D <.02mm		ID-B Run 5 E Filter Cake		ID-B Run 5 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Benzo(g,h,i)perylene	380.00	12.00								
Benzo(k)fluoranthene	380.00	12.00								
Benzoic acid	1800.00	58.00								
Benzyl alcohol	380.00	12.00								
Butyl benzyl phthalate	380.00	12.00								
Carbazole	380.00	12.00								
Chrysene	380.00	12.00								
Di-n-butyl phthalate	190.00	12.00								
Di-n-octyl phthalate	380.00	12.00								
Dibenzo(a,h)anthracene	380.00	12.00								
Dibenzofuran	380.00	12.00								
Diethyl phthalate	380.00	12.00								
Dimethyl phthalate	380.00	12.00								
Fluoranthene	380.00	12.00								
Fluorene	380.00	12.00								
Hexachlorobenzene	380.00	12.00								
Hexachlorobutadiene	380.00	12.00								
Hexachlorocyclopentadi	380.00	12.00								
Hexachloroethane	380.00	12.00								
Indeno(1,2,3-cd)pyrene	380.00	12.00								
Isophorone	380.00	12.00								
N-Nitroso-di-n-propyla	3700.00	110.00								
N-Nitrosodiphenylamine	380.00	12.00								
Naphthalene	380.00	12.00								
Nitrobenzene	380.00	12.00								
Pentachlorophenol	6000.00	110.00								
Phenanthrene	380.00	12.00								
Phenol	6000.00	91.00								
Pyrene	3200.00	96.00								
bis(2-Chloroethoxy)met	380.00	12.00								
bis(2-Chloroethyl)ethe	380.00	12.00								
bis(2-Chloroisopropyl)	380.00	12.00								
bis(2-Ethylhexyl)phtha	380.00	12.00								
p-Chloroaniline	380.00	12.00								
4,4'-DDD	18.00	0.12								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

0002245

6221

Soil: Sample Point	ID-B Run 5 INITIAL CHARACTERIZATION		ID-B Run 5 C .02-.475mm		ID-B Run 5 D <.02mm		ID-B Run 5 E Filter Cake		ID-B Run 5 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
4,4'-DDE	18.00	0.12								
4,4'-DDT	70.00	0.64								
Aldrin	34.00	0.30								
Aroclor-1016	91.00	0.59								
Aroclor-1221	91.00	0.59								
Aroclor-1232	91.00	0.59								
Aroclor-1242	91.00	0.59								
Aroclor-1248	91.00	0.59								
Aroclor-1254	180.00	1.20								
Aroclor-1260	180.00	1.20								
Dieldrin	57.00	0.53								
Endosulfan II	18.00	0.12								
Endosulfan sulfate	18.00	0.12								
Endosulfan-I	9.10	0.06								
Endrin	110.00	0.88								
Endrin aldehyde	18.00	0.12								
Endrin ketone	18.00	0.12								
Heptachlor	21.00	0.23								
Heptachlor epoxide	9.10	0.06								
Methoxychlor	91.00	0.59								
Toxaphene	180.00	1.20								
alpha-BHC	9.10	0.06								
alpha-Chlordane	91.00	0.59								
beta-BHC	9.10	0.06								
delta-BHC	9.10	0.06								
gamma-BHC (Lindane)	20.00	0.20								
gamma-Chlordane	91.00	0.59								
Total Organic Carbon	9640.00		22031.00		12684.00		60781.00		70197.00	

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ID-B RUN 6 PILOT PLANT

Soil: Sample Point	ID-B Run 6 INITIAL CHARACTERIZATION		ID-B Run 6 C .02-.475mm		ID-B Run 6 D <.02mm		ID-B Run 6 E Filter Cake		ID-B Run 6 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Cesium-137			0.28	13.00	0.18	14.00				
Gross Alpha	60.00	5300.00	31.50	85.40	47.10	394.00	1080.00	5720.00	7.40	16.20
Gross Beta	50.00	2900.00	126.00	44.60	193.00	165.00	1540.00	4240.00	41.10	18.80
Neptunium-237	1.80	33.00	0.46	0.08	0.68	0.20	0.20	0.06	0.47	0.31
Plutonium-238			0.05	0.84	0.08	0.18	0.13	0.06	0.21	0.30
Plutonium-239/240			0.05	0.15	0.13	0.03	0.29	0.07	0.14	0.01
Radium-226	2.40	1.00			1.60	1.60	0.53	1.10	1.20	0.19
Radium-228	3.60	3.70	1.80	0.02	1.60	0.71			1.10	0.17
Strontium-90			0.48	0.47	0.61	1.80			5.40	0.43
Technetium-99	17.00	30.00	1.90	26.80			4.60	108.00	1.00	9.80
Thorium, Total			8.80	1.10	12.50	1.10	35.10	7.20	4.80	0.08
Thorium-228	1.40	1.00	0.90	0.12	1.50	0.01	4.30	1.10	0.75	0.81
Thorium-230	2.20	1.00	2.20	0.41	3.70	0.64	11.50	4.40	1.30	1.00
Thorium-232	1.00	1.00	0.97	0.13	1.40	0.12	3.90	0.79	0.53	0.01
Uranium, Total	370.00	9500.00	180.00	180.00	283.00	704.00	3700.00	16100.00	41.70	44.30
Uranium-234	160.00	3300.00	23.40	79.50	34.70	269.00	1560.00	5590.00	4.30	23.40
Uranium-235/236	7.70	180.00	0.99	4.00	2.80	13.80	71.50	417.00	0.16	1.20
Uranium-238	180.00	3700.00	25.10	87.10	38.30	291.00	1590.00	6130.00	5.00	26.30
Aluminum	13100.00	0.35	34900.00	1.20	25000.00	0.07	39500.00	44.00	6660.00	0.18
Arsenic			4.70	0.00	13.50	0.00	31.90	0.00	2.00	0.00
Barium	100.00	1.40	232.00	0.14	182.00	0.57	56.70	0.26	68.40	0.12
Beryllium	0.80	0.00	1.30	0.00	1.40	0.00	5.20	0.01	0.35	0.00
Calcium	58200.00	576.00	10600.00	158.00	45400.00	599.00	26700.00	179.00	55300.00	813.00
Chromium	16.90	0.00	42.00	0.01	38.80	0.01	109.00	0.02	14.00	0.02
Cobalt	9.90	0.00	13.50	0.03	23.60	0.02	80.40	0.23		
Copper	28.80	0.00	35.90	0.01	58.10	0.02	172.00	0.03	10.30	0.01
Cyanide	1.40						0.77			
Iron	22400.00	0.04	50200.00	24.90	44200.00	0.27	142000.00	3.00	10700.00	1.50
Lead			22.80	0.00	7.70	0.00	50.80	0.00	10.50	0.01
Magnesium	15800.00	18.80	7980.00	35.30	11100.00	33.60	79400.00	494.00	3260.00	27.50
Manganese	576.00	1.00	216.00	1.50	982.00	2.70	5170.00	25.60	122.00	1.20
Mercury	0.02	0.00								
Nickel	21.30	0.01	39.40	0.19	93.20	0.12	310.00	1.10	17.10	0.12
Potassium	1420.00	3.40	5250.00	1.70	2900.00	3.80			1190.00	1.50
Silicon			365.00	8.40	295.00	5.20	952.00	49.60	226.00	3.60

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

00047

1229

000218

ID-B RUN 6 PILOT PLANT

Soil: Sample Point	ID-B Run 6 INITIAL CHARACTERIZATION		ID-B Run 6 C .02-.475mm		ID-B Run 6 D <.02mm		ID-B Run 6 E Filter Cake		ID-B Run 6 F Carbonate Treated Soil	
Analytes	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG	HSL AVG	TCLP AVG
Silver							6.20	0.02		
Sodium	149.00		477.00	0.20	5620.00	0.20	73000.00	515.00	253.00	0.20
Vanadium	23.90	0.00	59.40	0.01	45.20	0.01	97.20	0.01	13.90	0.01
Zinc	67.90	0.60	82.60	0.23	119.00	0.06	430.00	0.95	22.40	0.07
Di-n-butyl phthalate	100.00	9.00								
Total Organic Carbon	10600.00		22822.00		23422.00		7371.00		4424.00	

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ATTACHMENT IV
INITIAL AND FINAL CHARACTERIZATION DATA FOR TWELVE SOILS USED IN COC TESTING

AS-1 PLANT 9

Soil: Sample Point	AS-1 INITIAL CHARACTERIZATION				AS-1 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Plutonium-238	0.06	0.0			0.02	0.0	0.07	0.0
Plutonium-239/240	0.05	0.0			0.01	0.0		
Radium-226	0.90	0.0			1.00	0.0	3.90	0.0
Radium-228	0.75	0.0			0.49	0.0	1.40	0.0
Technetium-99					3.70	0.0	75.00	0.0
Thorium, Total	12.40	0.0						
Thorium-228	2.00	0.0			0.44	0.0	0.00	0.0
Thorium-230	12.10	0.0			0.41	0.0	0.04	0.0
Thorium-232	1.40	0.0			0.33	0.0	0.05	0.0
Uranium, Total	5580.00	0.0						
Uranium-234	77.40	0.0			13.00	0.0	430.00	0.0
Uranium-235					0.67	0.0	35.00	0.0
Uranium-235/236	4.30	0.0						
Uranium-238	63.90	0.0			10.00	0.0	370.00	0.0
Aluminum					9190.00	0.0	0.36	0.0
Arsenic	6.80	0.0			3.60	0.0	0.00	0.0
Barium	80.60	0.0			67.70	0.0	1.30	0.0
Beryllium	0.56	0.0						
Calcium					105000.00	0.0	1940.00	0.0
Chromium	17.30	0.0			15.40	0.0	0.04	0.0
Cobalt	9.80	0.0			10.60	0.0	0.01	0.0
Iron					21200.00	0.0	0.63	0.0
Lead	17.40	0.0			11.20	0.0	0.00	0.0
Magnesium					30500.00	0.0	35.30	0.0
Manganese	519.00	0.0			509.00	0.0	6.00	0.0
Mercury	0.09	0.0			0.05	0.0	0.00	0.0
Nickel	18.50	0.0			23.10	0.0	0.01	0.0
Potassium					1660.00	0.0	1.80	0.0
Silver	1.80	0.0			0.72	0.0	0.03	0.0
Sodium					1270.00	0.0	60.60	0.0
Vanadium	23.10	0.0			26.50	0.0	0.27	0.0
Zinc	49.80	0.0			51.30	0.0	0.21	0.0
Diethyl phthalate	150.00	0.0						
bis(2-Ethylhexyl)phtha	400.00	0.0						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000250

6721

AS-2 PLANT 2/3

Soil: Sample Point	AS-2 INITIAL CHARACTERIZATION				AS-2 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	0.88	0.0						
Plutonium-238	0.07	0.0			0.02	0.0	0.00	0.0
Plutonium-239/240	0.20	0.0			0.07	0.0	0.01	0.0
Radium-226	1.10	0.0			1.50	0.0	3.50	0.0
Radium-228	0.82	0.0			0.48	0.0	1.30	0.0
Technetium-99					1.20	0.0	37.00	0.0
Thorium, Total	8.70	0.0						
Thorium-228	1.60	0.0			0.43	0.0	0.19	0.0
Thorium-230	8.50	0.0			2.70	0.0	0.28	0.0
Thorium-232	0.95	0.0			0.24	0.0	0.07	0.0
Uranium, Total	4870.00	0.0						
Uranium-234	101.00	0.0			16.00	0.0	740.00	0.0
Uranium-235					0.91	0.0	41.00	0.0
Uranium-235/236	4.30	0.0						
Uranium-238	85.40	0.0			15.00	0.0	690.00	0.0
Aluminum					7380.00	0.0	0.59	0.0
Arsenic	4.90	0.0			4.90	0.0	0.00	0.0
Barium	66.00	0.0			69.40	0.0	0.63	0.0
Beryllium	0.57	0.0						
Calcium					91400.00	0.0	1530.00	0.0
Chromium	16.40	0.0			14.10	0.0	0.04	0.0
Cobalt	9.60	0.0			8.10	0.0	0.01	0.0
Iron					16700.00	0.0	0.67	0.0
Lead	10.20	0.0			25.40	0.0	0.02	0.0
Magnesium					31300.00	0.0	26.90	0.0
Manganese	478.00	0.0			467.00	0.0	4.30	0.0
Mercury					0.10	0.0	0.01	0.0
Nickel	16.90	0.0			17.10	0.0	0.01	0.0
Potassium					1030.00	0.0	1.50	0.0
Silver	3.00	0.0			1.30	0.0	0.03	0.0
Sodium					2290.00	0.0	135.00	0.0
Vanadium	22.00	0.0			23.40	0.0	0.08	0.0
Zinc	37.30	0.0			53.20	0.0	0.03	0.0
Benzo(a)pyrene	43.00	0.0						
Benzo(b)fluoranthene	75.00	0.0						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

1229

Soil: Sample Point	AS-2 INITIAL CHARACTERIZATION				AS-2 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Chrysene	48.00	0.0						
Di-n-butyl phthalate	100.00	0.0						
Diethyl phthalate	46.00	0.0						
Fluoranthene	98.00	0.0						
Pentachlorophenol	38.00	0.0						
Phenanthrene	75.00	0.0						
Pyrene	86.00	0.0						
bis(2-Ethylhexyl)phtha	5000.00	0.0						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000252

AS-3 PLANT 6

Soil: Sample Point	AS-6 INITIAL CHARACTERIZATION				AS-6 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	42.85	57.9			170.00	0.0		
Plutonium-238	0.01	0.0	0.01	0.0	0.09	0.0	0.02	0.0
Plutonium-239					0.23	0.0		
Plutonium-239/240	0.01	0.0	0.02	0.0				
Radium-226	273.50	191.6	890.00	0.0	67.00	0.0	210.00	0.0
Radium-228	0.45	0.0			0.63	0.0		
Technetium-99	32.55	33.2	3.50	0.0	0.45	0.0	3.00	0.0
Thorium-228	0.25	0.0	0.23	0.0	0.42	0.0	0.02	0.0
Thorium-230	3.70	1.0	0.17	0.0	1.90	0.0	0.13	0.0
Thorium-232	0.27	0.0	0.38	0.0	0.20	0.0	0.03	0.0
Uranium, Total								
Uranium-234	9.30	1.3	39.00	0.0	2.80	0.0	1.10	0.0
Uranium-235					0.10	0.0	0.09	0.0
Uranium-235/236	0.45	0.0						
Uranium-238	10.15	1.2	43.00	0.0	2.90	0.0	1.00	0.0
Aluminum	9855.00	205.1	0.03	0.0	7660.00	0.0		
Arsenic	7.95	0.1	0.00	0.0	5.90	0.0		
Barium	66.05	0.2	0.89	0.0	67.90	0.0		
Beryllium					0.70	0.0		
Calcium	47100.00	1697.1	686.00	0.0	52100.00	0.0		
Chromium	13.65	0.2	0.01	0.0	27.60	0.0		
Cobalt					2.90	0.0		
Copper	17.75	0.2	0.01	0.0	14.10	0.0		
Iron	19600.00	141.4	0.35	0.0	16300.00	0.0		
Lead	31.45	0.8	0.00	0.0	17.20	0.0		
Magnesium	16600.00	424.3	27.30	0.0	4110.00	0.0		
Manganese	572.50	2.1	0.02	0.0	120.00	0.0		
Nickel	19.50	1.0	0.01	0.0	23.80	0.0		
Potassium	1185.00	77.8	3.70	0.0	1330.00	0.0		
Selenium					0.93	0.0		
Sodium					72.70	0.0		
Vanadium	21.40	0.4	0.04	0.0	21.80	0.0		
Zinc	65.80	0.3	0.18	0.0	40.60	0.0		
Benzo(a)anthracene	31.00	1.4						
Benzo(a)pyrene	30.00	5.7						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

1229

Soil: Sample Point	AS-6 INITIAL CHARACTERIZATION				AS-6 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(b)fluoranthene	51.00	7.1						
Benzo(g,h,i)perylene	23.50	2.1						
Benzo(k)fluoranthene	20.00	2.8						
Chrysene	39.00	1.4						
Fluoranthene	80.00	2.8						
Indeno(1,2,3-cd)pyrene	22.50	0.7						
Phenanthrene	24.50	3.5						
Pyrene	69.00	2.8						
4,4'-DDE	1.50	0.0						
Aroclor-1254	25.50	2.1						
Endrin	2.55	0.4						

000254

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

AS-4 PILOT PLANT

Soil: Sample Point	AS-4 INITIAL CHARACTERIZATION				AS-4 H2SO4 WASHED SOIL				AS-4 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	49.25	41.2			4.60	0.0			51.00	0.0	50.00	0.0
Plutonium-238	41.90	11.3	0.96	0.0	56.00	0.0	2.90	0.0	77.00	0.0	3.90	0.0
Plutonium-239/240	4.05	1.1			5.30	0.0	0.24	0.0	7.60	0.0	0.54	0.0
Radium-226	256.50	55.9	130.00	0.0	66.00	0.0	53.00	0.0	480.00	0.0	230.00	0.0
Radium-228	254.00	2.8			270.00	0.0			230.00	0.0	1400.00	0.0
Technetium-99	30.15	2.6	36.00	0.0	2.80	0.0	69.00	0.0	7.60	0.0	14.00	0.0
Thorium-228	27.65	2.1	46.00	0.0	66.00	0.0	14.00	0.0	7.80	0.0	22.00	0.0
Thorium-230	5.65	1.3	0.18	0.0	11.00	0.0	2.30	0.0	1.60	0.0	0.51	0.0
Thorium-232	18.90	2.1	0.23	0.0	45.00	0.0	9.10	0.0	8.00	0.0	0.85	0.0
Uranium, Total												
Uranium-234	111.50	23.3	5100.00	0.0	28.00	0.0	430.00	0.0	72.00	0.0	1400.00	0.0
Uranium-235					0.68	0.0	7.10	0.0	1.40	0.0	27.00	0.0
Uranium-235/236	2.90	0.1										
Uranium-238	28.50	5.1	1400.00	0.0	9.40	0.0	120.00	0.0	17.00	0.0	380.00	0.0
Aluminum	13350.00	212.1	0.03	0.0	6730.00	0.0	2.20	0.0	8160.00	0.0	0.68	0.0
Arsenic	7.40	0.1	0.00	0.0	6.80	0.0	0.00	0.0	6.00	0.0	0.00	0.0
Barium	433.00	5.7	2.70	0.0	335.00	0.0	0.34	0.0	299.00	0.0	4.10	0.0
Beryllium					0.87	0.0	0.01	0.0				
Cadmium					0.29	0.0	0.01	0.0	0.36	0.0	0.02	0.0
Calcium	107000.00	2828.4	741.00	0.0	129000.00	0.0	1540.00	0.0	133000.00	0.0	1430.00	0.0
Chromium	82.15	11.5	0.01	0.0	19.70	0.0	0.02	0.0	56.90	0.0	0.04	0.0
Cobalt	24.25	0.6	0.00	0.0	3.50	0.0	0.04	0.0	15.50	0.0	0.04	0.0
Copper	1775.00	7.1	2.40	0.0	114.00	0.0	0.68	0.0	1130.00	0.0	10.50	0.0
Iron	21200.00	2121.3	0.03	0.0	12200.00	0.0	0.50	0.0	17400.00	0.0	0.32	0.0
Lead	324.50	46.0	0.05	0.0	397.00	0.0	0.98	0.0	360.00	0.0	0.20	0.0
Magnesium	26600.00	282.8	21.10	0.0	12200.00	0.0	76.30	0.0	32700.00	0.0	33.00	0.0
Manganese	557.50	23.3	0.87	0.0	144.00	0.0	2.80	0.0	485.00	0.0	3.20	0.0
Mercury	0.64	0.0	0.00	0.0	0.72	0.0	0.00	0.0	0.46	0.0	0.00	0.0
Nickel	78.80	7.9	0.09	0.0	16.00	0.0	0.18	0.0	53.30	0.0	0.24	0.0
Potassium	2190.00	212.1	2.20	0.0	2000.00	0.0	1.30	0.0	1650.00	0.0	1.40	0.0
Sodium	335.00	5.7	1380.00	0.0	198.00	0.0	3.70	0.0	1810.00	0.0	91.50	0.0
Vanadium	39.00	2.5	0.00	0.0	34.10	0.0	0.04	0.0	33.10	0.0	0.20	0.0
Zinc	177.50	6.4	0.40	0.0	29.90	0.0	0.37	0.0	127.00	0.0	1.30	0.0
Acenaphthene	72.00	9.9										
Anthracene	160.00	28.3										

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

1229

000256

Soil: Sample Point	AS-4 INITIAL CHARACTERIZATION				AS-4 H2SO4 WASHED SOIL				AS-4 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(a)anthracene	740.00	14.1										
Benzo(a)pyrene	685.00	49.5										
Benzo(b)fluoranthene	1100.00	0.0										
Benzo(g,h,i)perylene	600.00	70.7										
Benzo(k)fluoranthene	435.00	21.2										
Carbazole	120.00	14.1										
Chrysene	895.00	7.1										
Di-n-butyl phthalate	185.00	106.1										
Dibenzo(a,h)anthracene	130.00	0.0										
Dibenzofuran	35.00	4.2										
Dimethyl phthalate	34.00	0.0										
Fluoranthene	1850.00	70.7										
Fluorene	74.00	11.3										
Indeno(1,2,3-cd)pyrene	590.00	56.6										
Phenanthrene	1100.00	141.4										
Pyrene	1700.00	0.0										

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

AS-5 GRAPHITE FURNACE

Soil: Sample Point	AS-5 INITIAL CHARACTERIZATION				AS-5 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	3.15	0.2						
Plutonium-238	0.37	0.1	2.50	0.0	0.53	0.0	0.03	0.0
Plutonium-239					0.06	0.0		
Plutonium-239/240	0.47	0.2	0.30	0.0				
Radium-226	1.41	1.5	18.00	0.0	0.78	0.0	3.00	0.0
Radium-228	0.72	0.0			0.70	0.0		
Technetium-99	58.50	16.7	55.00	0.0	14.00	0.0	230.00	0.0
Thorium-228	0.88	0.3	2.00	0.0	1.70	0.0	0.33	0.0
Thorium-230	2.80	0.6	0.25	0.0	3.60	0.0	0.22	0.0
Thorium-232	0.77	0.3	0.53	0.0	0.65	0.0	1.00	0.0
Uranium, Total								
Uranium-234	42.20	6.8	2100.00	0.0	53.00	0.0	30.00	0.0
Uranium-235					3.70	0.0	1.40	0.0
Uranium-235/236	2.55	0.6						
Uranium-238	33.00	5.4	1600.00	0.0	41.00	0.0	24.00	0.0
Aluminum	9730.00	664.7	0.03	0.0	6490.00	0.0	0.11	0.0
Arsenic	9.90	0.0	0.00	0.0	7.00	0.0	0.00	0.0
Barium	111.50	7.8	1.50	0.0	118.00	0.0	0.30	0.0
Beryllium					0.86	0.0	0.01	0.0
Calcium	72500.00	1131.4	1780.00	0.0	61500.00	0.0	1110.00	0.0
Chromium	14.15	0.8	0.02	0.0	9.90	0.0	0.02	0.0
Cobalt					3.30	0.0	0.01	0.0
Copper	18.05	0.6	0.01	0.0	10.70	0.0	0.01	0.0
Iron	21600.00	3818.4	0.03	0.0	12900.00	0.0	0.94	0.0
Lead	24.35	0.1	0.01	0.0	15.90	0.0	0.01	0.0
Magnesium	16250.00	353.6	52.80	0.0	3910.00	0.0	67.40	0.0
Manganese	483.50	7.8	6.80	0.0	96.50	0.0	1.80	0.0
Nickel	21.05	0.1	0.04	0.0	12.70	0.0	0.03	0.0
Potassium	1260.00	183.8	4.80	0.0	1300.00	0.0	2.30	0.0
Selenium					0.70	0.0	0.00	0.0
Sodium					103.00	0.0	2.30	0.0
Vanadium	22.70	1.0	0.05	0.0	20.30	0.0	0.04	0.0
Zinc	62.75	3.0	0.21	0.0	31.90	0.0	0.19	0.0
2-Methylnaphthalene	675.00	7.1						
Anthracene	18.50	9.2						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

002527

1229

Soil: Sample Point	AS-5 INITIAL CHARACTERIZATION				AS-5 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(a)anthracene	70.50	0.7						
Benzo(a)pyrene	41.50	3.5						
Benzo(b)fluoranthene	93.00	9.9						
Benzo(g,h,i)perylene	105.00	7.1						
Benzo(k)fluoranthene	17.50	4.9						
Chrysene	120.00	0.0						
Di-n-butyl phthalate	74.00	36.8						
Dibenzofuran	160.00	14.1						
Fluoranthene	62.50	0.7						
Indeno(1,2,3-cd)pyrene	40.50	2.1						
Naphthalene	350.00	14.1						
Phenanthrene	455.00	49.5						
Phenol	195.00	21.2						
Pyrene	105.00	7.1						
Aroclor-1254	3450.00	70.7						
Aroclor-1260	2200.00	0.0						
Dieldrin	50.00	1.4						
Endrin	220.00	0.0						
gamma-Chlordane	21.00	1.4						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

AS-6 PADDY'S RUN

Soil: Sample Point	AS-6 INITIAL CHARACTERIZATION				AS-6 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	42.85	57.9			170.00	0.0		
Plutonium-238	0.01	0.0	0.01	0.0	0.09	0.0	0.02	0.0
Plutonium-239					0.23	0.0		
Plutonium-239/240	0.01	0.0	0.02	0.0				
Radium-226	273.50	191.6	890.00	0.0	67.00	0.0	210.00	0.0
Radium-228	0.45	0.0			0.63	0.0		
Technetium-99	32.55	33.2	3.50	0.0	0.45	0.0	3.00	0.0
Thorium-228	0.25	0.0	0.23	0.0	0.42	0.0	0.02	0.0
Thorium-230	3.70	1.0	0.17	0.0	1.90	0.0	0.13	0.0
Thorium-232	0.27	0.0	0.38	0.0	0.20	0.0	0.03	0.0
Uranium, Total								
Uranium-234	9.30	1.3	39.00	0.0	2.80	0.0	1.10	0.0
Uranium-235					0.10	0.0	0.09	0.0
Uranium-235/236	0.45	0.0						
Uranium-238	10.15	1.2	43.00	0.0	2.90	0.0	1.00	0.0
Aluminum	9855.00	205.1	0.03	0.0	7660.00	0.0		
Arsenic	7.95	0.1	0.00	0.0	5.90	0.0		
Barium	66.05	0.2	0.89	0.0	67.90	0.0		
Beryllium					0.70	0.0		
Calcium	47100.00	1697.1	686.00	0.0	52100.00	0.0		
Chromium	13.65	0.2	0.01	0.0	27.60	0.0		
Cobalt					2.90	0.0		
Copper	17.75	0.2	0.01	0.0	14.10	0.0		
Iron	19600.00	141.4	0.35	0.0	16300.00	0.0		
Lead	31.45	0.8	0.00	0.0	17.20	0.0		
Magnesium	16600.00	424.3	27.30	0.0	4110.00	0.0		
Manganese	572.50	2.1	0.02	0.0	120.00	0.0		
Nickel	19.50	1.0	0.01	0.0	23.80	0.0		
Potassium	1185.00	77.8	3.70	0.0	1330.00	0.0		
Selenium					0.93	0.0		
Sodium					72.70	0.0		
Vanadium	21.40	0.4	0.04	0.0	21.80	0.0		
Zinc	65.80	0.3	0.18	0.0	40.60	0.0		
Benzo(a)anthracene	31.00	1.4						
Benzo(a)pyrene	30.00	5.7						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000259

1229

Soil: Sample Point	AS-6 INITIAL CHARACTERIZATION				AS-6 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(b)fluoranthene	51.00	7.1						
Benzo(g,h,i)perylene	23.50	2.1						
Benzo(k)fluoranthene	20.00	2.8						
Chrysene	39.00	1.4						
Fluoranthene	80.00	2.8						
Indeno(1,2,3-cd)pyrene	22.50	0.7						
Phenanthrene	24.50	3.5						
Pyrene	69.00	2.8						
4,4'-DDE	1.50	0.0						
Aroclor-1254	25.50	2.1						
Endrin	2.55	0.4						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000260

AS-7 SOUTH OF KC-2 WAREHOUSE

Soil: Sample Point	AS-7 INITIAL CHARACTERIZATION				AS-7 H2SO4 WASHED SOIL				AS-7 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	2.30	1.6										
Plutonium-238	0.01	0.0	0.01	0.0	0.06	0.0	0.01	0.0	0.10	0.0	0.02	0.0
Plutonium-239					0.00	0.0						
Plutonium-239/240	0.03	0.0	0.02	0.0					0.10	0.0		
Radium-226	2.15	1.2	3.90	0.0	1.00	0.0	5.60	0.0	4.10	0.0	2.80	0.0
Radium-228	0.65	0.0	2.10	0.0	0.76	0.0			0.55	0.0	0.21	0.0
Technetium-99	2.55	2.3	0.83	0.0	0.58	0.0	1.50	0.0	0.65	0.0	48.00	0.0
Thorium-228	0.09	0.0	0.07	0.0	0.79	0.0	0.02	0.0	1.70	0.0	0.06	0.0
Thorium-230	0.43	0.2	0.11	0.0	1.80	0.0	0.03	0.0	4.80	0.0	0.21	0.0
Thorium-232	0.12	0.1	0.09	0.0	0.72	0.0	0.03	0.0	1.60	0.0	0.04	0.0
Uranium, Total												
Uranium-234	14.00	1.0	120.00	0.0	6.40	0.0	34.00	0.0	13.00	0.0	110.00	0.0
Uranium-235					0.25	0.0	1.90	0.0	0.91	0.0	3.50	0.0
Uranium-235/236	0.73	0.1										
Uranium-238	17.40	0.8	130.00	0.0	7.80	0.0	53.00	0.0	17.00	0.0	150.00	0.0
Aluminum	5230.00	226.3							6730.00	0.0	0.21	0.0
Arsenic	6.65	1.1	0.02	0.0					6.40	0.0	0.00	0.0
Barium	88.10	6.6	0.70	0.0	0.25	0.0	0.19	0.0	86.90	0.0	0.70	0.0
Beryllium					0.00	0.0	0.00	0.0				
Calcium	142000.00	4242.6	584.00	0.0	1170.00	0.0	1250.00	0.0	150000.00	0.0	1980.00	0.0
Chromium	18.50	2.8	0.01	0.0					20.70	0.0	0.05	0.0
Cobalt									7.90	0.0	0.03	0.0
Copper	93.55	79.8	0.02	0.0					42.30	0.0	0.02	0.0
Iron	17200.00	565.7			0.01	0.0	0.13	0.0	20900.00	0.0	0.06	0.0
Lead	99.40	15.0	0.04	0.0					81.40	0.0	0.03	0.0
Magnesium	31900.00	424.3	15.50	0.0	28.60	0.0	37.30	0.0	33600.00	0.0	28.10	0.0
Manganese	617.00	4.2	1.00	0.0	1.40	0.0	1.50	0.0	694.00	0.0	6.10	0.0
Mercury	0.08	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.13	0.0	0.00	0.0
Nickel	11.70	1.1	0.02	0.0					19.30	0.0	0.03	0.0
Potassium	647.50	29.0	2.20	0.0	2.10	0.0	1.50	0.0				
Sodium	494.00	0.0			1250.00	0.0	1410.00	0.0	1940.00	0.0	73.90	0.0
Thallium							0.00	0.0				
Vanadium	12.10	0.4	0.03	0.0					24.80	0.0	0.29	0.0
Zinc	120.50	9.2	0.19	0.0	0.05	0.0	0.17	0.0	154.00	0.0	0.39	0.0
1,1-Dichloroethene	56.00	0.0										

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000231

6721

Soil: Sample Point	AS-7 INITIAL CHARACTERIZATION				AS-7 H2SO4 WASHED SOIL				AS-7 CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzene	56.00	0.0										
Chlorobenzene	55.00	0.0										
Toluene	57.00	0.0										
Trichloroethene	52.00	0.0										
Trichlorofluoromethane												
2-Methylnaphthalene	345.00	21.2	40.00	0.0								
Acenaphthene	375.00	91.9	40.00	0.0								
Acenaphthylene	3350.00	353.6	40.00	0.0								
Anthracene	2350.00	70.7	40.00	0.0								
Benzo(a)anthracene	12500.00	707.1	40.00	0.0					3400.00	0.0	260.00	0.0
Benzo(a)pyrene	14500.00	707.1	40.00	0.0					3700.00	0.0	260.00	0.0
Benzo(b)fluoranthene	23500.00	2121.3	40.00	0.0					6900.00	0.0	260.00	0.0
Benzo(g,h,i)perylene	8850.00	495.0	40.00	0.0								
Benzo(k)fluoranthene	7900.00	1838.5	40.00	0.0								
Carbazole	590.00	0.0	40.00	0.0								
Chrysene	15500.00	707.1	40.00	0.0					4500.00	0.0	260.00	0.0
Di-n-butyl phthalate	780.00	268.7	40.00	0.0								
Dibenzo(a,h)anthracene	2700.00	141.4	40.00	0.0								
Dibenzofuran	265.00	49.5	40.00	0.0								
Fluoranthene	13500.00	707.1	40.00	0.0					5500.00	0.0	260.00	0.0
Fluorene	455.00	63.6	40.00	0.0								
Indeno(1,2,3-cd)pyrene	9750.00	353.6	40.00	0.0								
Naphthalene	400.00	42.4	40.00	0.0								
Phenanthrene	4200.00	282.8	40.00	0.0								
Pyrene	16000.00	1414.2	40.00	0.0					4800.00	0.0	260.00	0.0
Aroclor-1254	755.00	49.5	0.25	0.0								
Aroclor-1260	795.00	7.1	0.25	0.0								
Dieldrin	16.50	0.7	0.25	0.0								
Endosulfan II	33.00	5.7	0.25	0.0								
Endrin	72.00	2.8	0.25	0.0								
gamma-Chlordane	23.00	1.4	0.25	0.0								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000262

AS-8 D&D FACILITY (NE OF PROCESS AREA)

Soil: Sample Point	AS-8 INITIAL CHARACTERIZATION			
	HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV
Lead-210	2.40	1.0		
Plutonium-238	0.01	0.0		
Plutonium-239/240	0.02	0.0		
Radium-226	1.50	0.6		
Radium-228	0.90	0.1		
Technetium-99	2.93	3.6		
Thorium-228	0.50	0.1		
Thorium-230	1.28	0.5		
Thorium-232	0.49	0.1		
Uranium, Total				
Uranium-234	15.45	0.5		
Uranium-235/236	0.74	0.1		
Uranium-238	17.60	1.4		
Aluminum	13100.00	0.0		
Arsenic	9.00	0.0	0.02	0.0
Barium	88.70	0.6	0.61	0.0
Calcium	60550.00	3040.6	612.00	0.0
Chromium	37.85	25.5	0.01	0.0
Cobalt	12.20	0.7	0.00	0.0
Copper	672.50	802.6	0.01	0.0
Iron	27600.00	424.3		
Lead	72.30	44.8	0.04	0.0
Magnesium	14700.00	141.4	10.80	0.0
Manganese	844.50	29.0	0.38	0.0
Mercury	0.21	0.0	0.00	0.0
Nickel	39.80	9.2	0.01	0.0
Potassium	1475.00	35.4	2.90	0.0
Vanadium	27.00	0.4	0.04	0.0
Zinc	103.50	20.5	0.17	0.0
Trichlorofluoromethane				
2-Nitrophenol	17.50	2.1	40.00	0.0
Acenaphthylene	6.00	2.8	40.00	0.0
Anthracene	6.00	4.2	40.00	0.0
Benzo(a)anthracene	25.00	11.3	40.00	0.0
Benzo(a)pyrene	25.50	12.0	40.00	0.0

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000263

6221

000264

Soil: Sample Point	AS-8 INITIAL CHARACTERIZATION			
	HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV
Benzo(b)fluoranthene	60.00	21.2	40.00	0.0
Benzo(g,h,i)perylene	37.00	18.4	40.00	0.0
Benzo(k)fluoranthene	21.50	9.2	40.00	0.0
Benzoic acid	62.00	0.0		
Chrysene	47.50	24.7	40.00	0.0
Di-n-butyl phthalate	48.00	2.8	40.00	0.0
Di-n-octyl phthalate	740.00	42.4	40.00	0.0
Fluoranthene	49.50	21.9	40.00	0.0
Indeno(1,2,3-cd)pyrene	27.50	9.2	40.00	0.0
Naphthalene	11.00	0.0	40.00	0.0
Phenanthrene	26.50	12.0	40.00	0.0
Phenol	55.00	0.0	40.00	0.0
Pyrene	49.50	21.9	40.00	0.0
Aroclor-1254	1700.00	0.0	0.25	0.0
Aroclor-1260	1000.00	0.0	0.25	0.0
Dieldrin	26.00	0.0	0.25	0.0
Endrin	120.00	0.0	0.25	0.0
gamma-Chlordane	7.90	0.0	0.25	0.0

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

AS-9 EAST OF BUILDING 77/79

Soil: Sample Point	AS-9 INITIAL CHARACTERIZATION				AS-9 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Lead-210	55.60	75.5						
Plutonium-238	0.05	0.0	0.02	0.0	0.06	0.0	0.01	0.0
Plutonium-239					0.03	0.0		
Plutonium-239/240	0.03	0.0	0.01	0.0				
Radium-226	5.25	3.0	2.50	0.0	0.64	0.0	2.90	0.0
Radium-228	0.94	0.0			0.80	0.0		
Technetium-99	3.45	3.9	3.90	0.0	1.50	0.0	2.10	0.0
Thorium-228	0.28	0.1	0.05	0.0	0.46	0.0	0.04	0.0
Thorium-230	0.43	0.1	0.00	0.0	0.49	0.0	0.12	0.0
Thorium-232	0.28	0.0	0.03	0.0	0.34	0.0	0.04	0.0
Uranium, Total								
Uranium-234	17.50	0.0	68.00	0.0	2.40	0.0	4.20	0.0
Uranium-235					0.16	0.0	0.24	0.0
Uranium-235/236	0.96	0.0						
Uranium-238	18.10	0.0	71.00	0.0	2.50	0.0	4.40	0.0
Aluminum	12850.00	636.4	0.03	0.0	10900.00	0.0		
Antimony					8.30	0.0		
Arsenic	7.10	0.3	0.00	0.0	6.00	0.0		
Barium	81.65	1.8	1.10	0.0	82.30	0.0		
Beryllium					0.78	0.0		
Calcium	31900.00	424.3	653.00	0.0	32000.00	0.0		
Chromium	16.05	0.6	0.01	0.0	13.10	0.0		
Cobalt					4.00	0.0		
Copper	16.25	1.1	0.01	0.0	13.80	0.0		
Iron	22100.00	141.4	0.04	0.0	18200.00	0.0		
Lead	23.60	1.3	0.01	0.0	12.60	0.0		
Magnesium	10425.00	671.8	44.60	0.0	3760.00	0.0		
Manganese	532.50	54.4	1.40	0.0	157.00	0.0		
Nickel	17.25	0.9	0.01	0.0	15.50	0.0		
Potassium	1215.00	162.6	3.00	0.0	1600.00	0.0		
Sodium					99.60	0.0		
Vanadium	26.25	0.9	0.04	0.0	21.90	0.0		
Zinc	59.70	0.0	0.19	0.0	44.40	0.0		
Benzo(a)anthracene	22.00	0.0						
Benzo(a)pyrene	17.00	0.0						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000265

1229

Soil: Sample Point	AS-9 INITIAL CHARACTERIZATION				AS-9 H2SO4 WASHED SOIL			
	HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(b)fluoranthene	41.00	0.0						
Benzo(g,h,i)perylene	18.00	0.0						
Benzo(k)fluoranthene	15.00	0.0						
Benzoic acid	23.00	0.0						
Chrysene	32.00	0.0						
Di-n-butyl phthalate	42.00	0.0						
Fluoranthene	56.00	0.0						
Indeno(1,2,3-cd)pyrene	18.00	0.0						
Phenanthrene	28.00	0.0						
Phenol	14.00	0.0						
Pyrene	50.00	0.0						
Aldrin	0.50	0.0						
Aroclor-1254	24.50	3.5						
Endrin	2.65	0.1						
Endrin aldehyde	0.66	0.0						
Methoxychlor	6.50	4.9						

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

IDA Incinerator

Soil: Sample Point	IDA INITIAL CHARACTERIZATION				IDA H2SO4 WASHED SOIL				IDA CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Cesium-137	0.20	0.0	20.00	0.0								
Gross Alpha	685.00	210.5	229.00	127.5								
Gross Beta	262.50	26.3	100.00	53.5								
Neptunium-237	1.98	0.6	1.48	0.6								
Plutonium-238	0.43	0.2	1.00	0.0	0.05	0.0	0.01	0.0	0.04	0.0	0.01	0.0
Plutonium-239					0.03	0.0	0.00	0.0				
Plutonium-239/240	0.09	0.0	1.00	0.0					0.02	0.0		
Radium-226					0.51	0.0	2.50	0.0	1.30	0.0	0.73	0.0
Radium-228					1.10	0.0	24.00	0.0	1.60	0.0	1.10	0.0
Technetium-99	8.10	1.3	30.00	0.0	0.77	0.0	58.00	0.0	3.20	0.0	130.00	0.0
Thorium-228	2.25	0.1	0.88	0.3	0.52	0.0	0.28	0.0	0.66	0.0	0.08	0.0
Thorium-230	40.50	3.9	1.00	0.0	19.00	0.0	3.70	0.0	16.00	0.0	2.70	0.0
Thorium-232	2.20	0.1	1.00	0.0	0.57	0.0	0.02	0.0	0.71	0.0	0.04	0.0
Uranium, Total	350.00	14.1	937.50	276.7								
Uranium-234	157.50	22.2	378.75	141.6	34.00	0.0	470.00	0.0	27.00	0.0	120.00	0.0
Uranium-235					1.90	0.0	25.00	0.0	1.30	0.0	7.10	0.0
Uranium-235/236	6.65	0.6	9.38	4.3								
Uranium-238	167.50	22.2	405.00	155.0	38.00	0.0	540.00	0.0	29.00	0.0	130.00	0.0
Aluminum	9392.50	1021.4	1.47	0.9	5650.00	0.0	0.97	0.0	5000.00	0.0	1.60	0.0
Arsenic	9.43	1.3	0.01	0.0	7.00	0.0	0.00	0.0	8.10	0.0	0.00	0.0
Barium	90.65	3.1	3.07	1.8	96.90	0.0	0.28	0.0	71.20	0.0	1.20	0.0
Calcium	6660.00	1598.6	292.00	53.6	9480.00	0.0	122.00	0.0	10300.00	0.0	355.00	0.0
Chromium	15.13	0.8	0.01	0.0	11.00	0.0	0.00	0.0	11.00	0.0	0.01	0.0
Cobalt	8.83	1.7	0.00	0.0	14.70	0.0	0.07	0.0	10.00	0.0	0.03	0.0
Copper	16.20	3.9	0.00	0.0								
Cyanide	0.24	0.1	0.01	0.0								
Iron	17075.00	899.5	0.11	0.1	22500.00	0.0	1.90	0.0	17100.00	0.0	0.66	0.0
Lead	47.00	8.9	0.02	0.0	46.00	0.0	0.03	0.0	38.90	0.0	0.01	0.0
Magnesium	3147.50	817.5	38.80	4.3	1930.00	0.0	10.70	0.0	2660.00	0.0	55.70	0.0
Manganese	609.00	102.4	0.55	0.0	1120.00	0.0	8.30	0.0	821.00	0.0	7.60	0.0
Mercury					0.09	0.0	0.00	0.0	0.07	0.0	0.00	0.0
Nickel	17.20	2.1	0.02	0.0	19.40	0.0	0.07	0.0	22.70	0.0	0.08	0.0
Potassium	694.75	75.8	3.24	1.6								
Selenium					0.34	0.0	0.00	0.0				
Silicon	787.00	278.2	3.13	0.4								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

002067

6721

Soil: Sample Point	IDA INITIAL CHARACTERIZATION				IDA H2SO4 WASHED SOIL				IDA CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Silver	0.75	0.0	0.00	0.0								
Sodium									1690.00	0.0	186.00	0.0
Vanadium	24.23	2.0	0.00	0.0	27.50	0.0	0.00	0.0	23.80	0.0	0.05	0.0
Zinc					42.50	0.0	0.47	0.0	61.80	0.0	0.41	0.0
Fluoranthene	65.00	0.0	9.00	0.0								
Aroclor-1254	42.25	14.4	1.05	0.1								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

IDB PLANT 1 PAD

Soil: Sample Point	IDB INITIAL CHARACTERIZATION				IDB H2SO4 WASHED SOIL				IDB CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Gross Alpha	62.00	4.0	5475.00	350.0								
Gross Beta	49.00	2.0	3000.00	200.0								
Neptunium-237	1.70	0.2	32.50	1.0								
Plutonium-238					0.02	0.0	0.01	0.0	0.01	0.0	0.01	0.0
Plutonium-239					0.04	0.0						
Plutonium-239/240									0.04	0.0	0.01	0.0
Radium-226	2.50	0.2	1.00	0.0	0.10	0.0	1.20	0.0	2.30	0.0	1.70	0.0
Radium-228	3.60	0.0	4.00	0.6	0.61	0.0	3.20	0.0	0.53	0.0	3.10	0.0
Strontium-90	6.00	0.0	5.00	0.0								
Technetium-99	15.50	3.0	32.75	5.5	1.50	0.0	86.00	0.0	3.30	0.0	76.00	0.0
Thorium-228	1.35	0.1	1.00	0.0	0.30	0.0	0.04	0.0	0.57	0.0	0.26	0.0
Thorium-230	2.20	0.0	1.00	0.0	0.51	0.0	0.12	0.0	0.82	0.0	0.15	0.0
Thorium-232	1.05	0.1	1.00	0.0	0.21	0.0	0.02	0.0	0.63	0.0	0.02	0.0
Uranium, Total	367.50	5.0	9525.00	50.0								
Uranium-234	162.50	5.0	3425.00	250.0	9.20	0.0	160.00	0.0	14.00	0.0	720.00	0.0
Uranium-235					0.60	0.0	7.60	0.0	0.81	0.0	34.00	0.0
Uranium-235/236	7.68	0.1	217.50	75.0								
Uranium-238	180.00	0.0	3825.00	250.0	10.00	0.0	170.00	0.0	15.00	0.0	750.00	0.0
Aluminum	16175.00	3354.0	0.47	0.1	8490.00	0.0	0.03	0.0	10500.00	0.0	0.05	0.0
Arsenic					5.70	0.0	0.00	0.0	4.90	0.0	0.00	0.0
Barium	111.00	10.0	1.88	0.3	84.60	0.0	0.25	0.0	118.00	0.0	0.92	0.0
Beryllium	0.93	0.1	0.00	0.0								
Cadmium									4.90	0.0	0.00	0.0
Calcium	54825.00	3237.7	586.75	44.2	81400.00	0.0	1320.00	0.0	61900.00	0.0	1290.00	0.0
Chromium	19.98	3.2	0.00	0.0	12.50	0.0	0.04	0.0	15.30	0.0	0.04	0.0
Cobalt	10.60	0.9	0.00	0.0					12.90	0.0	0.00	0.0
Copper	30.10	2.3	0.00	0.0					30.80	0.0	0.00	0.0
Iron	23650.00	1982.4	0.05	0.0	18100.00	0.0	0.02	0.0	21200.00	0.0	0.02	0.0
Lead					14.80	0.0	0.01	0.0	15.50	0.0	0.01	0.0
Magnesium	16300.00	469.0	18.78	0.5	10400.00	0.0	53.80	0.0	171000.00	0.0	26.70	0.0
Manganese	571.75	38.2	1.05	0.1	345.00	0.0	2.40	0.0	759.00	0.0	4.10	0.0
Mercury	0.03	0.0	0.00	0.0								
Nickel	22.43	1.1	0.01	0.0	14.90	0.0	0.02	0.0	25.90	0.0	0.02	0.0
Potassium	2255.00	863.4	3.78	0.3	1250.00	0.0	5.50	0.0	1270.00	0.0	1.80	0.0
Silver									0.62	0.0	0.03	0.0

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

00239

1229

Soil: Sample Point	IDB INITIAL CHARACTERIZATION				IDB H2SO4 WASHED SOIL				IDB CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Sodium	160.25	18.0							3750.00	0.0	141.00	0.0
Vanadium	30.38	6.5	0.00	0.0	24.50	0.0	0.13	0.0	28.50	0.0	0.10	0.0
Zinc	74.35	6.4	1.00	0.3	42.10	0.0	0.18	0.0	68.40	0.0	0.03	0.0
1,2,4-Trichlorobenzene	3100.00	0.0	91.00	0.0								
1,2-Dichlorobenzene	380.00	0.0	12.00	0.0								
1,3-Dichlorobenzene	380.00	0.0	12.00	0.0								
1,4-Dichlorobenzene	3100.00	0.0	94.00	0.0								
2,4,5-Trichlorophenol	1800.00	0.0	58.00	0.0								
2,4,6-Trichlorophenol	380.00	0.0	12.00	0.0								
2,4-Dichlorophenol	380.00	0.0	12.00	0.0								
2,4-Dimethylphenol	380.00	0.0	12.00	0.0								
2,4-Dinitrophenol	1800.00	0.0	58.00	0.0								
2,4-Dinitrotoluene	2800.00	0.0	93.00	0.0								
2,6-Dinitrotoluene	380.00	0.0	12.00	0.0								
2-Chloronaphthalene	380.00	0.0	12.00	0.0								
2-Chlorophenol	6200.00	0.0	170.00	0.0								
2-Methylnaphthalene	380.00	0.0	12.00	0.0								
2-Methylphenol	380.00	0.0	12.00	0.0								
2-Nitroaniline	1800.00	0.0	58.00	0.0								
2-Nitrophenol	380.00	0.0	19.00	0.0								
3,3'-Dichlorobenzidine	750.00	0.0	24.00	0.0								
3-Nitroaniline	1800.00	0.0	58.00	0.0								
4,6-Dinitro-2-methylph	1800.00	0.0	58.00	0.0								
4-Bromophenyl phenyl e	380.00	0.0	12.00	0.0								
4-Chloro-3-methylpheno	7600.00	0.0	150.00	0.0								
4-Chlorophenylphenyl e	380.00	0.0	12.00	0.0								
4-Methylphenol	380.00	0.0	12.00	0.0								
4-Nitroaniline	1800.00	0.0	58.00	0.0								
4-Nitrophenol	6000.00	0.0	79.00	0.0								
Acenaphthene	3300.00	0.0	110.00	0.0								
Acenaphthylene	380.00	0.0	12.00	0.0								
Anthracene	380.00	0.0	12.00	0.0								
Benzo(a)anthracene	380.00	0.0	12.00	0.0								
Benzo(a)pyrene	380.00	0.0	12.00	0.0								
Benzo(b)fluoranthene	380.00	0.0	12.00	0.0								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

Soil: Sample Point	IDB INITIAL CHARACTERIZATION				IDB H2SO4 WASHED SOIL				IDB CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Benzo(g,h,i)perylene	380.00	0.0	12.00	0.0								
Benzo(k)fluoranthene	380.00	0.0	12.00	0.0								
Benzoic acid	1800.00	0.0	58.00	0.0								
Benzyl alcohol	380.00	0.0	12.00	0.0								
Butyl benzyl phthalate	380.00	0.0	12.00	0.0								
Carbazole	380.00	0.0	12.00	0.0								
Chrysene	380.00	0.0	12.00	0.0								
Di-n-butyl phthalate	109.00	76.9	10.33	1.5								
Di-n-octyl phthalate	380.00	0.0	12.00	0.0								
Dibenzo(a,h)anthracene	380.00	0.0	12.00	0.0								
Dibenzofuran	380.00	0.0	12.00	0.0								
Diethyl phthalate	260.00	169.7	10.50	2.1								
Dimethyl phthalate	380.00	0.0	12.00	0.0								
Fluoranthene	380.00	0.0	12.00	0.0								
Fluorene	380.00	0.0	12.00	0.0								
Hexachlorobenzene	380.00	0.0	12.00	0.0								
Hexachlorobutadiene	380.00	0.0	12.00	0.0								
Hexachlorocyclopentadi	380.00	0.0	12.00	0.0								
Hexachloroethane	380.00	0.0	12.00	0.0								
Indeno(1,2,3-cd)pyrene	380.00	0.0	12.00	0.0								
Isophorone	380.00	0.0	12.00	0.0								
N-Nitroso-di-n-propyla	3700.00	0.0	110.00	0.0								
N-Nitrosodiphenylamine	380.00	0.0	12.00	0.0								
Naphthalene	380.00	0.0	12.00	0.0								
Nitrobenzene	380.00	0.0	12.00	0.0								
Pentachlorophenol	6000.00	0.0	110.00	0.0								
Phenanthrene	380.00	0.0	12.00	0.0								
Phenol	6000.00	0.0	91.00	0.0								
Pyrene	3200.00	0.0	96.00	0.0								
bis(2-Chloroethoxy)met	380.00	0.0	12.00	0.0								
bis(2-Chloroethyl)ethe	380.00	0.0	12.00	0.0								
bis(2-Chloroisopropyl)	380.00	0.0	12.00	0.0								
bis(2-Ethylhexyl)phtha	209.00	241.8	10.50	2.1								
p-Chloroaniline	380.00	0.0	12.00	0.0								
4,4'-DDD	18.00	0.0	0.12	0.0								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000271

6271

Soil: Sample Point	IDB INITIAL CHARACTERIZATION				IDB H2SO4 WASHED SOIL				IDB CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
4,4'-DDE	18.00	0.0	0.12	0.0								
4,4'-DDT	70.00	0.0	0.64	0.0								
Aldrin	34.00	0.0	0.30	0.0								
Aroclor-1016	91.00	0.0	0.59	0.0								
Aroclor-1221	91.00	0.0	0.59	0.0								
Aroclor-1232	91.00	0.0	0.59	0.0								
Aroclor-1242	91.00	0.0	0.59	0.0								
Aroclor-1248	91.00	0.0	0.59	0.0								
Aroclor-1254	180.00	0.0	1.20	0.0								
Aroclor-1260	180.00	0.0	1.20	0.0								
Dieldrin	57.00	0.0	0.53	0.0								
Endosulfan II	18.00	0.0	0.12	0.0								
Endosulfan sulfate	18.00	0.0	0.12	0.0								
Endosulfan-I	9.10	0.0	0.06	0.0								
Endrin	110.00	0.0	0.88	0.0								
Endrin aldehyde	18.00	0.0	0.12	0.0								
Endrin ketone	18.00	0.0	0.12	0.0								
Heptachlor	21.00	0.0	0.23	0.0								
Heptachlor epoxide	9.10	0.0	0.06	0.0								
Methoxychlor	91.00	0.0	0.59	0.0								
Toxaphene	180.00	0.0	1.20	0.0								
alpha-BHC	9.10	0.0	0.06	0.0								
alpha-Chlordane	91.00	0.0	0.59	0.0								
beta-BHC	9.10	0.0	0.06	0.0								
delta-BHC	9.10	0.0	0.06	0.0								
gamma-BHC (Lindane)	20.00	0.0	0.20	0.0								
gamma-Chlordane	91.00	0.0	0.59	0.0								
Total Organic Carbon	9195.00	1807.4										

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000272

Soil: Sample Point	OU5-A INITIAL CHARACTERIZATION				OU5-A H2SO4 WASHED SOIL				OU5-A CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Cesium-137	0.38	0.1	20.00	0.0								
Gross Alpha	125.27	23.4	1082.25	315.4								
Gross Beta	71.50	12.1	326.75	62.4								
Plutonium-238					0.17	0.0	0.06	0.0	0.14	0.0	0.00	0.0
Plutonium-239/240					0.17	0.0			0.12	0.0		
Radium-226	1.15	0.1	282.33	54.7	0.60	0.0	2.40	0.0	1.60	0.0	1.30	0.0
Radium-228	1.33	0.5			0.98	0.0	8.40	0.0	0.69	0.0	0.88	0.0
Technetium-99	1.08	0.2	30.00	0.0	6.00	0.0	640.00	0.0	1.70	0.0	33.00	0.0
Thorium, Total	10.28	2.0	2.33	1.3								
Thorium-228	1.88	0.3	1.00	0.0	0.78	0.1	0.51	0.0	0.93	0.1	0.41	0.0
Thorium-230	4.52	0.6	1.00	0.0	3.60	0.8	0.35	0.0	3.65	1.3	0.54	0.0
Thorium-232	1.14	0.2	1.00	0.0	0.82	0.0	0.29	0.0	0.95	0.2	0.36	0.0
Uranium, Total	184.87	56.3	1722.50	92.9								
Uranium-234	65.86	6.2	648.75	96.1	40.00	0.0	2300.00	0.0	38.00	0.0	210.00	0.0
Uranium-235					4.40	0.0	160.00	0.0	2.20	0.0	13.00	0.0
Uranium-235/236	2.92	0.5	36.50	3.7								
Uranium-238	66.44	5.1	721.25	82.5	38.00	0.0	1900.00	0.0	38.00	0.0	230.00	0.0
Aluminum	5376.20	990.1	1.34	1.1	5800.00	0.0	0.49	0.0	3520.00	0.0	0.82	0.0
Arsenic	11.58	4.5	0.01	0.0	10.80	0.0	0.00	0.0	7.40	0.0	0.00	0.0
Barium	140.38	170.8	1.21	0.9	69.10	0.0	0.28	0.0	46.70	0.0	1.10	0.0
Beryllium	11.10	0.0	0.05	0.0	0.64	0.0	0.00	0.0				
Cadmium	8.90	0.0	0.05	0.0					0.35	0.0	0.01	0.0
Calcium	106876.60	7562.2	0.02	0.0	106000.00	0.0	1240.00	0.0	171000.00	0.0	1640.00	0.0
Chromium	32.82	17.3	0.04	0.1	34.30	0.0	0.04	0.0	31.80	0.0	0.04	0.0
Cobalt	25.26	40.0	0.14	0.2	5.80	0.0	0.01	0.0				
Copper	37.14	22.2	0.06	0.1	36.00	0.0	0.02	0.0	24.60	0.0	0.03	0.0
Cyanide	1.15	2.3										
Iron	18494.80	1185.0	1.04	0.9	20900.00	0.0	0.76	0.0	18500.00	0.0	1.50	0.0
Lead	156.20	18.6	0.07	0.0	170.00	0.0	0.09	0.0	197.00	0.0	0.03	0.0
Magnesium	26546.20	4209.4	33.56	2.4	6130.00	0.0	51.20	0.0	25300.00	0.0	27.00	0.0
Manganese	497.00	120.5	6.62	0.4	170.00	0.0	2.20	0.0	604.00	0.0	6.50	0.0
Mercury	0.23	0.0	0.00	0.0	0.29	0.0	0.00	0.0	0.10	0.0	0.00	0.0
Nickel	46.22	41.2	0.15	0.2	23.00	0.0	0.03	0.0	25.20	0.0	0.04	0.0
Potassium	792.00	173.0	1.70	0.2	1020.00	0.0	1.90	0.0				
Silicon	553.40	238.9	4.38	1.1								

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000273

6721

OU5-A MAINTENANCE BUILDING

Soil: Sample Point	OU5-A INITIAL CHARACTERIZATION				OU5-A H2SO4 WASHED SOIL				OU5-A CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Cesium-137	0.39	0.0	20.00	0.0								
Gross Alpha	127.68	22.8	1340.00	56.6								
Gross Beta	71.23	12.9	343.00	100.4								
Plutonium-238					0.17	0.0	0.06	0.0	0.14	0.0	0.00	0.0
Plutonium-239/240					0.17	0.0			0.12	0.0		
Radium-226	1.15	0.1	334.00	0.0	0.60	0.0	2.40	0.0	1.60	0.0	1.30	0.0
Radium-228	1.25	0.6			0.98	0.0	8.40	0.0	0.69	0.0	0.88	0.0
Technetium-99	1.07	0.2	30.00	0.0	6.00	0.0	640.00	0.0	1.70	0.0	33.00	0.0
Thorium, Total	10.48	2.3	2.63	1.4								
Thorium-228	1.80	0.3	1.00	0.0	0.72	0.0	0.51	0.0	0.85	0.0	0.41	0.0
Thorium-230	4.60	0.6	1.00	0.0	3.00	0.0	0.35	0.0	2.70	0.0	0.54	0.0
Thorium-232	1.16	0.2	1.00	0.0	0.83	0.0	0.29	0.0	0.80	0.0	0.36	0.0
Uranium, Total	170.30	62.5	1785.00	21.2								
Uranium-234	64.30	5.9	666.00	109.8	40.00	0.0	2300.00	0.0	38.00	0.0	210.00	0.0
Uranium-235					4.40	0.0	160.00	0.0	2.20	0.0	13.00	0.0
Uranium-235/236	2.90	0.6	35.50	3.9								
Uranium-238	65.20	5.0	720.00	101.0	38.00	0.0	1900.00	0.0	38.00	0.0	230.00	0.0
Aluminum	5507.75	1091.7	1.40	1.3	5800.00	0.0	0.49	0.0	3520.00	0.0	0.82	0.0
Arsenic	11.63	5.2	0.01	0.0	10.80	0.0	0.00	0.0	7.40	0.0	0.00	0.0
Barium	160.38	190.4	1.31	1.0	69.10	0.0	0.28	0.0	46.70	0.0	1.10	0.0
Cadmium	8.90	0.0	0.05	0.0					0.35	0.0	0.01	0.0
Calcium	109320.75	6035.2	0.02	0.0	106000.00	0.0	1240.00	0.0	171000.00	0.0	1640.00	0.0
Chromium	33.85	19.8	0.05	0.1	34.30	0.0	0.04	0.0	31.80	0.0	0.04	0.0
Cobalt	29.78	44.8	0.16	0.2								
Copper	39.18	25.1	0.07	0.1	36.00	0.0	0.02	0.0	24.60	0.0	0.03	0.0
Cyanide	1.41	2.5										
Iron	18318.50	1290.4	0.95	1.0	20900.00	0.0	0.76	0.0	18500.00	0.0	1.50	0.0
Lead	159.00	20.2	0.07	0.0	170.00	0.0	0.09	0.0	197.00	0.0	0.03	0.0
Magnesium	27182.75	4574.3	34.35	1.9	6130.00	0.0	51.20	0.0	25300.00	0.0	27.00	0.0
Manganese	520.50	125.2	6.80	0.2	170.00	0.0	2.20	0.0	604.00	0.0	6.50	0.0
Mercury	0.23	0.0	0.00	0.0	0.29	0.0	0.00	0.0	0.10	0.0	0.00	0.0
Nickel	50.80	46.1	0.17	0.2	23.00	0.0	0.03	0.0	25.20	0.0	0.04	0.0
Potassium	826.50	178.8	1.65	0.2	1020.00	0.0	1.90	0.0				
Silicon	562.25	274.9	4.48	1.3								
Sodium	228.50	7.0	5.30	0.0					1060.00	0.0	114.00	0.0

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

000274

1229

Soil: Sample Point	OU5-A INITIAL CHARACTERIZATION				OU5-A H2SO4 WASHED SOIL				OU5-A CARBONATE WASHED SOIL			
	HSL		TCLP		HSL		TCLP		HSL		TCLP	
Analytes	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Thallium	10.80	0.0	0.05	0.0					0.34	0.0	0.00	0.0
Vanadium	33.30	49.1	0.16	0.2	21.30	0.0	0.04	0.0	18.60	0.0	0.18	0.0
Zinc	416.50	55.7	1.50	0.2	212.00	0.0	0.43	0.0	283.00	0.0	0.70	0.0
1,1,1-Trichloroethane	5.50	1.7										
1,1-Dichloroethane	1.25	0.5										
1,2-Dichloroethene (To	13.00	2.2										
Carbon disulfide					27.00	0.0						
Tetrachloroethene					9.00	0.0						
Toluene	25686.67	44438.7										
Trichloroethene					130.00	0.0						
2-Methylnaphthalene	119.25	25.3	20.00	0.0								
Acenaphthene	157.67	183.9	20.00	0.0								
Benzo(a)anthracene	547.50	303.9	20.00	0.0	190.00	0.0	10.00	0.0				
Benzo(a)pyrene	505.00	227.8	20.00	0.0	100.00	0.0	10.00	0.0				
Benzo(b)fluoranthene	1045.00	523.5	20.00	0.0	230.00	0.0	10.00	0.0				
Benzo(k)fluoranthene	240.00	0.0	20.00	0.0								
Chrysene	682.50	283.6	20.00	0.0	200.00	0.0	10.00	0.0				
Dibenzofuran	140.00	99.0	20.00	0.0								
Fluoranthene	1262.50	695.0	20.00	0.0	410.00	0.0	10.00	0.0				
Indeno(1,2,3-cd)pyrene					57.00	0.0	10.00	0.0				
Phenanthrene	1195.00	871.4	20.00	0.0	300.00	0.0	10.00	0.0				
Pyrene	1165.00	626.4	20.00	0.0	290.00	0.0	10.00	0.0				
bis(2-Ethylhexyl)phtha	330.00	119.7	20.00	0.0								
Aroclor-1254	6750.00	1212.4			2200.00	0.0	1.00	0.0	2300.00	0.0	1.10	0.0
Aroclor-1260					550.00	0.0	1.00	0.0	640.00	0.0	1.10	0.0
Total Organic Carbon	28955.50	4073.9										
% Moisture	8002.50	5349.1										
% Solids	89275.00	805.7										

Units of Measure	HSL	TCLP
Radiological, activity	pCi/g	pCi/L
Uranium, Total; Thorium,Total	mg/kg	ug/L
Volatiles	ug/kg	ug/L
Semi-volatiles	ug/kg	ug/L
Pesticides	ug/kg	ug/L
Metals	mg/kg	mg/L

ATTACHMENT V
GEOTECHNICAL CHARACTERIZATION AND PARTICLE SIZE ANALYSES FOR ID-A AND ID-B SOILS

Cross Reference Index for Particle Size Analyses for the Two Soils Processed through the Soil Washing Pilot Plant Showing Process Run and Centrifuge Cycle

Client No.	Soil	Process Run	Centrifuge Cycle
7204	ID-A	1	1
7217	ID-A	1	2
7224	ID-A	1	3
7412	ID-A	2	1
7420	ID-A	2	2
7429	ID-A	2	3
7011	ID-B	1	1
7017	ID-B	1	2
7028	ID-B	1	3
7511	ID-B	2	1
7519	ID-B	2	2
7528	ID-B	2	3
1055/29-1	ID-A	Initial Geotechnical Characterization	
1055/29-2	ID-A	Initial Geotechnical Characterization	
1055/29-3	ID-B	Initial Geotechnical Characterization	
1055/29-4	ID-B	Initial Geotechnical Characterization	

Ms. Jenny Vance
IT Corporation
1550 Bear Creek Road
Oak Ridge, Tennessee 37830

November 20, 1992

ETDC Project Number: 483500.048.01 P.O. Number:

This is the Certificate of Analysis for the following samples:

Client Project ID: **Fernald OU5**
Date Received by Lab: **September 11, 1992**
Number of Samples: **Four (4)**
Sample Type: **Soil**

DRAFT

I. Introduction/Case Narrative

Four soil samples were received by IT/ETDC on September 11, 1992 for analysis of moisture content, particle size distribution, atterberg limits, specific gravity, cation exchange capacity, and total organic carbon content.

Please see Appendix A, the Sample Number Cross Reference List; Appendix B, the Analysis Results and the Analysis Dates; Appendix C, the Chain of Custody and Request for Analysis Records; and Appendix D, the Screen Results.

Reviewed and Approved:

Beverly L. Leamon
Project Manager, Geotechnical Services

II. Analytical Results/Methodology

REFERENCES: Annual Book of ASTM Standards, Section 4, Construction, Volume 04.08, Soil and Rock; Dimension Stone; Geosynthetics. EPA SW-846, Test Methods for Evaluating Solid Waste.

Moisture Content	**ASTM D 2216**
Particle Size	**ASTM D 422**
Atterberg Limits	**ASTM D 4318**
Specific Gravity	**ASTM D 854**
Cation Exchange Capacity	**SW-846, Method 9081**
Total Organic Carbon Content	**SW-846, Method 9060A**

III. Quality Control

Quality control checks such as duplicates and spikes (QC samples), are not normally applicable to geotechnical testing. This is due to the inability of obtaining samples with known characteristics, the heterogenous nature of the samples, and Quality Control procedures built-in to the analytical method.

QC measures to ensure accuracy and precision of test results include the following:

- 100% verification on all numerical results - all raw data entries, transcriptions and calculations entered by lab technicians are checked, recalculated and verified. Most data calculations are performed by computer programs.

- Data validation through test reasonableness - summaries of all test results for individual reports are reviewed to determine the overall reasonableness of data and to determine the presence of any data that may be considered outliers.

- Quality control procedures are built into most standardized geotechnical procedures. For example, many analyses routinely call for a re-analysis, specifying an acceptance criteria.

- Routine instrument calibration - all instruments, gauges and equipment used in testing are calibrated on a routine basis. All instrument calibration follows ASTM or manufacturer guidelines.

- Maintenance of all past calibration records - records and certification documents of all instruments, gauges and equipment are updated routinely and maintained in the Quality Control Coordinators Quality/Operations files.

- Use of trained personnel for conducting tests - all technicians are trained in the application of standard laboratory procedures for geotechnical analyses as well as the quality assurance measures implemented by IT.

IV. Data Qualification

Fine sieve and hydrometer results occasionally overlap due to organic debris, soluble salts or other contaminants contained in the sample. Data points are plotted as calculated. No attempt has been made to curve-fit the grainsize data points.

Total organic carbon content analysis was performed by IT/Austin. Specimens from each sample were sent by IT/ETDC, according to procedure specifications, to IT/Austin for TOC analysis. The TOC results presented in this report were transcribed directly from the final report issued by IT/Austin.

The cation exchange capacity procedure included analysis of blanks, duplicates and a matrix spike. Blanks were found to be less than the 0.1 mg/l ICP detection limit for sodium analysis. The matrix spike recovery was found to be 63.0 %. Relative percent difference for duplicate samples ranged from 0.7 % to 9.6 %.

APPENDIX A

Jenny Vance
IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01

CROSS-REFERENCE LIST

ETDC SAMPLE NO.	CLIENT SAMPLE NO.
ETDC-2850	1055/29-1
ETDC-2851	1055/29-2
ETDC-2852	1055/29-3
ETDC-2853	1055/29-4

DRAFT

APPENDIX B

Jenny Vance
IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01

SAMPLE ANALYSIS RESULTS

PROJECT NAME:	FERNALD OU5	USCS SYMBOL:	CL
PROJECT NO.:	483500.048.01	WATER CONTENT, %:	21.9
CUST. SAMPLE NO.:	1055/29-1	LIQUID LIMIT:	25.0
ETDC SAMPLE NO.:	ETDC-2850	PLASTICITY INDEX:	8.0
SPECIFIC GRAVITY:	2.6537 (MEASURED)	CATION EXCHANGE CAP.:	18.8 meq/100 g
TOTAL ORGANIC CARBON:			

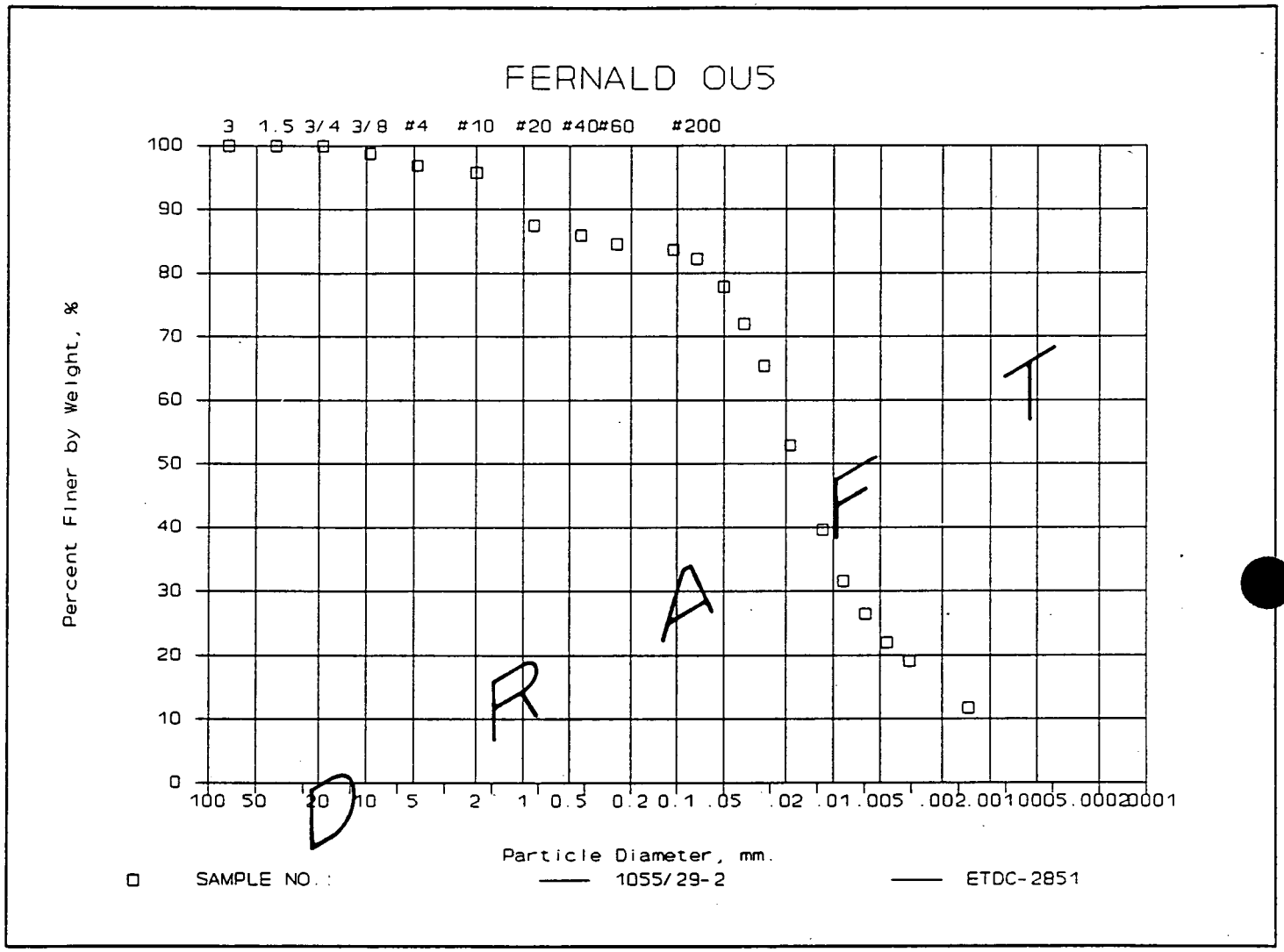
SIEVE ANALYSIS

SIEVE NO.	DIAMETER (mm)	PERCENT FINER (%)
3.0 in	75.000	100.0
1.5 in	37.500	100.0
0.75 in	19.000	99.5
0.375 in	9.500	98.4
NO. 4	4.750	96.5
NO. 10	2.000	95.4
NO. 20	0.850	86.9
NO. 40	0.425	85.2
NO. 60	0.250	83.9
NO. 140	0.106	82.8
NO. 200	0.075	81.6

HYDROMETER ANALYSIS

DIAMETER (mm)	PERCENT FINER (%)
0.0508	77.4
0.0374	72.2
0.0276	65.5
0.0187	54.3
0.0118	38.7
0.0085	32.7
0.0062	26.8
0.0045	22.3
0.0032	18.6
0.0014	11.2

Jenny Vance
IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01



Jenny Vance
IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01

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SAMPLE ANALYSIS RESULTS

PROJECT NAME:	FERNALD OU5	USCS SYMBOL:	CL
PROJECT NO.:	483500.048.01	WATER CONTENT, %:	14.3
CUST. SAMPLE NO.:	1055/29-3	LIQUID LIMIT:	34.0
ETDC SAMPLE NO.:	ETDC-2852	PLASTICITY INDEX:	18.0
SPECIFIC GRAVITY:	2.7248 (MEASURED)	CATION EXCHANGE CAP.:	18.1 meq/100 g
TOTAL ORGANIC CARBON:			

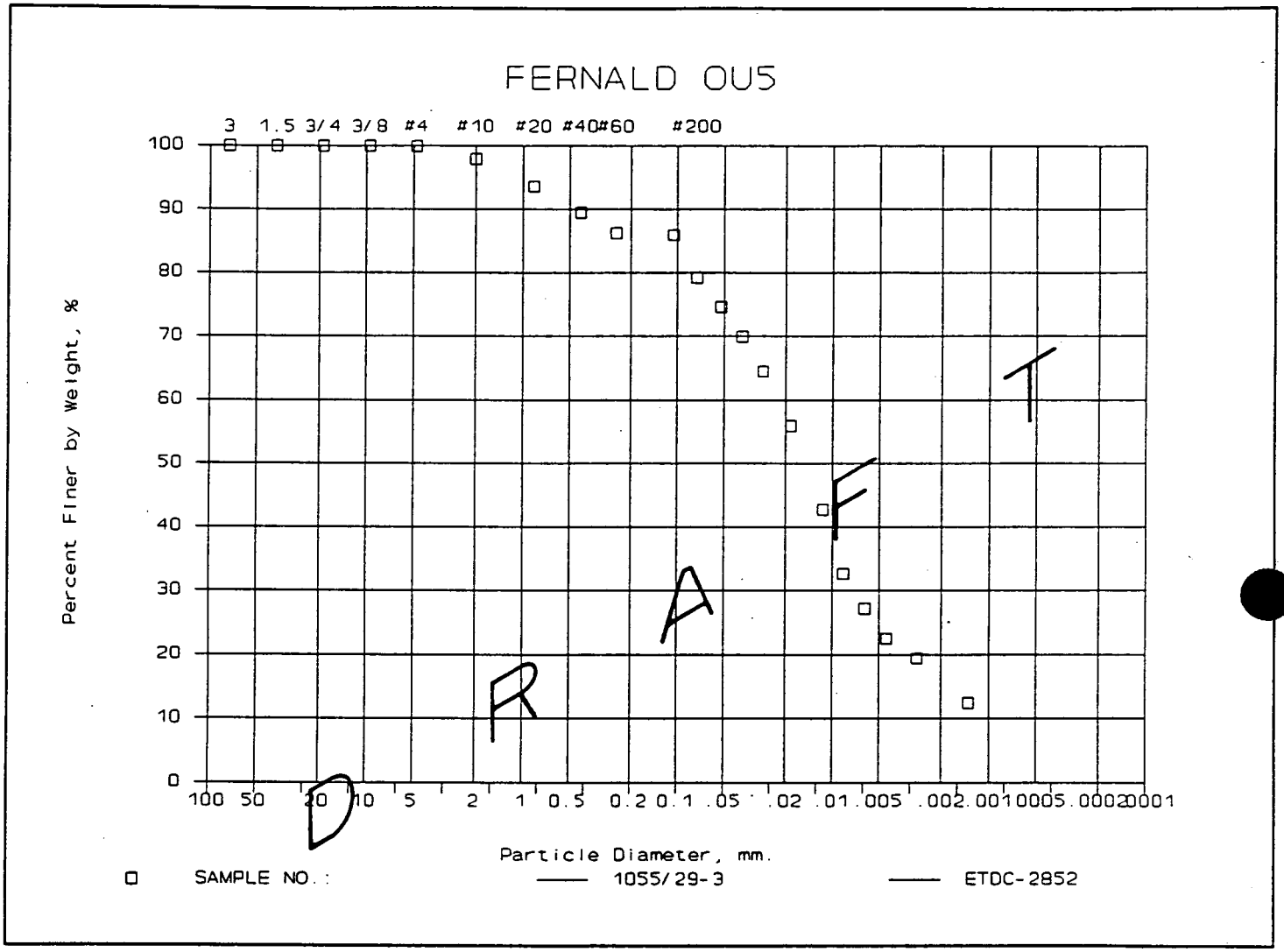
SIEVE ANALYSIS

SIEVE NO.	DIAMETER (mm)	PERCENT FINER (%)
3.0 in	75.000	100.0
1.5 in	37.500	100.0
0.75 in	19.000	100.0
0.375 in	9.500	100.0
NO. 4	4.750	99.9
NO. 10	2.000	97.9
NO. 20	0.850	93.6
NO. 40	0.425	89.5
NO. 60	0.250	86.2
NO. 140	0.106	86.0
NO. 200	0.075	79.2

HYDROMETER ANALYSIS

DIAMETER (mm)	PERCENT FINER (%)
0.0525	74.6
0.0383	70.0
0.0279	64.5
0.0185	56.0
0.0114	42.7
0.0085	32.6
0.0061	27.2
0.0045	22.5
0.0029	19.4
0.0014	12.4

Jenny Vance
IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01



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November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01

SAMPLE ANALYSIS RESULTS

PROJECT NAME:	FERNALD OU5	USCS SYMBOL:	CL
PROJECT NO.:	483500.048.01	WATER CONTENT, %:	14.0
CUST. SAMPLE NO.:	1055/29-4	LIQUID LIMIT:	33.0
ETDC SAMPLE NO.:	ETDC-2853	PLASTICITY INDEX:	18.0
SPECIFIC GRAVITY:	2.7456 (MEASURED)	CATION EXCHANGE CAP.:	20.4 meq/100 g
TOTAL ORGANIC CARBON:			

SIEVE ANALYSIS

SIEVE NO.	DIAMETER (mm)	PERCENT FINER (%)
3.0 in	75.000	100.0
1.5 in	37.500	100.0
0.75 in	19.000	100.0
0.375 in	9.500	99.4
NO. 4	4.750	98.9
NO. 10	2.000	95.8
NO. 20	0.850	91.5
NO. 40	0.425	87.6
NO. 60	0.250	84.4
NO. 140	0.106	84.0
NO. 200	0.075	76.9

HYDROMETER ANALYSIS

DIAMETER (mm)	PERCENT FINER (%)
0.0518	76.9
0.0383	70.6
0.0277	66.7
0.0182	59.6
0.0113	45.5
0.0084	35.3
0.0061	29.8
0.0044	25.1
0.0029	21.2
0.0014	13.3

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IT Corporation
November 20, 1992
Client Project ID: FERNALD OU5
ETDC Project No.: 483500.048.01

ANALYSIS DATES

ANALYSIS	ETDC-2850 (1055/29-1)	ETDC-2851 (1055/29-2)	ETDC-2852 (1055/29-3)	ETDC-2853 (1055/29-4)
MOISTURE CONTENT	11/09/92	11/09/92	11/09/92	11/09/92
PARTICLE SIZE	11/16/92	11/19/92	11/16/92	11/16/92
ATTERBERG LIMITS	11/17/92	11/18/92	11/18/92	11/19/92
SPECIFIC GRAVITY	11/13/92	11/13/92	11/13/92	11/13/92
CATION EXCHANGE CAPACITY	10/23/92	10/23/92	10/23/92	10/23/92
TOTAL ORGANIC CARBON CONTENT				

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5 Client No. 7204

Project Number: 419195 ETDC No. 7204

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.04807	92.3%
	0.03399	92.3%
	0.02403	92.3%
	0.01737	74.4%
	0.01142	51.3%
	0.00845	41.0%
	0.00618	33.3%
	0.00448	28.2%
	0.00316	23.1%
	0.00136	15.4%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5

Client No. 7217

Project Number: 419195

ETDC No. 7217

Specific Gravity 2.6500
Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.04922	100.8%
	0.03559	97.9%
	0.02661	89.2%
	0.01930	63.3%
	0.01226	40.3%
	0.00922	23.0%
	0.00652	23.0%
	0.00473	14.4%
	0.00334	8.6%
	0.00142	2.9%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5 Client No. 7224

Project Number: 419195 ETDC No. 7224

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.04807	93.7%
	0.03399	93.7%
	0.02461	91.1%
	0.01872	62.5%
	0.01169	46.9%
	0.00885	31.2%
	0.00652	20.8%
	0.00470	15.6%
	0.00331	10.4%
	0.00140	5.2%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5

Client No. 7412

Project Number: 419195

ETDC No. 7412

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

	Sieve No.	Diameter mm	Percent Finer
COARSE	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

	Sieve No.	Diameter mm	Percent Finer
FINE	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

	Diameter mm	Percent Finer
HYDROMETER	0.04807	103.0%
	0.03480	100.1%
	0.02517	97.3%
	0.01769	80.1%
	0.01153	54.4%
	0.00867	40.1%
	0.00633	31.5%
	0.00456	25.7%
	0.00322	20.0%
	0.00137	14.3%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5 Client No. 7420

Project Number: 419195 ETDC No. 7420

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.05107	120.4%
	0.03763	113.1%
	0.02797	102.1%
	0.01901	83.9%
	0.01226	51.1%
	0.00902	36.5%
	0.00652	29.2%
	0.00473	18.2%
	0.00331	14.6%
	0.00142	3.6%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5

Client No. 7429

Project Number: 419195

ETDC No. 7429

Specific Gravity 2.6500
Assumed

Moisture Content = NA

SIEVE ANALYSIS

	Sieve No.	Diameter mm	Percent Finer
COARSE	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

	Sieve No.	Diameter mm	Percent Finer
FINE	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

	Diameter mm	Percent Finer
HYDROMETER	0.04807	88.5%
	0.03399	88.5%
	0.02403	88.5%
	0.01769	68.9%
	0.01153	46.7%
	0.00867	34.4%
	0.00652	19.7%
	0.00470	14.8%
	0.00331	9.8%
	0.00140	4.9%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5 Client No. 7017

Project Number: 419195 ETDC No. 7017

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.05107	102.1%
	0.03763	95.9%
	0.02797	86.6%
	0.01872	74.3%
	0.01169	55.7%
	0.00856	46.4%
	0.00618	40.2%
	0.00451	30.9%
	0.00320	24.8%
	0.00137	15.5%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5

Client No. 7511

Project Number: 419195

ETDC No. 7511

Specific Gravity 2.6500 Assumed

Moisture Content = NA

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.04807	102.7%
	0.03559	97.0%
	0.02661	88.5%
	0.01821	74.2%
	0.01126	59.9%
	0.00845	45.7%
	0.00613	40.0%
	0.00448	31.4%
	0.00316	25.7%
	0.00137	14.3%

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PARTICLE SIZE ANALYSIS
ASTM D 422

Project Name: FERNALD OU5 Client No. 7528

Project Number: 419195 ETDC No. 7528

Specific Gravity 2.6500 Assumed

Moisture Content = NA

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SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

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FINE	Sieve No.	Diameter mm	Percent Finer
	#20	0.850	100.0%
	#40	0.425	100.0%
	#60	0.250	100.0%
	#100	0.149	100.0%
	#140	0.106	100.0%
	#200	0.075	100.0%

D

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer
	0.04807	81.5%
	0.03399	81.5%
	0.02403	81.5%
	0.01705	67.9%
	0.01051	58.8%
	0.00808	45.3%
	0.00598	36.2%
	0.00451	22.6%
	0.00320	18.1%
	0.00138	9.1%

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APPENDIX E

OFF-SITE DISPOSAL FACILITY WASTE ACCEPTANCE CRITERIA

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LIST OF ACRONYMS

DOE	U.S. Department of Energy
DOE-NV	U.S. Department of Energy - Nevada Field Office
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
LDR	land disposal restriction
LLW	low-level waste
MW	mixed waste
NTS	Nevada Test Site
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
WAC	waste acceptance criteria
WIPP	Waste Isolation Pilot Project

E.1.0 PURPOSE

This appendix summarizes the waste acceptance criteria (WAC) for the Nevada Test Site (NTS) and for a permitted representative commercial disposal facility near Clive, Utah. Appendix E provides a brief description of Operable Unit 5 wastes and a demonstration of compliance with each facility's WAC.

The Utah facility has been identified for purposes of remedial alternative development and evaluation. The WAC for the commercial facility and NTS were both considered in this appendix due to the anticipated extended duration of Operable Unit 5 remedial activities (up to 20 years for soil/sediment excavation and desorption and up to 35 years for wastewater treatment operations). For costing purposes in alternative evaluation, only the commercial facility was used.

E.2.0 GENERAL INFORMATION FOR POTENTIAL DISPOSAL FACILITIES

E.2.1 NEVADA TEST SITE

The NTS is located in Nye County, Nevada, with the southeast corner lying about 65 miles northwest of the city of Las Vegas, Nevada. The NTS encompasses about 1350 square miles, an area larger than the State of Rhode Island; dimensions vary from 28 to 35 miles in width (eastern to western border) and from 40 to 55 miles in length (northern to southern border). The NTS is surrounded on the east, north, and west sides by public access exclusion areas that provide a buffer zone between the test areas and public lands.

The NTS has been the primary location for testing the nation's nuclear explosive devices since January 1951. The NTS is operated by the U.S. Department of Energy (DOE) as the on-continent nuclear weapons test site. Since 1978, the NTS has also served as a major disposal facility for low-level waste (LLW) generated at the facility and at other DOE sites. On-site LLW is generated from three primary sources: laboratories, weapons testing activities, and decommissioning of retired test sites. Off-site LLW from other DOE sites must be prepackaged to meet NTS criteria. Both on-site and off-site waste is placed in shallow pits and trenches for disposal. Waste requiring greater confinement has been placed in augered shafts. While the majority of the packaged waste is unclassified, NTS disposes of a small amount of classified LLW.

The Fernald Environmental Management Project (FEMP) has been shipping LLW to NTS since August 1984. Shipments have historically consisted of backlog LLW that has accumulated since on-site disposal ceased in 1986. Shipment of additional waste streams generated from remedial activities within Operable Unit 5 would potentially require revisions to the current application for disposal.

E.2.2 REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY

The representative permitted commercial disposal facility is located on the eastern edge of the Great Salt Lake Desert, 3 miles west of the Cedar Mountains, near Clive, Utah. The desert area extends for approximately 60 miles from the Nevada border on the west to a series of north-south-trending mountain ranges on the east. A 10-mile area of state-owned land surrounds the site and is rarely used for recreational purposes.

On February 2, 1988, the representative permitted commercial disposal facility received its license for the disposal of naturally occurring radioactive material and, later, for LLW and mixed waste (MW). The site meets all the requirements of 40 CFR 192 and the Utah Radiation Control Rules of R447-25, which conform to 10 CFR 61. The facility also holds a Resource Conservation and Recovery Act (RCRA) Part B Permit from the Utah Division of Solid and Hazardous Waste. The permit allows the facility to accept, treat and dispose of a solid mixed waste that requires stabilization in order to meet

land disposal restrictions (LDRs). The total developed and permitted capacity of the facility is 2.5 million cubic yards. Of this capacity, 0.5 million cubic yards has already been disposed and 0.5 million cubic yards of capacity has firm contractual commitment, leaving 1.5 million cubic yards available. The draft Proposed Plan for Operable Unit 1 at the FEMP tentatively identifies the planned shipment of 630,000 cubic yards to this facility. On the basis of discussions with the facility, the available capacity could be expanded. Such expansion would require up to a 6-month permit revision cycle.

E.3.0 OPERABLE UNIT 5 WASTE STREAMS

Table E.3-1 summarizes waste streams potentially generated by Operable Unit 5 remedial activities and indicates the WAC classification for each stream. The table further indicates the representative off-site disposal facility contemplated to receive the waste streams for purposes of alternative development and evaluation.

TABLE E.3-1

OPERABLE UNIT 5 POTENTIAL WASTE STREAMS

Materials Potentially Generated from Remedial Actions Requiring Off-Site Disposal[a]	Waste Acceptance Criteria Classification	Representative Off-Site Disposal Facility
Soil/sediment contaminated with radioactive and other hazardous substances	LLW[b]	Permitted commercial disposal facility
Soil/sediment containing listed hazardous wastes following pretreatment to meet land disposal restrictions	Listed mixed waste	Permitted commercial disposal facility
Wastewater treatment sludge	LLW	Permitted commercial disposal facility
Soil washing sludge/debris	LLW	Permitted commercial disposal facility
Facility deconstruction residuals	LLW	Permitted commercial disposal facility
Facility deconstruction debris	LLW	Permitted commercial disposal facility
Excavation debris (roots, rubble, etc.)	LLW	Permitted commercial disposal facility
Miscellaneous remedial action wastes and debris (i.e., protective clothing, etc.)	LLW or clean solid waste	LLW - permitted commercial disposal facility or Nevada Test Site Solid waste - local sanitary landfill

[a] Includes soil/sediment pretreated to eliminate any detected Resource Conservation and Recovery Act characteristics or polychlorinated biphenyls above regulated limits.
[b] Low-level waste

E.4.0 WASTE ACCEPTANCE CRITERIA - NEVADA TEST SITE

The DOE's Nevada Operations Office (DOE-NV) establishes NTS WAC and requirements for waste certification and transfer under document number NVO-325. The criteria in NVO-325 apply to all defense radioactive wastes received at NTS for storage or disposal. WAC are consistent and in compliance with DOE Order 5820.2A and all applicable federal, state, and local regulatory requirements. NTS may only accept waste from generators designated by DOE-Headquarters and approved by DOE-NV.

Before shipping waste to the NTS, the generator must complete the application process and obtain DOE-NV approval. The application includes general items such as facility location, operating information and organizational charts, plans for waste handling and traceability, waste minimization plan, and funding as well as specific information on the waste streams. Once the application is approved, changes or additions to the application can be made. In addition, DOE-NV will conduct annual audits on the generating facility to ensure compliance with its WAC.

Waste Characterization

As part of the NTS waste acceptance criteria, a generator is required to demonstrate compliance with 40 CFR 261 through 268 and to provide information required under DOE Order 5820.2A for a performance assessment of the waste disposal site.

The NTS will not accept wastes regulated as hazardous under RCRA or wastes containing 50 parts per million or more of polychlorinated biphenyls (PCBs) under the Toxic Substance Control Act. Process knowledge and/or sampling and analysis may be used to demonstrate compliance with these requirements. The NTS requires the generator to submit a sampling and analysis plan for approval before shipping waste to the facility. Detailed guidance on preparation of the plan is provided in NVO-325.

Waste Stream Information

The NTS requires the generator to provide specific information for each waste stream that will be disposed of at the facility. Physical data (such as particle size, moisture content, and waste form) and chemical data (such as radiological and hazardous) must be provided for each waste stream being offered for disposal. In addition, the generator is required to submit a three-year forecast summary for each waste stream to be shipped that includes information such as container type and size, number of shipments, and expected total volume to be shipped.

Waste Certification

The NTS requires generators to develop a waste certification program to ensure all WAC are met. The program must be documented in the waste certification program plan, which defines the generator's quality assurance program as it applies to waste certification and characterization. NTS requires the generator to designate a waste certification official to certify that all WAC are met before shipment. The generator may also designate a package certifier, who must be independent of waste generation activities, and who certifies that the package to be shipped and its contents meet U.S. Department of Transportation, U.S. Environmental Protection Agency, and DOE-NV requirements.

E.5.0 WASTE ACCEPTANCE CRITERIA FOR A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY

The representative permitted commercial disposal facility confirms compliance with its WAC through an application process. Before shipping waste to the facility, the generator is required to complete several forms as appropriate: low-activity profile sheet (EC-0200), physical properties form (EC-0500), radiological evaluation (EC-0650), and/or a mixed waste profile form (EC-0175). Each of these forms requests specific information about the waste stream and establishes sampling and analysis requirements. Once a generator has completed the appropriate forms, submitted analytical lab results and received facility approval, shipments of waste may begin.

The radioactive materials license for the facility also places restrictions on the amount of waste the facility may have in active processing, maximum quantities of special nuclear material that may be handled, and maximum concentrations of mixtures of radionuclides that may be present in each waste stream. The representative permitted commercial disposal facility's WAC ensure compliance with the requirements of its radioactive and hazardous waste licenses.

Waste Characterization

69 The facility's radioactive material license, granted by the Utah Department of Environmental Quality, Division of Radiation Control, establishes maximum average concentrations permissible in the waste that is to be disposed. Concentrations are considered by individual isotope. If the waste is natural or depleted uranium, it must be under a given activity level. Table E.5-1 lists the radionuclide constituents of concern at the FEMP, their maximum detected levels and the maximum average concentrations permissible in waste disposed of at the permitted commercial facility. Of all the listed radionuclide constituents of concern in Table E.5.1, only three would not meet the WAC for the permitted commercial facility. Protactinium-231 is not a listed permissible waste and both radium-236's and uranium-235's maximum detected levels are above the maximum average concentrations allowable for the permitted commercial facility.

The facility is also permitted by the Utah Bureau of Solid and Hazardous Waste for disposal of "mixed" waste. Hazardous wastes on the permit include D-characteristic wastes, and most F-, P-, U-, and K-listed wastes. The facility is not permitted to accept F-listed dioxins.

The waste profile forms that must be completed before shipment provide the facility with the information needed to ensure compliance with these requirements. The generator is also required to send a sample of the waste before shipment. The facility uses this sample to verify that the waste meets all WAC.

Waste Certification

The representative permitted commercial disposal facility is responsible for waste certification under the terms of its license. The facility maintains a waste characterization plan that establishes the procedures for characterizing, sampling, and accepting incoming shipments at the facility. The first step is the waste generator's characterization as described above. The second step requires the facility to sample and analyze the incoming waste for radiological and chemical parameters. The facility then accepts or rejects the shipment based on the analytical results and the WAC. If the waste is accepted, final disposition takes place.

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TABLE E.5-1
CHARACTERIZATION OF WASTE FOR DISPOSAL AT A COMMERCIAL FACILITY

Radionuclide Constituents of Concern	FEMP Maximum Detected Level		Maximum Average Concentration in Waste for Disposal (pCi/g)
	Surface Soil (pCi/g)	Subsurface Soil (pCi/g)	
Cesium-137	4.26	2.94	5.6E+02
Neptunium-237	2.63	0.31	2.0E+03
Protactinium-231	5.04	Not available	Not listed
Lead-210	1.69E+02	34.0	2.3E+05
Plutonium-238	1.58E+02	1.58E+02	1.0E+04
Plutonium-240	12.9	5.50	1.0E+04
Radium-226	2.95E+03	1.37E+02	2.0E+03
Radium-228	5.58E+02	29.9	1.8E+03
Ruthenium-106	10.5	Not available	1.9E+04
Strontium-90	26.3	47.6	2.0E+04
Technetium-99	6.02E+02	2.05E+02	1.0E+05
Thorium-228	3.15E+02	19.5	6.8E+02
Thorium-230	7.9E+03	1.53E+02	1.5E+04
Thorium-232	2.83E+02	8.07	6.8E+02
Uranium-234	1.81E+04	3.19E+02	3.7E+04
Uranium-235	1.02E+03	36.2	7.7E+02
Uranium-236	5.0		3.6E+04
Uranium-238	1.91E+04	3.17E+02	2.8E+04

E.6.0 COMPLIANCE WITH WASTE ACCEPTANCE CRITERIA

Tables E.6-1 through E.6-4 provide specific waste acceptance requirements for NTS and the representative permitted commercial facility. The tables identify specific parameters each facility will use to determine if incoming waste is acceptable for disposal. The tables also indicate how Operable Unit 5 contaminated soil, sediment, and treatment residuals will comply with waste acceptance requirements.

TABLE E.6-1

COMPLIANCE WITH GENERAL CRITERIA

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Packaging	Packaging must be strong and tight and of a type used specifically for shipping low-specific-activity waste. Type A packaging must meet the requirements of 49 CFR 173.411 and 49 CFR 173.412. Type A packaging must also meet certification requirements of MLM-3245. Type B packaging must meet the requirements of 10 CFR 71.	Licensed material shall not be disposed of unless concentrations of radionuclides are appropriately homogeneous with the physical form of the waste. Bulk shipment of waste is preferred. Dept. of Transportation (DOT) packaging requirements are applicable.	The waste shipment program for NTS can be easily developed for compliance with the referenced requirements. Shipment to the representative permitted commercial disposal facility will be in bulk by rail. Containerization in bags and covered rail cars will meet DOT packaging requirements.
Bulk	Only low-level waste (LLW) is accepted in bulk and must be shipped in closed transport vehicles. Bulk waste is to be contained such that personnel can off load the waste without contaminating personnel or equipment. Bulk waste must meet the requirements of 49 CFR 173.425. Bulk waste containers may be returned to the waste generator.	LLW and MW may be shipped as volumetric bulky materials or structural debris. The representative facility requires that the optimum moisture content be maintained (determined by the Standard Proctor test [ASTM D-698]).	Contaminated soil/sediment and treatment residuals would be shipped to NTS and would be transported in sealed containers. Materials shipped to the permitted commercial facility would be transported in bulk and would meet the moisture content requirement. Wastewater treatment and soil washing residuals may require drying or the addition of absorbents to meet free water requirements.
Criticality	The quantity of fissile material within a package shall be limited so that an infinite array of such packages will remain subcritical. The quantity of fissile material shall be determined on the basis of a waste-specific nuclear safety analysis (49 CFR 173.451).	Representative facility limits on radionuclide concentrations in wastes preclude criticality concerns.	The radiological characteristics of the soil/sediment as documented by the Operable Unit 5 Remedial Investigation (RI) Report and the envisioned characteristics of treatment residuals preclude criticality concerns on a per shipment basis.
Decay heat	The quantity of radioactive material in a package or waste matrix shall be limited to the extent that the effects of nuclear decay heat will not adversely affect the physical integrity of a package or the chemical stability of its contents or the waste matrix generally (49 CFR 173.442).	Representative facility limits on radionuclide concentrations in wastes preclude decay heat concerns.	The radiological characteristics of the soil/sediment as documented by the Operable Unit 5 RI Report and the envisioned characteristics of treatment residuals preclude decay heat concerns on a per shipment basis.

TABLE E.6-1
(Continued)

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Radiation	The external radiation levels for packages shall not exceed 200 mrem/hr on contact during handling, shipment, and disposal (49 CFR 173.441). DOT regulatory exceptions will be acceptable on a case-by-case basis. Type B containers that require remote handling will be addressed on a case-by-case basis.	DOT requirements are applicable.	The relatively low activity concentrations associated with Operable Unit 5 contaminated soil and sediment and treatment residuals preclude the potential to exceed this limit. A waste shipment certification program shall be developed accordingly.
External contamination	Packages shall be within DOT contamination limits upon receipt at NTS (49 CFR 173.443).	DOT requirements are applicable for incoming vehicles or equipment. Vehicles or equipment shall not be released from the facility for unrestricted use if removable contamination exceeds 10 dpm/cm^2 or 2 dpm/cm^2.	Shipments will be made such that all DOT requirements are met. A shipment certification program shall be developed accordingly.
Activity	Transport requirements for LLW shall be met for strong, tight packages (49 CFR 173.421, 49 CFR 173.425). Where applicable, activity limits for Type A and Type B packages shall be met (49 CFR 173.431).	Allowable representative facility radionuclide activity levels are lower than DOT allowable.	Shipments to NTS will meet all DOT packaging requirements. Representative facility activity levels for shipment will be met which will preclude DOT concerns.
Multiple hazards	Material shall be packaged according to the most severe level of hazard (49 CFR 173.2).	DOT requirements are applicable.	Shipments will be made such that all DOT requirements are met.
Marking	All waste received from off-site generators shall be marked and labeled (49 CFR 172). Chemically hazardous material shall be labeled in accordance with 49 CFR 173.2. All packages shall be marked with a unique package identifier. Bar coding denoting shipment, package, and waste stream identification is required. Bulk waste shipments must be accompanied by appropriate waste identification documentation.	DOT requirements are applicable.	All shipments will meet DOT requirements for marking and labelling.

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TABLE E.6-2

COMPLIANCE WITH PACKAGE-SPECIFIC CRITERIA

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Closure	The package closure shall not be breached under normal handling conditions and shall not be the weakest structural element in the package.	Dept. of Transportation (DOT) requirements are applicable.	Shipments to NTS would meet DOT container requirements; bulk shipments to the representative facility would also meet DOT requirements for bulk shipping.
Strength	Packages (contents considered) shall be capable of supporting a uniformly distributed load of 4000 psf on any of the surfaces. (Sea/land containers, steel drums and bulk waste are exempted from this requirement.)	DOT requirements are applicable.	Shipments to NTS would meet DOT container requirements; bulk shipments to the representative facility would also meet DOT requirements for bulk shipping.
Handling	All waste packages shall be provided with permanently attached skids, cleats, offsets, rings, handles or other auxiliary lifting devices to allow handling by means of forklifts, cranes, or similar equipment. Lifting rings and other auxiliary lifting devices on the package must not inhibit stacking of the packages. Lifting devices must have a 5:1 safety factor based on the device's ultimate strength.	DOT requirements are applicable.	Bulk shipments to the representative facility would also meet DOT requirements for bulk rail shipping. Because the Fernald Environmental Management Project (FEMP) is currently shipping waste to NTS, compliance with the handling and shipping container safety requirements has been implemented.
Size	Dept. of Energy - Nevada Field Office (DOE/NV) recommends that 4- x 4- x 7-A or 4- x 2- x 7-A (width, height, length) boxes or 55-gallon steel drums be used. Other size containers are acceptable with approval of DOE/NV.	Bulk or packaged waste is permitted. Unpackaged debris shall be less than 10 inches in at least one dimension and no longer than 8 feet in any other dimension.	Bulk shipments to the representative facility would be treated before shipment to ensure compliance with size requirements. Because the FEMP is currently shipping waste to NTS, compliance with the size requirements has been implemented.

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TABLE E.6-2
(Continued)

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Weight	NTS imposes limits of 9000 lbs. per box and 1200 lbs. per 55-gallon drum. Packages exceeding these limits require crane handling and if approved by DOE/NV must be shipped in removable-top or removable-side trailers. Packages in excess of 9000 lbs. will result in additional disposal cost to the waste generator.	DOT requirements are applicable.	Bulk shipments to the representative facility would also meet DOT requirements for bulk rail shipping. Because the FEMP is currently shipping waste to NTS, compliance with the container weight requirements has been implemented.
Void space	Waste packages shall use package volume in such a fashion as to ensure matrix stability and efficiency (maximum amount of waste in minimum volume).	Void space in packages should be minimized.	Shipments to the representative facility would be in bulk: therefore void space requirements for containers do not apply.
Nonstandard Type A packaging	Use of Type A packaging not evaluated under the DOE Type A Package Certification Program (MLM-3245, DOT 7A Type A Certification Document) will not be permitted.	DOT requirements are applicable.	Shipments to NTS would meet DOT container requirements - waste would not be shipped in packaging not evaluated under the DOE program; shipments to the representative facility would meet DOT requirements for bulk shipping.
Packaging protection	Each waste package shall be prepared for shipment so as to minimize damage during transit. Preshipment storage shall be controlled to avoid adverse effects of weather or other factors on the containment capability of the waste packaging during handling, storage, and transport. The accumulation of moisture on or in packages before arrival at the NTS shall be avoided. Each waste container shall be provided with tamper indication devices once all certification actions have been taken.	DOT requirements are applicable.	There will be no preshipment storage before transport to the representative facility. Because the FEMP is currently shipping waste to NTS, compliance with the package protection requirements has been implemented.

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TABLE E.6-3

COMPLIANCE WITH WASTE-FORM CRITERIA

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Transuranics	Low-level waste (LLW) must have a transuranic nuclide concentration not greater than 100 nCi/g. Transuranic waste must meet all NTS acceptance criteria. Transuranic waste exceeding these requirements is accepted at NTS only for interim storage before shipment to the Waste Isolation Pilot Project (WIPP) facility. Certification that the waste form meets WIPP minimum waste acceptance criteria is required.	Acceptable activity limits preclude acceptance of transuranic waste.	The analytical data presented in the Remedial Investigation Report and projected treatment systems indicate that the soil/sediment and residuals in Operable Unit 5 do not meet the definition of a transuranic waste.
Hazardous waste	LLW offered for disposal at NTS waste management sites shall not exhibit any characteristics of or be listed as hazardous waste as identified in 40 CFR 261.	Mixed waste and hazardous waste are accepted by the representative facility.	Soil/sediment exhibiting a characteristic of a hazardous waste will be treated to remove the characteristic before shipment. Soil washing residuals and advanced wastewater treatment sludges are not expected to exhibit characteristics of hazardous waste. Soil containing listed hazardous waste from remedial activities adjacent to hazardous waste management units will be segregated and separately shipped to the representative facility. Sampling and analysis will be conducted during posttreatment to ensure compliance with this requirement.
Free liquids	Minor liquid residue remaining in well-drained containers, or liquids which have been entrapped, are acceptable. In no case shall free liquid content exceed 0.5 percent by volume. Use of Method 9095 (Paint Filter Test - EPA Publication SW-846) may be required to demonstrate compliance with this requirement.	Radioactive waste containing liquid shall not be accepted for disposal except as provided by the groundwater discharge permit number UGW 450005, issued by the Executive Secretary of the Utah Water Quality Board.	Contaminated soil/sediment will be transported with the addition of adsorbent to the extent required to ensure the waste form criteria is attained. Wastewater treatment sludges and soil washing residuals will be dewatered before shipment.

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TABLE E.6-3
(Continued)

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Particulate	Fine particulate wastes with radioactive contamination shall be immobilized so that the waste package contains no more than one weight percent of less than 10-μm-diameter particles or 15 weight percent of less than 200-μm-diameter particles. When immobilization is impractical, the waste packaging shall include a sealed liner and be overpacked.	Dept. of Transportation (DOT) requirements are applicable.	DOT containerization requirements for bulk shipment of LLW to the representative facility will be met by use of covered rail cars. Sealed boxes will be used for shipments to NTS.
Gases	Radioactive gases shall be stabilized or absorbed so that pressure in the waste package does not exceed 1.5 atmosphere at 20°C. Compressed gases (49 CFR 173.300) will not be accepted for disposal.	Not accepted for disposal.	Not applicable.
Stabilization	Where practical, waste shall be treated to reduce volume and provide a more physically and chemically stable waste form. Wastes shall not significantly react with the packaging during normal storage, shipping, and handling time.	No direct requirement.	No stabilization required for the shipment of contaminated soil/sediment; soil washing residuals and wastewater treatment sludges will be dewatered and mixed with absorbents as required. Stabilization of residuals will be completed, if required, to meet waste form requirements.
Etiologic agents	LLW containing pathogens, infectious wastes, or other etiologic agents (49 CFR 173.386) will not be accepted for disposal.	LLW containing pathogens, infectious wastes, or other etiologic agents (49 CFR 173.386) will not be accepted for disposal.	These requirements do not apply to Operable Unit 5 materials because the materials do not contain pathogens or infectious wastes.
Chelating agents	LLW containing chelating or complexing agents at concentrations greater than one percent by weight will not be accepted.	Identification of wastes containing more than 0.1% by weight of chelating agents.	These requirements do not apply to Operable Unit 5 materials because they do not contain chelating agents.
Bulk	Shall be solid and meet the requirements of 49 CFR 173.425(c)(3). Bulk mixed waste will not be accepted for disposal in Area 3.	Bulk LLW is the preferred waste form for disposal.	All materials offered for shipment would meet the waste-form criteria and the DOT's definition of solid waste. All material will meet all DOT requirements for shipping in bulk by rail for the representative facility or by containers on trucks for NTS.

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TABLE E.6-4

COMPLIANCE WITH MIXED WASTE ACCEPTANCE CRITERIA

Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Treated waste	Mixed waste (MW) must receive any required treatment before shipping to NTS. MW treatment must follow U.S. Environmental Protection Agency-approved methods and must be in compliance with 40 CFR 268.	Treated waste may be accepted. Non-radioactive hazardous waste must not be mixed with radioactive waste.	Resource Conservation and Recovery Act characteristic waste will meet treatment standards as required under 40 CFR 268 before disposal off site. Soil containing listed hazardous waste will be treated to the extent necessary to remove any land disposal restricted characteristics before transfer to the representative facility.
Asbestos	Radioactively contaminated asbestos capable of giving off friable asbestos dust must be wetted with water and surfactant (adsorbent additive required to control free liquid) and stored in double plastic bags having a combined wall thickness of at least 6 mil. The plastic bags must be overpacked in leak-proof metal or wood containers. Sea/land containers containing radioactive asbestos will be considered on a case-by-case basis. Any regulated asbestos waste must be segregated into a separate stream.	Waste regulated as asbestos may not be accepted by the facility.	Not applicable.
Radioactive waste	Radioactive waste must be treated in accordance with 40 CFR 268 Subpart D as applicable. Explosives, pyrophoric materials, or high-heat generators are not acceptable for MW disposal. Low-level waste (LLW) containing explosive or pyrophoric material in a form that may spontaneously explode or combust if the container is breached will not be accepted. Cyanide- and sulfide-bearing wastes in concentrations greater than 10 percent by weight (Cn^- or S^-) will not be accepted. (Potentially incompatible waste must be identified by the most appropriate compatibility group listed in 40 CFR 264, Appendix V, if accepted for disposal.)	Acceptance criteria for radioactive waste must be met to be accepted by the disposal facility.	Acceptance criteria for radioactive waste for the commercial disposal facility will be attained for all soil/sediment and treatment residuals. Soil washing residues from the sulfuric acid process would not attain NTS waste acceptance criteria.

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TABLE E.6-4
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Requirements	Nevada Test Site (NTS)	Representative Permitted Commercial Disposal Facility	Compliance with Requirements
Waste generator	All Dept. of Energy (DOE) defense facilities are eligible to use the NTS as a disposal or storage site provided NTS acceptance criteria are satisfied.	The representative facility does not accept LLW generated outside the region comprised of the states party to the Northwest Interstate Compact with Alaska, Hawaii, Idaho, Montana, Oregon, Utah, and Washington unless the provisions of Article IV and V of the Compact are met.	The FEMP is a DOE site eligible to use the NTS for disposal. The FEMP has satisfied the provisions of Article IV and V of the Northwest Interstate Compact.
Documentation	Extensive documentation, package labeling and permitting is required; see NVO-325 for details.	Specific forms must be filled out which describe waste stream information and waste physical properties.	All documentation will be completed before shipment of waste for off-site disposal.
Analytical data	Documentation and analysis of waste streams is required; see NVO-325 for details.	Analytical results should be submitted. Utah or certified Contract Laboratory Programs may be used. Samples of waste must be sent to the representative facility.	Sampling and analysis requirements and frequencies will be completed before shipment for off-site disposal.
Polychlorinated biphenyls (PCBs)	PCB-contaminated waste will not be accepted for disposal at NTS unless the PCB concentration meets municipal solid waste disposal levels (40 CFR 761.60).	PCB-contaminated waste will not be accepted for disposal at representative facility unless PCB concentrations meet municipal solid waste disposal levels.	Any PCB-contaminated soil exceeding waste acceptance requirements will be pretreated before shipment.

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LIST OF ACRONYMS

ACL	alternate concentration limit
AMS	air monitoring station
ARAR	applicable or relevant and appropriate requirement
COC	constituent of concern
COE	U.S. Army Corps of Engineers
CPC	constituent of potential concern
CPRG	cross-media preliminary remedial goal
CRARE	comprehensive response action risk evaluation
DMEPP	Design, Monitoring, and Evaluation Program Plan
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FOC	fraction of organic content
FS	feasibility study
GTF	Groundwater Treatment Facility
HDPE	high density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
HQ	hazard quotient
HWMU	hazardous waste management unit
ILCR	incremental lifetime cancer risk
ISCLT	Industrial Source Complex Long-Term Vision
MCL	maximum concentration limit
MPRG	modified preliminary remedial goal
MUSLE	Modified Universal Soil Loss Equation
NRC	Nuclear Regulatory Commission
ODAST	One-Dimensional Analytical Solute Transport
ORNL	Oak Ridge National Laboratories
PAH	polycyclic aromatic hydrocarbon
PC	personal computer
PCB	polychlorinated biphenyl
PRA	preferred remedial alternative
PRG	preliminary remedial goal

PRL	preliminary remedial level
PSP	Project Specific Plan
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
SCS	Soil Conservation Service
SOWC	Southwestern Ohio Water Company
SSOD	Storm sewer outfall ditch
STAR	Statistical Arrays
SWF&IM	Surface Water Flow and Infiltration Model
SWIFT	Sandia Waste Isolation Flow and Transport
TCLP	Toxicity Characteristic Leaching Procedure
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
VOC	volatile organic compound
WAC	waste acceptance criteria

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F.1.0 OVERVIEW OF THE FATE AND TRANSPORT MODELING PROCESS

Different stages of the Operable Unit 5 remedial investigation/feasibility study (RI/FS) process include fate and transport modeling, as shown in Figure F.1-1. This appendix presents the approach and results of the contaminant fate and transport modeling performed to support the selection and evaluation of preliminary remedial alternatives evaluated in the Operable Unit 5 feasibility study (FS) by determining required cleanup levels and simulating effects of various media-specific remedial actions. Modeling to support the site-wide residual risk assessment required in the comprehensive response action risk evaluation (CRARE) is described in Appendix H.

The effects that remedial actions have on future contaminant conditions within and around the Fernald Environmental Management Project (FEMP) are quantitatively evaluated in the Operable Unit 5 FS. Results of this evaluation are factored into the selection of acceptable remedial alternatives. Fate and transport modeling is conducted to determine required levels of cleanup to support the design of preliminary remedial alternatives and to simulate the future migration of residual contamination. In general, the purpose of contaminant fate and transport modeling is to provide predictions regarding future exposures, under given remedial scenarios, to on- and off-property receptors.

In addition to presenting quantitative modeling results to support the Operable Unit 5 FS, this appendix also provides rationale for and justifies assumptions regarding:

- Conceptual model of residual contaminant migration
- Important chemical characteristics
- Screening and selection of current and post-remediation contaminants of potential concern
- Critical model parameters.

Limitations of the modeling tools used as well as uncertainty analyses of modeling results are evaluated in this appendix, information that is useful during the remedial alternatives design process.

F.1.1 OVERALL OBJECTIVES

The main objective of the fate and transport modeling for the Operable Unit 5 remedial investigation (RI) was to determine the need for additional remedial actions that recover or contain contaminants that have already been released into the environment, after the source loadings have been stopped or reduced by the other operable units (described in separate RI/FS documents). The final Operable Unit 5 RI Report concludes that additional remedial actions are required in soil, sediment, perched groundwater, and the Great Miami Aquifer. Therefore, the objective of the fate and transport modeling for the Operable Unit 5 FS is to support the design and selection of remedial alternatives

that incorporate all the media- and source-specific remedial actions to be conducted at the FEMP by Operable Unit 5 to achieve various future land-use objectives.

During the FS process, contaminant fate and transport models are applied to predict contaminant migration from residual source areas to potential human or ecological receptors through environmental media such as air, surface water, and groundwater after various remedial actions over a 1000-year time frame. As in the RI, conservative assumptions are used in the models to simplify modeling procedures and to provide a "reasonable worst case" picture of future contamination conditions.

F.1.2 SUMMARY OF TERMINOLOGY

Definitions of the key terminologies frequently used in this appendix are summarized below.

- Land-Use Objective: A combination of protective levels and exposure receptors defined under one of the four overall future land-use scenarios at the FEMP.
- Remedial Component: A component of a remedial alternative that is used to handle a specific type of contaminated material such as soil, perched groundwater, and groundwater in the Great Miami Aquifer.
- Remedial Alternative: A combination of remedial components designed to achieve an overall land-use objective.
- Constituent of Potential Concern (CPC): A constituent that can reach environmental and human receptors with concentrations higher than conservative screening levels; designated through screening by fate and transport modeling.
- Constituent of Concern (COC): A constituent that can create unacceptable impacts to environmental and human receptors; designated through a complete risk analysis.
- Preliminary Remediation Goal (PRG): An acceptable contaminant concentration which only considers direct exposures to a single contaminated medium.
- Cross-Media Preliminary Remediation Goal (CPRG): A cleanup level for a contaminant source which incorporates all of the impacts caused by migration of a contaminant away from the source and through multiple transport media.
- Modified Preliminary Remediation Goal (MPRG): The lower concentration between the PRG and CPRG for a contaminated source medium.
- Preliminary Remediation Level (PRL): The cleanup concentration determined by considering the MPRG, the analytical detection limit, and the medium-specific background concentration.
- Waste Acceptance Criteria (WAC): The acceptable leachate or solid concentrations of waste materials disposed in an engineered facility such as consolidation area with earthen cover, consolidation with cap, and disposal facility.

- Residual Contamination: The contamination remaining after a remedial alternative has been implemented.

- Residual Risk Assessment: The task which quantifies future risks to the environmental and human receptors as a result of residual contamination. The residual risk assessment is conducted in the CRARE for the preferred remedial alternative.

F.1.3 ENVIRONMENTAL MEDIA, POTENTIAL CONTAMINANT TRANSPORT PATHWAYS, AND MODELING DOMAIN

Contaminant migration in the environmental media, changes to hydrogeological and geochemical conditions caused by remedial actions, and the effectiveness of engineered disposal facilities are all evaluated through modeling. The disposal facilities and the environmental media as sources or pathways for current and future residual contamination to be evaluated by the Operable Unit 5 FS include:

- Air in the vicinity of the FEMP
- The Great Miami Aquifer underlying and downgradient of the FEMP
- Surface water, sediment, and surface soil within and in the vicinity of the FEMP
- Surface and subsurface soils in the former production area
- Remaining affected soil within Operable Units 1, 2, and 4 boundaries after completion of remedial actions by these operable units
- All perched groundwater including that within Operable Units 1, 2, and 4 areas
- Future on-property engineered disposal facilities under consideration for Operable Unit 5 and a representative site-wide remedy.

Contaminant transport from the above-listed sources may be along the following pathways:

- Surface water runoff:
  - Erosion of contaminated surface soil into Paddys Run, the storm sewer outfall ditch (SSOD), and the northeast drainage ditch
  - Flow of contaminated surface runoff water into Paddys Run, the SSOD, and the northeast drainage ditch
  - Discharge of treated or untreated storm water and groundwater into the Great Miami River through the FEMP discharge outfall line during remedial action period.

- Groundwater transport:
  - Leaching of contaminants from contaminated soil through the glacial overburden to the underlying Great Miami Aquifer
  - Infiltration of contaminated perched groundwater through the glacial overburden to the underlying Great Miami Aquifer

- Lateral flow of contaminated perched groundwater in the overburden and seepage into surface water bodies
- Infiltration of contaminated surface water from Paddys Run and the SSOD to the Great Miami Aquifer
- Natural and induced flow of groundwater in the Great Miami Aquifer which can carry dissolved contaminants and, potentially, contaminants adsorbed to colloidal particles of up to 2 microns in diameter.

- Air emission:
  - Volatilization of organic compounds, wind erosion of contaminated particulate matter, and the direct release of radon gas.

The Operable Unit 5 fate and transport modeling domain encompasses these environmental media and pathways over an area large enough to cover all major potential contaminant receptor locations identified in the Operable Unit 5 RI baseline risk assessment, as shown in Figure F.1-2. Future conditions at these receptors are predicted in the FS residual risk assessment and used to quantify the effects of remedial actions. Additional future hypothetical on-property receptors are also evaluated during the FS.

F.1.4 FS MODELING TASKS

DOE Different sources of contamination and environmental media have different characteristics which need to be considered in designing remedial alternatives. Feasibility study fate and transport modeling is conducted for individual remedial components (e.g., soil excavation, disposal facility, and groundwater recovery well systems) which are common to all remedial alternatives. This "component" approach simplifies the design and evaluation of remedial alternatives and reduces the required number of modeling runs. Modeling tasks presented in this appendix include:

- Development of soil CPRGs (Section F.3.0)
- Evaluation of protective requirements for soil considering the air and surface water pathways (Section F.4.0)
- Development of WAC for disposal facilities (Section F.5.0)
- Evaluation and selection of the perched groundwater remedial actions (Section F.6.0)
- Evaluation and selection of the Great Miami Aquifer remedial actions (Section F.7.0)
- Optimization of the Great Miami Aquifer remedial action (Section F.8.0)

These tasks are briefly described on the next page.

CPRG Development

Allowable direct exposure concentrations (i.e., PRGs) for soil, perched groundwater, and groundwater in the Great Miami Aquifer are determined by risk calculations for given combinations of land-use objectives and protective levels. Because contaminants can migrate to receptors, away from the residual source areas, fate and transport modeling is used to back-calculate acceptable residual source concentrations based on acceptable exposure concentrations at the receptor locations away from the sources. These acceptable residual source concentrations which consider potential cross-media impacts, are the CPRGs. Area- and media-specific MPRGs and PRLs are then determined by combining both PRGs and CPRGs, as shown in Figure F.1-3. A comparison between PRLs and measured levels of contamination are used to determine the extent of areas that need to be remediated (e.g., excavated). The purposes, technical approaches, and assumptions for CPRG development for contaminated soil are presented in Section F.3.0.

Evaluation of Other Protective Requirements

As shown in Figure F.1-4, protective requirements in air and surface water pathways are not used to develop CPRGs. Because the contaminant source in these two pathways consists of contaminated residual surface soil, the remedial alternatives designed to protect the groundwater pathway can be easily refined by including clean earthen cover and vegetation for exposed soil to prevent air emission and surface runoff of contaminated soil. Therefore, the protective requirements for the air and surface water pathways are developed independent of the initial soil CPRG and incorporated into each remedial alternative during the refinement stage. This approach significantly simplifies the overall modeling and design processes of the FS. The purposes, technical approaches, and assumptions for CPRG development are presented in Section F.4.0.

Protective requirements for the air pathway are developed for the residual surface soil. COC-specific air inhalation PRGs are used to back-calculate acceptable surface soil concentrations considering future impacts to an off-property resident farmer scenario at the FEMP fenceline. Soil PRGs based on future on-property land use scenarios inside the FEMP fenceline are compared to these acceptable concentrations to ensure that different off-property receptors can also be protected.

Protective requirements for the surface water pathway are developed for the residual surface soil in each surface water drainage subbasin in the vicinity of the FEMP. The COC- and subbasin-specific requirements are presented as the acceptable subbasin-average surface soil concentrations that will not cause impacts to surface water bodies and subsequently the Great Miami Aquifer.

WAC Development

The purposes, technical approaches, and assumptions for WAC development are presented in Section F.5.0. WAC are acceptable leachate or solid concentrations for materials placed in a disposal facility (i.e., consolidation area with earthen cover, consolidation with cap, and disposal facility). The WAC are developed and applied to ensure the contaminated materials placed in these facilities will not recontaminate the environmental media in the future. The application procedure of the WAC during evaluation of disposal facilities in each remedial alternative is also discussed. WAC for the on-property consolidation and disposal facilities are required for determining the volumes of waste materials and contaminated soil that can be placed in each of these facilities. The volume of material that needs to be disposed of off property was determined by using the highest on-property WAC for each remedial alternative.

Perched Groundwater Remedial Action Evaluation and Selection

The technical approaches and assumptions used for modeling, to evaluate potential remedial actions for the perched groundwater remedial component, are presented in Section F.6.0. Effects of extraction and excavation of contaminated perched groundwater are simulated. Based on the results of these simulations which define the requirements and effectiveness of each potential remedial action, the most feasible remedy for perched groundwater can be selected and incorporated into all the remedial alternatives.

Great Miami Aquifer Remedial Action Evaluation and Selection

The technical approaches, constraints, and results of designing and evaluating groundwater recovery and containment well systems for the Great Miami Aquifer remedial component are presented in Section F.7.0. Based on acceptable contaminant concentrations in the Great Miami Aquifer, which is used as a drinking water source, groundwater recovery and treatment systems are required to clean up or contain the portion of the aquifer that has unacceptable contaminant concentrations. The selected groundwater remedial action will be conducted in parallel with the remedial actions for contaminant sources, such as contaminated soil and perched groundwater, which can impact the aquifer. However, the groundwater remedial action is expected to last longer than all of the other remedial actions at the FEMP. This remedial action is a common component of every remedial alternative.

DOE Optimization Study

An optimization of the selected Great Miami Aquifer remedial action approach is presented. The optimization identifies treatment strategies that can be used to satisfy regulatory requirements.

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F.1.5 OVERVIEW OF THE TECHNICAL APPROACH

The general technical approaches for all FS fate and transport modeling tasks are briefly summarized below.

F.1.5.1 Conceptual Model of Contaminant Migration

Operable Unit 5 includes all of the environmental media at the FEMP (i.e., groundwater, soil, surface water, sediment, air, flora and fauna). The Great Miami Aquifer and the perched groundwater zone in the glacial overburden are both part of the groundwater media. Surface soil and the underlying glacial deposits make up the soil media. The Great Miami River, Paddys Run, and the SSOD are examples of the surface water media. Sediment within these surface water bodies are part of the sediment media. Sediment media includes materials carried in storm water runoff or site effluent discharged to surface waters or drainage ditches. All of the air in the vicinity of the FEMP makes up the air media. Contaminant migration and further human exposures through flora and fauna are considered in the risk assessment, based on the modeled and measured contaminant concentrations in air, water, and soil.

Residual contaminants can migrate through multiple media pathways and impact potential receptors as shown in Figure F.1-5. These pathways have been the subject of Operable Unit 5 RI studies under the no-action scenario. Understanding the physical and chemical processes which control contaminant migration in these pathways is the basis for determining acceptable remedial alternatives in the FS. The Operable Unit 5 FS focuses on the effects that remedial actions have on contaminant migration in each of the pathways, and factors pathway-specific protective requirements into the remedial components.

Air Pathway

Before production activities ended, air emissions from the former production area were the most significant source of contamination to the environment. Residual contaminants in uncovered surface soil can impact potential receptors through the air pathway. Therefore, remedial alternatives need to be protective of the air pathway. Air emissions associated with Operable Unit 5 residual source areas may involve different types of release mechanisms. If organic compounds are present in the soil, volatilization of these compounds may occur. Radon gas, generated as a result of radioactive decay of radium-226, may be released. During periods of turbulent wind conditions, particles of contaminated surface soil can become suspended in the air and possibly inhaled by on- or off-property human receptors. In the event that previously covered subsurface contaminant sources become uncovered during remediation, the possible transport of this material by wind erosion could become a concern. The amount of material that may be suspended depends on the wind speed and other site conditions such as soil moisture, particle size, and vegetative cover. Any effective remedial action to

control contaminant migration through the air pathway should assess the need for providing sufficient earthen or vegetative cover for contaminated surface soil.

Surface Water Pathway

Surface water runoff is a viable transport pathway for all contaminated surface soil at the FEMP. During a rainfall event, soil particles are dislodged by the impact of raindrops and by the flow of runoff across the soil surface. The amount of soil erosion depends on the rainfall intensity, slope length, slope steepness, vegetative cover, and erosion controls which are in place. The dislodged soil particles travel overland in the runoff and eventually become sediment in the receiving water courses. Contaminants in the soil particles are also dissolved and transported into the runoff water and the receiving surface water. Surface water bodies considered in the FS include drainage ditches within the FEMP, SSOD, Paddys Run, and the Great Miami River. Some of the contaminated surface water can infiltrate into the Great Miami Aquifer through portions of the streambeds of Paddys Run and the SSOD where the streams have cut through the glacial overburden. The South Plume in the Great Miami Aquifer is an example of the impact caused by contaminant migration in the surface water pathway and subsequently the groundwater pathway. An effective long-term remedial action for controlling contaminant migration through surface water pathways needs to provide sufficient earthen or vegetative cover to minimize erosion of contaminated surface soil.

Groundwater Pathway

Rainfall and surface water runoff can infiltrate through the surface soil/sediment and percolate down to the perched water zone and the Great Miami Aquifer. When contaminant migration due to air emission and surface runoff are reduced by providing sufficient cover for residual contaminant source or disposal areas, the Great Miami Aquifer becomes the primary pathway by which residual contaminants could be transported to a human receptor regardless of the future land-use objective. Therefore, the development of PRLs and WAC considers the groundwater pathway first. Protective requirements due to the potential migration of contaminants in the air and surface water pathways are used to refine the remedial alternatives.

415 The migration of water and dissolved contaminants from the source to the receptor involves flow through both unsaturated (vadose zone) and saturated materials. Flow and contaminant transport in these materials is affected by the permeability and effective porosity of the media, the hydraulic gradient, and the degree of saturation. Another factor considered in fate and transport modeling is dispersion (mixing) within the groundwater. Attenuation and retardation are also considered as factors, and both factors may affect the transport of the solute through the system. The three major controlling mechanisms for the groundwater migration pathway are:

- The leaching of contaminants from the soil matrix into the dissolved phase

- The percolation of the contaminated leachate or perched water through the overburden to the underlying aquifer or discharge to surface water bodies through lateral migration through the perched water zone.

- The movement of groundwater in the Great Miami Aquifer.

The contaminant concentrations in leachate reaching groundwater depend on the precipitation/infiltration rate, the initial concentrations, contaminant mass, solubility of the contaminants, degradation rates, soil textures, soil hydraulic conductivities, depth to groundwater, and a number of other chemical- and soil-specific factors.

F.1.5.2 Development of Remedial Alternative

A remedial alternative is a combination of remedial components designed to achieve a specific land-use objective at a given protective level (i.e., hazard index [HI] or incremental lifetime cancer risk [ILCR] levels). Overall, 10 remedial alternatives are developed for 29 land use objectives and protective level combinations, and are evaluated in the Operable Unit 5 FS under four land-use scenarios. Accumulated impacts through all the contaminant migration pathways are considered during the detailed evaluation process for each remedial alternative. For example, the process of combining the protective requirements in all pathways for the soil remedial component, included in every alternative, is presented in Figure F.1-4. Contaminants can migrate through multiple pathways to potential receptors. Therefore, an acceptable remedial alternative needs to be protective of all of these pathways. However, it is very difficult to consider or simulate all the pathways simultaneously; therefore, the development of protective requirements focuses separately on groups of migration pathways. Three major groups of migration pathways are evaluated. The primary group includes perched water and groundwater pathways. Surface water runoff and infiltration into the Great Miami Aquifer through Paddys Run and the SSOD are evaluated as the second group. Impacts through the air pathway are simulated as the third group. After a preliminary remedial alternative is defined using the CPRGs, PRLs, and WAC determined for the primary migration pathways, protective requirements in the remaining pathways are incorporated to refine the soil remedial component (e.g., by adding additional excavation or engineering controls). A complete residual risk assessment for the representative remedial alternative is conducted as a part of the site-wide CRARE.

F.1.5.3 Fate and Transport Models

Contaminant fate and transport models for air, surface water, and groundwater are used to develop CPRGs, WAC, restoration requirements for perched groundwater and the Great Miami Aquifer, and to assess residual risk. Details of the development of the models are documented in the following technical reports and the Operable Unit 5 RI Report (DOE 1995):

- Groundwater Modeling Report - Summary of Model Development (U.S. Department of Energy [DOE] 1993c)

- Groundwater Modeling Evaluation Report and Improvement Plan (DOE 1993b)
- Development and Application of the ECTran Model to Support the RI/FS at the FEMP (DOE 1993a)
- Surface Water Flow and Infiltration Model Summary Report (DOE 1993d)
- SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994).

Applications of these models have also been demonstrated in the Operable Unit 5 final RI report. For details of the model developments and designs, reference should be made to these reports.

Model simulations are conducted to back-calculate CPRGs and WAC at current source areas or future disposal facilities, based on the exposure criteria set at future cross-media receptor locations. Effects and requirements of pumping systems in the Great Miami Aquifer are simulated during the evaluation process for the Great Miami Aquifer remedial component. Future receptor concentrations, due to residual contamination in soil, perched groundwater, and the Great Miami Aquifer under each remedial alternative (a combination of remedial components), are also predicted by modeling. Figure F.1-6 shows the categories of residual source terms and linkages to various fate and transport models for the overall residual risk assessment conducted in the CRARE.

F.1.5.3.1 Air Transport Model

All the air transport analyses are conducted in accordance with U.S. Environmental Protection Agency [EPA] guidance (EPA 1989). Two emission models and an air dispersion model are used to estimate air emissions from each source and to calculate annual average concentrations and deposition rates at various receptor locations. One emission model predicts the quantity of exposed soil that would be resuspended by the wind, and the other emission model (RAECOM) estimates the flux of radon-222 gas from soil containing radium-226. Particulate-phase contaminants examined in the first emission model include radionuclide, inorganic, and semivolatile organic contaminants. Volatile organic contaminants are not considered, as they would be expected to be released to the atmosphere prior to the start of the postremediation periods analyzed in the FS. A brief summary of these models is included in Table F.1-1.

Annual average concentrations and deposition rates for all COCs in the air pathway were determined using the EPA's computerized air dispersion model, Industrial Source Complex Long-Term Version 93109 (ISCLT2). This model is recommended by EPA for air pathway analysis of Superfund sites (EPA 1989). The ISCLT2 model was designed by the EPA for assessing the air quality impact of emissions at user-selected receptors from a variety of sources. It incorporates a steady-state Gaussian plume equation that is applicable for flat or gently rolling terrain. The ISCLT2 model calculates annual average concentrations and deposition rates due to airborne emissions at user-selected

receptors, based on sector-averaged statistical wind summaries known as statistical arrays (STAR). The ISCLT2 model defines sources as any point(s), area or volume that has the potential to generate emissions. The user is required to select from single or multiple point, area or volume sources as input to the model. Input data also includes emission rates from the sources, location and configuration sources, statistical summaries of wind speed, wind direction and atmospheric stability, and locations of receptors of interest.

In general, after the potential air quality impacts for each land-use objective are conceptualized, five major steps are required to complete the air pathway fate and transport modeling to determine the protective requirements or the residual risk:

- Residual sources of air emissions and contaminants released are identified based on specific remedial alternatives.
- The RAECOM model is used to determine the radon emission rates from each of the residual source areas.
- The particulate emission model is used to determine particulate emission rates from the residual source areas. Residual soil concentration data are used to determine the contaminant-specific emission rate from each of the residual areas.
- Additional inputs to the air dispersion model, such as meteorological data and receptor locations, are obtained or developed.
- The air dispersion model (ISCLT2) is used to determine contaminant air concentrations and deposition rates.

F.1.5.3.2 Surface Water Transport Model

Like air transport modeling, surface water transport modeling is used to refine the designs of remedial alternatives and to support the residual risk assessment. Fate and transport modeling via surface water is conducted using the Surface Water Flow and Infiltration Model (SWF&IM) (DOE 1993d) developed for the FEMP and the Operable Unit 5 RI. The SWF&IM is a combination of FEMP-specific hydrological conditions and several hydraulic and transport models used to simulate the various physical and chemical processes involved in the transport of contaminants from surface soil into surface water and the Great Miami Aquifer. The models which comprise the SWF&IM and their connections are described in detail in the documents referenced above. In addition, a summary of these models is presented below and in Table F.1-2.

The SWF&IM consists of the following components. Rainfall and runoff are simulated with the HEC-1 modeling code (U.S. Army Corps of Engineers [COE] 1990). Rating curves for cross sections along Paddys Run and the SSOD are generated using the Mannings Equation (Henderson

1966). The Mannings Equation is applied along Paddys Run and the SSOD to determine the elevation of water in the stream (stage) at each cross section location for a given flow rate (discharge).

76 To calculate infiltration from surface water to the Great Miami Aquifer, the computer code VS2DT
77 (Healy 1990) is applied at each cross section. VS2DT is a two-dimensional numerical groundwater model developed to simulate variably saturated flow conditions. The storm water depth is based on the runoff hydrographs produced using the HEC-1 code combined with the rating curves developed with the Mannings Equation. A time-varying depth of water is input into the VS2DT program for the infiltration calculations to simulate the fluctuation of flow depths in the streams during the representative storm event. The one-year 24-hour storm event is used as the representative storm. The output from VS2DT provides the infiltration volumes and patterns to the Great Miami Aquifer along the study length of Paddys Run and the SSOD. The runoff hydrographs and infiltration information are used in calculating contaminant concentrations and loadings. Detailed discussions of the calculation procedures used to determine the surface water contaminant mass loading rate into the aquifer are presented in Section F.4 and in the Operable Unit 5 RI Report, Appendix F.2.

78 The transport of contaminants centers on the use of the Modified Universal Soil Loss Equation (MUSLE) and Partitioning Equations, both of which are presented in the Superfund Exposure Assessment Manual (EPA 1988). The MUSLE equation is used to calculate the amount of sediment generated from the representative storm event in each subbasin. The partitioning equations are then used to determine the amount of contaminant which will be transported in the dissolved phase with the runoff and the amount that will be transported adsorbed to the sediment. As flows from different subbasins combine, the contaminant concentration in the combined flow is calculated based on a mass balance approach. The Universal Soil Loss Equation (USLE) (EPA 1988) is incorporated in the overall surface water modeling to determine the annual sediment loadings. Short-term impacts to sediment loading during the remediation process will not be quantified in the cleanup goal development process. However, engineering controls will be applied to reduce impacts to minimum levels during remediation.

The SWF&IM is implemented using two surface runoff patterns (i.e., with and without surface runoff controls such as the storm water retention basin). If the future surface water runoff under specific remedial alternatives can be approximated by these two patterns, the results of the hydraulic portion of the SWF&IM are not modified. In these cases, only the residual contaminant concentrations in the surface soil in each of the surface water drainage subbasins are redefined in the model. The SWF&IM predicts future surface water and sediment conditions and impacts to the Great Miami Aquifer under each remedial alternative.

F.1.5.3.3 Groundwater Transport Model

Models used to predict flow and contaminant transport in the groundwater pathways are described in the following subsections. These models are the main tools used to develop CPRGs and WAC and they are also used in the residual risk assessment. A summary of these models is presented in Table F.1-3.

427 The groundwater transport models are classified as screening models or primary models. The primary models (i.e., Sandia Waste Isolation Flow and Transport [SWIFT] and One-Dimensional Analytical Solute Transport [ODAST]/SWIFTLOAD) which cover the FEMP and its vicinity account for accumulative impacts from all the residual contaminant sources and predict future conditions to all the receptors in one simulation run. Primary models require very long computer run times and are not efficient for CPRG and WAC development where many iterative runs are usually required. Because source areas can be simulated individually in the development of CPRGs and WAC, a screening model (i.e., ECTran, DOE 1993a) is used to develop CPRGs and WAC for residual soil contamination and disposal areas separately. In general, the primary models are used to predict the cumulative residual impact for each remedial alternative whose design is based on these CPRGs and WAC. This modeling is conducted to determine the residual site-wide impacts and to verify that the CPRGs and WAC developed by the screening model are protective. The SWIFT model is also used directly to design the Great Miami Aquifer remedial component.

HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) model is used to define infiltration rates (seepage velocities) through the overburden and potential disposal areas, assuming the areas are capped or uncapped. The HELP model (EPA 1984) is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a waste area. The model accepts climatologic, soil, and design data and simulates a number of hydraulic processes including surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. The systems that can be modeled by HELP include various combinations of vegetation, cover soil, waste cells, special drainage layers, and relatively impermeable barrier soil.

The HELP model is designed to perform water budget calculations for a system having as many as nine layers by modeling each of the hydrological processes that occur. Each layer must be identified as either a vertical percolation, lateral drainage, waste, or barrier soil layer. The identification of each layer used in the model is critical because the program models water flow through the various types of layers in different ways. Runoff is computed using the Soil Conservation Service (SCS) runoff curve number method which considers daily precipitation totals. Percolation and vertical water routing are modeled using Darcy's Law for saturated flow, with modifications for unsaturated

conditions. Evapotranspiration is estimated using a modified Penman method, adjusted for limiting soil moisture conditions.

The HELP model produces a table of the daily results, monthly totals, and annual totals for each year if the options for detailed output are used. Following these outputs, the summary output is given. The summary includes average monthly totals, average annual totals, and peak daily values for the simulation variables. The average monthly total reports precipitation, runoff, evapotranspiration, and percolation through the base of each layer, and lateral drainage through each layer for a particular month for all the years of a simulation. The average annual total reports the values on an annual basis. The summary of peak daily values represents the maximum values that occurred on any day during the simulation period.

ODAST/SWIFTLOAD Model

DOE The ODAST/SWIFTLOAD model is used to define vertical contaminant transport from contaminated soil or perched water to the Great Miami Aquifer for the residual risk assessment. ODAST, which is a subroutine of SWIFTLOAD, evaluates the basic one-dimensional analytical solute transport equation as a function of seepage velocity (determined by the HELP model), dispersion coefficient, source decay, retardation factor, depletion time, and source rate. Additional descriptions of ODAST are provided in Attachment F.1 II. SWIFTLOAD has been developed as a data processing program to create an appropriate input file for the SWIFT model and runs ODAST as a subroutine on a cell by cell basis (SWIFTLOAD uses the same 120 by 112 grid as the SWIFT Great Miami Aquifer model). SWIFTLOAD reads an external file defining the layer thickness for each model cell and hydraulic and transport properties for each block.

The ODAST computer code (Javandel et al. 1984) is based on the solution originally developed by Van Genuchten and Alves (1982) and calculates the normalized concentrations of a given constituent in a uniform flow field from a source having a constant or varying concentration in the initial layer. ODAST is applicable to one-dimensional transport in homogeneous, semi-infinite media. ODAST model runs can be executed for only one constituent at a time, and the solution may be applied over any arbitrary segment of a waste area that is judged to be homogeneous. A superimposition technique is used to combine calculations for the two homogeneous layers comprising the conceptual model. The ODAST solution at the bottom of Layer 1 is divided into 1000 small time steps and a Layer 2 run is performed for each of these steps. Each of these Layer 2 runs assumes no source decay, a recharge period 1/1000 of the total modeling time, and a source concentration equal to the averaged Layer 1 solution for that time period. The solution at the bottom of Layer 2 is obtained by summing the results of the 1000 Layer 2 runs at specified time steps. For RI/FS modeling, concentrations are calculated up to 1000 years, typically in steps of 20 years. Constituents that migrate quickly, such as organics, require smaller time steps for accurate representation of loading curves.

Input parameters for ODAST are the dispersion coefficient, seepage velocity, retardation factor, source depletion time, solute decay factor, and source depletion factor. These are discussed below:

- Seepage velocity and the dispersion coefficient depend upon the characteristics of the waste area and the transport medium. Seepage velocity is calculated as an empirical function of the percolation rate obtained from the HELP model, saturated hydraulic conductivity, and porosity (EPA 1984). The dispersion coefficient is obtained as an empirical function of seepage velocity (Biggar and Nielsen 1976).

- The retardation factor accounts for transport delays due to reversible reactions between the chemical constituent and the vadose zone solid matrix. It is thus dependent on both solute and medium characteristics, and is calculated as a function of the constituent's partitioning coefficient and the bulk density and moisture content of the transport medium (Walton 1984; Mills et al. 1985).

- The solute decay factor is constituent dependent. This parameter accounts for biodegradation in organics and radioactive decay in radionuclides, and is zero for stable inorganics.

- Source depletion time and factor control the mass flux history of the constituent at the top of the modeled layer. Based on the upstream boundary condition, source mass flux decays exponentially. To calculate depletion time and factor for the waste at the top of Layer 1, the time-dependent expression for mass flow from the source is integrated from zero to the source depletion time. This integral is equated to the depleted mass of the constituent to provide a single equation in two unknowns. A second equation is obtained by arbitrarily specifying a mass depletion fraction. This is the level (very close to, but less than one) at which the source is declared depleted; technically, the source is depleted only as time approaches infinity. As stated previously, depletion factor is zero and depletion time is 1/1000 of the total modeling time for the Layer 2 runs.

SWIFT Great Miami Aquifer Model

The SWIFT Great Miami Aquifer model is used to simulate three-dimensional contaminant transport in the Great Miami Aquifer for the recovery well system design and residual risk assessment. The SWIFT code is a fully coupled, transient, three-dimensional, finite-difference model for groundwater flow and transport through both porous and fractured media. The mass transport equations solved include terms for convection, dispersion, retardation by sorption, and decay or degradation of the contaminant. The SWIFT code, originally developed by Sandia National Laboratory in the late 1970s for the High-Level Waste Program, has been revised several times to increase its capability and to change computer platforms. These revisions include the addition of fractured media, a free water surface, extended boundary conditions, conversion to Fortran 77, extended options for matrix solutions, and postprocessing. GeoTrans (1991) has converted SWIFT for use on 386 and 486 personal computers (PCs) and made additional changes to improve user friendliness and input and output control, the most recent version being SWIFT 2.54 (GeoTrans 1992).

SWIFT was selected from among several codes for use in developing a flow and transport model of the Great Miami Aquifer in the vicinity of the FEMP. Subsequent to selection of the code, the SWIFT code was specifically verified for use at the FEMP (IT 1990). A model of the Great Miami Aquifer was originally developed and calibrated from 1988 through 1990 (DOE 1993c). Since that time, additional data have been collected, new wells have been installed, and a large scale pumping test (South Plume pumping test) has been conducted. Based on these factors and agency comments, a model improvement program was initiated (DOE 1993b). The essential elements of this model improvement program were completed in March 1994 (DOE 1994c). The Operable Unit 5 RI and FS modeling makes use of this "improved" model.

Model simulations of the improved SWIFT Great Miami Aquifer model were performed using SWIFT/386 on a Powerbox PC microcomputer or SWIFT III on a Silicon Graphics Computer (Unix based). Simulation execution times for 1000-year solute transport runs varied between 24 and 60 hours. These 1000-year simulations generated extremely large output files and required peripheral hardware. Output was written to files from which relevant data was extracted using data manipulation programs written for that purpose. Contour plots were made using Golden Software's SURFER software package for selected constituents at different simulation times. Report graphics were imported into Intergraph Work Stations for preparation of final graphics.

ECTran Model

The ECTran model is used for simulating quasi-two-dimensional lateral perched water transport, one-dimensional vertical perched water transport, one-dimensional vertical surface water loading, and quasi-two-dimensional lateral transport in the Great Miami Aquifer during the PRL and WAC developments. The model is an efficient groundwater contaminant fate and transport model developed to support the RI/FS processes at the FEMP, and implemented in Excel 4.0®, a registered trademark of Microsoft. The Crystal Ball 3.0® add-on module for Excel, a registered trademark of Decisioneering, can be used with the ECTran model to perform Monte Carlo simulations. The ECTran model is a screening-level model that can be used to supplement other more complex fate and transport models during parameter estimation, risk assessment, cleanup goal development, alternate concentration limit (ACL) determination, and stochastical sensitivity analysis. The model is based on straightforward mass-balances and advection/dispersion analytical equations, but can be used to simulate a variety of complex conditions. The complete summary of the ECTran model's capabilities, development processes, and the proposed applications of the screening-level spreadsheet-based groundwater contaminant fate and transport model are presented in DOE 1993a. Highlights of the ECTran model's capabilities include the following:

- Uses analytical one-dimensional (1-D) flow and transport model with the vertical mixing process controlled by model sublayer thickness and rate of advective mass transfer instead of by classical dispersion tensor formulation in the vadose zone

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- Uses analytical 1-D flow and transport model with 2-D dispersion in the saturated zone
- Accepts zone- and layer-specific contaminant initial concentrations, decay rates and distribution coefficients
- Model can be separately and flexibly applied in any localized source area
- Age of source can be considered to estimate the current downgradient concentrations
- Capable of including an additional/secondary source loading from the glacial overburden into the lower unsaturated layer
- Can be used to consider impacts of pumping and/or containment in the source area on the exposure point concentrations
- Uses directly any specified uniform groundwater flow velocity
- Considers contaminated or clean upgradient groundwater recharge
- Uses mixing depth concept in the saturated zone instead of the thickness of the entire saturated zone in the aquifer
- Calculates layer- and zone-specific contaminant concentrations versus time
- Presents the output statistically and graphically without the need for postprocessing
- Calculates concentrations at the projected centerline of the contaminant plume
- Requires minimal run time so that many scenarios can be investigated.

ECTran model inputs include site-specific hydrogeologic and chemical information as well as physical information about the site. Hydrogeologic information such as vertical and horizontal hydraulic conductivity, hydraulic gradient, porosity, vertical and horizontal groundwater velocities, percent saturation, soil density, fraction of organic content, dispersion coefficient, and infiltration rate are all necessary model inputs. The typical chemical information for model input varies depending on the type of chemical to be modeled (i.e., radionuclide, organic, or inorganic). For the CPRG and WAC developments, the typical chemical input includes partition coefficient (K_d), half-life, and exposure criteria. Necessary physical information about the source area which would be used as model input includes the areal dimensions of the source, detailed description of the underlying geology, the source area orientation with respect to groundwater flow, and its distance from the selected exposure point.

F.1.5.4 Summary of Revisions in Technical Approach Between RI and FS

Hydrogeological and geochemical conditions greatly affect contaminant migration through environmental media. Therefore, accurate estimation of these parameters is essential for fate and transport modeling. Previous estimates of the hydrogeological and geochemical conditions for

Operable Unit 5 soil and COCs were defined within the Operable Unit 5 RI Report. Since the submittal of this document, additional data has become available and refined approaches to model calibration of contaminant migration through the glacial overburden have been developed. Revisions of geochemical and hydrogeological parameters and modeling approaches since the Operable Unit 5 RI Report are summarized in this subsection.

Update of the Gray Clay Thickness and Infiltration Rate Calculation

79 Solid block modeling was conducted for the glacial overburden using all the available soil boring data. Further evaluations and comparisons between the 3-D model and previous 2-D cross sections used in the RI allow a more accurate definition of the distribution of gray clay thickness to support the FS. The same database used in the RI was reanalyzed in more detail to update the geological cross sections. Based on this analysis, which also used 3-D solid block modeling, refinements were made in the original cross sections presented in the Operable Unit 5 RI Report. The gray clay thickness is critical in developing the CPRGs, WAC, and selecting of potential locations for the on-site disposal facilities. Based on the updated geological information, zones of infiltration rates were also revised and new infiltration rates calculated by using the HELP model. In general, the overall average infiltration rate remains the same. However, the revised zonation facilitates more efficient CPRG development and application processes. Geological interpretations of the thickness of the gray clay, presented and used for infiltration estimations in the OU5 RI Report, were refined for fate and transport modeling in the FS. Large infiltration areas, presented in the RI Report were sub-divided into smaller areas and area boundaries were more closely correlated with depositional and surface erosional features (i.e., the SSOD and Paddys Run).

The thickness of the gray clay was divided into four large zones in the RI Report for the purpose of calculating better estimates of infiltration rates (Figure 3-44; DOE 1995). These four large zones roughly correlate to depositional and erosional features. The level of detail pertaining to gray clay thickness is adequate for making gross estimations of infiltration. Many small areas exist within each of these large areas where the gray clay is thinner. These smaller areas needed to be assessed in the FS.

For the FS the four large RI infiltration zones (Figure 3-45; DOE 1995) were further subdivided into six zones (Figure F.2-11). The isopach map used to guide the zonation is shown in Figure F.2-10. The new zonation using six zones provides for the small areas where the gray clay is thinner. Figure F.2-12 shows the generalized cross sections for the FS zonation. Zone 1 of the RI Report became Zone V of the FS. The intent of this zone is to provide for a hypothetical continuous sand pathway from the perched water area beneath Plants 2/3, 8, and 1 to Paddy's Run, a pathway was not detected in the field. For the FS the southern boundary of this zone was modified to correspond to the pilot plant drainage ditch. The eastern boundary was modified to correspond to the perched groundwater

area capable of sustaining a groundwater yield of 1 gpm. Zone II of the RI Report was subdivided into Zones III and IV and Zones III and IV of RI were subdivided into Zones I,II,III, and IV in the FS. Zone VI in the FS is used to represent areas where no gray clay is present. The boundaries of these new six zones more closely matches depositional and surface erosional and drainage features (i.e., Paddy's Run and the SSOD).

Distribution of Uranium Geochemical Parameters

As presented in Table F.3.II-2 and Figure F.3.II-2 of the Operable Unit 5 Final RI Report, the variation of uranium geochemical parameters can be very significant in a relatively small area. Therefore, a simplified conceptual model was required to develop a manageable fate and transport model. Using only two sets of K_l and K_d values in the Operable Unit 5 area (in addition to all the other values used in other operable units that are directly incorporated in the Operable Unit 5 fate and transport model) may seem to oversimplify actual conditions. However, as long as the selected K_l and K_d values present reasonably conservative conditions at the FEMP, the fate and transport modeling results can support the baseline risk assessment (prepared as part of the RI). Additional K_l and K_d values for specific areas have been evaluated in the Operable Unit 5 FS to develop CPRGs and WAC for disposal facilities. In general, a higher resolution and better presentation of distributions of geochemical parameters are achieved in the FS.

Uranium K_d Value in the Gray Clay Layer

As described in the Operable Unit 5 Final RI Report (DOE 1995), vertical contaminant fate and transport modeling through the glacial overburden only includes the gray clay layer. Vertical migration of contaminant through the weathered overburden above the gray clay is assumed to be instantaneous. Based on measured data and model calibrations presented in Attachments F.3.I and F.3.II of the Operable Unit 5 Final RI Report, K_d values of uranium in the gray clay layer range between 4 L/kg (i.e., from lysimeter calibration) to higher than 2000 L/kg. A calculated K_d value of 15 L/kg was used to represent the baseline conditions in the Plant 2/3, Plant 6, and Plant 9 areas for fate and transport modeling. This K_d value was also verified by previous model calibration using the ECTran model summarized in Attachment F.3.II of the Operable Unit 5 Final RI Report.

80 As information presented in the Operable Unit 5 Final RI Report indicated, a K_d value of 15 L/kg is conservative but not the minimum value. The retardation factor in the gray clay layer calculated using a K_d value of 15 L/kg is about 165. In other words, uranium migrates 165 times slower than the groundwater seepage velocity, which is about 1 to 2 feet per year. These low migration rates in the overburden resulted in the long breakthrough times presented in the RI baseline conditions. For the purpose of baseline risk assessment, these long breakthrough times did not change the conclusions regarding the maximum level and sources of future Great Miami Aquifer groundwater contamination. Based on modeling results, Great Miami Aquifer uranium concentration can reach 9 mg/L in about

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200 years due to future surface water loading. Uranium breakthrough times through the glacial overburden in various areas of the site were calculated and discussed in Section F.5.4.3.5 of the Operable Unit 5 RI Report. Modeling results indicated that impacts to the Great Miami Aquifer exceeding the MCL (i.e., 20 μg/L) may occur within 60 years in certain areas.

81 A uranium K_d value of 3.1 L/kg for the gray clay layer throughout the FEMP is used in Operable
71 Unit 5 FS to develop soil CPRGs and WAC for disposal facilities. This value was determined by additional model calibrations with both ODAST and ECTran models and is representative for conditions observed in the lysimeter data from the southeast where the "gray clay" layer has relatively high silt content. This low uranium K_d value is used in the FS fate and transport modeling and is independent of the source K_l values as suggested by the geochemical conditions at the glacial overburden at the FEMP. Selection of this lower K_d value to represent the whole site allows the combined geochemical and hydrogeological uncertainties in the natural environment which control the migration rate of uranium through the overburden to be better bracketed in the Operable Unit 5 remedial alternatives. With this lower K_d value, the breakthrough time is about five times shorter than the baseline cases presented in the RI Report. Theoretically, higher K_d values can be used to simulate the contaminant desorption process in the subsurface soil after the source remediation. The higher K_d values mean that more contaminant mass will remain adsorbed to soil and not dissolve into the liquid phase and impact the groundwater. However, in order to be conservative for CPRG development and determination of residual impacts, the same low K_d value was used throughout the modeling for both adsorption and desorption processes. In general, the contaminant retardation factor in soil remains the same when the same K_d value is used before or after the source remediation.

82 It is important to point out that a K_d value of 24 L/kg is used for the engineered clay liner in the disposal cell during modeling to develop the WAC. This engineered clay liner will not have the same hydrogeological uncertainty and high degree of heterogeneity as in the natural "gray clay" layer encountered in the lysimeter test areas. Therefore, a higher K_d value (24 L/kg instead of 3.1 L/kg), which is closer to the reported capacity of homogeneous clay material under general subsurface geochemical conditions (i.e., high carbonate content) as is expected in the FEMP, is reasonable. This value is also justified by results of laboratory adsorption tests conducted with clay materials from a potential location of the cell east of the former production area. Information justifying the representativeness of the 24 L/kg K_d value for native clay materials was also presented in Attachment F.3.I of the Operable Unit 5 RI Report (DOE 1995).

82 All the currently available laboratory information supports the 24 L/kg K_d value for an engineered clay liner using homogeneous native clay material. The lower K_d value of 3.1 L/kg used in the modeling for the glacial overburden was determined through calibration against the natural conditions and included the effects of hydrogeological conditions that will not be encountered in the engineered

clay liner. The addition of chemical retardants which can further slow down contaminant migration through the liner are also being considered in the disposal facility design. The actual K_d values for the engineered clay liner will be based on a statistically valid set of analytical results from the materials ultimately chosen for the liner. Therefore, the value of 24 L/kg K_d is selected as being achievable through construction and engineering controls and is used in the modeling to develop the preliminary WAC for FS purposes.

Modification in the ECTran Model

Although no dispersion coefficient is required in the ECTran model, the overburden layer thickness used in the ECTran model has a similar effect created by the dispersion coefficient used in the ODAST model. Because the ECTran model assumes instantaneous mixing of contaminant mass in an entire model layer, a larger layer thickness corresponds to a higher dispersion coefficient. As a result, the ECTran model can underestimate the arrival time of a contaminant (i.e., faster than actual contaminant migration) through the overburden especially under low infiltration rates with large layer thicknesses. In previous applications of the ECTran model, only two model layers (one for gray clay and the other for unsaturated sand and gravel) were used to simulate the entire overburden regardless of the actual thickness.

To simulate contaminant migration through the gray clay layer more realistically under low infiltration rates, a reasonable model layer thickness is selected for the ECTran model by matching predicted concentrations through the gray clay layer using the ODAST model. A cross-verification study was conducted between the ECTran and ODAST model using a low infiltration rate. Results of this study are presented in Attachment F.1.I. In summary, a 3-foot sublayer structure is determined appropriate for the ECTran model.

The modified ECTran model was recalibrated against the lysimeter data for uranium presented in Table 3-19 of the Final Operable Unit 5 RI Report (DOE 1995). A uranium K_d value of 3.1 L/kg was determined appropriate for the gray clay layer during calibration. The ODAST model was also applied to match the lysimeter data with this K_d value as a verification of the dispersion coefficient used in the model. The procedure and results of this calibration are presented in Attachment F.1.I. The overall gray clay layer is simulated as multiple 3-foot sublayers with identical hydrogeological characteristics in the ECTran model to support CPRG and WAC development. It is important to note that this modification only creates significant differences under low infiltration rates.

Modification in the ODAST Model

Although the overall mass flow rate determined by the HELP model is correctly preserved, it is determined that the speed of vertical groundwater and contaminant migration through unsaturated sand and gravel in the Great Miami Aquifer can be underestimated by the original ODAST model,

especially when developing WAC for the disposal facilities with a cap. ODAST uses a traditional conceptual model of a uniform front of soil moisture migration and does not consider the potential of preferential flow created by localized saturated conditions and heterogeneity of permeability created by various depositional phases or environments in the Great Miami Aquifer. As a result, the simulated groundwater vertical seepage velocity in the unsaturated sand and gravel layer is in the same order of magnitude as in the gray clay layer when developing WAC for the disposal facility. The assumption of uniform front of moisture migration is reasonable for the gray clay layer; it may not be conservative for the sand and gravel layer, which has very high permeability.

Localized saturated conditions and heterogeneity may create fingering effects in the unsaturated Great Miami Aquifer sand and gravel where water can migrate in small "streams" at higher rates instead of a uniform front at lower rates. In reality, the groundwater vertical seepage velocity in the unsaturated sand and gravel layer can be as high as the vertical hydraulic conductivity of the sand and gravel layer and independent of the overall infiltration rate. The differences between the simulated and potential seepage velocities are significant under a low infiltration rate (i.e., below 1 inch per year) created by the cap of the disposal facility.

423 Although a potential error in seepage velocity calculation as a result of these considerations is significant only when the infiltration rate is low due to the infiltration barrier in the multilayer cap of a disposal facility, it was determined that the unsaturated sand and gravel layer will not be included whenever the ODAST model is applied in Operable Unit 5 FS fate and transport modeling. However, a similar modification in the ECTran model is not necessary because the ECTran model only uses mass flow rate (instead of seepage velocity as in the ODAST model) in the calculation of contaminant transport and assumes instantaneous mixing of contaminant mass in the entire unsaturated sand and gravel thickness. When simulated as a single model layer (i.e., not divided into smaller sublayers as for the gray clay layer described previously), the approach used in the ECTran model is still very conservative for the sand and gravel layer under low infiltration rate conditions.

F.1.5.5 Conservative Assumptions

Assumptions are necessary to simplify or conceptualize the natural environment and contaminant migration processes so that they can be simulated by models. Because of the complexities of natural conditions, there will always be uncertainties regarding modeling results. Therefore, model assumptions need to be conservative in order to ensure that remedial actions based on modeling results are protective of human and environmental receptors. Most of the conservative assumptions are associated with the estimation of the following parameters: infiltration rates, thicknesses and effectiveness of the natural or artificial barrier layers, geochemical conditions, chemical decay rates, and distance to receptor locations. Specific assumptions included in each fate and transport modeling task are presented in this appendix.

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TABLE F.1-1

MAJOR COMPONENTS OF THE AIR EMISSION AND DISPERSION MODELING

Model	Description and Use
RAECOM	RAECOM is a computer model developed by the U.S. Nuclear Regulatory Commission (NRC 1984) to simulate the emission of Radon-222 gas from soil and material containing Radium-226. RAECOM is used in this modeling effort to estimate the Radon-222 emission rate from FEMP surface soils and through cover soils placed over on-property consolidation areas. The output from RAECOM is used as input to ISCLT2.
Particulate Matter Emission Equations	The Particulate Matter Emission Equations are also presented in *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites* (EPA 1985). These equations are used in this modeling effort to estimate particulate matter emissions from surface soil caused by wind erosion. The results from these equations are used as input to ISCLT2.
ISCLT2	ISCLT2 is a computer model developed by the United States Environmental Protection Agency (EPA 1992) to simulate the dispersion of gas-phase and particulate-phase contaminants emitted to the atmosphere. ISCLT2 is used in this modeling effort to predict the airborne concentrations and deposition rates of contaminants emitted from the FEMP surface soils. The output from RAECOM and particulate matter emission models are used as input to ISCLT2.

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TABLE F.1-2

MAJOR COMPONENTS OF THE SURFACE WATER FLOW AND INFILTRATION MODELING

Model	Description and Use
HEC-1	HEC-1 is a computer model developed by the U.S. Army Corps of Engineers (USCOE 1990) to simulate rainfall and runoff. HEC-1 is used in this modeling effort to estimate the hydrologic parameters of the Paddys Run drainage basin which encompasses the FEMP. The output for HEC-1 is used as input for VS2DT, MUSLE, and the Partitioning Equations.
VS2DT	VS2DT is a computer model developed by the U.S. Geological Survey (USGS 1990) to simulate variably saturated groundwater flow in two dimensions. VS2DT is used in this modeling effort to estimate the amount and pattern of infiltration of surface water through the streambeds of Paddys Run and the SSOD.
MUSLE	The Modified Universal Soil Loss Equation presented in the Superfund Exposure Assessment Manual (EPA 1988) is used to estimate the amount of sediment which is generated by a single storm event. This equation is used in this modeling effort to estimate the amount of sediment generated by the representative storm event.
USLE	The Universal Soil Loss Equation presented in the Superfund Exposure Assessment Manual is used to estimate the annual amount of sediment produced in the subbasins of the Paddys Run drainage basin.
Partitioning Equations	The Partitioning Equations also are presented in the Superfund Exposure Assessment Manual. The partitioning equations consist of a series of equations used to determine the amount and concentration of contaminant released from the source surface soils in the dissolved phase (surface water) and the adsorbed phase (in sediments) from a single storm event.
SWF&IM	The Surface Water Flow and Infiltration Model is the term applied to collectively identify the above models used to simulate the rainfall, runoff, and Contaminant Transport. This is also sometimes referred to generically as the surface water model.

TABLE F.1-3

MAJOR COMPONENTS OF THE GROUNDWATER FATE AND TRANSPORT MODELING

Model	Description and Use
HELP	The HELP model is used in the OU5 analysis to define infiltration rates (seepage velocities) for use in travel time screening and in vadose zone modeling with ODAST. The HELP model (EPA 1984) is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a waste area. The systems that can be modeled by HELP include various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils.
ODAST	The ODAST model is used in the OU5 analysis to define vertical contaminant transport from contaminated soil or perched water to the GMA. The ODAST computer code is based on the solution originally developed by Ogata and Banks (1961) and calculates the normalized concentrations of a given constituent in a uniform flow field from a source having a constant or varying concentration in the initial layer. ODAST evaluates the basic one-dimensional analytical solute transport equation as a function of seepage velocity, dispersion coefficient, source decay, retardation factor, depletion time, and source rate.
ECTran	The ECTran model is a screening level groundwater contaminant fate and transport model implemented in Excel 4.0 which was developed to support the RI/FS processes at the FEMP. The Crystal Ball 3.0 add on module for Excel can be used with the ECTran model to perform Monte Carlo simulations. The ECTran model can be utilized to supplement other more complex fate and transport models during parameter estimation, risk assessment, cleanup goal development, and stochastical sensitivity analysis. The model is based on straight-forward mass-balances and advection/dispersion analytical equations, but can be used to simulate a variety of complex conditions.
SWIFT	The SWIFT Great Miami Aquifer is used for simulating the three dimensional contaminant transport in the Great Miami Aquifer. The SWIFT code is fully coupled, transient, 3-dimensional finite difference model for groundwater flow through both porous and fractured media. The mass transport equations solved include terms for convection, dispersion, retardation by sorption, and decay or degradation of the contaminant. The SWIFT code, originally developed by Sandia National Laboratory in the late 1970s for the High Level Waste Program, has been revised several times to increase its capability and to change computer platforms. The SWIFT GMA model was originally calibrated in 1989. Recently the model has been redesigned and recalibrated based on recent data.

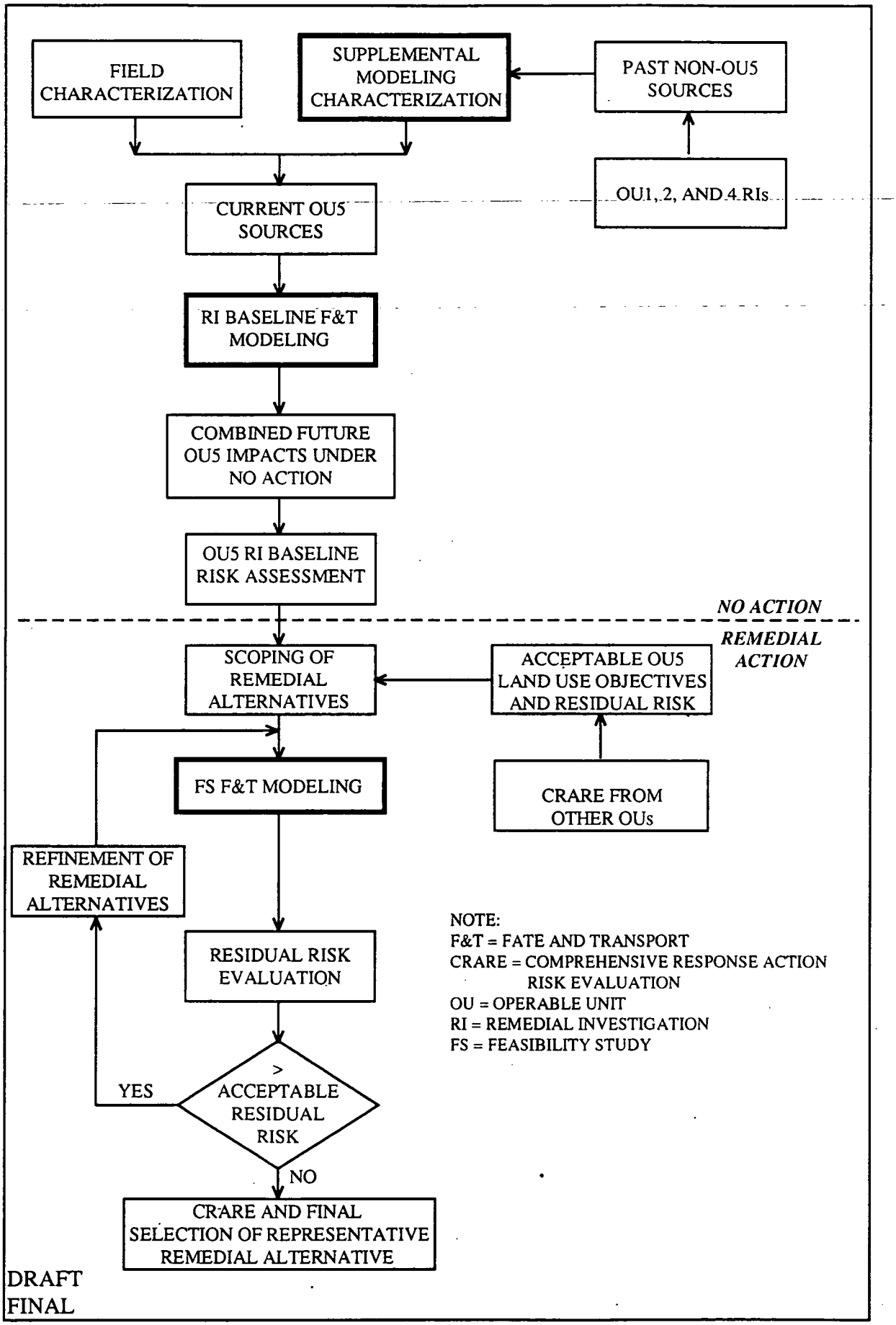


FIGURE F.1-1. OVERALL OPERABLE UNIT 5 RI/FS FATE AND TRANSPORT MODELING PROCESS

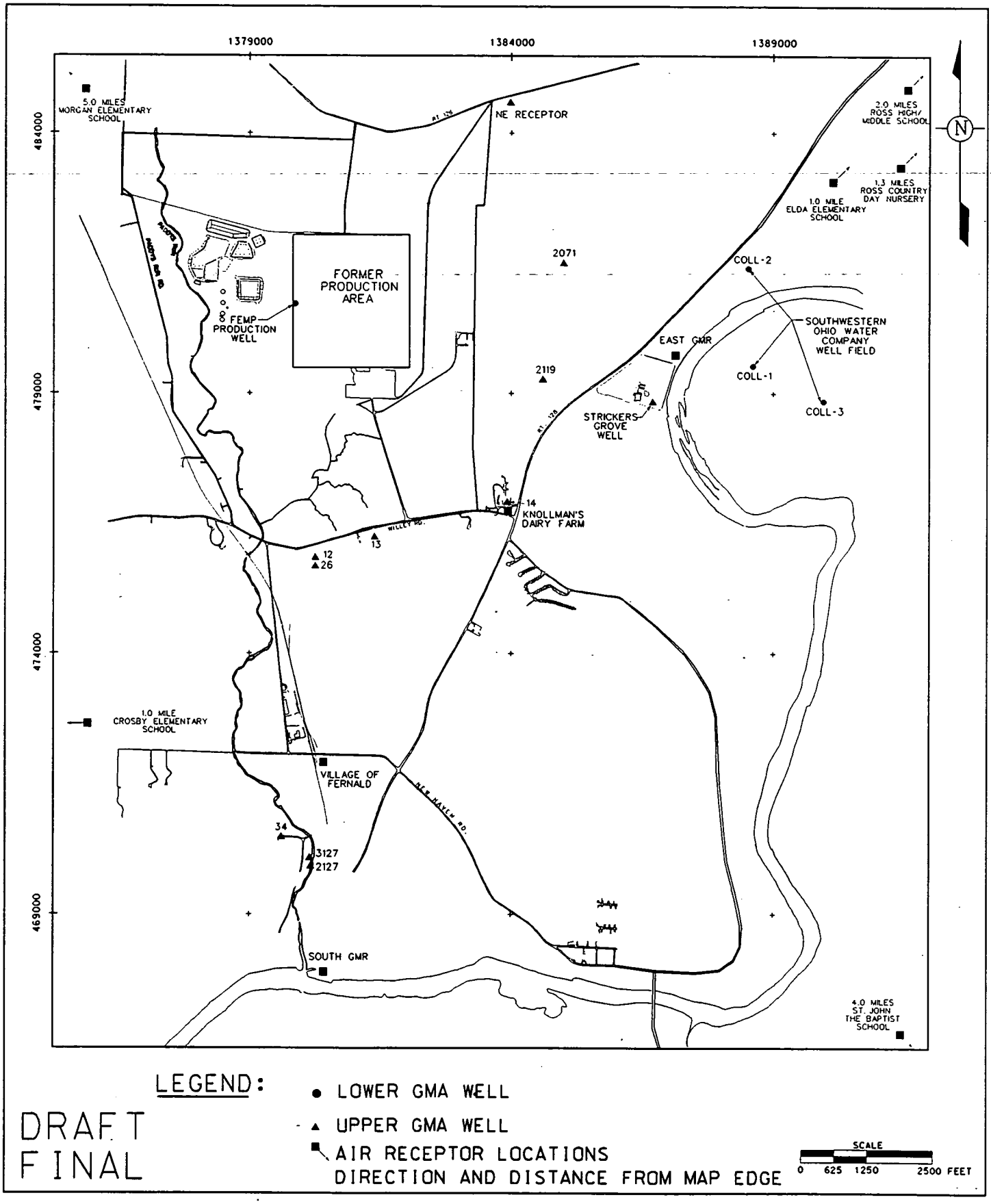
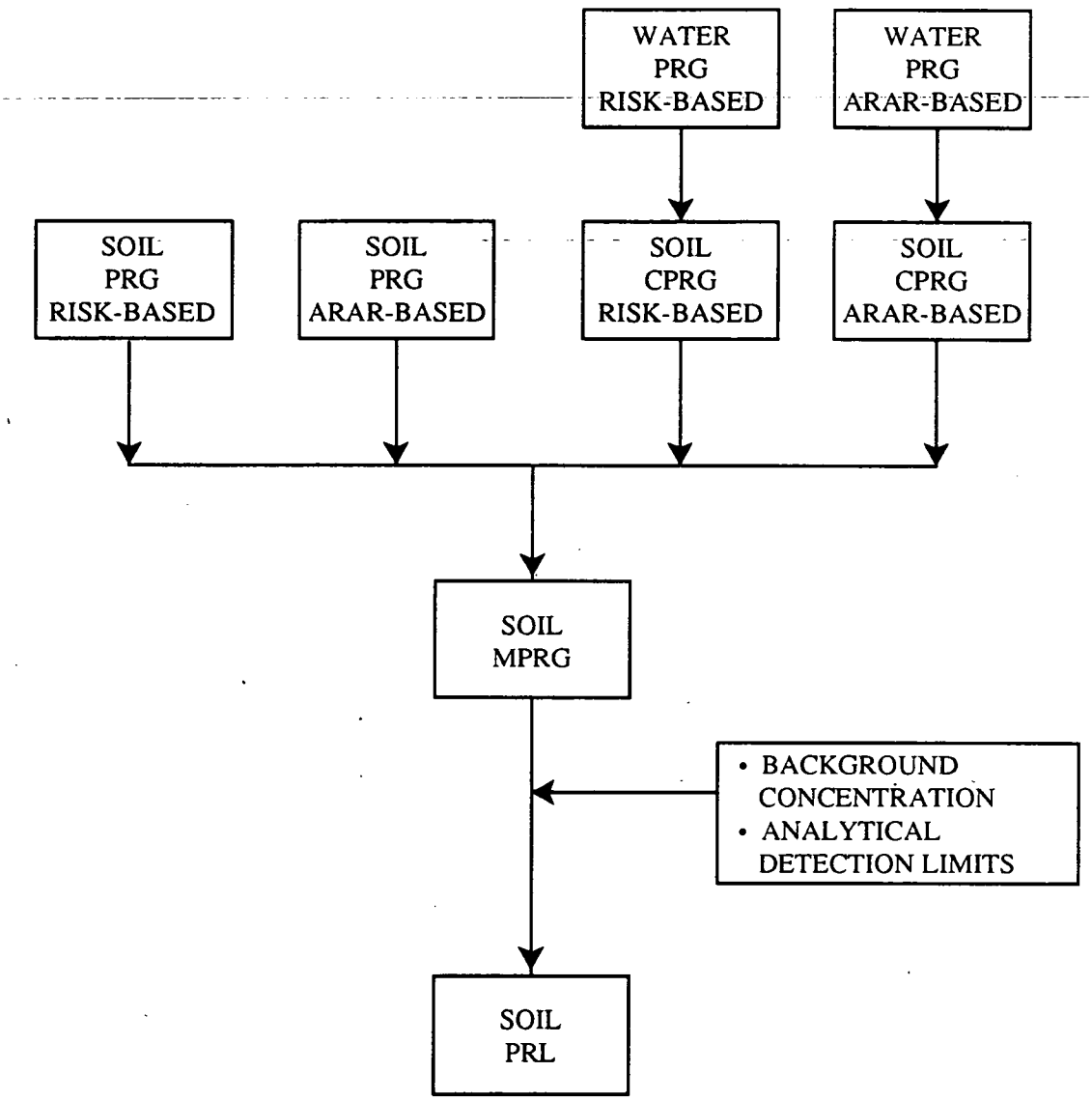


FIGURE F.1-2 RECEPTOR LOCATIONS FOR OPERABLE UNIT 5 FATE & TRANSPORT MODELING



PRG: PRELIMINARY REMEDIATION GOAL

CPRG: CROSS-MEDIA PRELIMINARY REMEDIATION GOAL

MPRG: MODIFIED PRELIMINARY REMEDIATION GOAL

PRL: PRELIMINARY REMEDIATION LEVEL

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FIGURE F.1-3. SOIL PRL DEVELOPMENT PROCESS

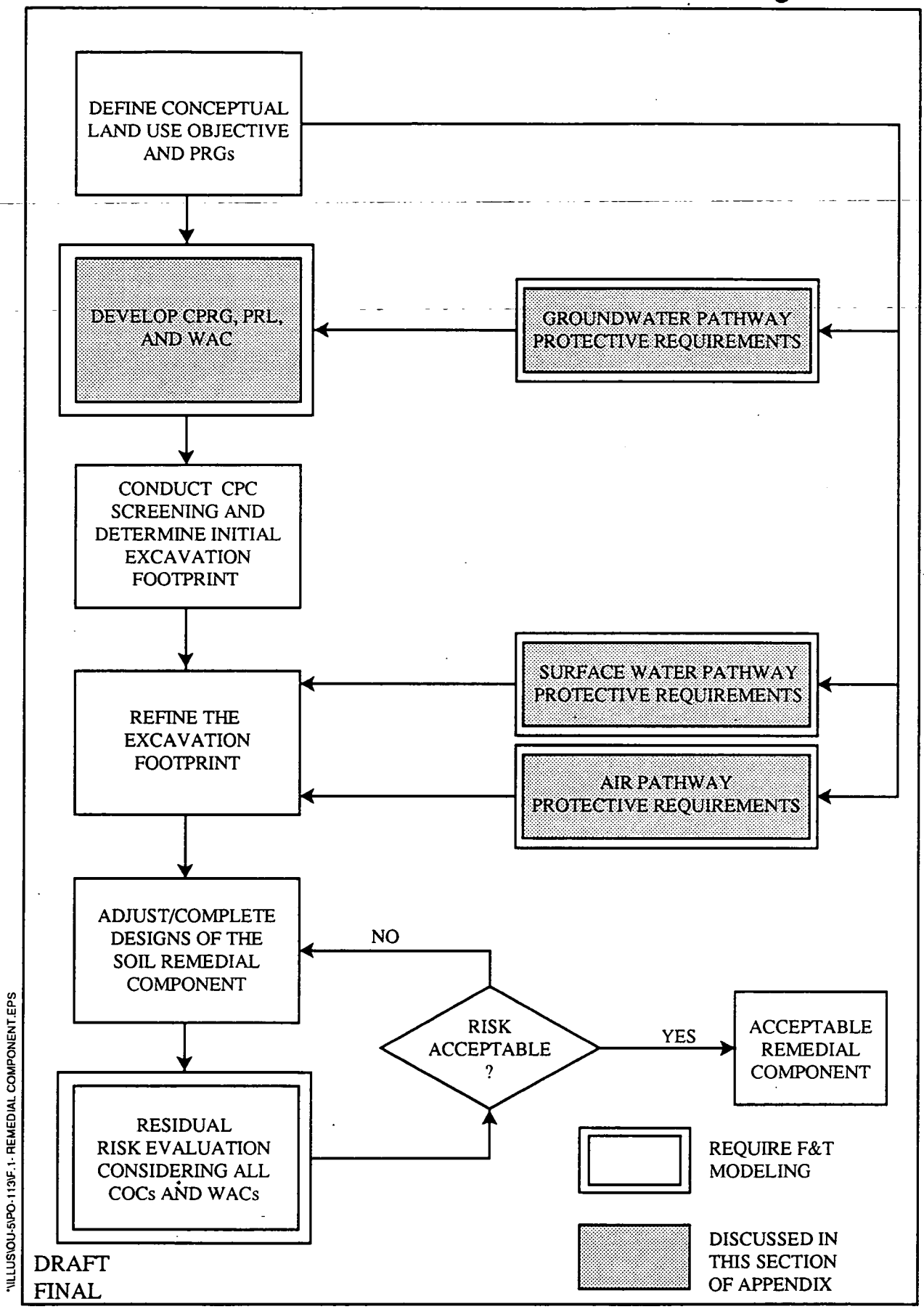

FIGURE F.1-4. SOIL REMEDIAL COMPONENT DESIGN PROCESS

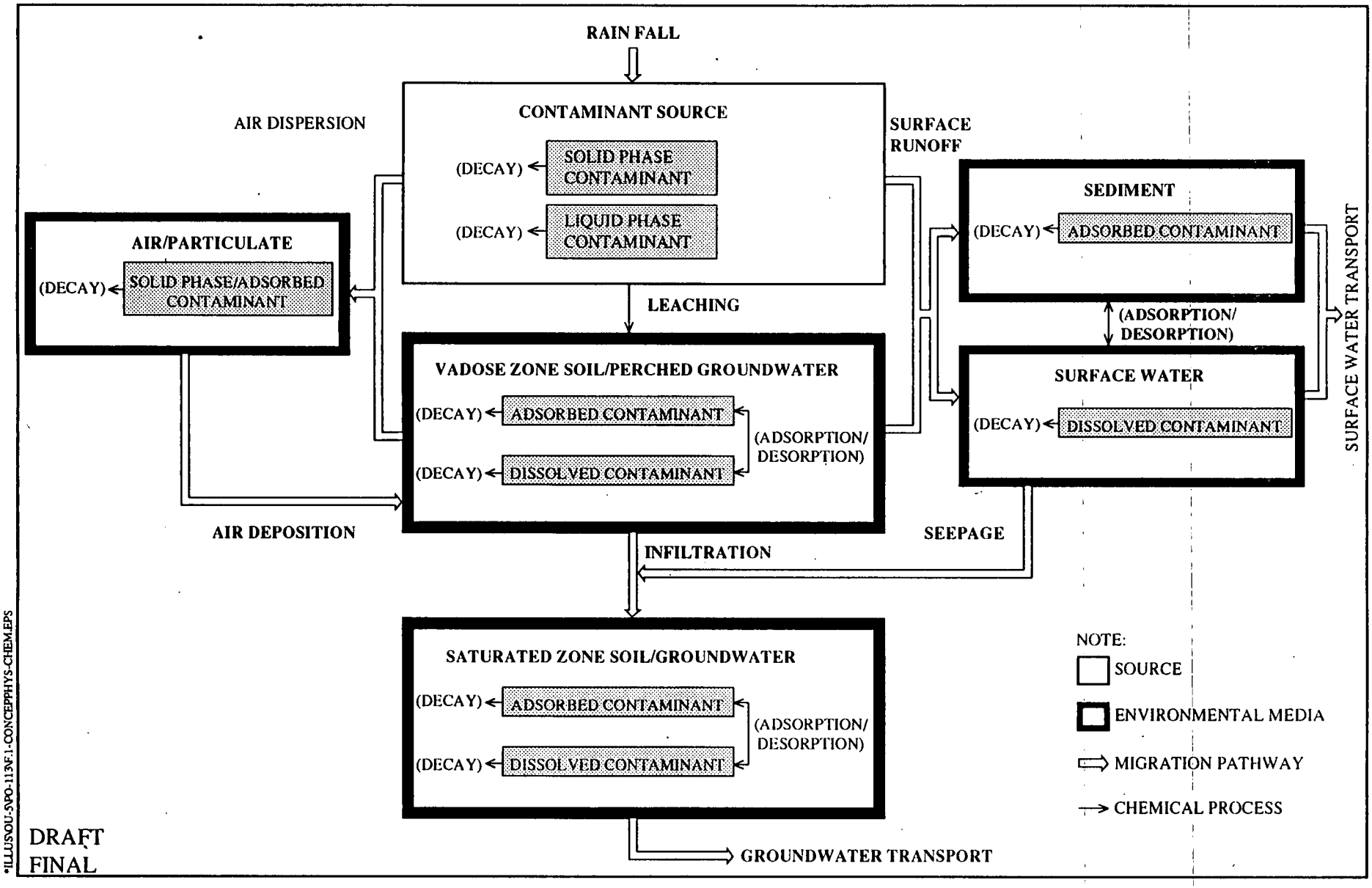

FIGURE F.1-5. CONCEPTUAL PHYSICAL AND CHEMICAL PROCESSES OF CONTAMINANT FATE AND TRANSPORT

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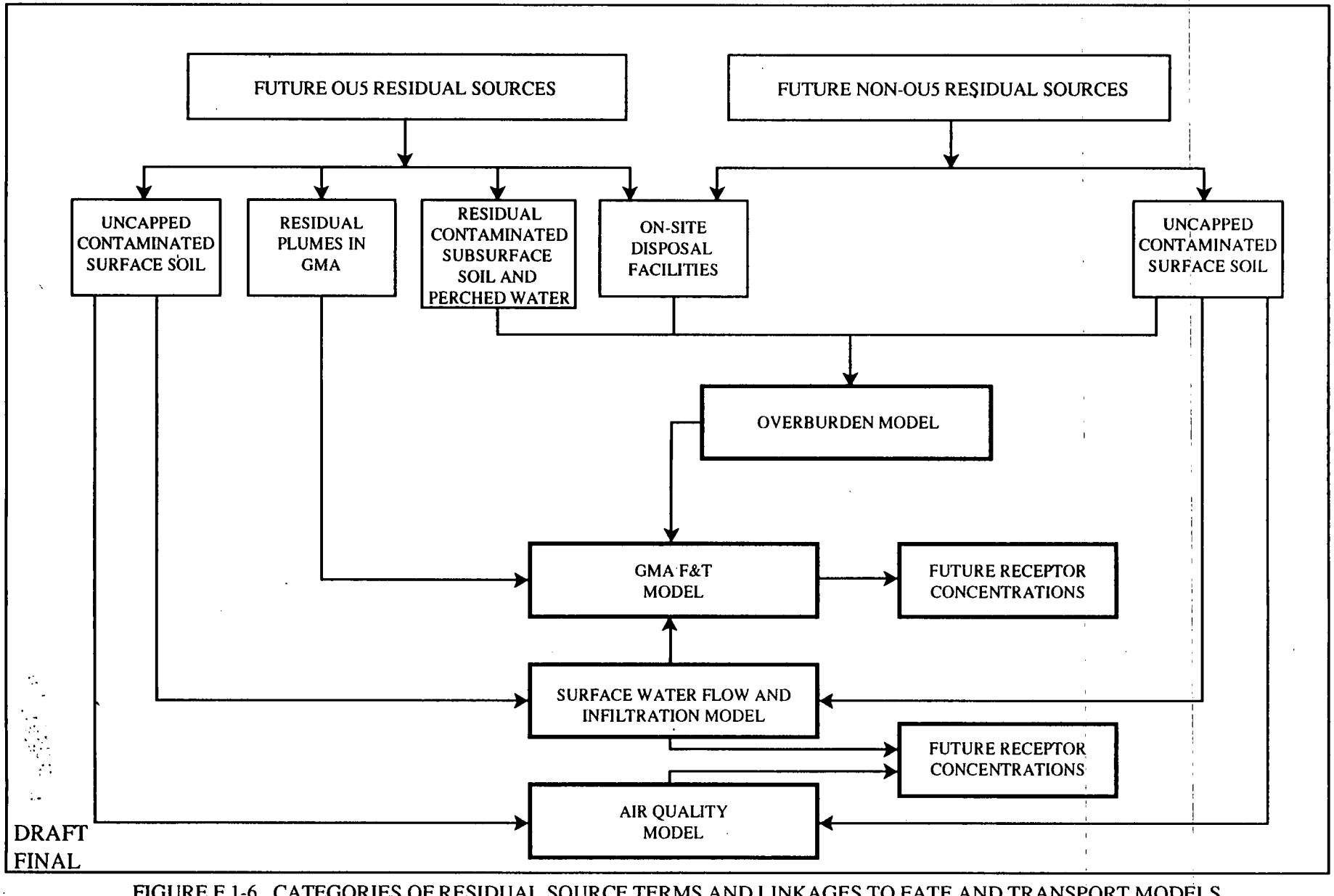

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FIGURE F.1-6. CATEGORIES OF RESIDUAL SOURCE TERMS AND LINKAGES TO FATE AND TRANSPORT MODELS

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Attachment
F2.I Operable Unit 5 Post-RI Field and Laboratory Geochemical Study

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F.2.0 GENERAL HYDROGEOLOGICAL, GEOCHEMICAL, AND CONTAMINATION CONDITIONS

F.2.1 SURFACE CONDITIONS

Future surface conditions including land-use scenarios, potential on-property receptors, vegetative coverage, dust emission, and runoff control are important factors in determining soil PRGs and protective requirements in both the air and surface water pathways. These factors are evaluated and incorporated in FS fate and transport modeling tasks requiring assumptions related to surface conditions.

F.2.1.1 Future Land Use Scenarios

Remedial alternatives for the Operable Unit 5 FS are considered under four future land-use scenarios. These scenarios include (1) unrestricted land use of the entire FEMP property, (2) maximum consolidation of contaminated soil and material with unrestricted land use for areas not set aside for consolidation and disposal, (3) maximum consolidation of contaminated soil and material with restricted (nonfarming) land use for areas not set aside for consolidation and disposal, and (4) continuous federal ownership with restricted land use of the entire FEMP property. Because there are various potential receptors within each future land-use scenario (e.g., industrial user, developed park user, and undeveloped park user under Land-Use Scenario 3) and these receptors can be protected at different levels, more detailed definitions of remedial targets are required. Overall, 11 risk-based cases, which are specific combinations of on-property receptors, off-property receptors, protective levels, and acceptable Great Miami Aquifer conditions, are defined under these four scenarios. Two risk-based cases are developed for Scenario 1, two for Scenario 2, five for Scenario 3, and two for Scenario 4, respectively. These cases are described in Section 2.0.

To obtain unrestricted land use of the entire site (Land-Use Objective 1), all soil and material with contamination that exceeds the on-property resident farmer PRLs would be removed to an off-property disposal facility. The residual soil for the entire site would have contaminant concentrations at or below the on-property resident farmer PRL values.

To obtain unrestricted land use of a portion of the site (Land-Use Objective 2), soil and material with contamination exceeding the on-property resident farmer PRLs would be excavated and consolidated into a central on-property location with various disposal facilities considered as separate alternatives. The excavated soil and material with concentrations exceeding WAC would be removed to an off-property disposal facility. The areas that are cleared for unrestricted land use would have contaminant concentrations at or below the on-property resident farmer PRL values.

To obtain restricted land use of a portion of the site (Land-Use Objective 3), soil and material with contamination exceeding specified PRLs would be excavated and consolidated into a central on-property location with various disposal facilities considered. The excavated soil and material with concentrations exceeding WAC would be removed to an off-property disposal facility. The areas to be cleared for restricted land use would have contaminant concentrations at or below the specified PRLs. These PRLs may allow the industrial or recreational uses.

For continuous federal ownership with institutional control (Land-Use Objective 4), soil and material with contamination exceeding the expanded trespasser PRLs may be excavated. The excavated soil may be placed in on-property or off-property disposal facilities depending on concentration levels. The areas that were not excavated will have contaminant concentrations at or below the expanded trespasser PRLs.

F.2.1.2 Surface Coverage

The assumed future surface coverage of the site needs to encompasses several possible land uses. The land uses which are considered in Operable Unit 5 FS are: agricultural, industrial, recreational (including developed park and undeveloped park), and continuous federal institutional controls (expanded trespasser scenario). The on-property agricultural land use requires the excavation of most of the site, so that the migration of contaminants via the surface water pathway does not require additional modeling to develop protective requirements in both air and surface water pathways. This is because the surface soil PRGs for this scenario require soil cleanup at or near the background soil concentrations. The background soil concentrations will automatically result in acceptable concentrations in the surface water pathway.

The development of air and surface water protective requirements incorporated one land cover to simulate the contaminant transport for all the other land uses. The land cover is assumed to be similar to a meadow covered with good grass. A meadow is described as continuous grass protected from grazing and generally mowed for hay (USDA 1986). The grass cover of a meadow would be similar to a park. The undeveloped park and the institutional control scenarios would all likely contain combinations of woods, grass, and brush. The woods and brush land covers are hydrologically similar to the grassed meadow. Fernald Risk Assessment Policy 93-9 directs that 85 percent vegetative cover should be used for the undeveloped park scenario. A ground cover is considered in good condition if it contains more than 75 percent vegetative cover (USDA 1986). The land cover used in the development of the air and surface water protective requirements is the good grass condition. Some area will be paved in the industrial land use scenario with smaller residual source area available to the surface runoff and air emission. Therefore, it is conservative to apply the same protective requirements developed for a park in the industrial land-use scenario.

F.2.1.3 Runoff Control

Presently, the runoff around the former production area and the waste pit areas is controlled (i.e., the runoff is collected and treated as necessary, then discharged to the Great Miami River). In development of the surface water protective requirements, it is assumed that the storm water controls are no longer functioning. This will lead to more conservative soil protective requirements because this condition will allow additional potentially contaminated runoff to reach Paddys Run and eventually the Great Miami River without treatment. Because of the long time frame of the modeling for this study (1000 years), it is likely that the storm water control will cease to function sometime during this time frame. The development of the protective requirement assumed that no storm water controls are in operation around the site.

F.2.2 SUBSURFACE CONDITIONS

Future subsurface conditions will not vary significantly from the current conditions except in areas where deep excavations (i.e., more than 10 feet) are required as a part of the remedial alternative. Groundwater flow conditions in the Great Miami Aquifer will also be affected during the groundwater remedial action period. However, the postremedial hydraulic conditions are not expected to change in the Great Miami Aquifer. The general subsurface conditions at the FEMP are evaluated and incorporated in groundwater fate and transport modeling tasks.

F.2.2.1 General Conceptual Model

431 Figure F.2-1 illustrates the major features of the conceptual model of the hydrogeology at the FEMP study area. The glacial overburden is both heterogeneous and anisotropic. It consists of clay, silt, sand and gravel with 60 to 80 percent of it being of silt and clay (Operable Unit 5 final RI Report, Section 3.4.5; DOE 1995). The upper portion of the glacial overburden sediment is oxidized (yellow-brown in color) and the lower portion is not (gray in color) (Section 3.6.1; DOE 1995). Most of the sand and gravel is situated beneath the western portion of the FEMP in lacustrine deposits. The distribution of sand and gravel beneath the eastern portion of the FEMP is more random and less dense. Figure F.2-2 illustrates where most of the coarser sand and gravel sediment within the glacial overburden is located and is useful for determining trends. Although interconnections may occur, the highlighted areas do not represent contiguous interconnected units of sediment but simply indicate where most of the coarser grained material is located.

The sediment within the glacial overburden is grouped into eight categories based upon grain size and degree of oxidation (Figure F.2-3). Hydraulic conductivities in the glacial overburden, calculated from slug tests, range from 1.87×10^{-6} cm/s (gray clay) to 3.07×10^{-2} cm/s (brown gravel). The gray clay found at the base of the glacial overburden is the least permeable sediment type and controls the vertical transport pathway. Core permeability measurements for the gray clay yield a hydraulic conductivity of 2.25×10^{-8} cm/s. Slug test results yield a hydraulic conductivity of 1.87×10^{-6} cm/s.

The total porosity of the gray clay is approximately 26 percent and the moisture content (by weight) is approximately 14.3 percent.

The Great Miami Aquifer lies beneath the glacial overburden, consists of sand and gravel outwash, and occupies a buried valley that roughly follows the Great Miami River Channel (Operable Unit 5 RI Report, Section 3.4.4). Overall the aquifer is not as heterogeneous and anisotropic as the glacial overburden deposit. Hydraulic conductivity in the Great Miami Aquifer, in the FEMP area, is approximately 300 to 500 ft/day. The horizontal to vertical ratio of hydraulic conductivity ranges from 5 to 15. Porosity is approximately 30 percent and the storage coefficient is 0.2.

Groundwater is present in the glacial overburden and is perched above the water table of the Great Miami Aquifer. The water table in the glacial overburden under the FEMP is situated approximately 3 to 5 feet beneath the ground surface and generally lies within the elevation range of 560 to 602 feet above mean sea level (AMSL) (Operable Unit 5 RI Report, Plate 3-5; DOE 1995). The slope of the water table follows surface topography and dips to the west and southwest. The gradient of the groundwater table varies, but beneath the production area it generally ranges between 0.008 and 0.015. The vertical gradient through the glacial overburden is close to 1 because of unsaturated conditions that exist beneath the deposit. Figure F.2-4 illustrates how fluid pressures change with depth due to the presence of saturated sediment within and unsaturated sediment beneath the glacial overburden. Fluid pressure is zero at the water table where it is in equilibrium with the atmospheric pressure, greater than atmospheric pressure in saturated conditions, and less than atmospheric pressure in unsaturated conditions. The water table in the Great Miami Aquifer slopes to the east and south, towards the Great Miami River, and generally lies at an elevation between 518 to 530 feet AMSL beneath the FEMP. The gradient ranges from 0.0008 in the New Haven Trough to 0.002 in Paddys Run Outlet (DOE 1995). Industrial users of groundwater within a 5-mile radius of the FEMP include the FEMP itself, the Southwestern Ohio Water Company (SOWC) (18.4 mgd), Albright and Wilson Company (290 gpm), and Ruetgers-Nease (10 gpm).

Contamination must either move through or around the glacial overburden to reach the Great Miami Aquifer. The low hydraulic conductivity of the gray clay, 1.87 x 10^{-6} cm/s (geometric mean of slug tests), appears to control the movement of fluids and contaminants. The low permeability of the gray clay could be increased by the presence of sand and gravel or the existence of fractures. The base of the glacial overburden is saturated, but directly beneath the glacial overburden unsaturated conditions are present. Because of the gray clay layer, the glacial overburden appears to be acting like a sponge, which is very slowly dripping into the unsaturated sediment which lie above the water table of the Great Miami Aquifer. The dripping is probably not uniform across the FEMP but greater in some locations due to the presence of sand, gravel and fractures. The hydrogeology of the glacial overburden is presented in more detail in Section 3.0 of the Operable Unit 5 RI Report (DOE 1995).

F.2.2.2 Perched Groundwater Zone

Potential future land use scenarios may include using perched groundwater as a drinking water source. Therefore, it is important to identify the perched groundwater zones that can sustain yields of 1 gpm or more. Yield from the glacial overburden is controlled by the distribution of sand and gravel within the silt and clay. Although all of the sediment is saturated (water table at approximately 3 to 5 feet below the ground surface), only areas with hydraulic conductivities greater than 1 x 10^{-4} cm/s appear to be capable of a sustained yield of 1 gpm. These areas exist where a larger percentage of sand and gravel is present. At the FEMP this area is along the north and east edge of a basin feature located in the western portion of the former production area and in channel deposits criss-crossing through the silt and clay.

84 One objective of the Glacial Till/Vadose Zone Hydraulic Study which was conducted in the summer and fall of 1993 was to determine the groundwater yield that could be obtained from wells pumping in the glacial overburden. Over 200 drilling logs and dozens of detailed cross sections were reviewed to identify areas within the glacial overburden that seemed most promising for delivering a sustainable yield of groundwater. The study concentrated on areas where a larger percentage of sand and gravel was present because several years of drilling and monitoring (for both water level and water quality) indicated that wells completed in clay and silt were slow to recharge, and wells completed in sand and gravel were quicker to recharge.

Data collected from seven yield tests and three constant rate pumping tests were used to identify areas and depositional features within the glacial overburden which are able to sustain a 1 gpm yield of groundwater. Figures F.2-5 and F.2-6 illustrate where the pumping tests were conducted in relation to the distribution of sand and gravel in the glacial overburden deposit. The area beneath Plant 8 and Plant 1 and a channel located in the waste pit area were able to sustain a 1 gpm yield. Drawdown trends indicate that hydraulic communication is enhanced by the distribution of sand and gravel within the clay and silt.

One large system of interconnected high yield perched groundwater zone was identified beneath Plant 8 and Plant 1. The areal extent of the system is limited by the surrounding silt and clay which have hydraulic conductivity values of 10^{-4} cm/s or less. The data indicate that this area could sustain a yield of approximately 1 gpm for longer than one week (Figure F.2-7).

A channel feature located in the waste pit area (most likely a point bar) was also identified as being able to sustain a yield of 1 gpm (Figures F.2-8 and F.2-9). Most of these channel features are probably located south of the Shandon Tributary as this was the source of sediment during the time that the glacial till was deposited. Areas away from the depositional influence of the Shandon

Tributary should have a lower potential for channel deposits, but channels could still exist. Full excavation would be required to identify the exact location of any and all channel deposits.

F.2.2.3 Gray Clay Thickness and Porosity

The highly contaminated perched groundwater observed in the glacial overburden is located in the weathered portion of the overburden which contains fractures and has been disturbed by construction activities. Therefore, vertical contaminant fate and transport modeling through the glacial overburden only includes the gray clay layer. Vertical migration of contaminants through the weathered overburden was assumed to be instantaneous. The thickness of gray clay varies across the site (Figure F.2-10). The thickness of gray clay is zero along portions of Paddys Run and the SSOD where the glacial overburden deposit has been eroded away. The thickness is also zero under some portions of the waste pit area and the former production area where excavation has removed it for the construction of site facilities. The thickness generally increases to the northeast, with the thickest gray clay occurring just northeast of the former production area.

Solid block modeling was conducted for the glacial overburden using all the available soil boring data. Further evaluations and comparisons between the three-dimensional model and previous two-dimensional cross sections used in the RI Report allow a more accurate definition of the gray clay thickness to support the FS. The gray clay thickness is critical in developing the CPRGs and selection of potential locations for the on-site disposal facilities.

79 Geological interpretations of the thickness of the gray clay, presented and used for infiltration estimations in the Operable Unit 5 RI Report, were refined for fate and transport modeling in the FS. Large infiltration areas presented in the RI Report were subdivided into smaller areas and area boundaries were more closely correlated with depositional and surface erosional features (i.e., the SSOD and Paddys Run).

The thickness of the gray clay was divided into four large zones in the RI Report for the purpose of calculating better estimates of infiltration rates (Figure 3-44; DOE 1995). These four large zones roughly correlate to depositional and erosional features. The level of detail pertaining to gray clay thickness is adequate for making gross estimations of infiltration. Many small areas exist within each of these large areas where the gray clay is thinner. These smaller areas needed to be assessed in the FS.

For the FS the four large infiltration zones (Figure 3-45; DOE 1995) were further subdivided into six zones (Figure F.2-11). The isopach map used to guide the zonation is shown in Figure F.2-10. The new zonation using six zones provides for the small areas where the gray clay is thinner. Figure F.2-12 shows the generalized cross sections for the FS zonation. Zone 1 of the RI Report became Zone

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V of the FS. The intent of this zone is to provide for a hypothetical continuous sand pathway from the perched water area beneath Plants 2/3, 8, and 1 to Paddys Run, a pathway was not detected in the field. For the FS the southern boundary of this zone was modified to correspond to the pilot plant drainage ditch. The eastern boundary was modified to correspond to the perched groundwater area capable of sustaining a groundwater yield of 1 gpm. Zone II of the RI Report was subdivided into Zones III and IV and Zones III and IV were subdivided into Zones I, II, III, and IV in the FS. Zone VI in the FS is used to represent areas where no gray clay is present. The boundaries of these new six zones more closely match depositional and surface erosional and drainage features (i.e., Paddys Run and the SSOD).

The gray clay is a clay-rich glacial till deposit. Porosity ranges for a glacial till are lower for clay. Fetter (1988) reports a range from 10 to 20 percent. Driscoll (1989) reports a range from 10 to 25 percent. Total porosity for the gray clay was calculated and ranged from 23 to 30 percent, with an average of 26 percent. For modeling infiltration it is assumed that effective porosity is 20 percent. This represents a 23 percent decrease in porosity from the calculated average of 26 percent. Infiltration was modeled using a smaller porosity because 1) effective porosity for clayey units is usually smaller than total porosity, and 2) seepage velocity is inversely proportional to effective porosity; the smaller the effective porosity the faster the seepage velocity and the faster the infiltration, resulting in a conservative representation of the system.

85 The seepage velocity is controlled by the overall equivalent vertical hydraulic conductivity of the overburden. Sublayer-specific thicknesses and hydraulic conductivities are used to determine this equivalent vertical hydraulic conductivity by calculating the harmonic mean. The harmonic mean is controlled by the thickness of gray clay which has the lowest conductivity in the overburden. Calculated vertical seepage velocities through the glacial overburden range from 0.846 ft/yr (30 feet of gray clay) to 2.15 ft/yr (10 feet of gray clay). Vertical advective travel times through the gray clay (using calculated seepage velocities) range from 41.4 years (30 feet of gray clay) to 13.5 years (10 feet of gray clay), (DOE 1995).

86 The calculations presented in this section relate to field data with an assumed K_h/K_v ratio of 10 for the purpose of preliminary description of the hydrogeological conditions. After water budget analysis and model calibration were conducted, the actual modeling of contaminant migration through overburden used a higher K_v value. The site-specific K_h/K_v ratio of 2.59 was determined through model calibration to match the reported groundwater recharge rate (i.e., 6 in./yr) in the area. Therefore, the seepage velocity through the overburden is about four times higher than the preliminary values presented.

F.2.2.4 Representative Overburden Cross Sections

To determine infiltration rates, the glacial overburden is subdivided into six zones on the basis of the thickness of the gray clay and the distribution of sand and gravel (Figure F.2-11). In addition to the gray clay layer, the weathered glacial overburden (i.e., brown clay, brown clay/sand, and brown/gray sand) is included in the HELP modeling for determining the surface infiltration and recharge rates to the Great Miami Aquifer through the overburden. The weathered overburden functions like a reservoir in the HELP model and results in a higher infiltration rate. However, the weathered layers are not included when simulating contaminant transport through the overburden. Therefore, no slowdown of contaminant migration due to retardation or adsorption through weathered layers are considered in modeling. The objective was to ensure that the overall modeling approach is conservative for estimating infiltration rate and contaminant migration. The representative overburden cross sections for the six infiltration zones are shown in Figure F.2-12.

Zone I covers that area of the FEMP where the thickness of gray clay ranges less than 1 foot up to 5 feet. An average thickness of 2.5 feet was assigned to the zone. The thickness of gray clay increases in Zones II, III, and IV respectively. Zone V consists of a fictitious sand layer approximately 15 feet thick for modeling purposes. The fictitious sand layer provides a model pathway for contamination to move from Plant 8, Plant 2/3, and Plant 1 west to Paddys Run or southwest to the pilot plant drainage ditch. In reality, this pathway does not exist as a continuous 15 foot thick sand layer. It really consists of a heterogeneous mixture of gravel, sand, silt, and clay. The possibility that a "short circuit" pathway through the heterogeneous mixture existed could not be ruled out, so it was decided to model a 15-foot-thick sand layer and conservatively provide for a pathway. The outline of a basin (defined in cross sections) was used to define the northern and eastern boundary, Paddys Run defines the western boundary, the pilot plant drainage ditch defines a portion of the southern boundary, and the presence of sand and gravel defines the rest of the southern boundary. In Zone VI the gray clay is absent and is therefore represented with a thickness of zero.

Because vertical fractures exist in the oxidized layers (brown clay and brown clay/sand), K_v and K_h in these layers are assumed to be similar and are represented by the slug test results directly where fractures in the brown/gray sand layer are less likely to occur due to the coarse nature of sand. K_v is commonly determined to be the slug test result (K_h) divided by 10.

F.2.2.5 Infiltration Rates

Figure F.2-13 illustrates the general water budget for the FEMP area. The annual average precipitation is 40.86 inches, or approximately 41 inches. The 50-year annual average water loss due to evapotranspiration is approximately 26 inches. Based on these two values approximately 15 inches of the annual precipitation is available for surface water runoff and aquifer recharge. Of this 15 inches, it is estimated that where glacial overburden is present that approximately 6 inches recharges

the Great Miami Aquifer and 9 inches becomes surface water runoff. Surface water runoff from the FEMP is to the west-southwest, following surface topography.

Based on the updated geological information and the six zones of representative gray clay thicknesses, new infiltration rates are calculated using the HELP model. The input data and simulated zone-specific infiltration rates are presented in Table F.2-1. In general, the overall average infiltration rate remains the same as in the Operable Unit 5 RI Report. However, the revised zonation facilitates more efficient CPRG development and application processes.

F.2.3 CONSTITUENTS OF CONCERN

F.2.3.1 Definition

Constituents which may adversely impact environmental media and human receptors are determined from sampling, analyses, and screening procedures. If the constituent may impact the environmental media and contributes significantly to the overall risk, then it is classified as a COC. A COC may impact one or several media. A COC in one media may also impact other media due to cross-media transport. In either case, an acceptable cleanup level (i.e., direct-contact PRG or CPRG) must be determined for each COC so that remediation can be performed to minimize the COC's impact on the environment.

For the Operable Unit 5 RI, sampling, analyses, and screening procedures were performed to determine the COCs. The baseline risk assessment outlines the COCs for each specific media. However, the baseline risk assessment results only summarize the final COC list for each media and do not show if the COC impacts only a specific media or other media due to cross-media transport. Additional screening was performed showing the COCs and the media, considering both direct contact and exposure and cross-media transport, which they impact. These screening results were used to finalize the list of COCs which require development of CPRGs.

F.2.3.2 General Technical Approach and Summary of Results

462 Table F.2-2 summarizes the COPC screening results for the Operable Unit 5 FS. The table includes screening results for five specific media including surface soil, groundwater, perched groundwater, surface water, and sediment. In addition, hazardous waste management unit (HWMU) COPCs are summarized in this table. The last column in Table F.2-2 identifies the COPCs that failed cross-media screening and may require CPRG development. Any COPCs that can cause unacceptable impacts due to direct contact and exposure are COCs and also require remediation considering media-specific PRGs.

Screening was conducted based upon a 1×10^{-7} ILCR or a hazard quotient (HQ) of 0.1. Maximum detections of contaminants in each media were screened against the media-specific criteria. Modeling

was also conducted to predict the COPC concentrations in groundwater from the surface soil or perched groundwater. This modeling accounted for cross-media migration of COPCs. The predicted COPC concentrations were compared to groundwater criteria. Additional modeling was conducted for surface soil and sediment to determine their cross-media impact on surface water and groundwater. The predicted concentrations were compared to surface water, sediment, and groundwater criteria.

The screening results for surface soil are summarized in the second and third columns of Table F.2-2. Column 2, entitled Surface Soil, indicates if the COPC was detected (D) or not detected (ND) in the media and also if it passed (P) or failed (F) the screening. For example, 1,1-dichloroethene was detected in the media and failed the screening, therefore a D/F symbol was used. Column 3, entitled DC SS, reiterates the COPCs that failed the screening using an X denotation.

Columns 4 and 5 in the table summarize the groundwater screening information. Column 4 summarizes the cross-media screening results. COPCs that failed the screening are denoted with an F and those that passed are labeled with a P. An X is used in Column 5 to denote the COPCs that failed screening against direct exposure to the groundwater.

Columns 6 and 7 in Table F.2-2 show the perched groundwater screening information. Column 6 summarizes the cross-media screening results, which consider migration of perched groundwater to surface water and eventually groundwater. A P or F symbol is also used in this column to signify passing or failing the screening. In addition, a NDP is used to designate a COPC that was detected in the perched groundwater, but not in the perched groundwater zone which has potential to laterally migrate to a surface water body within the modeling time frame (i.e., 1000 years). In Column 7 two symbols, X and x', are used to denote COPCs that failed the screening. The X indicates a COPC that failed screening based on direct/indirect contact/exposure with the indicated media and/or potential future cross-media impact. The x' signifies a COPC that was detected in perched groundwater outside the zone that can sustain a 1 gpm pumping rate but that failed screening based on direct/indirect contact/exposure and with potential to move into perched groundwater (using drinking water PRGs for the perched groundwater criteria).

Columns 8 through 11 in Table F.2-2 summarize the surface water and sediment screening results. Columns 8 and 10 present the cross-media screening results, that consider migration from surface soil to surface water. Columns 9 and 11 summarize screening results that consider direct exposure and contact to surface water and sediment, respectively. All symbols used in these columns are identical to symbols used in other columns with the exception of the NPRG and NDS symbols. NPRG suggests that no risk-based PRG can be developed to evaluate this contaminant due to a lack of

toxicity factors (i.e., slope factors or reference doses). NDS signifies that the COPC was not detected in the surface water modeling domain.

462 Column 12 in the table shows the COPCs for HWMUs. COPCs for HWMUs are included for comparison purposes only. The final column in Table F.2-2, Column 13, indicates if the COPC requires a CPRG to be developed considering all media and migration pathways. Only COPCs that fail either groundwater or surface water model screening (i.e., have "F" in Columns 4, 8, or 10) may require CPRGs.

F.2.3.3 Selection of Major COCs for FS Fate and Transport Modeling

Listed in the first column in Table F.2-2 are the COPCs for Operable Unit 5. The CPCs are listed under three categories, either an organic, inorganic, or radionuclide. A (c) designation is used in this column to denote COPCs which present greater than 95 percent of the total risk to receptors evaluated in the Operable Unit 5 RI Report. Table F.2-3 shows an abridged version of Table F.2-2 which presents only the COCs which contribute to 95 percent of the total risk. These are the COCs which require soil CPRG development in the FS.

As discussed above, Table F.2-3 was created from Table F.2-2 by eliminating those CPCs which did not contribute significantly to 95 percent of the risk for Operable Unit 5. This abbreviated table shows the same information as Table F.2-2, but only for COCs. One difference between the two tables is noticeable; the organics that comprise polycyclic aromatic hydrocarbon (PAHs), polychlorinated biphenyls (PCBs), and dioxins/furans have been grouped into these three categories instead of listing them individually. If any COC within the group failed the screening the entire group failed the screening and requires PRGs and/or CPRGs.

The development of soil CPRGs is discussed in Section F.3. Soil CPRGs are only developed for the COCs listed in Table F.2-3 that failed the cross-media screening in the groundwater pathway (i.e., consitutents that can create unacceptable cross-media impacts). Other COCs listed in Table F.2-3 will have PRLs based on PRGs only. Surface water and sediment protective requirements are presented in Section F.4. Protective requirements for these media were determined for all COPCs listed in Table F.2-3 that failed surface water or sediment screening. Also, for the residual risk evaluation purposes, the contaminants to be evaluated by fate and transport modeling are not limited to Table F.2-3 in all the pathways. All of the contaminants that still have significant residual concentrations after proposed remedial actions and that have high mobility in any migration pathway will be modeled to support the residual risk assessment.

F.2.4 GEOCHEMICAL CONDITIONS

Geochemical parameters that are important in the evaluation and modeling of contaminant migration in the environment are summarized in this subsection. The approaches used to determine appropriate values for these parameters are also presented. For ease of understanding and due to their different nature, geochemical conditions in soil and groundwater media are discussed separately.

F.2.4.1 Geochemical Parameters

Major constituent-specific geochemical parameters required in the fate and transport modeling include: (1) percent of extractable contaminant (K_e) in the sources, (2) leaching coefficient (K_l) in the sources, (3) solid-liquid partition coefficient (K_d) in the sources and the migration media, and (4) retardation factor (R_d) in the migration media. The distinction between the parameters K_l and K_d is based on the type of contaminant solid that is present in the soil. For K_l, a contaminant may be present as particulate and adsorbed forms, and the leaching coefficient measures contaminant mobilization due to both dissolution and desorption. K_d is solely a measurement of adsorption/desorption equilibrium between soil and water, which assumes the solid contaminant in excess of background is present only in adsorbed form. These parameters have significant impacts on the estimates of contaminant mass, concentrations, and loading and migration rates; therefore, it is important that values for these parameters are properly assigned.

Solid-Liquid Partition Coefficient (K_d)

Solid-liquid partition coefficients are used in fate and transport modeling to simulate the reversible adsorption/desorption processes of contaminants. K_d is a traditional measure of the mobility of a contaminant in the media. It is commonly defined for fate and transport modeling as the constant ratio between solid phase and dissolved phase concentrations of a chemical at equilibrium in (i.e., a linear isotherm). Therefore, chemicals with higher K_d values are more likely to be adsorbed onto soil materials and thus have less potential to migrate in the subsurface. K_d for radionuclide and inorganic constituents are dependent on the medium types and conditions. K_d for an organic constituent is usually calculated using the constituent-specific octanol/water partition coefficient (KOW) and area-specific fraction of organic content (FOC) as shown in Appendix F.2.3.2 of the Operable Unit 5 RI Report.

Source Leaching Coefficient (K_l)

In the Operable Unit 5 fate and transport model which describes uranium migration in the glacial overburden, K_l is used to define the initial aqueous loading of uranium. Uranium K_l is determined either by using laboratory tests or calculations of field data. The laboratory method used batch tests that contacted waste or contaminated soil with a distilled water solution adjusted to a pH of 5.6 with sulfuric acid. The K_l was calculated by dividing the uranium concentration on the solid (only uranium in excess of background) by the uranium concentration in solution. For the second method, an in situ

leaching coefficient is determined by dividing the uranium concentration for the contaminated soil (only uranium in excess of background) by the uranium concentration in perched groundwater contacting the soil. Distribution of site-specific values of uranium K_l and K_d is discussed in Appendix F.3.I and F.3.II of the Operable Unit 5 RI Report.

The K_l and K_d values are also determined separately for technetium due to existing evidence of large differences between site-specific K_l and literature K_d values. For other contaminants, K_d values in the media are used to approximate source K_l values. This is a very conservative approach for modeling. The solid phase concentrations used in the definition and calculation of K_l include both particulate and adsorbed forms of contaminants while only the adsorbed forms of contaminants are considered in the K_d definition and calculation. Therefore, for any contaminant K_l is at least as high as and usually higher than K_d by definition. Using the lower K_d value instead of K_l, for a given source solid concentration, a higher source leachate concentration can be generated in the fate and transport model. As a result, a higher receptor concentration will be predicted.

Percent of Extractable Contaminant in the Waste Materials (K_e)

Although the adsorption/desorption process is usually considered to be reversible in fate and transport modeling, in general, the longer a contaminant remains adsorbed to the surface of a solid the more likely it is to be incorporated into the solid by surface reactions where it is no longer available for desorption under environmental conditions. Therefore, an estimate of the percent of extractable contaminant in the sources, which are usually solid phase waste or soil, is required to determine the contaminant mass available for transport and leachate concentration.

For contaminated soil, a value of K_l can be calculated considering either the total or only the extractable contaminant mass in the soil. When a K_e of less than 100 percent is applied in the modeling, K_l will only be determined for the extractable portion of contaminant mass. The value of K_l is lower when only the extractable mass is considered. For example, when K_e is about 1 percent, the corresponding K_l is usually less than 1 percent of the K_l value based on total contaminant mass. When a value of K_l is determined only for the extractable portion, it is relatively constant throughout the site. Conceptually, for a contaminated soil, K_e will decrease with time and K_l, based only on the extractable mass, remains the same when extractable contaminant mass is dissolving. As a result, K_l based on the total mass will increase with time.

The Operable Unit 5 K_l study (DOE 1994), conducted to support the FS, demonstrates the current distributions of uranium K_e and K_l values as well as the differences between K_l values calculated based on total contaminant mass and only the extractable mass for the same contaminated soil. Results of this study are summarized in the next subsection. When K_e is applied in the modeling, the solid phase concentration, K_l and K_d will only be determined for the extractable portion of the

contaminant. Although site-specific information has been collected for the K_e of uranium, K_e is not applied in fate and transport modeling for any constituent (i.e., assumed as 100 percent) in the Operable Unit 5 RI/FS modeling. Although not directly applied in fate and transport modeling, the value and concept of K_e is important for understanding the contaminant release history and transport potential at the FEMP.

Retardation Factor (R_d)

The contaminant travel time from a source area to the exposure points is one of the major concerns in risk assessment. For determining the contaminant travel time, the retardation factor is defined as the ratio between the groundwater flow velocity and chemical migration velocity through the soil matrix. With dispersion it represents the 50th percentile concentration level of an advancing front of contamination. Because most contaminants have higher tendencies to adsorb to soil than they have to remain dissolved in water, they usually migrate slower than water in the subsurface environment. Therefore, R_d is usually greater than 1. In fate and transport modeling, R_d is estimated by considering both the contaminant characteristics (i.e., K_d) and the soil properties such as dry bulk density and moisture content.

F.2.4.2 Geochemical Conditions in Overburden

Geochemical information collected to understand the concepts of leaching and transport of uranium in the glacial overburden is presented in the Operable Unit 5 RI Report in Appendix F.3, Attachments I and II (DOE 1995). Attachment I describes the historical airborne release of uranium and geochemical concepts of the subsurface uranium distribution at the FEMP. Attachment II presents the zonation and values of geochemical parameters used for fate and transport modeling to support the baseline risk assessment. Geochemical information for other contaminants is generally taken from literature sources.

Two geochemical parameters, K_l and K_e, describe the leachability of a contaminant from a source material and the percent of the contaminant which is extractable from the source material, respectively. K_l is a source leaching coefficient which is a measure of a contaminant's mobility due to dissolution and desorption. This parameter is used to define the initial aqueous loading of a contaminant based on the extractable portion (i.e., K_e) of the contaminant in the soil. K_e defines the portion of the contaminant which is extractable from the source material. In general, the longer a contaminant remains adsorbed to the surface of a solid the more likely it is to be incorporated into the solid by surface reactions making it no longer available for desorption under environmental conditions. K_e is the parameter which can be used to define the extractable fraction of contaminant which can be mobilized due to desorption. K_e can also be used as a measure of the homogeneity of the contaminant (all soluble or insoluble) in the source material.

Various release histories and forms of uranium in FEMP contaminant sources resulted in different values of K_l and K_e for different source areas. The K_l and K_e values define the three types of material identified at the FEMP, two of which can be considered as source material (waste material and contaminated media) and the third being soil with background concentrations of uranium.

It was shown in Attachment II of the Operable Unit 5 RI Report that uranium K_l values of 15 L/kg and 325 L/kg were appropriate for contaminated soil in areas inside and outside portions of the production area, respectively. These values were used for fate and transport modeling and were determined using area-specific uranium concentrations measured in insitu leachate, waste material, perched water, toxicity characteristic leaching procedure (TCLP) samples, and/or batch test results. In addition, the percent of extractable uranium (K_e) in the waste material was described in this attachment. K_e was shown to range from 30 to 50 percent for waste material. Sources of information used to determine K_e included the Oak Ridge National Laboratories (ORNL) soil characterization and washing study (Lee and Marsh 1992) and Operable Unit 2 batch tests (DOE 1993). K_e was used by Operable Unit 5 to describe the data collected from lysimeters in the southeast portion of the FEMP.

At the time Attachments I and II of Appendix F.3 were written for the June 1994 draft of the Operable Unit 5 RI Report, a limited amount of data (for uranium only) was available to develop uranium K_l values for outside of the production area and to determine K_e values. There was little if any data available for other contaminants. Therefore, an additional investigation (including additional rounds of soil sampling, a series of two-step desorption batch tests) and TCLP analyses was conducted to support assumptions used for the fate and transport modeling performed as part of the Operable Unit 5 FS and to verify the assumptions made in the draft RI Report. This investigation was conducted to provide additional information on the leachability of other Operable Unit 5 COCs as well as uranium in surface and subsurface soil. It also provided information to better define the areal and vertical distribution of uranium and other COCs. This information was helpful in defining contaminant source terms and the need for remedial actions. The details of the project are described in the Project Specific Plan (PSP) for Operable Unit 5 K_l Soil Sampling and Analysis, Rev. 0, July 1994 (DOE 1994) and in Appendix F.2.I.

At the present time, only the preliminary K_l and K_e results for uranium and TCLP results for technetium-99 are available from the study and only these results are described Attachment F.2.I. A general summary of the study's results is given below. A complete summary of the study's results will be presented in a separate report. The report will include the details of the laboratory procedures and analyses which were conducted, as well as the details of sample collection, derivation of equations, calculation procedures, and final results.

In summary, the sampling and batch test results for uranium show that outside of the production area, the residual contamination (uranium oxides with a low solubility and high K_l), is contained in the top of the glacial overburden (0 to 2 inches). This supports Operable Unit 5's decision of using a high uranium K_l (325 L/kg) in the area outside of the former production area. The results also confirm that the soluble uranyl carbonate species (e.g., derived from uranium fluorides with low K_l), which were once present in the waste material deposited by air deposition (1950s and 1960s), has leached out and passed through the glacial overburden or is present deep within the glacial overburden and is of little consequence. The uranium remained in the aqueous phase and passed through the glacial overburden due to the high solubility of the uranium species and the low K_d of the glacial overburden. These results are evident from the high concentrations of uranium measured in the 0 to 2 inch interval and the low concentrations (background) measured in the 24 to 30 inch interval. Therefore, only the residual contamination which is contained in the top few inches of the soil column must be considered as a source of contamination for remediation modeling considerations.

The study results (soil sample analyses and TCLP results) for technetium-99 were used to determine K_l values for this contaminant. The technetium-99 K_l values, ranged from 7.8 L/kg to 198 L/kg with a geometric mean of 37 L/kg. This mean K_l (37 L/kg) for technetium-99 is approximately two orders of magnitude higher than the literature glacial overburden K_d (0.118 L/kg) which was originally being used as K_l for technetium-99. This site-specific K_l value was incorporated into the modeling performed for the Operable Unit 5 FS.

F.2.4.3 Geochemical Conditions in Groundwater

Constituents that are present in groundwater as solute (i.e., dissolved solids) will migrate in accordance with their affinity to adsorb onto solid particles. The affinity of a given constituent to adsorb is primarily a function of soil mineralogy, particle surface area, and the charge of the aqueous specie, which may be negative, neutral, or positive. Under the geochemical and mineralogical conditions present at the FEMP site, positively charged aqueous species (i.e., cations) have a greater affinity to adsorb relative to the neutral and negatively charged species (i.e., anions). Therefore, apparent distribution ratios (K_d) between soil and groundwater should be larger for cations relative to anions and neutral species, which implies anions and neutral species will migrate more readily. However, mineral solubility may control some constituent concentrations in groundwater (e.g., thorium), and the solubility concentration of the constituent may be sufficiently low to prevent migration regardless of the charge on the aqueous phase (e.g., $Th(HPO_4)_3^{-2}$). Finally, the K_d and/or solubility of a given constituent will determine how long the constituent remains in the perched groundwater/glacial overburden system, with large K_d values and/or low solubility resulting in long residence times. Evaluations of K_d values of major contaminants found in the groundwater system are summarized in this subsection.

Glacial Overburden Perched Groundwater

Aqueous speciation and applicable K_d values for inorganic and radionuclide constituents found in the glacial overburden groundwater are summarized in Table F.2-4. Aluminum, antimony, arsenic, neptunium, technetium, thorium, uranium, and vanadium species are dominated by anion complexes, with corresponding low to moderate K_d values. The low to moderate K_d values suggest greater mobility for these constituents relative to cations, with the exception of aluminum and thorium. Aluminum and thorium concentrations in groundwater are constrained to very low values by mineral solubility (see Table F.2-4 footnotes), and migration of these constituents is not expected beyond the area proximal to waste sources.

Copper, iron, and silver species are dominated by neutral aqueous complexes, and moderate K_d values have been estimated for these constituents. The moderate K_d values suggest limited mobility in the glacial overburden, although iron and silver are expected to be nearly immobile due to mineral solubility constraints (see Table F.2-4 footnotes). However, if oxygen-deficient waters are encountered in the waste sources and/or groundwater, iron may be mobilized by reduction to Fe(II).

Beryllium, cadmium, calcium, chromium, magnesium, manganese, radium, sodium, strontium, and thallium species are principally cations, and their corresponding K_d values are moderate to large. In the carbonate-rich soils of the glacial overburden, calcium, magnesium, manganese, and strontium concentrations will be controlled by carbonate mineral solubilities, resulting in aqueous concentrations that are near background values. Elevated groundwater values for these four constituents would indicate a proximal waste source; that is, extensive migration is not expected. Under the present redox conditions in the glacial overburden, chromium is predicted to exist as Cr(III), which forms a cation specie that is readily sorbed. However, if waste sources or parts of the glacial overburden are highly oxidizing, chromium will be oxidized to Cr(VI), which forms the mobile aqueous specie CrO_4^{-2}. Beryllium, cadmium, radium, sodium, and thallium are predicted to exist as simple divalent or monovalent cations. With the exception of sodium, the high K_d values for these constituents will result in their retention near the waste sources. Sodium is a major cation in all groundwater systems and its concentration can be quite large and variable, as it forms very soluble compounds (e.g., NaCl, NaOH, etc.).

Great Miami Aquifer

Aqueous speciation and applicable K_d values for seven constituents found in the Great Miami Aquifer are summarized in Table F.2-5. Antimony, arsenic, neptunium, technetium, and uranium species are dominated by anion complexes, with corresponding low K_d values. The lower K_d values will result in relatively shorter residence times in the Great Miami Aquifer for these constituents, after the source has been removed. Manganese and radium species are dominated by the divalent cations Mn^{+2} and Ra^{+2}, and higher K_d values for these constituents reflects the ability of negatively charged soil

particles to attract positively charged aqueous species. The relatively higher K_d values for manganese and radium will result in longer residence times in the Great Miami Aquifer for these constituents.

A comparison of the arsenic, manganese, and neptunium K_d values indicates considerable overlap in the reported range, in apparent contrast to the simple anion/cation breakdown mentioned above. The high end of the arsenic K_d range overlaps with low end of the manganese K_d range due to the high percentage of iron oxyhydroxide phases in soils (greater than 50 percent) used to obtain the cited arsenic K_d values. Iron oxyhydroxide phases have a high affinity for negatively charged aqueous species because their surfaces maintain a net positive charge up to a pH of about 8.5. K_d values for arsenic in Great Miami Aquifer are expected to be at the low end of this range, or lower, due to the low percentage of iron oxyhdroxide phases in the Great Miami Aquifer (estimated to be less than 10 percent, based on mineralogical analysis of glacial overburden). The higher end of the neptunium K_d range is a result of a portion of the neptunium being speciated as NPO_2^+, which is a cation that will adsorb more readily than the anion forms. Based on the dominant predicted species and iron oxyhydroxide content of the Great Miami Aquifer, the best estimate of K_d values for these constituents in the Great Miami Aquifer is the lowest value for arsenic and neptunium and the highest value for manganese.

Summary

The mobility of constituents in groundwater systems will be a function of the constituent solubility and K_d value. The migration of soluble constituents will be controlled by the soil mineralogy, particle surface area, and the charge of the aqueous specie, which should be reflected in the K_d value assigned to the constituent. Constituents that form anion complexes (e.g., TcO_4^-) generally have low K_d values, and these constituents will migrate more readily than cation species which are assigned higher K_d values (e.g., Ra^{+2}).

Additionally, the K_d value provides indirect information on the location of constituent source areas. Constituents with high K_d values will be retained near their sources, and their aqueous presence is usually limited to groundwater below these sources. Therefore, if a constituent has a high K_d and is found throughout a broad area of the aquifer, it indicates multiple sources over this area. In contrast, a constituent with a low K_d value may have a large areal extent and only a single source. The K_d value also affects the design of the recovery well system for the groundwater remedial component. In general, larger numbers of wells and longer pumping periods are required for contaminants with higher K_d values.

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F.2.5 REFERENCES

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TABLE F.2-1
HELP MODEL PARAMETERS AND RESULTS

Parameter	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	K_{sat} (cm/sec)
Layer Thickness (ft)							
Brown/Gray Sand	0	0	0	0	15	0	1.10×10^{-4}
Brown Clay/Sand	5	5	10	10	5	2.5	7.04×10^{-5}
Gray Clay	2.5	5	10	20	10	0	7.23×10^{-7}
Unsaturated Great Miami Aquifer	20	25	30	35	20	20	1.59×10^{-2}
AMC-II Runoff Curve Number	30.5	30.5	30.5	30.5	30.5	30.5	NA
Vegetative Cover Number	5.0	5.0	5.0	5.0	5.0	5.0	NA
Leaf Area Index	5.0	5.0	5.0	5.0	5.0	5.0	NA
Evaporative Zone Depth (in)	38	38	38	38	38	38	NA
Infiltration Rate (in/yr)	4.78	4.80	5.87	5.92	6.75	8.29	NA

NA = Not Applicable

TABLE F.2-2

SUMMARY OF SCREENING FOR OPERABLE UNIT 5 CONSTITUENTS OF POTENTIAL CONCERN[a]

Constituents of Potential Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[a]
Organics												
1,1-Dichloroethane	D/P		P		P	X	P		NPRG			N
1,1-Dichloroethene	D/F	X	P		P		F	X	P			Y
3,3'-Dichlorobenzidine	D/P		P		P		F	X	P			Y
4-Methylphenol	D/P		P		NDP		F	X	P			Y
4-Nitroaniline	D/P		F	X	P		F	X	P			Y
1,2-Dichloroethane[c]	D/P		F	X	P	x'	P		P			Y
Acetone	D/P		P		P		P		P		X	N
Benzene	D/P		P		P	X	F	X	P		X	Y
Bromoform	ND		P		P	x'	NDS		NDS			N
Bromomethane	D/P		P	X	NDP		F	X	P			Y
Bromodichloromethane	D/P		F	X	NDP		F	X	P			Y
Carbazole	D/F	X	F	X	P	X	P		P			Y
Carbon disulfide	D/P		P		P	X	P		P			N
Carbon tetrachloride	D/P		P		NDP	x'	NDS		NDS		X	N
Chloroform	D/P		P	X	NDP		F	X	P			Y
Chlorobenzene	D/P		P		P		P		P		X	N
bis(2-chloroisopropyl)ether	D/P		F	X	NDP		F	X	P			Y
Ethyl benzene	D/P		P		P		P		P		X	N
Ethyl ether	ND		ND		NDP		NDS		NDS		X	N
Methanol	ND		ND		NDP		NDS		NDS		X	N
Methyl isobutyl ketone (4-M-2-P)	D/P		P		P		P		NPRG		X	N
Methylene chloride	D/F	X	P	X	P	X	F	X	P		X	Y
Methyl ethyl ketone (2-Butanone)	D/P		P		P		P		P		X	N
4-Methylphenol	ND		P	X	P		F	X	P			Y
n-Nitrosodipropylamine	D/P		P		NDP	x'	P		P			N
n-Nitrososdiphenylamine	D/F	X	P		NDP		P		F	X		Y
Toluene	D/P		P		P		P		P		X	N
1,1,1-Trichloroethane	D/P		P		P	X	P		NPRG		X	N
1,1,2-Trichloroethane	D/P		P		P	X	P		P			N

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TABLE F.2-2
(Continued)

Constituents of Potential Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[a]
Organics (Continued)												
Tributyl phosphate	D/P		P		NDP	x'	P		P			N
Tetrachloroethene	D/F	X	P		P	x'	P	X	P		X	N
Trichloroethene[c]	D/F	X	P	X	P	X	P		P		X	N
Vinyl chloride	D/P		F	X	P	X	NDS		NDS			Y
Xylene	D/P		P		P		P		P		X	N
bis(2-ethylhexyl)phthalate	D/F	X	P		P	X	P	X	P			N
di-n-octyl phthalate	D/P		P		NDP		P	X	P			N
Pentachlorophenol	D/P		P		P	X	NDS		NDS			N
Benzoaanthracene	D/F	X	P		P		F	X	P			Y
Benzoapyrene[c]	D/F	X	P		P		F	X	P			Y
Benzobfluoranthene[c]	D/F	X	P		P		P		P			N
Benzo(k)fluoranthene	D/F	X	P		P		P		P			N
Chrysene	D/F	X	P		P		P		P			N
Dibenzo(a,h)anthracene[c]	D/F	X	P		P		F	X	P			Y
Indeno(1,2,3-cd)pyrene[c]	D/F	X	P		P		P		P			N
Phenanthrene	D/P		P		P		P		NPRG			N
Aroclor-1254[c]	D/F	X	P		P		F	X	F	X		Y
Aroclor-1260[c]	D/F	X	P		P		F	X	F	X		Y
Alpha-chlordane[c]	D/P		F	X	NDP		F	X	P			Y
Dieldrin	D/P		P		P		F	X	P			Y
Heptachlorodibenzo-p-dioxin	D/F	X	P		P		NDS		NDS			N
Heptachlorodibenzofuran	D/F	X	P		P		P		P			N
Octachlorodibenzo-p-dioxin[c]	D/F	X	P		P		P		P			N
Octachlorodibenzofuran	D/F	X	P		P		P		P			N

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TABLE F.2-2
(Continued)

Constituents of Potential Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[a]
Inorganics												
Antimony[c]	D/F	X	P	X	P		F	X	P			Y
Arsenic[c]	D/F	X	P	X	P	x'	F	X	P			Y
Barium	D/F	X	P		P		P	X	P		X	N
Beryllium[c]	D/F	X	P	X	P	X	F	X	P			Y
Boron	D/F	X	F	X	NDP	x'	P		P			Y
Cadmium[c]	D/F	X	P		P	X	P		P			N
Chromium vi	D/F	X	F	X	P	X	P	X	P		X	Y
Cobalt	D/P		P		P		P		P			N
Copper	D/F	X	P		P	X	P	X	P			N
Cyanide	D/P		P		P	x'	F	X	P			Y
Lead	D/F	X	P		P		F	X	F	X	X	Y
Magnesium[c]	D/F	X	F	X	P	X	F	X	P			Y
Manganese[c]	D/F	X	P	X	P	X	F	X	F	X		Y
Mercury[c]	D/F	X	F	X	P		F	X	P		X	Y
Molybdenum	D/F	X	P		P	x'	P		P			N
Nickel	D/F	X	P		P		P	X	P			N
Selenium	D/F	X	P		P		P		P			N
Silver[c]	D/F	X	P		P	X	P		P		X	N
Thallium	D/F	X	P		P	X	P		P			N
Uranium-total[c]	D/F	X	F	X	P	X	F	X	F	X		Y
Thorium-total	D/P		P		P	X	F	X	F	X		Y
Vanadium	D/F	X	P		P	X	P	X	P			N
Zinc	D/F	X	P		P		P	X	P			N
Nitrate	D/P		F	X	P	X	P	X	P			Y
Fluoride	ND		F	X	F	X	NDS		NDS			Y

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TABLE F.2-2
(Continued)

Constituents of Potential Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[e]
Radionuclides												
Cs137+1d	D/F	X	P		P		P		P			N
Np237+1d	D/F	X	F	X	P	x'	F	X	P			Y
Pb210+2d	D/F	X	P		P	X	F	X	F	X		Y
Pu238	D/F	X	P		P	x'	F	X	P			Y
Pu239/240	D/F	X	P		P	x'	F	X	P			Y
Ra226+4d[c]	D/F	X	P	X	P	X	F	X	F	X		Y
Ra228+1d[c]	D/F	X	P	X	P		F	X	F	X		Y
Sr90+1d[c]	D/F	X	F	X	P	x'	F	X	P			Y
Tc99[c]	D/F	X	F	X	P	X	F	X	P			Y
Th228+7d[c]	D/F	X	P		P	X	F	X	F	X		Y
Th230[c]	D/F	X	P		P	X	F	X	P			Y
Th232+10d[c]	D/F	X	P		P	X	F	X	F	X		Y
U234	D/F	X	F[d]	X	P	X	F[d]	X	P[d]			Y
U235+d/236[c]	D/F	X	F[d]	X	P	X	F[d]	X	F[d]	X		Y
U238+2d[c]	D/F	X	F[d]	X	P	X	F[d]	X	F[d]	X		Y

a COPCs include constituents from the OU5 RI, based upon a cancer risk level of $< 1 \times 10^{-7}$ or an HQ of 0.1. Also contains constituents detected in surface soil, sediment, groundwater and perched groundwater that could potentially have a cross-media impact based upon modeling.
b Media containing COPCs from HWMU's are not specified.
c COPCs which present greater than 95% of the total risk to receptors evaluated in the OU5 RI.
d During modeling isotope was considered as part of total uranium.
e COPC failed screening and should require a Cross-media PRG (CPRG) to be developed.
X Denotes COC based on direct/indirect contact/exposure with the indicated media and/or potential future cross-media impact.
x' Denotes COC based on direct/indirect contact/exposure with perched water, using drinking water PRGs for the perched water criteria, but COC was detected in perched water outside of perched water zone which can sustain 1 gpm pumping rate.
DC Direct Contact
DE Direct Exposure
D/P Denotes COPC was detected in surface soil and passed risk-based screening critieria of cancer risk greater or equal to 1E-7 or an HQ of 0.1 based on DC/DE.
D/F COPC was detected in surface soil and failed screening criteria of cancer risk greater or equal to 1E-7 or an HQ of 0.1 based on DC/DE.
P COPC passed modeling screening (P = no longer a problem).
F COPC failed modeling screening (F = still a problem).
ND Not detected in corresponding media
NDP COPC not detected in perched water zone which has potential to laterally migrate to surface water body
NDS COPC not detected in the surface water modeling domain
NPRG No risk-based PRG can be developed to evaluate this contaminant due to a lack of toxicity factors (i.e., slope factors or reference doses)
Y Yes, a CPRG should be developed for this COC
N No, a CPRG is not required for this COC

TABLE F.2-3

SUMMARY OF SCREENING FOR OPERABLE UNIT 5 CONSTITUENTS OF CONCERN[a] WHICH CONTRIBUTE 95 PERCENT OF OPERABLE UNIT 5 RISK

Constituents of Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[c]
Organics												
1,2-Dichloroethane[c]	D/P		F	X	P	x'	P		P			Y
Trichloroethene[c]	D/F	X	P	X	P	X	P		P		X	N
PAHs	D/F	X	P		P		F	X	P			Y
PCBs	D/F	X	F	X	P		F	X	F	X		Y
Dioxins/Furans	D/F	X	P		P		NDS		NDS			N
Inorganics												
Antimony[c]	D/F	X	P	X	P		F	X	P			Y
Arsenic[c]	D/F	X	P	X	P	x'	F	X	P			Y
Beryllium[c]	D/F	X	P	X	P	X	F	X	P			Y
Cadmium[c]	D/F	X	P		P	X	P		P			N
Magnesium[c]	D/F	X	F	X	P	X	F	X	P			Y
Manganese[c]	D/F	X	P	X	P	X	F	X	P			Y
Mercury[c]	D/F	X	F	X	P		F	X	P		X	Y
Silver[c]	D/F	X	P		P	X	P		P		X	N
Uranium-total[c]	D/F	X	F	X	P	X	F	X	F	X		Y

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TABLE F.2-3
(Continued)

Constituents of Concern	Surface Soil	DC SS	Vertical Migration from Soil or PW to GW	DE GW	Lateral Perched GW Migration	DE PW	Surface Water	DE SW	Sediment	DC S	HWMUs[b]	CPRG[e]
Radionuclides												
Ra226+4d[c]	D/F	X	P	X	P	X	F	X	F	X		Y
Sr90+1d[c]	D/F	X	F	X	P	x'	F	X	P			Y
Tc99[c]	D/F	X	F	X	P	X	F	X	P			Y
Th230[c]	D/F	X	P		P	X	F	X	P			Y
Th232 + 10d[c]	D/F	X	P		P	X	F	X	F	X		Y
U235+d/236[c]	D/F	X	F[d]	X	P	X	F[d]	X	F[d]	X		Y
U238+2d[c]	D/F	X	F[d]	X	P	X	F[d]	X	F[d]	X		Y

a COCs include constituents from the OU5 RI, based upon a cancer risk level of 10^{-7} or an HQ of 0.1. Also contains constituents detected in surface soil, sediment, groundwater and perched groundwater that could potentially have a cross-media impact based upon modeling.
b Media containing COCs from HWMU's are not specified.
c COCs which present greater than 95% of the total risk to receptors evaluated in the OU5 RI.
d During modeling isotope was considered as part of total uranium.
e COC failed screening and requires a Cross-media PRG (CPRG) to be developed.
X Denotes COC based on direct/indirect contact/exposure with the indicated media and/or potential future cross-media impact.
x' Denotes COC based on direct/indirect contact/exposure with perched water, using drinking water PRGs for the perched water criteria, but COC was detected in perched water outside of perched water zone which can sustain 1 gpm pumping rate.
DC Direct Contact
DE Direct Exposure
D/P Denotes COC was detected in surface soil and passed risk-based screening critieria of cancer risk greater or equal to 1E-7 or an HQ of 0.1 based on DC/DE.
D/F COC was detected in surface soil and failed screening criteria of cancer risk greater or equal to 1E-7 or an HQ of 0.1 based on DC/DE.
P COC passed modeling screening (P = no longer a problem).
F COC failed modeling screening (F = still a problem).
NDS COC not detected in the surface water modeling domain
Y Yes, a CPRG should be developed for this COC
N No, a CPRG is not required for this COC

TABLE F.2-4

SPECIATION OF SELECTED CONSTITUENTS IN PERCHED GROUNDWATER AND APPLICABLE K_d VALUES

Constituent	Species[a]	Molal Percent[b]	K_d (L/kg)
Aluminum	$Al(OH)_4$	91.75	99[d]
	$Al(OH)_3^o$	5.50	
	$Al(OH)_2^+$	1.56	
	AlF_2^+	0.76	
Antimony	$HSbO_2^o$	c	0.78 - 1.4[d]
	SbO_2	c	
	$Sb(OH)_3^o$	c	
Arsenic	AsO_3F^{-2}	96.7	5 - 16[e]
	$HAsO_3F$	3.25	
Beryllium	Be^{+2}	100	100 - 700[fj]
Cadmium	Cd^{+2}	100	160 - 500[f]
Calcium	Ca^{+2}	92.7	30 - 50[mn]
	$CaHCO_3^+$	4.19	
	$CaSO_4^o$	2.42	
Chromium	$Cr(OH)_2^+$	89.6	30 - 60[f]
	$Cr(OH)_3^o$	6.34	
	$CrOH^{+2}$	3.96	
Copper	$CuCO_3^o$	92.6	110[k]
	Cu^{+2}	3.85	
	$CuOH^+$	2.30	
	$Cu(OH_3)_2^{-2}$	0.99	
Iron	$Fe(OH)_3^o$	80.5	165 - 220[mo]
	$Fe(OH)_2^+$	18.2	
	$Fe(OH)_4^+$	0.53	
Magnesium	Mg^{+2}	91.1	p
	$MgHCO_3^+$	4.09	
	$MgSO_4^o$	3.97	

TABLE F.2-4
(Continued)

Constituent	Species[a]	Molal Percent[b]	K_d (L/kg)
Manganese	Mn^{+2}	84.0	50 - 180[m]
	$MnCO_3^{\circ}$	7.41	
	$MnSO_4^{\circ}$	3.64	
	$MnHCO_3^{+}$	2.57	
	$MnHPO_4^{\circ}$	2.17	
Neptunium	$Np(HPO_4)_5^{-6}$	100	2.4 - 15[d]
Radium	Ra^{+2}	100	700 - 1260[h]
Silver	$AgCl^{\circ}$	63.0	90 - 180[ms]
	Ag^{+}	28.4	
	$AgCl_2^{-}$	8.55	
Sodium	Na^{+}	98.9	q
	$NaHCO_3^{\circ}$	0.84	
Strontium	Sr^{+2}	95.7	20 - 110[m]
	$SrSO_4^{\circ}$	4.04	
Technetium	TcO_4^{-}	100	0.02 - 0.2[d]
Thallium	Tl^{+}	100	1500[r]
Thorium	$Th(HPO_4)_3^{-2}$	99.9	40 - 130[di]
Uranium	$UO_2(CO_3)_3^{-4}$	54.6	11 - 40[g]
	$UO_2(CO_3)_2^{-2}$	43.4	
	$UO_2PO_4^{-}$	0.88	
	$UO_2CO_3^{\circ}$	0.58	
Vanadium	$VO_2(OH)_2^{-}$	38.4	35 - 140[f]
	$H_2VO_4^{-}$	31.0	
	VO_3OH^{-2}	25.9	
	HVO_4^{-2}	4.73	

TABLE F.2-4
(Continued)

[a] Speciation based on EQ3/6 geochemical code, except antimony.
[b] Percent of total moles in solution that exist as indicated specie.
[c] Antimony species are not present in EQ3/6 database. Species anticipated to be present, based on Brookins (1988; Eh-pH Diagrams for Geochemistry, Springer-Verlag, New York) and Ames and Rai (1978; Radionuclide Interactions with Soil and Rock Media, USEPAOffice of Radiation Programs, EPA 520/6-78-007-A, Las Vegas Nevada).
[d] Ames and Rai (1978; see above citation).
[e] Bowell (1994; Adsorption of Arsenic by Iron Oxides and Oxyhydroxides in Soils, Applied Geochemistry, V. 9, pp 279 - 286).
[f] Gerritse, Vriesema, Dollenberg, and De Roos (1982; Effect of Sewage Sludge on Trace Element Mobility in Soils, Journal of Envrionmental Quality, V. 11, pp. 359 - 363).
[g] Table 5-1, Attachment 1 to Appendix F.3, OU5 RI draft, June 1994.
[h] Sheppard, Beals, Thibault, and O'Conner (1984; Soil Nuclide Distribution Coefficients and Their Statistical Distributions, Atomic Energy of Canada Limited, AECL-8364, Pinawa, Manitoba.
[i] Thorium concentration in perched groundwater is primarily controlled by ThO_2 solubility (i.e., concentrations of less than 10^{-14} mole/liter, about 2E-09 mg/L).
[j] Beryllium concentration in perched groundwater is primarily controlled by BeO solubility (i.e., concentrations less than 10^{-8} mole/liter,about 1E-04 mg/L).
[k] Tabulated value is an order of magnitude lower than K_d reported by Davis, Olsen, and Walker (1991; Distribution of Metals between Water and Entrained Sediment in Streams Impacted by Acid Mine Drainage, Clear Creek, Colorado, Applied Geochemistry, V. 6, pp. 333-348) to correct for sorption measured primarily on amorphous $Fe(OH)_3$. This correction is needed to give a more reliable K_d estimate for FEMP glacial overburden that contains 4 to 8 percent iron oxyhydroxide minerals.
[l] Aluminum concentration in perched groundwater is primarily controlled by the solubility of clay (e.g., gibbsite, $Al(OH)_3$) and feldspar (e.g., $KAlSiO_3$) minerals (i.e., concentrations less than 10^{-9}, about 3E-05 mg/L). If elevated aluminum concentrations are detected, it indicates collodial alluminum or a waste source that has high or low pH (i.e., greater than 10 or less than 4).
[m] Sheppard and Thibault (1990; Default Soil Solid/Liquid Partition Coefficients, K_ds, for Four Major Soil Types: A Compendium, Health Physics, V. 59, pp. 471-482).
[n] Calcium concentration in perched groundwater is primarily controlled by the solubility of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$).
[o] Iron concentration in perched groundwater is primarily controlled by the solubility of $Fe(OH)_3$ (i.e., concentrations less than 10^{-6} mole/liter, about 6E-02 mg/L). If elevated iron concentrations are detected, it indicates collodial iron or reduced iron (i.e., Fe^{+2}) is present in the groundwater sample.
[p] K_d value not found. Magnesium concentration in perched groundwater is primarily controlled by the solubility of dolomite ($MgCa(CO_3)_2$).
[q] K_d value not found.
[r] Table 5-4, OU4 RI Report, Final, November 1993.
[s] Silver concentration in perched groundwater is primarily controlled by the solubility of native silver (Ag) (i.e., concentrations less than 10^{-8} mole/liter, about 1E-03 mg/L). However, elevated silver concentrations may be detected if abundant chloride ion is present or oxidizing waters are encountered.

TABLE F.2-5

SPECIATION OF SELECTED CONSTITUENTS IN GREAT MIAMI AQUIFER AND APPLICABLE K_d VALUES

Constituent	Species[a]	Molal Percent[b]	K_d (L/kg)
Antimony	SbO_2^-	c	0.78 - 1.4[d]
	$Sb(OH)_3^o$	c	
	$HSbO_2^o$	c	
Arsenic	AsO_3F^{-2}	96.7	5 - 16[e]
	$HAsO_3F^-$	3.30	
Manganese	Mn^{+2}	87.3	10 - 30[f]
	$MnCO_3^o$	7.17	
	$MnSO_4^o$	2.86	
	$MnHCO_3^+$	2.48	
Neptunium	$Np(HPO_4)_5^{-6}$	95.0	2.4 - 15[d]
	$Np(OH)_5^-$	3.00	
	NpO_2^+	1.88	
Radium	Ra^{+2}	100	210 - 470[d]
Technetium	TcO_4^-	100	0.02 - 0.2[d]
Uranium	$UO_2(CO_3)_3^{-4}$	51.1	1.78[g]
	$UO_2(CO_3)_2^{-2}$	47.5	
	$UO_2CO_3^o$	0.71	

[a] Speciation based on EQ3/6 geochemical code, except antimony.
[b] Percent of total moles in solution that exist as indicated specie.
[c] Antimony species are not present in EQ3/6 database. Species anticipated to be present, based on Brookins (1988; Eh-pH Diagrams for Geochemistry, Springer-Verlag, New York) and Ames and Rai (1978; Radionuclide Interactions with Soil and Rock Media, USEPA Office of Radiation Programs, EPA 520/6-78-007-A, Las Vegas Nevada).
[d] Ames and Rai (1978; see above citation).
[e] Bowell (1994; Adsorption of Arsenic by Iron Oxides and Oxyhydroxides in Soils, Applied Geochemistry, V. 9, pp 279 - 286).
[f] Gerritse, Vriesema, Dollenberg, and De Roos (1982; Effect of Sewage Sludge on Trace Element Mobility in Soils, Journal of Envrionmental Quality, V. 11, pp. 359 - 363).
[g] Appendix F.3, OU5 draft RI, June 1994.

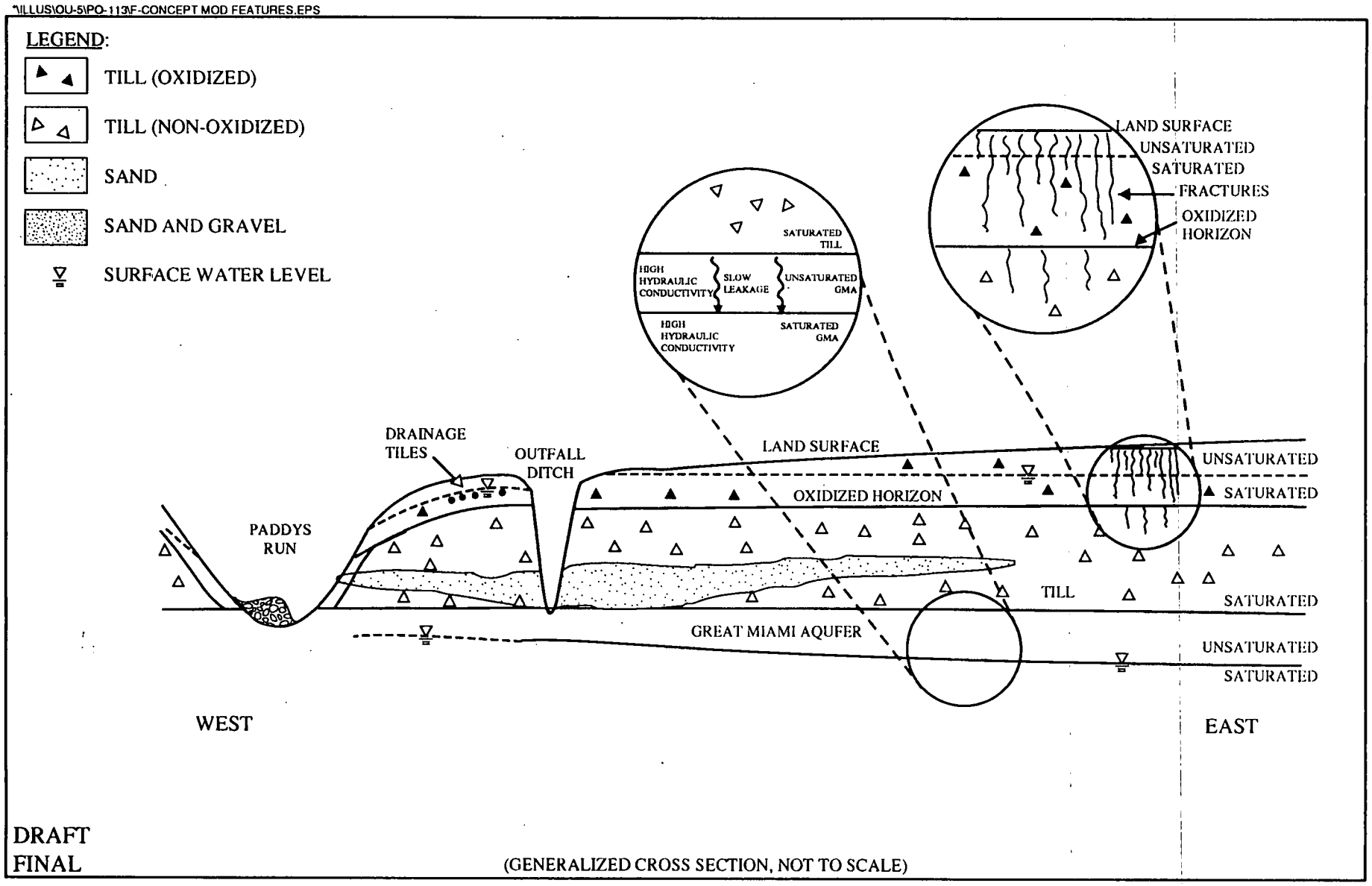

FIGURE F.2-1. MAJOR FEATURES OF THE CONCEPTUAL MODEL OF THE HYDROLOGY OF THE FEMP AREA

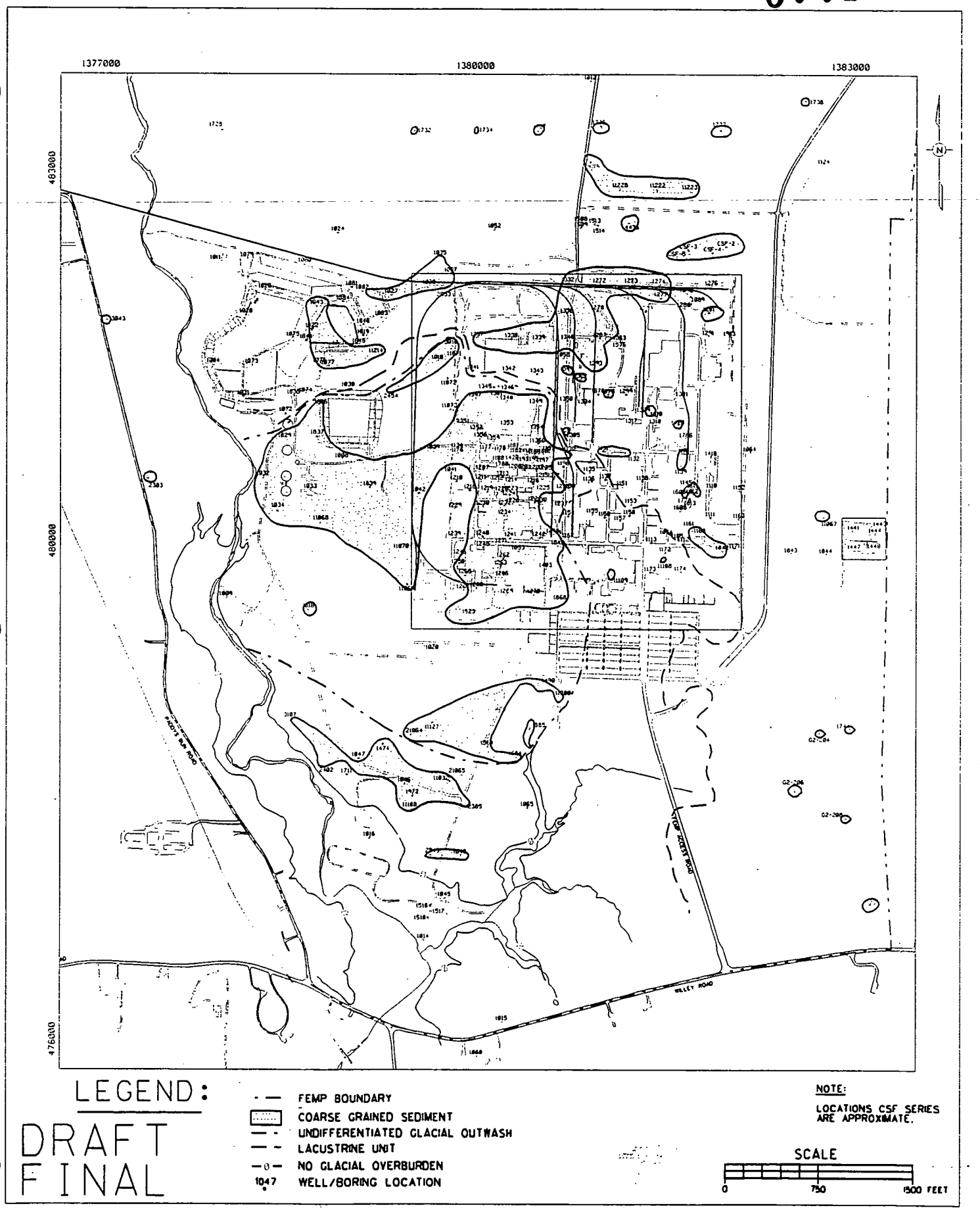

FIGURE F.2-2. DISTRIBUTION OF COARSE GRAINED SEDIMENT

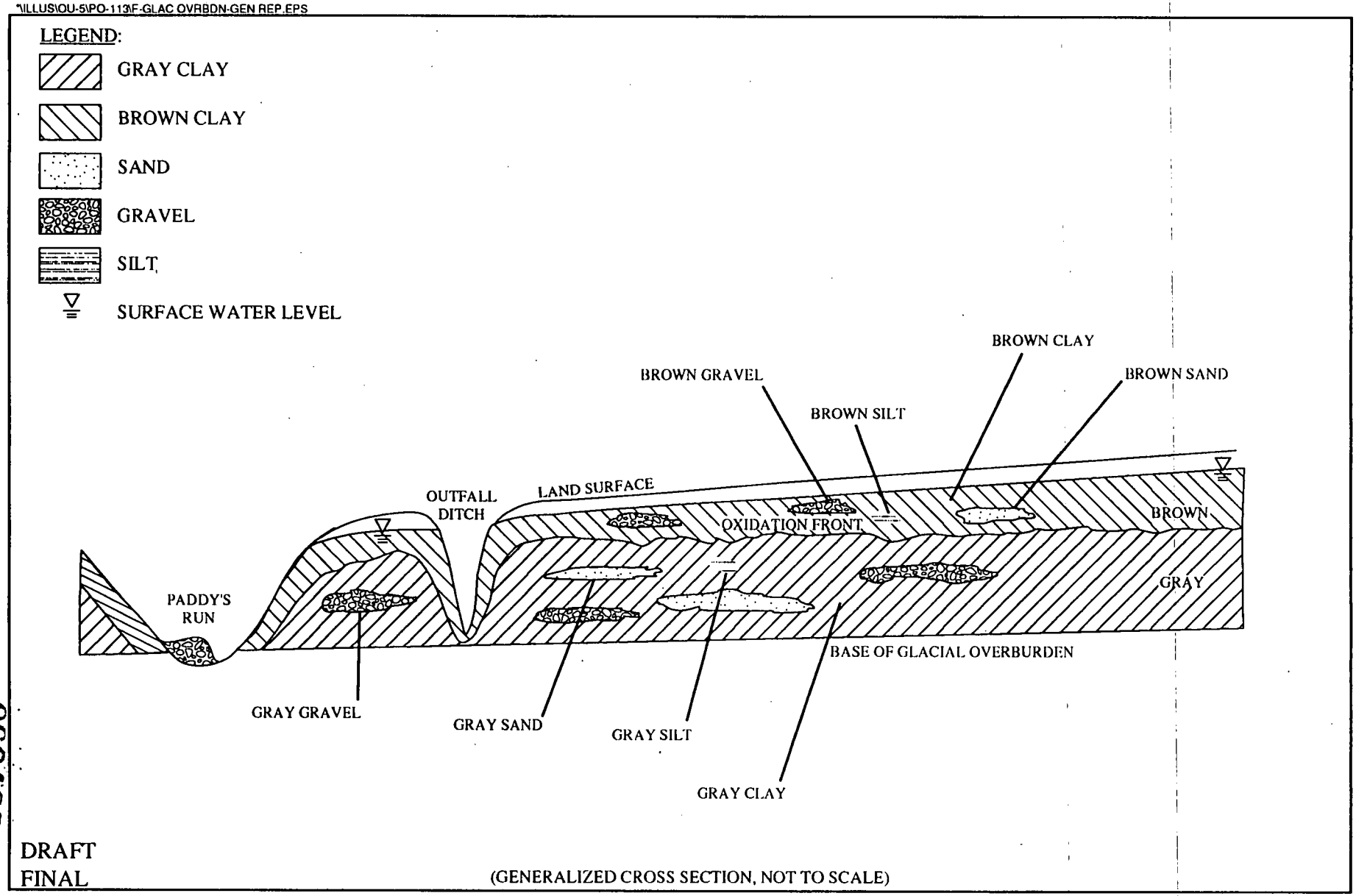

FIGURE F.2-3. GENERAL REPRESENTATION OF THE GLACIAL OVERBURDEN

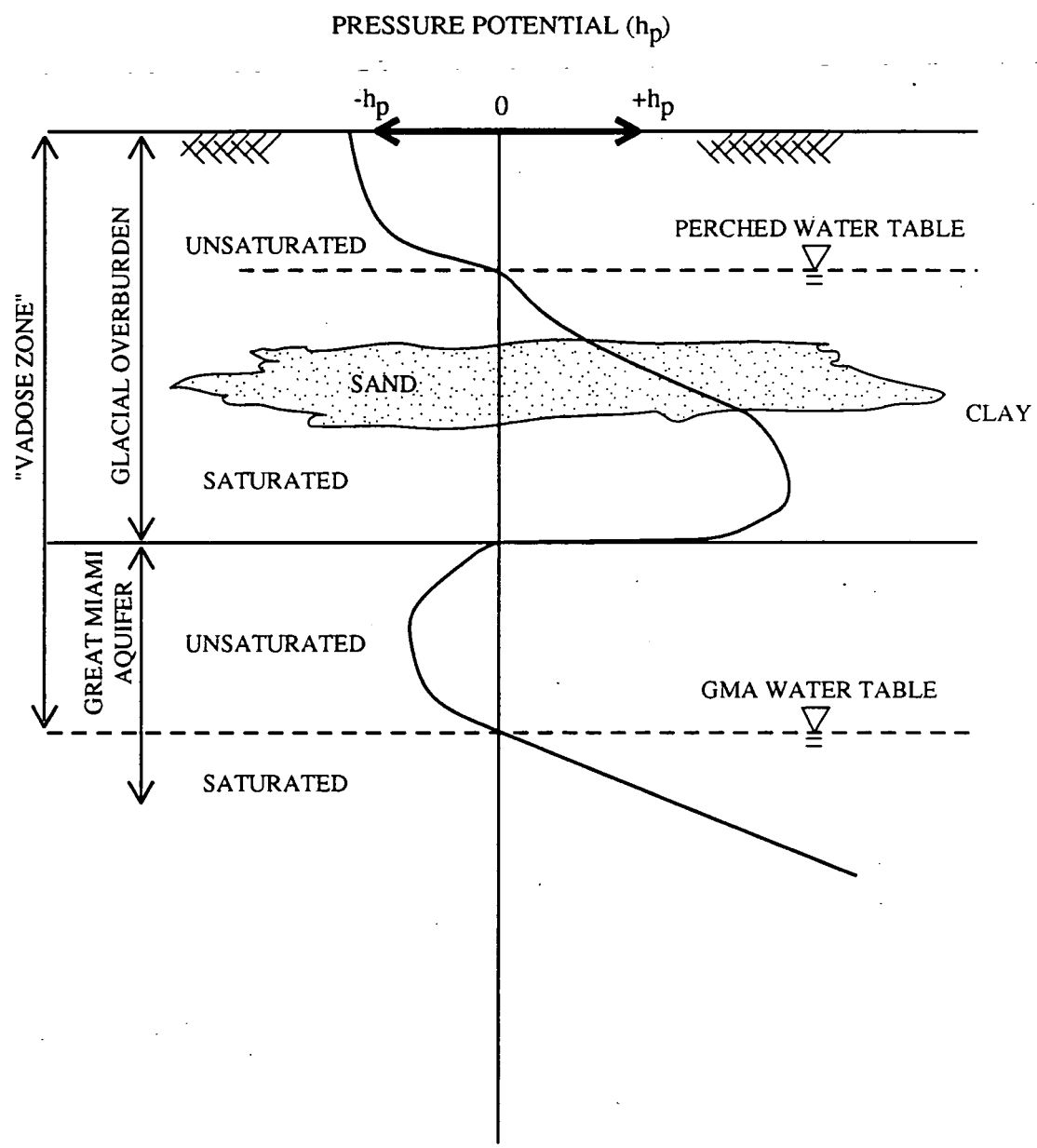

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FIGURE F.2-4. GENERAL PRESSURE HEAD PROFILE

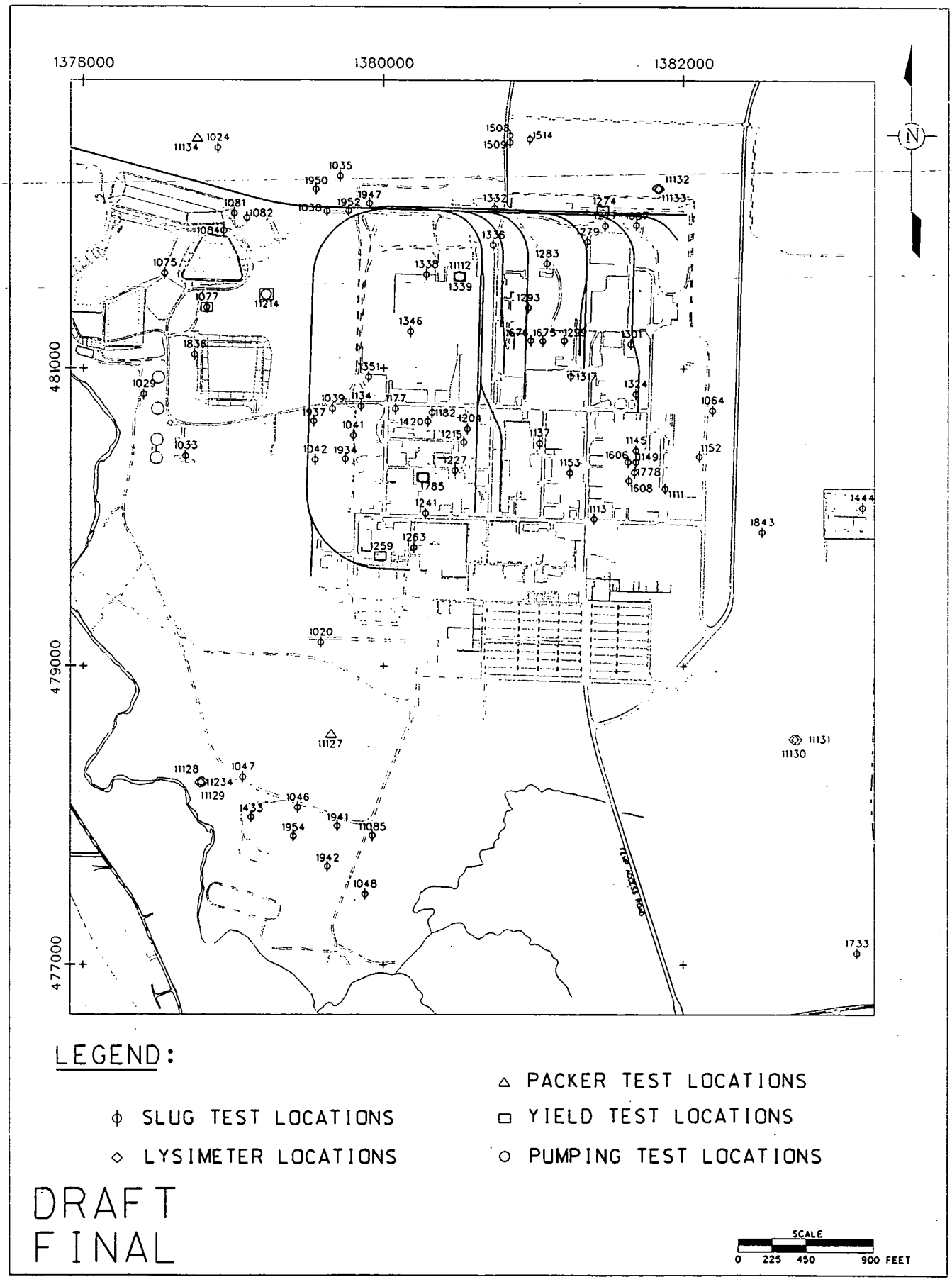


FIGURE F.2-5. HYDRAULIC TESTING LOCATIONS

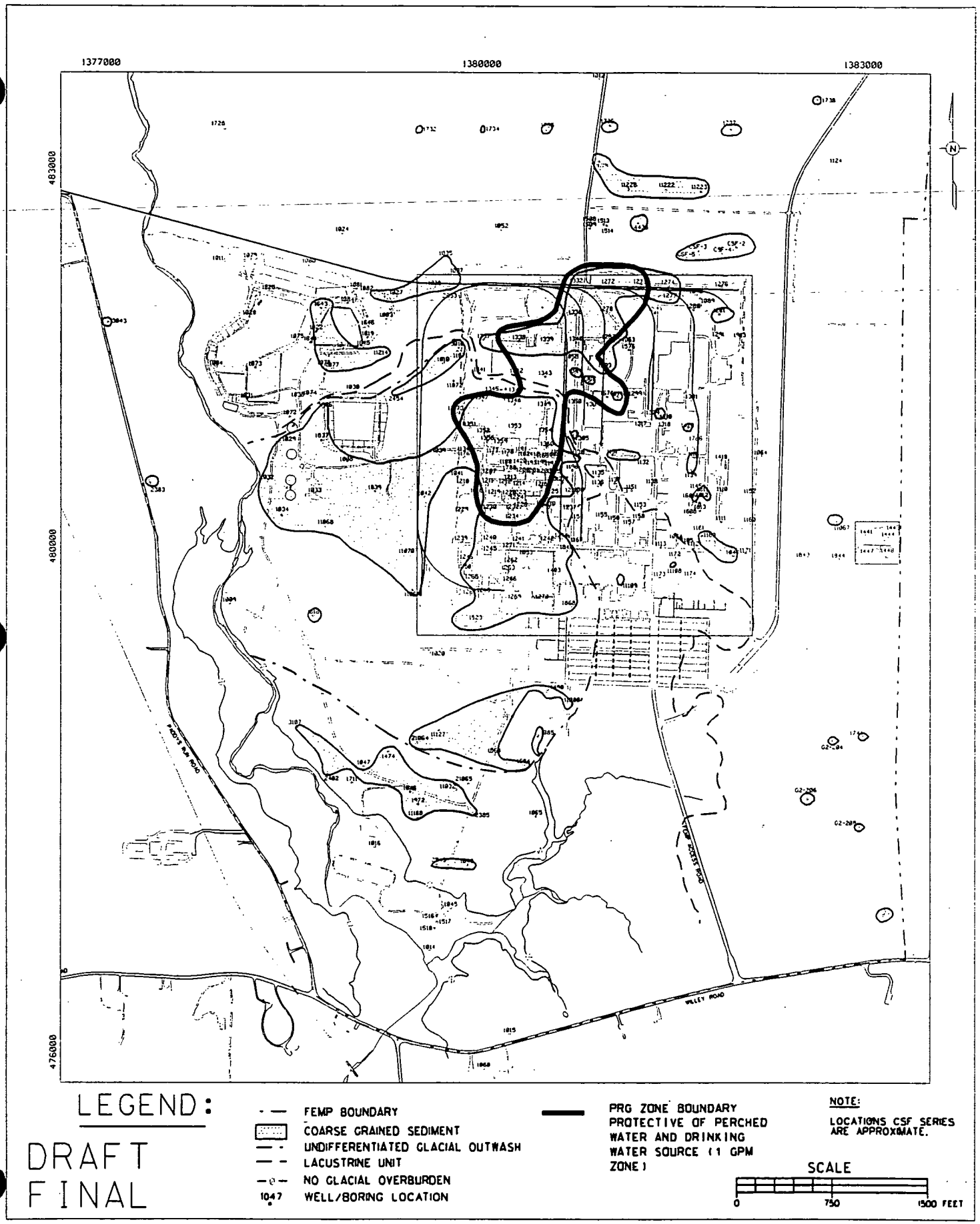


FIGURE F.2-6. DISTRIBUTION OF COARSE GRAINED SEDIMENT AND 1 GPM ZONE

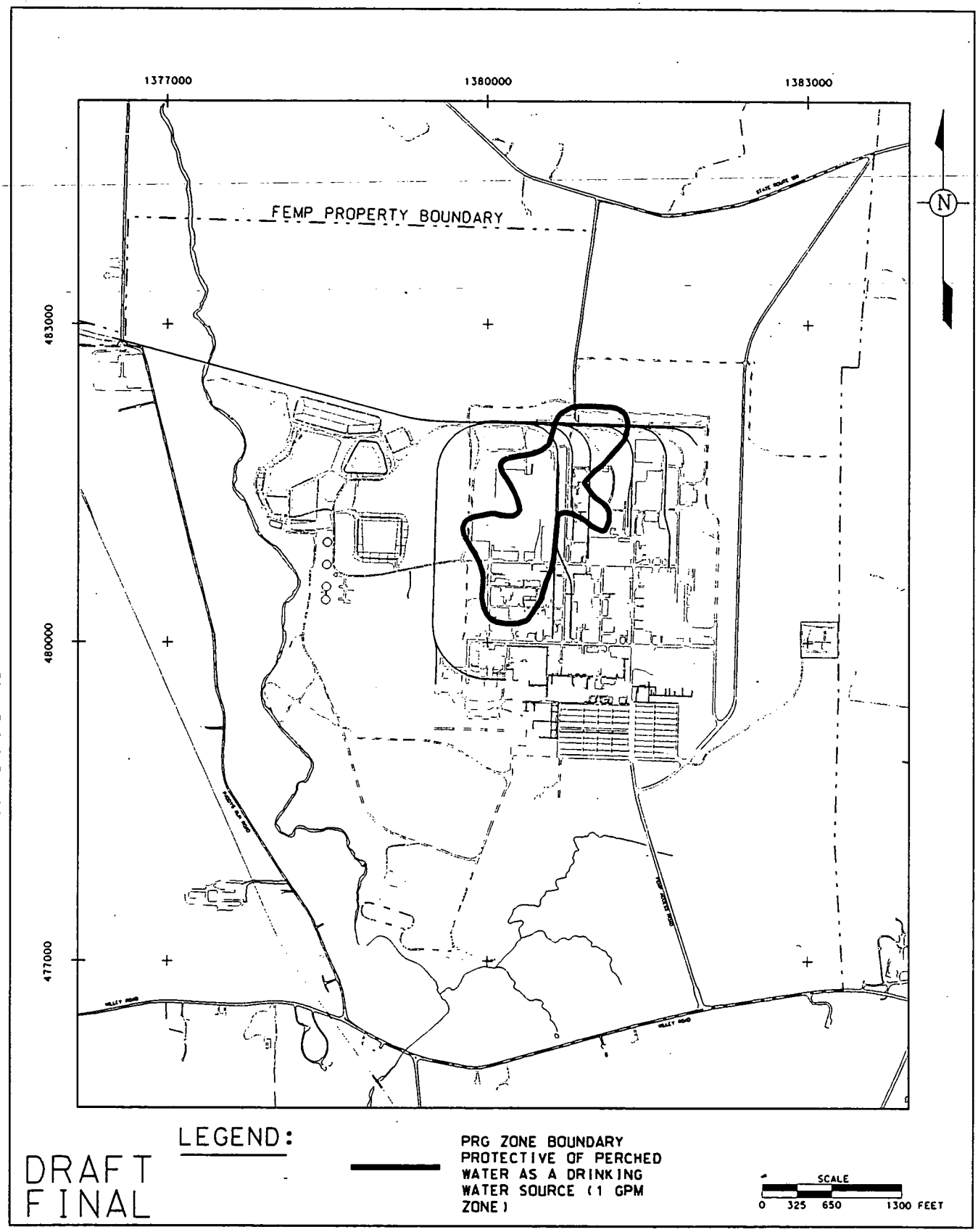
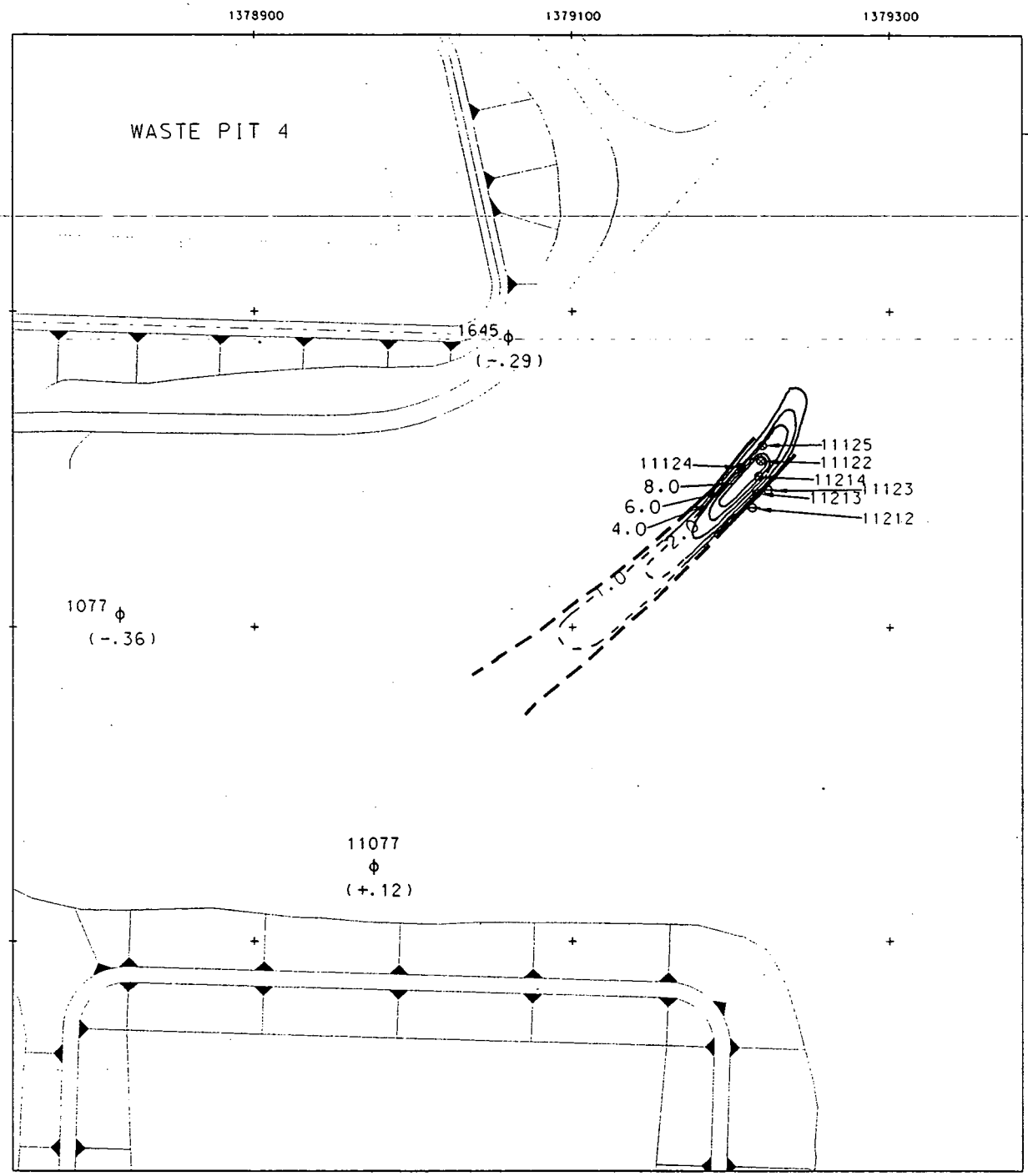


FIGURE F.2-7. PERCHED WATER ZONE WHICH CAN SUSTAIN 1 GPM



LEGEND:

1077 (-.36)	DRAWDOWN (IN FEET) AT WELL 1077
	BURIED CHANNEL
	CONTOUR
ϕ	MONITORING WELL
⊗	PIEZOMETER
⊗	PUMPING WELL
⊖	ABANDONED BORING

NOTES:

1. CUMULATIVE DRAWDOWN AFTER PUMPING WELL 11214 FOR 8740 MINUTES AT 2.0 GPM.
2. SOLID LINE INDICATES HIGH CONFIDENCE
3. DASHED LINE INDICATES LOWER CONFIDENCE

SCALE
0 25 50 100 FEET

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STATE PLANAR COORDINATE SYSTEM 1927

P0113/SKX02907.DGN

FIGURE F.2-8. DRAWDOWN PUMPING TEST IN WASTE PIT AREA

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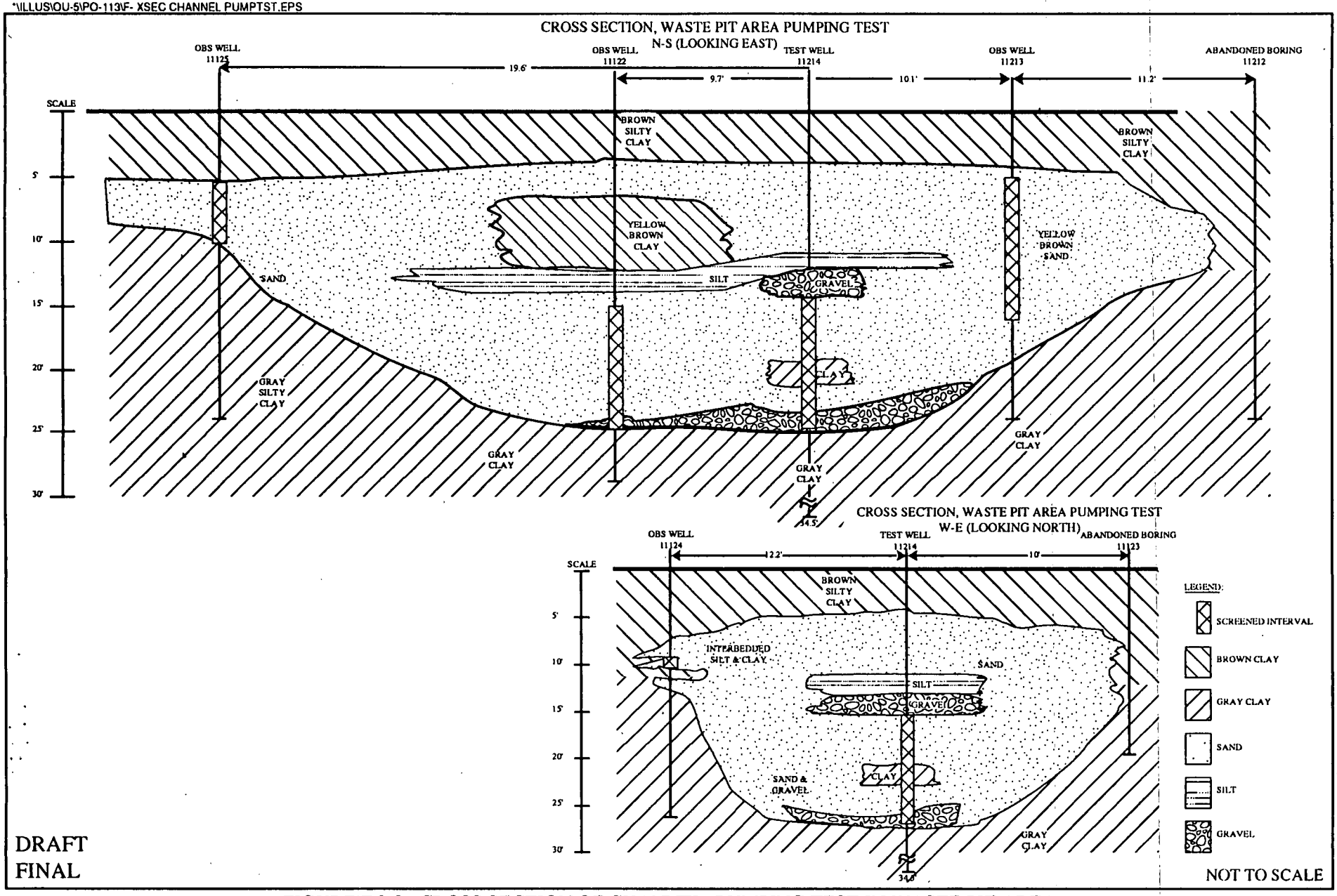

FIGURE F.2-9. CROSS SECTION OF CHANNEL, PUMPING TEST IN WASTE PIT AREA

000415

F 6 2 1

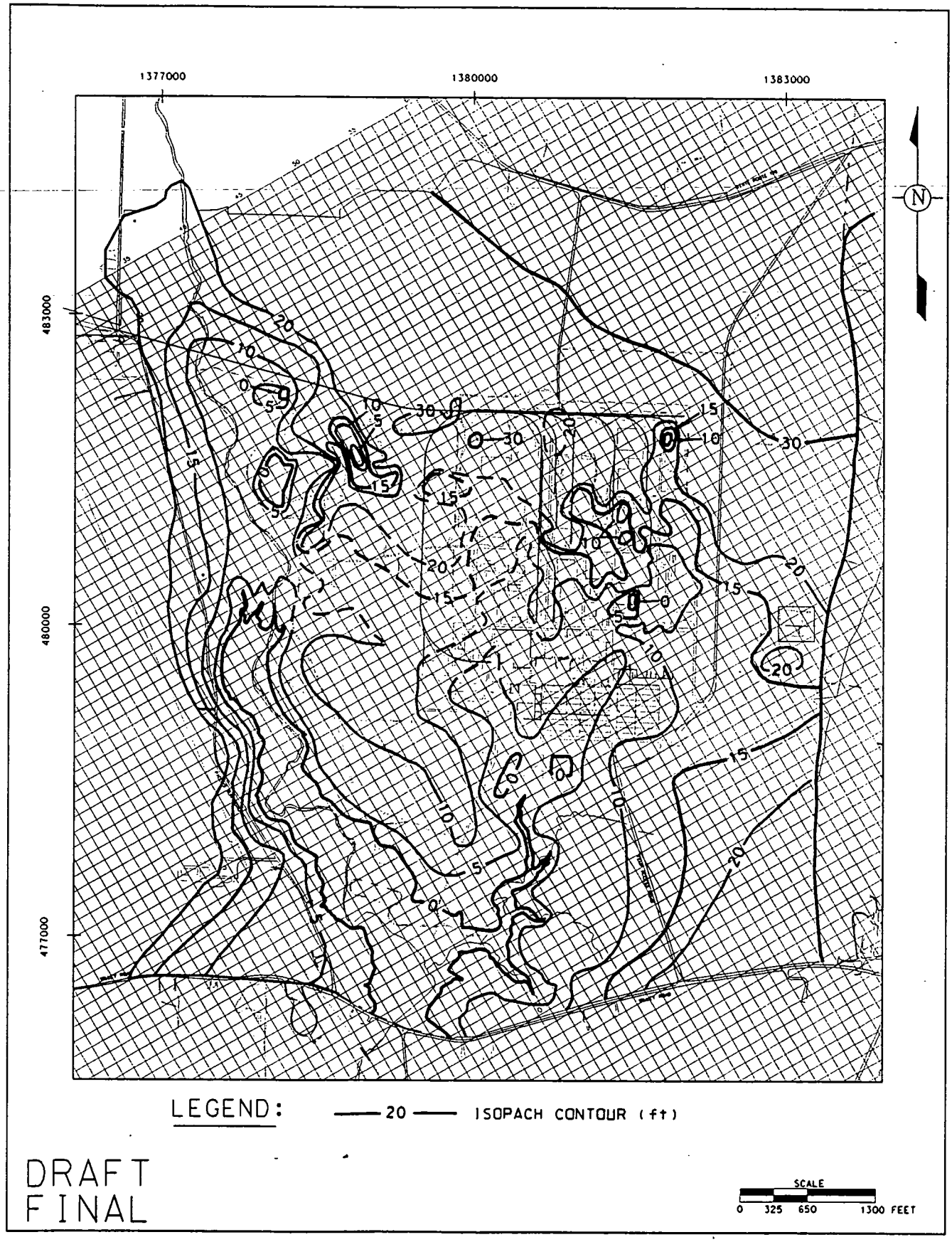

FIGURE F.2-10. ISOPACH OF GRAY CLAY

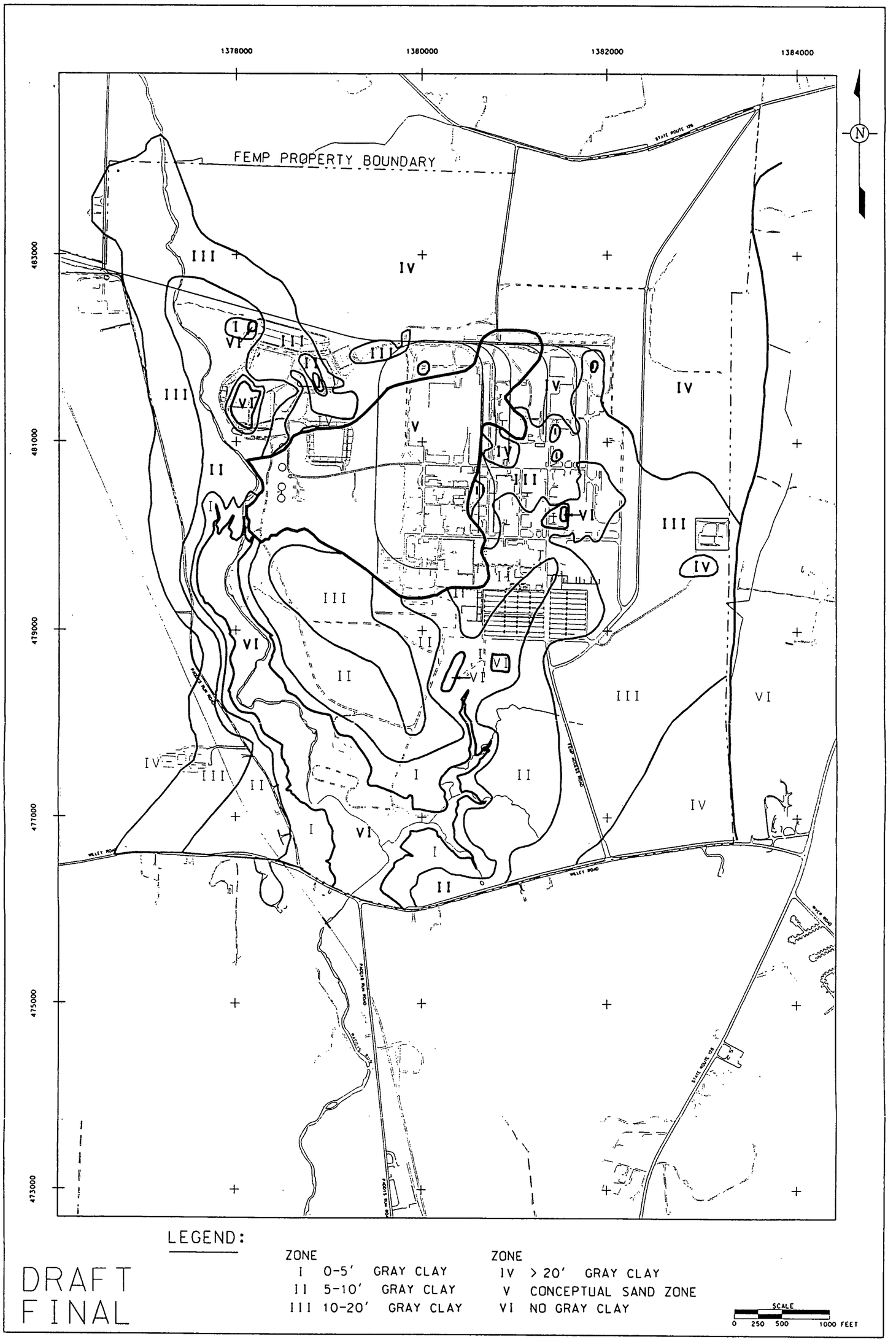

FIGURE F.2-11. INFILTRATION ZONES

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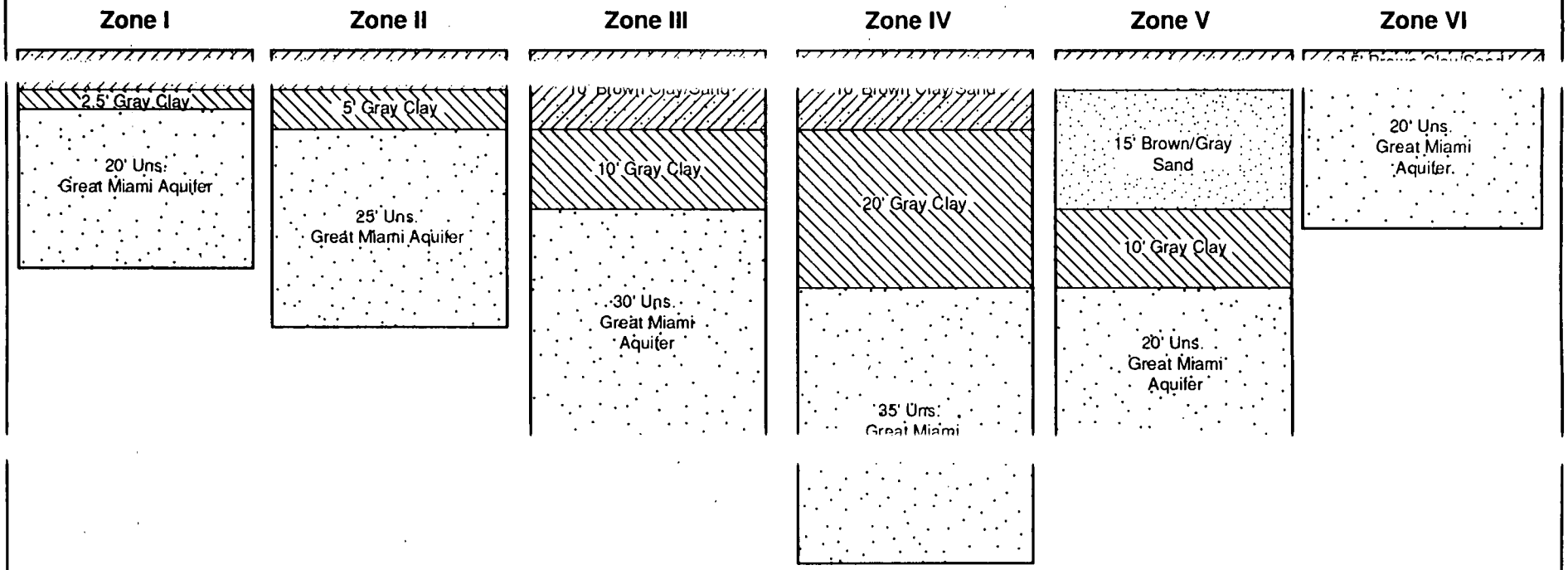

FORMATION	Kv (cm/sec)	POROSITY	DATA SOURCE
Gray Clay	7.23E -07	0.20	Kv from GO/UGMAS model calibration, ≈ 0.4 of geometric mean of slug test results
Brown/Gray Sand	1.10E -04	0.30	Harmonic mean of Kh from slug tests divided by 10
Brown Clay/Sand	7.04E -05	0.30	Harmonic mean of Kh from slug tests
Uns. GMA	1.59E -02	0.30	Kv from SWIFT Model Calibration

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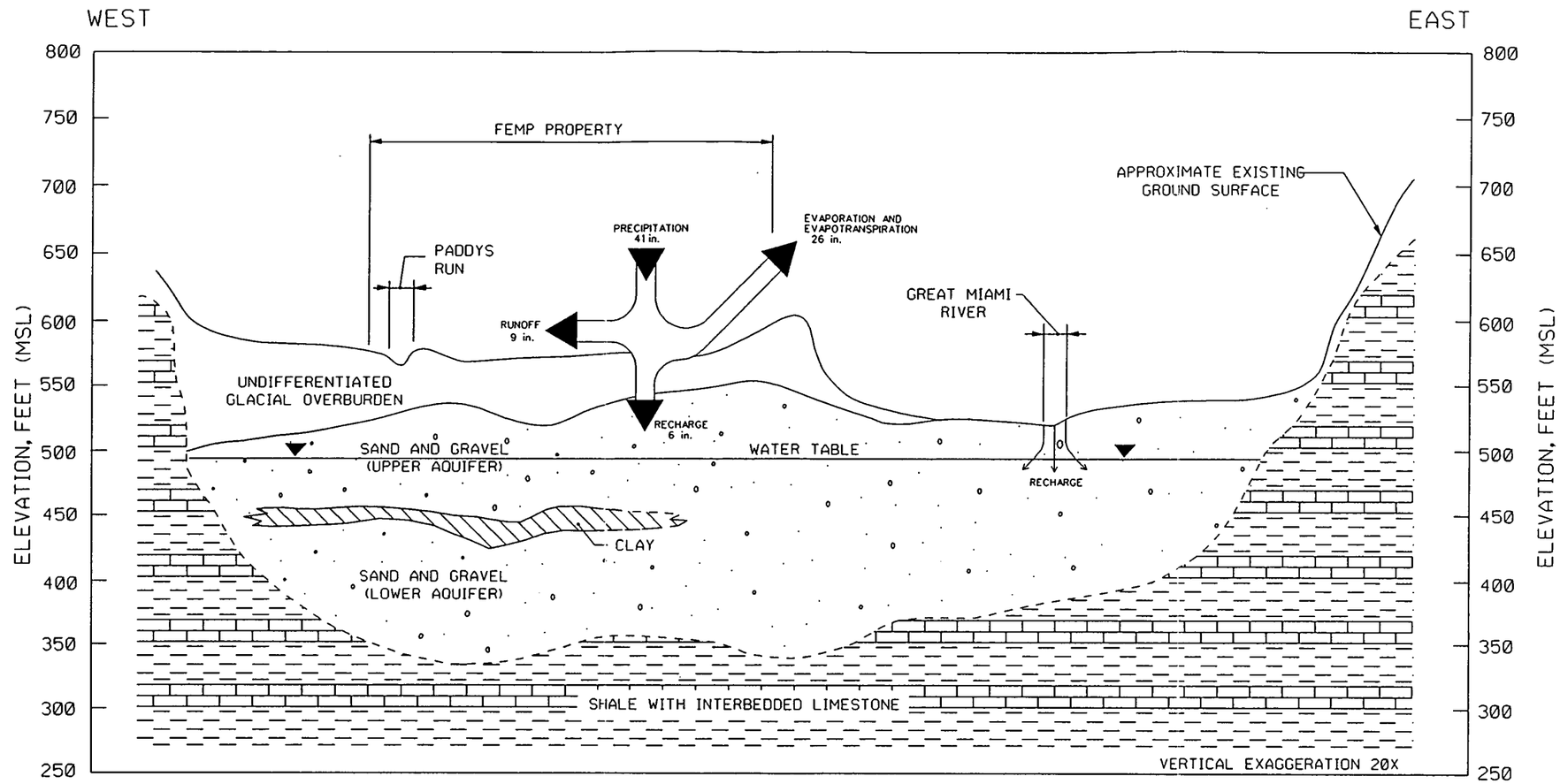
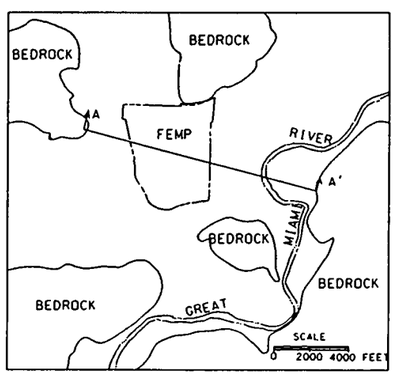
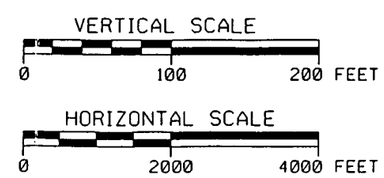
FIGURE F.2-12. GROUNDWATER FATE AND TRANSPORT MODELING - GENERALIZED CROSS SECTIONS



GENERALIZED CROSS SECTION



LOCATION OF CROSS SECTION



NOTE:
ALL VALUES ARE ANNUAL AVERAGES

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FIGURE F.2-13. FEMP HYDRAULIC BUDGET AND CONCEPTUAL PATHWAYS

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F.3.0 CROSS-MEDIA PRELIMINARY REMEDIATION GOALS

F.3.1 OBJECTIVE

A CPRG is a soil cleanup target which incorporates all the potential impacts caused by the migration of a contaminant away from a source and through multiple transport media. This section presents the approach and the results of fate and transport modeling which was conducted to develop soil CPRGs for the Operable Unit 5 FS. During CPRG development, intermedia migration of contaminants is considered using fate and transport modeling. In contrast, PRGs are developed for particular media without considering intermedia migration or using fate and transport models. Media- and scenario-specific PRGs are used as exposure criteria at selected receptor locations for developing CPRGs. These CPRGs are required to support the development of soil and perched water PRLs as shown in Figure F.1-3. The characteristics of CPRGs include the following:

- Based on current hydrogeologic conditions and future receptors
- Protective level-, contaminant-, media-, and location-specific
- Three zones, based on gray clay thickness and infiltration rate, cover the entire FEMP
- Uses the on-site Great Miami Aquifer and surface water bodies as the exposure media
- Assumes existing perched groundwater and Great Miami Aquifer contamination have been remediated
- Based on the maximum exposure concentrations in a 1000-year time frame after remedial action
- Considers all of the potential subsurface (i.e., Great Miami Aquifer groundwater and glacial overburden perched groundwater) transport pathways
- Does not consider cumulative impact from multiple source areas.

In general CPRGs are cleanup targets for media which act as a source of contaminant loading to other environmental media. For example, a soil CPRG is developed for contaminated soil which acts as a source of contamination to the Great Miami Aquifer. As identified in the Operable Unit 5 RI Report, there are two main media that acted as sources of contamination for cross-media transport in the subsurface pathway: contaminated soil and perched groundwater. Soil acts as a source of contamination to the Great Miami Aquifer, perched groundwater, surface water, and sediment. Perched groundwater acts as a source of contamination to the Great Miami Aquifer and surface water. For the CPRG development task, perched groundwater is assumed to be remediated (i.e., clean) and is not considered as a source of contamination. However, lateral contaminant migration via re-contaminated perched groundwater from residual soil contamination, through the vertical migration

pathway, is also considered. Section F.6.0, Perched Groundwater Remedial Action Evaluation, describes the actions that will be considered to remediate the perched groundwater in parallel with soil remedial action.

Fate and transport modeling is used to develop CPRGs; therefore a CPRG is dependent upon the hydrogeologic and geochemical parameters used in the model. Uranium is the major contaminant present at the FEMP and therefore the geochemical parameters related to uranium have been studied in detail. Depending on the form of uranium and geochemical conditions present, actual values of uranium K_l can range from less than 10 to higher than 10,000 L/kg. Two K_l values are used for uranium in the source soil during CPRG development including 325 L/kg and 15 L/kg. These representative values are determined using both measured data and model calibration. The higher K_l is for less soluble forms of uranium, while the lower K_l is for more soluble forms of uranium. Both forms of uranium are present at the FEMP. To better understand the effects of the different solubilities of uranium, both K_ls are applied universally across the site to give a range of soil CPRGs.

F.3.2 GENERAL TECHNICAL APPROACH

F.3.2.1 Contaminants of Concern

433 Contaminants which may adversely impact environmental media and human receptors are determined from sampling, analyses, and screening procedures and are labeled as COCs. The baseline risk assessment, presented in the Operable Unit 5 RI Report (DOE 1995), outlines the COCs for each transport pathway; an additional summary of the screening has been prepared and is presented in Section F.2.3. Described in this section are the COCs which impact the various media and the COCs which require CPRGs. Tables F.2-2 and F.2-3 summarize the screening results. Of the COPCs which failed the screening for the groundwater (vertical) and perched groundwater (lateral) migration pathways, seven contribute significantly to 95 percent of the Operable Unit 5 baseline risk and they are designated as COCs on Table F.2-3. Soil CPRGs, which are protective of both the groundwater and perched groundwater migration pathways, are necessary for these seven COCs. After soil remedial actions based on PRLs which incorporate CPRGs of these seven COCs, it is expected that residual amounts of other COCs in soil will not be significant enough to create cross-media impacts in the groundwater pathway. Therefore, PRG-based PRLs and protective requirements summarized in Section F.4 for other COCs are sufficient to refine remedial alternatives during the residual risk evaluation process.

F.3.2.2 Exposure Criteria and Pathways

Soil CPRGs are developed based on meeting media-specific exposure criteria at a specified exposure point. The major exposure point used for Operable Unit 5 FS CPRG development is the Great Miami Aquifer below the source of soil contamination. The exposure criteria applied at this point consist of

risk-based PRGs for the groundwater media, which considered the reasonable maximum exposure (RME) to farmer/child scenario, and the maximum contaminant level (MCL) if it is available. A MCL is the maximum permissible level of a contaminant in water which can be delivered to any user of a public water system. The MCL is selected as one of the exposure criteria since the Great Miami Aquifer is used as a public drinking water source. Two sets of exposure criteria, generally corresponding to two ILCR levels, 1×10^{-6} and 1×10^{-5}, were used to develop two separate CPRGs for each COC. For toxicants and contaminants which have MCLs, CPRGs were also determined using a HQ of 0.2 and/or a MCL as exposure criteria. The exposure criteria used for CPRG development are summarized in Table F.3-1.

Contaminants migrate from one media to another via a transport medium and mechanism. As shown in Figure F.1-5 there are four transport pathways (i.e., air dispersion, surface runoff, perched groundwater seepage, and groundwater infiltration) along which contamination migrates. Two of these pathways are considered for soil CPRG development. The vertical migration of contamination from soil to the Great Miami Aquifer groundwater via infiltrating precipitation is one pathway for contamination to migrate and is considered in CPRG development. This pathway is designated as the "vertical migration pathway." A secondary pathway considered is for contamination to migrate from the soil to the perched groundwater which in turn migrates laterally and eventually discharges through seeps to surface water. The surface water then migrates vertically through the bed of the stream to the Great Miami Aquifer. This pathway is designated as the "lateral migration pathway." These two subsurface migration pathways considered in the CPRG development are shown in Figure F.3-1. Other protective requirements in air and surface water pathways that may also impact the soil cleanup targets are developed and presented in Section F.4.

The vertical migration pathway to the Great Miami Aquifer is considered during CPRG development for the entire Operable Unit 5 area. The lateral migration pathway to the Great Miami Aquifer is only considered in areas where there is perched groundwater which can migrate laterally and discharge to surface water bodies within 1000 years (i.e., the selected modeling time frame). Additional information on the zonation of CPRG development is discussed below.

F.3.2.3 Zonation of CPRGs

The major factors influencing CPRG development are the thickness of gray clay present below the source and the area-specific infiltration rate. The thickness of gray clay in the FEMP ranges from 0 to approximately 35 feet (see Figure F.2-10). Three zones which cover the entire FEMP are selected based on gray clay thickness for CPRG development. These three zones (A, B, and C) are shown in Figure F.3-2. Zone A considers areas of FEMP which have no gray clay and subsequently a 0-foot clay thickness is used in this zone for CPRG development. The 0-foot gray clay isopach contour outlines Zone A. Zone B covers areas of FEMP which have between 0 and 20 feet of gray clay and

an average gray clay thickness of 10 feet is used for this zone during CPRG development. The 0- and 20- foot gray clay isopach contours show the boundaries of Zone B. Zone C includes the region of FEMP which has over 20 feet of clay and a 20-foot clay thickness is used for this zone to develop CPRGs. The 20-foot isopach contour is the boundary of Zone C. CPRGs are developed considering the vertical migration pathway within each of these three zones and corresponding gray clay thickness and representative infiltration rate. Estimation of infiltration rates is done by HELP modeling and is presented in Section F.2.2.5.

A portion of Zone B (i.e., 10-foot gray clay zone) includes perched groundwater which has the potential to laterally migrate to surface water and eventually impact the Great Miami Aquifer. Figures F.3-3 through F.3-9 show the COC-specific areas where perched groundwater can laterally migrate to the surface water. For this part of Zone B the lateral migration pathway is also considered for soil CPRG development. Within this portion of Zone B, the soil CPRGs, which are first developed for the vertical migration pathway, are considered as the future contaminant source to the laterally migrating perched groundwater. If these soil CPRGs created unacceptable contaminant concentrations in the Great Miami Aquifer, new soil CPRGs are developed considering the lateral migration pathway. Final CPRGs for the three zones are acceptable for both the vertical and lateral migration pathways.

As described above, CPRGs are developed for three zones which have different representative gray clay thicknesses. In addition each CPRG zone has a different infiltration rate. Overall, the FEMP is divided into six infiltration zones (Zones I through VI) based on stratigraphy. These six infiltration zones are shown in Figure F.2-11. Table F.2-1 which is discussed in Section F.2.2.5 summarizes the infiltration rates determined by HELP modeling for each of these zones. Representative infiltration rates for the three CPRG zones are selected from the maximum infiltration rates for any of the infiltration zones that fall within the CPRG zone. The infiltration rates which were selected are as follows: Zone VI infiltration rate is used for Zone A (0-foot gray clay zone); Zone V infiltration rate is used for Zone B (10-foot gray clay zone); and the Zone IV infiltration rate is used for Zone C (20-foot gray clay zone).

Areas with significant soluble uranium contamination identified in the Operable Unit 5 RI Report using batch test results, contaminated perched groundwater and soil concentration (see Attachments F.3.I and F.3.II in the Operable Unit 5 RI Report; DOE 1995) are also highlighted in Figure F.3-2. Examples of these areas include Plant 2/3, Plant 6, Plant 9, and the sewage treatment plant. A lower uranium K_l value (i.e., 15 L/kg) was used to develop uranium soil CPRGs in these areas.

F.3.2.4 Thickness of Residual Contaminated Soil

Within the three CPRG zones various residual source thicknesses are assumed for soil CPRG development. The hypothetical residual source thicknesses range from 0.1 to 2 feet in most cases and up to 20 feet in some cases during the modeling. This approach is used to ensure that the range of CPRGs developed represent the actual contaminated soil thicknesses which are present throughout the FEMP. By increasing the source thickness CPRGs decreased and asymptotically approached a minimum CPRG value. This is the reason that different maximum source thicknesses (2 feet to 20 feet) were used for different COCs. For some COCs the minimum CPRG was reached with as little as 2 feet of residual source material and for others the minimum CPRG was not reached until 20 feet of source material was used.

F.3.2.5 Modeling Tools

For CPRG development, investigation of cross-media migration of contaminants via the vertical and lateral pathways is accomplished using the ECTran model. In addition, the HELP model is used to estimate infiltration rates which are input in to the ECTran model. Simple dilution factors are also used during CPRG development to account for mixing of laterally migrating perched groundwater with surface water and subsequent mixing with the groundwater in the Great Miami Aquifer. The use of the ECTran model and dilution factors for CPRG development are described in more detail below. The HELP model is described in Section F.1.5.3 and Section F.2.2.5.

The ECTran model considers both vertical contaminant migration through the vadose zone and lateral groundwater and contaminant migration through the saturated zone. The original development of the ECTran model is described in "Development and Application of the ECTran Model to Support the RI/FS at the FEMP" (DOE 1993). Modifications are made to the model for the vertical migration pathway CPRG and WAC development tasks and they are described in Attachment F.1.I. The major modifications included: (1) inclusion of additional sublayers to represent the gray clay layer; (2) use of a different equation for the unsaturated Great Miami Aquifer; and (3) use of an improved equation for the saturated Great Miami Aquifer below the source.

Separate modifications are made to the original ECTran model to consider lateral migration of contamination in the perched groundwater within the glacial overburden. The modifications included the following: (1) Layer 1 in the model is considered to be the depleting source; (2) Layer 2 was the perched groundwater directly below the source and is assumed to be saturated; (3) lateral migration in the perched groundwater from the source area to the discharge point is handled with the same original transport equation; (4) two separate dilution factors are used to determine the effects of mixing of the perched groundwater with the surface water bodies and subsequently the Great Miami Aquifer; (5) additional attenuation of the contaminants due to migration in the surface water or through the

streambed and the underlying layers to the Great Miami Aquifer are not considered. These modifications are described in detail below.

Equation 1 is used in the ECTran model to represent the depleting source concentration for the lateral migration pathway. The equation uses a mass-balance analysis with solid- and dissolved-phase partitioning for the contaminants from the source area, assuming that the infiltrating precipitation contains residual source leachate or background contamination and that dispersion in the layer is negligible. Equation 1 gives the time-dependent leachate concentration for the layer:

$$\frac{dC_A}{dt} = \left[\frac{Q_1}{S_A V_{wA} + K_{dA} W_{sA}}\right] [CU_1 - C_A] - \lambda_A C_A \qquad (1)$$

For an initial condition of $C_A = C_{Ao}$, this equation is solved by direct integration to yield the following solution:

$$C_A = \frac{CU_1 - \{CU_1 - [1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]C_{Ao}\} \exp\left[-\frac{Q_1 + (S_A V_{WA} + K_{dA} W_{sA})\lambda_A}{S_A V_{WA} + K_{dA} W_{sA}} t\right]}{[1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]} \qquad (2)$$

where:
- CU_1 is the contaminant concentration in infiltrating precipitation (μg/L)
- Q_1 is the infiltration rate (L/day)
- C_A is the aqueous concentration in the source layer (μg/L)
- C_{Ao} is the initial leachate concentration in the soil (μg/L)
- S_A is the soil saturation fraction in the layer (dimensionless)
- V_{wA} is the void volume in the layer (L)
- K_{dA} is the aqueous/solid phase distribution coefficients in the layer (L/kg)
- W_{sA} is the dry weight of soil in the layer (kg)
- λ_A is the first-order chemical decay rate in the layer (day^{-1})
- t is time

A similar mass-balance/mass-partitioning approach, which includes a time-dependent source loading term and a secondary source are used for the perched groundwater zone under the contaminated soil and is presented in Equation 3.

$$\frac{dC_B}{dt} + \frac{K_2}{K_1} C_B = \frac{K_3}{K_1} + \frac{K_4}{K_1} \exp^{(-K_5 t)} \qquad (3)$$

Equation 3 can be solved using an integrating factor approach or the method of undetermined coefficients (DOE 1993) to yield Equation 4.

$$C_B = \frac{K_3}{K_2} + \frac{K_4}{K_2 - K_1 K_5}\exp(-K_5 t) + \left[C_{Bo} - \frac{K_3}{K_2} - \frac{K_4}{K_2 - K_1 K_5}\right]\exp\left(-\frac{K_2 t}{K_1}\right) \quad (4)$$

In which:
$K_1 = S_B V_{wB} + K_{dB} W_{sB}$
$K_2 = Q_1 + Q_2 + (S_B V_{wB} + K_{dB} W_{sB})\lambda_B$
$K_3 = Q_1 CU_1 / [1 + (S_A V_{wA} + K_{dA} W_{sA})(\lambda_A/Q_1)] + Q_2 CU_2$
$K_4 = Q_1 C_{Ao} - Q_1 CU_1 / [1 + (S_A V_{wA} + K_{dA} W_{sA})(\lambda_A/Q_1)]$
$K_5 = [Q_1 + (S_A V_{wA} + K_{dA} W_{sA})\lambda_A]/(S_A V_{wA} + K_{dA} W_{sA})$

And where:
CU_2 is the constant contaminant leachate concentration of the secondary source (μg/L)
C_B is the aqueous concentration in the layer (μg/L)
Q_2 is the perched water inflow rate of the secondary source (L/day)
S_B is the soil saturation fraction in the layer (dimensionless)
V_{wB} is the void volume in the layer (L)
K_{dB} is the aqueous/solid phase distribution coefficients in the layer (L/kg)
W_{sB} is the dry weight of soil in the layer (kg)
λ_B is the first-order chemical decay rate in the layer (day^{-1})

The transport equation used to consider lateral contaminant migration in the perched groundwater layer is presented in Equation 5. This equation is identical to the original equation used to represent contaminant transport in the saturated Great Miami Aquifer in ECTran (DOE 1993).

$$C(X, t, C_o) = \frac{C_o}{2}\exp\left\{\left(\frac{X}{2(D_x/V)}\right)\left[1 - \left(1 + \frac{4\lambda_C D_x}{V^2}\right)^{\frac{1}{2}}\right]\right\} erfc\left[\frac{X - Vt\left(1 + \frac{4\lambda_C D_x}{V^2}\right)^{\frac{1}{2}}}{2(D_x t)^{\frac{1}{2}}}\right] erf\left[\frac{Y}{4\left(\frac{D_y}{V}X\right)^{\frac{1}{2}}}\right] \quad (5)$$

where:
C is the downgradient concentration along the plume centerline caused by C_o (μg/L)
C_o is the groundwater concentration at or below the source (μg/L)
X is the distance downgradient to the exposure point from the source (ft)
V is the retarded contaminant velocity (ft/yr)
t is the elapsed time since the beginning of the source loading (years)
D_X is the principle value of the dispersion tensor in the x (longitudinal) direction (ft^2/yr)
Y is the source dimension in the y (lateral) direction (ft)
D_Y is the principle value of the dispersion tensor in the y (lateral) direction (ft^2/yr)
λ_c is the chemical decay rate (years^{-1})

87 Two dilution factors, one to account for the mixing of perched groundwater and surface water, and
434 another to account for mixing of infiltrating surface water and the Great Miami Aquifer, are developed and used during CPRG development and evaluation considering the lateral migration pathway. The surface water dilution factor is developed using an estimated perched groundwater discharge rate from along Paddys Run and the pilot plant drainage ditch and the estimated minimum base flow in Paddys Run. It is assumed that there is no base flow in the pilot plant drainage ditch.

The total flow of perched water is calculated based on the gradient of the average groundwater elevation contours of the Type 1 monitoring wells, lengths of seepage faces along the pilot plant drainage ditch and Paddys Run, and the estimated average perched groundwater zone thickness (15 feet). The perched groundwater zone gradients were based on the steeper contours within 400 feet of the seepage face. Basing the gradient on the steeper portion of the contours rather than the overall gradient of the perched water zone yielded a higher (more conservative) discharge rate from the perched groundwater zone. The seepage face lengths were taken as the distances along Paddys Run and the pilot plant drainage ditch where the perched groundwater zone sand and gravel is exposed on the streambanks. The surface water dilution factor is estimated to be 0.33. Equation 6 is used to estimate the factor.

$$D.F._{SW} = \frac{Q_{PW}}{Q_{PW} + Q_{SW}} \qquad (6)$$

where: Q_{PW} is the estimated total seepage rate of perched groundwater along Paddys Run and the pilot plant drainage ditch (0.099 ft^3/s)
Q_{SW} is the estimated minimum base flow rate for Paddys Run (0.2 ft^3/s [Dames and Moore 1985])

434 The Great Miami Aquifer dilution factor is estimated using a similar approach as the one used for the surface water dilution factor. The factor is used to account for dilution of infiltrating surface water from Paddys Run and the pilot plant drainage ditch to the Great Miami Aquifer. A representative Great Miami Aquifer flow rate is estimated using an average groundwater velocity of 306 ft/yr, a porosity of 0.3, a mixing depth of 10 feet, and an estimated width. Because groundwater flow is perpendicular to surface water flow, the width used to calculate the Great Miami Aquifer dilution factor is taken as the length of Paddys Run along which infiltration occurs. The estimated width is 2300 feet. The surface water infiltration rate is assumed to be equal to the perched groundwater discharge rate (Q_{PW}). The Great Miami Aquifer dilution factor was estimated to be 0.6. Equation 7 is used to estimate the factor.

$$D.F._{GMA} = \frac{Q_{SWI}}{Q_{SWI} + Q_{GMA}} \qquad (7)$$

where: Q_{SWI} is the estimated surface water infiltration rate to the Great Miami Aquifer (0.099 ft^3/s)
Q_{GMA} is the estimated flow rate for the Great Miami Aquifer (0.067 ft^3/s)

F.3.2.6 Summary of Assumptions

Assumptions are necessary to simplify or conceptualize the natural environment and contaminant migration processes to facilitate CPRG development. Because of the complexities of natural conditions, there will always be uncertainties regarding modeling results. Therefore, FS fate and transport modeling assumptions need to be both conservative and realistic in order to ensure that remedial actions based on modeling results are achievable (e.g., higher than background concentrations) and protective of human and environmental receptors. The assumptions which are made for CPRG development are summarized below.

- The brown, weathered clay is considered part of the till layer for infiltration calculations made using the HELP model. Since it is more permeable than the unweathered gray clay, including the brown clay in the infiltration calculations results in higher infiltration rates than using only the gray clay.

- The brown, weathered clay is not considered as part of the till layer during contaminant fate and transport simulations using the ECTran model. The brown clay is weathered and fractured and has limited ability to impede contaminant migration. By not considering this layer, higher contaminant concentrations can reach the perched groundwater and the Great Miami Aquifer in modeling results.

- CPRGs are developed for three zones which have different infiltration rates and gray clay thicknesses. Overall, the FEMP is divided into six infiltration zones based on stratigraphy. Representative infiltration rates for the three CPRG zones are the maximum infiltration rates from the infiltration zones which covered each of the CPRG zones.

- Measured and/or literature values for hydrogeologic and geochemical parameters which were used for fate and transport modeling represent natural conditions.

- The perched groundwater zone has been remediated and does not act as a significant contaminant source.

- A 1000-year time frame is sufficient to demonstrate long-term protectiveness.

72 - Cumulative impacts from multiple source areas are not considered and a representative source area size (125 feet by 125 feet) is adequate for CPRG development. Impacts to groundwater from a larger area are more significant than from a smaller area, given the same soil contaminant concentration. Therefore, for CPRG development purposes, a smaller source area size will result in a higher (i.e., less conservative) CPRG. It is conservative to use a 125- by 125-foot areal size as the basis for CPRG development. Most of the hot spots in the former production area are expected to be of similar or smaller areal size.

- Residual contaminated soil contains limited initial contaminant mass and this mass depletes with time due to dissolution and migration of contaminant with infiltrating water.

- Additional sublayers included in the revised ECTran model (vertical migration pathway) for the gray clay layer allows ECTran to adequately represent vertical dispersion.

89 • A minimum mixing depth of 10 feet is assumed for the Great Miami Aquifer. Ten feet is a reasonable assumption of well-screen length of typical groundwater production wells. Therefore, the minimum mixing thickness of 10 feet was set in modeling for determining the potential future impacts to Great Miami Aquifer groundwater users. This assumption was made to avoid the use of any unrealistically small mixing depth directly calculated by the mixing equation in the ECTran model which only considers the vertical infiltration rate, lateral travel time, and vertical dispersion. For the CPRG development purposes, 10 feet was also the maximum mixing depth used, because the calculated mixing depths were slightly smaller than 10 feet.

• A mixing depth of 15 feet is assumed for the perched groundwater layer. This thickness is the total thickness of the layer.

F.3.3 AREA- AND COC-SPECIFIC CPRGs

Soil CPRGs for Operable Unit 5 are developed for three zones, which are based on gray clay thickness. CPRGs are developed for the COCs which failed screening in the vertical and lateral migration pathway and which contribute significantly to 95 percent of the Operable Unit 5 risk. The COC-specific soil CPRGs which are developed for the vertical migration pathway are presented in Tables F.3-2 through F.3-9. CPRGs for different protective levels (i.e., 10^{-6} ILCR, HQ of 0.2, and MCL or 10^{-5} ILCR) and for various residual source thicknesses (i.e., 0.1 to 20 feet) are shown in these tables. COC- and soil-specific geochemical parameters (i.e., K_l and K_d) which are used for modeling are also included in each table. The final COC-specific soil CPRGs which are protective of the lateral migration pathway are summarized in Table F.3-10. These CPRGs are protective of both migration pathways for the area of Zone B which has the potential to migrate laterally in the perched groundwater zone. Table F.3-11 presents the site-wide representative CPRGs for all CPRG zones.

From Tables F.3-2 through F.3-9 it can be seen that soil CPRGs increase with increasing clay thickness and they decrease due to increasing residual source thickness. K_l and K_d also influence CPRGs and are most noticeable for the CPRGs developed with a thicker source layer. Table F.3-10 compares the soil CPRGs which are developed for the vertical and lateral migration pathway. These CPRGs are developed using a residual source thickness of 1 foot and a gray clay thickness of 10 feet. It is expected that the thickness of residual contaminated soil in the Zone B area will be less than 1 foot after soil remedial actions based on PRGs alone; therefore, a 1-foot contaminant source layer is conservative for the CPRG modeling. The lateral CPRGs are produced by using the initial soil CPRGs as the source contaminant concentration and ECTran and the dilution factors to predict the contaminant concentrations in surface water and the Great Miami Aquifer. If the predicted concentrations are acceptable, the original vertical CPRG is adopted as the lateral CPRG also. If the predicted concentration is unacceptable then a new lateral CPRG is developed for the COC.

From Table F.3-10 it can be seen that some of the soil CPRGs (strontium-90, technetium-99, 1,2-dichloroethane, and alpha-chlordane) which consider lateral migration are lower than the CPRGs

which consider vertical migration only. These are the COCs for which CPRGs are developed specifically for the lateral migration pathway. The other lateral soil CPRGs are adopted from the vertical CPRGs and therefore are identical to the CPRGs which only consider vertical migration.

Table F.3-11 summarizes the representative CPRGs for all CPRG zones, considering all of the CPRGs presented in Tables F.3-2 to F.3-10. For uranium, for which two K_l values were used during CPRG development, the CPRG developed using K_l = 15 L/kg in Zone B was selected for all the locations with a significant amount of soluble uranium contamination. The residual contaminated soil thickness in these low-K_l areas (also highlighted in Figure F.3-2) after soil excavation was assumed to be about 1.5 feet. Other zone-specific uranium CPRGs developed using K_l = 325 L/kg were listed for the remaining area. For uranium with high K_l and the other six COCs, a 1-foot thickness for residual contaminated soil after the cleanup was conservatively assumed (Table F.3-11). The more conservative CPRGs, which were developed for the lateral migration pathway, were selected as CPRGs for Zone B.

Excavation is the only remedial alternative considered in the Operable Unit 5 FS to remove contaminated soil for further disposal considerations. As presented in this section, soil CPRGs were developed to support the determination of volumes and extent of soil excavation required to remediate soil contamination. These soil CPRGs were developed by back-calculating the acceptable soil concentrations in representative 125- by 125-foot areas throughout the FEMP (see CPRG zones presented in Figure F.3-2) from the Great Miami Aquifer groundwater criteria. Soil with contaminant concentrations higher than these COC- and zone-specific CPRGs need to be excavated. However, potential remedial alternatives for the contaminated perched groundwater zone within the glacial overburden are evaluated separately using a different approach. The evaluation of perched groundwater zone remedial actions is presented in Section F.6. Excavation of the contaminated perched groundwater zone is one of the alternatives evaluated for the perched groundwater zone remedial actions. As a part of this evaluation, the extent of excavation required to achieve different remedial objectives was determined through modeling of impacts due to all the residual unexcavated perched groundwater contamination on a site-wide basis. All the COCs existing in the perched groundwater zone, based on available Type 1 monitoring well measurements, were screened and modeled to determine the final acceptable extent of excavation. Because the extent of excavation was determined directly through residual contaminant fate and transport modeling, no additional perched groundwater CPRGs are necessary, as they were for the soil medium.

F.3.4 APPLICATION OF CPRG

Applications of the soil CPRG in Operable Unit 5 FS are described below.

F.3.4.1 Screening of PRG

The highest acceptable uranium concentration in the Great Miami Aquifer is the MCL, which is independent of the future land-use and receptor scenarios. Therefore, the soil CPRG for uranium based on the requirement for protecting the Great Miami Aquifer at the MCL level can be used to screen risk-based surface soil PRGs for different future on-property receptors. The uranium CPRG for Zone C (20-foot gray clay thickness zone) with 1-foot of residual contaminated soil and a K_l value of 325 L/kg is selected as the screening CPRG. This uranium soil CPRG value is 154 mg/kg. Based on actual conditions at the site this CPRG is considered as the higher end of CPRG values. Any receptor scenarios that have risk-based uranium PRGs that are higher than this screening CPRG are screened from consideration because the soil PRGs will not be protective of the Great Miami Aquifer.

As a result of this PRG screening with an upper limit of 154 mg/kg, the highest soil PRG value, among PRGs for all the potential exposure scenarios considered, is 125 mg/kg. This PRG corresponds to the trespassing youth scenario at 10^{-6} ILCR level. All the potential receptor scenarios that have PRGs less than the screening CPRG are included in the Operable Unit 5 FS for further evaluation. The major objective of the FS is therefore to determine the required soil remedial actions to achieve these lower soil PRGs.

F.3.4.2 Development of PRL

Because many land-use objectives, exposure scenarios, and remedial alternatives will be evaluated in the FS before the final remedial level and actions are selected, protective-level specific PRLs are first defined for all the alternatives evaluated. PRLs are protective level-, contaminant-, area-, and exposure medium-specific.

Figure F.1-3 outlines the soil PRL development process used in the Operable Unit 5 FS. Each step in this process is designed to provide an intermediate remedial level. These intermediate remedial levels consider different sets of technical and nontechnical factors or contaminant exposure routes that eventually need to be incorporated into the overall PRL. For example, a PRG only considers the direct exposure to a single contaminated medium and available applicable or relevant and appropriate requirements (ARARs) and requirements to be considered (TBCs). A CPRG incorporates the impacts caused by migration of a contaminant away from the source and through multiple transport media. An MPRG is defined as the more stringent of either the PRG or the CPRG for a contaminated source medium. The PRL for a radiological contaminant is then determined by adding the medium-specific background concentration to the MPRG and comparing it against the analytical detection limit for the constituent. For non-radiological constituents, the MPRG is compared against the background value and the analytical detection limit; the higher value for each constituent derived from the comparisons was used as the PRL. In order to be protective of the potential future receptors of contamination, PRLs are determined for all the COCs listed in Table F.2-3 considering CPRGs. Although CPRGs

are not developed for other COCs as described earlier, the PRLs are also available for all the other COCs listed in Table F.2-2. Also all of the COCs that have potential to cause future cross-media impacts are modeled in the CRARE process.

During evaluation of required soil remedial actions, current contamination levels in the Operable Unit 5 source areas are compared to area-specific PRL concentrations. This site-wide comparison is first conducted for the predominant contaminant of concern at the FEMP (i.e., uranium). Results of the uranium comparison identified most of the source areas that require remedial actions under specific land-use objectives. During remedial actions contaminants in the same area will all be handled together. Therefore, for media volume estimation purposes, this process does not need to be repeated for other contaminants in the same areas. However, areas that do not have potential problems with uranium contamination are still evaluated based on the PRLs of the COCs present.

F.3.5 REFERENCES

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TABLE F.3-1

SUMMARY OF EXPOSURE CRITERIA USED FOR CPRG DEVELOPMENT

COC	HQ = 0.2 or ILCR = 10^{-6} Criteria (pCi/L or mg/L)	Specific Activity (pCi/μg)	HQ = 0.2 or ILCR = 10^{-6} Criteria (μg/L)	HQ = 0.2 or ILCR = 10^{-5} or MCL (μg/L)	Half-Life (years)
Radionuclides					
Strontium-90	3.09×10^{-1}	1.37×10^{8}	2.26×10^{-9}	2.26×10^{-8} [a]	2.86×10^{1}
Technetium-99	7.23×10^{0}	1.70×10^{4}	4.25×10^{-4}	4.25×10^{-3} [a]	2.13×10^{5}
Uranium-238	8.63×10^{-1}	3.36×10^{-1}	2.57×10^{0}	2.00×10^{1} [b]	4.47×10^{9}
Organics					
1,2-Dichloroethane	7.86×10^{-5}	NA	7.86×10^{-2}	5.00×10^{0} [b]	2.00×10^{0}
Alpha-chlordane	4.51×10^{-6}	NA	4.51×10^{-3}	2.00×10^{0} [b]	7.60×10^{0}
Inorganics					
Magnesium	3.52×10^{1}	NA	3.52×10^{4}	3.52×10^{4} [c]	NA
Mercury	1.58×10^{-4}	NA	1.58×10^{-1}	2.00×10^{0} [b]	NA

Notes: [a] = 1×10^{-5}
[b] = MCL or proposed MCL
[c] = HQ=0.2
HQ = Hazard Quotient
ILCR = Incremental Lifetime Cancer Risk
NA = Not Applicable

TABLE F.3-2

SOIL CPRGs (pCi/g) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: STRONTIUM-90 (K_l = 10 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			ILCR = 10^{-6}	ILCR = 10^{-5}
10 L/kg	0 ft	0.1	1.38×10^{3}	1.38×10^{4}
		0.25	1.40×10^{1}	1.40×10^{2}
		0.5	3.01×10^{0}	3.01×10^{1}
		1	1.35×10^{0}	1.35×10^{1}
		1.5	9.69×10^{-1}	9.69×10^{0}
		2	8.15×10^{-1}	8.15×10^{0}
	10 ft	0.1	5.63×10^{4}	5.63×10^{5}
		0.25	1.27×10^{3}	1.27×10^{4}
		0.5	3.21×10^{2}	3.21×10^{3}
		1	1.47×10^{2}	1.47×10^{3}
		1.5	1.08×10^{2}	1.08×10^{3}
		2	9.11×10^{1}	9.11×10^{2}
	20 ft	0.1	6.27×10^{6}	6.27×10^{7}
		0.25	2.19×10^{5}	2.19×10^{6}
		0.5	6.32×10^{4}	6.32×10^{5}
		1	3.00×10^{4}	3.00×10^{5}
		1.5	2.26×10^{4}	2.26×10^{5}
		2	1.95×10^{4}	1.95×10^{5}

ILCR = Incremental Lifetime Cancer Risk

TABLE F.3-3

SOIL CPRGs (pCi/g) FOR THE GROUNDWATER PATHWAY CONSTITUENT: TECHNETIUM-99 (K_l = 30 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			ILCR = 10^{-6}	ILCR = 10^{-5}
0.118 L/kg	0 ft	0.1	5.80×10^{0}	5.80×10^{1}
		0.25	4.05×10^{0}	4.05×10^{1}
		0.5	3.38×10^{0}	3.38×10^{1}
		1	3.01×10^{0}	3.01×10^{1}
		1.5	2.87×10^{0}	2.87×10^{1}
		2	2.79×10^{0}	2.79×10^{1}
		20	2.53×10^{0}	2.53×10^{1}
	10 ft	0.1	8.11×10^{0}	8.11×10^{1}
		0.25	5.24×10^{0}	5.24×10^{1}
		0.5	4.25×10^{0}	4.25×10^{1}
		1	3.71×10^{0}	3.71×10^{1}
		1.5	3.52×10^{0}	3.52×10^{1}
		2	3.40×10^{0}	3.40×10^{1}
		20	3.06×10^{0}	3.06×10^{1}
	20 ft	0.1	1.20×10^{1}	1.20×10^{2}
		0.25	7.12×10^{0}	7.12×10^{1}
		0.5	5.47×10^{0}	5.47×10^{1}
		1	4.57×10^{0}	4.57×10^{1}
		1.5	4.25×10^{0}	4.25×10^{1}
		2	4.08×10^{0}	4.08×10^{1}
		20	3.52×10^{0}	3.52×10^{1}

ILCR = Incremental Lifetime Cancer Risk

TABLE F.3-4

SOIL CPRGs (pCi/g) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: URANIUM-238 (K_l = 325 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			ILCR = 10^{-6}	MCL
3.1 L/kg	0 ft	0.1	9.98×10^0	7.77×10^1
		0.25	6.25×10^0	4.86×10^1
		0.5	4.94×10^0	3.84×10^1
		1	4.20×10^0	3.27×10^1
		1.5	3.93×10^0	3.06×10^1
		2	3.80×10^0	2.95×10^1
	10 ft	0.1	1.38×10^1	1.07×10^2
		0.25	8.06×10^0	6.28×10^1
		0.5	6.18×10^0	4.81×10^1
		1	5.17×10^0	4.03×10^1
		1.5	4.80×10^0	3.74×10^1
		2	4.64×10^0	3.61×10^1
	20 ft	0.1	2.14×10^1	1.66×10^2
		0.25	1.14×10^1	8.89×10^1
		0.5	8.27×10^0	6.43×10^1
		1	6.59×10^0	5.12×10^1
		1.5	5.98×10^0	4.65×10^1
		2	5.64×10^0	4.39×10^1

ILCR = Incremental Lifetime Cancer Risk

TABLE F.3-5

SOIL CPRGs (pCi/g) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: URANIUM-238 (K_d = 15 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			ILCR = 10^{-6}	MCL
3.1 L/kg	0 ft	0.1	1.44×10^{2}	1.12×10^{3}
		0.25	5.88×10^{0}	4.58×10^{1}
		0.5	1.76×10^{0}	1.37×10^{1}
		1	8.16×10^{-1}	6.35×10^{0}
		1.5	5.85×10^{-1}	4.55×10^{0}
		2	4.80×10^{-1}	3.74×10^{0}
	10 ft	0.1	1.34×10^{2}	1.04×10^{3}
		0.25	9.07×10^{0}	7.06×10^{1}
		0.5	2.83×10^{0}	2.20×10^{1}
		1	1.23×10^{0}	9.60×10^{0}
		1.5	8.43×10^{-1}	6.56×10^{0}
		2	6.72×10^{-1}	5.23×10^{0}
		10	2.93×10^{-1}	2.28×10^{0}
		20	2.44×10^{-1}	1.90×10^{0}
	20 ft	0.1	1.63×10^{2}	1.27×10^{3}
		0.25	1.43×10^{1}	1.11×10^{2}
		0.5	4.70×10^{0}	3.66×10^{1}
		1	2.03×10^{0}	1.58×10^{1}
		1.5	1.35×10^{0}	1.05×10^{1}
		2	1.04×10^{0}	8.13×10^{0}
		10	3.90×10^{-1}	3.03×10^{0}
		20	3.11×10^{-1}	2.42×10^{0}

ILCR = Incremental Lifetime Cancer Risk

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TABLE F.3-6

SOIL CPRGs (pCi/kg) FOR THE GROUNDWATER PATHWAY CONSTITUENT: 1,2-DICHLOROETHANE (K_l = 0.156 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			ILCR = 10^{-6}	MCL
0.156 mg/kg	0 ft	0.1	1.43×10^{0}	9.10×10^{1}
		0.25	2.52×10^{-2}	1.60×10^{0}
		0.5	6.03×10^{-3}	3.84×10^{-1}
		1	2.52×10^{-3}	1.60×10^{-1}
		1.5	1.79×10^{-3}	1.14×10^{-1}
		2	1.49×10^{-3}	9.48×10^{-2}
		20	7.94×10^{-4}	5.05×10^{-2}
	10 ft	0.1	1.21×10^{1}	7.70×10^{2}
		0.25	4.24×10^{-1}	2.70×10^{1}
		0.5	1.13×10^{-1}	7.19×10^{0}
		1	4.86×10^{-2}	3.09×10^{0}
		1.5	3.37×10^{-2}	2.14×10^{0}
		2	2.73×10^{-2}	1.74×10^{0}
		20	1.29×10^{-2}	8.21×10^{-1}
	20 ft	0.1	1.90×10^{2}	1.21×10^{4}
		0.25	9.67×10^{0}	6.15×10^{2}
		0.5	2.88×10^{0}	1.83×10^{2}
		1	1.28×10^{0}	8.14×10^{1}
		1.5	9.04×10^{-1}	5.75×10^{1}
		2	7.36×10^{-1}	4.68×10^{1}
		20	3.50×10^{-1}	2.23×10^{1}

ILCR - Incremental lifetime cancer risk
MCL - Maximum contaminant level

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TABLE F.3-7

SOIL CPRGs (pCi/kg) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: ALPHA CHLORDANE (K_l = 3.34 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			HQ = 0.2	MCL
3.34 mg/kg	0 ft	0.1	2.20×10^{-2}	9.76×10^{0}
		0.25	7.47×10^{-3}	3.31×10^{0}
		0.5	4.41×10^{-3}	1.96×10^{0}
		1	3.11×10^{-3}	1.38×10^{0}
		1.5	2.70×10^{-3}	1.20×10^{0}
		2	2.50×10^{-3}	1.11×10^{0}
	10 ft	0.1	1.04×10^{1}	4.61×10^{3}
		0.25	2.45×10^{0}	1.09×10^{3}
		0.5	1.22×10^{0}	5.41×10^{2}
		1	7.68×10^{-1}	3.41×10^{2}
		1.5	6.36×10^{-1}	2.82×10^{2}
		2	5.72×10^{-1}	2.54×10^{2}
	20 ft	0.1	3.50×10^{3}	1.55×10^{6}
		0.25	9.11×10^{2}	4.04×10^{5}
		0.5	4.71×10^{2}	2.09×10^{5}
		1	3.00×10^{2}	1.33×10^{5}
		1.5	2.50×10^{2}	1.11×10^{5}
		2	2.25×10^{2}	9.98×10^{4}

HQ - Hazard quotient
MCL - Maximum contaminant level

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TABLE F.3-8

SOIL CPRGs (pCi/kg) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: MAGNESIUM (K_t = 4.5 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			HQ = 0.2	MCL
4.5 mg/kg	0 ft	0.1	5.78×10^6	NA
		0.25	3.86×10^5	NA
		0.5	1.17×10^5	NA
		1	4.88×10^4	NA
		1.5	3.16×10^4	NA
		2	2.39×10^4	NA
		20	4.77×10^3	NA
	10 ft	0.1	9.29×10^7	NA
		0.25	1.44×10^6	NA
		0.5	2.93×10^5	NA
		1	9.92×10^4	NA
		1.5	5.87×10^4	NA
		2	4.18×10^4	NA
		20	6.06×10^3	NA
	20 ft	0.1	1.09×10^9	NA
		0.25	4.93×10^6	NA
		0.5	7.04×10^5	NA
		1	2.04×10^5	NA
		1.5	1.15×10^5	NA
		2	8.03×10^4	NA
		20	9.38×10^3	NA

HQ - Hazard quotient
MCL - Maximum contaminant level
NA - Not available

TABLE F.3-9

SOIL CPRGs (pCi/kg) FOR THE GROUNDWATER PATHWAY
CONSTITUENT: MERCURY (K_i = 10 L/kg)

Gray Clay K_d	Clay Layer Thickness	Contaminant Soil Thickness (ft)	Protective Level	
			HQ = 0.2	MCL
10 mg/kg	0 ft	0.1	1.04×10^{3}	1.32×10^{4}
		0.25	9.99×10^{0}	1.26×10^{2}
		0.5	1.80×10^{0}	2.28×10^{1}
		1	5.96×10^{-1}	7.54×10^{0}
		1.5	3.60×10^{-1}	4.56×10^{0}
		2	2.63×10^{-1}	3.33×10^{0}
	10 ft	0.1	5.69×10^{2}	7.20×10^{3}
		0.25	1.23×10^{1}	1.56×10^{2}
		0.5	2.75×10^{0}	3.48×10^{1}
		1	9.65×10^{-1}	1.22×10^{1}
		1.5	5.78×10^{-1}	7.32×10^{0}
		2	4.14×10^{-1}	5.24×10^{0}
	20 ft	0.1	5.50×10^{2}	6.96×10^{3}
		0.25	1.84×10^{1}	2.33×10^{2}
		0.5	4.63×10^{0}	5.86×10^{1}
		1	1.70×10^{0}	2.15×10^{1}
		1.5	1.03×10^{0}	1.30×10^{1}
		2	7.55×10^{-1}	9.56×10^{0}

HQ - Hazard quotient
MCL - Maximum contaminant level

TABLE F.3-10

SUMMARY OF SOIL CPRGs[a] CONSIDERING VERTICAL AND LATERAL MIGRATION

COC [b]	Soil CPRG Based on Vertical Migration to the Great Miami Aquifer		Soil CPRG Based on Lateral Migration of Perched Water	
	ILCR 10^{-6} or HQ = 0.2	ILCR = 10^{-5} MCL or HQ = 0.2	ILCR = 10^{-6} or HQ = 0.2	ILCR = 10^{-5} MCL or HQ = 0.2
Radionuclides (pCi/g)				
Strontium-90	1.47×10^{2}	1.47×10^{3}	2.95×10^{1}	2.95×10^{2}
Technetium-99	3.08×10^{-1}	3.08×10^{0}	2.60×10^{-1}	2.60×10^{0}
Uranium-238 [c]	5.17×10^{0}	4.04×10^{1}	5.17×10^{0}	4.04×10^{1}
Organics (mg/kg)				
1,2-Dichloroethane	4.86×10^{-2}	3.09×10^{0}	1.37×10^{-2}	8.71×10^{-1}
Alpha-chlordane	7.68×10^{-1}	3.41×10^{2}	2.03×10^{-2}	9.01×10^{0}
Inorganics (mg/kg)				
Magnesium	9.92×10^{4}	9.92×10^{4}	9.92×10^{4}	9.92×10^{4}
Mercury	9.65×10^{-1}	1.22×10^{1}	9.65×10^{-1}	1.22×10^{1}

[a] Soil CPRGs were developed using a source thickness of 1 foot and a gray clay thickness of 10 feet
[b] COCs which contribute significantly to 95% of the risk from Operable Unit 5
[c] CPRG for a uranium K_l = 325 L/kg

TABLE F.3-11

SUMMARY OF SITE-WIDE REPRESENTATIVE SOIL CPRGs[a]

	ZONE A		ZONE B [c]		ZONE C		LOW K_l AREAS [h]	
COC [b]	ILCR 10^{-6} [d]	MCL [e]	ILCR 10^{-6} [d]	MCL [e]	ILCR 10^{-6} [d]	MCL [e]	ILCR 10^{-6} [d]	MCL [e]
Radionuclides (pCi/g)								
Strontium-90	1.35×10^{0}	1.35×10^{1}	2.95×10^{1}	2.95×10^{2}	3.00×10^{4}	3.00×10^{5}	NA	NA
Technetium-99	3.01×10^{0}	3.01×10^{1}	2.60×10^{-1}	2.60×10^{0}	4.57×10^{0}	4.57×10^{1}	NA	NA
Uranium-238	4.20×10^{0} [f]	3.27×10^{1} [f]	5.17×10^{0} [f]	4.03×10^{1} [f]	6.59×10^{0} [f]	5.12×10^{1} [f]	8.43×10^{-1} [g]	6.56×10^{0} [g]
Organics (L/kg)								
1,2-Dichloroethane	2.52×10^{-3}	1.60×10^{-1}	1.37×10^{-2}	8.71×10^{-1}	1.28×10^{0}	8.14×10^{1}	NA	NA
Alpha-chlordane	3.11×10^{-3}	1.38×10^{0}	2.03×10^{-2}	9.01×10^{0}	3.00×10^{2}	1.33×10^{5}	NA	NA
Inorganics (L/kg)								
Magnesium	4.88×10^{4}	4.88×10^{4}	9.92×10^{4}	9.92×10^{4}	2.04×10^{5}	2.04×10^{5}	NA	NA
Mercury	5.96×10^{-1}	7.54×10^{0}	9.65×10^{-1}	1.22×10^{1}	1.70×10^{0}	2.15×10^{1}	NA	NA
Total Uranium	1.26×10^{1} [f]	9.81×10^{1} [f]	1.55×10^{1} [f]	1.21×10^{2} [f]	1.98×10^{1} [f]	1.54×10^{2} [f]	2.53×10^{0} [g]	1.97×10^{1} [g]

a Representative soil CPRG were developed using a post-remediation residual source thickness of 1 foot except the low K_l areas where the thickness is assumed to be 1.5 feet.
b COCs which contribute significantly to 95% of the risk from Operable Unit 5.
c ZONE B soil CPRGs also account for loading due to lateral migration of perched groundwater.
d Where ILCR 10^{-6} criteria not available, a HQ of 0.2 was used.
e Where MCLs not available, a ILCR 10^{-5}or HQ of 0.2 was used.
f Based on a uranium K_l value of 325 L/kg.
g Based on a uranium K_l value of 15 L/kg.
h As shown in Figure F.3-2.
NA Not Applicable

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*\ILLUS\OU-5\PO-113\F.3-CNCPT MOD LATERAL.EPS

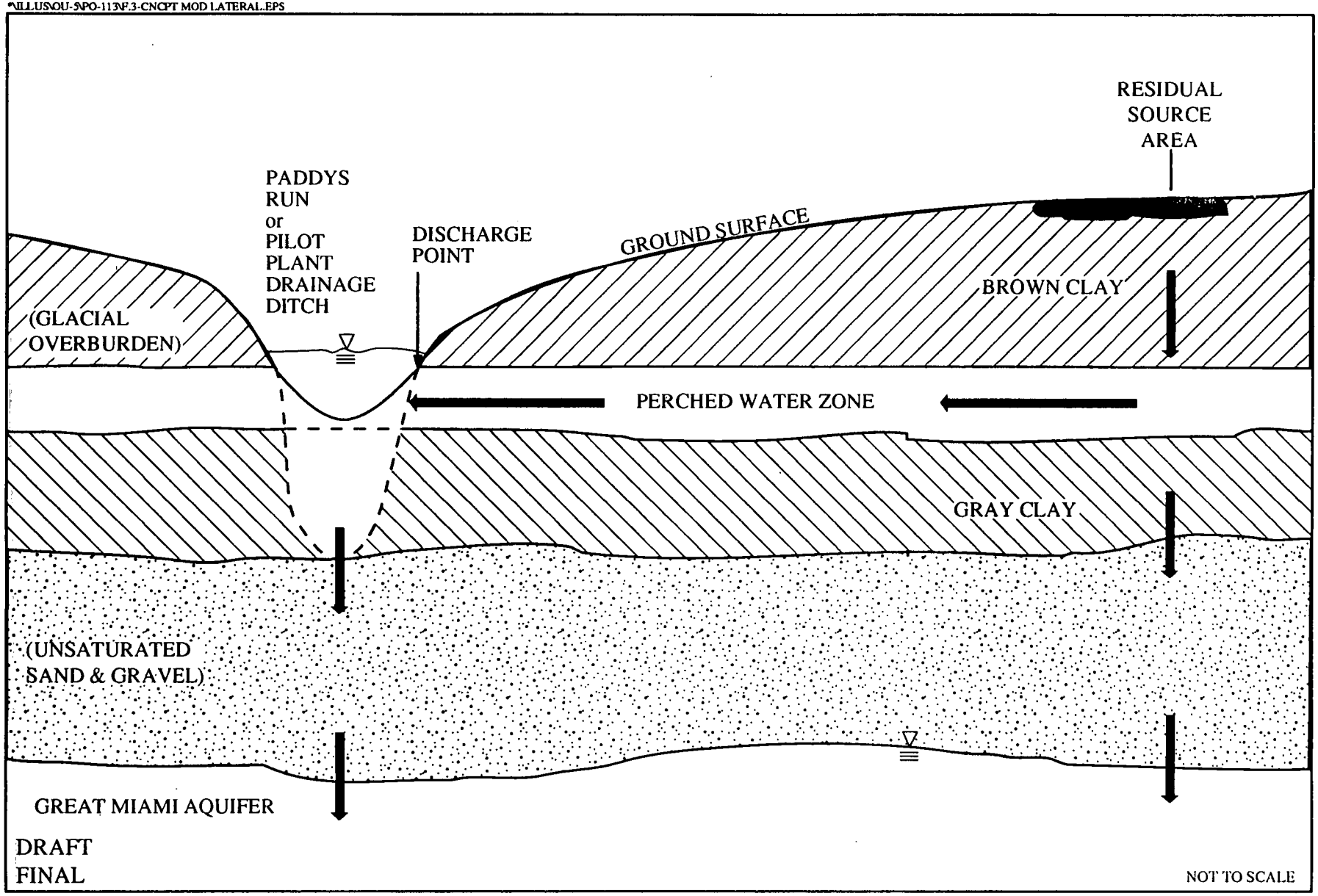


FIGURE F.3-1. CONCEPTUAL MODEL FOR VERTICAL LATERAL CONTAMINANT MIGRATION PATHWAY FOR CPRG DEVELOPMENT

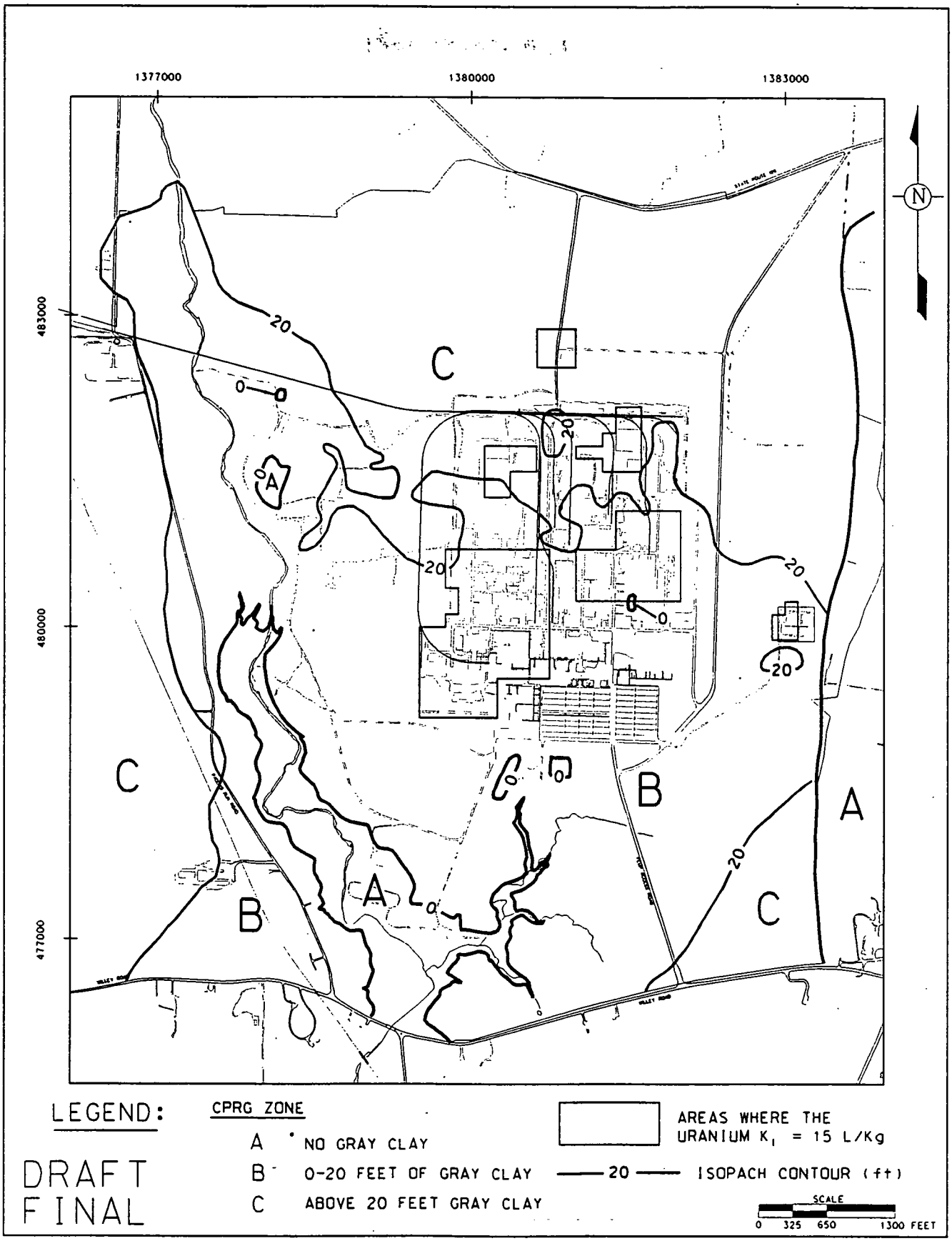
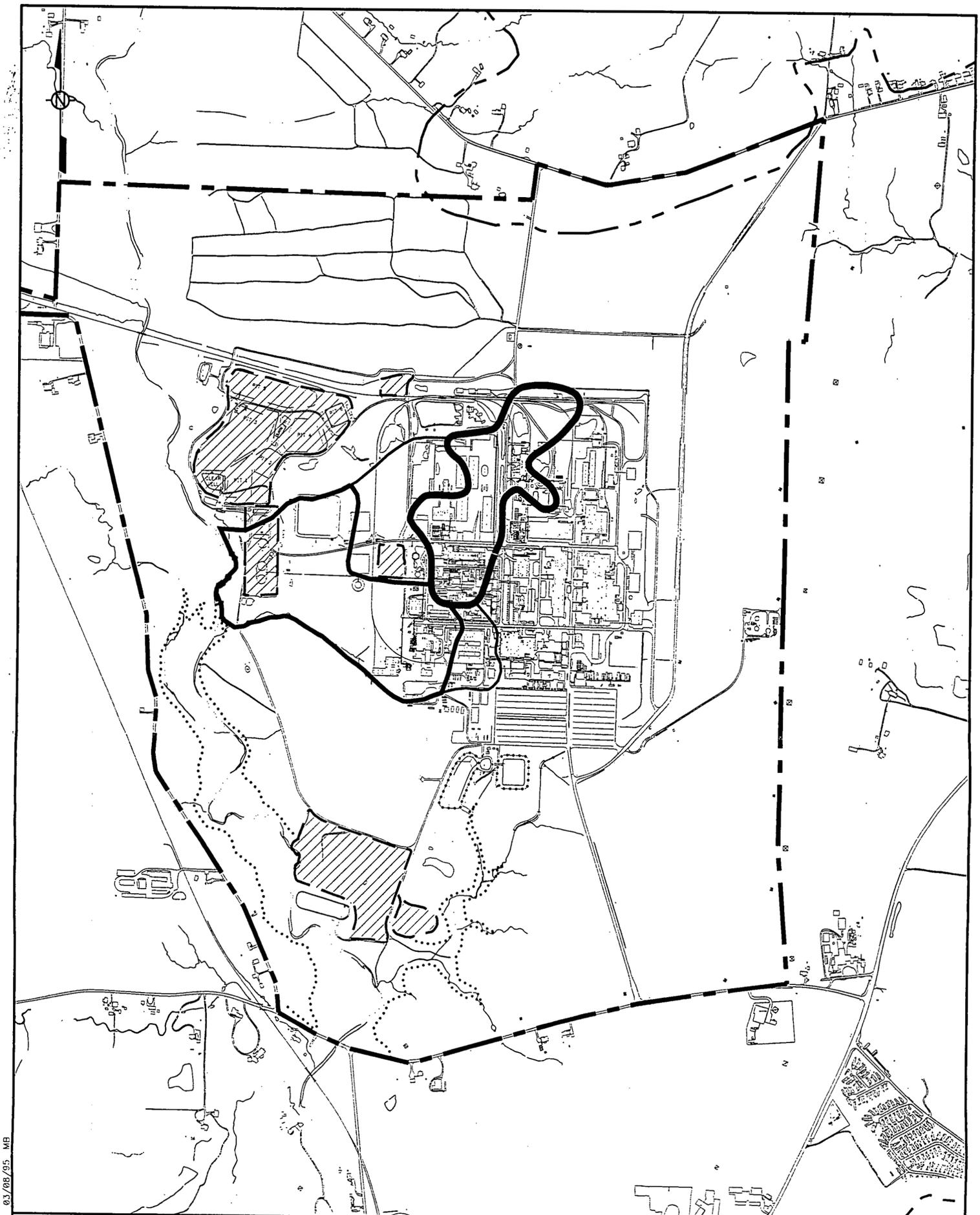


FIGURE F.3-2. CPRG ZONES



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF SURFACE WATER AND GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

DRAFT
FINAL

0 900 1800 FT
SCALE

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FIGURE F.3-3. Sr-90 CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER

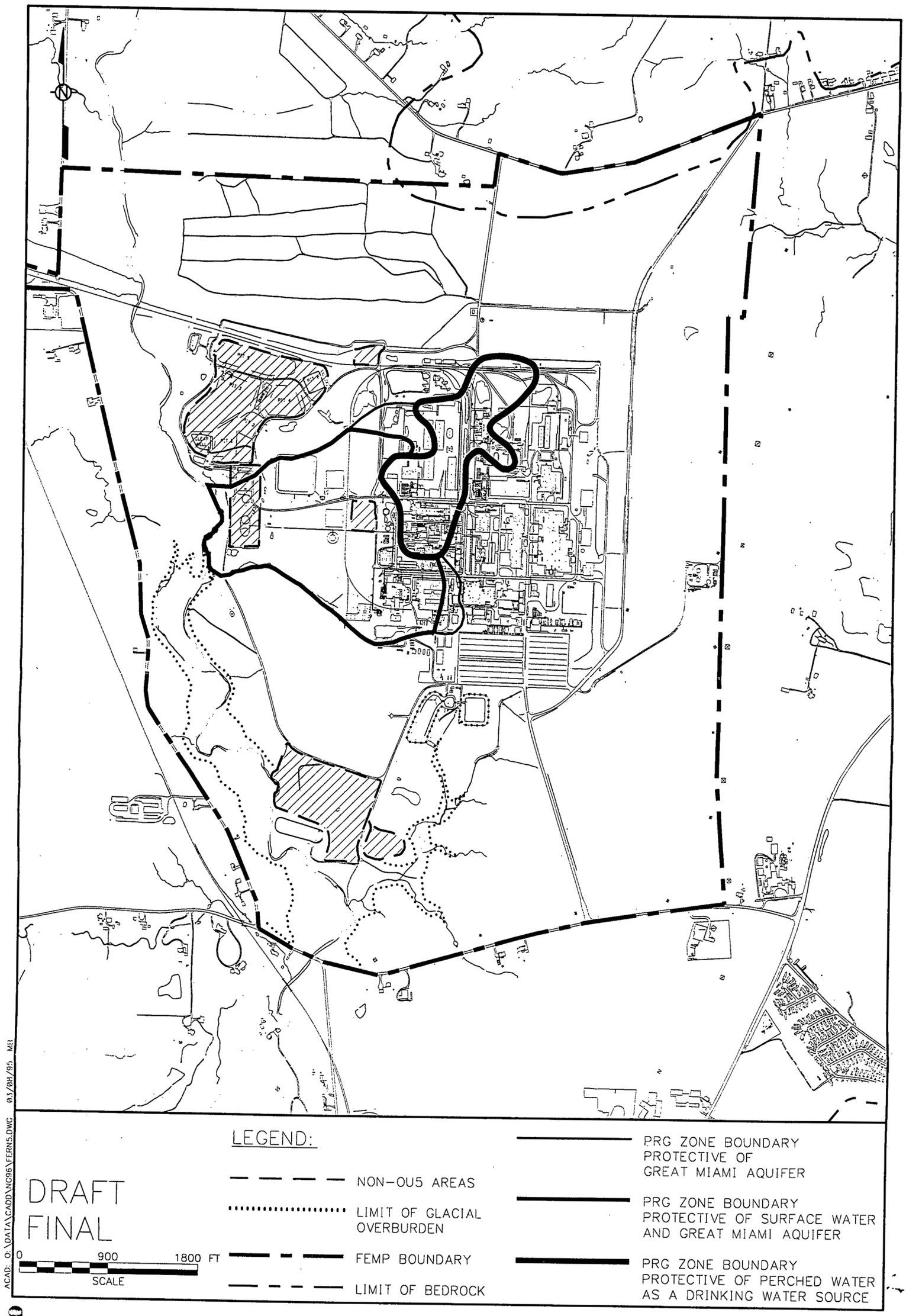
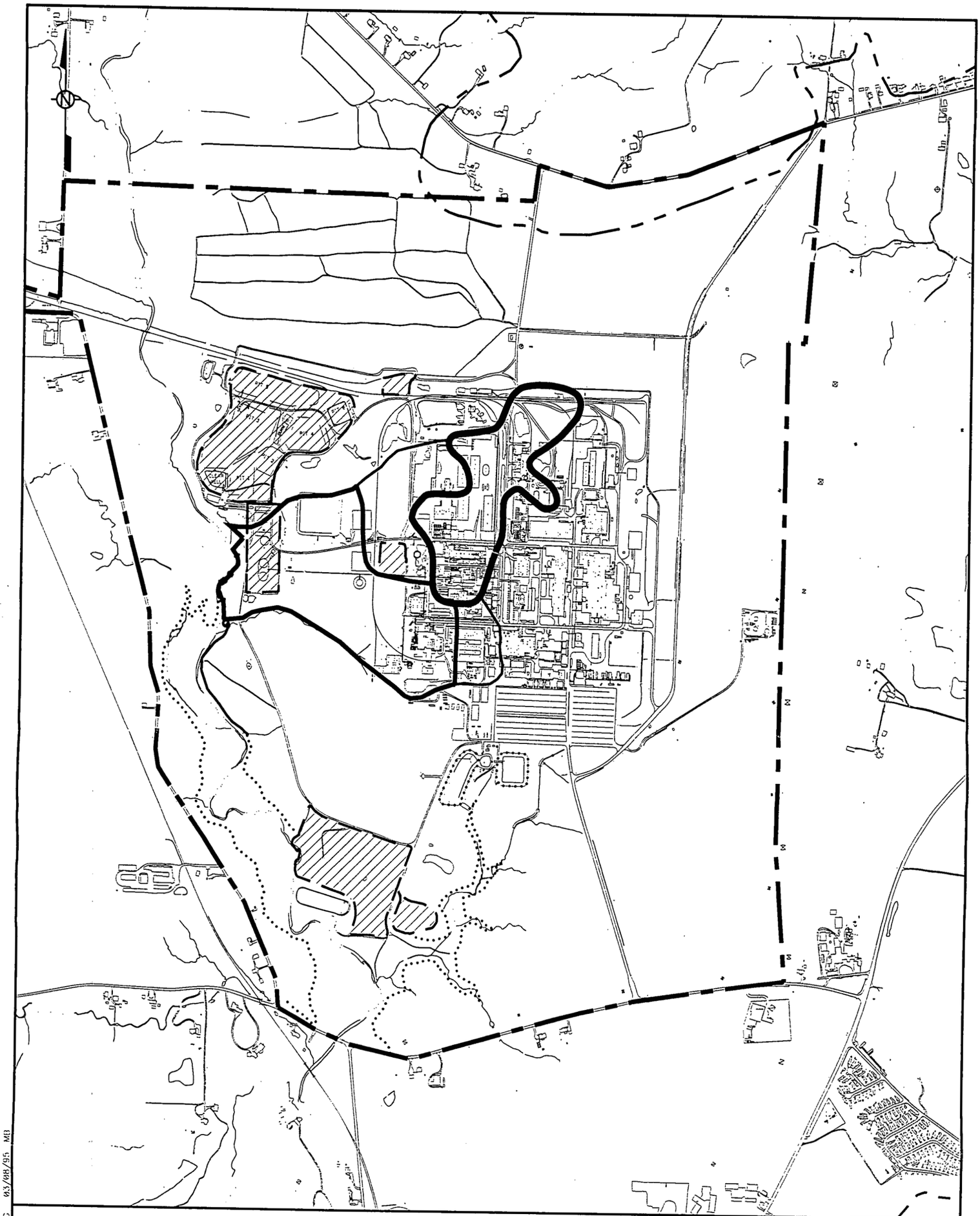


FIGURE F.3-4. Tc-99 CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF SURFACE WATER AND GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

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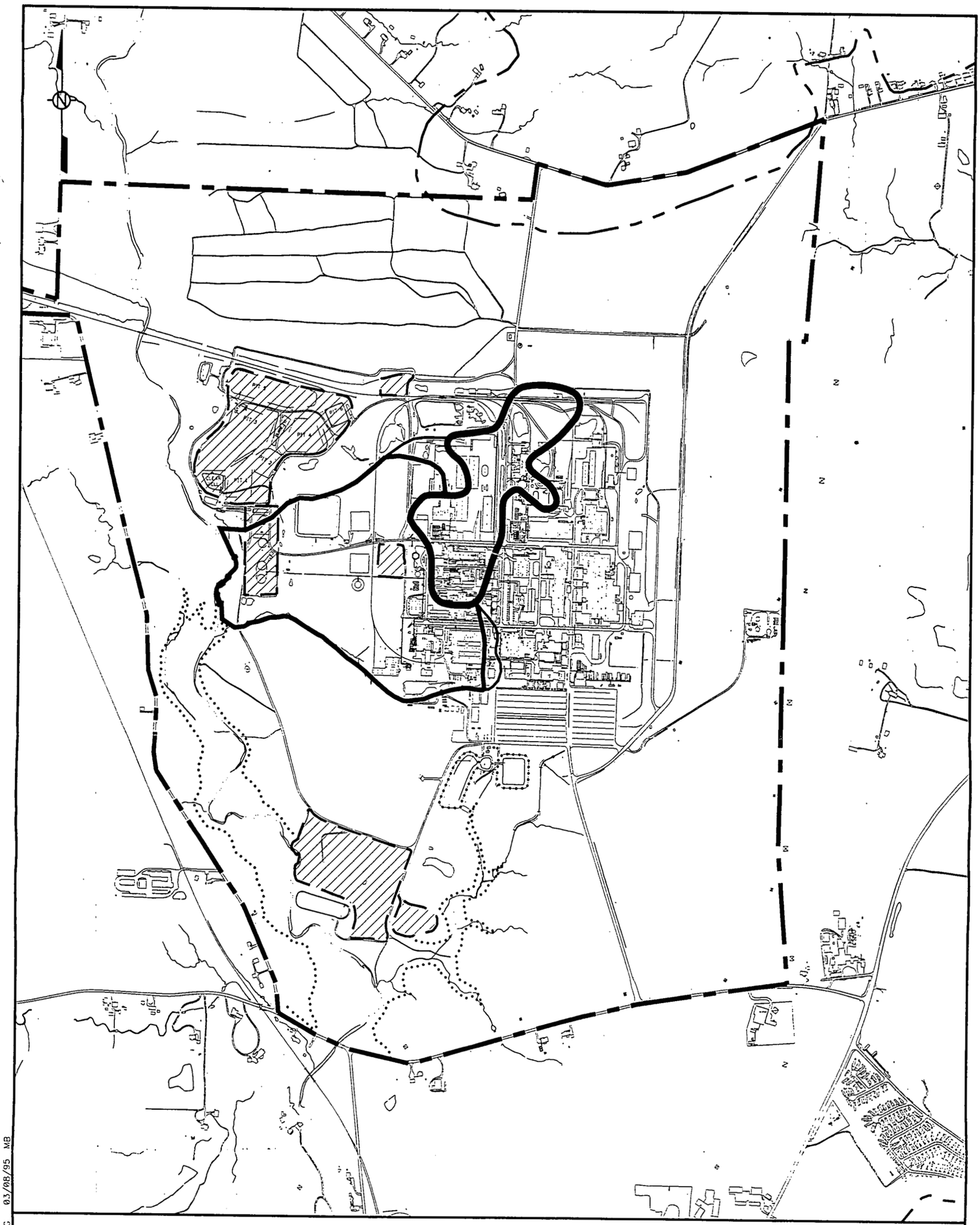
FIGURE F.3-5. U-238 CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
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- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

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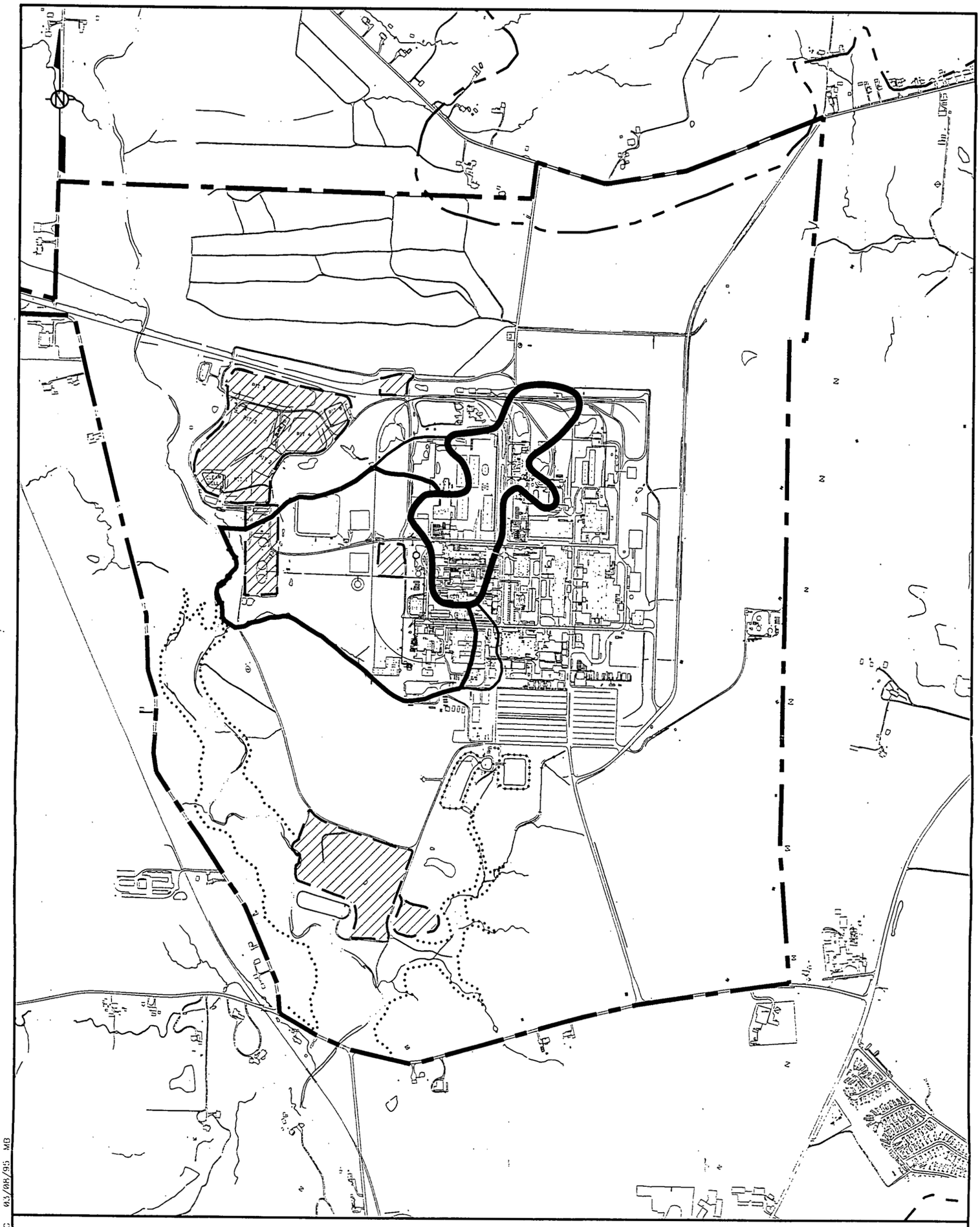
FIGURE F.3-6. 1,2-DICHLOROETHANE CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF SURFACE WATER AND GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

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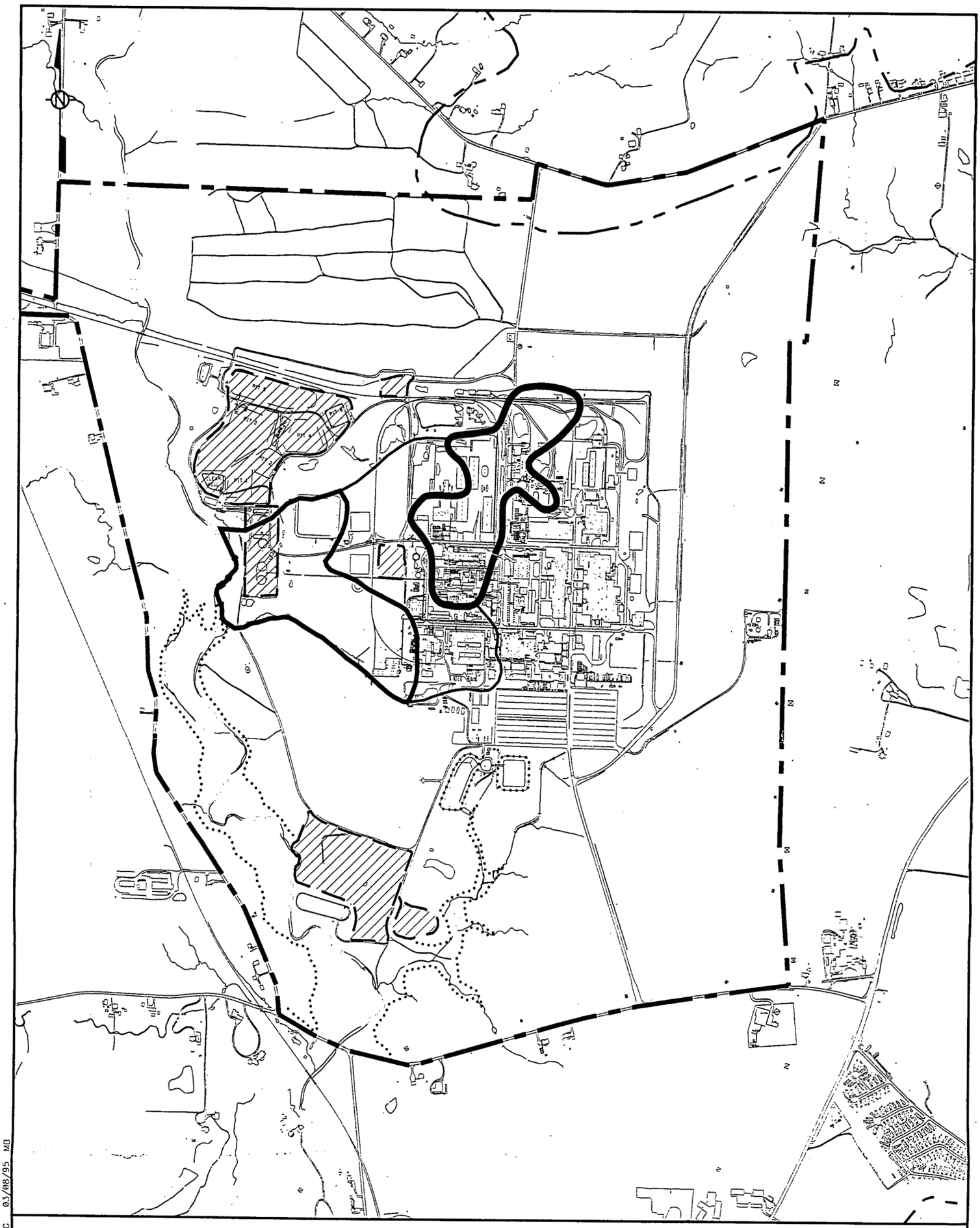
FIGURE F.3-7. ALPHA-CHLORDANE CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF SURFACE WATER AND GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

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SCALE

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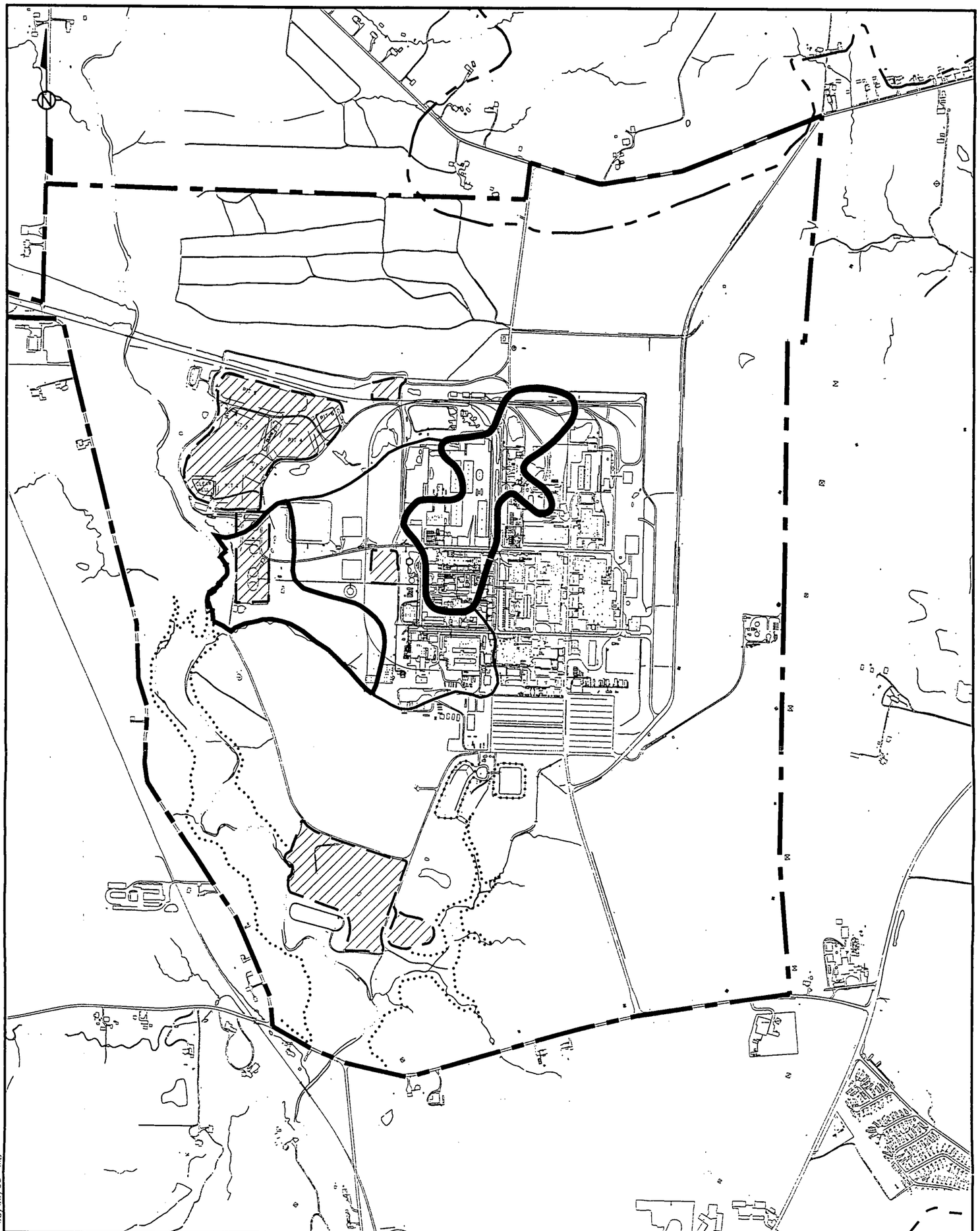
FIGURE F.3-8. MAGNESIUM CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER



LEGEND:

- NON-OU5 AREAS
- LIMIT OF GLACIAL OVERBURDEN
- FEMP BOUNDARY
- LIMIT OF BEDROCK
- PRG ZONE BOUNDARY PROTECTIVE OF GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF SURFACE WATER AND GREAT MIAMI AQUIFER
- PRG ZONE BOUNDARY PROTECTIVE OF PERCHED WATER AS A DRINKING WATER SOURCE

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FIGURE F.3-9. MERCURY CROSS-MEDIA PRELIMINARY REMEDIATION GOALS FOR PERCHED WATER

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F.4.0 EVALUATION OF PROTECTIVE REQUIREMENTS IN AIR AND SURFACE WATER PATHWAYS

This section presents the conceptual model and technical approach used for developing general protective requirements of surface soil residual contamination for the Operable Unit 5 FS, considering the surface soil as the source of contamination to the air and surface water pathways of contaminant migration. Residual contaminated soil is a source of contamination to the atmosphere via wind resuspension and dispersion. Soil is also a source of contamination to surface water runoff, sediment and to the Great Miami River via the surface water. This section discusses the development of long-term (after remediation is complete) protective requirements. The protective requirements are surface soil concentrations that will result in acceptable exposure concentrations to receptors by way of the surface water and air pathways. The protective requirements presented in this section together with soil CPRGs presented in Section F.3.0 cover all the potential cross-media migration routes of residual contamination as shown in Figure F.1-5.

F.4.1 OBJECTIVE

The objective of development of the long-term protective requirements is to determine soil concentration levels that result in acceptable concentrations in various media of the surface water and air migration pathways. For the surface water pathway the protective requirement of the surface soil is the average drainage subbasin contaminant concentration that will result in concentrations that are acceptable in the surface water, sediment and in the Great Miami Aquifer directly beneath the streambeds of Paddys Run and the SSOD. For the air pathway the protective requirements for the surface soil will result in acceptable contaminant concentrations in the air at the FEMP fence line for a RME resident farmer.

The purpose of the protective requirements developed in this section is to provide a preliminary tool which can be used to determine areas of the site which may require additional soil excavation or coverage as a part of the overall remediation based on the future land-use scenarios discussed in Section 2.1. The final determination of the acceptability of a remedial alternative is determined by the CRARE which uses all the anticipated residual contamination and considers effects of all the engineering controls.

F.4.2 GENERAL TECHNICAL APPROACH

The following subsections describe the exposure criteria used to develop the protective requirements, the conceptual model of the transport processes of the contaminants from the source surface soil, the modeling tools used to simulate the transport of the contaminants, and a summary of the major assumptions used in the development of the protective requirements in the air and surface water pathways.

F.4.2.1 Exposure Criteria

Exposure criteria are simply contaminant- and media-specific target risk levels developed for a given receptor. The exposure criteria usually are the maximum acceptable contaminant concentrations based on direct contact with the media from which the exposure occurs (i.e., PRGs). The exposure criteria for the air and surface water pathways are described in the following two subsections.

F.4.2.1.1 Air Exposure Criteria

The 10^{-5} ILCR and 0.2 HQ were used to develop air pathway protective requirements for the off-property resident farmer (adult and child) exposed to each airborne contaminant emitted from the FEMP. The ILCR values are applied to airborne carcinogens and the HQ values are applied to the airborne toxicants (noncarcinogens). The risk-based PRG values for airborne contaminants which meet the exposure criteria are presented in Table F.4-1.

The airborne PRGs are used to develop the air pathway protective requirements. Emissions of FEMP contaminants to the atmosphere will impact off-property receptors. The air pathway protective requirements are the maximum on-property soil concentrations that will prevent the off-property impacts from exceeding the airborne PRG values. The air pathway protective requirements are then compared to soil PRGs for various on-property target receptors. Nine combinations of on-property and off-property exposure criteria have been identified for soil excavation volume estimates. However, not all nine need to be analyzed for off-property air impacts.

Four combinations of on- and off-property exposure criteria need to be analyzed to verify compliance with the off-property target receptor (resident farmer) exposure criteria. These cases include the following on-property target receptors: commercial/industrial user, recreational user on developed park, recreational user on undeveloped park, and the expanded trespasser.

The soil PRGs developed for the on-property resident farmer are also protective of the off-property resident farmer because the exposure parameters used to develop the PRGs are the same for each farmer. Therefore, no additional analysis is required to demonstrate protection of the off-property resident farmer for the two cases in which the on-property resident farmer is the target receptor.

Three combinations include an off-property exposure criteria of 3.5×10^{-5} ILCR for the off-property resident farmer. Because this air pathway analysis will be used to verify compliance with a more stringent off-property criteria (1×10^{-5} ILCR) with the same on-property target receptor, no additional analyses are required for these three cases.

F.4.2.1.2 Surface Water Exposure Criteria

Two sets of protective requirements in the surface water pathway are developed based on two risk levels. The first set of protective requirements are based on the 1 x 10^{-6} ILCR for carcinogens and 0.2 HQ for noncarcinogens. The second set of protective requirements are based on the MCLs for the Great Miami Aquifer and the 1 x 10^{-5} ILCR or the HQ of 0.2 for sediment and surface water. The MCL is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system as regulated by EPA. If a MCL has not been established for a certain contaminant, the 1 x 10^{-5} or HQ of 0.2 level (whichever was smaller if both were available) is used for the Great Miami Aquifer criteria.

Of the nine combinations of exposure criteria identified for soil excavation volume estimates, the 1 x 10^{-6} and 1 x 10^{-5} resident on- and off-property farmer scenarios are the most stringent, so that if the soil concentrations meet the protective requirements for these risk scenarios they will be protective of the other seven exposure criteria. Therefore, protective requirements need only to be developed for the first two exposure criteria.

Most of the exposure criteria used for development of surface water protective requirements are based on direct contact with a particular media (no cross-media transport). The criteria used for the Great Miami Aquifer and surface water are based on the direct contact PRGs. The Great Miami Aquifer criteria are based on the PRG levels developed for the RME on-property farmer exposure scenario. The surface water criteria is based on the off-property user of meat and milk. The sediment criteria is based on the PRG for the recreational user scenario or the soil CPRG for sediment, whichever was lower. The sediment CPRGs are calculated to account for the potential migration of contaminants leaching out of the sediment and directly entering the Great Miami Aquifer through the streambeds of Paddys Run and the SSOD. The sediment CPRGs are the same as the soil CPRGs calculated using the ECTran model with a zero gray clay thickness and an assumed one-foot-thick contaminant source. The soil CPRG calculations are described and presented in Section F.3.2. Because more COCs are modeled in the surface water pathway, additional sediment CPRGs were developed from those presented in Section F.3.2. All of the exposure criteria developed for sediment are summarized in this section.

Tables F.4-2 and F.4-3 present the criteria that are used to develop the protective requirements for the 1 x 10^{-6} and 1 x 10^{-5} risk levels (or HQ of 0.2 and MCLs). The surface water protective requirements are developed for the constituents that account for 95 percent of the risk at the FEMP and that failed either the surface water or the sediment screenings (Table F.2-3).

F.4.2.2 Conceptual Model of Contaminant Transport

F.4.2.2.1 Air Pathway Conceptual Model

Wind erosion/resuspension of particulate matter represents a viable transport pathway for all contaminated surface soil in Operable Unit 5. Under windy conditions, surface soil particles can be resuspended and dispersed into the atmosphere. The particulate matter emission rate from the surface is dependent on the ambient wind speed, representative size of surface soil particles, moisture content and crustiness of the soil, and quantity of vegetative cover on the surface.

Volatilization of organic compounds or emission of radioactive decay products from contaminants in the soil also represent viable transport pathways. For assessing residual risk impacts, the emission of Rn-222 from the radioactive decay of Ra-226 in soil may be significant. The emission of volatile organic compounds is not considered significant for residual risk assessment because these compounds will have evaporated or been removed from the surface soil long before the time period analyzed for residual impacts.

In addition to direct inhalation, the off-property resident farmer can be exposed to airborne contaminants through deposition onto food crops and cattle feed/forage crops. Ingestion of contaminated fruits, vegetables, beef, and milk is accounted for in the development of PRGs for airborne contaminants listed in Table F.4-1.

F.4.2.2.2 Conceptual Model of the Surface Water Pathway

Surface water runoff is a viable transport pathway for all contaminated surface soil in Operable Unit 5. During a rainfall event, soil particles are dislodged by the impact of raindrops and by the flow of runoff across the soil surface. The amount of soil erosion depends on rainfall intensity, slope length, slope steepness, vegetative cover, and in-place erosion controls. The dislodged soil particles travel overland in the runoff and eventually become sediment in the receiving water courses. Contaminants in the soil particles can also be dissolved and transported into the runoff water and the receiving surface water. Some of the contaminated surface water can then infiltrate into the Great Miami Aquifer through portions of the streambeds of Paddys Run and the SSOD, where the streams have cut through the glacial overburden.

Surface sediment in the vicinity of the FEMP property consists of relatively impermeable glacial till and lacustrine deposits (clay, sand, silt, and gravel). Underlying this sediment are permeable glacial outwash sand and gravel that form the water-bearing unit of the Great Miami Aquifer. Water readily infiltrates into the unsaturated outwash deposits due to their porous nature. The water table elevation in the Great Miami Aquifer in and around the FEMP property is generally lower than the streambed elevation resulting in an unsaturated zone between the water table and the streambed. Significant amounts of water can infiltrate from streams into the unsaturated glacial outwash and then enter the

Great Miami Aquifer. This migration is the basis for modeling the surface water as a pathway of contamination to the groundwater.

As a rainfall event takes place, the rain saturates the top level of soil. As rain continues to fall, all of the rain cannot be absorbed in the soil and the excess becomes runoff. The concentration of contaminants in the soil and the water in the saturated soil are assumed to be in equilibrium. The force of the rainfall causes the soil particles to be dislodged from the ground surface and washed into the water courses where they become sediment. During a storm event, some of the water in the saturated soil runs off in addition to the rainfall which does not have a chance to soak into the contaminated soil. The surface water runoff therefore contains a smaller concentration of contaminant than the water in the saturated soil because of dilution with rainfall. Because of this, the surface water runoff and the sediment concentration will not be in equilibrium. The contaminant will then begin changing phases from sediment to the surface water to again reach an equilibrium. For short-term releases (the concentrations calculated during a storm event) it is assumed that the concentration in the sediment and the surface water do not change phases in the stream during the storm event. The modeled surface water concentrations are based on short-term releases. This assumption is made because flow of surface water in the vicinity of the FEMP is ephemeral so that the surface water and sediment do not have the time to reach a new equilibrium. In the development of the long-term protective requirements, it is assumed that the stream sediment can become saturated and stay saturated long enough for the contaminants in the water phase and the adsorbed phase to reach an equilibrium. The water in the saturated sediment can then migrate into the groundwater without dilution of additional surface water. This migration pathway along with the direct contact with sediment is used to determine the acceptable concentration in the sediment.

In developing the surface water protective requirements, the final remediated site surface conditions are used. The final site surface conditions could encompass several scenarios as described in Section F.2.1. The remediated site is assumed to be covered with good grass. The grass cover condition is hydrologically similar to the other proposed site surface conditions such as wooded and covered with brush. The protective requirements are developed for the long-term condition at the site. The protective requirements are therefore developed using the scenario in which the storm water controls (e.g., the storm water retention basins) around the site have been assumed to fail.

The FEMP property can be divided into several subbasins based on drainage divides to allow for the analysis of separate areas of the FEMP containing different surface conditions or storm water management systems, as shown in Figure F.4-1. The drainage subbasins do not correspond to the infiltration or perched groundwater zones used to develop the soil and perched water CPRGs because subsurface conditions change differently than surface conditions.

F.4.2.3 Modeling Tools

The following sections describe the modeling tools used to develop the protective requirements considering the air and surface water pathways of contaminant migration.

F.4.2.3.1 Air Pathway Modeling Tools

Air transport modeling is conducted in accordance with EPA guidance (EPA 1989). Particulate matter emission rates are estimated from measured fence line concentrations. Particulate-phase contaminants examined include radionuclides, inorganics, and semivolatile and nonvolatile organics. An air emission model (RAECOM; Nuclear Regulatory Commission [NRC] 1984) is used to estimate the flux of Rn-222 gas from soil containing Ra-226. Annual average air concentrations for all COCs are determined using the EPA's computerized air dispersion model (EPA 1992), the ISCLT2. This model is recommended by EPA for air pathway analysis of Superfund sites (EPA 1989). The ISCLT2 model is designed for assessing the air quality impact of emissions at user-selected receptors from a variety of sources. Brief summaries of these models are included in Table F.1-1.

F.4.2.3.2 Surface Water Pathway Modeling Tools

Like air transport modeling, surface water transport modeling is used to refine the designs of remedial alternatives and to support the CRARE residual risk assessment. Fate and transport modeling via surface water is conducted using the SWF&IM (DOE 1993) developed for the FEMP. The SWF&IM is a combination of FEMP-specific hydrological conditions and several hydraulic and transport models used to simulate the various physical and chemical processes involved in the transport of contaminants from surface soil into surface water and the Great Miami Aquifer. The models which comprise the SWF&IM and their connections are described in detail in the document referenced above. In addition, a summary of these models is presented below and in Table F.1-2.

The SWF&IM consists of the following components. Rainfall and runoff are simulated with the HEC-1 modeling code (COE 1990). Rating curves for cross sections along Paddys Run and the SSOD are generated using the Mannings equation (Henderson 1966). The Mannings equation is applied along Paddys Run and the SSOD to determine the elevation of water in the stream (stage) at each cross-section location for a given flow rate (discharge). To calculate infiltration from surface water to the Great Miami Aquifer, the computer code VS2DT (Healy 1990) is applied at each cross section. VS2DT is a two-dimensional numerical groundwater model developed to simulate variably saturated flow conditions. The storm water depth is based on the runoff hydrographs produced using the HEC-1 code combined with the rating curves developed with the Mannings equation. A time-varying depth of water is input into the VS2DT program for the infiltration calculations to simulate the fluctuation of flow depths in the streams during the representative storm event. The one-year 24-hour storm event is used as the representative storm. The output from VS2DT provided the infiltration volumes and patterns to the Great Miami Aquifer along the study length of Paddys Run

and the SSOD. The runoff hydrographs and infiltration information are used in calculating contaminant concentrations and loadings.

The transport of contaminants centered on the use of the MUSLE and partitioning equations, both of which are presented in the Superfund Exposure Assessment Manual (EPA 1988). The MUSLE equation is used to calculate the amount of sediment generated from the representative storm event in each subbasin. The partitioning equations are then used to determine the amount of contaminant transported in the dissolved phase with the runoff and the amount transported sorbed to the sediment. As flow from each different subbasin combines the contaminant concentration in the combined flow is calculated based on a mass-balance approach. The USLE (EPA 1988) is incorporated in the overall surface water modeling to determine the annual sediment loadings.

F.4.2.4 Summary of Assumptions

F.4.2.4.1 Air Pathway Summary of Assumptions

Several assumptions are incorporated into the development of the air pathway protective requirements and the comparison to soil PRGs. These assumptions are:

- Measured fence line contaminant concentrations from 1992 are assumed to provide a reasonable basis for estimating future particulate matter emissions from the site. Various remedial activities on the site during 1992 may have caused relatively high fence line concentrations for that year. These concentrations are higher than would be expected from the site when little or no activities occurred.

- A single air pathway protective requirement is developed for each contaminant. These contaminant-specific protective requirements are developed to be applicable over the entire site. This method is conservative because source areas located some distance from the fence line could be allowed to have a higher residual concentration without increasing the impact at the fence line.

- Contaminant concentrations in soil are assumed to be equal to contaminant concentrations in airborne particulate matter.

- The risk-based soil PRGs are assumed to represent the maximum allowable on-property soil concentrations for comparison to the air pathway protective requirements. No comparison to CPRG values developed previously is necessary because the final cleanup levels and residual soil concentrations must be less than or equal to the PRG values. A modeled CPRG can only be used to set the final cleanup level if it is less than the PRG value for a given contaminant.

75 - The impact of contaminated sediment from Paddys Run and the SSOD is assumed to be negligible to off-property receptors through the air pathway. Virtually the entire site, including Paddys Run and the SSOD, are modeled using on-property receptor soil PRGs. The surface area of Paddys Run and the SSOD is insignificant compared to the total modeled surface area. In addition, because the prevailing wind direction is toward the northeast, the maximum off-property impact will be along the north or east fence line. The

distances from Paddys Run and the SSOD to these fence lines are such that contaminated airborne sediment impacts will be negligible to off-property receptors.

F.4.2.4.2 Surface Water Pathway Summary of Assumptions

Several assumptions were incorporated into the development of the surface water pathway protective requirements. These assumptions are listed below:

- The contaminants in the sediment and the surface water do not change phases during short term releases of contaminants.
- The contaminants can leach out of the sediment during long-term releases and enter the Great Miami Aquifer.
- To develop the protective requirements for each subbasin, no combined loading affects are considered. It is felt that this assumption is justified in developing site-wide requirements because it is likely that a majority of the FEMP property will contain contamination at levels below the maximum allowable concentrations.
- The protective requirements are developed assuming that the runoff controls around the production area and the waste pit area have failed. This will create a conservative scenario because more contaminated area will discharge uncontrolled runoff to Paddys Run and consequently the Great Miami Aquifer.
- The pattern of infiltration through the streambeds does not change from the pattern of infiltration developed for the Operable Unit 5 RI Report. The remediation of the site will change the amount of runoff coming from remediated areas; however, most of the Paddys Run drainage basin and the site will not change significantly from its present hydrologic condition. The overall infiltration pattern will not change appreciably from the one developed in the RI. This assumption is discussed further in Section F.4.3.2.

F.4.3 PROTECTIVE REQUIREMENTS FOR LONG-TERM IMPACTS

F.4.3.1 Air Pathway Protective Requirements

Air pathway protective requirements for FEMP surface soil are the on-property soil concentrations that would protect the off-property resident farmer from excessive exposure to FEMP contaminants through the air pathway. Existing measurements of airborne contaminants at the FEMP fence line are used to determine the maximum inhalable particulate matter (PM_{10}) fence line concentration from on-property emissions. This PM_{10} concentration is used with the acceptable contaminant-specific airborne PRG (Table F.4-1) to determine the air pathway protective requirements for FEMP surface soil. The development of the protective requirements is summarized in Figure F.4-2.

The FEMP maintains nine air quality monitoring stations around the site, seven of which are along the fence line. The monitoring locations are presented in Figure F.4-3. The total uranium concentrations in air and surface soil at the seven fence line stations are used to estimate airborne

PM_{10} concentrations at the fence line. The data is obtained from the 1992 Fernald Site Environmental Report (FERMCO 1993).

The monitored particulate matter concentrations are not directly presented in the Environmental Report; however, these concentrations could be estimated by assuming that the uranium soil concentration at each monitoring station is equal to the uranium concentration in the airborne particulate matter collected at that station. The airborne PM_{10} concentration (grams per cubic meter [g/m^3]) is determined by dividing the airborne uranium concentration (picocuries per cubic meter [pCi/m^3]) by the uranium soil concentration (picocuries per gram [pCi/g]). The measured uranium concentrations in air and soil and estimated PM_{10} concentrations for each fence line station are presented in Table F.4-4.

The highest PM_{10} concentration estimated from monitored uranium concentrations is 20×10^{-6} grams per cubic meter (g/m^3), at Air Monitoring Station 2 (AMS 2). The 20×10^{-6} g/m^3 value compares well with the typical airborne dust concentration around the United States. A mean value of 15.5×10^{-6} g/m^3 was reported by DOE from 46 sampling locations in the United States (ORNL 1984).

Therefore, 20×10^{-6} g/m^3 is used to determine FEMP surface soil concentrations which would be protective of the off-property resident farmer from exposure through the air pathway. The air pathway protective requirement is calculated by dividing the resident farmer air pathway PRG (from Table F.4-1) by 20×10^{-6} g/m^3.

F.4.3.2 Surface Water Pathway Protective Requirements

As stated in Section F.4.2.3, the protective requirements are developed using the SWF&IM (DOE 1993b) developed for the FEMP. The remediation of the site will change the runoff characteristics of some of the remediated areas.

The excavation of the soil during remediation will have a significant effect on the amount of runoff coming from some of these areas. For instance, much of the production area is currently covered with buildings and pavement. During remediation these structures will be removed, which will have a significant affect on the following model input parameters; the runoff curve number in the HEC-1 model and the cover and erosion management practice factors in the MUSLE and USLE equations. The runoff curve number will effect the runoff volume and the dilution factors used to calculate the surface water and sediment concentrations. Therefore, the HEC-1 model is rerun for the remediated condition of the site. As indicated in the assumptions, the remediated areas of the site are assumed to be covered with good grass. The resulting runoff curve numbers and erosion cover factors that reflect the remediated site are presented in Table F.4-5.

A relatively small portion of the site (approximately 32 acres) located in the northeast corner of the site drains directly offsite and eventually to the Great Miami River. Under the remediation scenarios this area will be regraded so that surface water runoff from this area will flow to Paddys Run instead of the Great Miami River.

Because the excavation and remediation will affect the volume of surface water runoff from the site, the infiltration amount through the streambeds of Paddys Run and the SSOD will also vary slightly. Based on the sensitivity analysis presented in the Surface Water flow and Infiltration Model Summary Report (DOE 1993), the infiltration amount is fairly insensitive to the runoff volume. Although the amount of runoff coming off the excavated areas may change substantially, the overall flow volume in Paddys Run and the SSOD should not change substantially because the majority of the drainage basin will retain surface conditions similar to the present surface conditions. The total Paddys Run drainage basin is approximately 16 square miles. Because of this, it is assumed that the infiltration pattern of surface water entering Paddys Run and the SSOD does not change from the infiltration pattern used in the RI.

A flow chart of the procedure used to develop the long-term protective requirements for surface soil based on the surface water pathway is shown in Figure F.4-4. The procedure begins by defining the exposure criteria as discussed in Section F.4.2.1.2.

With the exposure criteria set as the surface water, Great Miami Aquifer groundwater, and sediment PRGs, the surface water model is iteratively run to determine the allowable average surface soil concentration for each subbasin that will result in a concentration just below the minimum criteria in all media. In determining the surface soil protective requirements, it is assumed that contamination does not come from any other source or any other subbasin, so that each subbasin is evaluated separately. Predicted contaminant concentrations in each media are compared to the criteria as follows:

- The predicted surface water concentration coming from each subbasin is compared to the surface water PRG before the runoff mixes with other contaminated subbasins or uncontaminated runoff from upstream drainage areas.
- The predicted groundwater concentration, under the stream reach in Paddys Run which has the highest mass of contaminant loading from the surface water for that subbasin, is compared to the PRG for the Great Miami Aquifer groundwater.
- The predicted sediment concentration coming from each subbasin is compared to the lower of PRG concentration for the sediment or the CPRG for sediment, as described in Section F.4.2.1.

To develop protective requirements, an initial surface soil concentration is determined by judgment. The surface soil concentration is then input into the surface water model for a single subbasin and the model is run. The predicted concentrations of contaminants in the surface water, Great Miami River, and sediment are compared to the appropriate media-specific criteria. If the initial soil concentration is unacceptable, the concentration is then varied and the model rerun until the surface water, Great Miami Aquifer, or sediment concentrations are all slightly less than or equal to the criteria. The COC's protective requirement could be controlled by any of the three media criteria. The procedure is then repeated for the next subbasin until a COC-specific subbasin average surface water protective requirement for all of the subbasins and COCs is determined.

Two K_l values, 325 and 15 L/kg are used for uranium during protective requirement development. The higher K_l is for less soluble forms of uranium while the lower K_l is for more soluble forms of uranium. Both forms of uranium are present at the FEMP site. To simulate the transport of the different forms of uranium, the K_l of 15 L/kg is used for areas suspected of containing the soluble forms of uranium. The production area, the sewage treatment plant area and the fire training area are all assigned a K_l value of 15 L/kg. The K_l values used for all of the COCs used in development of surface water protective requirements are shown in Table F.4-6 .

A summary of the surface water protective requirements developed for each subbasin shown in Figure F.4-1 is presented in Tables F.4-7 and F.4-8 for the 1×10^{-6} and 1×10^{-5} risk levels, respectively. These protective requirements reflect the average allowable soil concentration in each subbasin. Because these are average values, certain areas within each subbasin may have a concentration that is higher than the protective requirement as long as there are areas with lower concentrations to balance the overall average subbasin concentration.

F.4.4 EVALUATION AND APPLICATION OF PROTECTIVE REQUIREMENTS

As shown in Figure F.1-4, protective requirements in air and surface water pathways are not used to develop CPRGs. Because the contaminant source for these two pathways consists of contaminated residual surface soil, the remedial alternatives designed to protect the groundwater pathway can be easily refined by including additional excavation of residual contaminated soil. Therefore, the protective requirements for the air and surface water pathways are developed independent of the initial soil CPRG and incorporated into each remedial alternative during the refinement stage. The initial soil excavation foot print for each remedial alternative evaluated in the Operable Unit 5 FS is expanded during this process if it is determined necessary.

F.4.4.1 Air Pathway

Because an initial soil remedial design is based on on-property PRLs only, residual impacts to off-property receptors need to be evaluated. The air pathway protective requirements are compared to

surface soil PRGs for on-property RME receptors as well as to existing surface soil concentrations in a three-step screening process to determine if areas other than those already excavated would need further remediation. The screening process is presented in Figure F.4-5.

First, the surface soil PRG is compared to the protective requirement. If the contaminant-specific PRG is less than or equal to the protective requirement, no additional analysis is needed for that on-property receptor/contaminant combination since the PRG value would be protective of the off-property resident farmer.

Second, the maximum baseline surface soil concentration (95 percent upper confidence limit on the mean) is compared to the protective requirement. This step is included because the PRG values developed for surface soil are much higher than existing soil concentrations for many contaminants. If the maximum surface soil concentration is equal to or less than the protective requirement, no additional analysis is needed for that on-property receptor/contaminant combination because the maximum soil concentration would be protective of the off-property resident farmer.

Third, the area-specific baseline surface soil concentration presented in the Operable Unit 5 RI Report (DOE 1995) is modeled to determine the maximum baseline air concentration at the fence line. This modeled air concentration is compared to the airborne PRG value for the off-property resident farmer. This step is included because maximum surface soil concentrations typically do not occur near the fence line. The contribution from all FEMP sources is included in the modeled result. If the modeled result is equal to or less than the airborne PRG value, no additional analysis is needed for that on-property receptor/contaminant combination because the baseline air concentration at the FEMP fence line would be protective of the off-property resident farmer.

If a receptor/contaminant combination does not pass at least one of the screening steps, then additional remediation of surface soil to remove that contaminant would be necessary for protection of the off-property resident farmer.

Results of the first two screening steps are presented in Tables F.4-9 through F.4-12 for each of the on-property receptors considered. These results indicate that only one contaminant does not pass these screening steps. For a recreational user on an undeveloped park and for an expanded trespasser, the thorium-230 PRG and maximum baseline surface soil concentration exceed the air pathway protective requirement.

Air dispersion modeling was conducted to complete the third step in the screening process for thorium-230. The analysis was conducted by assuming that the entire site emitted PM_{10} and the maximum PM_{10} concentration in air was 20×10^{-6} g/m^3 at the FEMP fence line. The ISCLT2 model

was run with a unit emission rate (1 g/s/m^2) for all sources. The modeled fence line air concentration was corrected to 20 x 10^{-6} g/m^3 and the correction factor was multiplied by the modeled emission rate to determine the site-wide PM_{10} emission rate. The modeled maximum fence line concentration was 27.2 g/m^3 for a unit emission rate. Therefore, the site-wide PM_{10} emission rate was calculated to be 7.34 x 10^{-7} g/s/m^2. This emission rate was multiplied by the baseline soil concentrations of thorium-230 in each area of the FEMP to determine the contaminant emission rate from each area. The modeled areas are shown in Figure F.4-6 and the area-specific baseline soil concentrations are presented in Table F.4-13. The area-specific emission rates were then modeled with ISCLT2 to determine the maximum airborne fence line concentrations of thorium-230. Thirty-six fence line receptors were included in the analysis to identify the point of maximum impact.

The maximum modeled fence line concentration was 2.84 x 10^{-3} pCi/m^3 for thorium-230. This value is below the airborne PRG value presented in Table F.4-1. Therefore no additional analysis or remedial action is required for this compound.

Air emission and dispersion modeling is also conducted to verify that the surface soil PRG values for radium-226 would provide adequate protection to the off-property resident farmer from exposure to radon-222 gas emissions. Table F.4-14 presents the RAECOM model input and results as well as the ISCLT2 model results. These results indicate that the surface soil PRG values for radium-226 will provide adequate protection to the off-property resident farmer.

Existing soil concentrations as well as soil PRGs for each on-property receptor/contaminant combination have been analyzed for impacts to the off-property resident farmer. All contaminants for all on-property receptors have passed at least one of the three steps in the screening process described above. Therefore, no excavation other than that necessary to meet the soil PRLs is required to be protective of the off-property resident farmer through exposure to contaminants from the air.

F.4.4.2 Surface Water Pathway

To verify that the preliminary soil remedial designs developed using the surface soil PRG and soil CPRGs result in acceptable concentrations in the surface water pathway of contaminant migration, the surface water protective requirements are compared to the average subbasin surface soil concentration calculated based on the remedial objectives. The 11 remedial objectives evaluated in the Operable Unit 5 FS are described in Section 2.0. The average subbasin specific surface soil contaminant level is then calculated based on background concentrations for the excavated areas and the area-specific UCL (upper confidence level on the mean) contaminant concentrations developed for the Operable Unit 5 RI Report. If the average subbasin soil concentration based on the remediated site is below the surface water protective requirement, the remedial alternative is sufficiently protective of the surface water pathway.

The areas of excavation for the remediation objectives are presented in Section 2.0. For the RME farmer/child at 1 x 10^{-6} risk level the entire site is excavated and covered with clean soil. Because the entire site is excavated and backfilled, the average subbasin surface soil concentrations will also be at background concentrations. Because all the surface soil would be at background level, the contaminant transport in the surface water pathway will also be at acceptable levels so that a comparison with the 1 x 10^{-6} surface water protective requirements is not required.

The 1 x 10^{-5} surface water protective requirements (as presented in Table F.4-3) are compared with subbasin-specific average concentrations based on the remediation objective which produced the least amount of excavation. If this excavation scenario is acceptable, then the other more stringent remediation objectives requiring more excavation will also be acceptable. The representative excavation scenario which is used to develop the subbasin-specific average surface soil concentrations is the scenario presented in Section 2.0 for alternatives designed for undeveloped park recreational users at the 1 x 10^{-6} ILCR protective level. Figure F.4-7 presents the excavation areas for these alternatives.

Figure F.4-8 shows the source areas used in the Operable Unit 5 RI Report and the ones assigned a background concentration to simulate the remediated (excavated) condition. In some instances only a portion of a source area is excavated (Areas 570a, NEb, and 582a). If only a portion of an area is excavated, then the excavated area is assigned a background concentration and the unexcavated area is assigned the representative baseline UCL surface soil concentration as presented in Tables F.2.I-1 through F.2.I-3 in Attachment F.2.I of the Operable Unit 5 RI Report (DOE 1995). Area 581a is assumed to be fully excavated because all of the areas of elevated contaminant concentration will be excavated. The area-weighted average subbasin surface soil concentration is then calculated for each subbasin for each COC listed in Table F.4-1. The average concentration is then compared to the surface water protective requirement for the 1 x 10^{-5} risk level. Table F.4-15 presents the comparison of the surface water protective requirements with the subbasin-specific, area-weighted surface soil concentrations. It also shows that the remediation scenario for the 1 x 10^{-5} risk level provides acceptable average surface soil concentrations except for manganese in all subbasins. The acceptability of the manganese surface soil concentration is evaluated in the CRARE (Appendix G).

F.4.5 REFERENCES

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TABLE F.4-1

PRELIMINARY REMEDIATION GOALS FOR AIRBORNE CONTAMINANTS OFF-PROPERTY RESIDENT FARMER

Contaminant	10^{-5} ILCR or 0.2 HQ	Contaminant	10^{-5} ILCR or 0.2 HQ	Contaminant	10^{-5} ILCR or 0.2 HQ
Radionuclides (pCi/m3)		**Inorganics (mg/m3)**		**Organics (mg/m3)**	
Cesium-137 + 1d	3.94×10^{-2}	Antimony	2.98×10^{-5}	Aroclor-1254	5.96×10^{-8}
Lead-210 + 2d	9.30×10^{-3}	Arsenic	3.52×10^{-6}	Aroclor-1260	7.79×10^{-9}
Neptunium-237 + 1d	2.81×10^{-3}	Barium	3.93×10^{-4}	Benzo(a)anthracene	4.13×10^{-5}
Plutonium-238	2.14×10^{-3}	Beryllium	2.62×10^{-6}	Benzo(a)pyrene	3.60×10^{-7}
Plutonium-239/240	2.19×10^{-3}	Boron	4.35×10^{-3}	Benzo(b)fluoranthene	2.84×10^{-6}
Radium-226 + 8d	4.76×10^{-3}	Cadmium	7.65×10^{-6}	Benzo(k)fluoranthene	1.30×10^{-6}
Radium-228 + 1d	5.90×10^{-2}	Chromium VI	3.67×10^{-6}	Bis(2-ethylhexyl)phthalate	1.42×10^{-3}
Radon-222 + 4d	1.12×10^{1}	Copper	3.60×10^{-4}	Carbazole	3.53×10^{-4}
Strontium-90 + 1d	4.78×10^{-2}	Cyanide	4.42×10^{-3}	Chrysene	7.65×10^{-4}
Technetium-99	8.58×10^{-1}	Lead	ND	Dibenzo(a,h)anthracene	7.31×10^{-8}
Thorium-228 + 7d	1.10×10^{-3}	Magnesium	5.53×10^{-1}	Dichloroethene, 1,1-	3.32×10^{-5}
Thorium-230	2.97×10^{-3}	Manganese	3.86×10^{-5}	Heptachlorodibenzofuran	4.44×10^{-11}
Thorium-232 + 10d	7.77×10^{-4}	Mercury	1.08×10^{-6}	Heptachlorodibenzo-p-dioxin	2.34×10^{-11}
Uranium-234	3.30×10^{-3}	Molybdenum	1.44×10^{-4}	Indeno(1,2,3-cd)pyrene	4.82×10^{-7}
Uranium-235/236	3.43×10^{-3}	Nickel	1.84×10^{-4}	Methylene chloride	3.39×10^{-3}
Uranium-238 + 2d	3.57×10^{-3}	Selenium	8.07×10^{-5}	N-Nitrosodiphenylamine	4.97×10^{-3}
		Silver	8.39×10^{-6}	Octachlorodibenzofuran	6.15×10^{-11}
		Thallium	1.47×10^{-6}	Octachlorodibenzo-p-dioxin	9.30×10^{-11}
		Uranium	1.11×10^{-3}	Tetrachloroethene	3.42×10^{-4}
		Vanadium	1.28×10^{-3}	Trichloroethene	9.11×10^{-4}
		Zinc	2.44×10^{-5}		

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TABLE F.4-2

10^{-6} RISK CRITERIA USED IN DEVELOPMENT OF SURFACE WATER PROTECTIVE REQUIREMENTS

COC[a]	Great Miami Aquifer (μg/L)	Surface Water (μg/L)	Paddys Run Sediment (mg/kg)
Inorganics			
Antimony	1.55×10^{0}[b]	1.05×10^{3}[c]	8.04×10^{0}[d]
Arsenic	1.58×10^{-2}[e]	4.86×10^{0}[f]	1.10×10^{0}[g]
Beryllium	6.88×10^{-3}[e]	4.51×10^{0}[f]	2.03×10^{0}[g]
Magnesium	3.52×10^{4}[b]	1.56×10^{6}[c]	4.88×10^{4}[d]
Manganese	1.71×10^{1}[b]	9.36×10^{3}[c]	2.15×10^{2}[d]
Mercury	1.58×10^{-1}[b]	4.63×10^{0}[c]	5.96×10^{-1}[d]
Organics			
Alpha-Chlordane	4.51×10^{-3}[e]	6.86×10^{-1}[f]	3.11×10^{-3}[g]
Aroclor-1254	1.38×10^{-4}[e]	3.74×10^{-2}[f]	6.68×10^{-1}[h]
Aroclor-1260	2.35×10^{-5}[e]	2.86×10^{-3}[f]	6.68×10^{-1}[h]
Benzo(a)pyrene	1.69×10^{-3}[e]	3.36×10^{-2}[f]	1.93×10^{1}[h]
Dibenzo(a,h)anthracene	7.65×10^{-4}[e]	6.10×10^{-3}[f]	1.93×10^{1}[h]
Radionuclides			
Radium-226 + 8D	2.11×10^{-8}[e]	5.85×10^{-6}[f]	2.27×10^{-6}[g]
Strontium-90 + 1D	2.26×10^{-9}[e]	2.94×10^{-7}[f]	9.85×10^{-9}[g]
Technetium-99	4.25×10^{-4}[e]	8.71×10^{-3}[f]	9.23×10^{-6}[g]
Thorium-230	6.60×10^{-5}[e]	1.35×10^{0}[f]	8.88×10^{-1}[h]
Thorium-232 + 10D	9.45×10^{-1}[e]	1.94×10^{4}[f]	1.45×10^{1}[h]
Uranium-238 + 2D	3.00×10^{0}[i]	5.27×10^{2}[f]	1.25×10^{1}[g]

[a] COCs in this column are the constituents of concern that account for 95 percent of the health risk and failed either the surface water or sediment screening as shown in Table F.2-2
[b] Criteria are based on the groundwater PRG for the on-property RME farmer scenario, HI=0.2
[c] Criteria are based on the surface water PRG for the consumer of meat/milk, HI=0.2
[d] Criteria are based on the CPRG for contaminants leaching out of sediment into the groundwater, HI=0.2
[e] Criteria are based on the groundwater PRG for the on-property RME farmer scenario, 10^{-6}
[f] Criteria are based on the surface water PRG for the consumer of meat/milk, 10^{-6}
[g] Criteria are based on the CPRG for contaminants leaching out of sediment into the groundwater, 10^{-6}
[h] Criteria based on sediment PRG for recreational user, 10^{-6}
[i] CPRG risk target for total uranium in groundwater for the resident farmer, 10^{-6}

TABLE F.4-3

10^{-5} RISK CRITERIA USED IN DEVELOPMENT OF SURFACE WATER PROTECTIVE REQUIREMENTS

COC [a]	Great Miami Aquifer (μg/L)	Surface Water (μg/L)	Paddys Run Sediment (mg/kg)
Inorganics			
Antimony	6.00×10^{0} [b]	1.05×10^{3} [c]	8.44×10^{1} [d]
Arsenic	5.00×10^{1} [b]	4.86×10^{1} [e]	9.43×10^{2} [f]
Beryllium	4.00×10^{0} [b]	4.51×10^{1} [e]	3.28×10^{2} [f]
Magnesium	3.52×10^{4} [g]	1.56×10^{6} [c]	4.88×10^{4} [h]
Manganese	1.71×10^{1} [g]	9.63×10^{3} [c]	2.15×10^{2} [h]
Mercury	2.00×10^{0} [b]	4.63×10^{0} [c]	7.54×10^{0} [i]
Organics			
Alpha-Chlordane	2.00×10^{0} [b]	6.86×10^{0} [e]	1.38×10^{0} [i]
Aroclor-1254	5.00×10^{-1} [b]	3.74×10^{-1} [e]	6.68×10^{0} [f]
Aroclor-1260	5.00×10^{-1} [b]	2.86×10^{-2} [e]	6.68×10^{0} [f]
Benzo(a)pyrene	2.00×10^{-1} [b]	3.36×10^{-1} [e]	1.93×10^{2} [f]
Dibenzo(a,h)anthracene	7.65×10^{-3} [j]	6.10×10^{-2} [e]	1.93×10^{2} [f]
Radionuclides			
Radium-226 + 8D	2.02×10^{-5} [b]	5.85×10^{-5} [e]	2.27×10^{-5} [i]
Strontium-90 + 1D	2.26×10^{-8} [j]	2.94×10^{-6} [e]	9.85×10^{-8} [k]
Technetium-99	4.25×10^{-3} [j]	8.71×10^{-2} [e]	9.23×10^{-5} [k]
Thorium-230	6.60×10^{-4} [j]	1.35×10^{1} [e]	8.88×10^{0} [f]
Thorium-232 + 10D	9.45×10^{0} [j]	1.94×10^{5} [e]	1.45×10^{2} [f]
Uranium-238 + 2D	2.00×10^{1} [b]	5.27×10^{3} [e]	9.82×10^{1} [i]

[a] COCs in this column are the constituents of concern that account for 95 percent of the health risk and failed either the surface water or sediment screening as shown in Table F.2-3
[b] Criteria are based on the MCL
[c] Criteria are based on the surface water PRG for the consumer of meat/milk, HQ=0.2
[d] Criteria are based on sediment PRG for the recreational user, HQ=0.2
[e] Criteria are based on the surface water PRG for the consumer of meat/milk, 10^{-5}
[f] Criteria are based on sediment PRG for the recreational user, 10^{-5}
[g] Criteria are based on the groundwater PRG for the on-property RME farmer scenario, HQ=0.2
[h] Criteria are based on the CPRG for contaminants leaching out of sediment into the groundwater, HQ=0.2
[i] Criteria are based on the CPRG for contaminants leaching out of sediment into the groundwater, MCL
[j] Criteria are based on the groundwater PRG for the on-property RME farmer scenario, 10^{-5}
[k] Criteria are based on the CPRG for contaminants leaching out of sediment into the groundwater, 10^{-5}

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TABLE F.4-4

PRELIMINARY FENCE LINE PARTICULATE MATTER CONCENTRATION ESTIMATES

Fence Line Air Monitoring Station No.	Measured Uranium Concentration in Air (pCi/m^3)[a]	Measured Uranium Concentration in Soil (pCi/g)[a]	Estimated Airborne PM_{10} Concentration (g/m^3)
AMS 1	1.2×10^{-4}	1.1×10^{1}	$1/1 \times 10^{-5}$
AMS 2	1.1×10^{-4}	5.6×10^{0}	2.0×10^{-5}
AMS 3	1.7×10^{-4}	2.6×10^{1}	6.5×10^{-6}
AMS 4	3.6×10^{-5}	3.9×10^{0}	9.2×10^{-6}
AMS 5	3.2×10^{-5}	4.5×10^{0}	7.1×10^{-6}
AMS 6	5.3×10^{-5}	5.3×10^{0}	1.0×10^{-5}
AMS 7	3.1×10^{-5}	1.3×10^{1}	2.4×10^{-6}

Source: FERMCO 1993
[a] Corrected for background
[b] Values presented are for top 1.97 in. of soil

TABLE F.4-5

SCS[a] CURVE NUMBERS AND COVER FACTORS USED FOR THE REMEDIATED SITE

Subbasin	Curve Number	Cover Factor
560	62.65	0.042
570	76.70	0.042
575	69.02	0.042
580	71.95	0.042
581	69.29	0.042
582	66.52	0.042
PDAR	65.00	0.042
WPA	69.77	0.042
NE	59.70	0.042

[a] Soil Conservation Service (DOE 1993)

TABLE F.4-6

PARTITIONING COEFFICIENT USED FOR SURFACE WATER MODELING

Constituent of Concern	K_1 (L/kg)
Antimony	2.50×10^2
Arsenic	2.00×10^2
Beryllium	1.30×10^3
Magnesium	4.50×10^0
Manganese	1.80×10^2
Mercury	1.00×10^1
Alpha-chlordane	3.34×10^0
Aroclor-1254	5.93×10^3
Aroclor-1260	7.15×10^3
Benzo(a)pyrene	5.29×10^3
Dibenzo(a,h)anthracene	5.17×10^3
Radium-226 + 8D	6.96×10^2
Strontium-90 + 1D	1.00×10^1
Technetium-99	$30/1.18 \times 10^{-1}$
Thorium-230	5.80×10^3
Thorium-232 + 10D	5.80×10^3
Uranium-238 -2D	325/15

Values presented in Operable Unit 5 RI Report, Table F.2.3-5

TABLE F.4-7

PROTECTIVE REQUIREMENTS OF THE SURFACE SOIL FOR THE SURFACE WATER PATHWAY
10^{-6} OR HQ = 0.2 CRITERIA

COC	560	570	575	580	581	582	PDAR	WPA	NE
Inorganics (mg/kg)									
Antimony	8.04×10^{0b}	8.04×10^{0b}	8.04×10^{0b}	8.04×10^{0b}	8.04×10^{0b}	8.05×10^{0b}	8.05×10^{0b}	8.04×10^{0b}	8.04×10^{0b}
Arsenic	1.02×10^{0a}	8.60×10^{-1a}	1.10×10^{0b}	6.84×10^{-1a}	1.34×10^{-1a}	1.44×10^{-1a}	1.95×10^{-1a}	1.10×10^{0b}	1.10×10^{0b}
Beryllium	2.03×10^{0b}	2.03×10^{0b}	2.03×10^{0b}	1.93×10^{0a}	3.80×10^{-1a}	4.06×10^{-1a}	5.51×10^{-1a}	2.03×10^{0b}	2.03×10^{0b}
Magnesium	5.04×10^{4b}	4.45×10^{4a}	5.05×10^{4b}	3.54×10^{4a}	6.97×10^{3a}	7.45×10^{3a}	1.01×10^{4a}	5.04×10^{4b}	5.04×10^{4b}
Manganese	2.15×10^{2b}	2.15×10^{2b}	2.15×10^{2b}	2.15×10^{2b}	1.31×10^{2a}	1.40×10^{2a}	1.90×10^{2a}	2.15×10^{2b}	2.15×10^{2b}
Mercury	5.19×10^{-1a}	4.36×10^{-1a}	6.05×10^{-1b}	3.47×10^{-1a}	6.82×10^{-2a}	7.29×10^{-2a}	9.89×10^{-2a}	6.05×10^{-1b}	6.05×10^{-1b}
Organics (mg/kg)									
Alpha-chlordane	3.25×10^{-3b}	3.25×10^{-3b}	3.25×10^{-3b}	3.25×10^{-3b}	6.70×10^{-4a}	7.16×10^{-4a}	9.72×10^{-4a}	3.25×10^{-3b}	3.25×10^{-3b}
Aroclor-1254	2.65×10^{-1a}	2.23×10^{-1a}	4.99×10^{-1a}	1.77×10^{-1a}	3.48×10^{-2a}	3.72×10^{-2a}	5.04×10^{-2a}	4.57×10^{-1a}	6.68×10^{-1b}
Aroclor-1260	5.44×10^{-2a}	4.57×10^{-2a}	1.02×10^{-1a}	3.63×10^{-2a}	7.15×10^{-3a}	7.63×10^{-3a}	1.04×10^{-2a}	9.38×10^{-2a}	5.90×10^{-1c}
Benzo(a)pyrene	2.89×10^{0a}	2.43×10^{0a}	5.39×10^{0c}	1.93×10^{0a}	3.80×10^{-1a}	4.06×10^{-1a}	5.51×10^{-1a}	4.99×10^{0a}	5.13×10^{0c}
Dibenzo(a,h)anthracene	9.29×10^{-1c}	1.08×10^{0a}	9.56×10^{-1c}	8.56×10^{-1a}	1.68×10^{-1a}	1.80×10^{-1a}	2.44×10^{-1a}	9.04×10^{-1c}	9.10×10^{-1c}
Radionuclides (pCi/g)									
Radium-226 + 8D	2.25×10^{0}	2.25×10^{0}	2.25×10^{0}	2.25×10^{0}	6.19×10^{-1}	6.61×10^{-1}	8.97×10^{-1}	2.25×10^{0}	2.24×10^{0}
Strontium-90 +1D	1.02×10^{0}	8.53×10^{-1}	1.37×10^{0}	6.78×10^{-1}	1.33×10^{-1}	1.43×10^{-1}	1.93×10^{-1}	1.37×10^{0}	1.37×10^{0}
Technetium-99	3.59×10^{-1}	3.57×10^{-1}	3.62×10^{-1}	3.52×10^{-1}	8.41×10^{-2}	9.00×10^{-2}	1.23×10^{-1}	3.55×10^{-1}	3.59×10^{-1}
Thorium-230	2.55×10^{3}	2.14×10^{3}	4.81×10^{3}	1.71×10^{3}	3.35×10^{2}	3.58×10^{2}	4.86×10^{2}	4.40×10^{3}	1.83×10^{4}
Thorium-232 + 10D	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}	1.60×10^{0}
Uranium-238 + 2D	4.20×10^{0}	4.20×10^{0}	4.20×10^{0}	4.20×10^{0}	4.20×10^{0}	4.20×10^{0}	9.42×10^{-1}	4.20×10^{0}	4.20×10^{0}

[a] Groundwater PRG criteria control
[b] Sediment PRG criteria control
[c] Surface water PRG criteria control

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TABLE F.4-8

PROTECTIVE REQUIREMENTS OF THE SURFACE SOIL FOR THE SURFACE WATER PATHWAY
10^{-5} OR HQ = 0.2 CRITERIA

COC	560	570	575	580	581	582	PDAR	WPA	NE
Inorganics (mg/kg)									
Antimony	8.45×10^{1}[b]	8.45×10^{1}[b]	8.45×10^{1}[b]	8.44×10^{1}[b]	6.38×10^{1}[a]	6.82×10^{1}[a]	8.45×10^{1}[b]	8.45×10^{1}[b]	8.45×10^{1}[b]
Arsenic	2.86×10^{2}[c]	3.38×10^{2}[c]	2.95×10^{2}[c]	3.50×10^{2}[c]	2.82×10^{2}[c]	2.82×10^{2}[c]	2.78×10^{2}[c]	2.79×10^{2}[c]	2.81×10^{2}[c]
Beryllium	3.28×10^{2}[b]	3.28×10^{2}[b]	3.28×10^{2}[b]	3.28×10^{2}[b]	2.21×10^{2}[a]	2.36×10^{2}[a]	3.21×10^{2}[a]	3.28×10^{2}[b]	3.28×10^{2}[b]
Magnesium	5.04×10^{4}[b]	4.45×10^{4}[a]	5.05×10^{4}[b]	3.54×10^{4}[a]	6.97×10^{3}[a]	7.45×10^{3}[a]	1.01×10^{4}[a]	5.04×10^{4}[b]	5.04×10^{4}[b]
Manganese	2.15×10^{2}[b]	2.15×10^{2}[b]	2.15×10^{2}[b]	2.15×10^{2}[b]	1.31×10^{2}[a]	1.40×10^{2}[a]	1.90×10^{2}[a]	2.15×10^{2}[b]	2.15×10^{2}[b]
Mercury	1.38×10^{0}[c]	1.63×10^{0}[c]	1.43×10^{0}[c]	1.69×10^{0}[c]	8.64×10^{-1}[a]	9.23×10^{-1}[a]	1.25×10^{0}[a]	1.35×10^{0}[c]	1.35×10^{0}[c]
Organics (mg/kg)									
Alpha-chlordane	7.05×10^{-1}[c]	8.32×10^{-1}[c]	7.27×10^{-1}[c]	8.62×10^{-1}[c]	2.97×10^{-1}[a]	3.18×10^{-1}[a]	4.31×10^{-1}[a]	6.86×10^{-1}[c]	6.91×10^{-1}[c]
Aroclor-1254	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]	6.68×10^{0}[b]
Aroclor-1260	6.02×10^{0}[c]	6.68×10^{0}[b]	6.20×10^{0}[c]	6.68×10^{0}[b]	5.92×10^{0}[c]	5.92×10^{0}[c]	5.85×10^{0}[c]	5.86×10^{0}[c]	5.90×10^{0}[c]
Benzo(a)pyrene	5.23×10^{1}[c]	6.18×10^{1}[c]	5.39×10^{1}[c]	6.40×10^{1}[c]	4.50×10^{1}[a]	4.81×10^{1}[a]	5.08×10^{1}[c]	5.10×10^{1}[c]	5.13×10^{1}[c]
Dibenzo(a,h)anthracene	9.29×10^{0}[c]	1.08×10^{1}[a]	9.56×10^{0}[c]	8.56×10^{0}[a]	1.68×10^{0}[a]	1.80×10^{0}[a]	2.44×10^{0}[a]	9.04×10^{0}[c]	9.10×10^{0}[c]
Radionuclides (pCi/g)									
Radium-226 + 8D	2.25×10^{1}	2.25×10^{1}[b]	2.25×10^{1}[b]	2.25×10^{1}[b]	2.25×10^{1}[b]	2.25×10^{1}[b]	2.25×10^{1}[b]	2.25×10^{1}[b]	2.24×10^{0}[b]
Strontium-90 +1D	1.02×10^{1}	8.53×10^{0}[a]	1.37×10^{1}[b]	6.78×10^{0}[a]	1.33×10^{0}[a]	1.43×10^{0}[a]	1.93×10^{0}[a]	1.37×10^{1}[b]	1.38×10^{1}[b]
Technetium-99	3.59×10^{0}	3.57×10^{0}[b]	3.62×10^{0}[b]	3.52×10^{0}[b]	8.41×10^{-1}[a]	9.00×10^{-1}[a]	1.23×10^{0}[a]	3.55×10^{0}[b]	3.59×10^{0}[b]
Thorium-230	2.55×10^{4}	2.14×10^{4}[a]	4.81×10^{4}[a]	1.71×10^{4}[a]	3.35×10^{3}[a]	3.58×10^{3}[a]	4.86×10^{3}[a]	4.40×10^{4}[a]	1.83×10^{5}[b]
Thorium-232 + 10D	1.60×10^{1}	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]	1.60×10^{1}[b]
Uranium-238 + 2D	3.30×10^{1}	3.30×10^{1}[b]	3.30×10^{1}[b]	3.30×10^{1}[b]	3.30×10^{1}[b]	3.30×10^{1}[b]	6.28×10^{0}[a]	3.30×10^{1}[b]	3.30×10^{1}[b]

[a] Groundwater PRG criteria control
[b] Sediment PRG criteria control
[c] Surface water PRG criteria control

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90 **TABLE F.4-9**
91 **COMPARISON OF AIR PATHWAY PROTECTIVE REQUIREMENTS TO SOIL PRG AND BASELINE SOIL CONCENTRATION FOR COMMERCIAL/INDUSTRIAL USER**

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Radionuclides (pCi/g):					
Cesium-137 + 1d	1.46E-01	1.97E+03	Yes	NA	NA
Lead-210 + 2d	2.40E+00	4.65E+02	Yes	NA	NA
Neptunium-237 + 1d	5.94E-01	1.41E+02	Yes	NA	NA
Plutonium-238	4.25E+00	1.07E+02	Yes	NA	NA
Plutonium-239/240	4.19E+00	1.10E+02	Yes	NA	NA
Radium-226 + 8d	4.75E-02	2.38E+02	Yes	NA	NA
Radium-228 + 1d	1.00E-01	2.95E+03	Yes	NA	NA
Radon-222 + 4d	NA	NA	Yes	NA	NA
Strontium-90 + 1d	4.41E+01	2.39E+03	Yes	NA	NA
Technetium-99	1.20E+03	4.29E+04	Yes	NA	NA
Thorium-228 + 7d	5.20E-02	5.50E+01	Yes	NA	NA
Thorium-230	1.24E+01	1.49E+02	Yes	NA	NA
Thorium-232 + 10d	3.39E-02	3.89E+01	Yes	NA	NA
Uranium-234[d]	6.76E+00	1.65E+02	Yes	NA	NA
Uranium-235/236[d]	1.82E-01	1.72E+02	Yes	NA	NA
Uranium-238 + 2d	4.05E+00	1.79E+02	Yes	NA	NA
Inorganics (mg/kg):					
Antimony	1.69E+01	1.49E+03	Yes	NA	NA
Arsenic	1.49E+00	1.76E+02	Yes	NA	NA
Barium	3.98E+03	1.97E+04	Yes	NA	NA
Beryllium	4.20E-01	1.31E+02	Yes	NA	NA
Boron	1.46E+03	2.18E+05	Yes	NA	NA
Cadmium	1.64E+01	3.83E+02	Yes	NA	NA
Chromium VI	1.70E+01	1.84E+02	Yes	NA	NA
Copper	7.56E+03	1.80E+04	Yes	NA	NA
Cyanide	4.09E+03	2.21E+05	Yes	NA	NA
Lead	NA	NA	NA	NA	NA
Magnesium	1.59E+05	1.00E+06	Yes	NA	NA
Manganese	4.74E+01	1.93E+03	Yes	NA	NA
Mercury	3.04E+00	5.40E+01	Yes	NA	NA
Molybdenum	4.07E+02	7.20E+03	Yes	NA	NA
Nickel	8.52E+02	9.20E+03	Yes	NA	NA

TABLE F.4-9 (Continued)

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Selenium	5.95E+02	4.04E+03	Yes	NA	NA
Silver	1.02E+03	4.20E+02	No	1.72E+01	Yes
Thallium	9.08E+00	7.35E+01	Yes	NA	NA
Uranium	4.91E+01	5.55E+04	Yes	NA	NA
Vanadium	6.65E+02	6.40E+04	Yes	NA	NA
Zinc	1.86E+04	1.22E+03	No	3.52E+02	Yes
Organics (mg/kg):					
Aroclor-1254	6.64E-02	2.98E+00	Yes	NA	NA
Aroclor-1260	6.64E-02	3.90E-01	Yes	NA	NA
Benzo(a)anthracene	1.28E+01	2.07E+03	Yes	NA	NA
Benzo(a)pyrene	1.96E-01	1.80E+01	Yes	NA	NA
Benzo(b)fluoranthene	1.59E+00	1.42E+02	Yes	NA	NA
Benzo(k)fluoranthene	3.76E+00	6.50E+01	Yes	NA	NA
Bis(2-ethylhexyl)phthalate	1.63E+02	7.10E+04	Yes	NA	NA
Carbazole	7.09E+00	1.77E+04	Yes	NA	NA
Chrysene	1.96E+02	3.83E+04	Yes	NA	NA
Dibenzo(a,h)anthracene	1.96E-01	3.66E+00	Yes	NA	NA
Dichloroethene, 1,1-	2.33E-01	1.66E+03	Yes	NA	NA
Heptachlorodibenzofuran	4.28E-04	2.22E-03	Yes	NA	NA
Heptachlorodibenzo-p-dioxin	4.28E-04	1.17E-03	Yes	NA	NA
Indeno(1,2,3-cd)pyrene	7.14E-01	2.41E+01	Yes	NA	NA
Methylene chloride	2.09E+01	1.70E+05	Yes	NA	NA
N-Nitrosodiphenylamine	2.90E+01	2.49E+05	Yes	NA	NA
Octachlorodibenzofuran	4.28E-03	3.08E-03	No	1E-05 DL	Yes
Octachlorodibenzo-p-dioxin	4.28E-03	4.65E-03	Yes	NA	NA
Tetrachloroethene	2.07E+00	1.71E+04	Yes	NA	NA
Trichloroethene	1.40E+01	4.56E+04	Yes	NA	NA

[a]Based on 1.0E-05 ILCR to off-site farmer/child.

[b]Results of preliminary screening against soil PRG.

[c]Results of secondary screening against maximum soil concentration (95% upper confidence limit [UCL]) in OU5 RI database.

[d]U-234 and U-235/236 PRG calculated from U-238 risk-based PRG and relative abundances of uranium isotopes at the FEMP.

DL = Detection limit

NA = Not applicable

TABLE F.4-10

COMPARISON OF AIR PATHWAY PROTECTIVE REQUIREMENTS TO SOIL PRG AND BASELINE SOIL CONCENTRATION FOR RECREATIONAL USER ON DEVELOPED PARK

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Radionuclides (pCi/g):					
Cesium-137 + 1d	3.19E-01	1.97E+03	Yes	NA	NA
Lead-210 + 2d	1.60E+01	4.65E+02	Yes	NA	NA
Neptunium-237 + 1d	1.43E+00	1.41E+02	Yes	NA	NA
Plutonium-238	3.34E+01	1.07E+02	Yes	NA	NA
Plutonium-239/240	3.26E+01	1.10E+02	Yes	NA	NA
Radium-226 + 8d	1.05E-01	2.38E+02	Yes	NA	NA
Radium-228 + 1d	2.20E-01	2.95E+03	Yes	NA	NA
Radon-222 + 4d	NA	NA.	Yes	NA	NA
Strontium-90 + 1d	2.90E+02	2.39E+03	Yes	NA	NA
Technetium-99	7.88E+03	4.29E+04	Yes	NA	NA
Thorium-228 + 7d	1.10E-01	5.50E+01	Yes	NA	NA
Thorium-230	1.26E+02	1.49E+02	Yes	NA	NA
Thorium-232 + 10d	7.48E-02	3.89E+01	Yes	NA	NA
Uranium-234[d]	1.92E+01	1.65E+02	Yes	NA	NA
Uranium-235/236[d]	5.17E-01	1.72E+02	Yes	NA	NA
Uranium-238 + 2d	1.15E+01	1.79E+02	Yes	NA	NA
Inorganics (mg/kg):					
Antimony	7.99E+01	1.49E+03	Yes	NA	NA
Arsenic	4.78E+00	1.76E+02	Yes	NA	NA
Barium	3.96E+04	1.97E+04	No	5.12E+02	Yes
Beryllium	9.74E-01	1.31E+02	Yes	NA	NA
Boron	6.43E+03	2.18E+05	Yes	NA	NA
Cadmium	7.15E+01	3.83E+02	Yes	NA	NA
Chromium VI	1.14E+02	1.84E+02	Yes	NA	NA
Copper	7.14E+04	1.80E+04	No	2.07E+02	Yes
Cyanide	3.86E+04	2.21E+05	Yes	NA	NA
Lead	NA	NA	NA	NA	NA
Magnesium	6.94E+05	1.00E+06	Yes	NA	NA
Manganese	2.14E+02	1.93E+03	Yes	NA	NA
Mercury	1.31E+01	5.40E+01	Yes	NA	NA
Molybdenum	2.18E+03	7.20E+03	Yes	NA	NA

TABLE F.4-10 (Continued)

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Nickel	5.70E+03	9.20E+03	Yes	NA	NA
Selenium	3.68E+03	4.04E+03	Yes	NA	NA
Silver	9.65E+03	4.20E+02	No	1.72E+01	Yes
Thallium	5.88E+01	7.35E+01	Yes	NA	NA
Uranium	2.15E+02	5.55E+04	Yes	NA	NA
Vanadium	3.75E+03	6.40E+04	Yes	NA	NA
Zinc	9.34E+04	1.22E+03	No	3.52E+02	Yes
Organics (mg/kg):					
Aroclor-1254	1.10E-01	2.98E+00	Yes	NA	NA
Aroclor-1260	1.10E-01	3.90E-01	Yes	NA	NA
Benzo(a)anthracene	4.35E+01	2.07E+03	Yes	NA	NA
Benzo(a)pyrene	6.60E-01	1.80E+01	Yes	NA	NA
Benzo(b)fluoranthene	5.36E+00	1.42E+02	Yes	NA	NA
Benzo(k)fluoranthene	1.27E+01	6.50E+01	Yes	NA	NA
Bis(2-ethylhexyl)phthalate	4.37E+02	7.10E+04	Yes	NA	NA
Carbazole	1.09E+01	1.77E+04	Yes	NA	NA
Chrysene	6.60E+02	3.83E+04	Yes	NA	NA
Dibenzo(a,h)anthracene	6.60E-01	3.66E+00	Yes	NA	NA
1,1-Dichloroethene	3.57E-01	1.66E+03	Yes	NA	NA
Heptachlorodibenzofuran	7.31E-04	2.22E-03	Yes	NA	NA
Heptachlorodibenzo-p-dioxin	7.31E-04	1.17E-03	Yes	NA	NA
Indeno(1,2,3-cd)pyrene	2.41E+00	2.41E+01	Yes	NA	NA
Methylene chloride	3.22E+01	1.70E+05	Yes	NA	NA
N-Nitrosodiphenylamine	4.45E+01	2.49E+05	Yes	NA	NA
Octachlorodibenzofuran	7.31E-03	3.08E-03	No	1E-05 DL	Yes
Octachlorodibenzo-p-dioxin	7.31E-03	4.65E-03	No	1E-05 DL	Yes
Tetrachloroethene	3.16E+00	1.71E+04	Yes	NA	NA
Trichloroethene	2.15E+01	4.56E+04	Yes	NA	NA

[a]Based on 1.0E-05 ILCR to off-site farmer/child.

[b]Results of preliminary screening against soil PRG.

[c]Results of secondary screening against maximum soil concentration (95% upper confidence limit [UCL]) in OU5 RI database.

[d]U-234 and U-235/236 PRG calculated from U-238 risk-based PRG and relative abundances of uranium isotopes at the FEMP.

DL = Detection limit

NA = Not applicable

TABLE F.4-11
COMPARISON OF AIR PATHWAY PROTECTIVE REQUIREMENTS TO SOIL PRG AND BASELINE SOIL CONCENTRATION FOR REC. USER ON UNDEVELOPED PARK

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Radionuclides (pCi/g):					
Cesium-137 + 1d	7.13E-01	1.97E+03	Yes	NA	NA
Lead-210 + 2d	3.70E+01	4.65E+02	Yes	NA	NA
Neptunium-237 + 1d	3.19E+00	1.41E+02	Yes	NA	NA
Plutonium-238	7.83E+01	1.07E+02	Yes	NA	NA
Plutonium-239/240	7.66E+01	1.10E+02	Yes	NA	NA
Radium-226 + 8d	2.36E-01	2.38E+02	Yes	NA	NA
Radium-228 + 1d	4.90E-01	2.95E+03	Yes	NA	NA
Radon-222 + 4d	NA	NA	Yes	NA	NA
Strontium-90 + 1d	6.94E+02	2.39E+03	Yes	NA	NA
Technetium-99	1.88E+04	4.29E+04	Yes	NA	NA
Thorium-228 + 7d	2.50E-01	5.50E+01	Yes	NA	NA
Thorium-230	2.85E+02	1.49E+02	No	2.75E+03	No
Thorium-232 + 10d	1.67E-01	3.89E+01	Yes	NA	NA
Uranium-234[d]	4.28E+01	1.65E+02	Yes	NA	NA
Uranium-235/236[d]	1.15E+00	1.72E+02	Yes	NA	NA
Uranium-238 + 2d	2.56E+01	1.79E+02	Yes	NA	NA
Inorganics (mg/kg):					
Antimony	9.59E+01	1.49E+03	Yes	NA	NA
Arsenic	1.21E+01	1.76E+02	Yes	NA	NA
Barium	6.83E+04	1.97E+04	No	5.12E+02	Yes
Beryllium	1.51E+00	1.31E+02	Yes	NA	NA
Boron	7.39E+03	2.18E+05	Yes	NA	NA
Cadmium	8.21E+01	3.83E+02	Yes	NA	NA
Chromium VI	2.99E+02	1.84E+02	No	4.69E+00	Yes
Copper	2.18E+05	1.80E+04	No	2.07E+02	Yes
Cyanide	1.18E+05	2.21E+05	Yes	NA	NA
Lead	NA	NA	NA	NA	NA
Magnesium	7.96E+05	1.00E+06	Yes	NA	NA
Manganese	2.46E+02	1.93E+03	Yes	NA	NA
Mercury	1.49E+01	5.40E+01	Yes	NA	NA
Molybdenum	2.86E+03	7.20E+03	Yes	NA	NA
Nickel	1.49E+04	9.20E+03	No	7.22E+01	Yes

TABLE F.4-11 (Continued)

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Selenium	5.43E+03	4.04E+03	No	5.90E+00	Yes
Silver	2.95E+04	4.20E+02	No	1.72E+01	Yes
Thallium	9.09E+01	7.35E+01	No	7.70E-01	Yes
Uranium	2.46E+02	5.55E+04	Yes	NA	NA
Vanadium	5.11E+03	6.40E+04	Yes	NA	NA
Zinc	1.17E+05	1.22E+03	No	3.52E+02	Yes
Organics (mg/kg):					
Aroclor-1254	1.31E-01	2.98E+00	Yes	NA	NA
Aroclor-1260	1.31E-01	3.90E-01	Yes	NA	NA
Benzo(a)anthracene	1.33E+02	2.07E+03	Yes	NA	NA
Benzo(a)pyrene	2.02E+00	1.80E+01	Yes	NA	NA
Benzo(b)fluoranthene	1.64E+01	1.42E+02	Yes	NA	NA
Benzo(k)fluoranthene	3.87E+01	6.50E+01	Yes	NA	NA
Bis(2-ethylhexyl)phthalate	8.18E+02	7.10E+04	Yes	NA	NA
Carbazole	1.24E+01	1.77E+04	Yes	NA	NA
Chrysene	2.02E+03	3.83E+04	Yes	NA	NA
Dibenzo(a,h)anthracene	2.02E+00	3.66E+00	Yes	NA	NA
Dichloroethene, 1,1-	4.06E-01	1.66E+03	Yes	NA	NA
Heptachlorodibenzofuran	8.83E-04	2.22E-03	Yes	NA	NA
Heptachlorodibenzo-p-dioxin	8.83E-04	1.17E-03	Yes	NA	NA
Indeno(1,2,3-cd)pyrene	7.36E+00	2.41E+01	Yes	NA	NA
Methylene chloride	3.67E+01	1.70E+05	Yes	NA	NA
N-Nitrosodiphenylamine	5.05E+01	2.49E+05	Yes	NA	NA
Octachlorodibenzofuran	8.83E-03	3.08E-03	No	1E-05 DL	Yes
Octachlorodibenzo-p-dioxin	8.83E-03	4.65E-03	No	1E-05 DL	Yes
Tetrachloroethene	3.58E+00	1.71E+04	Yes	NA	NA
Trichloroethene	2.45E+01	4.56E+04	Yes	NA	NA

[a]Based on 1.0E-05 ILCR to off-site farmer/child.

[b]Results of preliminary screening against soil PRG.

[c]Results of secondary screening against maximum soil concentration (95% upper confidence level [UCL]) in OU5 RI database.

[d]U-234 and U-235/236 PRG calculated from U-238 risk-based PRG and relative abundances of uranium isotopes at the FEMP.

DL = Detection limit

NA = Not applicable

TABLE F.4-12

COMPARISON OF AIR PATHWAY PROTECTIVE REQUIREMENTS TO SOIL PRG AND BASELINE SOIL CONCENTRATION FOR EXPANDED TRESPASSER

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Radionuclides (pCi/g):					
Cesium-137 + 1d	1.12E+00	1.97E+03	Yes	NA	NA
Lead-210 + 2d	4.59E+01	4.65E+02	Yes	NA	NA
Neptunium-237 + 1d	4.96E+00	1.41E+02	Yes	NA	NA
Plutonium-238	1.03E+02	1.07E+02	Yes	NA	NA
Plutonium-239/240	1.00E+02	1.10E+02	Yes	NA	NA
Radium-226 + 8d	3.69E-01	2.38E+02	Yes	NA	NA
Radium-228 + 1d	7.69E-01	2.95E+03	Yes	NA	NA
Radon-222 + 4d	NA	NA	Yes	NA	NA
Strontium-90 + 1d	8.52E+02	2.39E+03	Yes	NA	NA
Technetium-99	2.32E+04	4.29E+04	Yes	NA	NA
Thorium-228 + 7d	3.98E-01	5.50E+01	Yes	NA	NA
Thorium-230	4.28E+02	1.49E+02	No	2.75E+03	No
Thorium-232 + 10d	2.62E-01	3.89E+01	Yes	NA	NA
Uranium-234[d]	6.71E+01	1.65E+02	Yes	NA	NA
Uranium-235/236[d]	1.81E+00	1.72E+02	Yes	NA	NA
Uranium-238 + 2d	4.02E+01	1.79E+02	Yes	NA	NA
Inorganics (mg/kg):					
Antimony	7.92E+01	1.49E+03	Yes	NA	NA
Arsenic	1.68E+01	1.76E+02	Yes	NA	NA
Barium	5.87E+04	1.97E+04	No	5.12E+02	Yes
Beryllium	2.01E+00	1.31E+02	Yes	NA	NA
Boron	6.09E+03	2.18E+05	Yes	NA	NA
Cadmium	6.77E+01	3.83E+02	Yes	NA	NA
Chromium VI	4.60E+02	1.84E+02	No	4.69E+00	Yes
Copper	1.94E+05	1.80E+04	No	2.07E+02	Yes
Cyanide	1.05E+05	2.21E+05	Yes	NA	NA
Lead	NA	NA	NA	NA	NA
Magnesium	6.57E+05	1.00E+06	Yes	NA	NA
Manganese	2.03E+02	1.93E+03	Yes	NA	NA
Mercury	1.23E+01	5.40E+01	Yes	NA	NA
Molybdenum	2.37E+03	7.20E+03	Yes	NA	NA
Nickel	2.30E+04	9.20E+03	No	7.22E+01	Yes
Selenium	4.54E+03	4.04E+03	No	5.90E+00	Yes

TABLE F.4-12
(Continued)

Contaminant	On-Property Receptor Soil PRG, 0.2 HQ or 10^{-6} ILCR	Air Pathway Protective Soil Conc. for RME Farmer/Child[a]	Is Soil PRG Protective of Air Pathway to Off-site Farmer[a,b]	Soil Conc. (UCL) from OU5 RI Database	Is Soil UCL Protective of Air Pathway to Off-site Farmer[a,c]
Silver	2.62E+04	4.20E+02	No	1.72E+01	Yes
Thallium	7.61E+01	7.35E+01	No	7.70E-01	Yes
Uranium	2.03E+02	5.55E+04	Yes	NA	NA
Vanadium	4.25E+03	6.40E+04	Yes	NA	NA
Zinc	9.66E+04	1.22E+03	No	3.52E+02	Yes
Organics (mg/kg):					
Aroclor-1254	1.70E-01	2.98E+00	Yes	NA	NA
Aroclor-1260	1.70E-01	3.90E-01	Yes	NA	NA
Benzo(a)anthracene	2.90E+01	2.07E+03	Yes	NA	NA
Benzo(a)pyrene	2.90E+00	1.80E+01	Yes	NA	NA
Benzo(b)fluoranthene	2.90E+01	1.42E+02	Yes	NA	NA
Benzo(k)fluoranthene	2.90E+02	6.50E+01	No	1.20E+01	Yes
Bis(2-ethylhexyl)phthalate	1.10E+03	7.10E+04	Yes	NA	NA
Carbazole	1.60E+01	1.77E+04	Yes	NA	NA
Chrysene	2.90E+03	3.83E+04	Yes	NA	NA
Dibenzo(a,h)anthracene	2.90E+00	3.66E+00	Yes	NA	NA
Dichloroethene, 1,1-	5.30E-01	1.66E+03	Yes	NA	NA
Heptachlorodibenzofuran	1.20E-03	2.22E-03	Yes	NA	NA
Heptachlorodibenzo-p-dioxin	1.20E-03	1.17E-03	No	5E-05 DL	Yes
Indeno(1,2,3-cd)pyrene	2.90E+01	2.41E+01	No	7.90E-02	Yes
Methylene chloride	4.80E+01	1.70E+05	Yes	NA	NA
N-Nitrosodiphenylamine	6.60E+01	2.49E+05	Yes	NA	NA
Octachlorodibenzofuran	1.20E-02	3.08E-03	No	1E-05 DL	Yes
Octachlorodibenzo-p-dioxin	1.20E-02	4.65E-03	No	1E-05 DL	Yes
Tetrachloroethene	4.70E+00	1.71E+04	Yes	NA	NA
Trichloroethene	3.20E+01	4.56E+04	Yes	NA	NA

[a]Based on 1.0E-05 ILCR to off-site farmer/child.
[b]Results of preliminary screening against soil PRG.
[c]Results of secondary screening against maximum soil concentration (95% upper confidence limit [UCL]) in OU5 RI database.
[d]U-234 and U-235/236 PRG calculated from U-238 risk-based PRG and relative abundances of uranium isotopes at the FEMP.
DL = Detection limit.
NA = Not applicable.

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TABLE F.4-13

BASELINE SOIL CONCENTRATIONS OF THORIUM-230

Surface Area Designation[a]	Th-230 Concentration in Surface Soil (pCi/g)
560A	1.79E+00
560B	4.52E+00
560C	1.51E+01
560D	1.14E+03
570A	7.01E+00
570B	2.29E+02
570C	1.50E+00
570D	5.80E+01
570E	8.40E+00
575A	1.42E+01
575B	1.70E+00
580A	1.20E+00
581A	1.81E+00
581B	2.80E+01
581C	3.36E+00
581D	8.06E+02
582A	2.97E+00
582B	1.48E+01
WPAA	9.04E+00
5NEC	1E-01 DL
Waste Pit 1	1.50E+00
Waste Pit 2	1.50E+00
Waste Pit 3	1.50E+00
Waste Pit 4	1.50E+00
Waste Pit 5	1.50E+00
Waste Pit 6	1.50E+00
Burn pit	1.50E+00
Clearwell	1.50E+00
SF-Great Miami Acquifer	1.37E+00
SF-Till	4.41E+00
SF-Fill	1.38E+01

TABLE F.4-13
(Continued)

Surface Area Designation[a]	Th-230 Concentration in Surface Soil (pCi/g)
560A	1.79E+00
IFP-Great Miami Acquifer	2.03E+00
IFP-Till	1.62E+00
AFP-Great Miami Acquifer	1.42E+00
AFP-Till	3.60E+00
SWL-Till	3.10E+00
LSP-Till	2.49E+00
OU4 Soil	5.01E+00
PAA	2.75E+03
PAB	2.29E+01
PAC	7.46E+01
PAD	8.21E+00
PAE	8.21E+00
PAF	1.03E+01
PAG	2.06E+02
PAH	2.19E+02
PAI	1.50E+00

[a] See Figure F.4-8.
DL - Detection limit

TABLE F.4-14

RADON MODELING INPUT AND OUTPUT

Parameter	On-Property RME Receptor			
	Commercial/ Industrial	Recreational User on Developed Park	Recreational User on Undeveloped Park	Expanded Trespasser
Ra-226 soil PRG (pCi/g)	4.75E-02	1.05E-01	2.36E-01	3.69E-01
Soil bulk density[a] (g/cm^3)	1.44	1.44	1.44	1.44
Layer thickness[b] (cm)	45	45	45	45
Soil porosity[c]	0.457	0.457	0.457	0.457
Soil moisture[c] content (dry Wt%)	16.9	16.9	16.9	16.9
Rn-222 emission rate ($pCi/s/m^2$)	1.24E-02	2.73E-02	6.14E-02	9.62E-02
Rn-222 fence line concentration (pCi/m^3)	3.58E-01	7.90E-01	1.78E+00	2.77E+00

[a] Surface soil bulk density estimated from values reported in soil surveys of Hamilton (USDA 1982) and Butler (USDA 1980) counties.

[b] Surface soil layer thickness assumed to be 18 instead of 6 inches to conservatively estimate radon flux from surface soil.

[c] Soil porosity and moisture content taken from HELP model runs for groundwater analysis. These values were used to be consistent with groundwater modeling.

TABLE F.4-15

COMPARISON OF 10^{-5} SURFACE WATER PROTECTIVE REQUIREMENTS AND SUBBASIN AVERAGE CONCENTRATIONS BASED ON REMEDIATION

COC		Subbasin 560	Subbasin 570	Subbasin 575	Subbasin 580	Subbasin 581	Subbasin 582	Subbasin PDAR	Subbasin WPA	Subbasin NE
Inorganics (mg/kg)										
	Avg. Conc.	2.69×10^{0}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.60×10^{-1}
Antimony	SWPR[a]	8.45×10^{1}	8.45×10^{1}	8.45×10^{1}	8.44×10^{1}	6.38×10^{1}	6.82×10^{1}	8.45×10^{1}	8.45×10^{1}	8.44×10^{1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.07×10^{1}	5.71×10^{0}	6.77×10^{0}	6.50×10^{0}	5.56×10^{0}	8.54×10^{0}	5.67×10^{0}	5.56×10^{0}	5.79×10^{0}
Arsenic	SWPR	2.86×10^{2}	3.38×10^{2}	2.95×10^{2}	3.50×10^{2}	2.82×10^{2}	2.82×10^{2}	2.78×10^{2}	2.79×10^{2}	2.81×10^{2}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.39×10^{0}	1.01×10^{0}	1.44×10^{0}	6.00×10^{-1}	6.00×10^{-1}	1.39×10^{0}	7.62×10^{-1}	6.00×10^{-1}	6.84×10^{-1}
Beryllium	SWPR	3.28×10^{2}	3.28×10^{2}	3.28×10^{2}	3.28×10^{2}	2.21×10^{2}	2.36×10^{2}	3.21×10^{2}	3.28×10^{2}	3.28×10^{2}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	2.27×10^{4}	7.78×10^{3}	2.33×10^{4}	8.85×10^{3}	1.93×10^{3}	1.91×10^{3}	4.75×10^{3}	1.93×10^{3}	2.30×10^{3}
Magnesium	SWPR	5.04×10^{4}	4.45×10^{4}	5.05×10^{4}	3.54×10^{4}	6.97×10^{3}	7.45×10^{3}	1.01×10^{4}	5.04×10^{4}	5.04×10^{4}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	8.53×10^{2}	6.96×10^{2}	1.25×10^{3}	4.43×10^{2}	8.14×10^{2}	6.22×10^{2}	9.37×10^{2}	8.14×10^{2}	9.64×10^{2}
Manganese	SWPR	2.15×10^{2}	2.15×10^{2}	2.15×10^{2}	2.15×10^{2}	1.31×10^{2}	1.40×10^{2}	1.90×10^{2}	2.15×10^{2}	2.15×10^{2}
	Acceptable?	No	No	No	No	No	No	No	No	No
	Avg. Conc.	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}	3.00×10^{-1}
Mercury	SWPR	1.38×10^{0}	1.63×10^{0}	1.43×10^{0}	1.69×10^{0}	8.64×10^{-1}	9.23×10^{-1}	1.25×10^{0}	1.35×10^{0}	1.35×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

TABLE F.4-15
(Continued)

COC		Subbasin 560	Subbasin 570	Subbasin 575	Subbasin 580	Subbasin 581	Subbasin 582	Subbasin PDAR	Subbasin WPA	Subbasin NE
Organics (mg/kg)										
	Avg. Conc.	ND	ND	ND	ND	ND	ND	3.79×10^{-4}	ND	ND
Alpha-chlordane	SWPR	7.05×10^{-1}	8.32×10^{-1}	7.27×10^{-1}	8.62×10^{-1}	2.97×10^{-1}	3.18×10^{-1}	4.31×10^{-1}	6.86×10^{-1}	6.91×10^{-1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	ND	ND	ND	ND	ND	ND	ND	0.00	0.00
Aroclor-1254	SWPR	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}	6.68×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	ND	ND		ND	ND	ND	ND	ND	ND
Aroclor-1260	SWPR	6.02×10^{0}	6.68×10^{0}	6.20×10^{0}	6.68×10^{0}	5.92×10^{0}	5.92×10^{0}	5.85×10^{0}	5.86×10^{0}	5.90×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	ND	1.49×10^{-2}	4.68×10^{-2}	ND	ND	ND	1.26×10^{-2}	ND	ND
Benzo(a)pyrene	SWPR	5.23×10^{1}	6.18×10^{1}	5.39×10^{1}	6.40×10^{1}	4.50×10^{1}	4.81×10^{1}	5.08×10^{1}	5.10×10^{1}	5.13×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	SWPR	9.29×10^{0}	1.08×10^{1}	9.56×10^{0}	8.56×10^{0}	1.68×10^{0}	1.80×10^{0}	2.44×10^{0}	9.04×10^{0}	9.10×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

TABLE F.4-15
(Continued)

COC		Subbasin 560	Subbasin 570	Subbasin 575	Subbasin 580	Subbasin 581	Subbasin 582	Subbasin PDAR	Subbasin WPA	Subbasin NE
Radionuclides (pCi/L)										
	Avg. Conc.	1.03×10^{0}	1.14×10^{0}	7.73×10^{-1}	3.00×10^{-1}	1.22×10^{0}	1.08×10^{0}	1.41×10^{0}	1.22×10^{0}	1.22×10^{0}
Radium-226 + 8D	SWPR	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.25×10^{1}	2.24×10^{1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.17×10^{0}	4.65×10^{-1}	4.03×10^{-1}	4.24×10^{-1}	3.00×10^{-1}	1.19×10^{0}	3.17×10^{-1}	3.00×10^{-1}	1.69×10^{0}
Strontium-90 +1D	SWPR	1.02×10^{1}	8.53×10^{0}	1.37×10^{1}	6.78×10^{0}	1.33×10^{0}	1.43×10^{0}	1.93×10^{0}	1.37×10^{1}	1.38×10^{1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.03×10^{0}	ND	ND	ND	ND	ND	ND	ND	ND
Technetium-99	SWPR	3.59×10^{0}	3.57×10^{0}	3.62×10^{0}	3.52×10^{0}	8.41×10^{-1}	9.00×10^{-1}	1.23×10^{0}	3.55×10^{0}	3.59×10^{0}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.73×10^{0}	3.02×10^{0}	1.13×10^{1}	1.20×10^{0}	1.50×10^{0}	2.95×10^{0}	1.50×10^{0}	1.50×10^{0}	1.50×10^{0}
Thorium-230	SWPR	2.55×10^{4}	2.14×10^{4}	4.81×10^{4}	1.71×10^{4}	3.35×10^{3}	3.58×10^{3}	4.86×10^{3}	4.40×10^{4}	1.83×10^{5}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	1.03×10^{0}	1.01×10^{0}	8.40×10^{-1}	8.00×10^{-1}	1.08×10^{0}	1.16×10^{0}	1.05×10^{0}	1.08×10^{0}	1.11×10^{0}
Thorium-232 + 10D	SWPR	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}	1.60×10^{1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Avg. Conc.	6.40×10^{0}	3.19×10^{0}	7.04×10^{0}	1.80×10^{0}	1.08×10^{0}	5.23×10^{0}	1.69×10^{0}	1.08×10^{0}	4.07×10^{0}
Uranium-238 + 2D	SWPR	3.30×10^{1}	3.30×10^{1}	3.30×10^{1}	3.30×10^{1}	3.30×10^{1}	3.30×10^{1}	6.28×10^{0}	3.30×10^{1}	3.30×10^{1}
	Acceptable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a] SWPR - Surface water protective requirement
ND - Not detected in all samples

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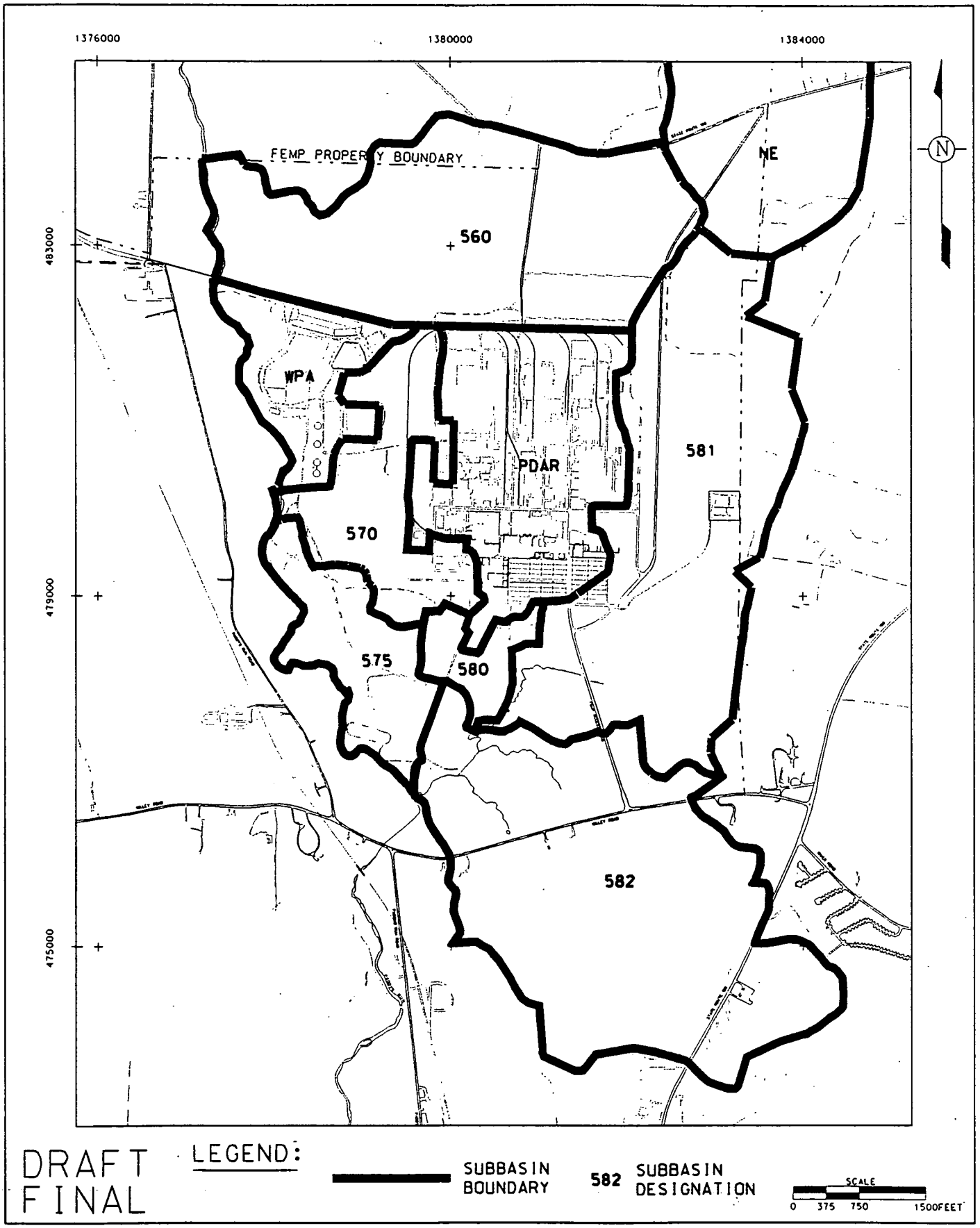

FIGURE F.4-1. DRAINAGE SUB-BASINS WHICH COVER THE FEMP

ESTIMATE AIRBORNE PARTICULATE MATTER
CONCENTRATION AT FEMP FENCELINE
(FROM DATA IN ANNUAL SITE ENVIRONMENTAL REPORT FOR 1992)

MEASURED U CONC. IN AIR (pCi/m^3) / MEASURED U CONC. IN SOIL (pCi/g)
= ESTIMATED PARTICULATE MATTER CONC. IN AIR (g/m^3)

PARTICULATE MATTER CONC. = 2.0E-05 g/m^3
(MAXIMUM FROM 7 MONITORING STATIONS)

↓

CALCULATE AIR PATHWAY PROTECTIVE REQUIREMENTS
(i.e., ALLOWABLE SOIL CONCENTRATIONS)

1. RADIONUCLIDES
[AIRBORNE PRG, pCi/m^3] / [2.0E-05 g/m^3]
= AIR PATHWAY PROTECTIVE REQUIREMENT, pCi/g.

2. CHEMICALS
[AIRBORNE PRG, mg/m^3] x [1000 g/kg] / [2.0E-5 g/m^3]
=AIR PATHWAY PROTECTIVE REQUIREMENT, mg/kg.

↓

COMPARE PROTECTIVE REQUIREMENTS TO
ON-PROPERTY RECEPTOR SOIL PRGs
AND BASELINE SOIL CONCENTRATIONS

"ILLUS\OU-5\PO-113\F-DEVELOP AIR PATH REQ.EPS

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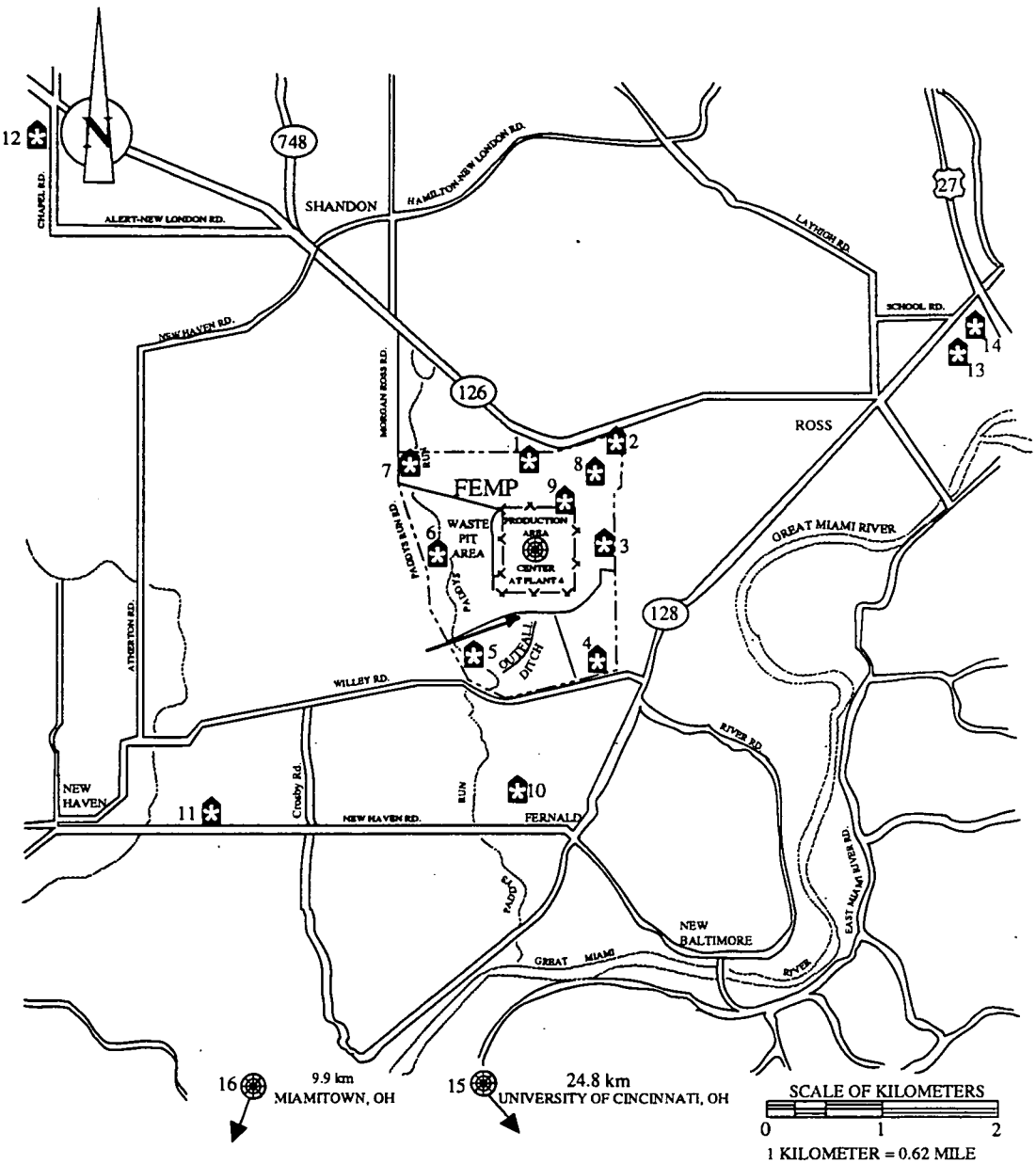
FIGURE F.4-2. DEVELOPMENT OF AIR PATHWAY PROTECTIVE REQUIREMENTS



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NOT TO SCALE

"ILLUS\OU-5\PO-113\F-AIR MONITORING.EPS

FIGURE F.4-3. FEMP AIR QUALITY MONITORING STATIONS

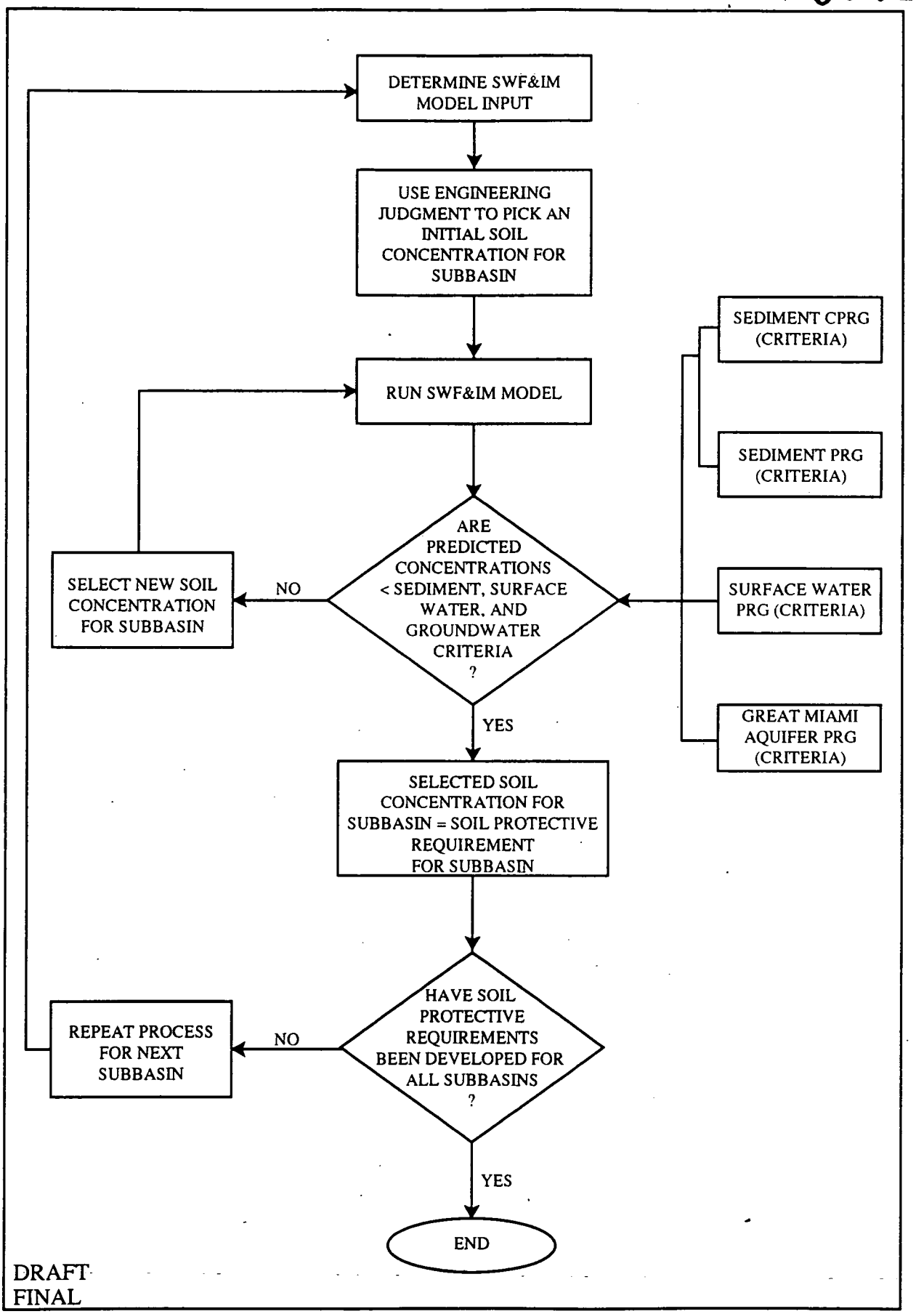
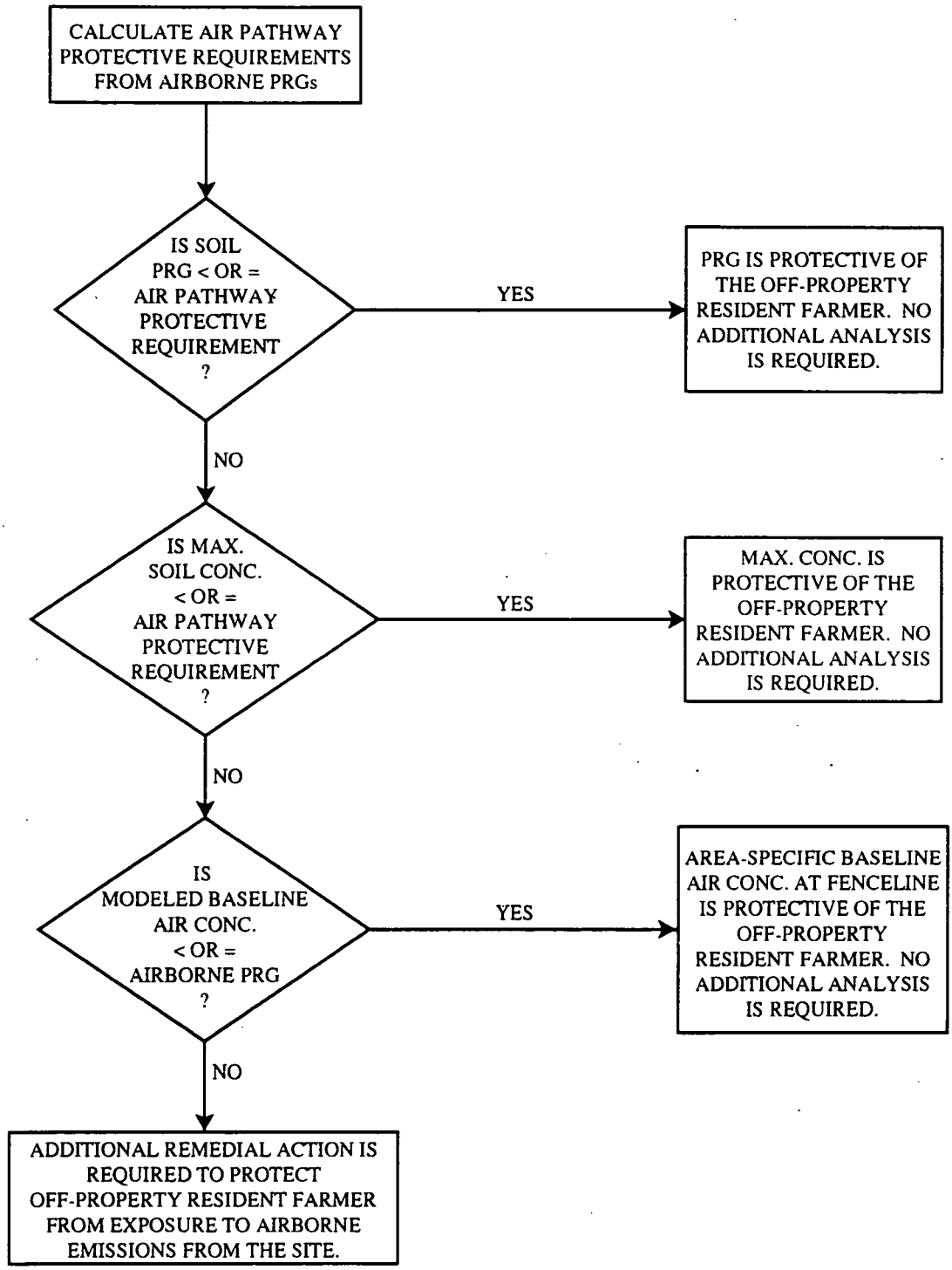


FIGURE F.4-4. FLOW CHART OF PROTECTIVE REQUIREMENT DEVELOPMENT PROCESS FOR SURFACE WATER PATHWAY



"\ILLUS\OU-5\PO-113\F-PROTECT REQ SCREEN.EPS

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FIGURE F.4-5. AIR PATHWAY PROTECTIVE REQUIREMENTS SCREENING PROCESS

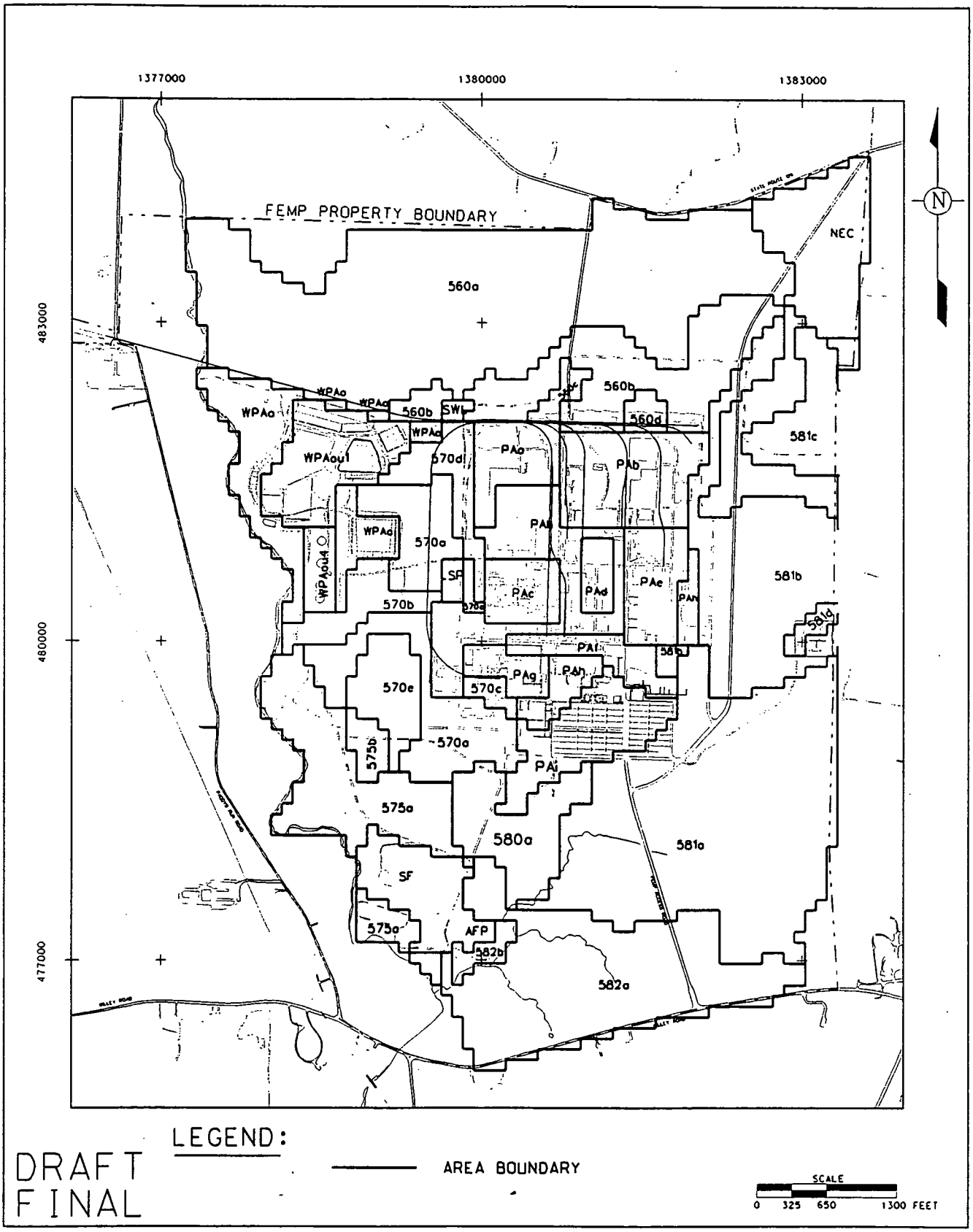

FIGURE F.4-6. FEMP SURFACE AREAS USED IN AIR DISPERSION MODELING

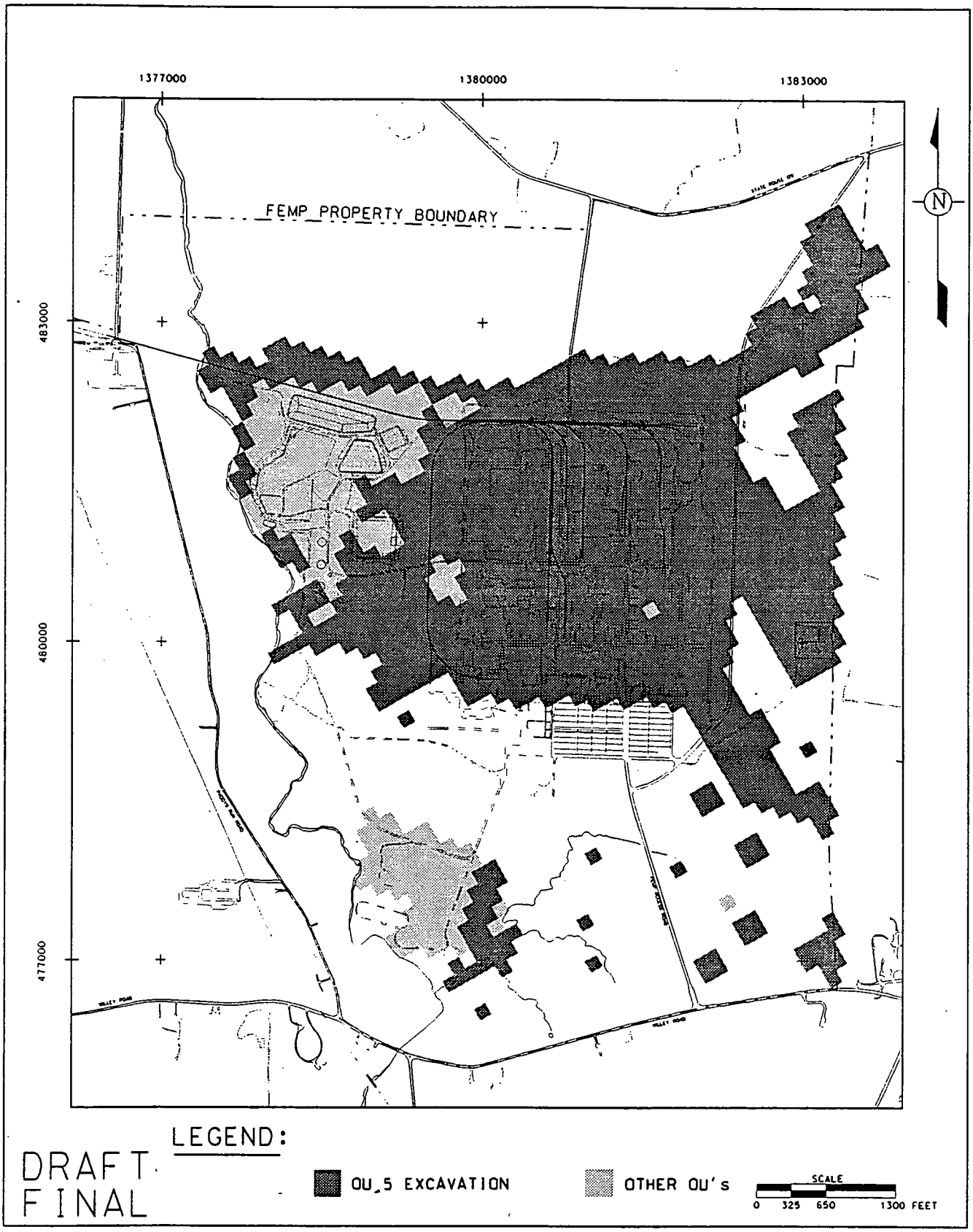

FIGURE F.4-7. ALTERNATIVES 3A AND 3D EXCAVATION AREAS

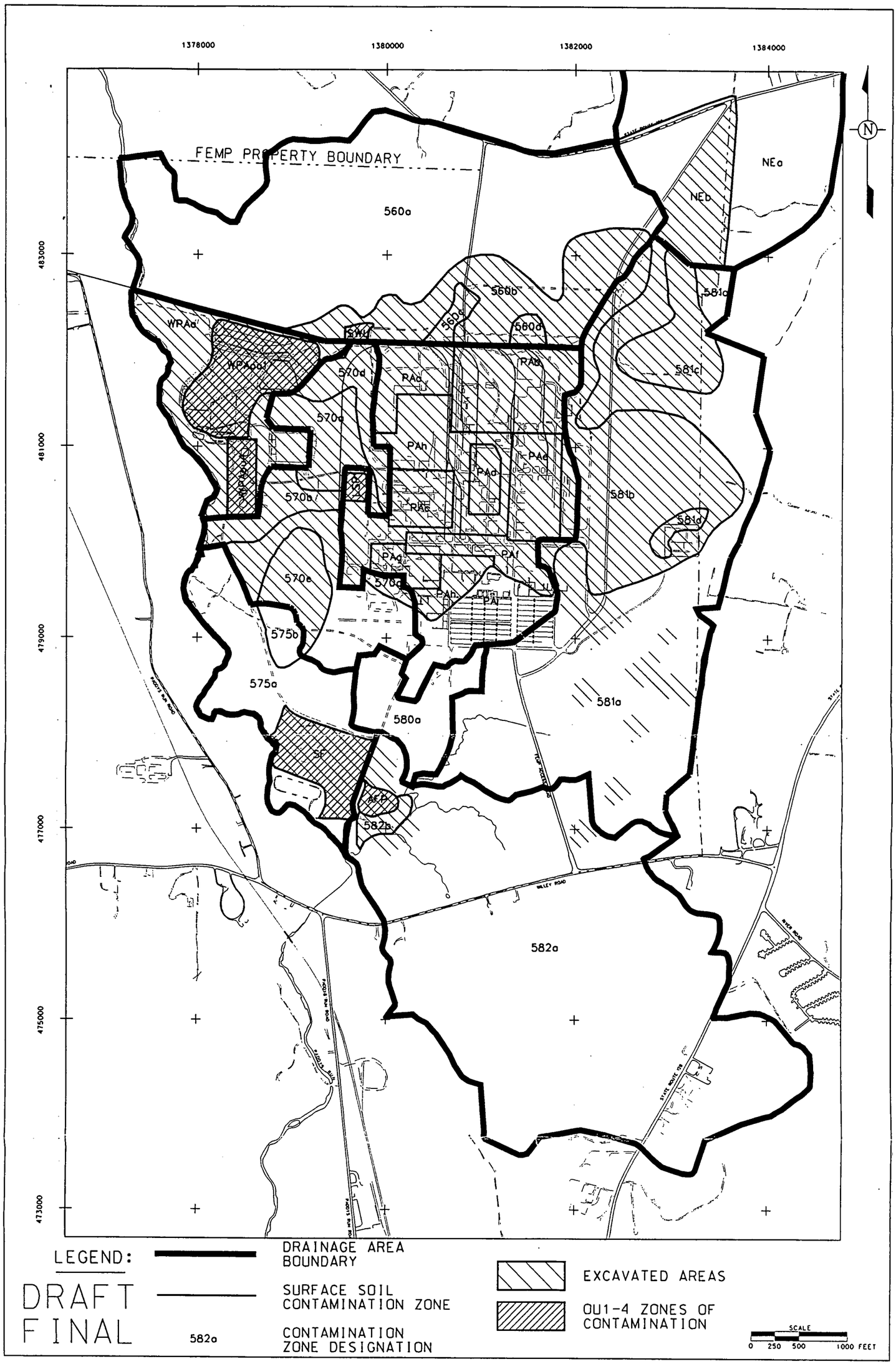

FIGURE F.4-8. CONTAMINANT SOURCE AREAS AND AREAS OF EXCAVATION USED TO DEVELOP SURFACE WATER PROTECTIVE REQUIREMENTS

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Attachments

F.5.I WAC for RCRA-Regulated Constituents
F.5.II Summary of Modeling Results for Long-Term Performance Evaluation of the Disposal Cell

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F.5.0 WASTE ACCEPTANCE CRITERIA

F.5.1 OBJECTIVE

Waste acceptance criteria (WAC) are required for remedial alternatives which include certain on-site disposal facilities or remedial components. The WAC development process is very similar to the CPRG development process described in Section F.3.0. However, the WAC development process also considers the benefits of engineering controls and potential waste treatments that can significantly change hydrogeological and geochemical conditions. Because potential disposal facilities will be located outside of the infiltration conceptual sand zone area (see Figure F.2-11, Zone V) and will include an earthen cover or cap, only the vertical migration of contaminants through the overburden into the Great Miami Aquifer is considered as the potential pathway of cross-media impact in the WAC development process. Analyses of air and surface water migration pathways are not required.

Initially, the maximum acceptable leachate concentrations for contents of the disposal facilities are determined by fate and transport modeling. The leaching potential, solubility, and mobility of different contaminants and the effects of waste treatment are then considered to convert these leachate concentrations into solid phase WAC. For example, treated soil with higher solid phase concentrations can still satisfy the WAC because the residual contaminants have reduced solubilities. All of the contaminated areas and media that exceed PRLs are evaluated for possible remedial options under each remedial alternative and land-use objective. The general evaluation procedure for determining volumes of contaminated soil is illustrated in Figure F.5-1. As shown in the figure, WAC for different remedial components are used to determine the volume of contaminated soil that needs to be handled by each component.

Land-use objectives, which are combinations of receptors and protective levels, determine the PRLs for soil remedial actions. Therefore, the process outlined in Figure F.5-1 is conducted for each of the relevant land-use objectives under the four land-use scenarios. This process does not need to be repeated for every remedial alternative designed to achieve the same land-use objective. In other words, WAC and initial volume estimations are developed for all the potential on-site disposal components that may be included in any site-wide remedial alternative for soil. It is important to note that not all the components shown in Figure F.5-1 are considered in every remedial alternative. For example, an unrestricted land-use alternative does not allow contaminated material which exceeds PRLs to be left on site. Therefore, final distribution of contaminated soil among the remedial components will be based on the availability of components to each remedial alternative and land-use objective. However, for the preliminary volume estimation, all of the components (i.e., consolidation with earthen cap, consolidation with multilayer cap, disposal cell, and off-site disposal) and their WAC are considered. Volumes estimated for components that are not included in an alternative will be targeted into the next more protective available component (see Figure F.5-1) during the detailed

evaluation of an alternative. To further illustrate this process, Figures F.5-2 to F.5-5 show the simplified alternative-specific process for each alternative defined in Section 4.0 of the Operable Unit 5 FS. These general alternatives (i.e., alternative A, B, and C) are applied with different PRL and WAC values for each land-use scenario and receptor/protective level combination defined in Section 2.0 of the FS.

F.5.2 GENERAL TECHNICAL APPROACH

The technical approach to fate and transport modeling conducted to develop WAC is summarized below. Assumptions used to ensure that the model conservatively estimates future impacts to receptors are also summarized. Unlike the PRL development process, as shown in Figure F.1-3, WAC are determined directly by fate and transport modeling.

F.5.2.1 Types of Disposal Facilities

As shown in Figure F.5-1, three types of disposal facilities are evaluated for use in the three potential alternatives (i.e., alternatives A, B, and C) being investigated for on-site disposal of contaminated soil. They include consolidation area with earthen cover (in alternative C), consolidation area with cap (in alternative B), and disposal cell (in alternative A). General descriptions of these facilities are provided below.

Consolidation Area with Earthen Cover

The initial option being considered for on-site disposal is consolidation of contaminated soil with low concentrations with minimum surface cover. The consolidation area with earthen cover disposal facility has a simple design and is the least restrictive for contaminant migration of the three disposal facilities. For the consolidation area, contaminated soil from various areas is placed directly on existing grade in the former production area and consolidated after the completion of remedial actions for the perched groundwater zone. The soil is then covered with an earthen cover. This option is likely to be effective for contaminated material with lower contaminant mobility and concentration levels and would be the least expensive of the three on-site disposal options which are evaluated. The earthen cover placed over the contaminated soil is used to prevent erosion and migration due to wind and runoff. The current geologic strata which are present under this area will have a great affect on the acceptable level of contamination which can be disposed of in the facility. Each strata has certain contaminant transport properties that will affect the contaminant migration potential for COCs. These properties are considered during the WAC development.

General details of the facility include the following: up to 40 feet of contaminated soil will be mounded over existing soil; the soil will be covered with an earthen material and vegetation; the area over which the soil will be mounded has an underlying natural gray clay layer in the glacial

overburden approximately 22 feet thick; and the infiltration rates through the earthen cover and waste material will be similar to natural infiltration rates (i.e., 5.92 inches per year).

Consolidation Area with Cap

The consolidation area with cap disposal facility has a more complicated design and provides average restriction for contaminant migration as compared to the other two proposed disposal facilities. The design of the facility consists of placing contaminated soil from various areas on existing grade and covering the soil with a multilayer cap. This option is likely to be effective for contaminated material with lower contaminant mobility and concentration levels and would be the moderately expensive option as compared to the other two on-site disposal options. The current geologic strata which are present under this area will have a great affect on the acceptable level of contamination which can be disposed in this area. Each strata has certain contaminant transport properties that will affect the contaminant migration potential for COCs. These properties are considered during the WAC development. The cap placed over the contaminated soil is used to prevent erosion and migration due to wind and runoff, as well as to restrict infiltration and bio-intrusion. The difference between this and the disposal cell is the absence of an engineered clay liner.

General details of the facility include the following: up to 40 feet of contaminated soil will be mounded over existing soil; the area over which the soil will be mounded has an underlying clay layer approximately 22 feet thick; and the infiltration rates through the cap are much less than natural infiltration rates and are identical to the infiltration rate for the disposal facility because it is controlled by the cap, which is included in both facilities.

Disposal Cell

438 The disposal cell facility has a complicated design and is the most restrictive for contaminant migration of the three disposal facilities. The general design of the facility consists of placing contaminated soil on a designed clay liner and covering the soil with a multilayer cap. Due to its design, a disposal cell can typically accommodate waste with higher levels of contaminant mobility and concentration. The on-site disposal cell option is the most expensive of the three options which are investigated. The area which is selected for the location of the facility has relatively significant amounts of gray clay in the underlying glacial overburden to impede contaminant migration. In addition to the existing gray clay, a 3-foot clay liner will be placed under the contaminated soil to provide additional protection against contaminant migration. The liner system also includes geosynthetic membranes and leachate collection layers as shown in Figure F.5-6. The cap, which will be placed over the contaminated soil, is used to prevent erosion and migration due to wind and runoff, as well as to restrict infiltration and biointrusion.

General details of the facility include the following: up to 40 feet of contaminated soil will be mounded over a 3-foot thick engineered clay liner; a cap will be place over the soil and liner; the area over which the soil will be mounded has an underlying gray clay layer approximately 22 feet thick; and the infiltration rates through the facility will be much less than natural infiltration rates and are estimated by HELP model simulation.

F.5.2.2 Important Factors for WAC Development

General Considerations and Characteristics of WAC

WAC which specify the protective requirements in the subsurface transport pathways are required to design soil remedial components which utilize certain on-property disposal facilities. The WAC development process is very similar to the CPRG development process; however, the WAC development process also considers the benefits of engineering controls and waste treatments that can significantly change hydrogeological and geochemical conditions. Finally WAC are presented as acceptable solid phase concentrations for contents of the disposal facilities so that leaching potential, solubility, and mobility of different forms of contaminants and effects of waste treatment can be considered. All of the contaminated areas and media that have COC concentrations which exceed their PRLs are evaluated for possible remedial components using WAC developed for each of the facilities under each land-use objective which specifies the required protective level in the Great Miami Aquifer.

The general evaluation procedure for contaminated soil is illustrated in Figure F.5-1. As shown, various WAC (i.e., WAC_1 through WAC_3) for different remedial components are required to determine the total volumes of contaminated soil that can be handled by each component. The components include consolidation area with earthen cover, consolidation area with cap, on-site disposal cell, and off-site disposal. Preliminary designs of the acceptable site-wide soil remedial alternatives, which are combinations of the above-listed components, use these volume estimates.

93 High yielding areas of perched water and lateral migration in the perched water zone underlying the potential on-property disposal areas will be minimized by engineering controls or removed by excavation during remedial actions for contaminated perched water. Perched groundwater will always be present in the glacial overburden unless there is no gray clay layer to impede vertical flow, but perched groundwater yield can be greatly reduced by removing the larger deposits of sand and gravel in the glacial overburden or by reducing the surface recharge. Additional hydrogeological investigations in the potential disposal facility location are currently being conducted to provide additional hydrogeological characterization of the area. The multilayer cap of the disposal cell will reduce future infiltration rates directly through the disposal area. Also, as part of the disposal cell design, a channel around the facility will divert surface runoff from up-gradient areas to reduce the

impact of surface runoff and local recharge rate. Therefore, the chance of the future existence of a high-yield perched groundwater zone directly under the disposal facility will be very small. Therefore, for all options, WAC are developed considering only the vertical migration pathway for contaminants to the Great Miami Aquifer groundwater. The conceptual model and technical approach for soil CPRG development considering contaminant migration via the groundwater pathway is discussed in Section F.3.0. A similar conceptual model and approach are also used for WAC development. The noteworthy differences between CPRG and WAC development include: the lower infiltration rates used for the proposed cap on the two disposal facilities for WAC development (i.e., WAC_2 and WAC_3), and the size of the source areas considered for WAC development is larger.

The infiltration rates for the earthen cover and cap vary due to design details. The source size used for each component is identical at 1000 feet by 1000 feet for WAC modeling purposes. The infiltration rates for each component are presented below in the appropriate section. The only potential exposure point considered for WAC development includes the Great Miami Aquifer under the source (i.e., on-property), which is the same as for CPRG development.

Determination of Infiltration Rate

Because WAC are very sensitive to infiltration rates, determination of infiltration rates through different facilities with various surface covers is the most important task in the WAC development process. Based on the options defined in the preliminary remedial alternatives, there are three types of surface covers which need to be considered for the potential on-property disposal areas. For the consolidation area, a multilayer cap and a simple earthen cover will be evaluated. A multilayer cap is also used for the disposal cell option. General design cross section of the multilayer cap and underlying clay liner is shown in Figure F.5-6. Infiltration rates for each of the three cover designs in every infiltration zone shown in Figure F.2-11 are determined in this section.

The HELP model is used to estimate infiltration rates to the Great Miami Aquifer through a multi-layer cap and an earthen cover for the infiltration zones which cover the potential locations of these facilities (see Figure F.2-11). Seepage is simulated through the layers of the cap or cover, waste soil material and liners where present, and underlying natural soil strata of the generalized geological cross section for the infiltration zone. For the baseline conditions, effects of the geotextile and geomembrane layers are not considered in the infiltration rate estimation process. The leachate collection system is also assumed to not be functioning. Only during the sensitivity analysis for WAC are the effects of these layers evaluated.

439 The HELP model is used to calculate a water budget for the disposal area by apportioning input to the model in the form of precipitation on the area and to the possible output mechanisms (runoff, evapotranspiration, lateral discharge to drains at the edge of the cap or liner, or downward vertical

infiltration). Hydraulic properties for each layer are determined from field data or selected from default soil characteristics which are part of the HELP model documentation. HELP default climatological data for Cincinnati, Ohio, is used for the simulations. Only climatological data between 1974 to 1978 is included in the HELP model database. Therefore, data for this five-year period was used repeatedly as consecutive five-year periods to emulate long-term conditions. Each HELP simulation is run until the change in soil moisture content in all layers at the end of consecutive 5-year periods is less than 0.1 percent.

Table F.5-1 summarizes the annual infiltration rates from the HELP model for these facilities. In Table F.5-1, infiltration rates for the two facilities that include a multilayer cap are from additional HELP model simulations, while the infiltration rate for the consolidation area with earthen cover case is assumed to be the current infiltration rate in Zone IV. Figure F.2-12 shows the generalized cross section and hydrological properties of the five infiltration zones modeled (i.e., Zones I to V in Figure F.2-11). Each surface cover is simulated in each infiltration zone so all potential locations of the disposal area can be evaluated.

Preliminary Footprint and Location of the On-Site Disposal Area

The footprint of the proposed consolidation and disposal area is shown in Figure F.5-7. This proposed area is based on the hydrogeological conditions and preliminary estimates for total volumes of uranium-contaminated soil that will require excavation. The area has assumed dimensions of 1000 feet by 1000 feet for the purpose of WAC development. Although the final dimensions of the disposal facility may be larger, the WAC developed with these assumed dimensions are still very conservative. The size is conservative because during WAC development the contaminant concentration in the whole facility is assumed to be uniform and equal to the maximum acceptable concentration. In fact, much of the waste which will be placed into the disposal facility would be much less than the WAC concentration. On average the waste concentration in the disposal facility can be orders of magnitude lower than the WAC. However, preliminary sensitivity analysis between WAC and sizes of each facility are evaluated by modeling. Results of this analysis are considered when finalizing the dimensions of the area and determining the corresponding allowable volumes of contaminated soil which can be placed in the area. The actual size of the selected disposal facility will be used in the modeling to support the residual risk assessment in the CRARE.

Hydrogeologic and Geochemical Input Parameters

Site- and soil-specific hydrogeologic parameters and site- and COC-specific geochemical parameters used for WAC development are summarized in Tables F.5-2 and F.5-3, respectively. Included in Table F.5-2 are the hydraulic conductivities, porosities, bulk densities, and FOC used for modeling. Table F.5-3 summarizes the COC-specific K_l, K_d, half-life, and specific activity (radionuclides only).

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Exposure Criteria

Great Miami Aquifer exposure criteria for the RME resident farmer/child exposure scenario applied in WAC development include 1 x 10^{-6} and 1 x 10^{-5} ILCRs. For toxicants, WAC using exposure criteria at a HQ of 1.0 for total uranium and of 0.2 for other contaminants are also developed. For contaminants that have MCLs, WAC corresponding to MCLs are also determined. Exposure criteria considered during the WAC development are summarized in Table F.5-4. Contaminants listed in this table are the COPCs in the groundwater pathway that are identified in the Operable Unit 5 RI Report and in the screening table, Table F.2-2, in Section F.2.3. Based on these exposure criteria, WAC are developed using the fate and transport models and modeling processes described in this section.

General Modeling Approach

The modeling approach for WAC development can be summarized as follows:

- The entire disposal area is considered as one future contaminant source.
- The pertinent ECTran model input is taken directly from the input data used for CPRG modeling runs conducted under Section F.3.
- The infiltration rate through the two facilities which include a multi-layer cap are determined by HELP simulations as previously described. The only difference between the consolidation with a cap and the disposal cell is the engineered clay liner. The infiltration rates for the two facilities are identical because of the assumption that the basal liner drains in the disposal cell have failed. For the consolidation area with earthen cover, infiltration is assumed to be equal to the current infiltration rate (i.e., 5.92 inches per year) at the selected foot print area for the on-site disposal facility.
- The potential exposure point for developing the WAC is the Great Miami Aquifer under the facility.
- An iterative procedure is used to back-calculate an acceptable leachate concentration from the waste (i.e., initial WAC) based on meeting the Great Miami Aquifer groundwater PRG. The Great Miami Aquifer groundwater PRG is developed for the RME resident farmer/child exposure scenario. The acceptable leachate concentrations are then converted using K_t to develop corresponding solid phase WAC.

F.5.2.3 Modeling Tools

A contaminant fate and transport model for the groundwater pathway is used to develop WAC. Model simulations are conducted to back-calculate WAC at future disposal facilities, based on the exposure criteria set at receptor locations. For the WAC development, groundwater and contaminant migration within the overburden and saturated Great Miami Aquifer are simulated by ECTran (DOE 1993). Because source areas can be simulated individually in the development of WAC, ECTran can be used to develop WAC for each disposal facility.

The ECTran model is appropriate for WAC development because it is more conservative and can be used efficiently to develop numerous COC-specific WAC and because the source areas, which require WAC, can be simulated individually for the initial design purposes. Modifications have been incorporated into the original ECTran version to consider multiple sublayers within the gray clay layer and engineered clay liner during WAC development. The modifications to ECTran are described in Attachment F.1.I.

F.5.2.4 Summary of Assumptions

Assumptions are necessary to simplify or conceptualize the natural environmental and migrational processes so that they can be simulated by models. Also, conservative modeling assumptions are made for developing WAC to ensure that they are acceptable. The modeling assumptions are summarized below.

- The brown, weathered clay is considered part of the till layer for infiltration calculations made using the HELP model. Because it is more permeable than the unweathered gray clay, including the brown clay in the infiltration calculations results in higher infiltration rates than using only the gray clay.

440 - The brown, weathered clay is not considered part of the till layer during contaminant fate and transport simulations using the ECTran model; the brown clay is weathered and fractured and has limited ability to impede contaminant migration. Not considering this layer adds conservatism by modeling higher concentrations reaching the Great Miami Aquifer faster.

- A 1000-year modeling period is chosen for WAC development (i.e., the predicted maximum impact within 1000 years should not exceed the groundwater PRG).

- For the on-site disposal cell and the consolidation with cap options, because of the low infiltration rate and potential high concentrations, the contaminant source used in the ECTran model for WAC development is assumed to remain constant for the entire modeling period for most of the COCs except for those that have low K_d values (i.e., less than 1 L/kg) in clay. Because of the low K_d values, these COCs' mass can migrate from the disposal facility in a shorter period of time. It is therefore not realistic to assume that the total mass of these COCs is sufficient to sustain constant loading for 1000 years at the initial leachate concentration level. A 40-foot-thick depleting source is simulated for developing WAC for these COCs.

- For the consolidation with earthen cover option, because of the relatively higher infiltration rate, the contaminant source used in the ECTran model for WAC development is simulated as a 30-foot-thick depleting contaminant source. Only a 30-foot source is assumed for this option because the WAC are expected to be lower and therefore a smaller amount of contaminated soil can be disposed of under this alternative.

- A minimum mixing depth of the Great Miami Aquifer is assumed to be 10 feet for the disposal cell and the consolidation area with cap options.

- The mixing depth of the Great Miami Aquifer is estimated using the equation (i.e., Equation 8) presented in the ECTran development document (DOE 1993) for the consolidation area with earthen cover option.

As indicated in the last two assumptions, two approaches were used to determined the mixing depth of the Great Miami Aquifer considering the infiltration rate and actual exposure scenario of a groundwater user. Ten feet is a reasonable assumption of well-screen length of typical groundwater production wells. Therefore, the minimum mixing depth of 10 feet was set in modeling for determining the potential future impacts to Great Miami Aquifer groundwater users. This assumption was made to avoid the use of any unrealistically small mixing depth directly calculated by the mixing equation under low infiltration rate conditions such as under the two disposal facilities with cap. The mixing equation only considers the vertical infiltration rate, lateral travel time, and vertical dispersion. This equation is reasonable and was directly used for higher infiltration rate conditions such as under the consolidation area without a multilayer cap.

F.5.3 CONSOLIDATION AREA WITH EARTHEN COVER

F.5.3.1 Earthen Cover and Underlying Overburden Cross Section

Figure F.5-8 shows the conceptual model of a consolidation area with earthen cover. The earthen cover is assumed to be placed over 30 feet of contaminated soil that has been excavated and placed in the disposal area. Tables F.5-2 and F.5-5 summarizes the thickness, hydraulic conductivity and porosity values used in the various layers of the conceptual earthen cover.

F.5.3.2 Infiltration Rate

The steady-state annual infiltration rate through the earthen cover and generalized geological profiles into the aquifer is estimated to be approximately 5.92 inches per year. This infiltration rate is from the HELP model simulation for infiltration ZONE IV under current conditions.

F.5.3.3 COC-Specific WAC

Protective level-specific WAC are developed for 15 COCs (see Table F.2-2) for the consolidation area with earthen cover option. These WAC are presented in Table F.5-6. The WAC are presented in the same units as PRLs so they can be directly compared. Additional WAC developed for constituents regulated under the Resource Conservation and Recovery Act (RCRA) are included in Attachment F.5.I.

F.5.4 CONSOLIDATION AREA WITH CAP

F.5.4.1 Cap and Underlying Overburden Cross Section

Figure F.5-9 shows the conceptual model of the consolidation area with cap simulated by using ECTran. The modeled multilayer cap is assumed to be placed on contaminated material over in situ

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soil. Tables F.5-2 and F.5-5 summarize the layer thickness, permeability and porosity values used to model the various layers of the facility.

F.5.4.2 Infiltration Rate

For the HELP simulations of the multilayer cap, credit has not been taken for the synthetic barrier layers in the design (i.e., the geosynthetic clay and geomembrane layers). The steady-state annual infiltration rate through the cap and generalized geologic profiles into the aquifer is estimated to be 0.89 in./yr. Additional discussions about the infiltration rate estimation are presented in Section F.5.5.2.

In general, the HELP modeling showed that vertical percolation rates are functions of the cap properties, the most important of which appears to be the hydraulic conductivities of the cap's barrier and lateral drain layers, and the drainage lengths of the drain layers. In general, more permeable lateral drainage layers and less permeable barrier layers lower vertical percolation. Longer drainage length induces more vertical percolation because the heads on the underlying barrier layers are greater.

F.5.4.3 COC-Specific WAC

Protective level-specific WAC are developed for 15 COCs for the consolidation area with cap option. These WAC are summarized in Table F.5-7. The WAC are presented in the same units as PRLs so they can be directly compared. Additional WAC developed for RCRA-regulated constituents are included in Attachment F.5.I.

F.5.5 DISPOSAL CELL

F.5.5.1 Disposal Cell and Underlying Overburden Cross Section

Figure F.5-10 shows the conceptual model of the disposal cell simulated by using ECTran. Tables F.5-2 and F.5-5 summarize the layer thickness, permeability, and porosity values used to model the various layers of the cap, waste material, and liner of the conceptual disposal cell.

F.5.5.2 Infiltration Rate

The steady-state annual infiltration rate through the cell into the aquifer was estimated to be 0.89 inches per year. This infiltration rate is estimated using the HELP model without including the geotextile and geomembrane layers. The total volume of seepage is a function of the disposal cell's size.

The requirement for 1000-year disposal cell longevity implies that the synthetic materials need to be backed up by natural materials (because at present, there is no evidence that synthetic materials will perform satisfactorily for 1000 years). Thus, for the HELP simulations to determine the infiltration

rates for WAC development, credit has not been taken for synthetic barrier layers (i.e., the geosynthetic and geomembrane layers). The leachate collection system is also assumed to not be functioning and its simulated flow rate is added to the overall vertical infiltration rate. Other assumptions regarding the barrier and drainage layers' performances are used during the sensitivity analysis of the WAC and a conceptual long-term performance evaluation of the disposal cell.

In general, the HELP modeling showed that vertical percolation rates are a function of the cap properties, the most important of which appear to be the hydraulic conductivity of the cap's barrier, lateral drain layers and the drainage lengths of the drain layers. In general, more permeable lateral drainage layers and less permeable barrier layers lower vertical percolation through the waste material. Longer drainage lengths induce more vertical percolation because the heads on the underlying barrier layers are greater.

F.5.5.3 Geochemical Conditions of the Engineered Clay Liner

Based on the calibration results described in Attachment F.1.I, a uranium K_d value of 3.1 L/kg for the gray clay layer in the glacial overburden throughout the FEMP is selected for the Operable Unit 5 FS to develop soil CPRGs and WAC for disposal facilities. This K_d represents the natural adsorption conditions which occur within the gray clay. This value was determined by model calibrations with both ODAST and ECTran models and is representative of conditions observed at the southeast lysimeter location. This lower K_d value could be the result of a small "short circuit" pathway through the gray clay, (i.e., a sand lense or fracture). Such pathways, while hard to identify in the field, can be accounted for in the model by lowering K_d.

An engineered clay liner will be used as part of the disposal cell. In comparison, this clay liner will be homogeneous and placed and compacted to specifications unlike the natural clay. The natural clay is more heterogeneous and was placed randomly due to natural deposition processes. It is reasonable to assume that this engineered clay liner will not have the same hydrogeological uncertainty and high degree of heterogeneity as in the natural "gray clay" layer encountered in the lysimeter test area. Therefore, a higher K_d value which is closer to reported capacity of real clay material, under general subsurface geochemical conditions (i.e., high carbonate content) expected in the FEMP, is reasonable. A uranium K_d value of 24 L/kg is selected for the clay liner. This value is also justified by results of laboratory adsorption tests conducted with clay materials from the potential location of the cell east of the former production area (see Attachment F.3.I of the Operable Unit 5 RI Report).

For all the other COCs, conservatively selected literature K_d values for clay are used. During the construction process, chemical absorbents may be mixed into this clay liner to improve the geochemical performance of the liner (i.e., achieving higher K_d values). This option will be evaluated during the design of the disposal cell.

F.5.5.4 COC-Specific WAC

Protective level-specific WAC are developed for 15 COCs for the disposal cell. These WAC are summarized in Table F.5-8. The WAC are presented in the same units as PRLs so they can be directly compared. Additional WAC developed for RCRA regulated constituents are included in Attachment F.5.I.

F.5.5.5 Sensitivity Analysis

Sensitivity analyses are conducted to investigate the effect of layer thickness, location of exposure point, uranium K_d value in the Great Miami Aquifer, and infiltration rate on the WAC for uranium.

Layer Thickness

During WAC development the liner thickness is 3 feet. For the sensitivity analysis various clay liner thicknesses (3, 6, and 9 feet) are tested to determine their effect on the WAC. For the thicker liners, the liner is divided into sublayers of 3-foot thickness in the ECTran Model (see Attachment F.1.I). Table F.5-9 presents the WAC which are developed for the three liner thicknesses. Figure F.5-11 graphically shows the relationship between WAC and the liner thickness and uranium K_d values.

In addition to testing the clay liner thickness, the effects of the gray clay and unsaturated Great Miami Aquifer sand and gravel thickness are also evaluated. The effectiveness of the gray clay and unsaturated Great Miami Aquifer are tested by removing one or both of the layers during WAC development. The original WAC development procedure included both layers. By removing the layers from the model one at a time, the effect of each is determined. Tables F.5-10 and F.5-11 show the resulting WAC with only the gray clay layer removed and with both the gray clay layer and unsaturated Great Miami Aquifer removed, respectively. For the layer thickness sensitivity analyses, the infiltration rate is assumed to be constant for all the cases because infiltration rate is controlled by the multilayer cap design which is the same in all the cases.

Exposure Point and K_d Value in the Great Miami Aquifer

Only one exposure point, which is under the disposal cell, is considered in the WAC development process. Also, only one uranium K_d value (i.e., 1.78 L/kg) in the Great Miami Aquifer is used for the WAC development. An alternate Great Miami Aquifer exposure point and a range of adsorption K_d values are used to test the WAC sensitivity to these two parameters. The FEMP fenceline which is about 500 feet from the downgradient edge of the disposal cell is used as the alternate exposure point of a Great Miami Aquifer groundwater user. A K_d range between 1.78 to 12 L/kg is selected as the potential uranium K_d values in the aquifer. This range was determined during previous study of the Great Miami Aquifer geochemical conditions (DOE 1993). The groundwater exposure criterion is set at 20 μg/L.

Figure F.5-12 shows the trend of disposal cell WAC developed using combinations of these two parameters. As shown in this figure, the WAC value used in the Operable Unit 5 FS (i.e., 1000 mg/kg) is at the lower end of all the resulting WAC values.

Infiltration Rate

The final sensitivity analysis performed for WAC development was to investigate the effects of the infiltration rate. A range of constant infiltration rates (i.e., 0.4 inches per year to 4.0 inches per year) was used to develop the WAC. Table F.5-12 summarizes the WAC developed for this range of infiltration rates. Figure F.5-13 graphically shows the relationship between WAC and the infiltration rates and uranium K_l values. A more detailed evaluation of the effects of time-related infiltration rates on performance of the disposal cell are summarized below in Section F.5.5.6.

F.5.5.6 Conceptual Long-Term Performance Evaluation

The long-term performance of the proposed disposal cell is tested using the ECTran model and Monte Carlo simulation (Crystal Ball Software). Because the final design of the on-site cell is not yet available, this evaluation is only a simplified conceptual level study. The objective is to demonstrate the feasibility of an on-site disposal cell and compliance with ARARs for the Operable Unit 5 FS. This evaluation also provides useful information, such as required life times for components in the disposal cell for design considerations.

The WAC development process uses a reasonable worst-case approach to simulate the disposal facilities evaluated in the FS, assuming the multilayer cap will allow a maximum infiltration rate of 0.89 inches per year in a 1000-year time frame. It is determined that hypothetical conditions that are worse than the baseline condition used in the WAC development need to be evaluated in the long-term performance evaluation for the disposal cell. These conditions can include the eventual failure of portions of the clay layer in the multilayer cap and therefore a much higher infiltration rate than the one used to develop the WAC. The relationship between occurrence times of these hypothetical failures and their impacts are the focuses of this conceptual long-term performance evaluation. The engineering design process will consider this information and ensure that the final design of the on-site disposal cell, together with the WAC, are acceptable from a long-term performance stand point.

Technical Approach

Unlike the approach used for the WAC development, the conceptual long-term performance evaluation intends to simulate the disposal cell with less conservative and more realistic assumptions regarding the characteristics of materials in the cell and the glacial overburden, so that the long-term performance and potential impacts due to hypothetical failures can be better described. Therefore, hypothetical cap failures and reasonable credit for the gray clay layer in the glacial overburden and a hydraulic barrier layer in the cell, which are not fully considered in the WAC development, are all

simulated. Excluding any of these three factors in the evaluation cannot provide a complete understanding of the long-term impacts of the on-site disposal cell.

For the purposes of a long-term performance evaluation, it is reasonable to take limited credit for the bentonite geocomposite layer and using the average gray clay thickness under the disposal cell. Based on literature information, the bentonite geocomposite layer is assumed to have a performance life time of about 200 years. With this additional hydraulic barrier layer, average gray clay thickness, and the average uranium source concentration, more realistic predictions regarding the performance of the cell and future breakthrough of uranium can be obtained. Although seemingly changing the modeling approach, it is important to point out that the bentonite geocomposite layer is not considered and the minimum gray clay thickness is used in the WAC development, so that these reasonably conservative WAC and good engineering of the disposal cell can provide long-term protection to the environment.

As described above, the major factor which will affect the performance and acceptability of the disposal cell is the integrity (i.e., infiltration rate) of the facility with time. To investigate this, Monte Carlo simulations are performed. For each simulation the infiltration rate through the disposal cell increased with time, simulating hypothetical failure of parts of the cell. The infiltration rate is assumed constant for each of the three time intervals selected to represent the entire modeling period (1000 years). Three infiltration rates are determined by steady-state HELP modeling (see Table F.5-13) before the Monte Carlo simulations to support the long-term performance evaluation are performed. Each of these three infiltration rates (i.e., 0.04, 0.89, and 8.7 inches per year) represents the potential hydraulic impact of a specific hypothetical future condition of portions of the disposal cell. Statistics (i.e., mean and standard deviation) are used to describe the occurrence or starting times of each type of failure and, therefore, increased infiltration rate. Based on these three infiltration rates, time-weighted average constant infiltration rates over each of the three time intervals are used in the simulations over the entire disposal area.

The proposed disposal cell has total dimensions of 1860 feet by 1860 feet, which is based on the preliminary volume estimation for all the contaminated soil and waste materials at the FEMP that will be considered for on-site disposal (see Appendix H.3). Within this total dimension, the area that would contain waste materials is about 1500 feet by 1500 feet. Under the footprint of the proposed disposal cell, the average gray clay thickness is about 30 feet, as shown in Figures F.5-7 and F.2-10. A thinner gray clay layer (i.e., 22 feet) is used for the WAC development purpose. However, the average gray clay thickness (i.e., 30 feet) is used in the long-term performance evaluation. The uranium source term is assumed to be 100 mg/kg, which is a conservative estimate of the average concentration in the cell (see Appendix H.3), and a constant leachate concentration of 6.67 mg/L (i.e., using a uranium K_d value of 15 L/kg for the entire cell). Three separate Monte Carlo

simulations are performed and all Monte Carlo simulations are conducted with a minimum of 1000 trials.

Infiltration Rates and Hypothetical Performance Lifetimes

For the performance evaluation, the infiltration rate used in ECTran was modified so that it could vary with time. By modifying the infiltration rate with time, the effect of hypothetical cell component failures with time can be investigated. A series of infiltration rates are estimated by HELP modeling with assumptions regarding the long-term effectiveness of disposal cell components.

A 0.04 inches per year infiltration rate is estimated for the disposal cell with most components (i.e., cap, liner, and bentonite geocomposite layer) intact except the geotextile fabric, the high density polyethylene (HDPE) flexible membrane, and the bottom leachate collection system. Expected performance lifetimes for artificial materials such as the geotextile fabric and HDPE flexible membrane are much shorter than natural materials (i.e., clay and bentonite), and therefore are not included in the long-term performance evaluation. It is assumed that the bottom leachate collection system will be plugged at the end of the active maintenance period.

A 0.89 inches per year infiltration rate is estimated for the disposal cell assuming the bentonite geocomposite layer has also failed. This is the constant infiltration rate used in the WAC development. The highest infiltration rate considered in this analysis, 8.7 inches per year, is simulated for the disposal cell assuming the upper clay layer failed (i.e., permeability increased to natural brown clay level). This infiltration rate is higher than the current conditions (i.e., 5.9 inches per year used for earthen cover case) because of a ponding effect in the cell. The HELP model input and output used to determine these three infiltration rates are presented in Table F.5-13. These three infiltration rates are used to develop a step function which is governed by defined probabilities of occurrence times for the two higher infiltration rates during a 1000-year period in the Monte Carlo simulations.

The 0.04 and 0.89 inches per year infiltration rates are applied in the first two time intervals directly. Because catastrophic failures of the entire disposal cell are not expected, a representative time- and area-weighted average infiltration rate for the hypothetically deteriorating disposal cell is estimated for the last time interval instead of using the maximum infiltration rate of 8.7 inches per year directly. (See the dashed and solid lines representing the infiltration rate in Figure F.5-14. The last type of hypothetical failure represents the conditions when the permeability in expanding portions of the upper clay layer in the multilayer cap increases to a level that is equivalent to that of the natural brown clay. Considering the nature of this hypothetical failure and the overall size of the disposal cell, a 3.0 inches per year average infiltration rate over the entire cell is determined reasonable for the third time interval.

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The first simulation used the following distribution of infiltration rates over time: for Time Interval 1, an infiltration rate of 0.04 inches per year starting from time 0 is used; for Time Interval 2, a second infiltration rate of 0.89 inches per year with a mean occurrence time of 200 years and a standard deviation of 50 years is used; and for Time Interval 3, an infiltration rate of 3.0 inches per year with a mean occurrence time of 600 years and a standard deviation of 200 years is used.

The second simulation uses a mean occurrence time of 700 years and a standard deviation of 200 years for Time Interval 3. The third simulation uses a mean occurrence time of 800 years and a standard deviation of 200 years for Time Interval 3. The assumption regarding occurrence time of Time Interval 2 remains the same for all three simulations.

As mentioned earlier, each occurrence time represents the time of hypothetical failures of a group of components in the disposal cell and the beginning of a higher infiltration rate. The 0.04 inches per year infiltration rate is for the period when the disposal cell has the most components (i.e., cap, liner, and bentonite geocomposite layer) intact except the geotextile fabric, HDPE flexible membrane, and the bottom leachate collection system. The 0.89 inches per year infiltration rate is for the period in which the bentonite geocomposite layer is also assumed to have failed. The final infiltration rate, 3.0 inches per year, is for the disposal cell assuming portions of the upper clay layer failed (i.e., permeability increased to the natural brown clay level). As an example, assumptions regarding the pattern of these three infiltration rates defined in the first simulation is shown in Figure F.5-14. The upper half of Figure F.5-14 shows a pattern of the conceptual time-varying infiltration rate with the mean occurrence times of the two higher infiltration rates. The probability density functions of the occurrence times of the first and second infiltration rate increases are also shown in the figure.

In general, the mean occurrence time of Time Interval 2 (i.e., 200 years) is the expected performance life time of a well-constructed geomembrane (i.e., bentonite geocomposite layer) in the disposal cell (DOE 1989). The different mean occurrence times (i.e., 600, 700, and 800 years) of Time Interval 3 used in the three simulations represent different levels of the hypothetical performance life time of the cap. The standard deviation of the first occurrence time is 50 years while 200 years is used for the second occurrence time. These two values reflect the uncertainty factors of the expected performance life times of these two components. Because the performance life time of the clay layer is less predictable than the geomembrane, a larger uncertainty factor is used for the clay layer.

Summary of Results

Results of the three Monte Carlo simulations are summarized in Table F.5-14. From Table F.5-14, it can be seen that the first Monte Carlo simulation (i.e., assuming the mean time till the occurrence of a cap failure is 600 years) predicted a mean 1000-year maximum Great Miami Aquifer uranium concentration of 20.04 μg/L. The results of these simulations also include other information such as the following: there is 64 percent chance that the maximum uranium concentration in the Great Miami

Aquifer within 1000 years will be less than 20 μg/L; and the probability of the uranium concentration in the groundwater being less than 2.40 μg/L at 500 years is 100 percent. In other words, uranium concentrations in the aquifer due to future loading from the disposal cell will be much less than 20 μg/L within the first 500 years, even if the cap's mean performance life time is only 600 years with a relatively high standard deviation of 200 years.

Similar statistics for the other two Monte Carlo simulations are also presented in Table F.5-14. The third simulation, which uses the longest mean occurrence time (800 years) for the third infiltration rate (3.0 inches per year), resulted in the lowest predicted mean uranium 1000-year maximum concentration (7.30 μg/L) and the highest percent chance (88 percent) for the predicted uranium concentration to be less than 20 μg/L at 1000 years. The complete Monte Carlo simulation results are included in Attachment F.5.II.

From results of these three simulations, the following conclusions can be made:

- The WAC and WAC application procedure developed and used in the Operable Unit 5 FS will generally provide conservative design requirements for the on-site disposal cell.
- With very high certainty, the future impacts due to the on-site disposal cell will be insignificant within the first 200 years regardless of the performance life time of the upper clay layer in the multilayer cap.
- With very high certainty, the future impacts due to the on-site disposal cell will be insignificant within the first 500 years even if the mean performance life time of the upper clay layer in the multilayer cap is only 600 years.
- With 81 percent chance, the future long-term impacts (i.e., within 1000 years) due to the on-site disposal cell will be acceptable even if the mean performance life time of the upper clay layer in the multilayer cap is only 700 years.
- With high certainty, the future long-term impacts (i.e., within 1000 years) due to the on-site disposal cell will be acceptable if the mean performance life time of the upper clay layer in the multilayer cap is longer than 800 years.

F.5.6 APPLICATION OF WAC

Land-use objectives, which are combinations of receptors and protective levels, determine the PRLs for soil remedial actions. Therefore, the process outlined in Figure F.5-1 is conducted for each of the relevant remediation objectives under the four land-use scenarios. Final distribution of excavated contaminated soil and waste materials among the remedial components will be based on the availability of components to each remedial alternative. However, for the preliminary volume estimation, all of the components (i.e., consolidation with earthen cap, consolidation with multilayer cap, disposal cell, and off-site disposal) and their WAC are considered. Volumes estimated for components that are not included in an alternative will be targeted into the next more protective

available component in Figure F.5-1 during the detailed evaluation of an alternative. To further illustrate this process, Figures F.5-2 to F.5-5 show the simplified alternative-specific process for each alternative defined in Section 4.0 of the Operable Unit 5 FS. These general alternatives (e.g., alternative A, B, and C) are applied with different PRLs and WAC for each land-use objective defined in Section 2.0.

The comparison between contaminant concentrations in excavated soil and facility-specific WAC are contemplated by this FS to be conducted on a unit-volume basis instead of a total-average basis for the entire facility. Every batch of soil evaluated during the process would have contaminant concentrations lower than the WAC in order to be accepted into a disposal facility. For the preliminary volume estimation purpose, the size of each unit-volume or batch is defined as the three-dimensional model-block size used in the solid block modeling process. In general, its maximum size is equal to 125 feet by 125 feet by 1 foot (i.e., 579 yd^3). With this approach, the actual average contaminant concentrations within each facility will be much lower than the WAC.

F.5.7 REFERENCES

U. S. Department of Energy, 1989, "UMTRA Project, Remedial Action Planning and Disposal Cell Design, to Comply with the Proposed EPA Standards (40 CFR Part 192)," Section 3.2, page 8, UMTRA-DOE/AL 400503.0000.

U.S. Department of Energy, 1993, "Development and Application of the ECTran Model to Support the RI/FS at the FEMP," Fernald Environmental Management Program, Prepared by Halliburton NUS, DOE, Fernald Field Office, Cincinnati, OH.

TABLE F.5-1

SUMMARY OF HELP MODEL PARAMETERS AND RESULTING INFILTRATION RATES THROUGH THE DISPOSAL FACILITIES FOR WAC DEVELOPMENT

Parameter	Zone I	Zone II	Zone III	Zone IV	Zone V	K_{sat} (cm/sec)
Layer Thickness (ft)						
Top Soil	2.25	2.25	2.25	2.25	2.25	1.20×10^{-4}
Bio-Drain	4.5	4.5	4.5	4.5	4.5	1.00×10^{-1}
Sub-Barrier 1 (clay)	2	2	2	2	2	1.00×10^{-7}
Contaminated Soil	36.5	36.5	36.5	36.5	36.5	1.20×10^{-4}
Leachate Collection System[a]	1	1	1	1	1	1.00×10^{-1}
Sub-Barrier 2[a] (clay)	3	3	3	3	3	1.00×10^{-7}
Brown/Gray Sand					15	1.10×10^{-4}
Brown Clay/Sand	5	5	10	10	5	7.04×10^{-5}
Gray Clay	2.5	5	10	20	10	7.23×10^{-7}
Unsaturated Great Miami Aquifer	20	25	30	35	20	1.59×10^{-2}
AMC-II Runoff Curve Number	58	58	58	58	58	NA
Vegetative Cover Number	3	3	3	3	3	NA
Leaf Area Index	2	2	2	2	2	NA
Evaporative Zone Depth (in)	21	21	21	21	21	NA
Total Infiltration Rate (in/yr)[b]						
Disposal Cell	0.89	0.89	0.89	0.89	0.89	NA
Consolidation Area with Cap	0.89	0.88	0.88	0.88	0.88	NA

[a] These layers are absent in the consolidation area with cap design.
[b] Includes volume rate estimated for the leachate collection system which will be plugged.
NA = Not Applicable

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TABLE F.5-2

HYDROGEOLOGIC PARAMETERS FOR WAC DEVELOPMENT

		Disposal Facilities		
Parameters	Layer Type	On-Site Disposal Cell	Consolidation Area with Cap In Place	Consolidation Area with Earthen Cover
Porosity	Contaminated Soil	0.4	0.4	0.4
	Gray Clay	0.2	0.2	0.2
	Unsaturated GMA	0.3	0.3	0.3
	GMA	0.3	0.3	0.3
Density (gm/cm^3)	Contaminated Soil	1.78	1.78	1.78
	Gray Clay	1.78	1.78	1.78
	Unsaturated GMA	1.6	1.6	1.6
	GMA	1.6	1.6	1.6
Saturation	Contaminated Soil	0.6	0.6	0.6
	Gray Clay	0.95	0.95	0.95
	Unsaturated GMA	0.13	0.13	0.13
	GMA	1.0	1.0	1.0
Horizontal Seepage Velocity (ft/yr)	GMA	304	304	304
Vertical Hydraulic Conductivity (ft/day)	Unsaturated GMA	45	45	45

TABLE F.5-3

GEOCHEMICAL AND CHEMICAL PARAMETERS USED FOR WAC DEVELOPMENT

COC	K_t (L/kg)	Gray Clay K_d (L/kg)	UGMA K_d (L/kg)	GMA K_d (L/kg)	Half-Life (years)	Specific Activity (Ci/g)
Radionuclides						
Np-237	55	55	5	5	2.14×10^{6}	7.05×10^{-4}
Sr-90	10	10	2.5	2.5	2.86×10^{1}	1.37×10^{2}
Tc-99	30	0.118	0.07	0.07	2.13×10^{5}	1.70×10^{-2}
Total Uranium	15 or 325	3.1	1.78	1.78	4.47×10^{9}	3.36×10^{-7}
Organics						
1,2-Dichloroethane	0.156	0.156	0.0295	0.0295	1.999	NA
Carbazole	10.8	10.8	2.04	2.04	No Decay	NA
Vinylchloride	2.21×10^{-2}	2.21×10^{-2}	4.16×10^{-3}	4.16×10^{-3}	7.91×10^{0}	NA
Alpha-chlordane	3.34	3.34	0.631	0.631	No Decay	NA
Bis(2-chloroisopropyl)ether	0.699	0.699	0.132	0.132	No Decay	NA
Bromodichloromethane	0.421	0.421	0.0794	0.0794	No Decay	NA
4-Nitroaniline	0.136	0.136	0.0256	0.0256	No Decay	NA
Inorganics						
Boron	3	3	3	3	No Decay	NA
Chromium vi	37	37	3.7	3.7	No Decay	NA
Magnesium	4.5	4.5	4.5	4.5	No Decay	NA
Mercury	10	10	10	10	No Decay	NA

NA = Not Applicable

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TABLE F.5-4
EXPOSURE CRITERIA (MEDIA-SPECIFIC PRGs) USED FOR WAC DEVELOPMENT

COC	Unit	Risk-Based GMA PRG ILCR 10^{-6}	Risk-Based GMA PRG ILCR 10^{-5}	Risk-Based GMA PRG ILCR 10^{-4}	Unit	HQ = 0.2	Unit	MCL
Radionuclides:								
Np-237 + 1D	pCi/L	7.83×10^{-2}	7.83×10^{-1}	7.83×10^{0}	NA	NA	NA	NA
Sr-90 + 1D	pCi/L	3.09×10^{-1}	3.09×10^{0}	3.09×10^{1}	NA	NA	NA	NA
Tc-99	pCi/L	7.23×10^{0}	7.23×10^{1}	7.23×10^{2}	NA	NA	NA	NA
Uranium-238	pCi/L	8.63×10^{-1}	8.63×10^{0}	8.63×10^{1}	μg/L	1.77×10^{1}	μg/L	2.00×10^{1}
Organics:								
1,2-Dichloroethane	μg/L	7.86×10^{-2}	7.86×10^{-1}	7.86×10^{0}	NA	NA	μg/L	5.00×10^{0}
Carbazole	μg/L	1.14×10^{0}	1.14×10^{1}	1.14×10^{2}	NA	NA	NA	NA
Vinyl chloride	μg/L	1.03×10^{-2}	1.03×10^{-1}	1.03×10^{0}	NA	NA	μg/L	2.00×10^{0}
Bis(2-chloroisopropyl)ether	μg/L	1.63×10^{-1}	1.63×10^{0}	1.63×10^{1}	NA	NA	NA	NA
Alpha-chlordane[a]	μg/L	4.51×10^{-3}	4.51×10^{-2}	7.03×10^{-2}	μg/L	7.03×10^{-2}	μg/L	2.00×10^{0}
Bromodichloromethane	μg/L	4.01×10^{-1}	4.01×10^{0}	4.01×10^{1}	NA	NA	μg/L	1.00×10^{2}
4-Nitroaniline	NA	NA	NA	NA	μg/L	1.52×10^{1}	NA	NA
Inorganics:								
Boron	NA	NA	NA	NA	μg/L	3.26×10^{2}	NA	NA
Magnesium	NA	NA	NA	NA	μg/L	3.52×10^{4}	NA	NA
Mercury	NA	NA	NA	NA	μg/L	1.58×10^{-1}	μg/L	2.00×10^{0}
Chromium (VI)	NA	NA	NA	NA	μg/L	2.22×10^{1}	NA	NA

[a] PRG and MCL of chlordane are used
NA = Not Applicable

TABLE F.5-5

SUMMARY OF DISPOSAL OPTION LAYER THICKNESS

Disposal Option	Waste Thickness (ft)	Liner Thickness (ft)	Gray Clay Thickness (ft)	Unsaturated GMA (ft)	Mixing Depth in GMA (ft)
Consolidation with Earthen Cover	30	NA	22	20	30
Disposal Cell	40	3	22	20	10
Consolidation with Cap	40	NA	22	20	10

NA = Not Applicable

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TABLE F.5-6
WAC FOR CONSOLIDATION AREA WITH EARTHEN COVER

Constituent of Concern	Unit	Protective Levels				
		ILCR 10^{-6}	ILCR 10^{-5}	ILCR 10^{-4}	HQ = 0.2	MCL
Radionuclide:						
Np-237 + 1D	pCi/g	2.99×10^{1}	2.99×10^{2}	2.99×10^{3}	NA	NA
Sr-90 + 1D	pCi/g	8.55×10^{3}	8.55×10^{4}	8.55×10^{5}	NA	NA
Tc-99	pCi/g	1.47×10^{0}	1.47×10^{1}	1.47×10^{2}	NA	NA
Total Uranium (K_l=325 L/kg)	mg/kg	5.68×10^{0}	5.68×10^{1}	5.68×10^{2}	1.96×10^{2} [a]	4.42×10^{1}
Total Uranium (K_l=15 L/kg)	mg/kg	2.62×10^{-1}	2.62×10^{0}	2.62×10^{1}	9.03×10^{0} [a]	2.04×10^{0}
Organic:						
1,2 - Dichloroethane	mg/kg	9.20×10^{1}	9.20×10^{2}	9.20×10^{3}	NA	5.85×10^{3}
Carbazole	mg/kg	1.80×10^{-1}	1.80×10^{0}	1.80×10^{1}	NA	NA
Vinyl chloride	mg/kg	9.55×10^{-5}	9.55×10^{-4}	9.55×10^{-3}	NA	1.85×10^{-2}
Bis(2-chloroisopropyl)ether	mg/kg	1.42×10^{-3}	1.42×10^{-2}	1.42×10^{-1}	NA	NA
Alpha - chlordane	mg/kg	1.80×10^{-4}	1.80×10^{-3}	2.81×10^{-3}	2.81×10^{-3}	7.98×10^{-2}
Bromodichloromethane	mg/kg	2.13×10^{-3}	2.13×10^{-2}	2.13×10^{-1}	NA	5.31×10^{-1}
4 - Nitroaniline	mg/kg	NA	NA	NA	2.80×10^{-2}	NA
Inorganic:						
Boron	mg/kg	NA	NA	NA	1.57×10^{1}	NA
Magnesium	mg/kg	NA	NA	NA	2.53×10^{3}	NA
Mercury	mg/kg	NA	NA	NA	5.54×10^{-2}	7.01×10^{-1}
Chromium vi	mg/kg	NA	NA	NA	6.81×10^{2}	NA

[a] HQ = 1.0
NA - Not Applicable

TABLE F.5-7
WAC FOR CONSOLIDATION AREA WITH CAP

Constituent of Concern	Unit	Protective Levels				
		ILCR 10^{-6}	ILCR 10^{-5}	ILCR 10^{-4}	HQ=0.2	MCL
Radionuclide:						
Np-237 + 1D	pCi/g	1.06×10^{7}	1.06×10^{8}	1.06×10^{9}	NA	NA
Sr-90 + 1D	pCi/g	3.04×10^{8}	3.04×10^{9}	3.04×10^{10}	NA	NA
Tc-99	pCi/g	2.91×10^{0}	2.91×10^{1}	2.91×10^{2}	NA	NA
Total Uranium (K_l = 325 L/kg)	mg/kg	2.92×10^{2}	2.92×10^{3}	2.92×10^{4}	1.04×10^{4} [a]	2.27×10^{3}
Total Uranium (K_l = 15 L/kg)	mg/kg	1.35×10^{1}	1.35×10^{2}	1.35×10^{3}	4.64×10^{2} [a]	1.05×10^{2}
Organics:						
1,2-Dichloroethane	mg/kg	*	*	*	NA	*
Carbazole	mg/kg	1.22×10^{3}	1.22×10^{4}	1.22×10^{5}	NA	NA
Vinyl Chloride	mg/kg	4.21×10^{-3}	4.21×10^{-2}	4.21×10^{-1}	NA	8.17×10^{-1}
Bis(2-chloroisopropyl)ether	mg/kg	2.44×10^{-3}	2.44×10^{-2}	2.44×10^{-1}	NA	NA
Alpha-Chlordane	mg/kg	3.12×10^{-3}	3.12×10^{-2}	4.87×10^{-2}	4.87×10^{-2}	1.38×10^{0}
Bromodichloromethane	mg/kg	3.57×10^{-3}	3.57×10^{-2}	3.57×10^{-1}	NA	8.90×10^{-1}
4-Nitroaniline	mg/kg	NA	NA	NA	4.37×10^{-2}	NA
Inorganics:						
Boron	mg/kg	NA	NA	NA	5.11×10^{2}	NA
Chromium vi	mg/kg	NA	NA	NA	*	NA
Magnesium	mg/kg	NA	NA	NA	6.08×10^{5}	NA
Mercury	mg/kg	NA	NA	NA	7.68×10^{2}	9.72×10^{3}

[a] HQ = 1.0
NA = Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

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TABLE F.5-8

WAC FOR DISPOSAL CELL

Constituent of Concern	Unit	Protective Levels				
		ILCR 10^{-4}	ILCR 10^{-5}	ILCR 10^{-6}	HQ=0.2	MCL
Radionuclide						
Np-237 + 1D	pCi/g	3.12×10^{10}	3.12×10^{9}	3.12×10^{8}	NA	NA
Sr-90 + 1D	pCi/g	5.67×10^{11}	5.67×10^{10}	5.67×10^{9}	NA	NA
Tc-99	pCi/g	2.91×10^{2}	2.91×10^{1}	2.91×10^{0}	NA	NA
Total Uranium (K_d = 325 L/kg)	mg/kg	2.87×10^{5}	2.87×10^{4}	2.87×10^{3}	9.91×10^{4} [a]	2.24×10^{4}
Total Uranium (K_d = 15 L/kg)	mg/kg	1.33×10^{4}	1.33×10^{3}	1.33×10^{2}	4.57×10^{3} [a]	1.03×10^{3}
Organics						
1,2-Dichloroethane	mg/kg	*	*	*	NA	*
Carbazole	mg/kg	7.27×10^{5}	7.27×10^{4}	7.27×10^{3}	NA	NA
Vinyl Chloride	mg/kg	7.79×10^{-1}	7.79×10^{-2}	7.79×10^{-3}	NA	1.51×10^{0}
Bis(2-chloroisopropyl)ether	mg/kg	2.44×10^{-1}	2.44×10^{-2}	2.44×10^{-3}	NA	NA
Alpha-Chlordane	mg/kg	1.02×10^{-1}	6.51×10^{-2}	6.51×10^{-3}	1.02×10^{-1}	2.89×10^{0}
Bromodichloromethane	mg/kg	3.62×10^{-1}	3.62×10^{-2}	3.62×10^{-3}	NA	9.03×10^{-1}
4-Nitroaniline	mg/kg	NA	NA	NA	4.42×10^{-2}	NA
Inorganics						
Boron	mg/kg	NA	NA	NA	1.04×10^{3}	NA
Chromium vi	mg/kg	NA	NA	NA	*	NA
Magnesium	mg/kg	NA	NA	NA	*	NA
Mercury	mg/kg	NA	NA	NA	4.47×10^{3}	5.66×10^{4}

[a] HQ = 1.0
NA = Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5-9

SENSITIVITY ANALYSIS ON URANIUM WAC FOR DISPOSAL CELL - LINER THICKNESS

Liner Thickness (ft)	3 (1 sublayer)	6 (2 sublayers)	9 (3 sublayers)
WAC (pCi/L)	2.32×10^4	2.67×10^5	3.46×10^6
WAC (mg/kg) (K_l = 325 L/kg)	2.24×10^4	2.58×10^5	3.35×10^6
WAC (mg/kg) (K_l = 15 L/kg)	1.03×10^3	1.19×10^4	1.55×10^5

Protective Level: MCL, Exposure Point: Great Miami Aquifer
Infiltration Rate: 0.89 in/yr
Cell Size: 1000 ft x 1000 ft
Gray Clay Thickness: 22 ft, K_d: 3.1 L/kg
Sand Layer Thickness: 20 ft, K_d: 1.78 L/kg
Liner K_d: 24 L/kg, Each Liner Thickness: 3 ft

TABLE F.5-10

SENSITIVITY ANALYSIS ON URANIUM WAC FOR DISPOSAL CELL - WITHOUT GRAY CLAY LAYER

		Uranium WAC (mg/kg) with K_l = 15 L/kg			
Exposure Point	Without Liner	1 Liner (3 ft)	2 Liners (6 ft)	3 Liners (9 ft)	4 Liners (12 ft)
Great Miami Aquifer	1.27×10^2	4.59×10^2	2.32×10^3	1.57×10^4	1.30×10^5
Fence Line	1.56×10^2	6.10×10^2	3.32×10^3	2.42×10^4	2.17×10^5

Protective Level: MCL
Infiltration Rate: 0.89 in/yr
Cell Size: 1000 ft x 1000 ft
Sand Layer thickness = 20 ft, K_d: 1.78 L/kg
Liner K_d: 24 L/kg, Each Liner Thickness: 3 ft

TABLE F.5-11

SENSITIVITY ANALYSIS ON URANIUM WAC FOR DISPOSAL CELL - WITHOUT BOTH GRAY CLAY LAYER AND UNSATURATED GREAT MIAMI AQUIFER SAND LAYER

	Uranium WAC (mg/kg) with K_d = 15 L/kg				
Exposure Point	1 Liner (3 ft)	2 Liners (6 ft)	3 Liners (9 ft)	4 Liners (12 ft)	5 Liners (15 ft)
Great Miami Aquifer	2.06×10^2	7.90×10^2	4.26×10^3	2.93×10^4	2.45×10^5
Fence Line	2.57×10^2	1.06×10^3	6.13×10^3	4.55×10^4	4.08×10^5

Protective Level: MCL
Infiltration Rate: 0.89 in/yr
Cell Size: 1000 ft x 1000 ft
Liner K_d: 24 L/kg, Each Liner Thickness: 3 ft

TABLE F.5-12

SENSITIVITY ANALYSIS ON URANIUM WAC FOR DISPOSAL CELL TO INFILTRATION RATES

Infiltration Rate (in/yr)	0.40	0.89	1.00	1.50	2.00	2.50	3.00	3.50	4.00
WAC (pCi/L)	7.53×10^{6}	2.32×10^{4}	1.11×10^{4}	1.11×10^{3}	2.94×10^{2}	1.27×10^{2}	7.42×10^{1}	4.94×10^{1}	3.73×10^{1}
WAC (mg/kg) (K_l = 325 L/kg)	7.29×10^{6}	2.24×10^{4}	1.07×10^{4}	1.07×10^{3}	2.84×10^{2}	1.23×10^{2}	7.01×10^{1}	4.77×10^{1}	3.61×10^{1}
WAC (mg/kg) (K_l = 15 L/kg)	3.36×10^{5}	1.03×10^{3}	4.94×10^{2}	4.94×10^{2}	1.31×10^{1}	5.66×10^{0}	3.23×10^{0}	2.20×10^{0}	1.67×10^{0}

Protective Level: MCL, Exposure Point: Great Miami Aquifer
Cell Size: 1000 ft by 1000 ft
Gray Clay Thickness: 22 ft, K_d: 3.1 L/kg
Sand Layer Thickness: 20 ft, K_d: 1.78L/kg
Liner Thickness: 3 ft, K_d: 24 L/kg

TABLE F.5-13

SUMMARY OF HELP MODEL PARAMETERS AND RESULTING INFILTRATION RATES THROUGH THE DISPOSAL FACILITIES FOR LONG-TERM PERFORMANCE EVALUATION

Parameter	Case 1[a]	Case 2[b]	Case 3[c]	K_{sat} (cm/sec)
Layer Thickness (ft)				
Top Soil	2.25	2.25	2.25	1.20×10^{-4}
Bio-Drain	4.5	4.5	4.5	1.00×10^{-1}
Bentonite Geocomposite	0.08	NA	NA	2.00×10^{-9}
Sub-Barrier 1 (clay)	2	2	2	1.00×10^{-7} [d]
Contaminated Soil	36.5	36.5	36.5	1.20×10^{-4}
Leachate collection system	1	1	1	1.00×10^{-1}
Sub-Barrier 2 (clay)	3	3	3	1.00×10^{-7}
Brown Clay/Sand	10	10	10	7.04×10^{-5}
Gray Clay	15	15	15	7.23×10^{-7}
Unsaturated Great Miami Aquifer	30	30	30	1.59×10^{-2}
AMC-II Runoff Curve Number	58	58	58	
Vegetative Cover Number	3	3	3	
Leaf Area Index	2	2	2	
Evaporative Zone Depth (in)	21	21	21	
Total Infiltration Rate (in/yr)[e]	0.04	0.89	8.70	

[a] Case 1 - Disposal cell with failure of geotextile fabric, HDPE membrane layer, and bottom leachate collection system.
[b] Case 2 - Disposal cell with additional failure of the Bentonite Geocomposite layer.
[c] Case 3 - Disposal cell with additional failure of sub-barrier 1 (clay).
[d] Hydraulic conductivity for Case 3 is increased to 7.04×10^{-5} cm/sec for sub-barrier 1.
[e] Including volume rate estimated for the leachate collection system which will be plugged.

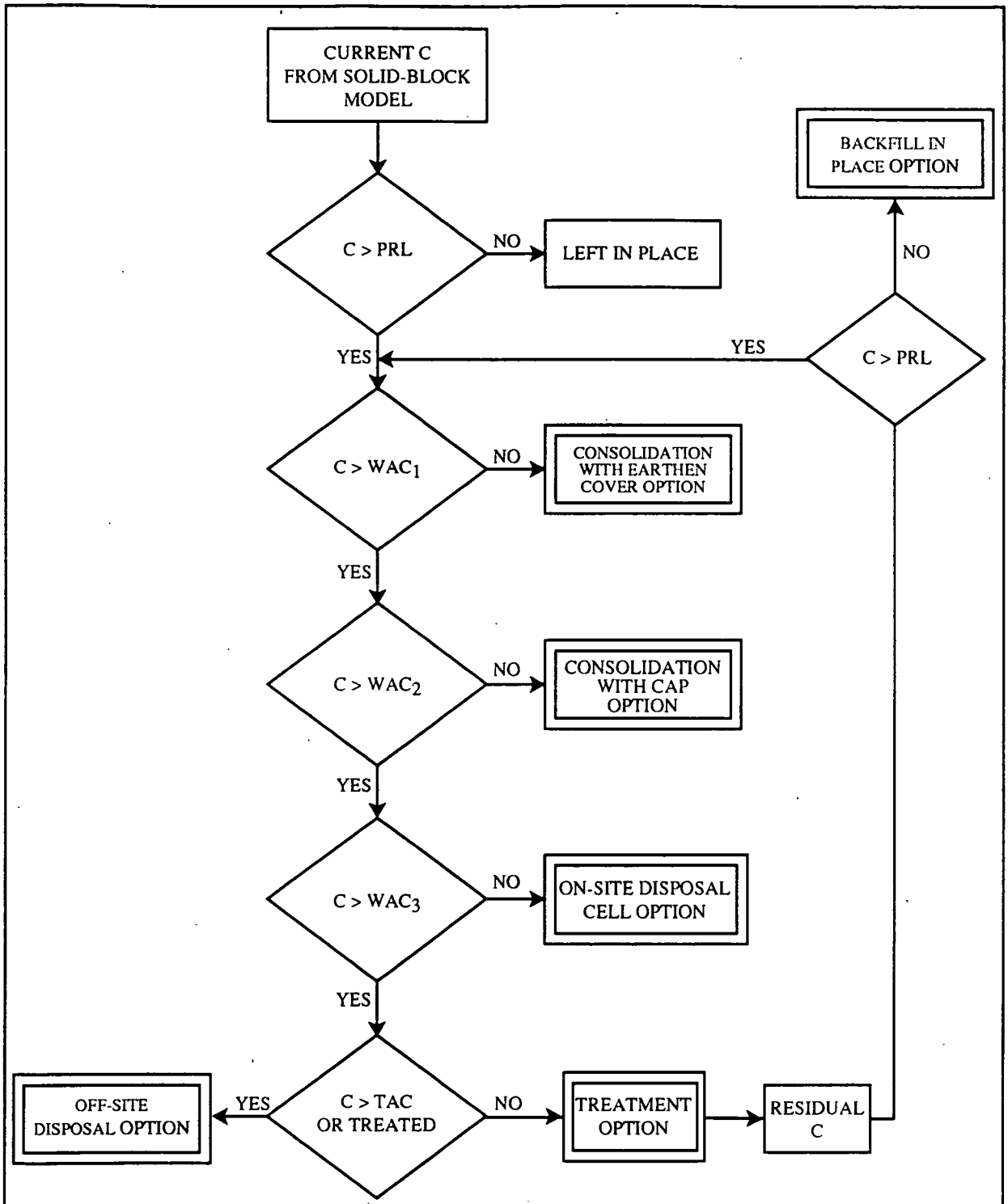
TABLE F.5-14

SUMMARY OF MONTE CARLO SIMULATIONS FOR CONCEPTUAL LONG-TERM PERFORMANCE EVALUATION OF THE DISPOSAL CELL

Assumptions in Monte Carlo Simulation				Monte Carlo Simulation Results			
Time 1		Time 2		Mean GMA Concentration at 1000 yr (μg/L)	Percentile of the GMA concentration at 1000 yr less than 20 (μg/L)	100% chance of the GMA concentration at 500 yr less than the following value (μg/L)	100% chance of the GMA concentration at 200 yr less than the following value (μg/L)
Mean (yr)	Standard Dev. (yr)	Mean (yr)	Standard Dev. (yr)				
200	50	600	200	20.04	64%	2.40	0.00
200	50	700	200	11.77	81%	1.52	0.00
200	50	800	200	7.30	88%	0.91	0.00

Disposal Cell Size: 1500 ft by 1500 ft
Liner Thickness: 3 ft, Liner K_d = 24 L/kg
Gray Clay Thickness = 30 ft, Gray Clay K_d = 3.1 L/kg
Sand Layer Thickness = 20 ft, Sand K_d = 1.78 L/kg
Constant Source Leachate Concentration = 6670 μg/L
Infiltration Rate Assumption:

0.04 in/yr from 0 to Time 1, 0.89 in/yr from Time 1 to Time 2, and 3.0 in/yr from Time 2 to 1000 yr where Time 1 and Time 2 are the time point when a certain capping material fails as shown in Figure F.5-14.



C: CURRENT OR TREATED CONTAMINANT CONCENTRATION IN SOIL (OR SOIL LEACHATE)
PRL: PRELIMINARY REMEDIAL LEVEL
WAC_1: WASTE ACCEPTANCE CRITERIA FOR CONSOLIDATION WITH EARTHEN COVER
WAC_2: WASTE ACCEPTANCE CRITERIA FOR CONSOLIDATION WITH CAP
WAC_3: WASTE ACCEPTANCE CRITERIA FOR DISPOSAL CELL
TAC: TREATMENT ACCEPTANCE CRITERIA

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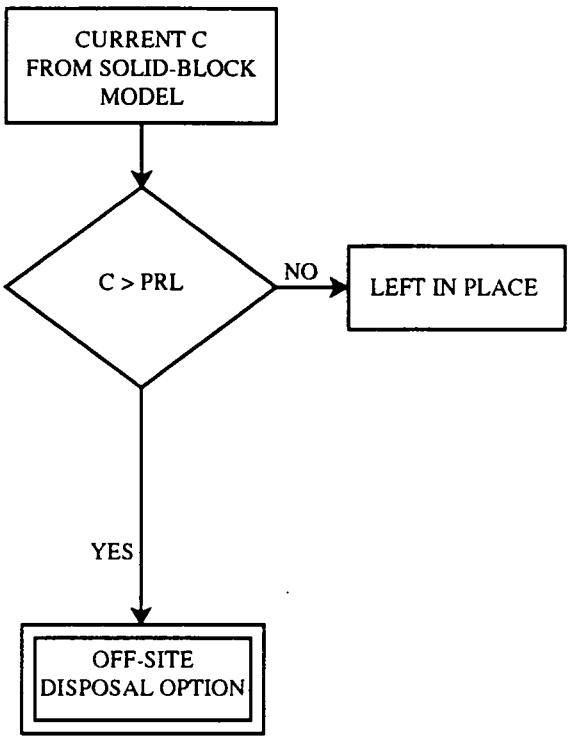
"ILLUS\OU-5\PO-113\F.5-SOIL VOL EST.EPS

FIGURE F.5-1. GENERAL SOIL DISPOSAL VOLUME ESTIMATION PROCESS



C:	CURRENT OR TREATED CONTAMINANT CONCENTRATION IN SOIL (OR SOIL LEACHATE)
PRL:	PRELIMINARY REMEDIAL LEVEL (PRG OR CPRG)

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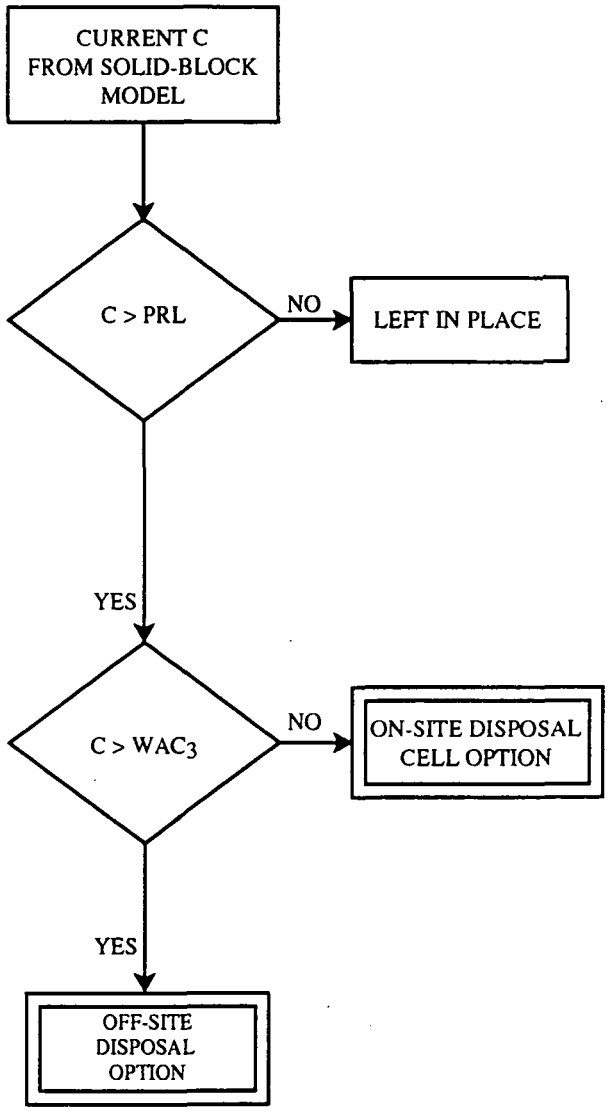
FIGURE F.5-2. SOIL VOLUME ESTIMATION PROCESS FOR THE PRELIMINARY DESIGN OF REMEDIAL ALTERNATIVE FOR LAND USE SCENARIO 1



C:	CURRENT OR TREATED CONTAMINANT CONCENTRATION IN SOIL (OR SOIL LEACHATE)
PRL:	PRELIMINARY REMEDIAL LEVEL
WAC_3:	WASTE ACCEPTANCE CRITERIA FOR DISPOSAL CELL

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FIGURE F.5-3. SOIL DISPOSAL VOLUME ESTIMATION PROCESS FOR ALTERNATIVE A

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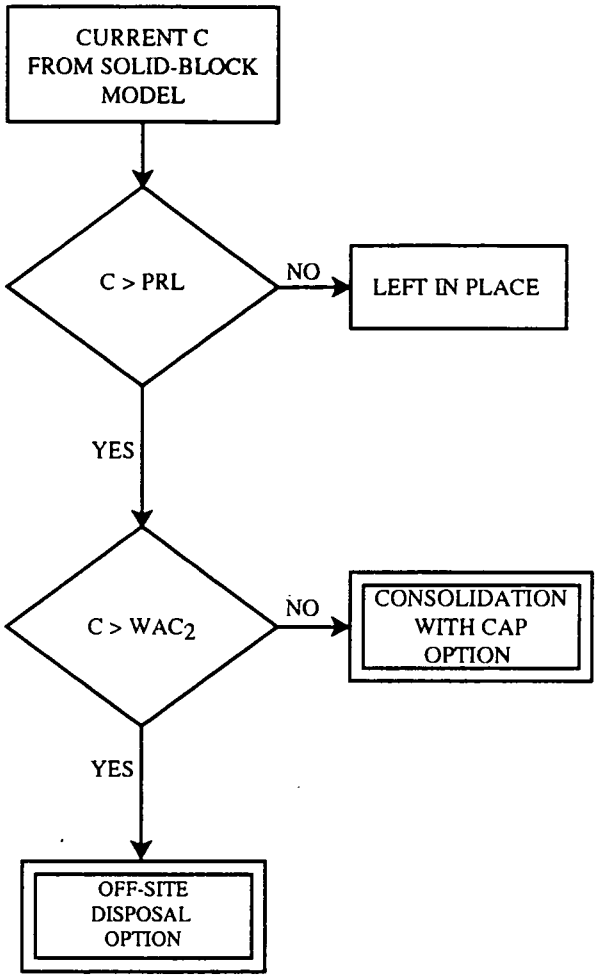

C:	CURRENT OR TREATED CONTAMINANT CONCENTRATION IN SOIL (OR SOIL LEACHATE)
PRL:	PRELIMINARY REMEDIAL LEVEL
WAC_2:	WASTE ACCEPTANCE CRITERIA FOR CONSOLIDATION WITH CAP

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FIGURE F.5-4. SOIL DISPOSAL VOLUME ESTIMATION PROCESS FOR ALTERNATIVE B

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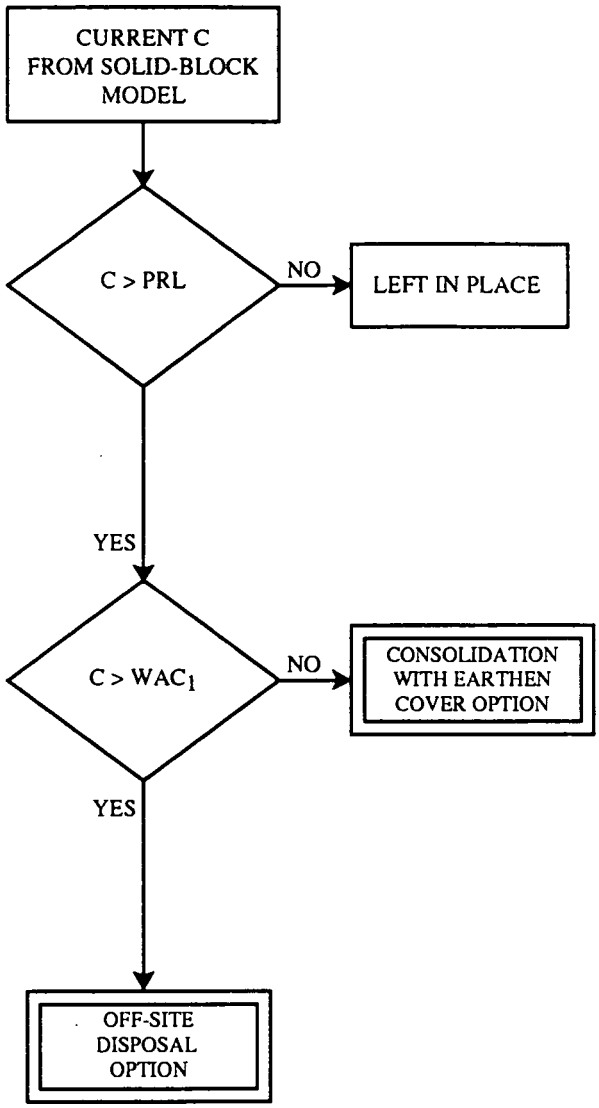

C:	CURRENT OR TREATED CONTAMINANT CONCENTRATION IN SOIL (OR SOIL LEACHATE)
PRL:	PRELIMINARY REMEDIAL LEVEL
WAC_1:	WASTE ACCEPTANCE CRITERIA FOR CONSOLIDATION WITH EARTHEN COVER

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FIGURE F.5-5. SOIL DISPOSAL VOLUME ESTIMATION PROCESS FOR ALTERNATIVE C

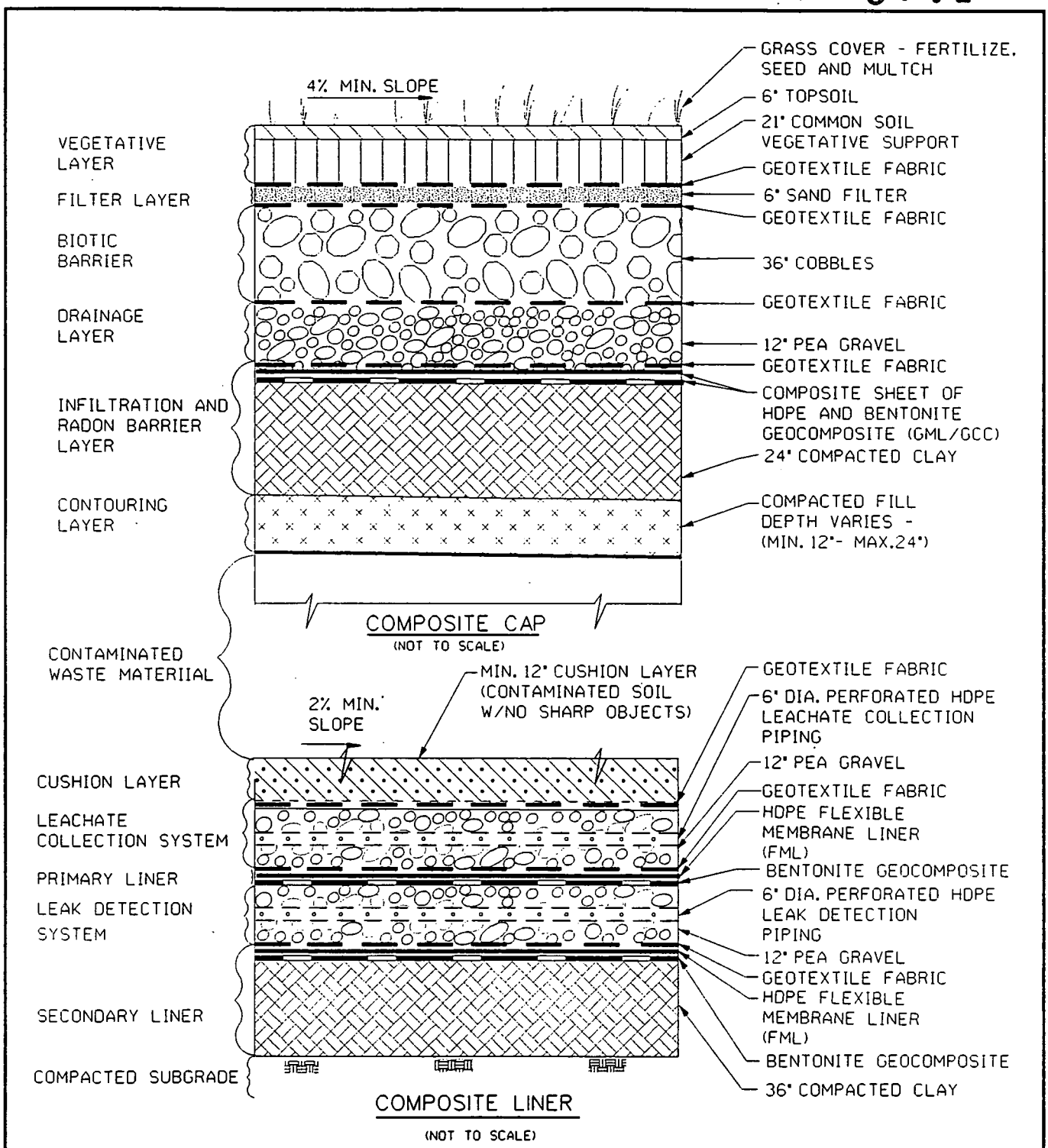

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FIGURE F.5-6. - TYPICAL DETAIL COMPOSITE CAP AND LINER

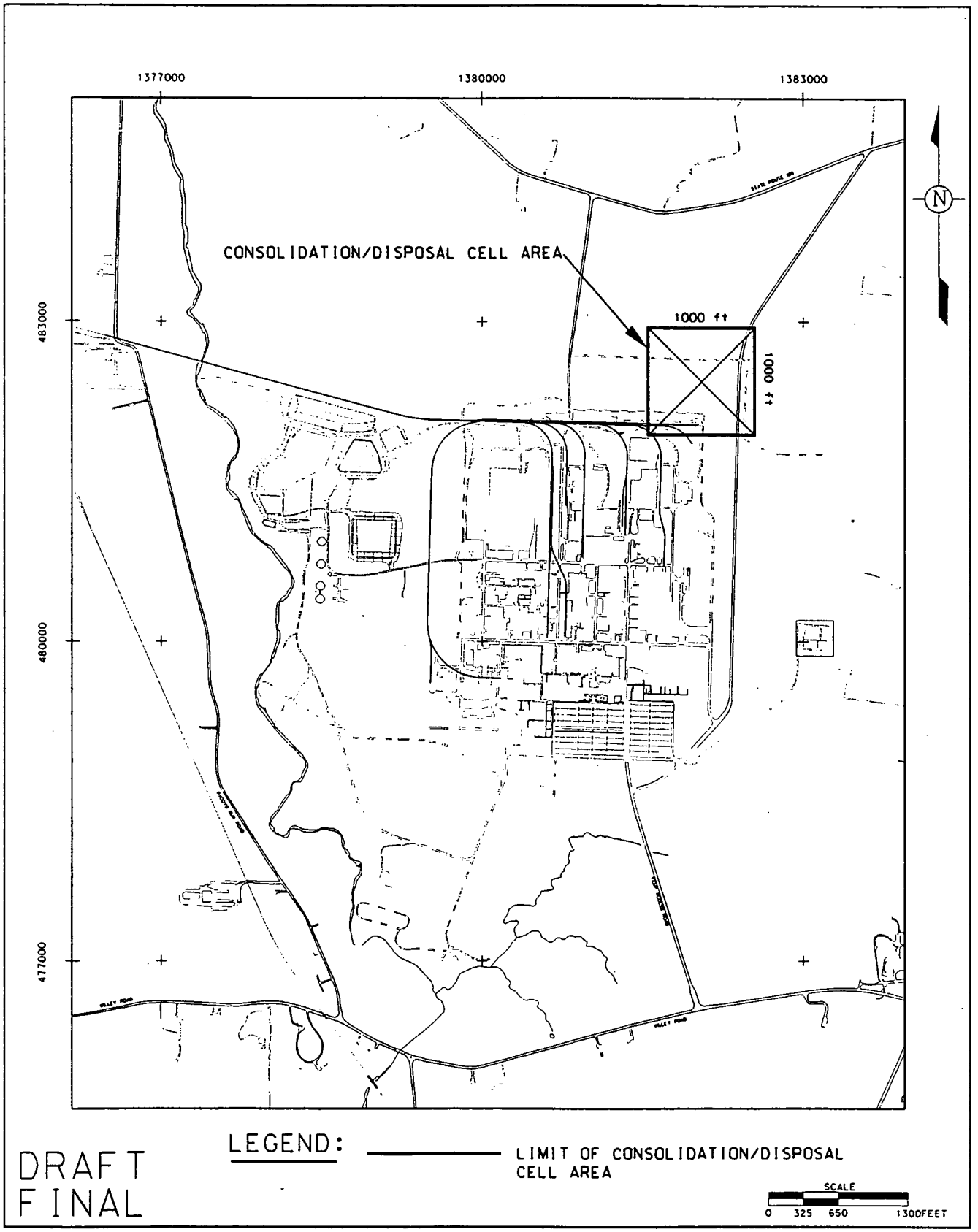

FIGURE F.5-7. FOOTPRINT OF CONSOLIDATION/ DISPOSAL CELL AREA USED FOR WAC DEVELOPMENT

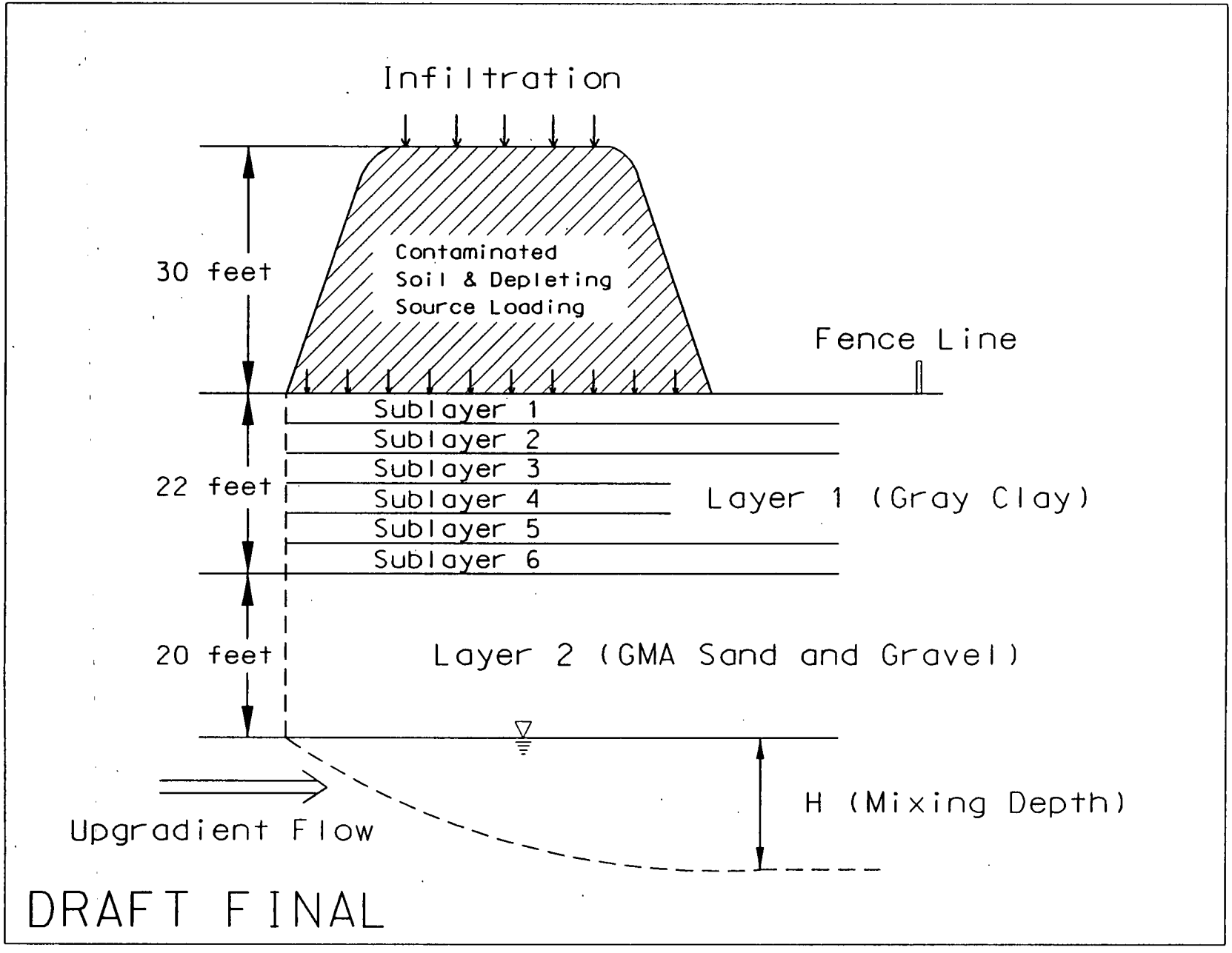

FIGURE F.5-8. CONCEPTUAL MODEL OF CONSOLIDATION AREA WITH EARTHEN COVER

P0113/SKX0381.DGN

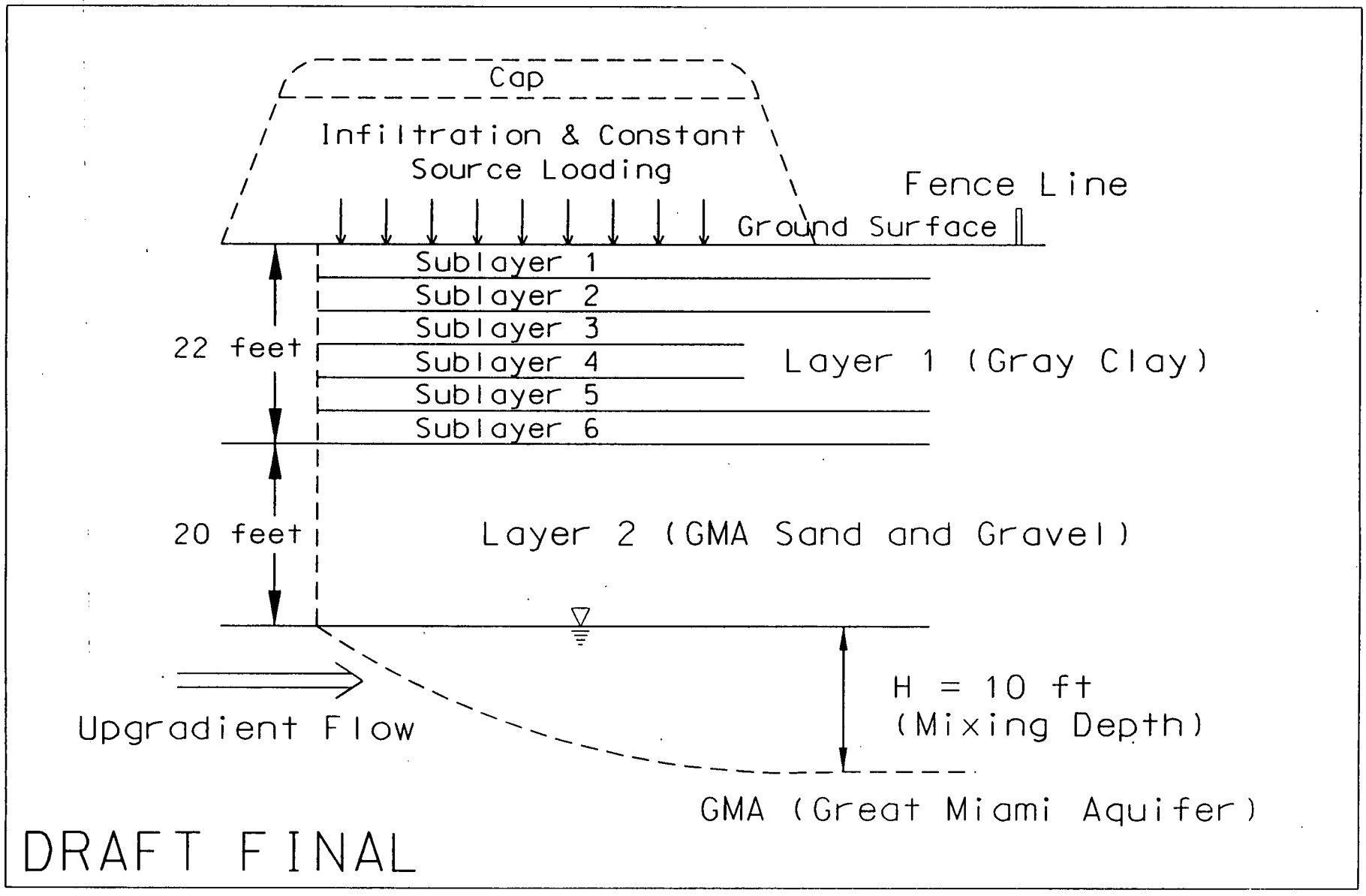

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FIGURE F.5-9. CONCEPTUAL MODEL OF CONSOLIDATION AREA WITH CAP

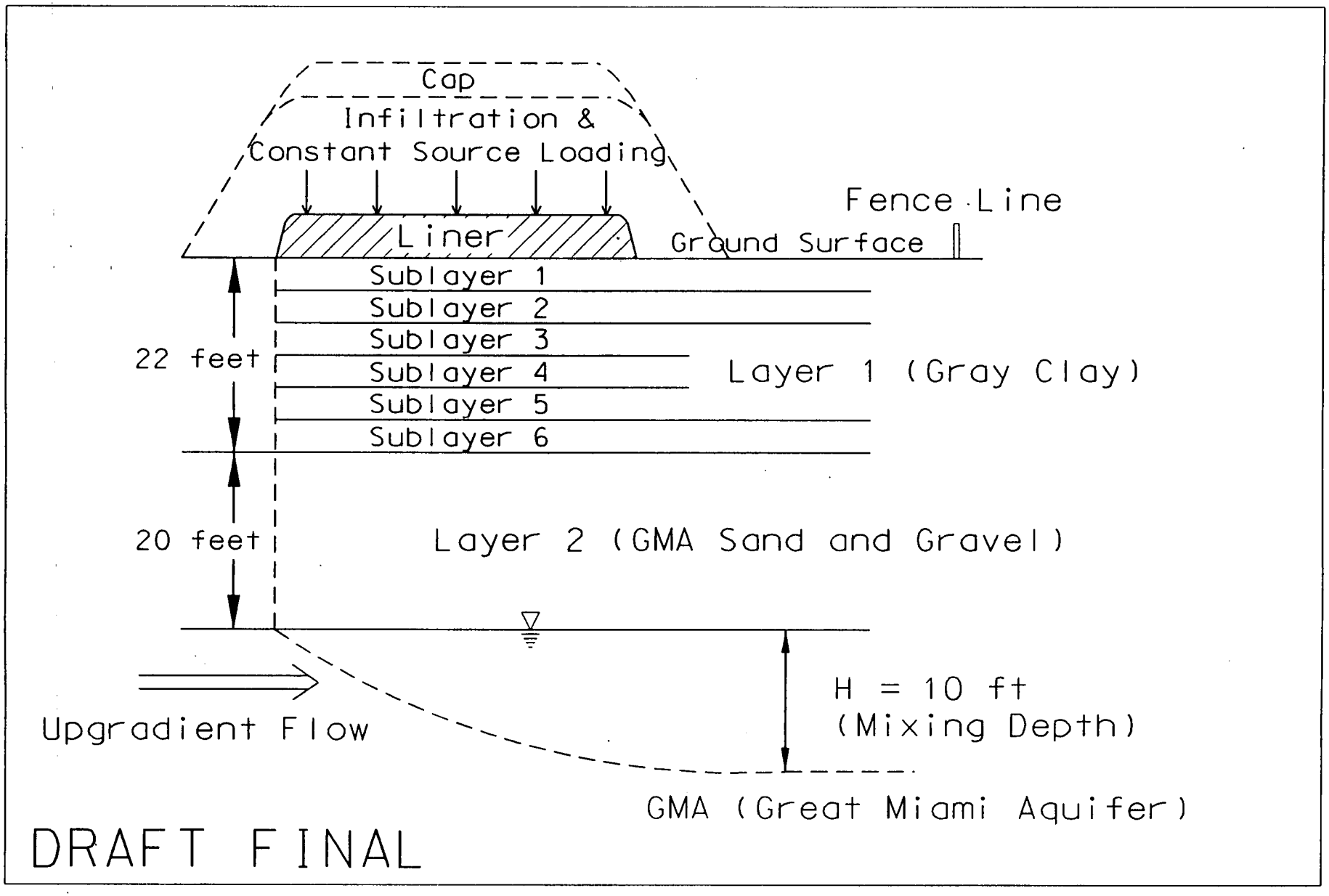
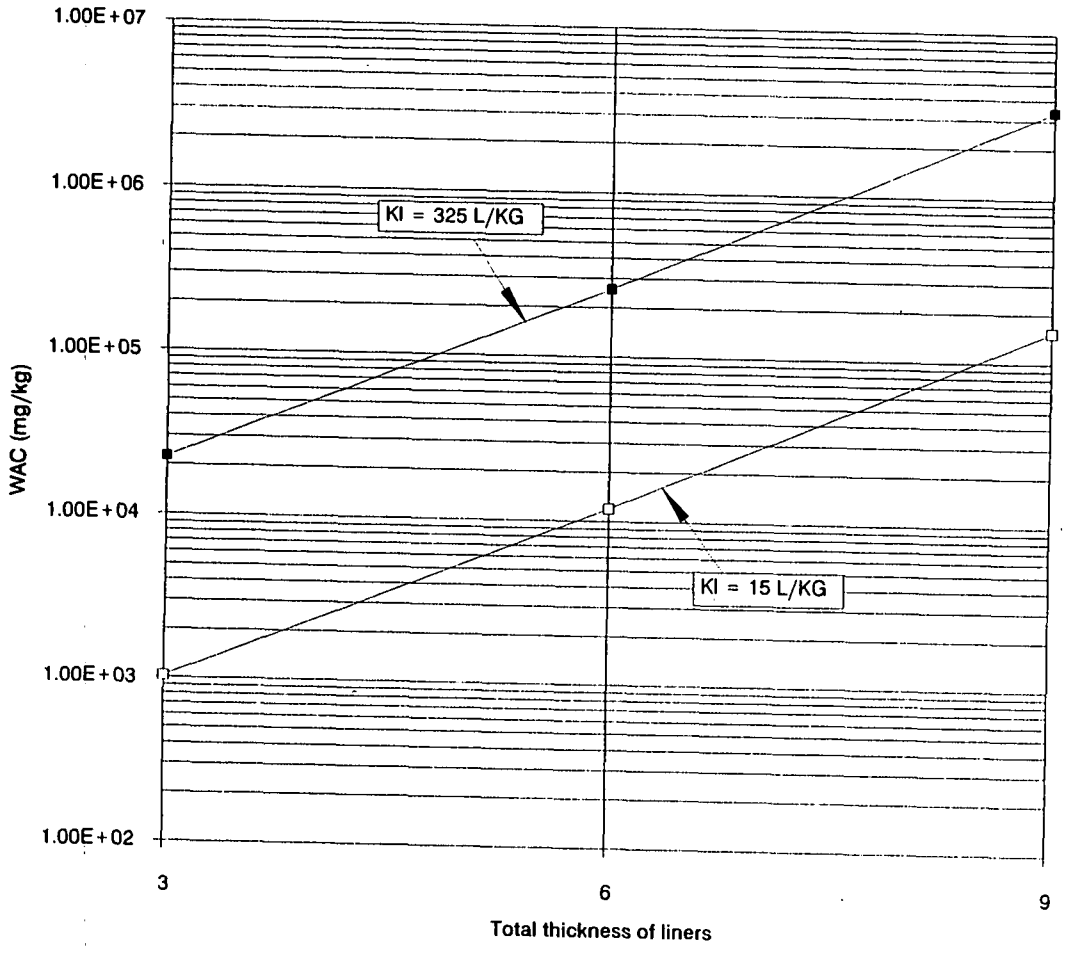


FIGURE F.5-10. CONCEPTUAL MODEL OF ON-SITE DISPOSAL CELL



Protective Level : MCL, Exposure Point: GMA

Infiltration Rate = 0.89 in/yr

Liner Kd = 24 L/KG, Each Liner Thickness = 3 ft

Gray Clay Thickness = 22 ft, Kd = 3.1 L/KG

Sand Layer Thickness = 20 ft, Kd = 1.78 L/KG

Cell size : 1000 ft x 1000 ft

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FIGURE F.5-11 - RELATIONSHIP BETWEEN WACs AND LINER THICKNESS

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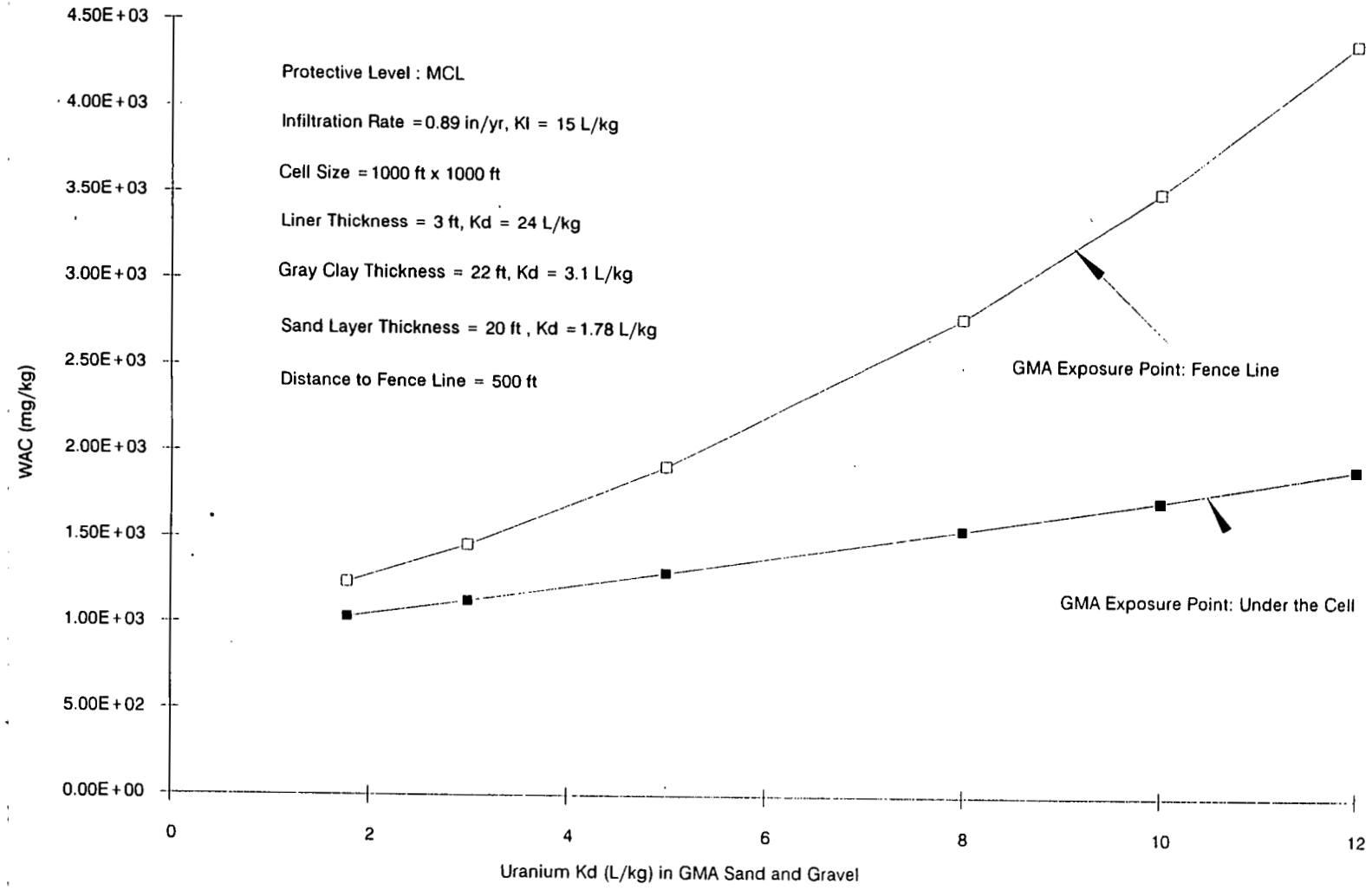

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FIGURE F.5-12 - SENSITIVITY OF WAC FOR DISPOSAL CELL TO EXPOSURE POINT LOCATION AND URANIUM K_d VALUES FOR THE GREAT MIAMI AQUIFER

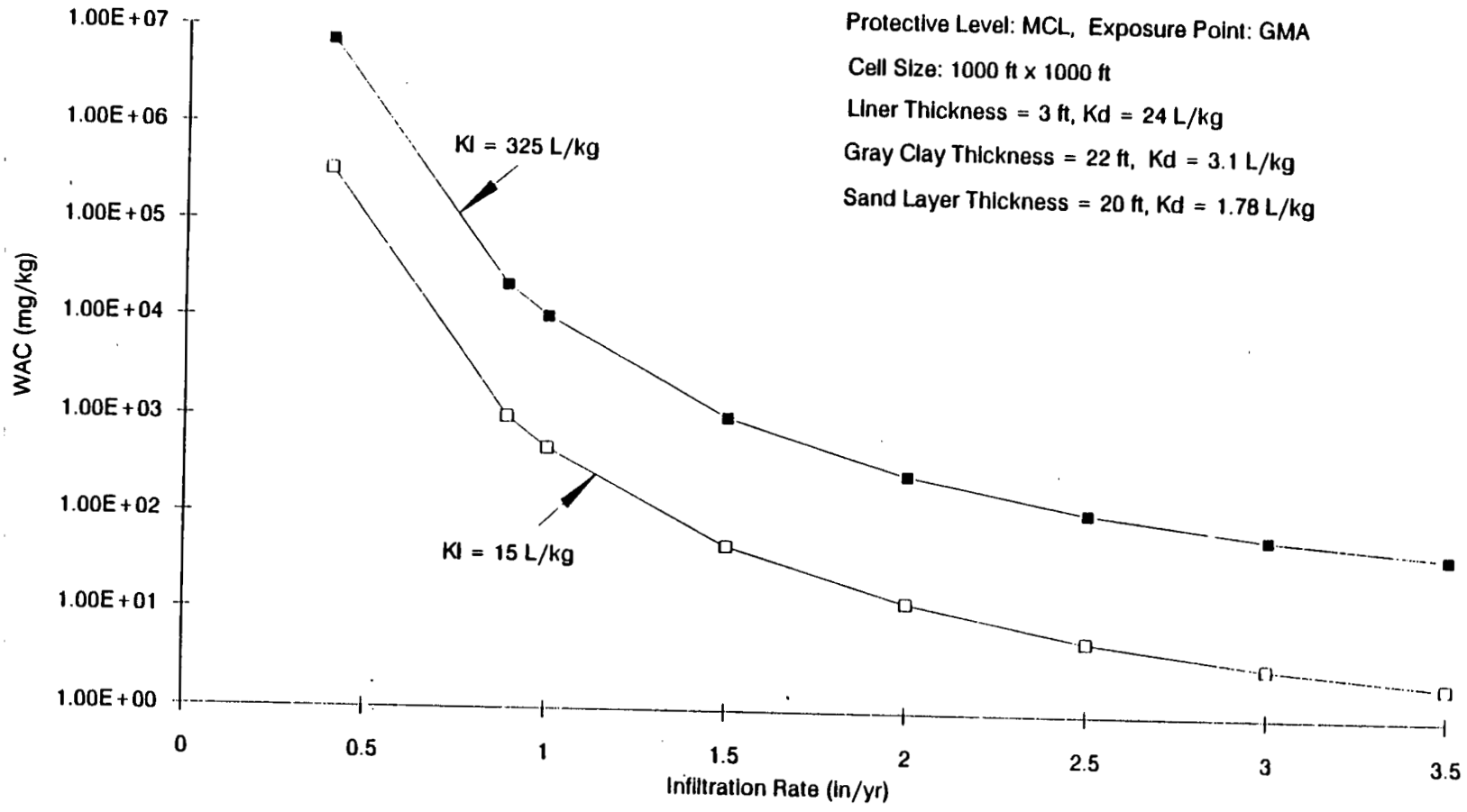

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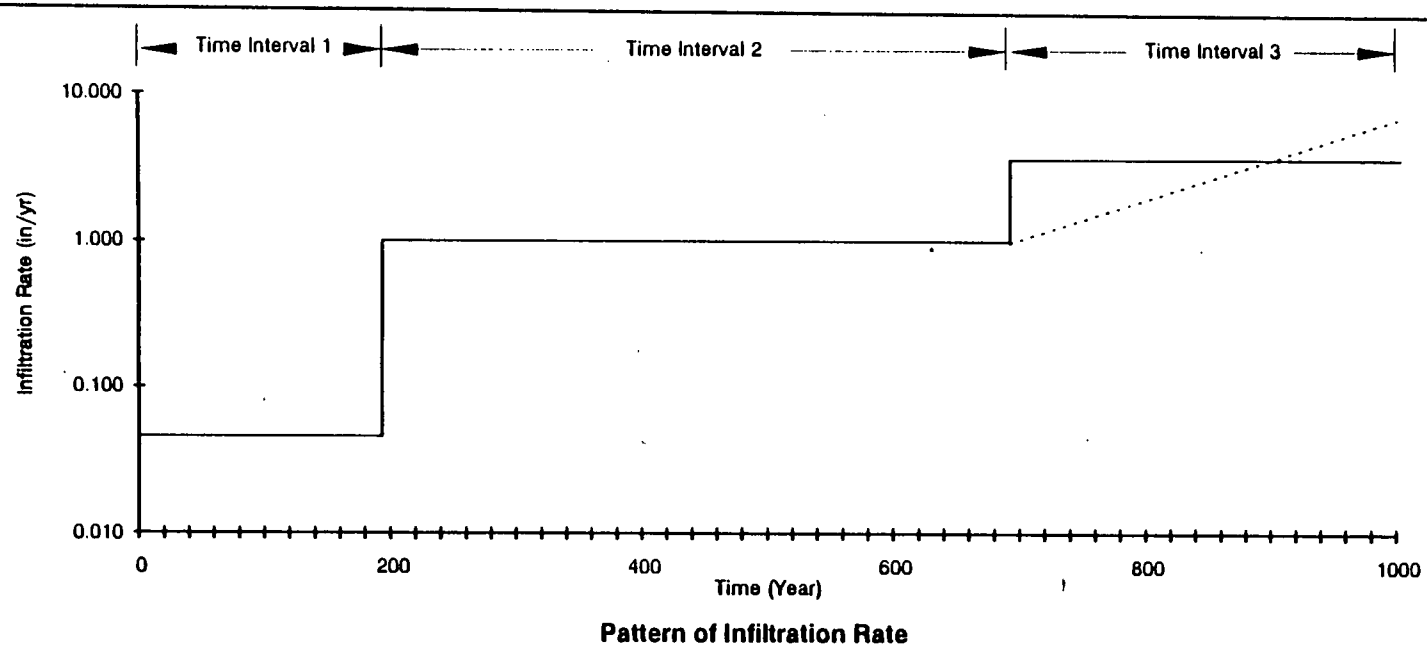
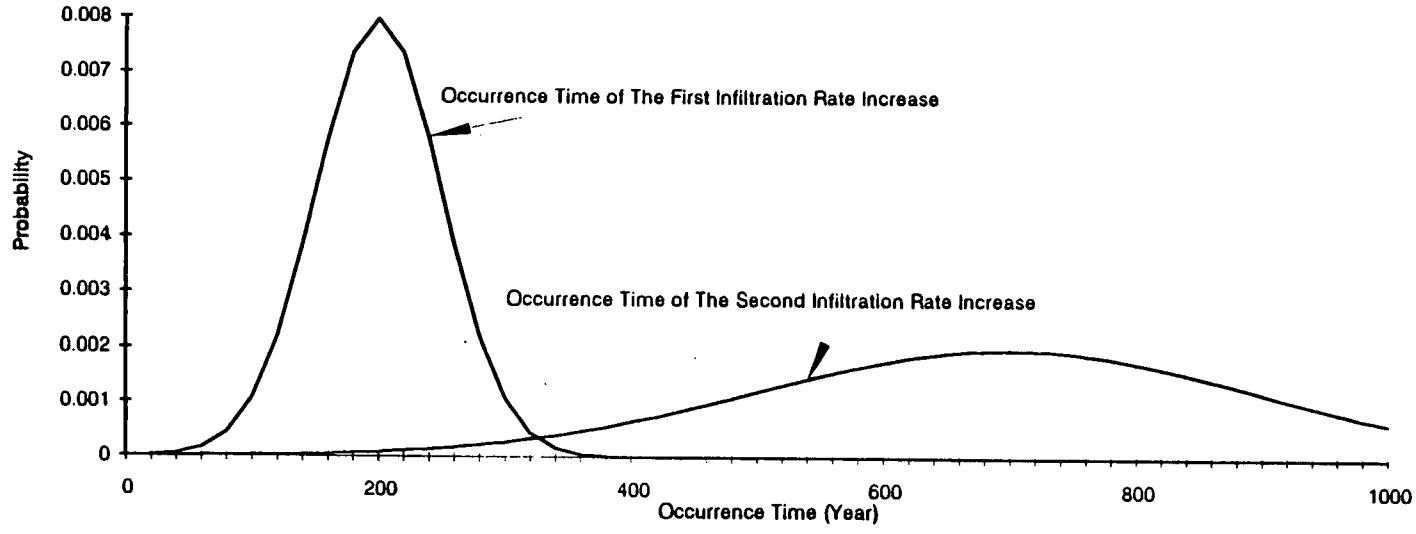
FIGURE F.5-13 - SENSITIVITY ANALYSIS ON WAC FOR DISPOSAL CELL TO INFILTRATION RATES



Pattern of Infiltration Rate



Probability Density Function of Occurrence Time of Infiltration Rate Increase

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FIGURE F.5-14 - CONCEPTUAL DISTRIBUTION OF THE INFILTRATION RATES THROUGH THE DISPOSAL CELL

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F.6.0 PERCHED GROUNDWATER REMEDIAL ACTION EVALUATION

SUMMARY

The objective of this study is to determine the most reasonable method for addressing contamination in perched groundwater zones and to provide a basis for a cost estimate to support the development and evaluation of overall remedial action components for the Operable Unit 5.

Groundwater modeling has been performed to study the technical feasibility of five remedial action components for perched groundwater which will be used to develop remedial alternatives. The studied components fall into two major categories and are listed below:

Extraction Components

- Collection trenches
- Vertical pumping wells
- Excavation of contaminated perched groundwater zone soil

Containment Components

- Collection trenches
- Vertical pumping wells

Before conducting detailed modeling, each component was assessed against three protection criteria which provide for the protection of the following media and future potential receptors. These criteria pertain to potential health risks or protective requirements of the following water sources:

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- Perched groundwater in the 1 gpm zone as a drinking water source
- The Great Miami Aquifer
- Surface water bodies and the Great Miami Aquifer that is in contact with surface water.

All three criteria must be met in order for the component to meet remedial objectives. Of the components studied, all failed one or more of the above criteria with the exception of the excavation component. Based on the evaluation criteria shown above, three perched groundwater remediation cases were developed to represent possible future land use scenarios with different combinations of risk levels and receptors. These cases have levels of protective requirements that when met will result in constituents with acceptable residual concentrations migrating from the perched groundwater to other media.

Results of modeling indicate that all five components are technically feasible if sufficient conditional assumptions are applied. Implementation of the trench and well designs for both removal/extraction and containment/control components, however, may not be practicable based on the nature and extent of the preliminary system design (i.e., large number of wells and trenches required) or long operational time frames.

For comparison purposes, each of the extraction components was designed to remediate the perched groundwater within 35 years. This time period is equal to the proposed design life of groundwater treatment options which will be required by two of the three extraction components considered herein and by Great Miami Aquifer remedial components. This time requirement is not placed on the containment components because of the passive nature of those systems.

Using this 35-year clean-up requirement, an early conclusion of the modeling was that based on the local water budget, there is insufficient water available in the perched zone to achieve the necessary flushing for cleanup in 35 years using extraction trenches or wells. Therefore, the trench and well extraction component designs include artificial recharge to the glacial overburden in order to sustain an adequate extraction rate to complete remediation in the required time frame.

Among the components using extraction techniques, only the excavation component meets all of the protection criteria. Trenches and wells may not provide protection of the Great Miami Aquifer based on the vertical gradients that exist across the gray clay unit between the perched zone and the underlying Great Miami Aquifer. Additionally, the use of recharge trenches or injection wells, described above, will further increase vertical gradients (due to local mounding) and exacerbate the vertical contaminant migration rate. Results indicate that between 3500 and 58,000 lineal feet of trenches and between 34 and 3200 wells would be required to remediate uranium plumes within 35 years. Note that the large ranges in number of wells and trench length are due to uncertainties associated with site conditions (see Section F.6.2).

Neither of the components using containment techniques meet the criteria for protecting perched drinking water sources because by definition their objective is to contain contamination within the perched groundwater zone. The containment components also potentially fail to protect the Great Miami Aquifer based on the vertical gradients described above. In addition, the operational periods for containment trenches and wells are on the order of hundreds to thousands of years.

The excavation of contaminated perched groundwater zones appears to be the most straightforward and effective strategy for remediating perched groundwater within the glacial overburden of the five components evaluated. Future potential loading to the Great Miami Aquifer from residual contamination left in place (following excavation of areas of higher contamination) results in a maximum future uranium concentration of less than 6 micrograms per liter (μg/L) for all cases modeled.

F.6.1 INTRODUCTION

F.6.1.1 Objective

The objective of this study is to determine the most reasonable method for addressing contamination in perched groundwater zones and to provide a basis for a cost estimate to support the development and evaluation of overall remedial action components for the Operable Unit 5.

Groundwater modeling has been performed to study the technical feasibility of five remedial action components for perched groundwater which will be used to develop remedial alternatives. The studied components fall into two major categories and are listed below:

Extraction Components	Containment Components
• Collection trenches	• Collection trenches
• Vertical pumping wells	• Vertical pumping wells
• Excavation of contaminated perched groundwater zone soil	

F.6.1.2 Technical Approach

Figure F.6-1 presents the approach used in evaluating the five perched groundwater remedial action components. After defining the constraints of the analyses, initial conditions, geochemical parameters, and protection criteria, modeling was performed to study the technical feasibility of each component. For the extraction components, systems were defined to remediate the perched groundwater zone within 35 years. This time requirement is not placed on the containment components because of the passive nature of those systems.

Section F.6.2 provides modeling background information including the conceptual model of the perched groundwater system, simplifying assumptions, model parameters, local water budget analysis, evaluation criteria and initial perched groundwater conditions. Sections F.6.3 and F.6.4 present the technical approach and modeling results for the evaluation of extraction and containment components, respectively. A comparison of results, discussion of the feasibility of each component, and recommendations are contained in Section F.6.5. Summary and conclusions are presented in Section F.6.6. Attachment F.6.I provides additional details of the analytical procedures used in the modeling.

F.6.2 MODELING BACKGROUND

F.6.2.1 Conceptual Model

Figure F.6-2 shows the perched groundwater zone considered in this evaluation based on both lateral and vertical migration pathways. The areal footprint of the perched groundwater zone corresponds to Infiltration Zone V which is described in Section F.2.2.

The footprint of Infiltration Zone V has been defined based on the distribution of coarse-grained sediment bodies within the glacial overburden which may potentially provide a lateral contaminant migration pathway to Paddys Run and the pilot plant drainage ditch. Once contamination enters these surface water features, surface flow is possible to an area where direct infiltration into the Great Miami Aquifer can occur (see Section F.3.2). In addition, a vertical contaminant migration pathway exists through the glacial overburden to the Great Miami Aquifer.

A portion of the Infiltration Zone V has been identified as a potential future drinking water source within the glacial overburden (see Section F.3). The hydraulic conductivity of sediment within the footprint of this zone are high enough (10^{-3} centimeters per second [cm/s] range) to provide an estimated sustainable groundwater yield of approximately 1 gallon per minute (gpm). This estimated yield is based on pumping tests which are presented in the Operable Unit 5 RI Report (DOE 1995a). As such, this zone is hereinafter referred to as the 1 gpm zone.

Section F.2.2 provides a detailed discussion of the FEMP subsurface conditions, some of which are summarized below. The glacial overburden within Infiltration Zone V is both heterogeneous and anisotropic. It consists of glacial tills which contain a heterogeneous mixture of sand and gravel in a clay-rich matrix and lacustrine basin deposits which contain predominately clay and silt with some sand and gravel. Although glacial tills do not characteristically contain laterally extensive sand and gravel, lacustrine deposits may.

Figure F.6-3 presents the conceptual model of the perched groundwater unit used in the evaluation of the remedial components. Based on the distribution of lacustrine deposits, the possibility of a preferred but undetected lateral pathway through potentially interconnected sand and gravel deposits between Plant 8, Plant 2/3 and Plant 1 areas to Paddys Run and the pilot plant drainage ditch was assessed. To conservatively account for this, an idealized 15-foot-thick brown/gray sand layer within the glacial overburden was defined in Infiltration Zone V. Conceptually, this creates a large sand body sandwiched between 5 feet of brown clay/sand on top and 10 feet of gray clay on the bottom.

For modeling purposes, the idealized sand unit was used as the perched groundwater zone. It was assumed the conductive material within this idealized perched groundwater unit is laterally continuous, hydraulically connected, homogeneous, and uniform in thickness.

This conceptual model is quite different from the localized sand and gravel lenses surrounded by less permeable silt and clay which make up most of the glacial overburden within Infiltration Zone V. However, this conceptual model was developed to accommodate the practical limitations of model applications as well as to conservatively provide for a lateral transport pathway to surface water bodies.

Figure F.6-4 presents averaged perched groundwater level contours at the FEMP. Groundwater is present in the glacial overburden and is perched above the water table of the Great Miami Aquifer (i.e., there is an unsaturated zone between the perched groundwater zone and the Great Miami Aquifer water table). The perched water table lies approximately 3 to 5 feet below the ground surface.

F.6.2.1.1 Assumptions

Assumptions are necessary to simplify the natural environment and contaminant migration processes so that they are amenable to simulation by mathematical models. A certain level of conservativeness is normally included as part of the assumptions so that simulation results may be utilized to establish certain limits for the design of groundwater remedial components. In this evaluation, several simplifying and conservative assumptions were incorporated into the analysis. These assumptions include:

- The perched groundwater zone is homogeneous, isotopic, laterally continuous, and of uniform thickness. This assumption ignores the naturally inherent heterogeneity. The results obtained from simulations are expected to be indicative of the minimum requirements (e.g., total trench length, number of wells, operation period, etc.,) for the following remedial components: collection trenches; vertical extraction wells; containment trenches; and containment wells.

- The brown clay/sand unit, the brown/gray sand, and the unsaturated Great Miami Aquifer are absent (i.e., thickness is zero) in the vertical fate and transport simulations using the ODAST/SWIFTLOAD model for the excavation component base cases. By not including these layers, contaminants reach the Great Miami Aquifer more quickly and at higher concentrations.

- The perched groundwater zone is always saturated so that vertical downward leakage always occurs. Vertically downward leakage from the perched groundwater zone is due to the existence of a downward vertical hydraulic gradient across the clay layer. The presence of a downward vertical gradient across the gray clay layer is due to several factors, including: (a) the existence of hydrostatic pressure at the top surface of the clay layer; (b) the relatively low hydraulic conductivity of the clay (compared with sand/silt in the perched zone); and (c) the presence of lower pressure (approximately atmospheric) at the lower clay surface due to the significant contrast between the hydraulic conductivities of the clay zone and the Great Miami Aquifer sand. As long as the sand/silt above the clay layer remains saturated, the downward vertical gradient exists.

- For the trench and well components, the vertical flow and transport components were assumed to be unmitigated by the remedial components. However, the vertical migration of constituents was assumed to be negligibly small compared with the required injection and extraction rates within the perched groundwater zone. In the analysis of the well and trench components, the flow and transport in the perched zone were assumed to be predominantly horizontal.

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- For the excavation component, the remedial action is assumed to be completed within a short period of time. After excavation, the horizontal components of groundwater flow and constituent transport were assumed to be essentially eliminated due to the use of low hydraulic conductivity of the fill materials in the excavated zones. Once filled and compacted, the groundwater flux through the remediated zones would be negligibly small compared with more transmissive neighboring zones. In the analysis of the excavation component, the flow and transport in the perched zone were assumed to be predominantly vertical.

- Remediation of perched groundwater using extraction components will be completed within a 35-year period. This time period is equal to the proposed design life of FEMP groundwater treatment options.

- Source concentrations within the perched groundwater zone modeled are based solely on current concentrations in type 1 wells within Infiltration Zone V. The underlying gray clay unit and the overlying overburden do not function as sources of contamination to the perched groundwater zone during and after the remediation period.

- Source concentrations within perched groundwater outside of Infiltration Zone V do not function as sources of contamination through lateral migration to the perched groundwater zone considered in this analysis. It is assumed that these areas will be remediated concurrently with the overlying soil.

The last two assumptions reflect the uncertainties associated with identified migratory processes and the site conditions. They have a direct impact on the assessment of the trench and well components. The above simplifying assumptions were used to evaluate the minimum requirements for the trench and well components.

95 Infiltration Zone V has been found to contain larger areas of coarse-grained sediment. Some of these areas have relatively higher yields. Zone V was conservatively assumed to be a zone of continuous coarse-grained material for the modeling purposes. On the other hand, the glacial overburden contains isolated smaller areas of coarse-grained sediment and low yields outside Infiltration Zone V. Therefore, perched groundwater has limited lateral migration potential and low yields. Outside of Infiltration Zone V only vertical migration is assumed to occur. Hydraulic extraction techniques such as wells and trenches would be an infeasible remedial alternative for such discontinuous, low-yield materials, and the only feasible alternative for remediation would be excavation. Because perched groundwater contamination outside of Infiltration Zone V most likely occurred through the vertical migration pathway from overlying soil, remediation of contaminated perched groundwater would occur as part of the soil remediation by excavation as summarized in Section 2 of the FS.

To simplify the transport modeling processes within and in the vicinity of Infiltration Zone V for the analysis, it was assumed that only Infiltration Zone V has both lateral and vertical perched groundwater migration. Therefore, the detailed perched groundwater modeling analysis was limited

to Infiltration Zone V to test the feasibility of both hydraulic extraction and excavation remedial methods.

In this evaluation, sensitivity analyses of selected model parameters were performed to quantify the ranges of uncertainty associated with modeling results. These analyses are described in more detail for each evaluated component. Results are summarized in Section F.6.5.2.

F.6.2.1.2 Parameters

Tables F.6-1 through F.6-4 summarize the physical and geochemical parameters used in the evaluation. These values were obtained from the Operable Unit 5 RI Report (DOE 1995a) and Section F.2.2.

444 Solid-liquid partitioning coefficients (K_d) for the perched sand unit were evaluated based on speciation of constituents within the perched groundwater as described in Section F.2.4. Sediment within the sand body within Infiltration Zone V has horizontal hydraulic conductivities ranging from 0.436 to 67.2 feet per day based on slug tests conducted in the brown/gray sand (DOE 1994a). The values of hydraulic conductivity in Tables F.6-1 and F.6-2 are consistent with results from previous model calibration and field tests. The values of hydraulic conductivity in Table F.6-1 were obtained from the calibration of the GO/UGMAS model (DOE 1994b). These values were used in analyzing the regional scenarios (Section F.6.3.1) which are not location-dependent. The values of hydraulic conductivity in Table F.6-2, however, were used to analyze the pumping wells, collection trenches, and containment trenches scenarios (Sections F.6.3.2, F.6.3.3, and F.6.4.1), which are location-dependent because the densities of the remedial options are dictated by the distributions of chemical concentrations. In Table F.6-2, the values of hydraulic conductivity within respective chemical-concentration zones (Section F.6.3.2.2) are based on geometric averages of hydraulic conductivity values of the coarse-grained portion determined by slug tests. In these zones, the geometric averages of hydraulic conductivity are similar to the values of hydraulic conductivity determined by pumping tests. Because of the relative abundance of the slug test results with respect to the chemical-concentration zones, the slug-test values were preferred to those of the pumping-test values. A uniform porosity of 0.30 was assigned to the sand body.

F.6.2.1.3 Water Budget Analysis

A local water budget was calculated for Infiltration Zone V using the perched groundwater contour map (Figure F.6-4). In order to evaluate the feasibility of the proposed remedial components, a preliminary assessment was conducted based on the local water budget. The preliminary assessment is based on a comparison between two quantities: the maximum possible extraction rate within a given period of time (35 years), Q_1^M; and the necessary extraction rate within a prescribed period of time to reduce the initial contaminant concentration to a target concentration, Q_2. If Q_2 is greater than Q_1,

then recharge/injection is required in order to deplete contaminants within the 35-year time frame. Details of the calculation procedure are presented in Section 1 of Attachment F.6.I.

96 The slope of the perched water table is west-southwest towards Paddys Run and the pilot plant drainage ditch over most of Infiltration Zone V. In the ensuing subsections, remediation scenarios with identical pumping and injection rates are analyzed. With the zero net extraction rate, the net drawdown of the groundwater is also approximately zero. Therefore, the regionally averaged vertical discharge is likely to remain relatively constant. On the eastern side of the 1 gpm zone, the perched water table locally slopes eastward toward a north-south trending ditch in the production area. Perched groundwater recharge and discharge boundaries used for the lateral transport components (trenches and wells) are also presented in Figure F.6-4.

94 Based on the principle of mass conservation (Ponce 1989), Q_I^M may be estimated from

$$Q_I^M = Q_I + \frac{b\theta A_{tot}}{\Delta t} \qquad \text{(F6-1)}$$

where

Q_I^M = maximum possible extraction rate (ft^3/day)
Q_I = net influx due to lateral recharge and infiltration available for extraction (ft^3/day)
Δt = time interval of interest (day)
A_{tot} = total area of aquifer (ft^2)
θ = porosity (dimensionless)
b = aquifer thickness (ft)

94 In order to dewater the perched zone completely within a given time period, the average extraction rate must be at least equal to the sum of the net influx due to lateral recharge and infiltration and the rate necessary to remove the groundwater stored in the perched zone. The first term on the right hand side of Equation (F6-1) represents the net influx, while the second term represents the average extraction rate required for the removal of groundwater stored in the perched zone within a time period of Δt. Additional details are presented in Section 1 of Attachment F.6.I.

Q_I^M as shown in Equation (F6-1) implies that the aquifer will have been completely dewatered after the prescribed 35-year remediation period.

The net influx into Infiltration Zone V may be determined from the local long-term steady-state water budget, as follows:

$$Q_{Infil} + Q^{H}_{Inflow} - Q^{V}_{Disch} - Q^{H}_{Disch} = 0 \qquad \text{(F6-2)}$$

Q_{Infil}	=	areal recharge rate due to infiltration (ft^3/day)
$Q_{Inflow}{}^{H}$	=	lateral inflow rate (ft^3/day)
$Q_{Disch}{}^{V}$	=	vertical discharge rate (ft^3/day)
$Q_{Disch}{}^{H}$	=	lateral discharge rate (ft^3/day)

To simplify the lateral component modeling, it was assumed that the total lateral inflow rate was equal to the total lateral outflow rate. This assumption can be substantiated by the absence of significant perched groundwater mounds. Following the above assumption, it may be inferred that the areal infiltration rate to the Great Miami Aquifer is approximately equal to the natural vertical infiltration rate to the perched groundwater zone.

Because the areal recharge rate (vertical infiltration rate) is approximately equal to the vertical discharge rate (i.e., $Q_{Infil} + Q^{V}_{Disch}$), it may be inferred that the lateral inflow rate is equal to the lateral discharge rate (i.e., $Q^{H}_{Inflow} + Q^{H}_{Disch}$). Based on the fact that the vertical discharge rate is relatively constant even with pumping, the following approximation could be made such that

$$Q_I \approx Q^{H}_{Inflow} \approx Q^{H}_{Disch} \qquad \text{(F6-3)}$$

which, in turn, may be estimated from:

$$Q_I \approx Q^{H}_{Disch} = \sum_{i=1}^{n_{seg}} L_i I_i b_i K_i \qquad \text{(F6-4)}$$

where

n_{seg}	=	number of lineal segments along discharge boundaries of the subject area
L_i	=	length of segment i along discharge boundaries (ft)
I_i	=	average hydraulic gradient along segment i (ft/ft)
K_i	=	average hydraulic conductivity along segment i (ft/day)
b_i	=	average perched-zone saturated thickness along segment i (ft)

Equation (F.6-4) implies that Q_I is the total groundwater discharge from the perched zone to the drainage ditches. During the remediation period, it is imperative that the perched groundwater zone is kept saturated in order to remove the maximum amount of contaminants within a given period of time without leaving a fraction of contaminants relatively immobile in the desaturated zone. Therefore, the lower bound for the amount of water available for extraction from the perched groundwater zone could be approximated by:

$$Q_1^L = Q_I \frac{L_{cont}}{\sum_{i=1}^{n_{seg}} L_i} \qquad \text{(F6-5)}$$

where

Q^L_1 = lower bound of extraction rate required for remedial action (ft^3/day)

L_{cont} = zone length normal to the groundwater flow direction in the contaminated zone (ft)

Using the observed perched groundwater gradient (0.010 to 0.04, see Table F.6-5), the assumed average saturated thickness of the perched zone (15 feet), and the average horizontal hydraulic conductivity in the area of recharge and discharge boundaries within Infiltration Zone V, the total lateral inflow rate and outflow rate was estimated for Infiltration Zone V. As estimated using Equation (F.6-4), the total lateral inflow rate of between 9.81 and 19.25 gpm is similar to the estimated total outflow rate of 14.80 gpm (Table F.6-5). Figure F.6-3 shows the perched groundwater elevation contours and the approximate location of areas of lateral recharge and discharge within Infiltration Zone V.

Based on HELP (EPA 1984) modeling described in Section F.2.2, approximately 6.75 inches per year infiltrates through the glacial overburden and the unsaturated Great Miami Aquifer to the Great Miami Aquifer beneath Infiltration Zone V. This infiltration rate corresponds to a total recharge rate to the Great Miami Aquifer beneath Infiltration Zone V of 31.5 gpm. This recharge rate will not be significantly affected by the extraction.

F.6.2.2 Evaluation Criteria and Modeling Cases

Before conducting detailed modeling, each component was assessed against three protection criteria which provide for the protection of the following media and future potential receptors. These criteria involve the protection of:

- Perched groundwater in the 1 gpm zone as a drinking water source (Criterion 1)
- The Great Miami Aquifer as a drinking water source (Criterion 2)
- Surface water bodies and the Great Miami Aquifer which is in contact with surface water (Criterion 3).

All three criteria must be met in order for the component to meet remedial objectives. It should be noted that criterion 3 conditions are less stringent than those for criteria 1 and 2. Therefore, if the protective conditions for criteria 1 and 2 are met, then criterion 3 should also be satisfied.

Of the components studied, all failed one or more of the above criteria, with the exception of the excavation component. As shown by the preliminary assessment results presented in Table F.6-6, the only component which meets all three criteria is excavation. Protection of receptors would immediately be realized upon completion of excavation of contaminated perched zone material.

Trench and well components may not be protective of the Great Miami Aquifer (criterion 2) while they are being implemented due to the pervasive downward migration within Infiltration Zone V. Because the downward vertical gradient is responsible for the vertical migration of contaminants from the perched zone to the Great Miami Aquifer, the only way to curtail or reverse the downward migration of contaminants across the clay layer is through complete dewatering of the perched zone or inducing negative pressure throughout the perched zone. The latter would be extremely difficult, if not impossible to accomplish. The former, complete dewatering, is nearly physically impossible to accomplish. Both methods would require possibly indefinite maintenance. Furthermore, both methods may leave a significant amount of contaminant in a relatively immobile sorbed phase in the vadose zone.

Because trench and well components alone do not completely eliminate the vertical migration of contamination to the Great Miami Aquifer, criterion 2 may not be met under normal conditions. However, upon completion of remediation using trenches or wells, the residual contamination in the perched groundwater zone would be protective of the Great Miami Aquifer and criterion 2 would be met. Therefore, detailed modeling of these components was conducted in order to more fully evaluate their technical feasibility.

Containment components, for the purpose of collecting, containing and reducing the migration potential of contaminant plumes in the perched groundwater, do not reduce the toxicity of contaminants. This means that criterion 1 cannot be met for contaminant plumes within the 1 gpm zone using containment components. Therefore, contaminant plumes within the 1 gpm zone were not evaluated for Cases 1 and 2, described below, which require protection of perched drinking water sources. For these cases, it was assumed that contaminant plumes within the 1 gpm zone exceeding the drinking water criteria would be remediated using other components.

Based on the evaluation criteria shown above, three perched groundwater remediation cases were developed to represent possible future land use scenarios with different combinations of risk levels and receptors. These cases have levels of protective requirements that when met will result in constituents with acceptable residual concentrations migrating from the perched groundwater to other media.

Based on similar exposure criteria, the three perched groundwater remediation cases evaluated for each component were divided into three groups designated below. Exposure criteria are contaminant- and media-specific target risk levels developed for a given receptor. The exposure criteria are usually the maximum acceptable constituent concentrations based on direct contact with the media from which the exposure occurs (i.e., PRGs). The exposure criteria for each of the three cases is described below. Table F.6-7 provides a summary of the levels of protection provided by each case.

To support unrestricted land use at 10^{-6} ILCR or 0.2 HQ protective levels, Case 1 requires the remedial alternative to be protective of:

- Perched groundwater as a drinking water source in the 1 gpm zone to the 10^{-6} ILCR or 0.2 HQ PRG for the resident farmer/child
- The Great Miami Aquifer to the 10^{-6} ILCR or 0.2 HQ PRG for the resident farmer/child.

In order to support unrestricted land use at 10^{-5} ILCR or 0.2 HQ protective level, Case 2 requires the alternative to be protective of:

- Perched groundwater as a drinking water source in the 1 gpm zone to MCLs, if available, or to the 10^{-5} ILCR or 0.2 HQ PRG for the resident farmer/child
- The Great Miami Aquifer to MCLs, if available, or to the 10^{-5} ILCR or 0.2 HQ PRG for the resident farmer/child.

For all of the other land use objectives, Case 3 requires the alternative to be protective of:

- The Great Miami Aquifer to MCLs, if available, or to the 10^{-5} ILCR or 0.2 HQ PRG for the resident farmer/child.

F.6.2.3 Initial Perched Groundwater Conditions

F.6.2.3.1 Plume Boundaries and Initial Conditions

Table F.6-8 presents the list of perched groundwater CPCs. These constituents have been retained for further modeling after being prescreened and screened against background concentrations.

E-series plates from the Operable Unit 5 RI Report (DOE 1995) which presented isoconcentration contours for Type 1 wells was the data source used to define plume boundaries, initial and background concentrations used in the modeling. Uranium-238 (unfiltered data) plume maps presented higher concentrations than the total uranium plume maps, and were therefore used to develop concentration terms.

The evaluation of the excavation component included applicable CPCs for which RI plates were available to estimate a maximum excavation footprint. The evaluation of trench and well extraction and containment components is based solely upon on the distribution of uranium-238 concentrations. The reasons for the adoption of this approach include: (a) the elevated uranium-238 contamination footprint in the perched groundwater zone encompasses most of the other CPCs; (b) the uranium-238 K_d is greater than those of many of the other CPCs, thereby requiring a greater extraction rate for uranium-238 than for other constituents with similar concentrations and cleanup targets; and (c) the proportionately greater associated risk of uranium-238 compared to other CPCs.

F.6.2.3.2 Perched Groundwater Constituent Screening

Before modeling, constituents were screened against remedial components based on their mobility and distribution within Infiltration Zone V. Table F.6-8 presents the results of the screening.

First, CPCs within Infiltration Zone V with maximum concentrations below the 10^{-7} ILCR or 0.1 HQ concentrations were not retained for detailed modeling for any component.

Second, a constituent mobility screening consisting of two parts, physical time of travel through the vadose zone to the Great Miami Aquifer and radiological and organic decay over this time period, was conducted. Travel time screening is performed on CPCs based on distance, retardation factor, velocity, and dispersion. The organic or radiological decay constants for constituents were compared to the minimum calculated travel time. If a constituent has undergone 30 half-lives during this travel time, then it is assumed that negligible mass remains after this period.

Based on the results of the mobility screening, any constituent which reached the Great Miami Aquifer within 35 years was not retained for detailed modeling for the trench and well components. These components are not considered feasible for remediating CPCs which reach the Great Miami Aquifer before the 35-year remediation period defined for these components has expired (i.e., the component may not be protective of the Great Miami Aquifer during the 35-year period of operation for these constituents).

In addition, any constituent which failed to reach the Great Miami Aquifer within 1000 years and was not located within the 1 gpm zone was not retained for detailed modeling for the excavation component.

The final column in Table F.6-8 presents the remedial components considered feasible for each CPC.

F.6.3 EVALUATION OF PERCHED GROUNDWATER EXTRACTION COMPONENTS

F.6.3.1 Excavation

Excavation can be used to physically remove contamination within perched groundwater zones. Presented below is a preliminary analysis of excavation as a means of remediation and the impacts of residual perched groundwater contamination.

F.6.3.1.1 Objective

The primary objective of the excavation component modeling is to determine the lateral extent of the perched groundwater zone that must be excavated in order to meet the primary protection criteria.

F.6.3.1.2 Technical Approach

Three cases, each involving different risk levels and receptors, were evaluated for the excavation component modeling. These cases have been described in Section F.6.2.2.

The final excavation footprints used to meet the protective requirements for the three cases modeled result from the following combinations:

- Case 1 - Excavation Footprints 1, 2, and 3
- Case 2 - Excavation Footprints 1 and 2
- Case 3 - Excavation Footprint 1

For each of the cases, the resultant footprint was overlain onto CPC Type 1 plume maps from the Operable Unit 5 RI Report to determine the residual contaminant to be left in place. These residual concentrations were used to develop loading terms for modeling.

One-dimensional modeling of contaminant travel through the glacial overburden and unsaturated Great Miami Aquifer was simulated using ODAST (Javandel et al. 1984), which is a subroutine of SWIFTLOAD. SWIFTLOAD was developed to create an appropriate input file for the SWIFT Great Miami Aquifer Model and runs ODAST on a cell-by-cell basis. The SWIFT Great Miami Aquifer model (Geotrans 1993; DOE 1994b) was used to simulate three-dimensional contaminant transport in the Great Miami Aquifer.

SWIFT Great Miami Aquifer model simulations were performed using SWIFT III on a Silicon Graphics Computer (Unix based). A 1000-year period was modeled.

Loading terms were developed based on the perched groundwater constituent concentrations for each of the modeled grid blocks as described below. No loading due to soil above the perched

groundwater zone was considered in the modeling so that effects due to perched groundwater constituent concentrations could be objectively evaluated.

As shown in Figure F.6-5, three areas of perched groundwater excavation have been defined as the basis for performing the excavation component modeling. These are:

- Excavation Footprint 1: Perched groundwater zone area with constituent concentrations which could produce concentrations above MCLs or 10^{-5} PRGs in the Great Miami Aquifer
- Excavation Footprint 2: Remaining 1 gpm zone
- Excavation Footprint 3: Additional perched groundwater zone area with constituent concentrations which could produce concentrations above 10^{-6} PRGs in the Great Miami Aquifer.

99 Excavation Footprint 1 provides protection of the Great Miami Aquifer by excavating perched groundwater concentrations which could produce future concentrations in the Great Miami Aquifer above MLCs or the 10^{-5} ILCR or 0.2 HQ PRG for the resident farmer/child. It should be noted that Excavation Footprint 1 includes perched groundwater zone areas outside of Infiltration Zone V. As discussed in Section 2.0 of the FS, these areas contain high perched groundwater concentrations which have the potential to only move vertically to the Great Miami Aquifer. These areas will be excavated regardless of the remedial option selected for Infiltration Zone V. Contaminated perched groundwater outside of Infiltration Zone V which is in close proximity to Operable Unit 1 waste lagoons will be remediated concurrently with that operable unit. Excavation Footprint 2 provides full protection of perched groundwater as a drinking water source by excavating areas in the 1 gpm zone that are not included in Excavation Footprint 1. Excavation Footprint 3 provides further protection of the Great Miami Aquifer by excavating perched groundwater concentrations which could produce future concentrations in the Great Miami Aquifer above the 10^{-6} ILCR or 0.2 HQ PRG for the resident farmer/child. Each excavation footprint was defined in an iterative modeling process. The following paragraphs describe the approach used for defining the excavation and residual contamination footprints for each of the evaluated cases.

A travel time screening was performed to determine which perched groundwater constituents reach the Great Miami Aquifer in 1000 years. Table F.6-8 presents the results of the screening and which constituents are retained for further excavation component modeling. Constituents that do not reach the Great Miami Aquifer in 1000 years and which have perched groundwater plumes entirely outside of the 1 gpm zone are not retained for further evaluation in the excavation component modeling.

100 For modeling purposes, a 125- by 125-foot grid area was used to define the unit area of excavation and residual contamination footprints. The RI Report Type 1 well plume maps were used to define concentration terms. Based on preliminary modeling efforts, uranium-238 concentrations exiting the vadose zone decreased about 1.16 orders of magnitude (15 times) in the Great Miami Aquifer. An anticipated 1 order of magnitude concentration decrease between the vadose zone and the Great Miami Aquifer was used to preliminarily estimate excavation/residual contamination footprints.

Tables F.6-1 and F.6-3 summarize the physical and geochemical parameters used in the modeling.

Excavation Footprint 1

Excavation Footprint 1 was defined to remove perched groundwater zones that contain constituent concentrations which could produce future concentrations in the Great Miami Aquifer above MCLs or the 10^{-5} ILCR or 0.2 HQ PRG for the resident farmer/child. The footprint was created through an iterative modeling process.

101 First, MCLs, if available, or the Great Miami Aquifer 10^{-5} ILCR PRGs were compared to constituent concentrations in the perched groundwater. Both uranium-238 and technetium-99 concentrations exceeded the Great Miami Aquifer MCLs or 10^{-5} ILCR PRGs. The initial excavation footprint was expanded in an iterative process. Based on previous modeling, it was believed that residual uranium-238 concentrations below 175 pCi/L in the perched groundwater would not produce concentrations in the Great Miami Aquifer above the MCL of 20 μg/L. The initial excavation footprint was set at the approximate location of the 250 pCi/L uranium-238 concentration contour. Based on inspection of the well data and concentration contours, the remaining contaminated area bounded by the 5 and 250 pCi/L contours was used to define grid blocks of residual perched groundwater uranium-238 contamination to be modeled. Grid blocks within the 5 and 100 pCi/L contours were assigned an "average" uranium-238 concentration of 40 pCi/L. Grid blocks within the 100 and 250 pCi/L contours were assigned an "average" uranium-238 concentration of 175 pCi/L. In addition, one additional grid block containing technetium-99 concentrations greater than 100 pCi/L was conservatively included in the initial excavation footprint. Grid block 48,74 was included based on its interior proximity to surrounding grid blocks already included in the excavation footprint due to uranium-238 concentrations.

Grid blocks and concentrations for other constituents were defined outside of the initial excavation footprint using the same process. Modeling was performed using SWIFTLOAD/ODAST for the residual contamination left in place for each constituent. The maximum uranium-238 concentration exiting vadose zone layer 2 was 364 μg/L. SWIFT modeling was performed for uranium-238 using the ODAST output as SWIFT input. The maximum concentration in the Great Miami Aquifer was 22 μg/L. Because this concentration exceeded the MCL of 20 μg/L, the excavation footprint was

expanded. No other constituents leached through the vadose zone in concentrations greater than 1 order of magnitude above Great Miami Aquifer MCLs or 10^{-5} ILCR PRGs.

Next, the excavation footprint was expanded south of the production area to the approximate location of the 100 pCi/L concentration contour for uranium-238. Grid blocks with residual contamination between 5 and 100 pCi/L were assigned an "average" concentration of 40 pCi/L. In addition, three additional grid blocks corresponding to the laboratory building where organic and nitrate plumes occurred were also conservatively included in the expanded excavation footprint.

Excavation Footprint 2

The final Excavation Footprint 1 includes a portion of the 1 gpm zone based on protection of the Great Miami Aquifer to MLCs or 10^{-5} ILCR PRGs. To provide full protection of the 1 gpm zone to eliminate the possibility of a future resident using the perched groundwater as a drinking water source, the remaining portion was included in Excavation Footprint 2. Constituents exceeding MCLs or the perched groundwater 10^{-6} and 10^{-5} PRGs for the resident farmer/child within the 1 gpm zone were: uranium-238, technetium-99, magnesium, manganese, and nitrate. Uranium-238 concentrations generally exceed the PRGs over most of the 1 gpm zone.

Excavation Footprint 3

Excavation Footprint 3 provides further protection of the Great Miami Aquifer by excavating perched groundwater concentrations outside of Excavation Footprints 1 and 2 which could produce future concentrations in the Great Miami Aquifer above the 10^{-6} ILCR or 0.2 HQ PRG for the resident farmer/child.

Excavation Footprint 3 was created through an iterative modeling process. Based on previous modeling, it was believed that residual uranium-238 concentrations below 40 pCi/L in the perched groundwater would not produce concentrations in the Great Miami Aquifer above the 10^{-6} PRG of 3 μg/L. The initial Excavation Footprint 3 was set at the approximate location of the 100 pCi/L uranium-238 concentration contour. Based on inspection of the well data and isoconcentration contours, the remaining contaminated area bounded by the 5 and 100 pCi/L contours was used to define grid blocks of residual perched groundwater uranium-238 contamination to be modeled. Grid blocks within these areas were assigned an "average" uranium-238 concentration of 40 pCi/L.

Grid blocks and concentrations for other constituents were defined outside of the initial excavation footprint using the same process. Modeling was performed using SWIFTLOAD/ODAST for the residual contamination left in place for each constituent. The maximum uranium-238 concentration exiting vadose zone layer 2 was 86 μg/L. SWIFT modeling was performed for uranium-238 using

the ODAST output as SWIFT input. The maximum concentration in the Great Miami Aquifer was 5.88 μg/L.

Because this concentration exceeded the Great Miami Aquifer 10^{-6} PRG of 3 μg/L and other constituents which had vadose zone exiting concentrations greater than 1 order of magnitude above the Great Miami Aquifer 10^{-6} PRGs, the excavation footprint was expanded. The excavation footprint was expanded south of the production area to the approximate location of the 50 pCi/L concentration contour for uranium-238. Grid blocks with residual contamination between 5 and 50 pCi/L were assigned an "average" concentration of 25 pCi/L. The excavation footprint was also expanded to include grid blocks corresponding to technetium-99 concentrations that were more than 1 order of magnitude above the Great Miami Aquifer 10^{-6} PRG.

As presented on Table F.6-9, for each of the cases, only six constituents, uranium-238, neptunium-237, strontium-90, technetium-99, magnesium and nitrate, had residual concentration plumes outside the representative excavation footprint. However, neptunium-237 and strontium-90 were not modeled for Cases 2 and 3 because the intial concentrations were less than the target cleanup concentrations (see Tables F.6-11 and F.6-12). Figures F.6-6 through F.6-11, Figures F.6-12 through F.6-15, and Figures F.6-16 through F.6-19 illustrate the grid blocks with loading outside the final excavation footprint and initial concentrations for each constituent modeled for Case 1, Case 2 and Case 3, respectively.

As expected, an increase in the number of grid blocks and residual concentrations occurs with decreasing levels of protection. That is, more grid blocks have loading and concentration terms which are higher for Case 3 (protective of Great Miami Aquifer to MCLs or 10^{-5} PRGs) than for Case 1 (protective of the Great Miami Aquifer and perched groundwater to 10^{-6} PRGs).

To evaluate the sensitivity of modeling results to selected parameters, additional sensitivity simulations for uranium were performed for Cases 1 and 2. Only one input parameter at a time was varied. Uncertainty analysis of K_d (DOE 1994b) shows that the time of travel is sensitive to K_d variation. A uranium K_d value of 3.1 L/kg was used for vadose zone layer 1 for the baseline cases (i.e., Cases 1 and 2). A uranium K_d value of 15 L/kg was used for vadose zone layer 1 in order to assess the impact of varying that parameter for the first sensitivity cases (i.e., Sensitivity Cases 1a and 2a). These K_d values are based on the range of site values described in Section F.2.4. As previously stated, the thickness of the unsaturated Great Miami Aquifer (vadose zone layer 2) was set equal to zero for the baseline modeling cases. Additional ODAST runs were made to evaluate the impact of nonzero vadose zone layer 2 thicknesses (i.e., Sensitivity Cases 1b and 2b). Vadose zone layer 2 thickness is variable across the modeled area.

F.6.3.1.3 Results

Case 1

Modeling was performed using SWIFTLOAD/ODAST for the residual contamination outside the final Case 1 excavation footprint (i.e., Excavation Footprints 1, 2, and 3 as shown in Figure F.6-5). Table F.6-10 provides a summary of the Great Miami Aquifer 10^{-6} PRGs and maximum concentrations exiting the vadose zone. The maximum uranium-238 concentration exiting vadose zone layer 2 was 86 μg/L. No other constituents had exiting concentrations more than 1 order of magnitude above the Great Miami Aquifer 10^{-6} PRG.

SWIFT modeling was performed for uranium-238 using the ODAST output as SWIFT input. As shown in Figure F.6-20, the maximum future uranium-238 concentration in the Great Miami Aquifer of 2.944 μg/L occurred at 250 years.

Case 2

Modeling was performed using SWIFTLOAD/ODAST for the residual contamination outside the final Case 2 excavation footprint (i.e., Excavation Footprints 1 and 2 as shown in Figure F.6-5). Table F.6-11 provides a summary of the Great Miami Aquifer MCLs or 10^{-5} ILCR PRGs and maximum concentrations exiting the vadose zone. The maximum uranium-238 concentration exiting vadose zone layer 2 was 86 μg/L. No constituent had exiting concentrations more than 1 order of magnitude above MCLs or the Great Miami Aquifer 10^{-5} ILCR PRG.

SWIFT modeling was performed for uranium-238 using the ODAST output as SWIFT input. As shown in Figure F.6-21, a maximum future uranium-238 concentration in the Great Miami Aquifer of 5.36 μg/L occurred at 170 years.

Case 3

Modeling was performed using SWIFTLOAD/ODAST for the residual contamination outside the final Case 3 excavation footprint (i.e., Excavation Footprint 1 as shown in Figure F.6-5). Table F.6-12 provides a summary of the Great Miami Aquifer MCL or 10^{-5} ILCR, PRGs and maximum concentrations exiting the vadose zone. The maximum uranium-238 concentration exiting vadose zone layer 2 was 86 μg/L. No other constituents had vadose zone exiting concentrations greater than 1 order of magnitude above MCLs or 10^{-5} ILCR PRGs.

SWIFT modeling was performed for uranium-238 using the ODAST output as SWIFT input. As shown in Figure F.6-22, a maximum future uranium-238 concentration in the Great Miami Aquifer of 5.36 μg/L occurred at 170 years.

Sensitivity Cases

Sensitivity simulations were performed for uranium-238 for Cases 1 and 2 using SWIFTLOAD/ODAST (Sensitivity Cases 1a, 2a, 1b and 2b) and SWIFT (Sensitivity Cases 1a and 2a). Table F.6-13 provides a summary of the input parameters, maximum uranium-238 concentrations exiting the vadose zone, and maximum future uranium-238 concentrations in the Great Miami Aquifer for base and sensitivity simulations.

Results indicate that the maximum concentration exiting vadose zone layer 2 for sensitivity cases are lower and arrive later (47 μg/L at 270 years for Sensitivity Cases 1a and 2a and 82 μg/L at 160 years for Sensitivity Cases 1b and 2b) than for the base cases (86 μg/L at 70 years for Cases 1 and 2). Maximum future uranium-238 concentrations in the Great Miami Aquifer are also lower for sensitivity cases (1.13 μg/L at 700 years for Sensitivity Case 1a and 2.35 μg/L at 370 years for Sensitivity Case 2a) than for base cases (2.94 μg/L at 250 years for Case 1 and 5.36 μg/L at 170 years for Case 2).

F.6.3.2 Trenches

In general, groundwater recovery through collection trenches/French drain systems is appropriate in aquifers of little thickness, where otherwise a great number of large diameter wells are necessary to obtain a sufficient area of contact with the formation; and in areas where drawdown accompanying abstraction must be kept as small as possible (Huisman 1972). Presented below is a preliminary analysis of trenches as an active means of remediation. In other words, the trenches are intended for both recharge and extraction to expedite the removal of contaminants.

F.6.3.2.1 Objective

The main objective of the trench component modeling is to design a trench system that will remediate perched groundwater contamination in the Infiltration Zone V area within 35 years to concentrations that meet the primary protection criteria.

F.6.3.2.2 Technical Approach

Three cases, each involving different risk levels and receptors, were evaluated for the trench component modeling. These cases have been described in Section F.6.2.2.

Table F.6-14 lists CPCs that have been retained based on preliminary screening of constituents by component. Constituents which reach the Great Miami Aquifer through vertical migration within 35 years have not been retained for further evaluation using trenches. However, as discussed in Section F.6.2.3, detailed modeling was only performed for uranium-238.

The approach presented in Figure F.6-23 was employed to evaluate the necessity to use a passive or active remedial approach. This is accomplished by comparing the amount of available perched groundwater for sustainable extraction and the amount of water required to deplete the contaminant within 35 years. The amount of the available water for sustainable extraction for Infiltration Zone V may be obtained from the water budget calculation as described in Section F.6.2.1. Results of the flow rate estimate are presented in Table F.6-5.

Infiltration Zone V was divided into several subzones depending on the characteristics of local hydrogeology and uranium-238 concentration. There are two major classes of zones: the inside 1 gpm zone (I 1GPM); and the outside 1 gpm zone (O 1GPM). Each zone class was further subdivided into several subzones according to the local hydrogeology and uranium concentration.

As shown in Figure F.6-24, uranium-238 concentrations were subdivided into six subzones in order to meet the cleanup requirements for Case 1. The inside 1 gpm zone was subdivided into four subzones. Subzones I 1GPM-1, I 1GPM-2, and I 1GPM-3 are areas in which elevated uranium concentrations have been detected. Subzone I 1GPM-4 represents an area where uranium concentration is slightly above the perched water 10^{-6} PRG. The outside 1 gpm zone has been subdivided into two subzones, O 1GPM-1 and O 1GPM-2, based on the allowable residual concentrations indicated in the excavation modeling. Area-weighted average uranium concentrations associated with all the subzones are also presented in Figure F.6-24.

Concentration subzones for Case 2 and Case 3, which are presented in Figures F.6-25 and F.6-26, respectively, are different than those presented for Case 1 because of the different target cleanup concentrations used. The target cleanup concentrations (and the associated risk levels) for zones in each respective case have been outlined in Section F.6.3 and are summarized in Table F.6-15 for uranium-238. Major subzone characteristics (area-weighted concentration in each subzone, and subzone area and its dimensions) are presented in Tables F.6-16 through F.6-19.

Figures F.6-24 through F.6-26 present the uranium-238 contamination/remediation footprint by subzone required to be remediated for Cases 1, 2, and 3, respectively, in order to meet the three protection criteria described earlier. These subzones were defined in part based on the results of the excavation component modeling. Residual uranium-238 concentrations which were protective of the perched water and Great Miami Aquifer for each evaluated case were used as target concentrations in the trench modeling. As shown on Table F.6-15, target concentrations which are protective of the Great Miami Aquifer are lower than the applicable surface water PRGs. Therefore, by extension, these target concentrations are also protective of the surface water.

Subsequent to the estimation of Q_1^M (see Section F.6.2.1), the lower limit of available groundwater for sustainable extraction rate, Q_1^L, and the extraction rate required to deplete contaminants within a given period of time, Q_2, were estimated for each of the subzones in accordance with the procedure presented in Section F.6.2.1. Q_1^L, and Q_2 values shown in Table F.6-20 are the total rates for Infiltration Zone V. Q_1^L was estimated based on the ratio of subzone width to the total discharge boundary length. Q_2 was estimated based on the assumed remediation period of 35 years, area-weighted subzone uranium concentration in Table F.6-16, target cleanup concentrations specified earlier in Section F.6.3.2, subzone dimensions in Tables F.6-17 through F.6-19, and physical and geochemical parameters in Table F.6-2.

As shown in Table F.6-20, the required extraction rate to deplete uranium-238 within 35 years is in general much greater than that of the available groundwater for a sustainable extraction rate. Based on the decision flow chart shown in Figure F.6-23, injection (i.e., recharge trenches) is necessary to maintain the saturation of the perched zone while the perched zone is being extracted at the rate of Q_2. In the ensuing analysis, the procedure was further simplified by assuming that the injection rate is equal to Q_2.

A typical injection-extraction system is shown in Figure F.6-27. The system consists of parallel and equally spaced discharge and recharge trenches. The required injection rate is applied to the subzone through the recharge trenches. An equal amount of contaminated perched groundwater is simultaneously extracted from the discharge trenches. In addition to the removal of contaminants, the extraction of groundwater through the discharge trenches serves to prevent the formation of groundwater mounds as well as the lateral spreading of contaminants from the subzone due to recharge. The spacing between the trenches shown in Figure F.6-27 is designed to maintain the full saturation of the perched zone at all times to keep the contaminants as mobile as possible. In addition, the spacing also serves to achieve the maximum possible lateral hydraulic gradient (and therefore flow rate) within the perched zone in order to minimize the operational time requirement without flooding the area of operation. The spacing between two adjacent trenches is determined from:

$$\Delta L = \left[\frac{K \Delta H}{(\theta + \rho_b K_d)\left[\frac{1}{\Delta t} \ln\left(\frac{c_o}{c_{target}} \right) - \lambda \right]} \right]^{\frac{1}{2}} \qquad \text{(F6-6)}$$

where

ΔL = spacing between two adjacent trenches (ft)
c_o = initial concentration (mg/L)
c_{target} = target remedial concentration (mg/L)
λ = decay constant (1/day)

ρ_b = bulk density of soil matrix (g/ml)
K_d = partitioning coefficient (ml/g)
Δt = time interval of interest (35 years)
ΔH = head difference between the two adjacent trenches ($\leq$ 5 ft)
K = hydraulic conductivity (ft/day)
Θ = porosity (dimensionless)

94 Details of the derivation of Equation (F6-6) and of the calculation procedure are presented in Section 2 of Attachment F.6.I. Two values of partitioning coefficient, K_d, shown in Table F.6-2, were used in the calculation. Uncertainly analysis of K_d (DOE 1994b) shows that the time of travel is sensitive to K_d variation. Two uranium K_d values, 1.78 mL/g and 15 mL/g, were used for the perched sand zone in order to assess the impact of varying that parameter. The K_d value of 1.78 mL/g is based on site data for the unsaturated Great Miami Aquifer (DOE 1993) and model calibration efforts (DOE 1993, 1994b). The K_d value of 15 mL/g is based on site data for the perched sand unit (DOE 1995).

Also shown in the Table F.6-2, are two values of hydraulic conductivity used for all subzones in the I 1GPM zone and the O 1GPM-2 area. An inspection of the currently available hydraulic conductivity data for sand and gravel in this general area revealed that the data are divided into two somewhat distinct sets: the relatively low hydraulic conductivity (0.164 to 30.2 ft/ day) and the relatively high hydraulic conductivity (30.2 to 67.2 ft/ day) (DOE 1994a). The geometric means of these two data sets (1.64 and 47.11 ft/day, respectively) were used in the analysis.

F.6.3.2.3 Results

Using the subzone dimensions in Tables F.6-17 through F.6-19, the target remedial concentrations found in Table F.6-15, the initial concentration presented in Table F.6-16, the parameters in Table F.6-2, and Equation (F6-6), trench spacings for all the subzones were determined. The results are summarized in Table F.6-21. As noted in the previous section, two values of K_d and two values of hydraulic conductivity were used in the calculation of trench spacing and length. The results shown in Table 6-21 are presented as a function of K_d (1.78 and 15 L/kg) and a weighting factor, W, which is used to express reliance on the range of hydraulic conductivity and the degree of conservativeness used in the design. For W=1, the design is conservative and relies solely on the low sand unit hydraulic conductivity. The reverse is true for W=0. In reality, the idealized conceptual brown/gray homogeneous sand unit consists of sand and gravel in a clay-rich deposit, and a lacrustine basin deposit which contains predominantly clay and silt with some sand and gravel. Effective values of hydraulic conductivity in many localized areas are likely to be low. As a result, the W factor is likely to approach the value of unity. Depending on the combination between partitioning coefficient and hydraulic conductivity, the required total lineal trench length varies between approximately 3500 and 58,000 feet. The areal distribution of trenches required to remediate uranium-238 plumes for

Case 3 is presented in Figure F.6-28. The line density shown in Figure F.6-28 is representative of the trench spacing required for each subzone.

F.6.3.3 Vertical Pumping Wells

Vertical pumping wells are a series of wells completed in the perched zone and used to contain and remove the contaminated groundwater simultaneously. Presented below is a preliminary analysis relating to the use of vertical pumping wells as an active means of remediation. In other words, the vertical pumping wells are intended for both injection and extraction in order to expedite the removal of contaminants.

F.6.3.3.1 Objective

The main objective of the well component modeling is to design a vertical pumping well system that will remediate perched groundwater contamination within 35 years to concentrations that meet the primary protection criteria.

F.6.3.3.2 Technical Approach

Three cases, each involving different risk levels and receptors, were evaluated for the well component modeling. These cases have been described in Section F.6.2.2.

Table F.6-14 lists CPCs that have been retained based on preliminary screening of constituents by component. Constituents which reach the Great Miami Aquifer through vertical migration within 35 years have not been retained for further evaluation using wells. However, as discussed in Section F.6.2.3, detailed modeling was only performed for uranium-238.

The approach outlined in Figure F.6-23 was employed to determine the necessity for injection and the extraction and injection rates required to remove uranium from the perched zone within 35 years. This part of the analysis is identical to that in Section F.6.3.2.3, the results of which are presented in Tables F.6-5 and F.6-20. Based on the results shown in these two tables, it was concluded that injection would be necessary for the prescribed remediation period of 35 years.

The uranium-238 contamination/remediation footprints described in Section F.6.3.2.2 and presented in Figures F.6-24 through F.6-26 for each of the evaluated cases were also used in the evaluation of wells.

A typical injection-extraction system is shown in Figure F.6-29. The system consists of a matrix of injection and extraction wells equally spaced in a given subzone. Details of subzone determination are provided in Section F.6.3.2.2. A cell in the matrix comprises an extraction well located in the middle and four surrounding injection wells. The required total injection rate is distributed through

all the injection wells. An equal amount of contaminated groundwater is simultaneously extracted from the discharge wells. Within the injection-extraction well matrix, the injection rate is identical to the extraction rate. Injection wells along the edges of the matrix are assigned with injection rates smaller than those in the matrix interior in order to keep the total extraction rate identical to the total injection rate.

In addition to the removal of contaminants, the injection-extraction system also serves to prevent the formation of groundwater mounds as well as the lateral spreading of contaminants from the subzone due to recharge. The spacing between the wells shown in Figure F.6-29 is designed to maintain the full saturation of the perched zone at all times to keep the contaminants as mobile as possible. In addition, the well spacing serves to achieve the maximum possible lateral hydraulic gradient (and therefore flow rate) within the perched zone in order to minimize the operational time requirement without flooding the area of operation.

The drawdown or upconing at any point within the injection-extraction well matrix was determined from (Bear 1972):

$$\phi = KbH = \sum_{i=1}^{n_w} \frac{q_i}{2\pi} \ln(r_i) \qquad \text{(F6-7)}$$

where

- Φ = velocity potential function (ft^3/day)
- K = hydraulic conductivity (ft/day)
- b = saturated thickness of the perched zone (ft)
- H = hydraulic head of the perched zone (ft)
- q_i = injection or pumping rate (positive denotes injection and negative denotes pumping) (ft^3/day)
- r_i = radial distance from center of well i (ft)
- n_w = total number of wells

The spacing between two adjacent injection wells is determined based on the following constraint:

$$\Delta H_{max} = H_{inj}(\delta r) - H_{pmp}(\delta r) \leq B_{CL} \qquad \text{(F6-8)}$$

where

- δr = small distance from well center typically equal to the radius of gravel packing (ft)
- H_{inj} = hydraulic head adjacent to gravel packing of an injection well (ft)
- H_{pmp} = hydraulic head adjacent to gravel packing of a pumping well (ft)
- ΔH_{max} = maximum hydraulic head difference (ft)
- B_{CL} = thickness of overlying brown clay unit (5 ft)

94 Details of the derivation of Equations (F6-7) and (F6-8) and of the calculation procedure are presented in Section 3 of Attachment F.6.I. Similar to the approach for the trenches presented in Section F.6.3.2.2, two values of partitioning coefficient, K_d, shown in Table F.6-2, were used in the calculation. Two values of hydraulic conductivity, discussed in Section F.6.3.2.2, were used for all subzones in the I 1GPM zone and the O 1GPM-2 area.

F.6.3.3.3 Results

Using the subzone dimensions in Tables F.6-17 through F.6-19, the target concentrations found in Table F.6-15, the initial concentrations presented in Table F.6-16, the parameters in Table F.6-2, and Equations (F6-7) and (F6-8), well spacing and the corresponding total number of wells for each subzone were determined. The results shown in Table 6-22 are presented as a function of K_d (1.78 and 15 L/kg) and a weighting factor, W, which is used to express reliance on the range of hydraulic conductivity and the degree of conservativeness used in the design. For W=1, the design is conservative and relies solely on the low sand unit hydraulic conductivity. The reverse is true for W=0. In reality, the idealized conceptual brown/gray homogenous sand unit consists of sand and gravel in a clay-rich deposit, and a lacrustine basin deposit which contains predominantly clay and silt with some sand and gravel. Effective values of hydraulic conductivity in many localized areas are likely to be low. As a result, the W factor is likely to approach the value of unity. The required total number of wells varies between approximately 34 and 3200, depending on the combination between partitioning coefficient and hydraulic conductivity.

F.6.4 EVALUATION OF PERCHED GROUNDWATER CONTAINMENT COMPONENTS

Presented below is a preliminary analysis of trenches as a passive means of containment of perched groundwater.

F.6.4.1 Objective

The primary objective of the trench component modeling is to determine the technical feasibility, trench configuration and operational time frames required to contain perched groundwater contamination under natural flow gradients in order to meet the primary objective criteria.

F.6.4.2 Technical Approach

Three cases, each involving different risk levels and receptors, were evaluated for the containment trench component modeling. These cases have been described in Section F.6.2.2.

Table F.6-14 lists CPCs that have been retained based on preliminary screening of constituents by component. Constituents which reach the Great Miami Aquifer through vertical migration within 35 years have not been retained for further evaluation using trenches. However, as discussed in Section F.6.2.3, detailed modeling was only performed for uranium-238.

In this analysis, a containment trench is defined as the trench which is used for the purpose of extraction at the rate equal to the natural groundwater flow rate in the perched zone. The operational period of the trench is from the completion of the trench to the time at which the concentration of the contaminant of interest attenuates to the target concentration.

Consider a containment trench located at a distance L along a natural flow line from the centroid of the trench (Figure F.6-30). The analysis consists of determining the required operational period of the trench based on the history of the effluent concentration of the contaminant of interest at the trench. In the analysis, it is conservatively assumed that lateral hydrodynamic dispersion is absent so that the analysis may be carried out one-dimensionally along the flow direction.

With the following initial conditions:

$$c = c_o; \qquad -\frac{W_P}{2} \le x \le \frac{W_P}{2} \tag{F6-9}$$

$$c = 0; \qquad \textit{elsewhere} \tag{F6-10}$$

and a one-dimensional transport equation (Bear 1972):

$$(\theta+\rho_b K_d)\frac{\partial c}{\partial t} + \theta v\frac{\partial c}{\partial x} = \frac{\partial}{\partial x}\theta D_L\frac{\partial c}{\partial x} - \lambda(\theta+\rho_b K_d)c \tag{F6-11}$$

the concentration at the trench at time t is given by (Carslaw and Jaeger 1959):

$$c(L,t) = 0.5\exp(-\lambda t)\left[erfc\left(\frac{L-\frac{v}{R_d}t-0.5W_p}{2\sqrt{\frac{D_L}{R_d}t}}\right) - erfc\left(\frac{L-\frac{v}{R_d}t+0.5W_P}{2\sqrt{\frac{D_L}{R_d}t}}\right)\right] \tag{F6-12}$$

where

c	=	contaminant concentration (mg/L)
c_o	=	initial concentration of the plume (mg/L)
W_P	=	plume width along the considered flowline (ft)
x	=	distance along the considered flowline from the centroid of the plume (ft)
L	=	distance along the considered flowline from the centroid of the plume to the axis of the trench (ft)
R_d	=	$\left(1+\frac{\rho_b}{\theta}K_d\right)$ = retardation factor (dimensionless)
λ	=	decay constant (1/day)
ρ_b	=	bulk density of soil matrix (g/mL)

K_d	=	partitioning coefficient (mL/g)
b	=	thickness of the perched zone (ft)
Δt	=	time interval of interest (35 years)
v	=	groundwater velocity $= -\frac{K}{\theta}\frac{\partial H}{\partial x}$ (ft/day)
K	=	hydraulic conductivity (ft/day)
θ	=	porosity (dimensionless)
H	=	hydraulic head in the perched zone (ft)

The analytical framework outlined above is based on an assumption that only one plume of uniform concentration, c_o, exists. Several plumes may be included in the analysis through the use of superposition. Table F.6-2 summarizes the physical and geochemical parameters used in the modeling. Details of the calculation procedure are presented in Section 4 of Attachment F.6.I.

Uncertainly analysis of K_d (DOE 1994b) shows that the time of travel is sensitive to K_d variation. Two uranium K_d values, 1.78 and 15 mL/g, were used for the perched sand zone in order to assess the impact of varying that parameter.

Based on the results of the excavation component modeling, residual perched groundwater concentrations which were protective of the Great Miami Aquifer for each evaluated case were used as target concentrations in the containment trench modeling. As shown on Table F.6-15, target concentrations which are protective of the Great Miami Aquifer are lower than the applicable surface water PRGs. Therefore, by extension, these target concentrations are also protective of the surface water.

Uranium-238 contamination subzones based on the target cleanup concentrations for the evaluated cases have been developed as described in Section F.6.3.2.2. For each subzone the concentration within each area is approximately uniform. The average concentration in the subzone was used as the initial concentration, c_o, for the containment trench modeling cases. The plume width, W_P, for each subzone was measured (Tables F.6-17 through F.6-19).

Figures F.6-24 through F.6-26, present the uranium-238 contamination/remediation footprint by subzone required to be contained for each case, except that for Cases 1 and 2, 1 gpm zone plumes were not considered. Based on the preliminary screening of components described in Section F.6.2.2, containment trenches failed to meet the objectives of criterion 1, protection of perched groundwater drinking water sources within the 1 gpm zone. Therefore, contaminant plumes within the 1 gpm zone were not evaluated using containment trenches for Cases 1 and 2 which require protection of perched drinking water sources. For these cases, it was assumed that contaminant

plumes within the 1 gpm zone exceeding the drinking water criteria would be remediated using other components. Because protection of perched drinking water sources is not required by Case 3, contaminant plumes within the 1 gpm zone were evaluated using containment trenches for this case.

For modeling purposes, idealized containment trenches were positioned downgradient of uranium-238 plumes exceeding the target concentrations for each case, normal to the direction of perched groundwater flow. Figure F.6-31 presents the approximate locations of trenches used for containment of uranium-238 for Case 1. These locations generally correspond to perched groundwater discharge boundaries within Infiltration Zone V presented in Figure F.6-4.

After determination of approximate parameter values applicable to the subzone plume area required to be contained, Equation (F6-12) was used to determine contaminant concentration at time t. The minimum required operational period of the containment trench was then determined from the time at which the contaminant concentration attenuates to the target concentration.

F.6.4.3 Results

Table F.6-23 provides a summary of the time frames required to reach the target concentrations (i.e., containment trench operational periods) for each case evaluated. Depending on the K_d of the contained perched sand unit and subzone area, the operational time frames range from 232 to 1854 years, 174 to 1784 years, and 174 to 2664 years for Case 1, Case 2, and Case 3, respectively. Operational periods are longer for Case 3 because uranium-238 plumes within the 1 gpm zone were also contained.

Increasing K_d values for uranium will produce more total mass in the perched zone to be depleted because the dissolved concentration is fixed and the adsorbed mass increases with higher K_d. The increased total mass created when a K_d of 15 mL/g was used created a large impact on the operational time periods for containment trenches. The operational time for the higher K_d cases were approximately eight times longer than for the lower K_d cases. It should be noted that even the minimum operational periods are considerably longer than the 35-year design life of site water treatment facilities.

A separate analysis was not performed for containment of plumes through the use of vertical pumping wells. However, based on the size of the capture zone generated by a single containment well, a minimum number of wells required to contain the plume could be estimated. Because of the functional similarity between the containment wells and containment trenches, the required operational period could then be obtained from the procedure described above. It is anticipated that operational periods similar to those estimated for containment trenches would be required for containment wells.

F.6.5 COMPARISON OF COMPONENTS

F.6.5.1 Discussion of Results

Excavation

Preliminary analyses were conducted to determine the perched groundwater excavation footprints that would provide protection of various media and receptors for three cases. Because the results of the analyses were intended for comparative purposes, the site conditions were simplified for the analyses. Simplifying assumptions are described in Sections F.6.2 and F.6.3.1. Two of the assumptions are: homogeneity of the geochemical and hydrogeological properties within each vadose zone layer; and uniform distribution of contaminant concentrations based on isoconcentration contours.

In reality, the distributions of such properties are not uniform. For instance, to simplify the modeling, initial concentration terms were developed based on approximate average concentrations between isoconcentration contours. Therefore, the excavation footprints represent only an approximate, not an absolute boundary that will provide protection of various media and receptors. To ensure success of the excavation component, it is necessary for the actual detailed design to take into account the variability of contaminant concentrations and hydrogeologic properties. It is likely that detailed design modeling will provide different excavation footprints from those determined by this feasibility modeling.

Extraction Trenches/Wells

Preliminary analyses were conducted for the evaluation of the feasibility of the two components. Because the results of the analyses were intended for comparative purposes, the site conditions were simplified for the analyses. The simplified site conditions are listed as part of the assumptions in Section F.6.2 and Sections 2 and 3 of Attachment F.6.I. Two of the assumptions are: homogeneity of the geochemical and hydrogeologic properties within each subzone; and uniform distribution of uranium in each subzone. These assumptions allow the spacing between trenches and wells to be uniform. In reality, the distributions of hydrogeologic properties are not homogeneous. Furthermore the distribution of uranium concentration is not uniform, nor are those of other contaminants.

To ensure a complete success of these options, it is necessary that the actual detailed design take into account the variability of the contaminant concentrations and the hydrogeologic properties. Additional site characterization may be necessary in order to minimize the uncertainty associated with contaminant concentration distributions and hydrogeologic properties. It is likely that the actual trench/well spacings will be different from those determined by the analyses to accommodate the actual site conditions, and that the actual design will have to be more conservative than the analyses reported herein to circumvent site uncertainties. Consequently, the actual total lineal trench length and the actual total number of wells will be greater than those indicated in this report.

Containment Trenches/Wells

Preliminary analyses were conducted to determine potential time periods necessary for the operation of containment trenches and containment wells. Results indicate that the required operational periods are likely to be hundreds or thousands of years. Because of the inordinately long operational period and the absence of protection to the Great Miami Aquifer during the operational period, these two components are not likely to be considered viable.

F.6.5.2 Uncertainty Analysis

There are three major types of uncertainty which may have a direct impact on the modeling results: parameter uncertainty, model assumptions, and process uncertainty. These uncertainties were assessed through sensitivity analyses. The sensitivity analysis results are presented in previous subsections and summarized below.

Model Assumptions

As stated in Section F.6.2.1.1, several simplifying and conservative assumptions were incorporated into the analysis. These assumptions were used to make the naturally complex site conditions amenable to mathematical simulation without losing salient characteristics of the actual environment at the site. Therefore, the interpretation of modeling results should be carried out in a manner consistent with the intent of the assumptions. For example, the following two assumptions, homogeneity of material properties, and uniformity of geometry, have a direct impact on the analysis of trenches and wells. They allow the trenches and wells to be uniformly spaced within a given subzone. The variation of thickness of the transmissive zone (the brown/gray sand) is not expected to alter the spacing requirements if the local extraction and injection rates are modified in accordance with the variation of thickness (see Attachments F.6.I.2, and F.6.I.3 for theoretical background). The uncertainty relating to the homogeneity of material properties was indirectly evaluated through the variation of hydraulic conductivity. The results of this parameter variation are discussed as part of parameter uncertainty below.

In the analysis of the excavation option, it was assumed that the unsaturated zone above the Great Miami Aquifer was absent, and the ability of the unsaturated Great Miami Aquifer zone (vadose zone layer 2) to delay the travel time of contaminants between the water table in the upper Great Miami Aquifer and the Great Miami Aquifer gray clay interface was not taken into consideration. As shown in Table F.6-13, the presence of the upper Great Miami Aquifer could result in additional decay, due to longer travel time, and approximately four percent reduction in contaminant concentration exiting the vadose zone.

Parameter Uncertainty

Parameter uncertainty arises from the fact that a finite amount of data is available at any given site. For the evaluation of the remedial components, the following parameters were considered important in the assessment of remedial components: hydraulic conductivity and K_d.

103 In the sensitivity analysis for the uncertainty of horizontal hydraulic conductivity in the perched zone, two values of hydraulic conductivity were used (1.64 and 47.1 ft/day) in the vicinity of the 1 gpm zone. The range of the mean value of hydraulic conductivity was evaluated by using a weighing factor and two bounding hydraulic conductivity values as shown in the footnotes of Tables F-6-21 and F-6-22. The sensitivity analysis of hydraulic conductivity was conducted under two K_d conditions as shown in the first column of the tables. As can be seen in these tables, the uncertainty associated with the mean value of hydraulic conductivity is relatively significant. The uncertainty associated with the mean value of hydraulic conductivity causes a variation by a factor of up to four for the total lineal trench lengths and by an order of magnitude for the total number of wells. Because of the spatial variability of the material properties at the site, the spacing between the trenches and wells would have to be modified so as to accommodate the variability of the material properties. The spatial variability of material properties in the glacial overburden is relatively complex and is reflective of a complex depositional history as described in Section F.2.2. When dealing with the actual site uncertainty, it may be necessary to be conservative with the design of remedial components and the range of uncertainty may be greater than that shown in this analysis. Possible extreme variability associated with the material properties (e.g., variation over several orders of magnitude for the values of hydraulic conductivity) may result in incomplete success of remediation through extraction. Contaminants may remain immobile in soil blocks with relatively low hydraulic conductivity (approximately three orders of magnitude smaller than hydraulic conductivity in neighboring blocks). Removal of contaminants from these soil blocks is controlled by molecular diffusion which is a very slow process (see Section F.6.5.3 for examples). For the excavation option, the migration of contaminants in the vertical direction is dictated by the prescribed infiltration rate. Therefore, the variation of vertical hydraulic conductivity does not play an important role in vertical migration of contaminants in the vadose zone.

Uncertainty associated with the K_d was also analyzed through sensitivity analyses. Results are presented in the previous subsections. As shown in Tables F.6-21 and F.6-22, the impact of K_d uncertainty on the total lineal trench length and the total number of wells is quite significant. As can be seen in the tables, the uncertainty based on the range of K_d for the perched sand unit used in the analysis (1.78 to 15 L/kg) results in the variation of total lineal trench length by a factor of up to three and the variation of total well number by a factor of up to five. As shown in Table F.6-23, based on the range of K_d used, the required operational period for containment trenches/wells could

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vary by a factor of seven. For the excavation option, the K_ds used for the gray clay were 3.1 and 15 L/kg. As shown in Table F.6-13, the variation of K_d changes in contaminant concentrations exiting the vadose zone. As the K_d increases, the exiting concentrations could decrease by a factor of two and the time taken to reach maximum concentration in the Great Miami Aquifer could increase by a factor of up to three.

Process Uncertainty

Process uncertainty relating to a remedial component is mainly due to the adsorption/desorption process. The current analysis is based on the assumption that the process is in equilibrium at all time. Because of the fact that relatively high injection and extraction rates are necessary to deplete the contaminants within a 35-year time frame, the groundwater velocity within the remediated zones during that time period would be much greater than the natural groundwater velocity. Under this situation, it is possible that the desorption process may not be in equilibrium and may result in a longer operational period. The effects due to uncertainty associated with K_d were indirectly investigated by varying the K_d as part of parameter uncertainty. If the trench and/or well options are selected, it may be necessary to evaluate the desorption process under nonequilibrium conditions before completing the design of remedial components.

F.6.5.3 Technical Issues

Because the downward vertical gradient is responsible for the vertical migration of contaminants from the perched zone to the Great Miami Aquifer, the only way to curtail or reverse the downward migration of contaminants across the clay layer is through complete dewatering of the perched zone or inducing negative pressure throughout the perched zone. The latter would be extremely difficult and would possibly require indefinite maintenance. The former, complete dewatering, would be physically impossible to accomplish. Furthermore, both methods may leave a significant amount of uranium in a relatively immobile sorbed phase in the vadose zone.

Based on the water budget calculation (see Section F.2.6.1), the amount of water available for sustained extraction is a small fraction of the amount of water required to deplete contaminants in the perched zone within a reasonable period of time. Therefore an injection-extraction system is necessary for the active trench and well components. Injection, however, is likely to increase the vertical migration rate of uranium because injection tends to increase the hydrostatic pressure at the top clay interface and, subsequently, the vertical gradient across the clay layer and the vertical migration rate of contaminants.

According to the hydraulic conductivity data from Infiltration Zone V, there are several zones of relatively low hydraulic conductivity. These zones include the low conductivity zones within the perched-zone sand and the fine-grained silt and clay lenses within the sand unit (DOE 1994a). The

hydraulic conductivities of these zones vary from approximately 10^{-3} to 10^{-1} ft/day. Some of these zones lie beneath contaminant sources at the ground surface and may have received a significant amount of contaminants during the past four decades. Contaminants in these zones are relatively immobile due to the low hydraulic conductivity of the zone and the abundance of fine-grained materials which tend to adsorb contaminants more readily. The major mass transfer mechanism between these zones and the surrounding coarse grained, higher hydraulic conductivity zones is through molecular diffusion. A preliminary analysis was conducted to determine the remediability of the low-hydraulic-conductivity zones under typical remedial scenarios with trenches and vertical extraction/injection wells. Details of the analysis are presented in Section 5 of Attachment F.6.I.

Results shown in Section 5 of Attachment F.6.I indicate that for a low-hydraulic-conductivity zone of 60 feet in width, it may take thousands of years to remove contaminants through molecular diffusion. Within the period of 35 years, it is possible to remove contaminants only from within a few feet from the block surface. The distribution (degree of abundance) of this type of low-hydraulic-conductivity blocks within the perched zone is complex due to glacial overburden depositional processes. A significant presence of this type of block may render the remedial alterative scenarios using trenches and vertical wells impractical.

The current analysis is based on an assumption that the underlying gray clay unit and the overlying overburden do not function as sources of contamination to the perched zone during and after the remediation period. This is a technical issue for the trench/well components. For the excavation component, it will be addressed through confirmatory sampling which is part of the excavation procedure.

Recently, it has been realized that the adsorption/desorption process may not be instantaneous and that the contaminant concentrations in the sorbed and aqueous phases may not be in complete equilibrium (Harvey et al. 1994). A desorption process slower than predicted by the equilibrium model may pose a problem in terms of the remediation time period. The rate of desorption under nonequilibrium conditions is not accurately known. The final design of the trench and well components will have to account for this uncertainty.

Uncertainty relating to the distribution of K_d, hydraulic conductivity, and initial contaminant concentrations will play a key role in the final design of the remedial option. To circumvent these uncertainties, the final remedial design will have to be conservative. Since the economic criteria are not part of this analysis, it has not been determined whether the conservativeness of the design will render the chosen remedial component prohibitive due to cost.

F.6.5.4 Feasibility of Components

Excavation

This component is considered technically feasible.

Active Trenches

This component is considered technically feasible. However, there are several aspects that must be carefully considered before selecting this option:

- There are difficulties associated with the trench/drain construction/installation. Because the required depth of trenches or drains is significant (greater than 5 feet), extra precaution must be exercised to avoid the failure of the trench walls and the instability of the sand unit in the perched zone. Reinforcement, anchoring, and dewatering during construction may be necessary. For trenches which are closely spaced, the required slope for stable excavated walls may be dimensionally impractical and other construction methods may be necessary.

- The success of this component depends on the uncertainty associated with site conditions. As mentioned in the earlier subsection, the final detailed design may have to be significantly more conservative than the preliminary design presented in this evaluation to compensate for the uncertainties associated with the site.

- This component does not afford immediate protection for the Great Miami Aquifer during the period of remediation and must be carried out conjunctively with other complementary remedial activities for the Great Miami Aquifer during that time period.

- This component does not address potential recontamination due to molecular diffusion from the contaminants remaining in the overburden, the gray clay unit, and soil blocks with low hydraulic conductivity.

Vertical Injection/ Extraction Wells

This component is considered technically feasible. However, there are several aspects that must be carefully considered before selecting this option:

- The success of this component depends on the degree of uncertainty associated with site conditions. As mentioned in the earlier subsection, the final detailed design may have to be significantly more conservative than the preliminary design presented in this evaluation to compensate for the uncertainties associated with the site.

- This component does not afford immediate protection for the Great Miami Aquifer during the period of remediation and must be carried out conjunctively with other complementary remedial activities for the Great Miami Aquifer during that time period.

- This component does not address potential recontamination due to molecular diffusion from the contaminants remaining in the overburden, the gray clay unit, and soil blocks with low hydraulic conductivity.

Containment Trenches/Wells

This component is considered technically feasible. However, there are several aspects that must be carefully considered before selecting this option:

- The success of this component depends on the degree of uncertainty associated with site conditions. As mentioned in the earlier subsection, the final detailed design may have to be significantly more conservative than the preliminary design presented in this evaluation to compensate for the uncertainties associated with the site.

- This component does not afford immediate protection for the Great Miami Aquifer during the period of remediation and must be carried out conjunctively with other complementary remedial activities for the Great Miami Aquifer during that time period.

- This component does not address potential recontamination due to molecular diffusion from the contaminants remaining in the overburden, the gray clay unit, and soil blocks with low hydraulic conductivity.

- Operational periods are in the range of hundreds to thousands of years.

F.6.5.5 Recommendation of Selected Component

The recommendation of the remedial component to address the contamination problem in the perched groundwater zone is based solely on technical merit. The consideration of economic criteria, which should not be overlooked before making the final selection of the most appropriate and economically feasible remedial component, is beyond the scope of this evaluation.

Based on the analysis and results presented in the preceding sections, it is recommended that the excavation component be adopted. This recommendation is based on the following reasons:

- This component provides immediate protection to the Great Miami Aquifer and perched drinking water sources. Vertical migration from the perched zone is eliminated. Furthermore, part of the adversely impacted gray clay unit and blocks with low hydraulic conductivity and significantly elevated contaminant concentrations may also be removed during the excavation to avoid potential recontamination in the future.

- The degree of uncertainty relating to site glacial sedimentation is inconsequential. This method is not dependent on hydrogeologic and geochemical performance of the materials in the perched groundwater zone.

F.6.6 SUMMARY AND CONCLUSIONS

Groundwater modeling has been performed to study the technical feasibility of five remedial action components for perched groundwater which will be used to develop remedial alternatives. The studied components fall into two major categories and are listed below:

Extraction Components
- Collection trenches
- Vertical pumping wells
- Excavation of contaminated perched groundwater zone soil

Containment Components
- Collection trenches
- Vertical pumping wells

Modeling results indicate that all five components are technically feasible if sufficient conditional assumptions are applied. Implementation of the trench and well designs for both removal/extraction and containment/control components, however, may not be practicable based on the nature and extent of the preliminary system design or long operational time frames.

Among the components using extraction techniques, only the excavation component meets all of the protection criteria. Trenches and wells may not provide protection of the Great Miami Aquifer based on the vertical gradients that exist across the gray clay unit between the perched sand unit and the underlying Great Miami Aquifer. Additionally, the use of recharge trenches or injection wells will further increase vertical gradients and exacerbate the vertical contaminant migration rate. Results indicate that between 3500 and 58,000 lineal feet of trenches and between 34 and 3200 wells would be required to remediate uranium-238 plumes within 35 years. Note that the large ranges in number of wells and trench lengths are due to uncertainties associated with site conditions.

In addition, owing to uncertainties related to the hydrogeologic and geochemical assumptions of the idealized perched sand unit, trench and well component designs may represent the minimum requirements. The actual designs may have to be more conservative to compensate for the degree of uncertainties associated with glacial sediment.

Neither of the components using containment techniques meet the criteria for protecting perched drinking sources because by definition their objective is to contain contamination within the perched groundwater zone. The containment components also potentially fail to protect the Great Miami Aquifer based on the vertical gradients described above. In addition, the operational periods for containment trenches and wells are on the order of hundreds to thousands of years.

The excavation of contaminated perched groundwater zones appears to be the most straightforward and effective strategy for remediating perched groundwater within the glacial overburden of the five

components evaluated. Future potential loading to the Great Miami Aquifer from residual contamination left in place (following excavation of areas of higher contamination) results in a maximum future uranium concentration of less than 3 μg/L for Case 1 and 6 μg/L for Cases 2 and 3.

F.6.7 REFERENCES

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TABLE F.6-1

444 **GENERAL PHYSICAL AND CHEMICAL PARAMETERS USED IN PERCHED**
463 **GROUNDWATER EXCAVATION COMPONENT MODELING**

Parameter	Units	Perched Sand Layer[a]	Vadose Zone Layer 1[b]	Vadose Zone Layer 2[c]
Bulk density	g/mL	1.86×10^{0}[d]	2.19×10^{0}[d]	1.86×10^{0}[d]
Porosity	(%)/100	3.00×10^{-1}[e]	2.00×10^{-1}[f]	3.00×10^{-1}[e]
Vertical hydraulic conductivity	ft/day	NA[g]	2.05×10^{-3}[d]	$4.50 \times 10^{+1}$[di]
Moisture content	(%)/100	3.00×10^{-1}[d]	2.00×10^{-1}[f]	2.04×10^{-1}[d]
Soil-dependent parameter 1/(2b+3)		NA	3.90×10^{-2}[d]	9.00×10^{-2}[d]
Thickness	ft	15[h]	Variable	0, Variable

[a] Conceptual perched sand layer
[b] Glacial overburden gray clay
[c] Unsaturated sand and gravel
[d] Operable Unit 5 Remedial Investigation Report (DOE 1995)
[e] SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994c)
[f] See Section F.2.2.3
[g] Not applicable
[h] See Section F.2.2.4
[i] Glacial Overburden/Upper Great Miami Aquifer System Model Development Report (DOE 1994b)

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TABLE F.6-2

GENERAL PHYSICAL AND CHEMICAL PARAMETERS OF THE PERCHED SAND UNIT USED IN PERCHED GROUNDWATER TRENCH AND WELL COMPONENT MODELING

Parameter	Location	Value	Remarks
Hydraulic conductivity	Western region of the outside-1-gpm zone	2 ft/day	1 test value
	Along discharge boundaries	3.55 ft/day	Geometric average of 8 test values[a]
	Interior and 1-gpm zones	1.64 ft/day	Geometric average of 6 test values, low hydraulic conductivity zone[a]
		47.11 ft/day	Geometric average of 6 test values, high hydraulic conductivity zone[a]
	Along recharge boundaries	4.48 ft/day	Geometric average of 4 test values
Porosity	Site-wide	0.3	Model calibration[b]
Bulk density	Site-wide	1.855 g/mL	
Uranium partitioning coefficient (K_d)	Site-wide	1.78 L/kg	Based on site data[c] and Great Miami Aquifer model calibration efforts[d]
		15 L/kg	Based on site data from perched sand unit[c]
Uranium decay constant	Site-wide	4.25×10^{-13}/day	
Thickness	Infiltration Zone V	15 ft	Based on conceptual model
Hydraulic gradient	Infiltration Zone V	0.01 - 0.0158	Along discharge boundaries
		0.0167 - 0.04	Along recharge boundaries

[a] FEMP Glacial Till/Vadose Zone Hydraulic Investigation Report (DOE 1994a)
[b] South Plume Removal Action Pumping Test Report (DOE 1993b)
[c] Operable Unit 5 Remedial Investigation Report (DOE 1995)
[d] Groundwater Modeling Report - Summary of Model Development (DOE 1993a) and SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994c)

TABLE F.6-3

DISTRIBUTION COEFFICIENTS, RETARDATION FACTORS, AND DECAY CONSTANTS FOR MODELED PERCHED GROUNDWATER CONSTITUENTS USED IN THE EXCAVATION COMPONENT MODELING

Constituent	K_d Layer 1 (mL/g)	K_d Layer 2[a] (mL/g)	R_d Layer 1	R_d Layer 2[a]	Decay Constant (1/day)
Radionuclides					
Uranium-238	3.10×10^{0}	1.78×10^{0}	3.49×10^{1}	1.72×10^{1}	4.25×10^{-13}
	1.50×10^{1}		1.65×10^{2}		
Neptunium-237	5.50×10^{1}	5.00×10^{0}	6.03×10^{2}	4.65×10^{1}	8.87×10^{-10}
Strontium-90	1.00×10^{1}	2.50×10^{0}	1.11×10^{2}	2.37×10^{1}	6.64×10^{-5}
Technetium-99	1.18×10^{-1}	7.00×10^{-2}	2.29×10^{0}	1.64×10^{0}	8.92×10^{-9}
Inorganics					
Nitrate	0.00	0.00	1.00×10^{0}	1.00×10^{0}	NA[b]
Magnesium	4.50×10^{0}	4.50×10^{0}	5.03×10^{1}	4.19×10^{1}	NA

[a] When layer 2 thickness of 0 was modeled, these values were not used
[b] Not applicable

TABLE F.6-4

SPECIATION OF PERCHED GROUNDWATER CONSTITUENTS AND APPLICABLE K_d VALUES USED IN THE TRENCH AND WELL COMPONENT MODELING

CPC	Range of Perched Sand K_d (L/kg)	Selected Perched Sand K_d (L/kg)
Radionuclides		
Neptunium-237	2.4 - 15	5
Radium-226	700 - 1260	700
Strontium-90	20 - 110	20
Thorium-228	40 - 130	130
Thorium-230	40 - 130	130
Thorium-232	40 - 130	130
Uranium-234	11 - 40	1.78[a], 15[b]
Uranium-235/236	11 - 40	1.78[a], 15[b]
Uranium-238	11 - 40	1.78[a], 15[b]
Uranium-Total	11 - 40	1.78[a], 15[b]
Inorganics		
Arsenic	5 - 16	16
Beryllium	100 - 700	250
Cadmium	160 - 500	160
Chromium	30 - 60	45
Copper	110	35
Fluoride	DNA[c]	DNA[c]
Magnesium	4.5	4.5
Manganese	50 - 180	20
Nitrate	0	0
Silver	90 - 180	90
Thallium	1500	1500
Vanadium	35 - 140	200
Organics		
Benzene	0.141	0.141
Carbazole	2.04	2.04
Carbon disulfide	0.152	0.152
Carbon tetrachloride	0.562	0.562

TABLE F.6-4
(Continued)

CPC	Range of Perched Sand K_d (L/kg)	Selected Perched Sand K_d (L/kg)
Organics (Continued)		
Methylene chloride	0.0186	0.0186
Trichloroethene	0.355	0.355
Vinyl chloride	0.00416	0.00416

[a] SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994c)
[b] Section F.2.4 of the FS
[c] Data not available

TABLE F.6-5

SUMMARY OF RECHARGE AND DISCHARGE RATES AND DEPLETION RATE OF PERCHED GROUNDWATER STORAGE FOR INFILTRATION ZONE V

Rate	Total Length (ft)	Geometric Average Hydraulic Conductivity (ft/day)	Hydraulic Gradient	Flow Rate (gpm)
Discharge rate	4200	3.55[a]	0.01 - 0.0158	14.80
Recharge rate	1400	4.48[b] - 8.79[c]	0.0167 - 0.04	9.81 - 19.25

	Total Area (ft)	Porosity	Time Period (years)	Flow Rate (gpm)
Groundwater storage depletion rate	4.6×10^6	0.3	35	8.2

[a] Geometric mean of hydraulic conductivity values from 8 locations close to Infiltration Zone V discharge boundary (see also Table F.6-2)
[b] Geometric mean of hydraulic conductivity values from 4 locations close to Infiltration Zone V recharge boundary
[c] Geometric mean of hydraulic conductivity values in the vicinity of and interior to the 1 gpm zone

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TABLE F.6-6

PRELIMINARY FEASIBILITY SCREENING OF PERCHED GROUNDWATER REMEDIAL COMPONENTS

Remedial Alternative	Criterion 1 Protective of Perched Drinking Water Sources?	Criterion 2 Protective of GMA?	Criterion 3 Protective of Surface Water Bodies?
Removal/Extraction			
Excavation	Yes	Yes	Yes
Trenches	Yes	No[a]/Yes[b]	Yes
Wells	Yes	No[a]/Yes[b]	Yes
Containment/Control			
Trenches	No	No[a]	Yes
Wells	No	No[a]	Yes

[a] Under normal conditions, vertical migration of contaminants from the perched zone to the Great Miami Aquifer is not eliminated using trenches and wells due to the downward vertical gradients.

[b] After completion of perched water remediation using trenches or wells, the residual conditions will be protective of the Great Miami Aquifer.

TABLE F.6-7

SUMMARY OF LEVELS OF PROTECTION PROVIDED BY PERCHED GROUNDWATER REMEDIATION CASES

	Protective of Perched Water as Drinking Water Source?		Protective of the Great Miami Aquifer as Drinking Water Source?	
	10^{-6} PRGs[a]	MCLs or 10^{-5} PRGs[a]	10^{-6} PRGs[a]	MCLs or 10^{-5} PRGs[a]
Case 1	Yes	Yes	Yes	Yes
Case 2	No	Yes	No	Yes
Case 3	No	No	No	Yes

[a] Preliminary remediation goals are based on MCLs, if avaliable, 10^{-5} or 10^{-6} ILCR or 0.2 hazard quotients for the resident farmer/child

TABLE F.6-8

PERCHED GROUNDWATER REMEDIAL COMPONENT SCREENING RESULTS BY CONSTITUENT

Perched Groundwater Constituent of Potential Concern	Data Source (Draft RI Report Plate No.)	Screen Out Constituents below the 10^{-7} ILCR or 0.1 HQ within Infiltration Zone V (All Alternatives)	Screen Out Constituents which Reach GMA in 35 Years (Trench and Well Alternatives)[a]	Screen Out Constituents which Do Not Reach GMA in 1,000 Years and are Outside of 1 GPM Zone (Excavation Alternative)[b]	Feasible Remedial Alternatives[c]
Radionuclides					
Lead-210	NA				T,E,W
Neptunium-237	E-31				T,E,W
Plutonium-238	E-29, -30	Yes			NA
Plutonium-239/240	E-28	Yes			NA
Radium-226	E-3, -14			Yes	T,W
Strontium-90	E-23, -24				T,E,W
Technetium-99	E-25, -26		Yes		E
Thorium-228	E-21, -22			Yes	T,W
Thorium-230	E-11, -12			Yes	T,W
Thorium-232	E-15, -16			Yes	T,W
Total Thorium	E-17, -18			Yes	T,W
Uranium-234	E-7, -8				T,E,W
Uranium-235/236	E-9, -10				T,E,W
Uranium-238	E-5, -6				T,E,W
Total Uranium	E-1 through E-4				T,E,W

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TABLE F.6-8
(Continued)

Perched Groundwater Constituent of Potential Concern	Data Source (Draft RI Report Plate No.)	Screen Out Constituents below the 10^{-7} ILCR or 0.1 HQ within Infiltration Zone V (All Alternatives)	Screen Out Constituents which Reach GMA in 35 Years (Trench and Well Alternatives)[a]	Screen Out Constituents which Do Not Reach GMA in 1,000 Years and are Outside of 1 GPM Zone (Excavation Alternative)[b]	Feasible Remedial Alternatives[c]
Inorganics					
Arsenic	E-36			Yes	T,W
Beryllium	E-38			Yes	T,W
Cadmium	E-39			Yes	T,W
Chromium	E-41				T,E,W
Copper	E-43			Yes	T,W
Cyanide	E-44	Yes			NA
Fluoride	NA				T,E,W
Magnesium	E-47				T,E,W
Manganese	E-48			Yes	T,W
Molybdenum	E-50	Yes			NA
Nitrate	E-69				T,E,W
Silver	E-54			Yes	T,W
Thallium	E-56				T,W
Vanadium	E-57			Yes	T,W

TABLE F.6-8
(Continued)

Perched Groundwater Constituent of Potential Concern	Data Source (Draft RI Report Plate No.)	Screen Out Constituents below the 10^{-7} ILCR or 0.1 HQ within Infiltration Zone V (All Alternatives)	Screen Out Constituents which Reach GMA in 35 Years (Trench and Well Alternatives)[a]	Screen Out Constituents which Do Not Reach GMA in 1,000 Years and are Outside of 1 GPM Zone (Excavation Alternative)[b]	Feasible Remedial Alternatives[c]
Organics					
1,1-Dichloroethane	E-60		Yes		E
1,1,1-Trichloroethane	E-61		Yes		E
1,1,2-Trichloroethane	NA		Yes		E
1,2-Dichloroethane	E-63		Yes		E
bis(2-ethylhexyl)phthalate	NA				T,E,W
Benzene	NA		Yes		E
Bromoform	NA		Yes		E
Carbazole	NA				T,E,W
Carbon Disulfide	NA				T,E,W
Methylene Chloride	NA				T,E,W
Pentachlorophenol	NA		Yes		E
Tetrachloroethene	E-64		Yes		E
Trichloroethene	E-65				T,E,W
Vinyl Chloride	NA				T,E,W

[a] If constituent reaches the GMA within 35 years, the trench and well alternatives (i.e., lateral transport) are not considered feasible alternatives.
[b] If constituent does not reach the GMA within 1,000 years and the plume is outside of the PRG zone protective of perched drinking water sources, the excavation alternative is not necessary for protection of the GMA or the perched drinking water zone. Other alternatives which are protective of surface waters will be considered for these constituents.
[c] T = Trench Alternative, E = Excavation Alternative, W = Vertical Well Alternative.

TABLE F.6-9

PERCHED GROUNDWATER CONSTITUENTS OF POTENTIAL CONCERN FOR THE EXCAVATION COMPONENT

Constituents of Potential Concern	Plume Located Outside of the Excavation Footprints in Infiltration Zone V
Radionuclides	
Lead-210	No
Neptunium-237	Yes
Plutonium-238	No
Plutonium-239/240	No
Strontium-90	Yes
Technetium-99	Yes
Uranium-234	Yes
Uranium-235/236	Yes
Uranium-238	Yes
Total Uranium	Yes
Inorganics	
Chromium	No
Fluoride	No
Magnesium	Yes
Nitrate	Yes
Organics	
1,1-Dichloroethane	No
1,1,1-Trichloroethane	No
1,1,2-Trichloroethane	No
1,2-Dichloroethane	No
bis(2-ethylhexyl)phthalate	No
Benzene	No
Bromoform	No
Carbazole	No
Carbon disulfide	No
Methylene chloride	No
Pentachlorophenol	No
Tetrachloroethene	No
Trichloroethene	No
Vinyl chloride	No

TABLE F.6-10

EXCAVATION MODELING RESULTS FOR PERCHED GROUNDWATER - CASE 1

Perched Water CPC	Maximum Initial Perched Groundwater Concentration (mg/L)	GMA 1 x 10^{-6} PRG for RME Farmer/Child (mg/L)	GMA Background Concentration (mg/L)	GMA Target Concentration[a] (mg/L)	Maximum Concentration Exiting Vadose Zone Layer 2 (mg/L)	Exiting Concentration >1 Order of Magnitude Above GMA Target Concentration	Maximum Concentration in GMA (mg/L)
Uranium-238	1.19×10^{-1}	1.833×10^{-3}	1.200×10^{-3}	3.033×10^{-3}	8.577×10^{-2}	Yes	2.944×10^{-3} [b]
Technetium-99	3.53×10^{-6}	4.253×10^{-7}	1.294×10^{-6}	1.719×10^{-6}	2.396×10^{-6}	No	NA
Neptunium-237	7.09×10^{-7}	1.111×10^{-7}	0.000	1.111×10^{-7}	2.737×10^{-17}	No	NA
Strontium-90	2.19×10^{-11}	2.255×10^{-12}	4.745×10^{-12}	7.000×10^{-12}	3.275×10^{-16}	No	NA
Magnesium	7.50×10^{1}	7.710×10^{0}	3.850×10^{1}	4.621×10^{1}	5.765×10^{1}	No	NA
Nitrate	1.50×10^{1}	1.01×10^{1}	1.140×10^{1}	2.150×10^{1}	7.869×10^{0}	No	NA

[a] Target concentrations are the sum of the PRG concentration and the background concentration.
[b] Maximum concentration occurs at grid block 44,78 at 250 years.
GMA - Great Miami Aquifer
NA - Not Applicable

TABLE F.6-11

EXCAVATION MODELING RESULTS FOR PERCHED GROUNDWATER - CASE 2

Perched Water CPC	Maximum Initial Perched Groundwater Concentration (mg/L)	MCL or GMA 1×10^{-5} PRG for RME Farmer/Child (mg/L)	GMA Background Concentration (mg/L)	GMA Target Concentration[a] (mg/L)	Maximum Concentration Exiting Vadose Zone Layer 2 (mg/L)	Exiting Concentration >1 Order of Magnitude Above GMA Target Concentrations	Maximum Concentration GMA (mg/L)
Uranium-238	1.19×10^{-1}	2.000×10^{-2}	NA[b]	2.000×10^{-2}	8.577×10^{-2}	No	5.36×10^{-3}[c]
Technetium-99	1.18×10^{-5}	4.253×10^{-6}	1.294×10^{-6}	5.547×10^{-6}	8.100×10^{-6}	No	NA
Neptunium-237	7.09×10^{-7}	1.111×10^{-6}	0.000	1.111×10^{-6}	NM	NA	NA
Strontium-90	2.19×10^{-11}	2.255×10^{-11}	4.745×10^{-12}	2.730×10^{-11}	NM	NA	NA
Magnesium	7.50×10^{1}	7.710×10^{0}	3.850×10^{1}	4.621×10^{1}	5.856×10^{1}	No	NA
Nitrate	1.50×10^{1}	1.000×10^{1}	NA[b]	1.000×10^{1}	7.869×10^{0}	No	NA

[a] Target concentrations are the sum of the PRG concentration and the background concentration, unless MCL is available.
[b] Not applicable because MCL is available.
[c] Maximum concentration occurs at grid block 42,74 at 170 years.
GMA - Great Miami Aquifer
NA - Not applicable
NM - Not modeled because initial concentration is less than the target concentration.

TABLE F.6-12

EXCAVATION MODELING RESULTS FOR PERCHED GROUNDWATER - CASE 3

Perched Water CPC	Maximum Initial Perched Groundwater Concentration (mg/L)	MCL or GMA 1×10^{-5} PRG for RME Farmer/Child (mg/L)	GMA Background Concentration (mg/L)	GMA Target Concentrations[a] (mg/L)	Maximum Concentration Exiting Vadose Zone Layer 2 (mg/L)	Exiting Concentration > 1 Order or Magnitude Above GMA Target Concentration	Maximum Concentration in GMA (mg/L)
Uranium-238	1.19×10^{-1}	2.000×10^{-2}	NA[b]	2.000×10^{-2}	8.577×10^{-2}	No	5.36×10^{-3}[c]
Technetium-99	1.18×10^{-5}	4.253×10^{-6}	1.294×10^{-6}	5.547×10^{-6}	8.100×10^{-6}	No	NA
Neptunium-237	7.09×10^{-7}	1.111×10^{-6}	0.000	1.111×10^{-6}	NM	NA	NA
Strontium-90	2.19×10^{-11}	2.255×10^{-11}	4.745×10^{-12}	2.730×10^{-11}	NM	NA	NA
Magnesium	7.50×10^{1}	7.710×10^{0}	3.850×10^{1}	4.621×10^{1}	5.856×10^{1}	No	NA
Nitrate	5.00×10^{1}	1.000×10^{1}	NA[b]	1.000×10^{1}	3.626×10^{1}	No	NA

[a] Target concentrations are the sum of the PRG concentration and the background concentration unles MCL is available unless MCL is available.
[b] Not applicable because MCL is avaiable.
[c] Maximum concentration occurs at grid block 42,74 at 170 years.
GMA - Great Miami Aquifer.
NM - Not modeled because initial concentraion is less than the target concentration.
NA - Not applicable.

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TABLE F.6-13

SUMMARY OF SENSITIVITY ANALYSES FOR EXCAVATION COMPONENT MODELING

Case	Vadose Zone Layer 1 K_d (L/Kg)	Vadose Zone Layer 2 Thickness (ft)	Maximum Concentration Exiting Vadose Zone (mg/L)	Time of Maximum (years)	Maximum GMA Concentration (mg/L)	Time of Maximum (years)
Case 1	3.1	0	8.577×10^{-2}	70	2.944×10^{-3}	250
Sensitivity Case 1a	15	0	4.728×10^{-2}	270	1.134×10^{-3}	700
Sensivitity Case 1b	3.1	variable	8.205×10^{-2}	160	NM	NM
Case 2	3.1	0	8.577×10^{-2}	70	5.36×10^{-3}	170
Sensitivity Case 2a	15	0	4.728×10^{-2}	270	2.35×10^{-3}	370
Sensivitity Case 2b	3.1	variable	8.205×10^{-2}	160	NM	NM

NM = Not Modeled

TABLE F.6-14

PERCHED GROUNDWATER CONSTITUENTS OF POTENTIAL CONCERN FOR THE TRENCH/WELL COMPONENTS

RADIONUCLIDES	INORGANICS	ORGANICS
Lead-210	Arsenic	1,1,2-Trichloroethane
Neptunium-237	Beryllium	bis(2-ethylhexyl)phthalate
Plutonium-238	Cadmium	Carbazole
Plutonium-239/240	Chromium	Carbon disulfide
Radium-226	Copper	Methylene chloride
Strontium-90	Cyanide	Trichloroethene
Thorium-228	Fluoride	Vinyl chloride
Thorium-230	Magnesium	
Thorium-232	Manganese	
Total thorium	Molybdenum	
Uranium-234	Nitrate	
Uranium-235/236	Silver	
Uranium-238	Thallium	
Total uranium	Vanadium	

TABLE F.6-15

SUMMARY OF PERCHED GROUNDWATER PRELIMINARY REMEDIATION GOALS FOR URANIUM-238

	Uranium-238 Concentration (mg/L)
Perched water 10^{-6} ILCR PRG for resident[a] farmer/child	3.06×10^{-3}
Perched water MCL for resident farmer/child	2.00×10^{-2}
Perched water background concentration	1.40×10^{-3}
Perched water 10^{-6} target concentration[b] protective of perched drinking water sources	4.46×10^{-3}
Perched water MCL target concentration protective of perched drinking water sources	2.00×10^{-2}
Perched water target concentration protective of the Great Miami Aquifer[c] at 3 μg/L (10^{-6} ILCR PRG with background)	7.44×10^{-2}
Perched water target concentration protective of the Great Miami Aquifer[c] at 20 μg/L (MCL)	1.48×10^{-1}
Surface water (Paddys Run) 10^{-6} ILCR PRG for user of meat/milk	5.31×10^{-1}
Surface water (Paddys Run) 10^{-5} ILCR PRG for user of meat/milk	$3.79 \times 10^{+0}$

[a] The selected PRG is the lower of the uranium-total or uranium-238 PRGs
[b] Target concentrations are the sum of PRGs and background concentrations
[c] Concentrations protective of the Great Miami Aquifer are based on the results of the excavation modeling which defined residual perched groundwater concentrations that did not impact the Great Miami Aquifer above Great Miami Aquifer target concentrations

TABLE F.6-16
SUMMARY OF AREA-WEIGHTED URANIUM-238 CONCENTRATIONS USED IN PERCHED GROUNDWATER TRENCH AND WELL COMPONENT MODELING

Area	Case 1 (μg/L)	Case 2 (μg/L)	Case 3 (μg/L)
Inside 1 gpm Zone			
I1GPM-1	5691.4	5691.4	7100
I1GPM-2	218	218	361.3
I1GPM-3	73.2	73.2	-
I1GPM-4	10.56	-	-
Outside 1 gpm Zone			
O1GPM-1	830	1030.7	1032.7
O1GPM-2	634	1060.1	1060.1

TABLE F.6-17

SUMMARY OF SUBZONE DIMENSIONS - CASE 1

Subzone	Area [a] (ft^2)	Length[b] (ft)	Width[c] (ft)
Inside 1 gpm Zone			
I 1GPM-1	421,600	703	600
I 1GPM-2	24,800	124	200
I 1GPM-3	148,800	372	400
I 1GPM-4	852,800	1066	800
Outside 1 gpm Zone			
O 1GPM-1	47,119	157	300
O 1GPM-2	768,800	961	800

[a] Determined from uranium-238 concentration contours
[b] Along flow direction
[c] Normal to flow direction

TABLE F.6-18

SUMMARY OF SUBZONE DIMENSIONS - CASE 2

Subzone	Area [a] (ft^2)	Length[b] (ft)	Width[c] (ft)
Inside 1 gpm Zone			
I 1GPM-1	421,600	703	600
I 1GPM-2	24,800	124	200
I 1GPM-3	148,800	372	400
Outside 1 gpm Zone			
O 1GPM-1	37,200	124	300
O 1GPM-2	431,519	540	800

[a] Determined from uranium-238 concentration contours
[b] Along flow direction
[c] Normal to flow direction

TABLE F.6-19

SUMMARY OF SUBZONE DIMENSIONS - CASE 3

Subzone	Area [a] (ft^2)	Length[b] (ft)	Width[c] (ft)
Inside 1 gpm Zone			
I 1GPM-1	337,280	562	600
I 1GPM-2	13,638	105	130
Outside 1 gpm Zone			
O 1GPM-1	37,200	124	300
O 1GPM-2	431,519	540	800

[a] Determined from uranium-238 concentration contours
[b] Along flow direction
[c] Normal to flow direction

TABLE F.6-20

SUMMARY OF Q_1^{L}[a] AND Q_2[b] USED IN THE TRENCH/WELL COMPONENT MODELING FOR URANIUM-238 CONTAMINATION FOOTPRINT

Extraction Rate		Case 1	Case 2	Case 3
Q_1^{L} (gpm)		10.92	8.10	6.45
Q_2 (gpm)	K_d = 1.78 (L/kg)	132.81	78.29	49.24
	K_d = 15 (L/kg)	1037.30	611.49	384.60

[a] Lower limit of naturally available perched water extraction rate
[b] Required remedial extraction rate

TABLE F.6-21

SUMMARY OF LINEAL TRENCH LENGTHS (FEET) FOR EVALUATED REMEDIAL COMPONENT CASES FOR URANIUM-238

K_d (L/kg)	Weighting Factor[a]	Case 1	Case 2	Case 3
1.78	0	7049	4567	3513
	0.5	15,015	8,894	6569
	1	22,985	13,221	9624
15	0	14,101	8,635	6528
	0.5	36,389	20,732	15,069
	1	58,677	32,829	23,610

[a] Total trench length = (W) * $L_{1.64}$ + (1-W) $L_{47.11}$

W = weighting factor
$L_{1.64}$ = total trench length based on K = 1.64 ft/day
$L_{47.11}$ = total trench length based on K = 47.11 ft/day

TABLE F.6-22

SUMMARY OF TOTAL WELL NUMBERS FOR EVALUATED REMEDIAL COMPONENT CASES FOR URANIUM-238

K_d (L/kg)	Weighting Factor[a]	Case 1	Case 2	Case 3
1.78	0	65	44	34
	0.5	322	194	132
	1	579	344	231
15	0	265	163	123
	0.5	1721	1008	674
	1	3176	1854	1224

[a] Total number of wells = $W * N_{1.64} + (1 - W) * N_{47.11}$

w = weighting factor
$N_{1.64}$ = number of wells based on K = 1.64 ft/day
$N_{47.11}$ = number of wells based on K = 47.11 ft/day

TABLE F.6-23

SUMMARY OF OPERATIONAL PERIODS REQUIRED FOR CONTAINMENT TRENCHES (YEARS) FOR EVALUATED REMEDIAL COMPONENT CASES FOR URANIUM-238

Area	K_d (L/kg)	Case 1	Case 2	Case 3
Outside 1 gpm Zone				
01GPM-1	1.78	232	174	174
	15	1804	1344	1344
01GPM-2	1.78	238	230	470[a]
	15	1854	1784	2664[a]

[a] Modeled plume also includes contamination inside 1 gpm zone.

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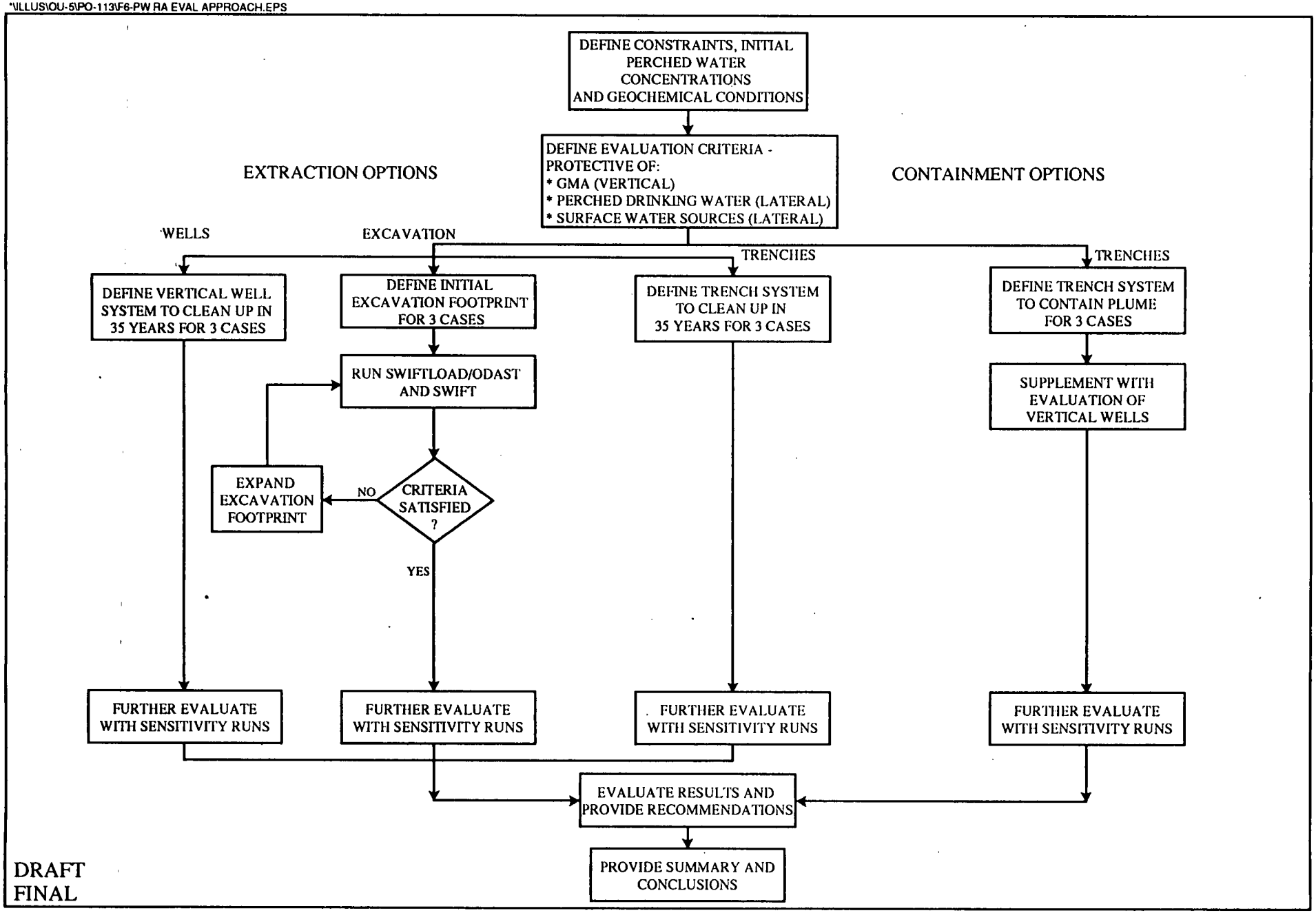

FIGURE F.6-1. FLOWCHART OF PERCHED GROUNDWATER REMEDIAL ACTION EVALUATION APPROACH

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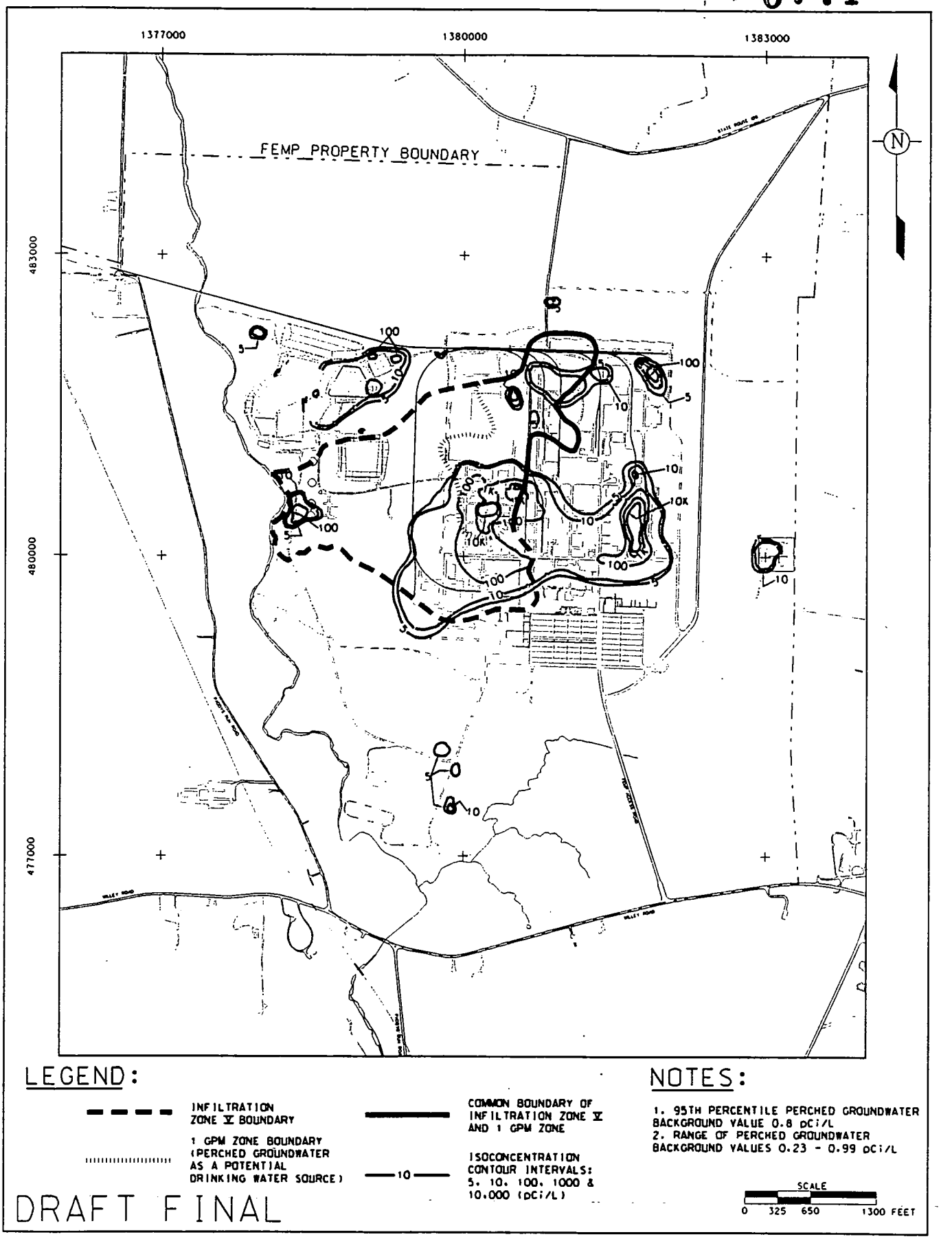

FIGURE F.6-2. PERCHED GROUNDWATER ZONE CONSIDERED IN COMPONENT MODELING AND U-238 VALUES (pCi/L) IN FEMP TYPE 1 WELLS

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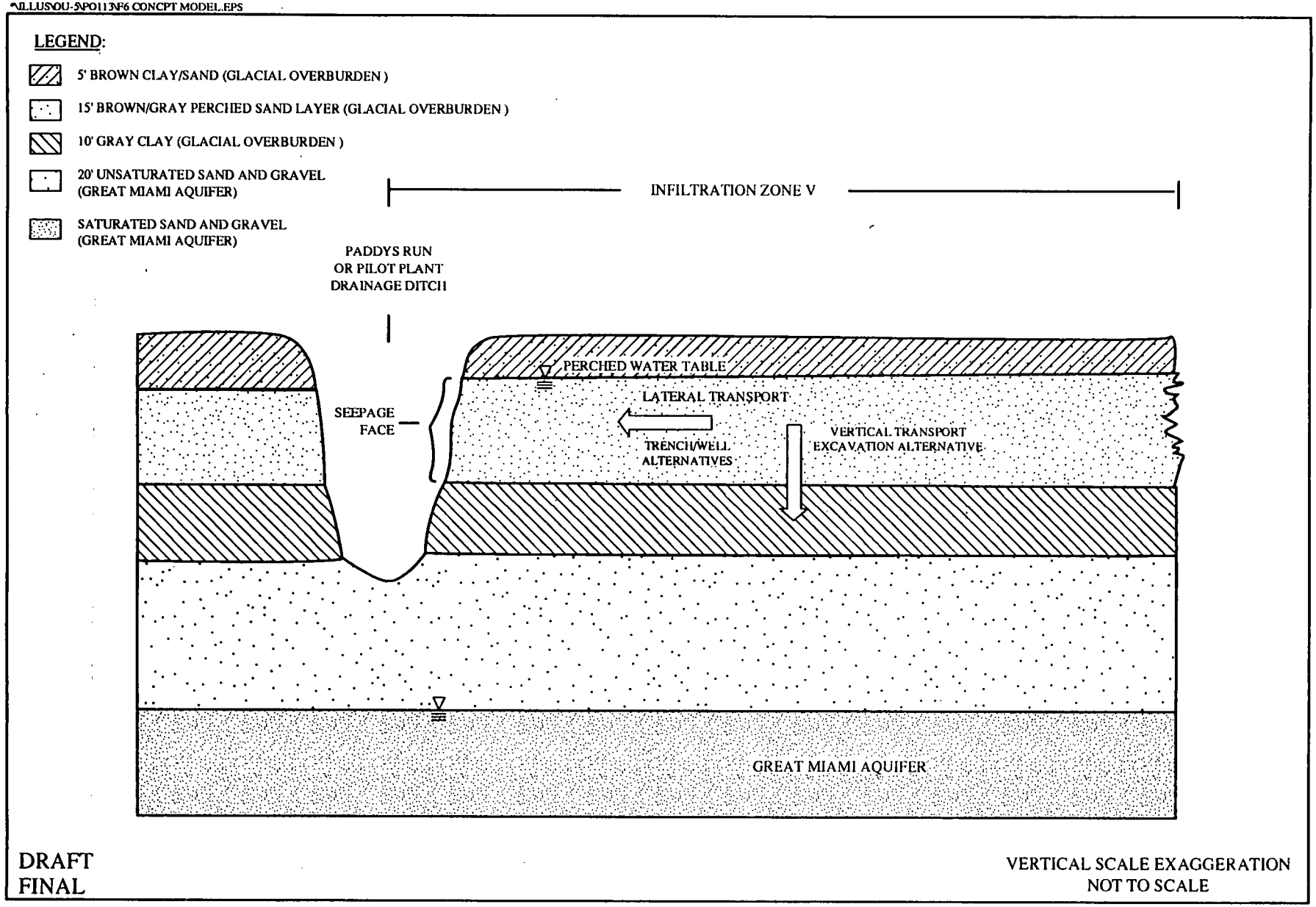

FIGURE F.6-3. CONCEPTUAL MODEL OF PERCHED GROUNDWATER WITHIN INFILTRATION ZONE V

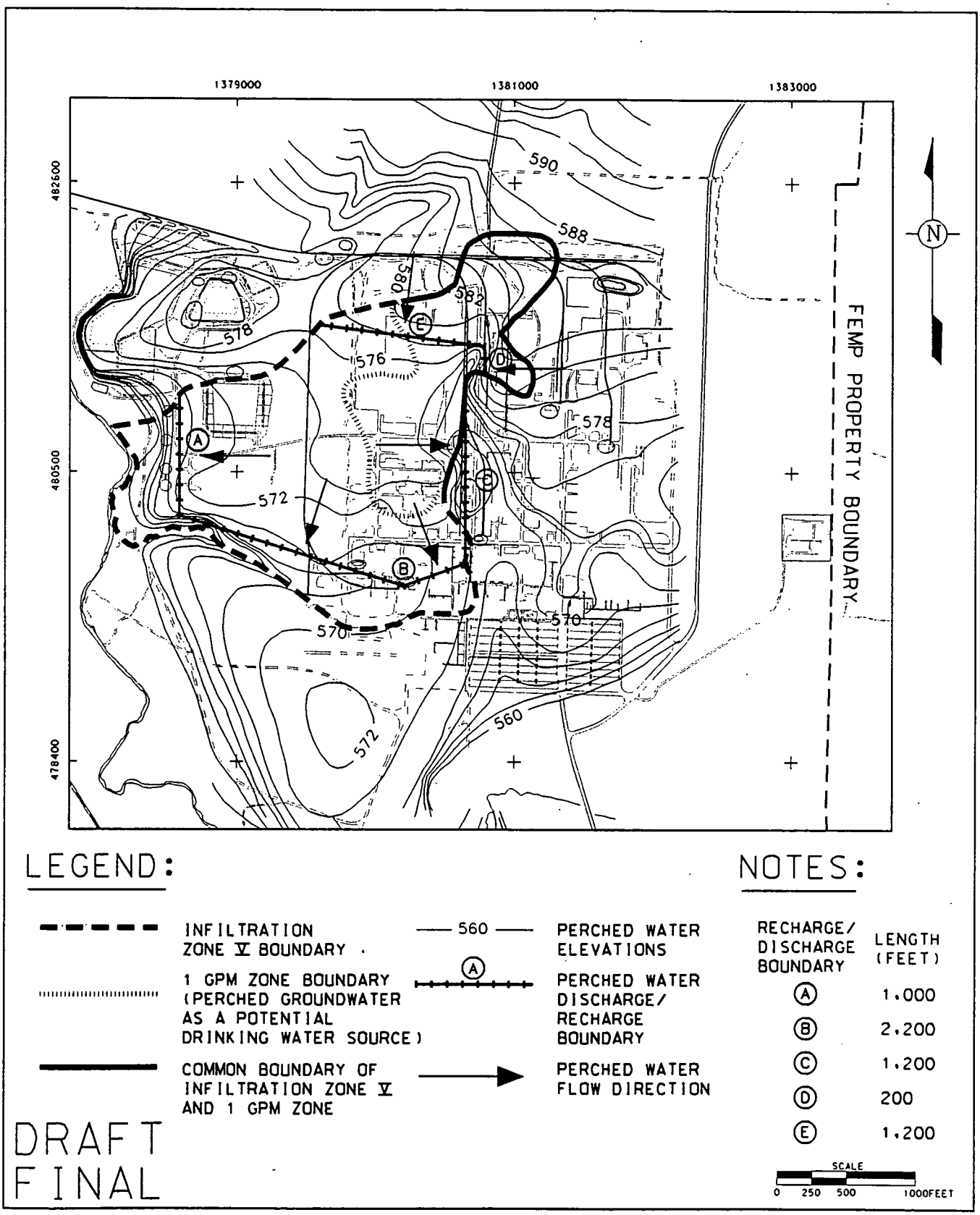

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FIGURE F.6-4. AVERAGE PERCHED WATER CONTOURS AND APPROXIMATE RECHARGE AND DISCHARGE BOUNDARIES

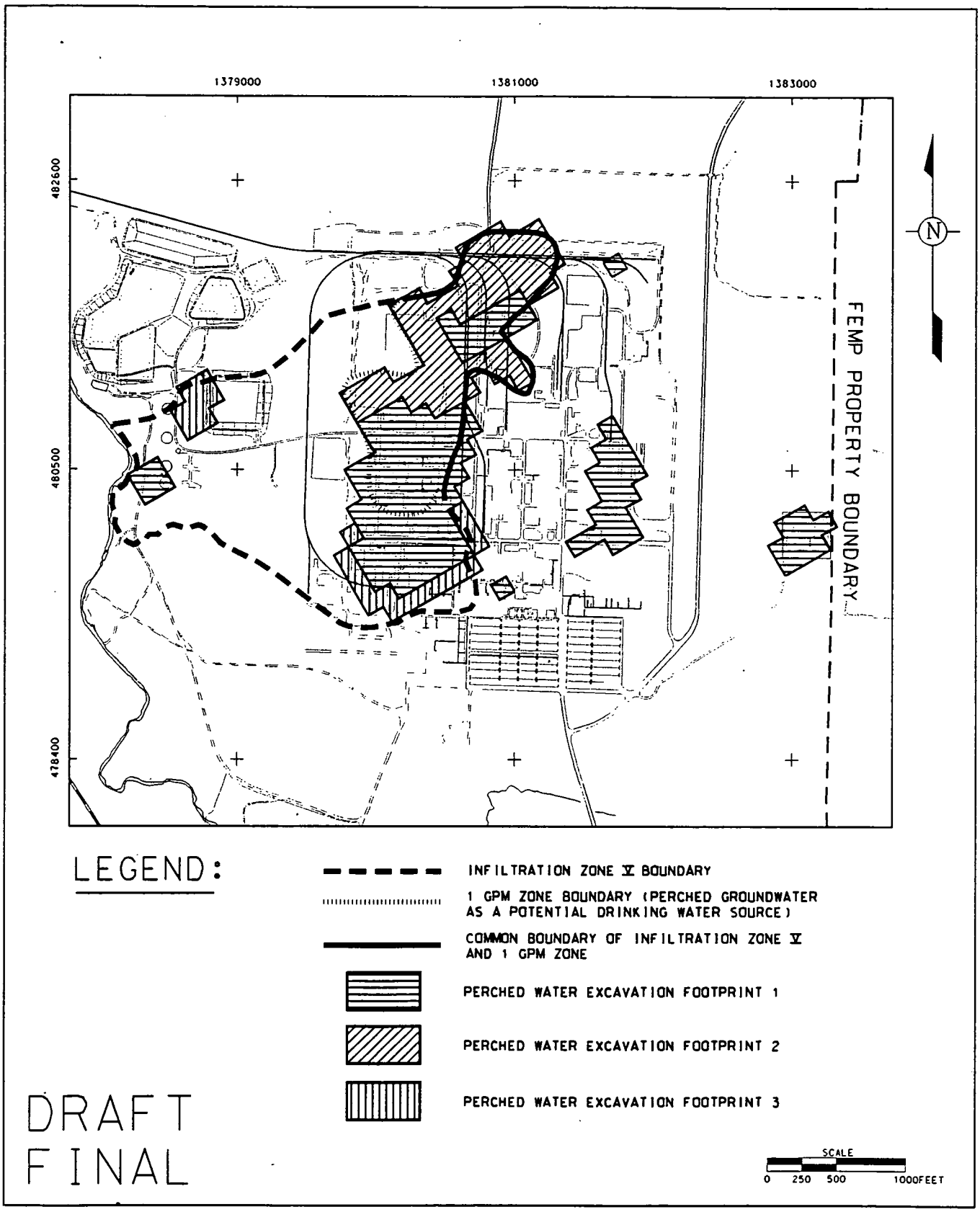

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FIGURE F.6-5. PERCHED WATER EXCAVATION FOOTPRINTS

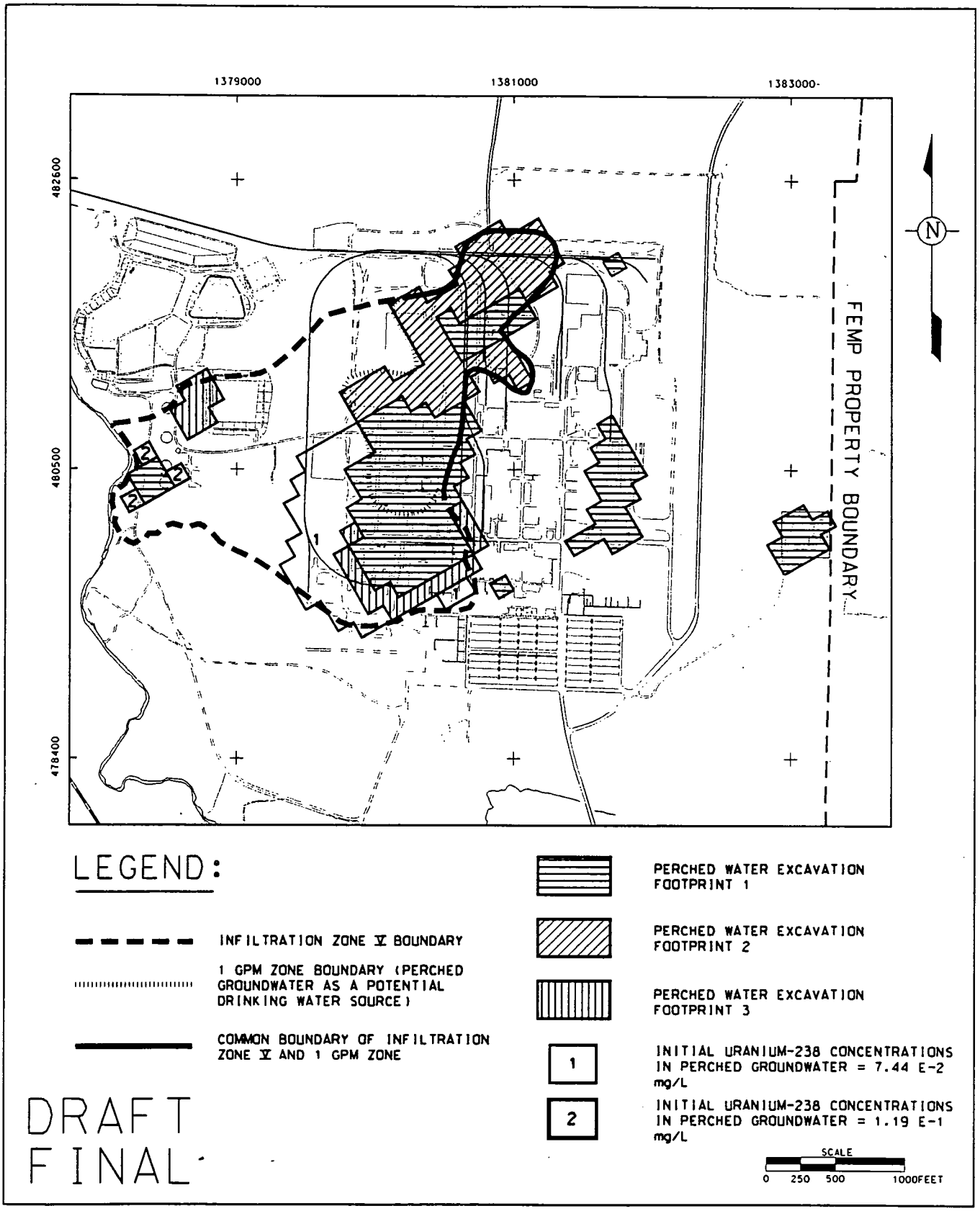

FIGURE F.6-6. INITIAL URANIUM-238 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 1

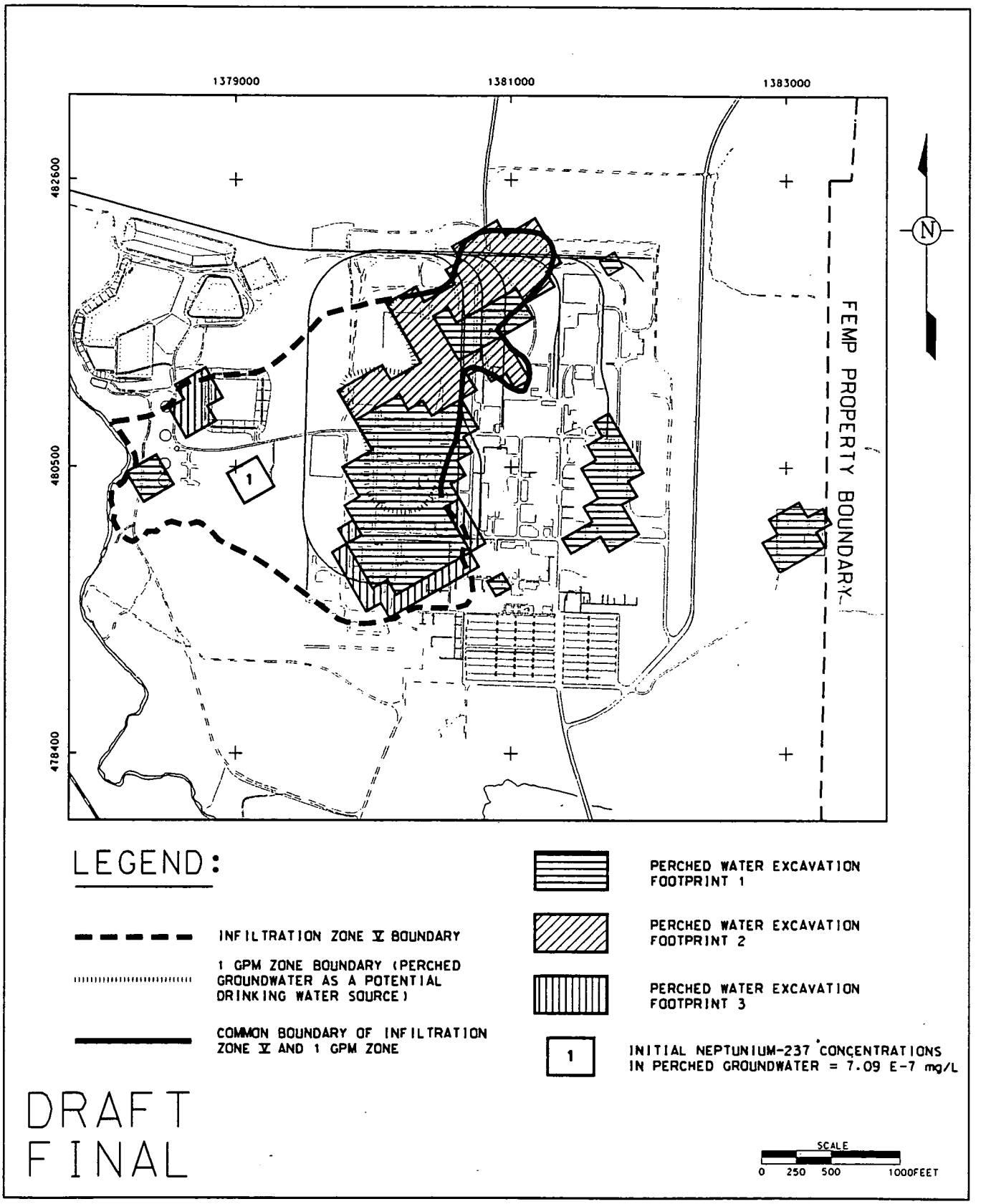

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FIGURE F.6-7. INITIAL NEPTUNIUM-237 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 1

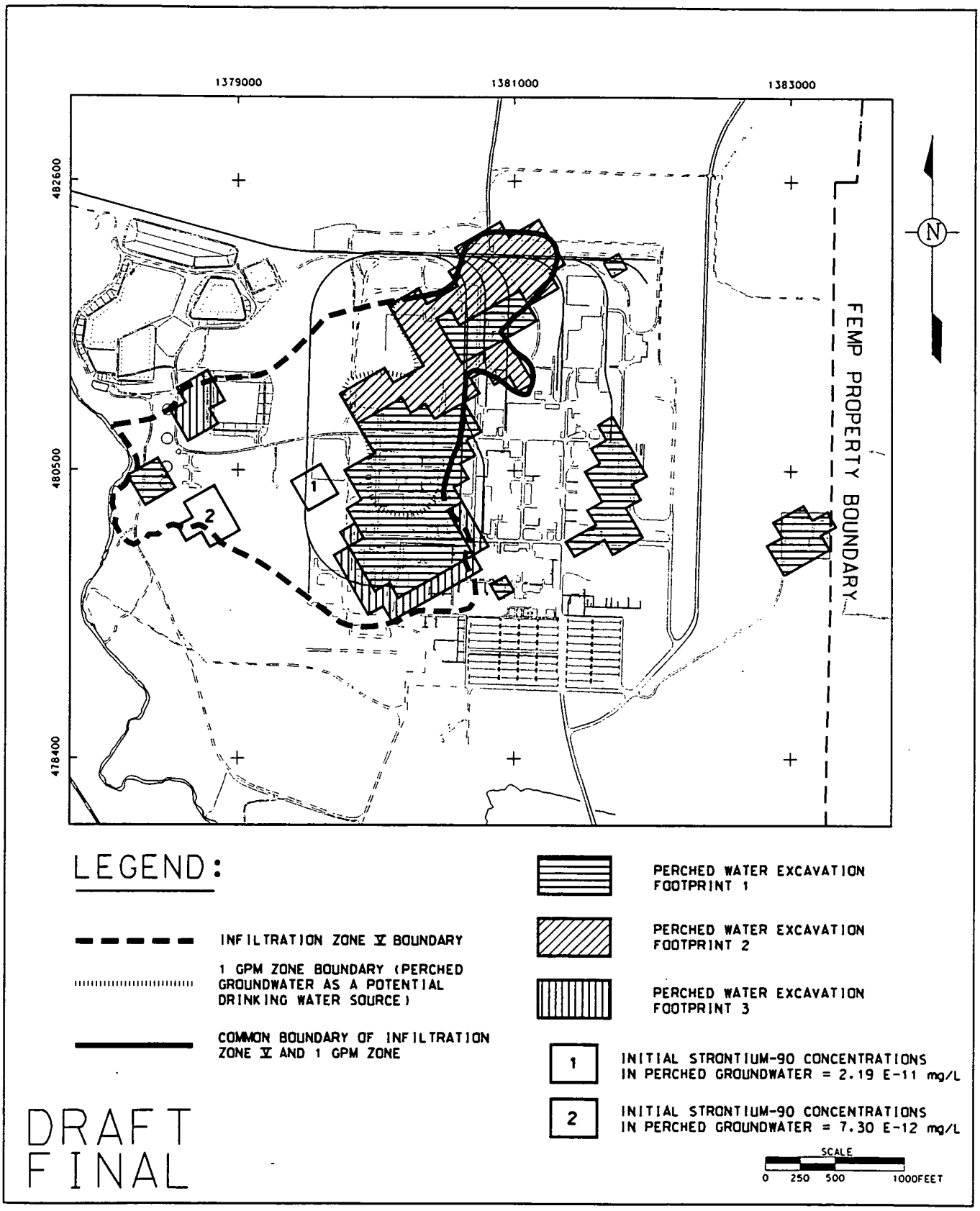

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FIGURE F.6-8. INITIAL STRONTIUM-90 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 1

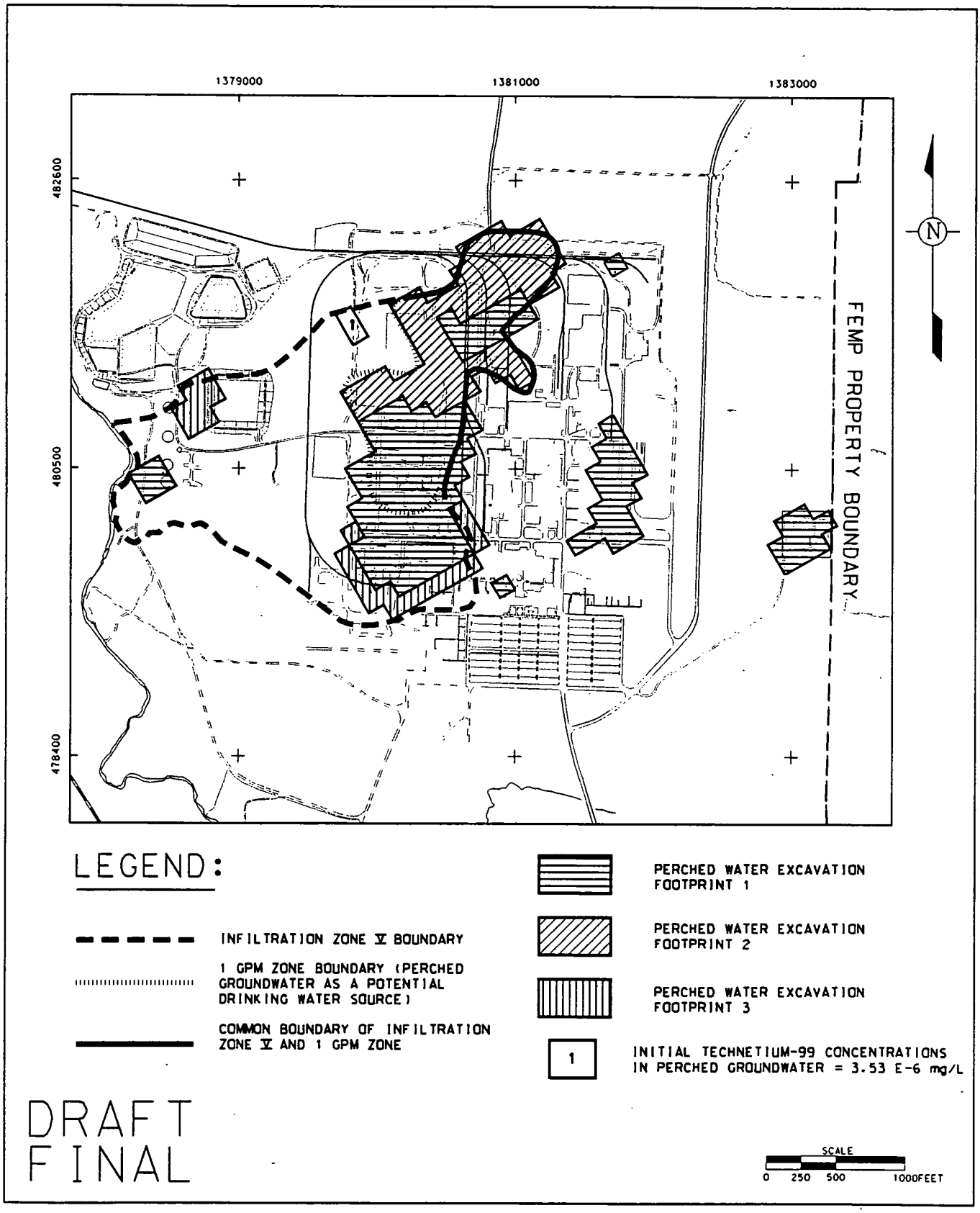

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FIGURE F.6-9. INITIAL TECHNETIUM-99 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 1

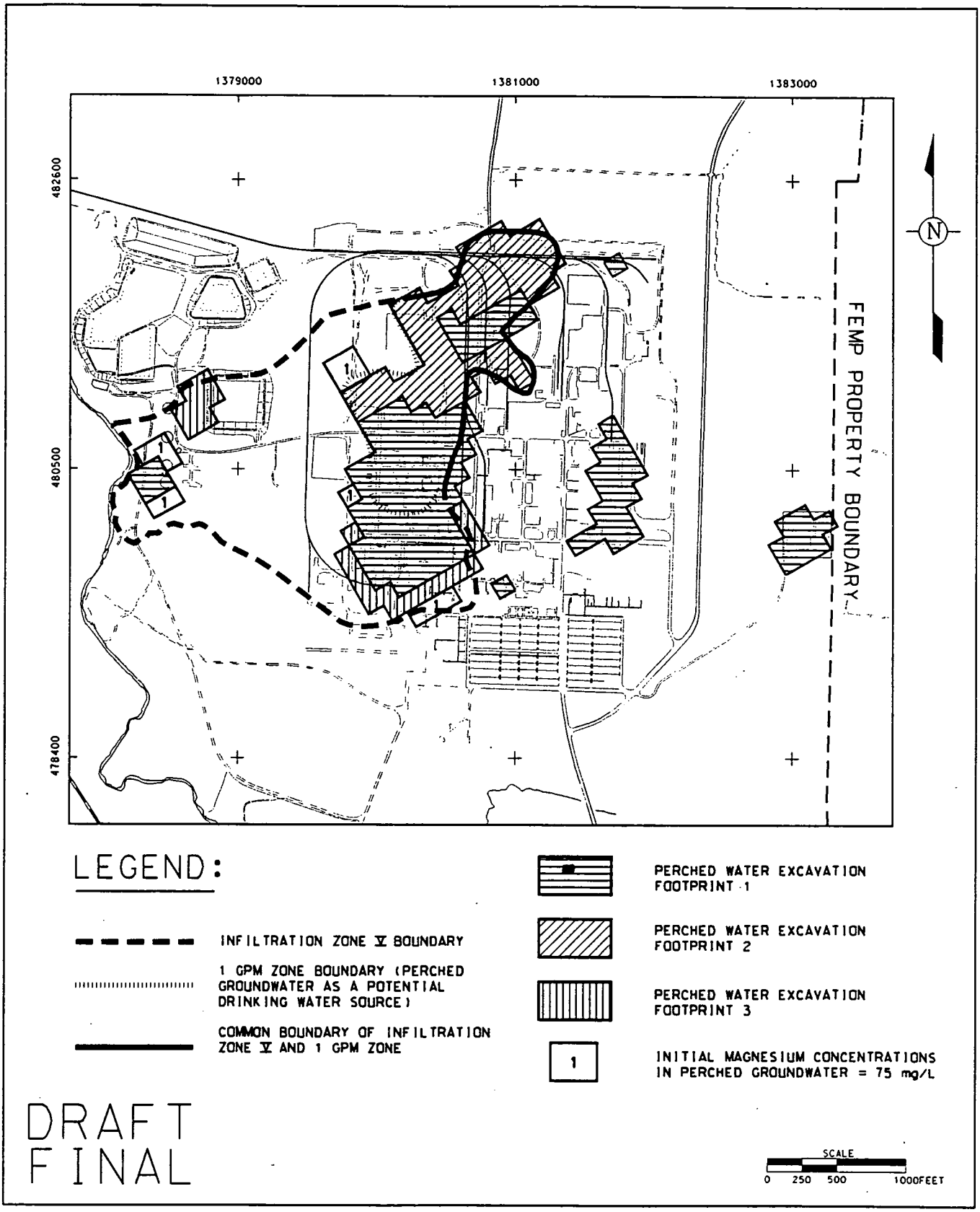

FIGURE F.6-10. INITIAL MAGNESIUM CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING CASE 1

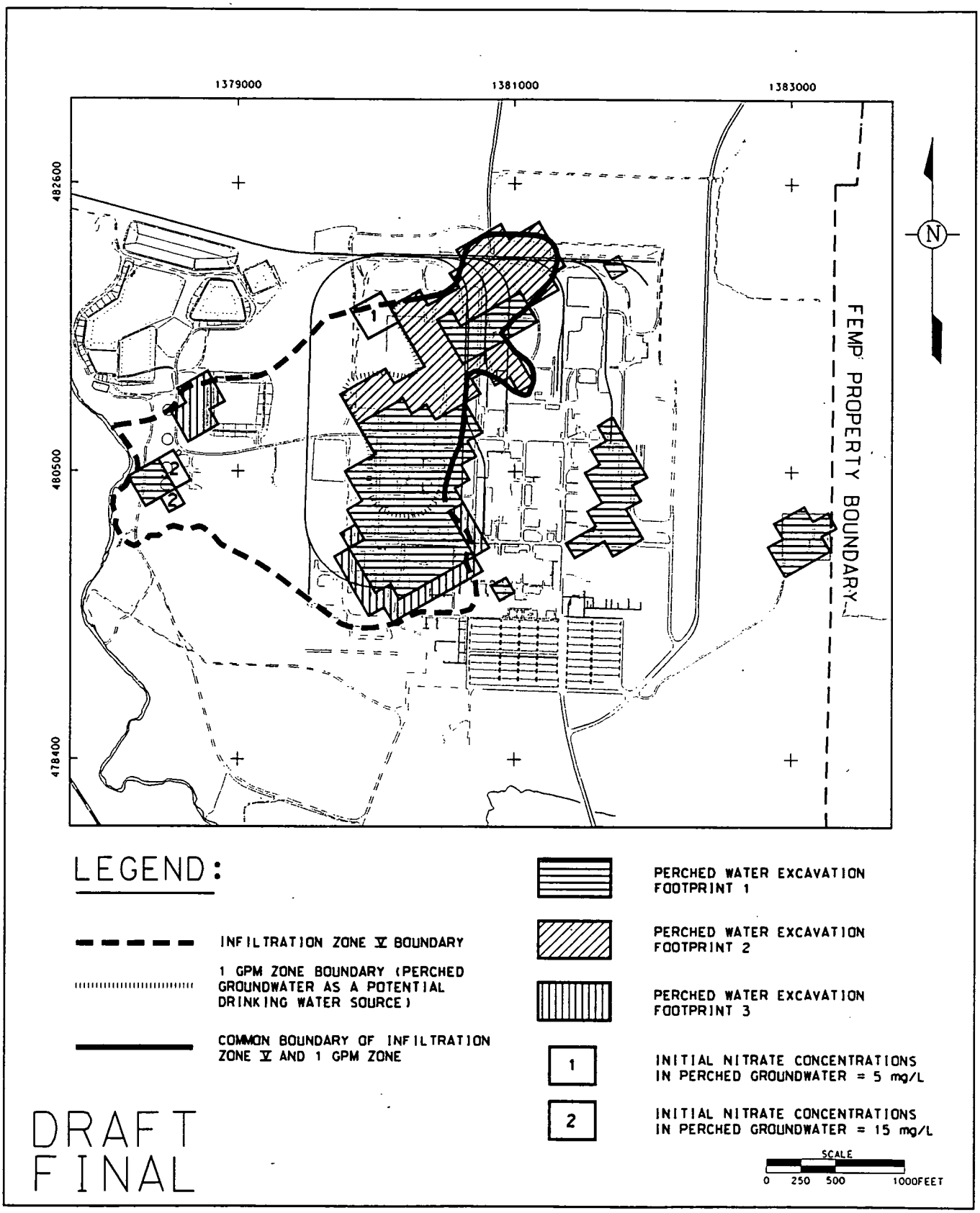

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FIGURE F.6-11. INITIAL NITRATE CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 1

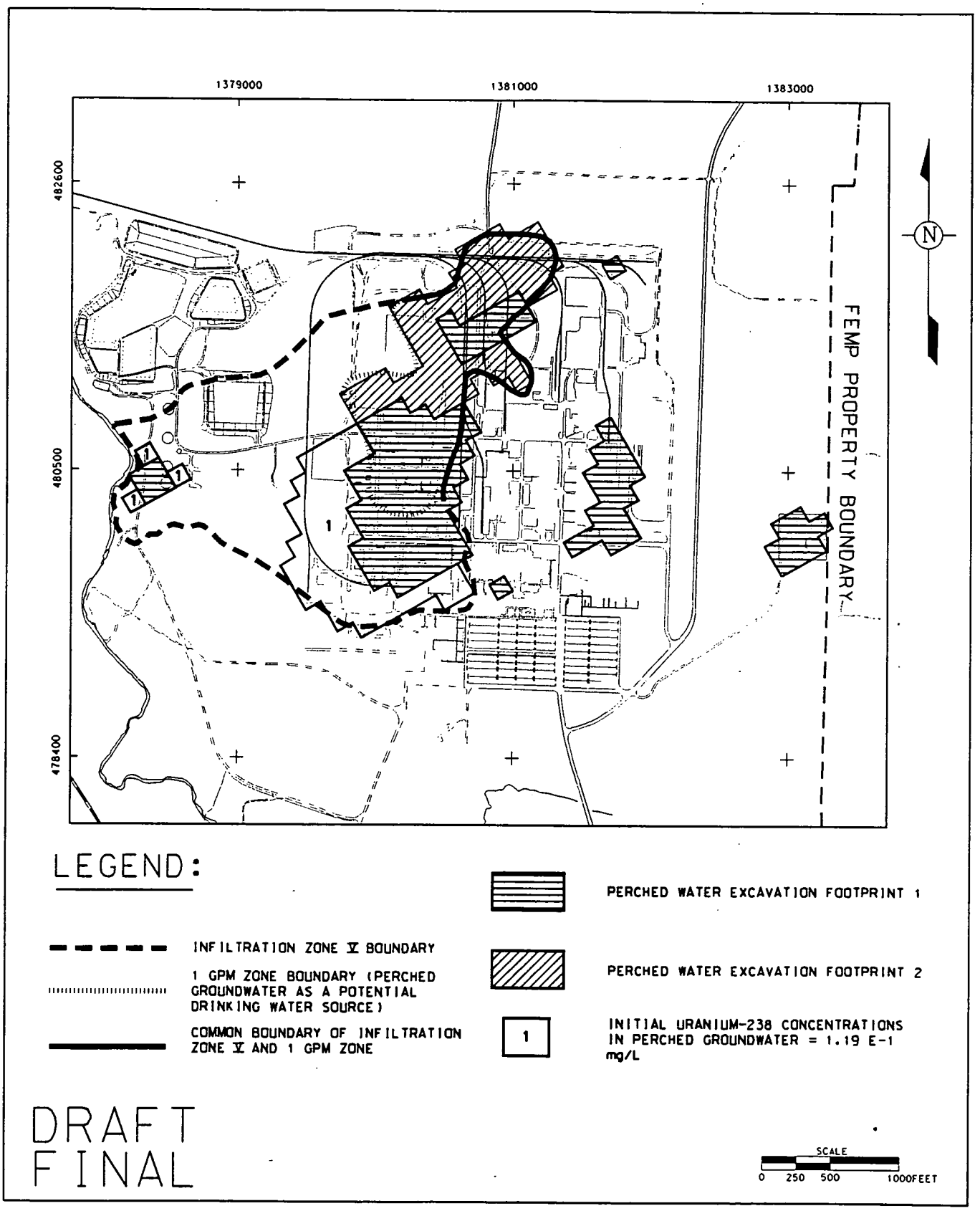

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FIGURE F.6-12. INITIAL URANIUM-238 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 2

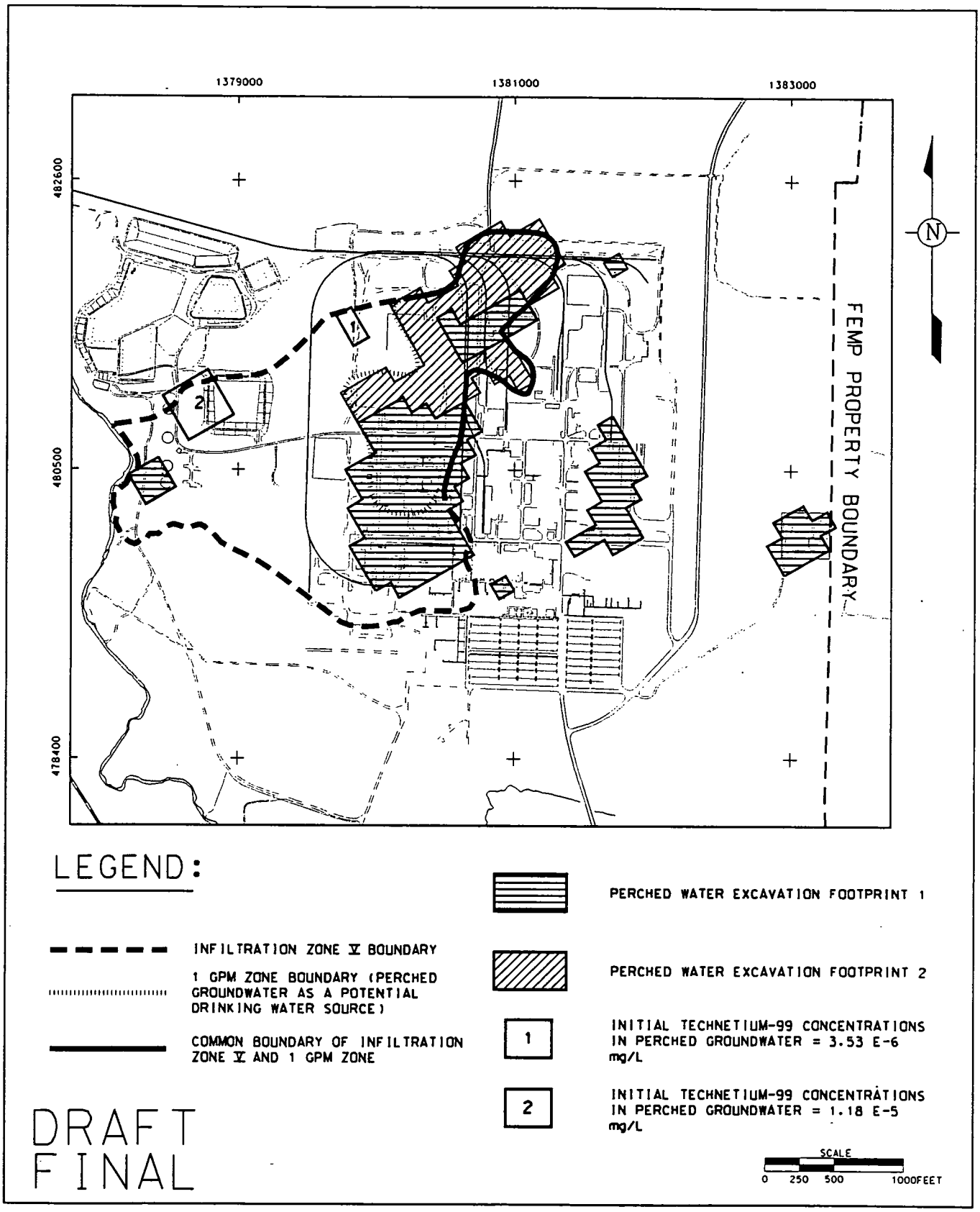

FIGURE F.6-13. INITIAL TECHNETIUM-99 CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 2

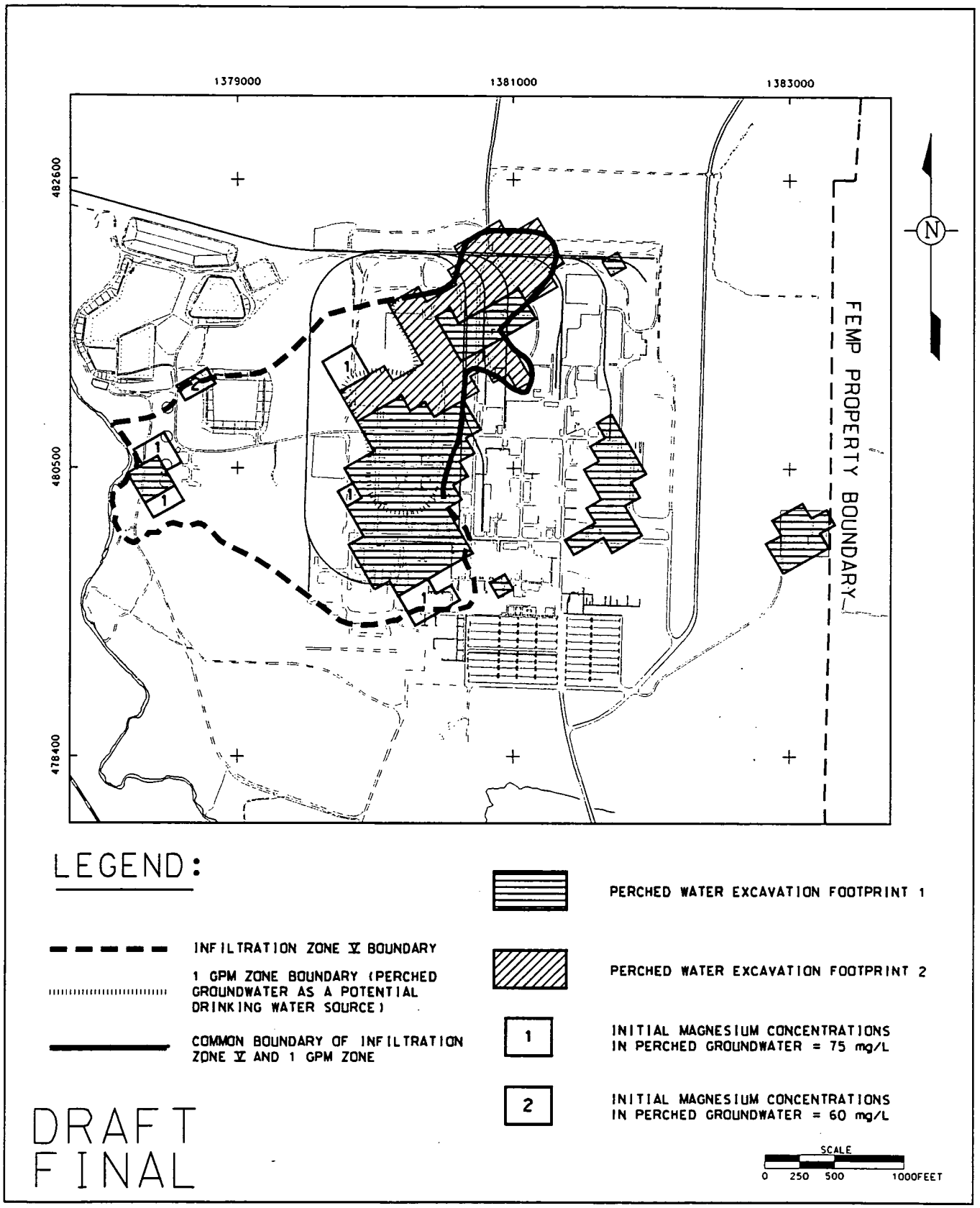

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FIGURE F.6-14. INITIAL MAGNESIUM CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 2

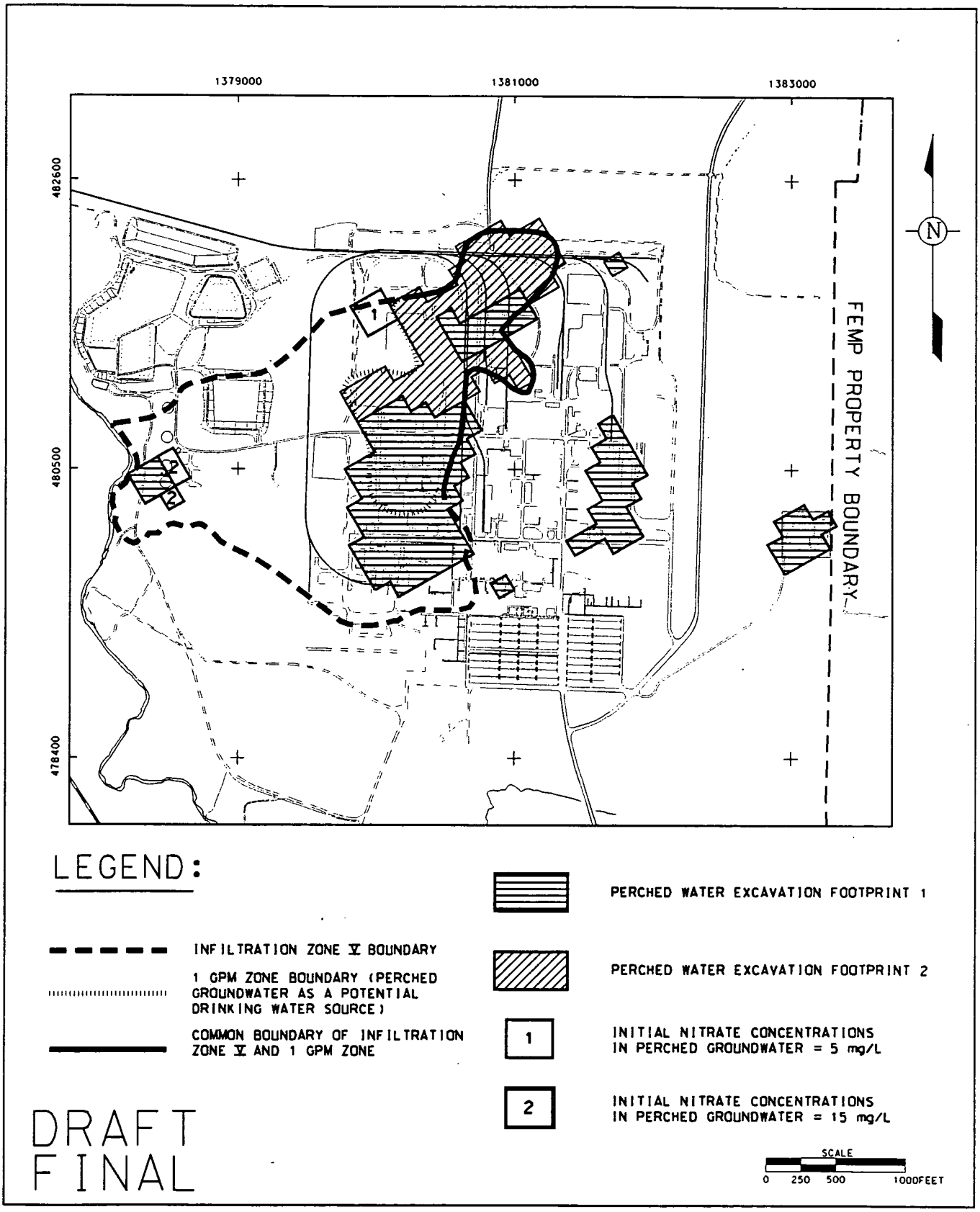

FIGURE F.6-15. INITIAL NITRATE CONCENTRATIONS IN PERCHED WATER FOR EXCAVATION COMPONENT MODELING - CASE 2

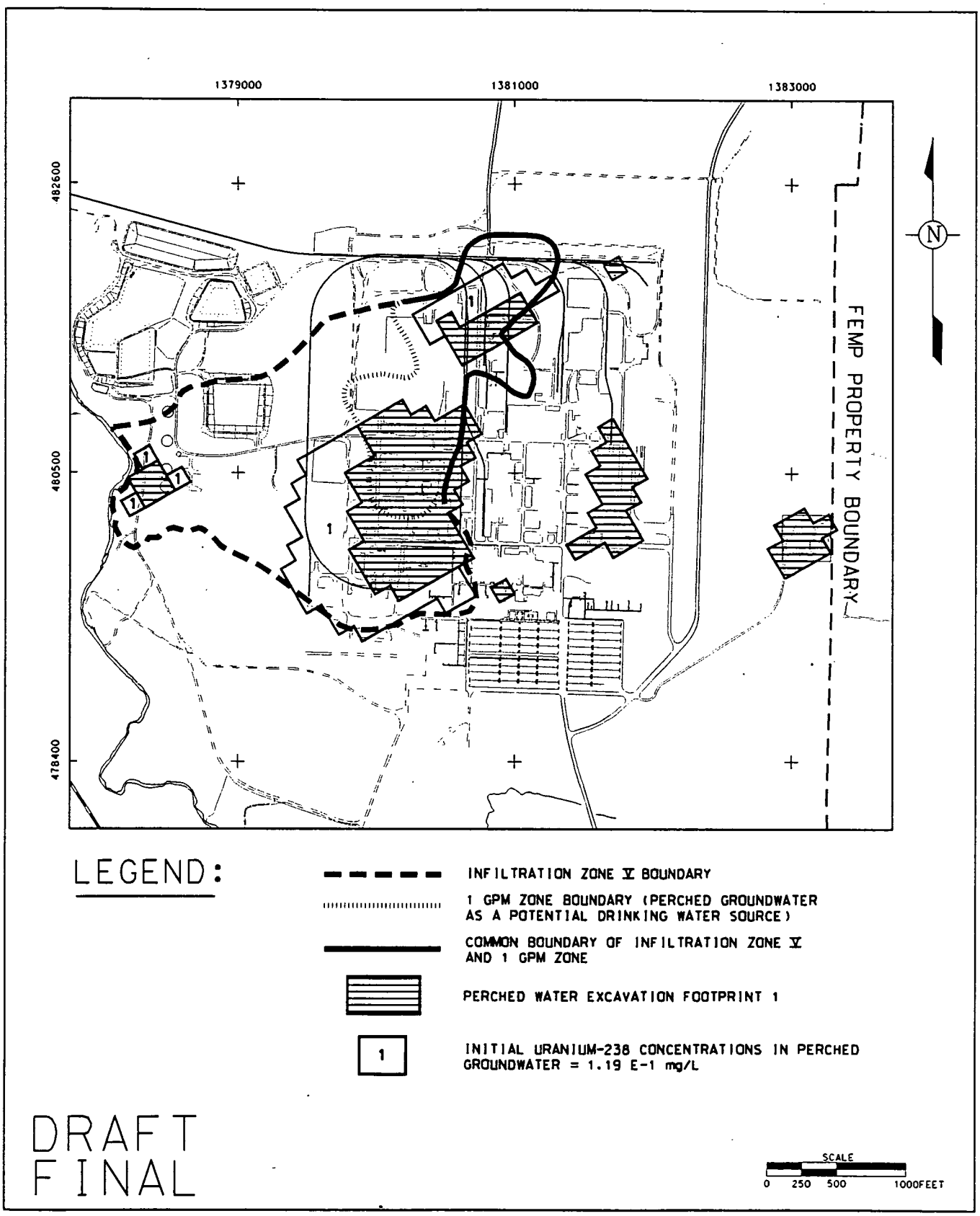

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FIGURE F.6-16. INITIAL URANIUM-238 CONCENTRATIONS IN PERCHED WATER FOR THE EXCAVATION COMPONENT MODELING - CASE 3

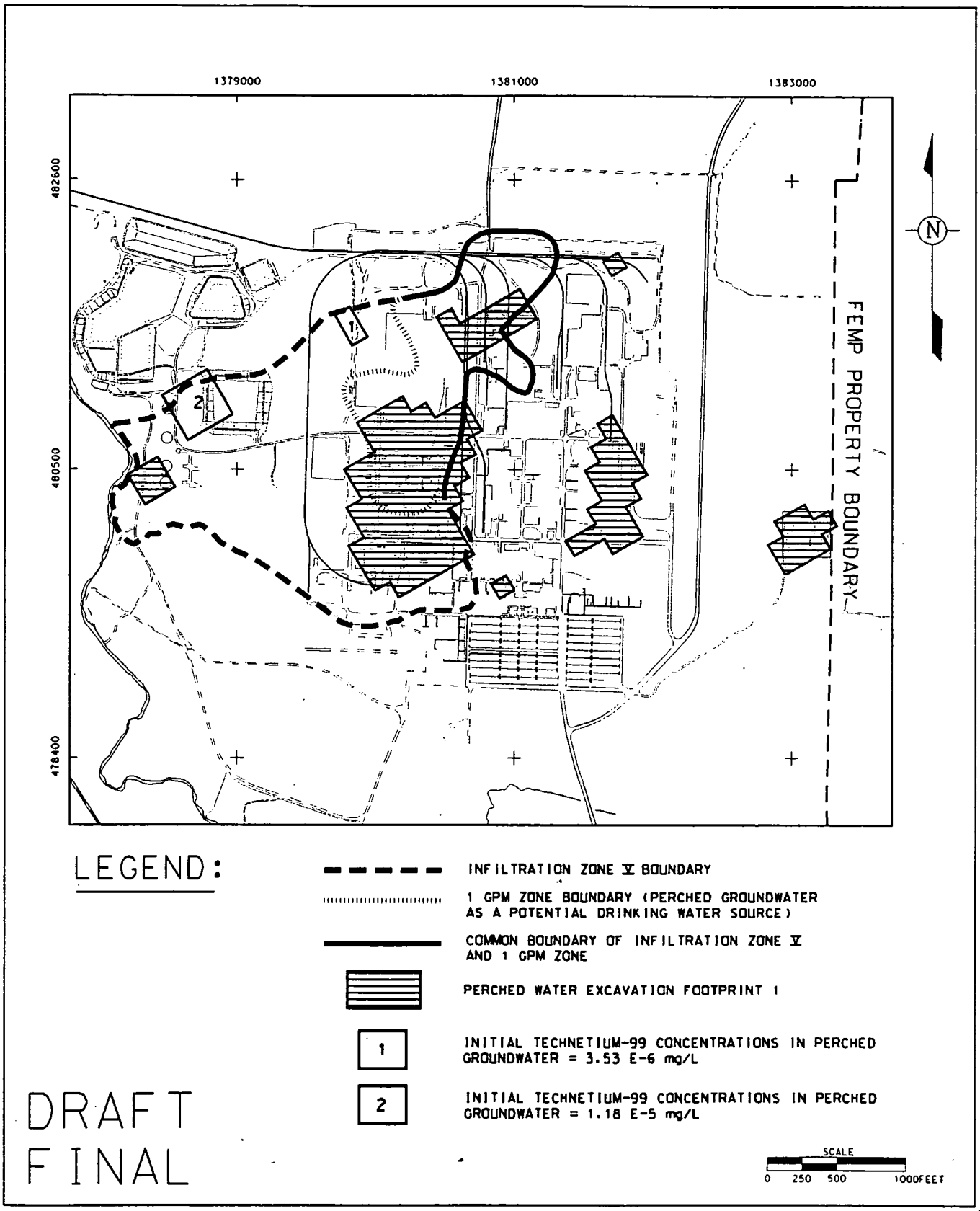


FIGURE F.6-17. INITIAL TECHNETIUM-99 CONCENTRATIONS IN PERCHED WATER FOR THE EXCAVATION COMPONENT MODELING - CASE 3

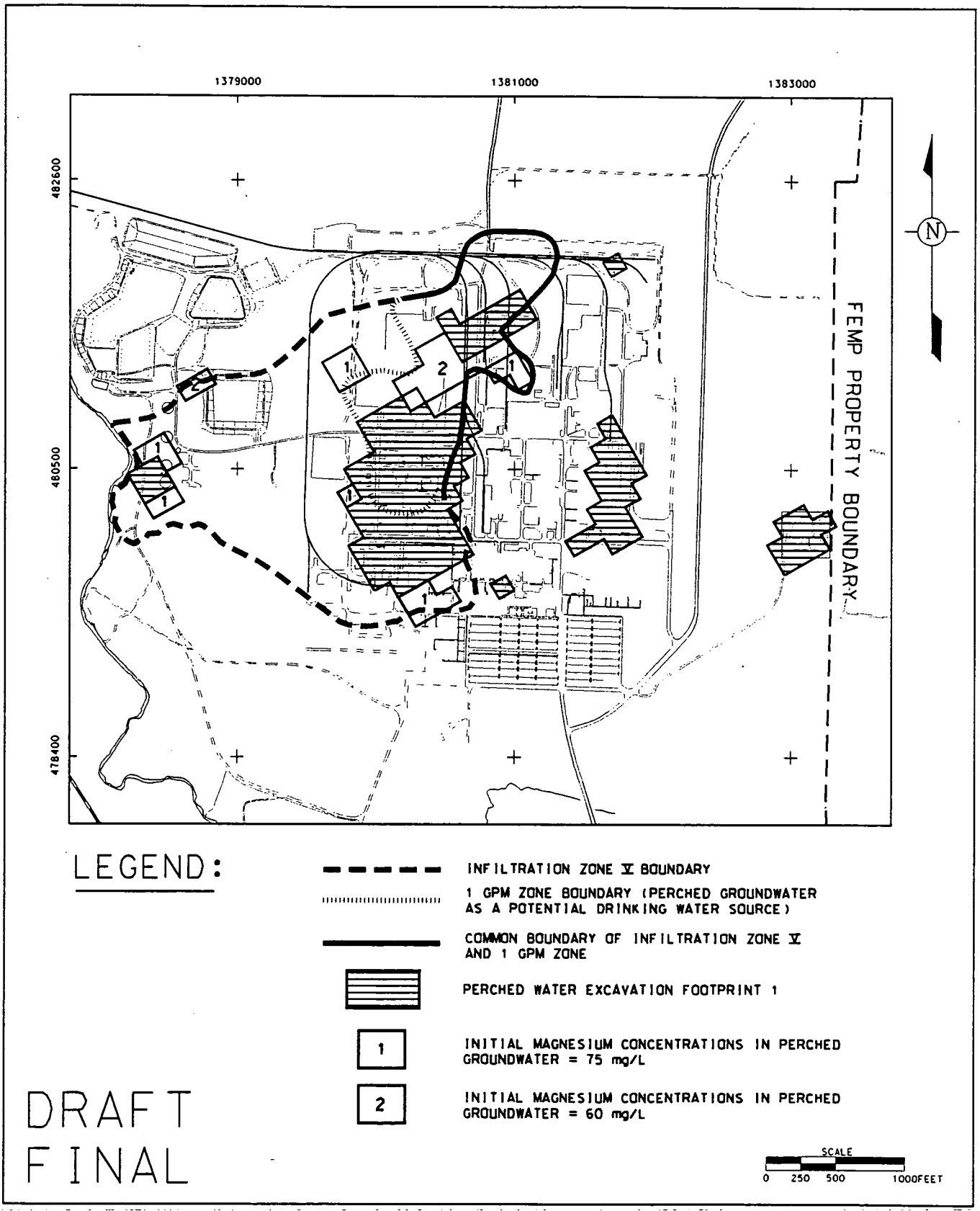


FIGURE F.6-18. INITIAL MAGNESIUM CONCENTRATIONS IN PERCHED WATER FOR THE EXCAVATION COMPONENT MODELING - CASE 3

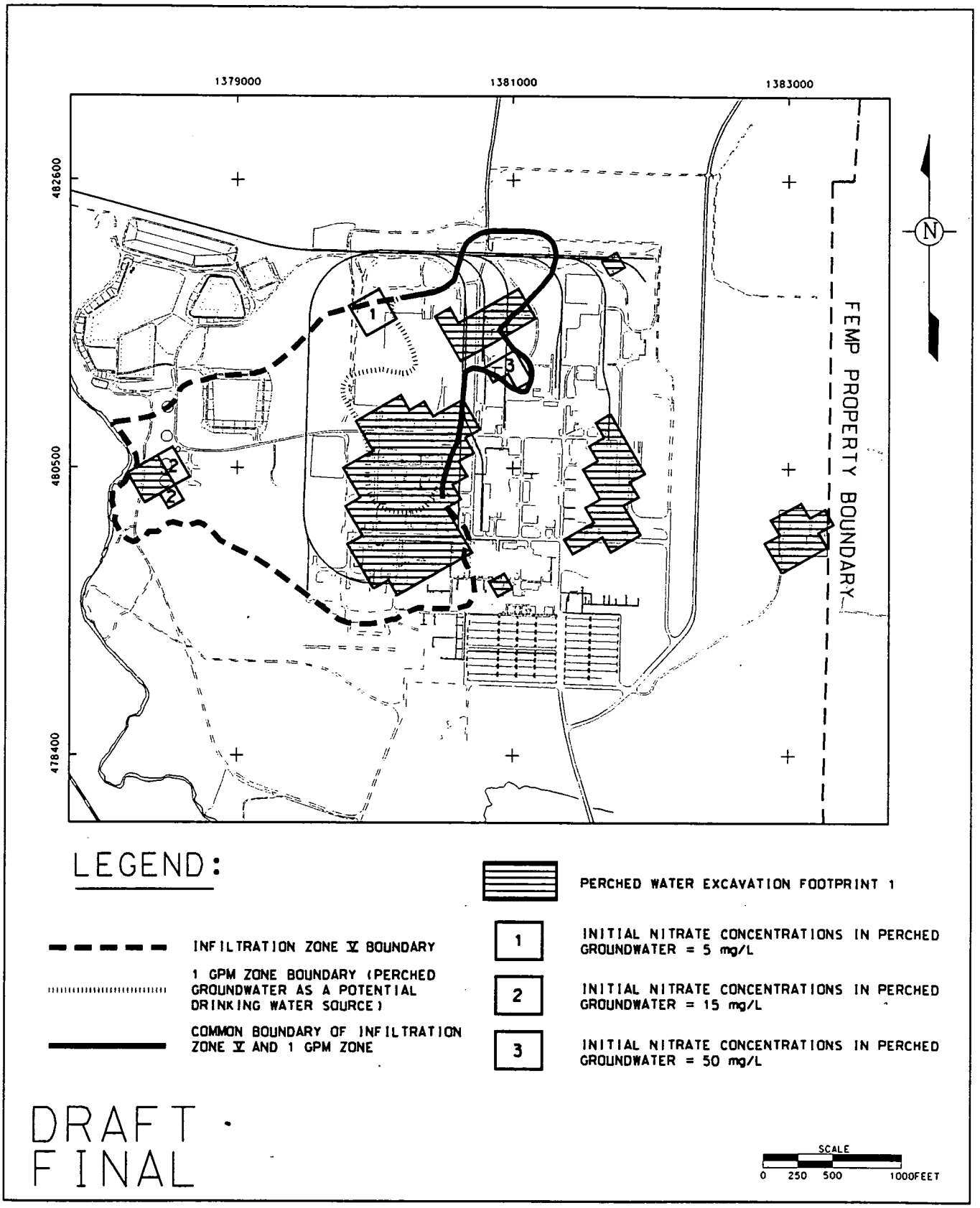


FIGURE F.6-19. INITIAL NITRATE CONCENTRATIONS IN PERCHED WATER FOR THE EXCAVATION COMPONENT MODELING - CASE 3

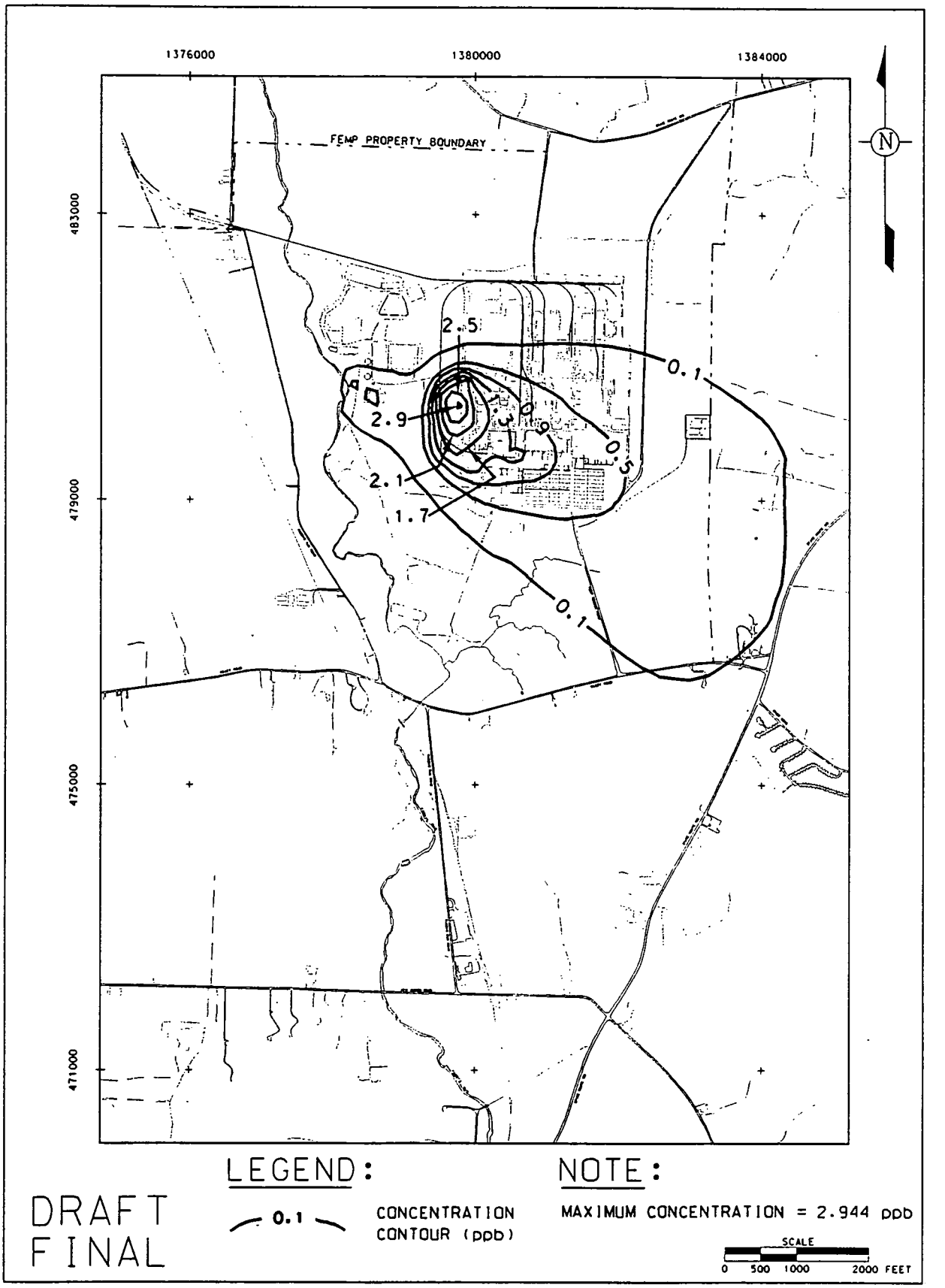


FIGURE F.6-20. URANIUM-238 CONCENTRATIONS IN THE GREAT MIAMI AQUIFER AT 250 YEARS FROM PERCHED GROUNDWATER NOT EXCAVATED - CASE 1

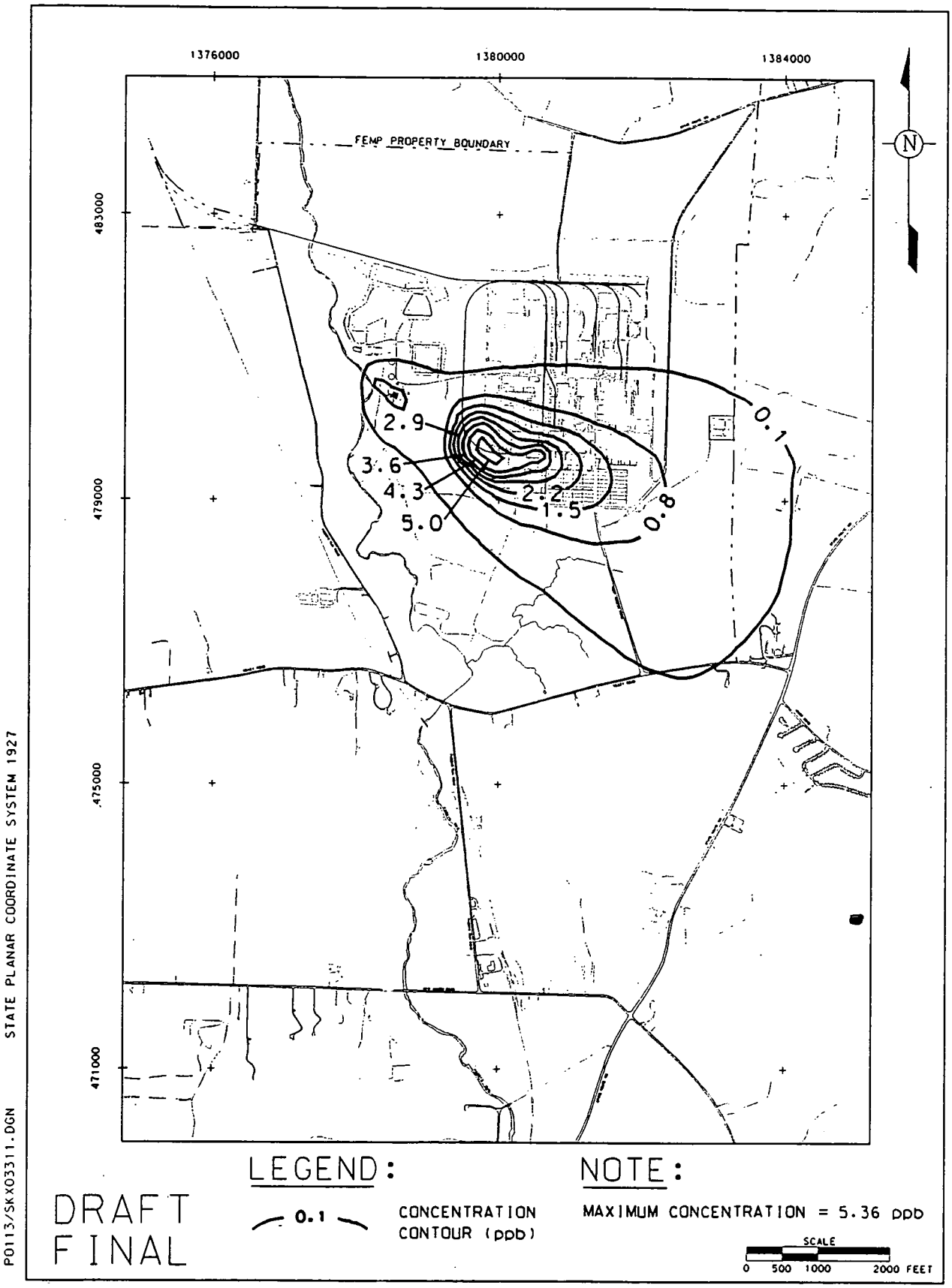


FIGURE F.6-21. URANIUM-238 CONCENTRATIONS IN THE GREAT MIAMI AQUIFER AT 170 YEARS FROM PERCHED GROUNDWATER NOT EXCAVATED - CASE 2

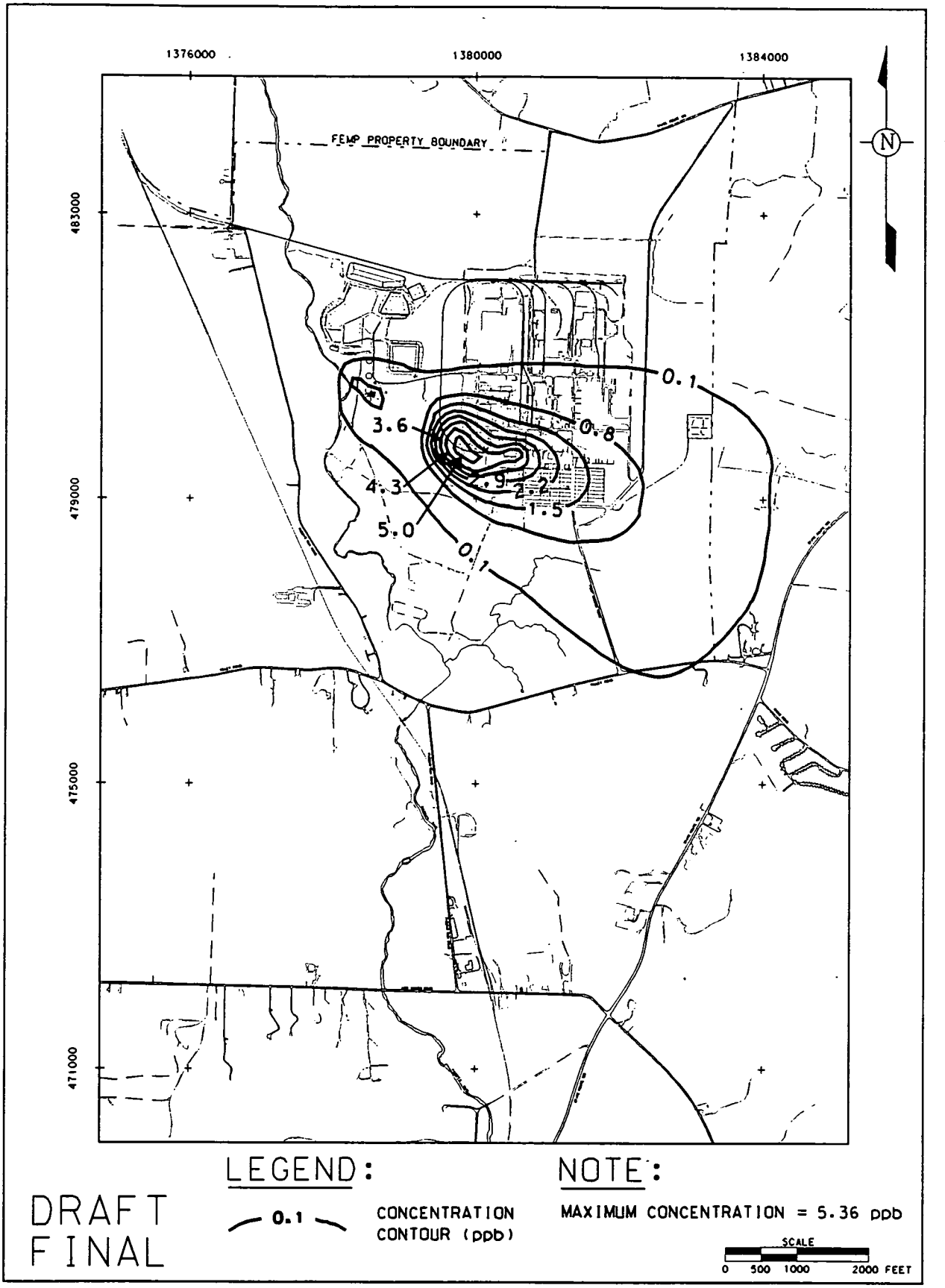
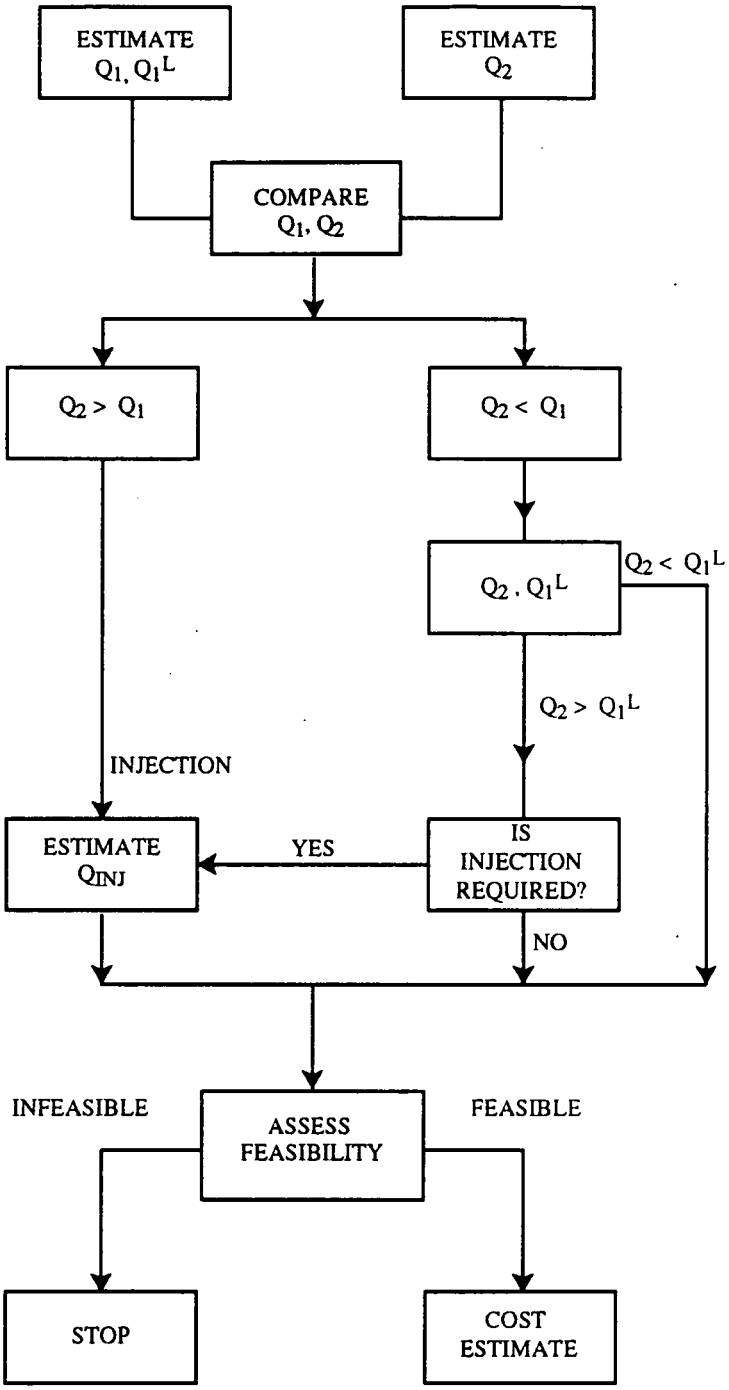


FIGURE F.6-22. URANIUM-238 CONCENTRATIONS IN THE GREAT MIAMI AQUIFER AT 170 YEARS FROM PERCHED GROUNDWATER NOT EXCAVATED - CASE 3



NOTE:

Q_1 = MAXIMUM DISCHARGE RATE POSSIBLE IN INFILTRATION ZONE V IN 35 YEARS

Q_2 = EXTRACTION DISCHARGE RATE REQUIRED TO DEPLETE PLUME TO APPLICABLE MCL OR PERCHED WATER PRG FOR RESIDENT FARMER/CHILD IN 35 YEARS

Q_1^L = LOWER LIMIT OF MAXIMUM DISCHARGE RATE (Q_1)

Q_{INJ} = INJECTION RATE DUE TO INJECTION REQUIRED TO DEPLETE PLUME IN 35 YEARS

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FIGURE F.6-23. APPROACH FOR EVALUATING FEASIBILITY OF TRENCHES/WELLS FOR PERCHED WATER REMEDIATION

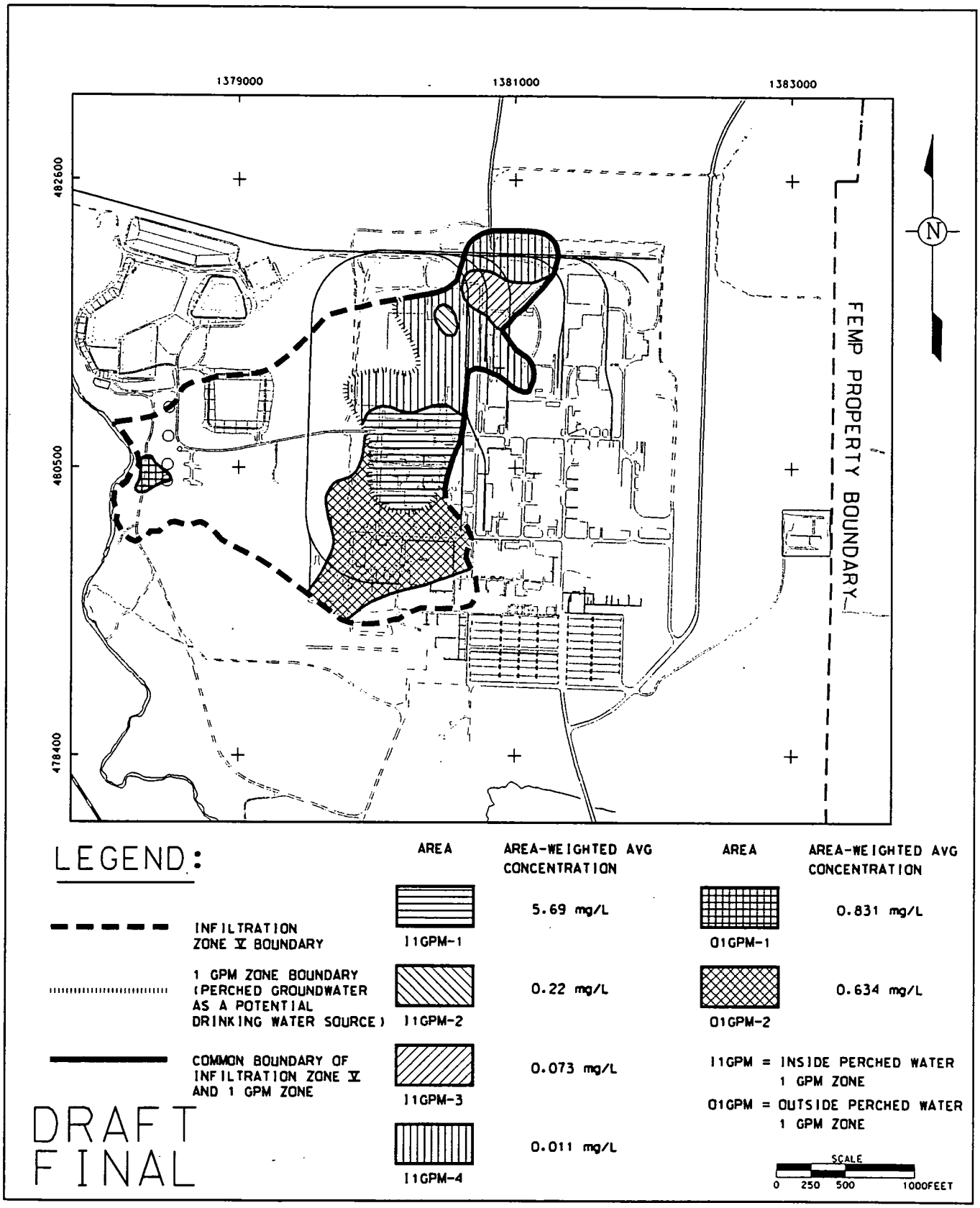

FIGURE F.6-24. URANIUM-238 PERCHED WATER REMEDIATION AREAS FOR TRENCH/WELL COMPONENTS MODELING - CASE 1

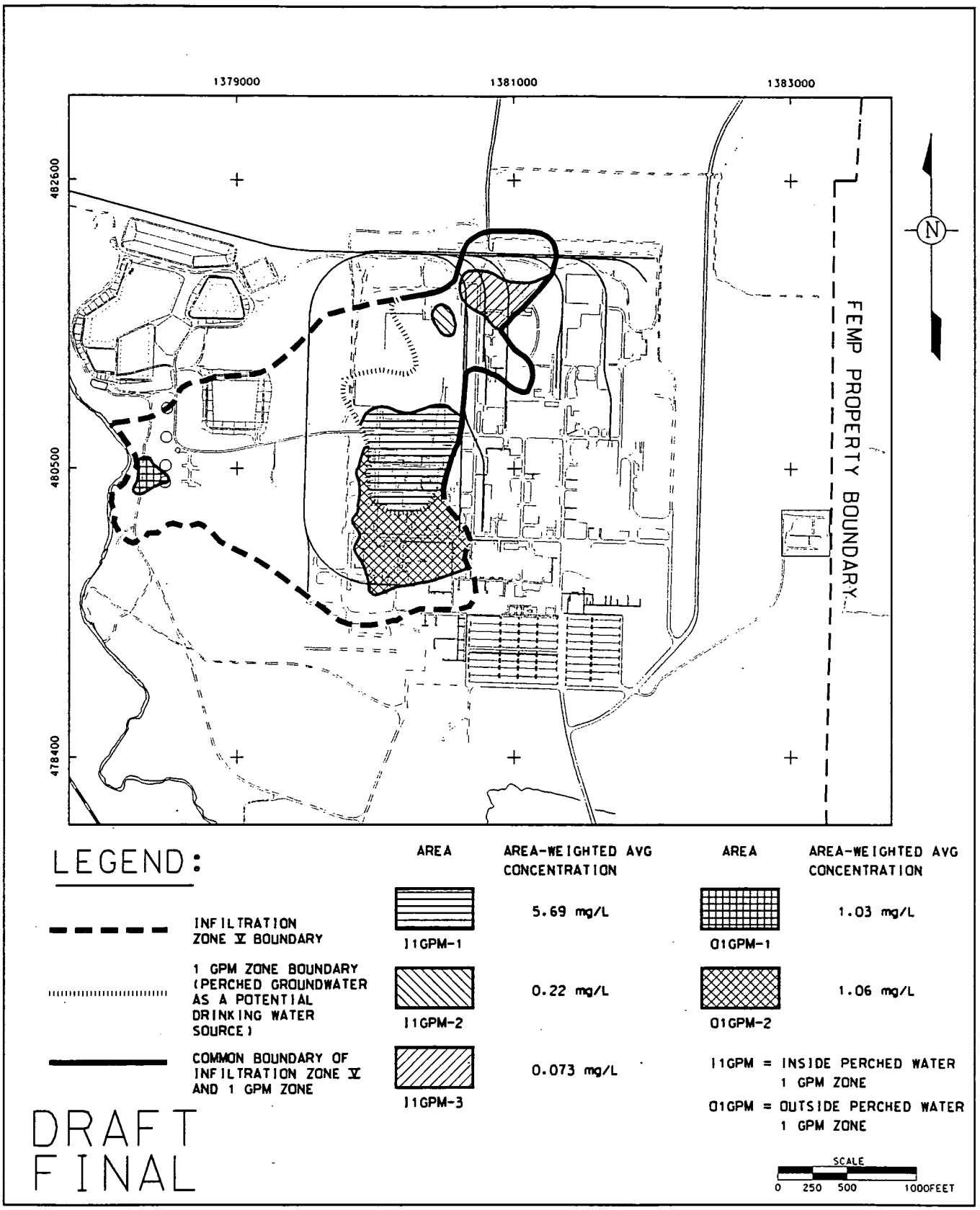

FIGURE F.6-25. URANIUM-238 PERCHED WATER REMEDIATION AREAS FOR TRENCH/WELL COMPONENTS MODELING - CASE 2

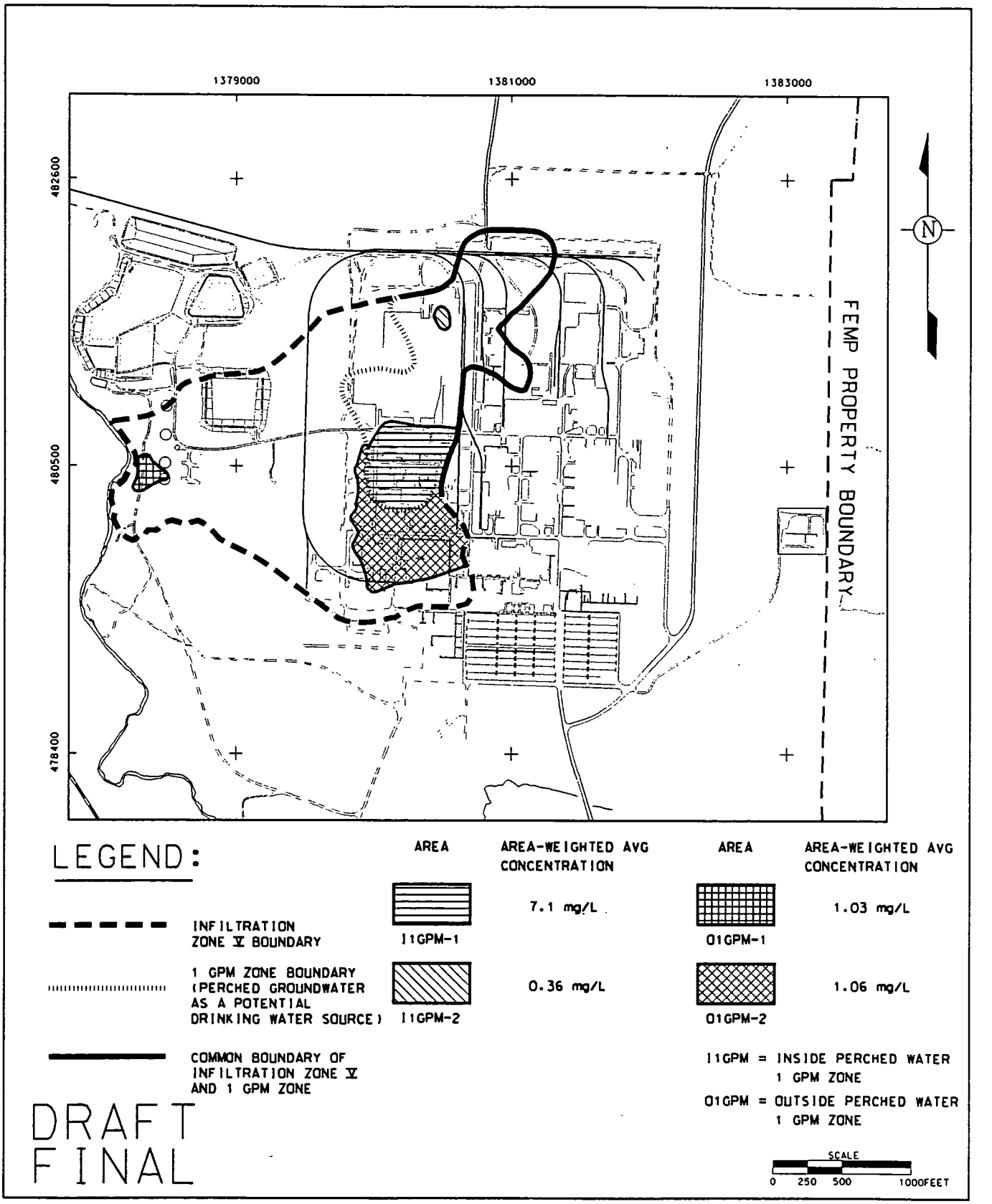

FIGURE F.6-26. URANIUM-238 PERCHED WATER REMEDIATION AREAS FOR TRENCH/WELL COMPONENTS MODELING CASE 3

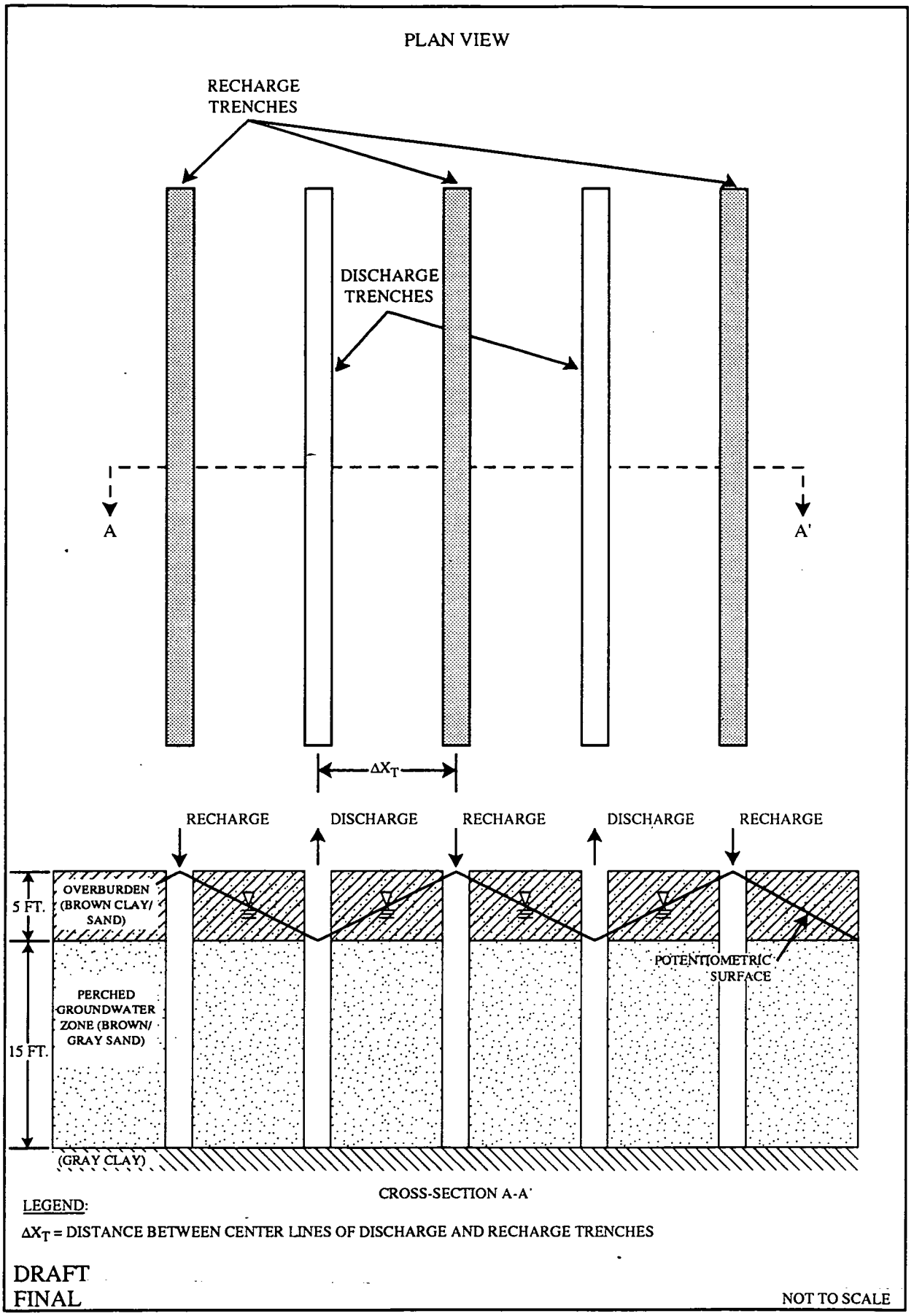

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FIGURE F.6-27. IDEALIZED CONFIGURATION OF REMEDIAL TRENCHES

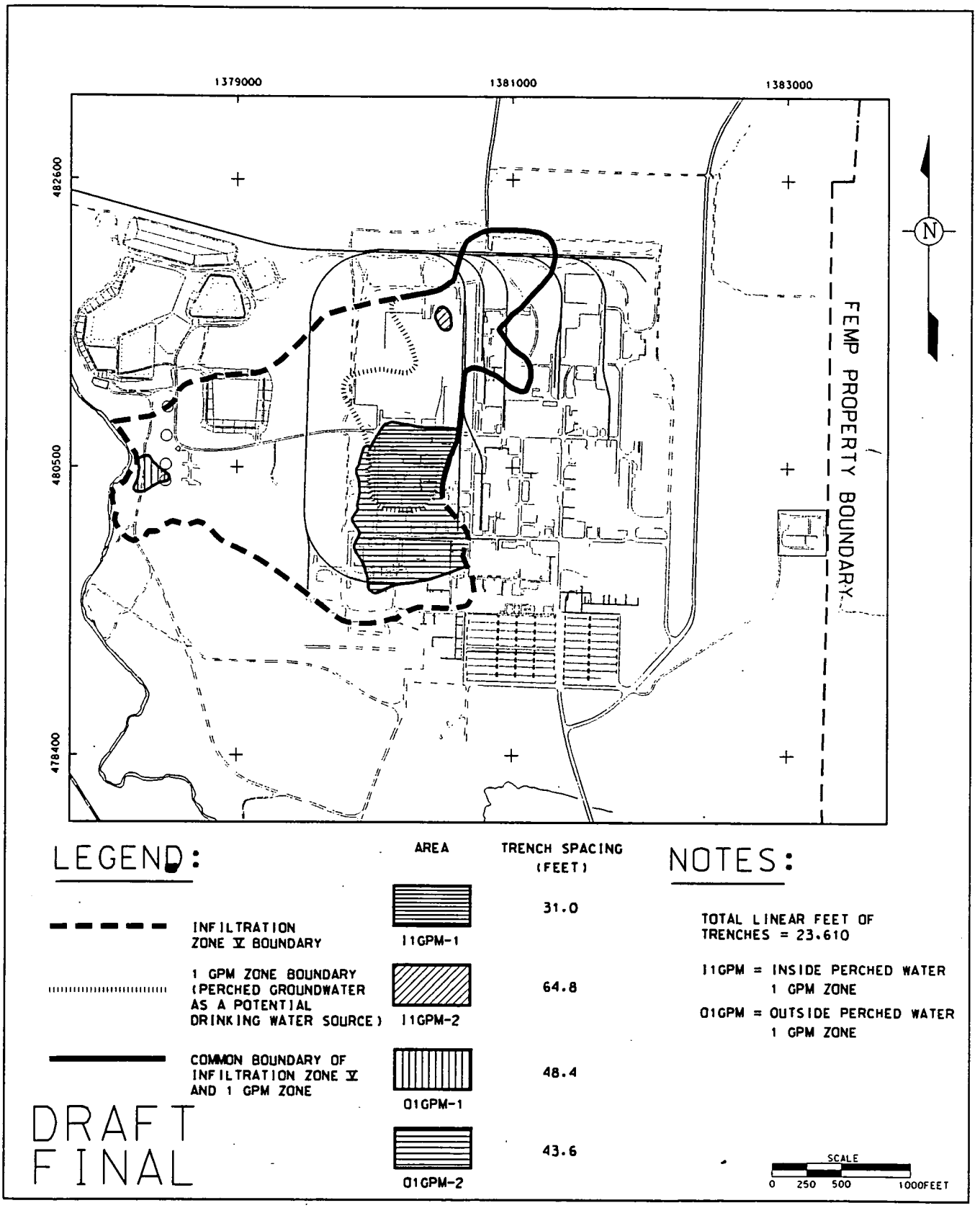

FIGURE F.6-28. AREAL DISTRIBUTION OF PERCHED GROUNDWATER REMEDIAL TRENCHES FOR URANIUM-238 (K_d = 15 ml/g ; K_h = 1.64 ft/day) - CASE 3

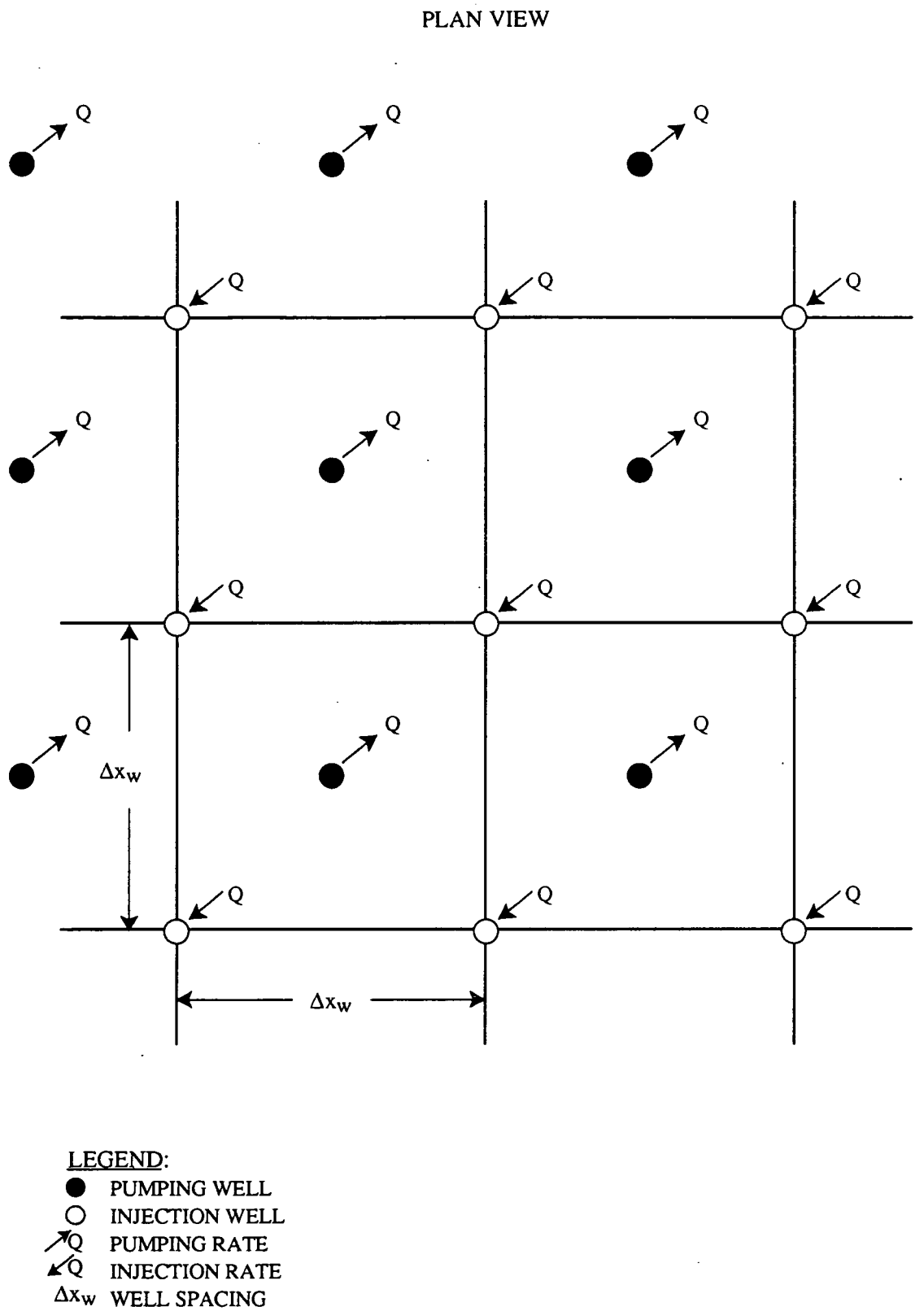

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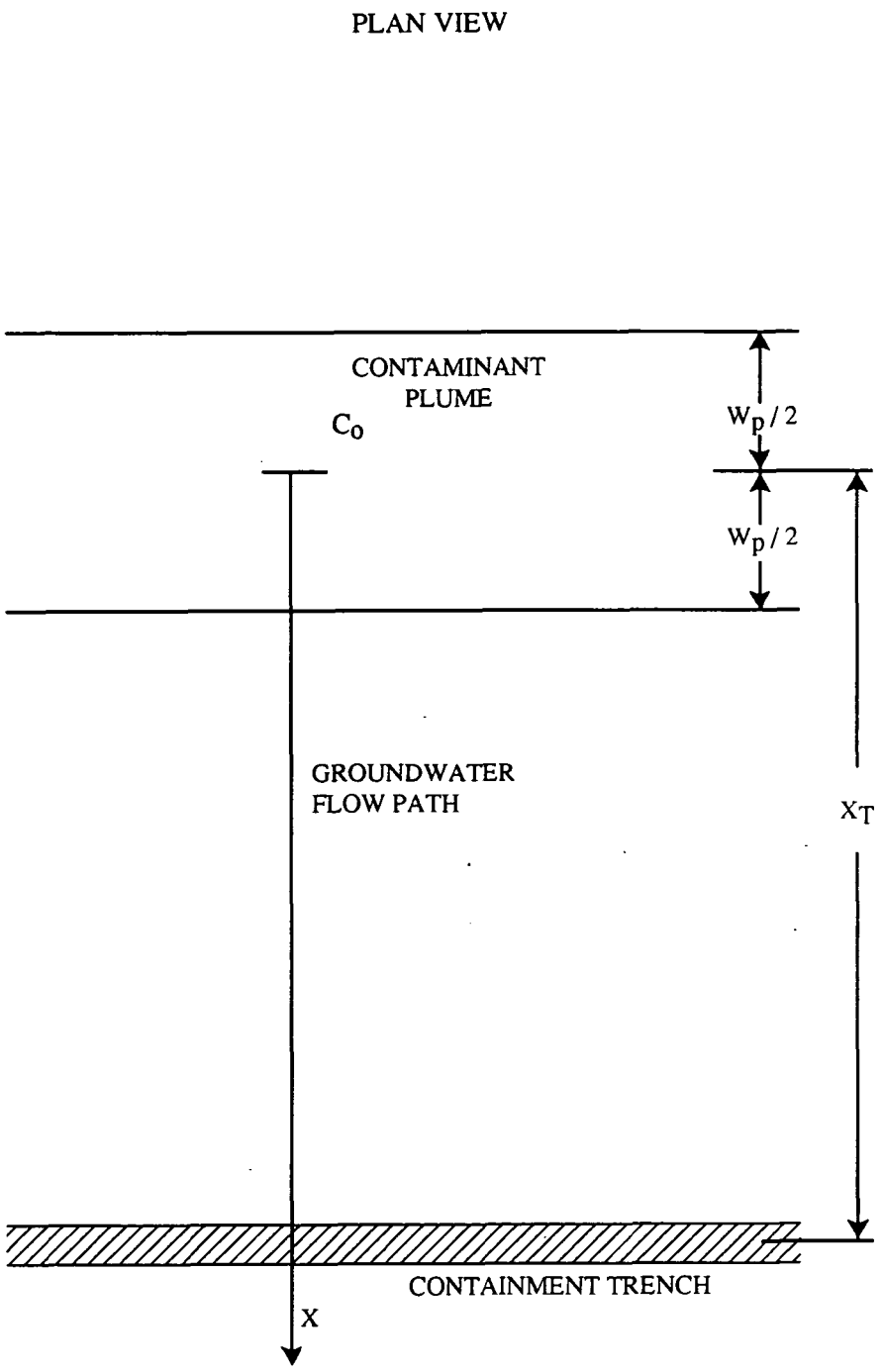
FIGURE F.6-29. IDEALIZED CONFIGURATION OF PUMPING AND INJECTION WELLS AND A PUMPING-INJECTION REMEDIAL SYSTEM.



LEGEND:

C_o = INITIAL PLUME CONCENTRATION
W_p = PLUME WIDTH ALONG FLOW PATH
X_T = DISTANCE FROM TRENCH TO PLUME CENTROID

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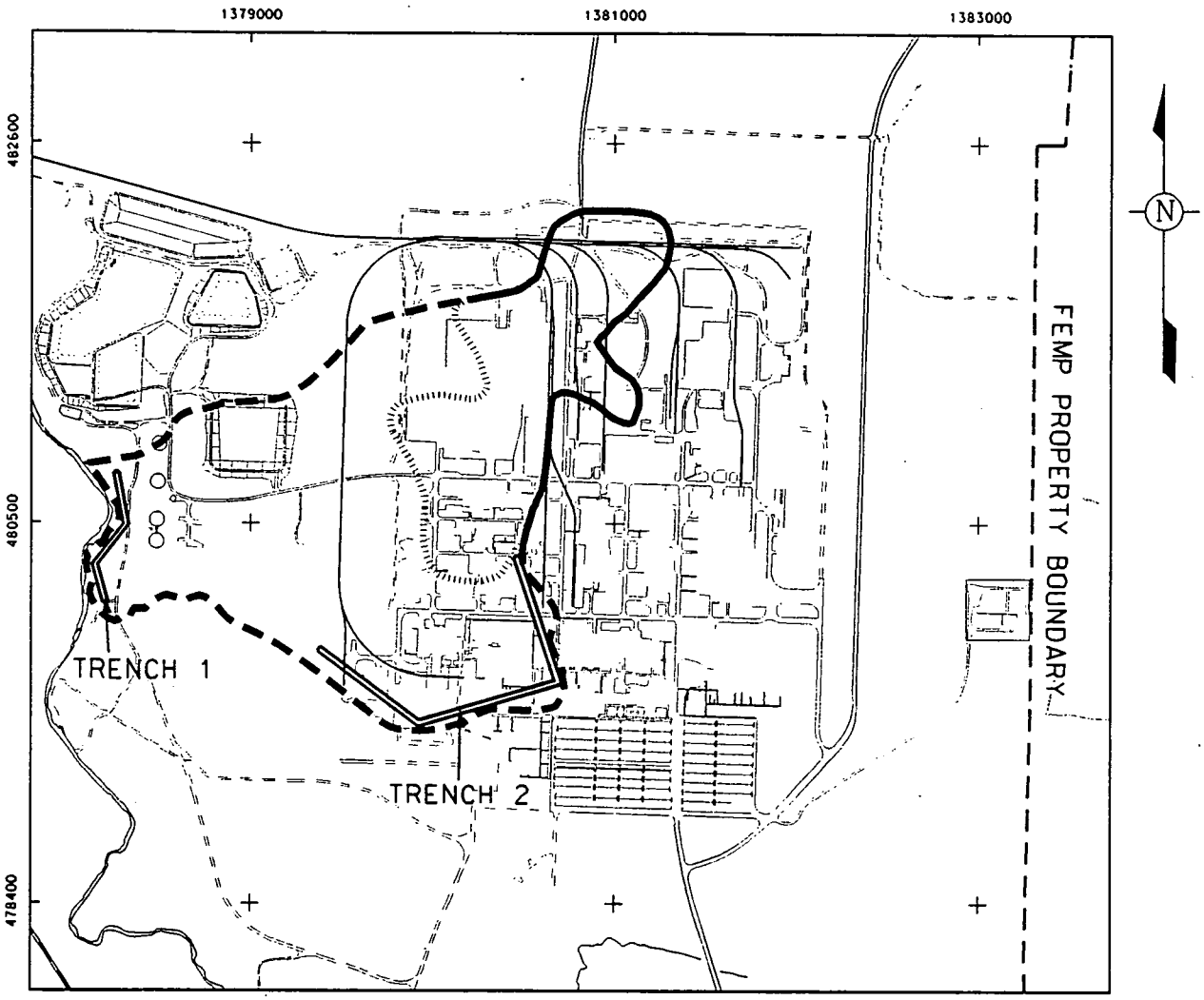
FIGURE F.6-30. IDEALIZED CONTAINMENT TRENCH LOCATED DOWNGRADIENT FROM AN IDEALIZED CONTAMINANT PLUME



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LEGEND:

- INFILTRATION ZONE V BOUNDARY
- 1 GPM ZONE BOUNDARY (PERCHED GROUNDWATER AS A POTENTIAL DRINKING WATER SOURCE)
- COMMON BOUNDARY OF INFILTRATION ZONE V AND 1 GPM ZONE

NOTES:

CONTAINMENT TRENCH	LENGTH (FEET)
1	800
2	2200

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SCALE
0 250 500 1000FEET

FIGURE F.6-31. APPROXIMATE LOCATIONS OF CONTAINMENT TRENCHES FOR URANIUM-238 - CASE 1

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F.7.0 GREAT MIAMI AQUIFER GROUNDWATER EXTRACTION STRATEGY

F.7.1 INTRODUCTION

Modeling was performed to preliminarily site and size groundwater remediation systems in the Great Miami Aquifer. This modeling was conducted to support the analysis of aquifer remediation options in the Operable Unit 5 FS. The SWIFT Great Miami Aquifer model, created for the FEMP investigation and remediation by contractors for the DOE, was used for the analysis.

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F.7.1.1 Objective

The objective of this study is to provide a reasonable yet conservative estimate of the size (number of wells, pumping rate and duration of pumping) of systems that will restore the Great Miami Aquifer to the 20 and 3 μg/L uranium concentrations or contain on-property concentrations greater than 20 μg/L. This siting and sizing information will provide a reasonable basis for cost estimates of such systems. Based on this study, the feasibility of using a pump-and-treat approach for aquifer restoration will be determined. Four system designs are considered:

- No-Additional-Action Design - continue pumping the existing South Plume recovery wells with no additional wells to determine the time required to reduce the maximum uranium concentration below 20 μg/L and 3 μg/L.
- Groundwater Restoration to 20 μg/L Design - remediate the groundwater below the FEMP property and beyond so that the maximum remaining uranium concentration in the Great Miami Aquifer is 20 μg/L.
- Groundwater Restoration to 3 μg/L Design - remediate groundwater below the FEMP property and beyond so that the maximum remaining uranium concentration in the Great Miami Aquifer is 3 μg/L.
- Groundwater Containment to 20 μg/L Design - prevent concentrations greater than 20 μg/L to migrate off property. Remediate groundwater so that the maximum uranium concentration in the Great Miami Aquifer is 20 μg/L.

Simple designs of direct extraction of groundwater without enhancements are considered at this stage in the project because analysis in the design process is focused on larger scale issues of overall performance and implementability of the extraction system and not on specific issues of design refinement. It is recognized that a more efficient pumping system could be obtained through inclusion of design enhancements or more sophisticated design and operational optimization techniques such as reinjection, air sparging, and pulse pumping. However, because design enhancements and optimization techniques will increase the performance and efficiency of the extraction system, cost estimates based upon a simple system will be conservative. Given the unknowns in hydrogeologic

systems, this added conservatism seems appropriate at this stage of the project. Refinement of the selected scenario with optimization techniques or enhancements will occur during preliminary design.

F.7.1.2 Technical Approach

DOE Figure F.7-1 outlines the approach to designing the Great Miami Aquifer groundwater extraction or contaminant system. After defining the constraints of the analysis, the initial conditions, and the geochemical parameters, the four extraction designs were defined. An evaluation of multiple scenarios was only carried out for the restoration to 20 μg/L design; although the information obtained in this evaluation was used for developing the restoration to 3 μg/L design and the containment to 20 μg/L design. The extraction of other COCs was simulated for only the two more aggressive designs (restoration to 20 μg/L and restoration to 3 μg/L) both are effective in reducing the maximum concentration below applicable standards (MCL, 10^{-5} or 10^{-6} ILCR-based levels) for five of the seven other constituents with contaminant plumes. Each design was simulated with a higher desorption K_d to determine an upper bound cleanup time. Finally, model limitations and strategies for design, operation and monitoring were assessed.

F.7.2 MODELING BACKGROUND

A review of general hydrological, geochemical, and contaminant conditions is provided in Section F.2.0. Background information is provided in this section to support the analysis of groundwater extraction designs. This information includes:

- The modeling constraints
- Evaluation criteria
- The SWIFT Great Miami Aquifer model parameters
- The initial concentrations of uranium in the Great Miami Aquifer
- The aquifer zones
- The initial concentrations and geochemical parameters of other COCs that have been identified with Great Miami Aquifer concentrations greater than the 10^{-6} risk screening levels
- The approach used to simulate a higher desorption K_d.

These constraints, conditions, and criteria are described below.

F.7.2.1 Constraints

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The following constraints have been imposed on the modeling to simplify the analysis and to ensure that consistent conditions are used so that the different extraction and containment cases may be compared:

- Figure F.7-2 provides a time line of projected contaminant loading and pumping. Pumping of the Great Miami Aquifer will occur over a period determined by the cleanup goal of a particular design to a maximum of 400 years (assuming time 0 is the year 1995). A 5-year construction period is assumed for new extraction wells and the groundwater treatment facility (GTF); thus the existing South Plume extraction wells will be pumped from Year 0 (1995) while new extraction wells will start pumping at Year 5 (2000). Since the GTF has a 35-year design life, extracted groundwater will be treated at the GTF until Year 40 (2035). Groundwater extracted after Year 40 (if necessary) will either be discharged directly to the Great Miami River (if the concentration is acceptable) or the treatment plant will be upgraded or replaced.

- Remediation of the other operable units will be completed at Year 20 (2015) (see Figure F.7-2). During the remediation period, loading to the Great Miami Aquifer from the other operable units will be constant at the current levels as determined by modeling from the respective operable unit RIs. Following remediation, loading from the operable units will be negligible.

104 - Loadings to the Great Miami Aquifer from surface water and Operable Units 1 and 2 will be constant at the rate determined in the Operable Unit 5 RI Report (DOE 1995) until Year 20 (see Table F.7-1). After Year 20, at the assumed completion of remediation, the contaminant loadings from these sources will be negligible.

- Extraction designs will attempt to reduce the maximum aquifer uranium concentration below the 20 μg/L or 3 μg/L cleanup goal (representing the MCL or the 10^{-6} risk-based standard) within a minimum amount of time while maintaining a reasonable extraction efficiency.

- Extraction designs will be developed based on the uranium plume, as defined by the 3 μg/L contour. The effectiveness of the selected extraction system to remove other COCs in the Great Miami Aquifer will also be modeled.

- The maximum total groundwater discharged from each pumping scenario will be 7500 gallons per minute (gpm). This 7500 gpm value represents the planned treatment capacities of the GTF dedicated to groundwater remedial action.

- For this analysis, extraction wells may be located anywhere to effectively remove contaminants; i.e., well locations are not constrained by site features or the presence of waste units.

- Each extraction well will have a maximum pumping rate of 500 gpm based on aquifer hydraulics and the results of the present pumping of the South Plume recovery well system.

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- Based on recent monitoring results and present operational strategies, the pumping of the South Plume recovery well system will include all 5 wells pumping at 300 gpm. The SOWC production wells will be pumped a total of 25 million gallons per day (Mgd) based on projections of future pumping. Presently, these wells are pumped from 18 to 21 Mgd. The FEMP production wells will essentially be out of service by the time groundwater remediation begins because the site is expected to receive all of its water from the Cincinnati Water Works' new public water supply system by the end of 1995.

- Pumping simulations will be conducted in a steady-state flow mode with constant pumping rates over a limited number of defined pumping periods. Transient analysis will not be conducted as part of this study.

- The objective of this analysis is to provide reasonable and conservative designs for analysis of groundwater extraction effectiveness and cost, so a simple direct extraction philosophy is followed. Reinjection or other extraction enhancement systems (e.g., sparging) will not be initially considered in this analysis but will be considered during preliminary design. Likewise, sophisticated optimization techniques to refine the selected design and operation of the system are not included within this analysis, but will be considered for the preliminary design effort.

F.7.2.2 Evaluation Criteria

The following criteria were used to evaluate each of the extraction designs:

- Removal Rate: While mass removal is not a direct performance standard, mass reduction directly relates to the performance of a particular extraction system design. Therefore, percentage reductions of uranium in the aquifer are considered over time. Often mass remaining curves flatten and approach or become asymptotic with time. At this point, the system has become relatively inefficient at removing further contamination. These curves are inspected to determine when this asymptotic effect occurs.

  Mass removal is complicated by the fact that loading from Operable Units 1 and 2 and surface water continue from Year 0 to Year 20. Therefore, the "total mass" or the mass based on initial conditions plus the added mass changes with time. In presentation of the normalized results, the convention of using the total mass (which includes any loaded mass) has been used.

- System Efficiency: Since a major cost of pump and treat systems is the treatment of extracted contaminated groundwater, the reduction of the total volume of extracted groundwater through increased system efficiency can reduce both capital and operating costs of the groundwater extraction and treatment system. Efficiency is dependent on well location and pumping rate in relation to the plume (which changes with time).

  Uranium removal efficiency is defined as the ratio of the mass of uranium removed from the Great Miami Aquifer (lbs) to the volume of groundwater pumped (millions of gallons). Incremental efficiency is defined as the rate of removal over a smaller block of time. In the present analysis, the incremental efficiency is calculated over the preceding 5-year interval and not over the entire time since the beginning of the simulation. By calculating

it in this manner, the curve is more sensitive to changes in efficiency over time. Cumulative efficiency is defined as the efficiency over the entire period of interest; the total mass removed divided by the total water pumped.

- Distribution of Remaining Uranium: The primary purpose of the groundwater extraction system is recovery of contaminant mass from the groundwater so that the maximum groundwater concentration is reduced below applicable risk levels. Therefore, while overall percentage reduction of mass is desirable; from a risk assessment perspective, the maximum remaining groundwater concentration in the aquifer dictates when the pumps may be turned off. It is also desirable for systems to confine the remaining contamination in a small concentrated area(s) thus facilitating continued control and cleanup of the contamination. To the greatest extent possible, contamination should be maintained on FEMP property.

  In a similar fashion to the mass remaining curves, the maximum concentration curves often flatten and approach or become asymptotic with time. At this point, the system has become relatively inefficient at reducing aquifer contaminant concentrations. These curves are inspected to determine when this asymptotic effect occurs.

- Average Concentration of Extraction Systems: To support GTF process design, average concentrations of uranium and of other constituents from each extraction system (each design is broken into multiple systems) are graphed over time. These concentrations represent the water in the pipelines that will go to the treatment plant.

F.7.2.3 SWIFT Great Miami Aquifer Model Parameters

The model used for simulating groundwater extraction and containment was developed for DOE by IT initially (DOE 1993b) and revised by (DOE 1994c) using SWIFT, a three-dimensional, finite difference flow and transport code (GeoTrans 1993). The model simulates, in three dimensions, the flow of groundwater and solute transport in the Great Miami Aquifer as influenced by hydrological and geological conditions in the vicinity of the FEMP. Details of development and recent improvements are presented elsewhere (DOE 1994c).

The model's chemical-physical parameters are shown in Table F.7-2. These values were derived during the recent flow and solute transport calibration (DOE 1994c).

F.7.2.4 Initial Great Miami Aquifer Uranium Concentrations

Initial concentrations of uranium in the Great Miami Aquifer at the beginning of the modeled period were derived from the five sources listed below.

- Source 1: Field results of total uranium (unfiltered) in Type 2, 3, and 4 wells (see Section F.2) from the maximum of any time concentration contours; as presented in Plates E.81 and E.82 in the Operable Unit 5 RI Report (DOE 1995). In the South Plume area south of Willey Road, these concentration contours were updated with the most recent monitoring data from the operation of the South Plume recovery wells.

- Source 2: 1990 Great Miami Aquifer uranium concentrations developed through geostatistical analysis of field data; as presented in the SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994c).

- Source 3: 1993 Great Miami Aquifer uranium concentrations developed through geostatistical analysis of field data; as presented in the SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994c).

- Source 4: Results of groundwater fate and transport modeling for the Operable Unit 2 RI Report (DOE 1994b)

- Source 5: Results of groundwater fate and transport modeling for the Operable Unit 1 RI Report (DOE 1994a).

Figure F.7-3 shows the process that was used to develop the initial Great Miami Aquifer uranium concentrations. The objective of this process was to establish conservative initial concentrations (i.e., representative of the most mass in the Great Miami Aquifer). The maximum unfiltered groundwater samples from Types 2 and 3 monitoring wells (Source 1) were gridded onto the model grid using the Inverse Distance algorithm in SURFER to create a depiction of the plume for the model. Contours of these gridded files were compared to the plates in the RI Report to discern whether similar trends were created and changes were made to create similar trends. For example, particular contours were input as a series of values to conserve the contours. Because Type 2 wells are screened at depths corresponding to Layer 1 of the SWIFT Great Miami Aquifer model and Type 3 wells are screened at depths corresponding to Layer 3 of the model, well monitoring data could be directly translated to their respective model layers.

Grid files with concentrations defined for each model block (on the 120-by-112 SWIFT Great Miami Aquifer model grid) were available from Sources 2, 3, 4, and 5 because both the geostatistical analysis and fate and transport modeling used this grid. Grid files from Sources 2, 3, 4, and 5 were electronically combined such that the highest value for each cell was retained. One area to the southeast of the site (generally east of State Route 128) and an area west of Paddys Run, which were identified by the 1993 Geostatistical Analysis as having elevated uranium concentrations, were considered artifacts of the kriging process and were disregarded due to a lack of corroborating well data.

"Combined" files for model Layers 1 and 3 were compared to contour maps from Source 1 for Type 2 and Type 3 wells. "Final combined" contour maps for Layers 1 and 3 were generated to conservatively present all the data from all five sources. The adjusted contours were then electronically converted back to individual grid (cell by cell) values. Model Layer 2 initial concentrations were generated by averaging the final combined concentrations for Layers 1 and 3. Final contour plots of initial uranium concentrations in Layers 1 through 6 are shown in Figures

F.7-4 through F.7-7.

Operable Unit 5 RI results indicate that there is limited contamination detected above the risk based standard (less than 3 parts per billion [μg/L]) detected in Type 4 wells screened at a depth corresponding to Model Layer 6. Therefore, plumes were defined in Layers 1, 2 and 3 from the data sets shown above.

106 For the locations where uranium was detected in Type 4 wells, the model block containing the well (and the blocks immediately above in Layers 4 and 5) was set with the appropriate concentration (i.e., maximum detected). Most of the contamination found in Type 4 wells (at the bottom of the aquifer) is relatively localized. Section 4.8.3 of the Operable Unit 5 RI Report presents a summary of the nature and extent of contamination in the Great Miami Aquifer and Figure 4-97 illustrates where total uranium contamination in Type 4 wells has been recorded. The reported concentration of 103 ppb is an error. This contamination is present at shallower levels and is not from the base of the aquifer. The 1.5 ppb value noted in the northeast corner of the production area comes from an area where several wells were plugged and abandoned due to leaking joints (DOE 1995).

F.7.2.5 Aquifer Zones

For modeling and analysis purposes, the uranium groundwater plume has been divided into 5 zones (see Figure F.7-8). These 5 zones have been termed "aquifer zones." Groundwater extraction systems in these zones are given the same numeric designation as the zone the system resides within.

For each aquifer zone, constituent mass and maximum concentration are calculated initially and at specified times during the simulations. Tracking constituent removal and maximum concentration from these zones allows a more detailed analysis of the effectiveness of the extraction systems in different site areas. However, because water and solute may cross the boundaries between zones based on differing well configurations, calculations of mass removed by the extraction wells located within a particular zone does not necessarily coincide with initial mass calculated in a zone. In other words, these zones do not represent actual areas of capture for any particular scenario, but rather identify those geographic areas where each of the respective systems will have the greatest impact.

Table F.7-3 shows the initial conditions for dissolved and adsorbed uranium mass and maximum concentration calculated for each model layer within each zone. These values were calculated from the plumes depicted in Figures F.7-4 through F.7-7 and considered dissolved concentrations greater than 3 μg/L of uranium and a partition coefficient (K_d) of 1.78 liters per kilogram (L/kg). Based on these assumptions, the Great Miami Aquifer contains a total (adsorbed and dissolved) of 16,000 pounds (lbs) of uranium at the beginning of each model simulation with the much larger fraction adsorbed. The largest percentage of the mass was estimated to reside in the South Field area adjacent

and below the SSOD. This area is within Zone 2. Layer 2 contains the majority of the mass because its saturated thickness is typically three times that of Layer 1 or Layer 3.

F.7.2.6 Initial Conditions of Other COCs

Figures F.7-9 through F.7-14 and Table F.7-4 show the initial concentrations in the first layer for seven constituents that have been identified with concentrations greater than 10^{-6} risk-based screening levels. These contour plots were developed from maximum well concentrations collected at any time for each of these constituents. Concentrations in other layers were determined in a manner analogous to that of uranium. Block concentrations representing the plumes of these other constituents in the Great Miami Aquifer were included as initial conditions in the SWIFT Great Miami Aquifer model simulations. Each of these seven constituents with initial plumes were simulated with the SWIFT Great Miami Aquifer model using the groundwater restoration to 20 μg/L and 3 μg/L designs.

F.7.2.7 Geochemical Parameter Development

108 Table F.7-5 shows the modeling parameters for the seven other constituents in the Great Miami Aquifer which have concentrations greater than screening levels. These modeling parameters include the distribution coefficient (K_d), retardation factor (R), and surface water loading rates. The derivation of these K_ds is discussed in Appendix F.2.4. These K_d values are considered to provide conservatively high estimates of clean up times. From a groundwater extraction perspective and given complete hydraulic capture, the upper limit K_d represents a more difficult situation for extraction than a lower K_d. Therefore the upper limit K_d was used to add conservatism in the cleanup time estimation.

108 Based on Plates E-132 and E-133 in the RI Report, three localized VOC plumes exist close to Paddys Run. These plumes are also adjacent to contaminant sources such as the Clearwell (Operable Unit 1's waste pit area), inactive flyash pile (Operable Unit 2's South Field area), and the pilot plant drainage ditch. Because of the volatile characteristics of volatile organic compounds (VOCs), significant concentrations are not expected in the surface water runoff. Results of surface water modeling conducted in the Operable Unit 5 RI Report (Table F.2.4-4) showed that only benzene has notable mass loading into the aquifer through the Paddys Run streambed; results also indicated that groundwater concentrations due to this mass loading are insignificant (Table F.2.4-3) (DOE, 1995). Therefore, the source of these VOC plumes is probably the vertical loading through overburden from the above-mentioned source areas and not the surface water runoff. Because the impacts of surface water loading are insignificant, the model simulations of groundwater pumping focus only on the effectiveness of the pumping operation on existing VOC plumes in the aquifer without including surface water loading of VOCs.

F.7.2.8 Approach to Higher Desorption K_d Modeling

An important issue in evaluating uncertainty in this analysis is the value and approach used for the adsorption/desorption of contaminant between the solid and dissolved states. This phenomenon is represented in the site model by the partition coefficient or K_d. Typically models represent this process with a single value of K_d (1.78 L/kg for uranium in the FEMP case based on Great Miami Aquifer site data and the model calibration). An evaluation of the geochemistry at the site indicates that desorption of uranium will likely occur at a slower rate than adsorption (see Section F.2.4), so it becomes more difficult to extract contamination from the groundwater system and the extraction period necessary to clean up the aquifer will be longer.

Because slower desorption makes uranium extraction more difficult, a second simulation was needed to assess extraction at this slower desorption rate and thus provide an "upper bound" for the time it takes to reduce the maximum concentration below a particular standard. Because K_d in SWIFT represents a reversible process at equilibrium, SWIFT is presently not able to directly model this slower desorption phenomenon. SWIFT receives input of initial dissolved concentrations and K_d and defines adsorbed mass based on these values. Therefore, if the K_d is changed, then the adsorbed mass will be changed proportionately. Because the mass has been determined (DOE 1994c) with historical release records and model calibration, it is desired to maintain the same amount of total mass. Thus, a method was devised to simulate this phenomenon while conserving mass.

The method that will be used to simulate this phenomenon includes:

- Determining the length of time a particular design takes to remove a pore volume of the aquifer over the volume of the plume. This value represents the time during which the original dissolved mass has been removed. Because the initial plume conditions. including volume, are fixed for all designs, this time value is only a function of the pumping rate for the different designs. This time was calculated as 10 years for the no-additional action design and 7 years for the other three designs. These time frames include the initial 5 years of only pumping the south plume extraction system wells. The high pumping rates result in a quick removal of a pore volume.

109 - Changing the K_d to 12 at this calculated time. The upper range for the adsorption K_d was chosen to simulate desorption. After increasing K_d, the dissolved concentrations were adjusted to reset the total sorbed mass approximately back to the original value that occurred at time = 0. Based on data presented in the Geochemical Program Issues 3 and 5 Report, which was included in the Groundwater Modeling Report - Summary of Model Development (DOE 1993a), 12 L/kg was selected to represent an average upper limit aquifer K_d value.

- Simulate groundwater extraction with the selected design pumping until the maximum concentration in the aquifer is reduced below the applicable target.

This technique allows the model to simulate the slower desorption process that could be expected to occur. Slower desorption makes contaminant recovery more difficult; therefore, a more conservative depiction of plume recovery is presented.

F.7.3 NO-ADDITIONAL-ACTION DESIGN MODELING

F.7.3.1 Description

The existing South Plume recovery well system consists of five operating extraction wells located off property to the south of the FEMP (see Figure F.7-15). This system was installed in 1993 as a hydraulic barrier to prevent further southward migration of the off-site uranium plume (known as the South Plume). The South Plume recovery well system, referred to in this report as Extraction System 4, is used in all of the designs.

The no-additional-action design is evaluated to define the time required to reduce maximum concentrations below applicable standards with only Extraction System 4 pumping and to provide a baseline for comparison of the other three designs. In order to compare these results with the other designs, the times required to reduce the maximum concentration below both 20 μg/L and 3 μg/L without additional pumping are calculated with the model. Simulations were run for both the baseline K_d of 1.78 L/kg and for the upper limit K_d (desorption) of 12 L/kg (see Section F.7.2.7). By running both cases, a range of the time required to reduce concentrations below 20 μg/L and 3 μg/L is calculated.

110 The well locations, depths, screened intervals, and pumping rates for the no-additional-action design are presented in Table F.7-6. The well locations are presented in Figure F.7-15. The no-additional-action design continues operation of Extraction System 4 at its current extraction rate (300 gpm from each well; 1500 gpm total) until the 3 μg/L cleanup goal is reached or for a maximum of 1000 years. Although additional capacity exists, it is not desirable to increase the pumping rate of the Extraction System 4 due to the presence of the Paddys Run Road Site plume which lies just south of the extraction wells.

This design does not (nor was it intended to) retain the uranium plume on the FEMP, as the on-property uranium plume is free to travel beyond the southern boundary.

F.7.3.2 Modeling Results

The results of no-additional-action design simulations with the baseline K_d of 1.78 L/kg are discussed below:

- Rate of Removal: Figure F.7-16 presents the system performance for this scenario. After 40 years of pumping, Extraction System 4 has removed over 35 percent of the total uranium from the Great Miami Aquifer while after 100 years over 65 percent of

the mass has been removed. It takes about 300 years to remove 90 percent of the uranium mass.

- Removal Efficiency: Incremental system efficiency is calculated over the preceding 5 year period and is expressed as the mass of uranium removed (lbs) per million gallons of pumped groundwater. Incremental efficiency of the system is 0.27 lbs/Mgal at the beginning of the cleanup period and falls to approximately 0.05 lbs/Mgal after 100 years. After 200 years, efficiency becomes less than 0.02.

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111A
111B

- Maximum Concentration Reduction: Maximum concentrations in each model zone for Layers 1, 3 and 6 are graphed over time in Figure F.7-17A. Maximum concentrations in each model zone for Layers 2, 4, and 5 are presented in Figure F.7-17B. These figures show that approximately 90 and 340 years will be required to reduce the maximum concentration below 20 μg/L and 3 μg/L, respectively. These maximum concentrations occur in Zone 4, where the South Plume recovery wells are located. This figure shows that the maximum Zone 5 concentration does stay below 20 ppb over the entire time frame although it remains above 10 ppb for approximately 50 years. Contamination contour plots for Model Layer 1 after 45, 85, and 345 years are shown in Figures F.7-18 through 20. The 3 μg/L contour footprint at 45 years is an elongated oval extending from the northern portion of the production area to New Haven Road south of the site. At 345 years, the remaining plume has shifted to the east. This remnant plume to the east is the result of an area of uranium concentration, not originally within the South Plume recovery well capture zone, that has migrated to the southeast.

F.7.3.3 Modeling Results of Higher Desorption K_d Case

The results of no-additional-action design simulations with higher desorption K_d of 12 L/kg are discussed below:

- Rate of Removal: Figure F.7-21 presents the system performance for this case. After 40 years of pumping, Extraction System 4 has removed over 17 percent of the total uranium from the Great Miami Aquifer while after 100 years over 24.9 percent of the mass has been removed. At the end of the simulation at 400 years, only 56 percent of the mass has been removed.

- Removal Efficiency: Incremental efficiency of the system is 0.27 lbs/Mgal at the beginning of the cleanup period and falls to approximately 0.03 lbs/Mgal after 100 years. After 200 years, efficiency becomes less than 0.03 lbs/Mgal.

- Maximum Concentration Reduction: Maximum concentrations in each model zone for Layers 1, 3 and 6 are graphed over time in Figure F.7-22. This figure shows that approximately 170 and >405 years will be required to reduce the maximum concentration below 20 μg/L and 3 μg/L, respectively. Zone 2 (i.e., South Field and the SSOD areas) which contains the greatest initial mass, requires the most time to reduce the maximum concentration. Contamination contour plots for Model Layer 1 after 40, 150, and 400 years are shown in Figures F.7-23 through 25. The 3 μg/L contour footprint at 40 years is an elongated oval extending from the northern portion of the production area to more than 2000 feet south of Willey Road south of the site. At 150 years, the plume has reduced in concentration (from 100 to 19 μg/L) and the remaining plume has shifted slightly to the east.

F.7.3.4 Evaluation of Other Constituents

112 The groundwater flow and solute transport modeling conducted for the no-additional-action scenario was based on existing conditions and projected future loading conditions of uranium contamination. Only uranium was considered because, based on sampling, uranium is the predominant contaminant on site and in the Great Miami Aquifer, and typically has accounted for the large majority of the risk as predicted in the operable unit risk assessments (DOE 1993a, 1994a, 1994b, and 1995). Characterization efforts have also shown that uranium is present in most contaminated areas; thus, the uranium plume will typically occur in the same locations as the other constituents.

To check how effective the no-additional-action scenario is at removing other constituent plumes, simulation results from the RI Report (DOE 1995d) are summarized in Table F.7-7. As shown in the table, the concentrations of most constituents, except for those of neptunium-127 and radium-226, exceed the screening level concentrations. It should be noted here that the constituent loading rates adopted in the simulations documented in the RI Report reflected the condition of no remediation in the overlying contaminated soil. Therefore, the maximum constituent concentrations shown in Table F.7-7 may be regarded as the upper-bound concentrations of the no-additional-action scenario. Results for the transport of the total VOCs were not available in the RI Report and, therefore, were not included in the table. Individual VOCs of concern were presented in the RI Table 5-38.

F.7.4 GROUNDWATER RESTORATION TO 20 μg/L DESIGN

F.7.4.1 Description

The primary objective of the groundwater restoration to 20 μg/L design modeling is to select and evaluate a system design that will reduce aquifer maximum uranium concentrations to 20 μg/L (i.e., the MCL of uranium). The secondary objectives are to accomplish this restoration within a reasonable amount of time and at a reasonable extraction efficiency. To meet this objective, extraction scenarios were defined in accordance with the constraints defined in Section F.7.2, and were modeled to determine the relative effects of varying the numbers, pumping rates, and locations of the extraction wells. Based on an analysis of the results, the scenario that best met the criteria was selected for detailed evaluation. This detailed evaluation included more analysis of aquifer zone and extraction well concentrations; assessing the capture of other constituents found in the Great Miami Aquifer, and assessing the effect of a higher desorption K_d on system effectiveness. Simulations were run for both the baseline K_d of 1.78 L/kg and for the upper limit K_d (desorption) of 12 L/kg (see discussion in Section F.7.2-7 and F.7.2-8). By running both cases, a range of the time required to reduce concentrations below 20 μg/L is calculated.

Scenarios were developed of varying numbers, locations and pumping rates of extraction wells in the Great Miami Aquifer. Scenarios were developed based on plume location, flow patterns, analytical model analysis, and capture zone analysis. Three extraction options with unique well locations were

formulated with each being pumped at two different total pumping rates to make a total of six scenarios. The three "A" scenarios were pumped at a total rate of 7500 gpm and the three "B" scenarios at a total rate of 6300 gpm. Each scenario was progressively refined based on the results of the previous scenarios. For analysis purposes, wells within these scenarios were grouped into four extraction systems based on location within aquifer zones (see Figure F.7-8). One of these extraction systems, the Extraction System 4, already exists in Zone 4 while the other four systems are proposed.

A minimum of 18 and a maximum of 30 extraction wells were simulated (including the South Plume recovery wells). The modeling considers a 40-year time frame because all six scenarios were successful in reducing maximum concentrations below the 20 μg/L standard within 40 years. The pumping scenarios and the model results for each scenario are discussed below.

F.7.4.2 Extraction Scenarios 1A and 1B

Description

Well locations, depths, screened intervals, and pumping rates of Scenario 1A and 1B wells are shown in Table F.7-8. The well locations are shown in Figure F.7-26. In this scenario, wells are strategically located downgradient of the existing plumes in an attempt to provide an efficient extraction system and to prevent the uranium plumes from migrating off property. This scenario modeled fewer wells (i.e., 18 wells) with higher pumping rates when compared to the other scenarios. The new wells begin pumping at Year 5 for a combined scenario pumping rate of 7500 gpm for Scenario 1A and 6300 gpm for Scenario 1B. The only difference between Scenario 1A and 1B is the pumping rate.

Three additional extraction systems (comprising a total of 13 additional wells) are added to the five wells already provided by Extraction System 4. Extraction System 1 consists of five extraction wells in the vicinity of the waste pit area located generally along the downgradient periphery of the waste pit area uranium plume (see Figures F.7-4 and F.7-26). Extraction System 2 consists of six wells; with three wells located along the downgradient periphery of the uranium plumes in the South Field area near the southern perimeter of the FEMP property and the remaining three wells located immediately downgradient from the SSOD. Extraction System 3 is a single well sited to remove a small plume in the vicinity of Plant 6. An additional well was added to Extraction System 4, north of the 5 existing wells.

Scenario 1 Results

The addition of Extraction Systems 1, 2, and 3 in Scenario 1 provides for the recovery of contaminated groundwater further upgradient of Extraction System 4 (nearer the source of the contamination) before it leaves site property. Scenario 1 results applied to the three measurement criteria are discussed below.

- Rate of Removal: Figures F.7-27 and F.7-28 present the system performance for these scenarios. After 40 years of pumping, Scenario 1A has removed 88.4 percent of the total uranium from the Great Miami Aquifer while Scenario 1B has removed 86.2 percent.

- Removal Efficiency: Incremental efficiency of Scenario 1A is 0.22 lbs/Mgal at the beginning of the cleanup period, 0.27 lbs\Mgal when the new extraction wells are started after 5 years, falls to 0.04 lbs/Mgal after 25 years of pumping and further decreases from years 25 to 40. (see Figure F.7-27). Scenario 1B shows a similar curve of efficiency over time only with slightly higher values. Cumulative system efficiency after 40 years is 0.126 lbs/Mgal for Scenario 1A and 0.145 lbs/Mgal for Scenario 1B.

113 451 - Maximum Concentration Reduction: Figures F.7-29A and F.7-30 show the uranium concentration over time for each aquifer zone for representative model layers 1, 3 and 6 for Scenarios 1A and 1B. Uranium concentrations in Layers 2, 4, and 5 for Scenarios 1Aand 1B are shown in Figures F.7-29B and F.7-30B, respectively. Scenarios 1A and 1B reduce the maximum uranium concentration for all aquifer zones below 20 μg/L in 30 and 35 years, respectively. The drop in maximum concentrations after year 20 in Zones 1, 2 and 3 is caused by the completion of Operable Units 1 and 2 remedial activities and surface water loading at Year 20. As expected, Scenario 1A with the higher pumping rate reduces maximum concentration faster. For both scenarios, the reduction of Zone 2 maximum concentration takes the full cleanup time while the other zones take less time. Lower model layers clean up in a shorter time although the solute is extracted at a slower rate; thus the curves are flatter. This is not only due to the pumps being placed in the shallow aquifer and preferentially extracting shallow groundwater, but also artificial vertical dispersion in the model (see Section F.7.7 for further discussion).

  Contamination contour plots for Model Layer 1 after 40 years for Scenarios 1A and 1B are shown in Figures F.7-31 and F.7-32. The maximum concentrations at 40 years for Scenarios 1A and 1B are 9.0 and 12.3 μg/L respectively. Again this is the expected result with the higher pumping rate reducing the maximum concentration to a lower value. Plumes for each scenario have a similar shape with the maximum concentration occurring approximately at the southern property line.

F.7.4.3 Extraction Scenarios 2A and 2B

110 Description

Well locations, depths, screened intervals, and pumping rates of Scenario 2 wells are identified in Table F.7-9. The well locations are shown in Figure F.7-33. In Scenario 2, 12 additional wells (when compared to Scenario 1) are located within the existing plumes in an attempt to more aggressively remediate the plume. Two wells are added in the waste pit area (Extraction System 1), 9 wells are added in South Field (Extraction System 2) and one more off-property well is added in the South Plume area north of the present South Plume recovery wells in Extraction System 4. In addition, minor adjustment to some well locations were made. Because the total pumping rate is fixed, Scenarios 2A and 2B use a higher number of wells with lower individual pumping rates when compared to Scenario 1. A greater number of wells with lower pumping rates allows more targeting of plume hot areas and allows more operational flexibility although with greater capital costs. The

new wells begin pumping at Year 5 for a combined scenario pumping rate of 7500 gpm for Scenario 2A and 6300 gpm for Scenario 2B.

Scenario 2 Results

Scenario 2 results applied to the three measurement criteria are discussed below:

- Rate of Removal: Figures F.7-34 and F.7-35 present the system performance for these scenarios. After 40 years of pumping, Scenario 2A has removed 89.0 percent of the total uranium from the Great Miami Aquifer while Scenario 1B has removed 86.4 percent. The rate of uranium removal is relatively slow from 0 to 5 years when only the original South Plume extraction wells are pumping, increases dramatically from years 5 to 10 after the installation of the new wells, and gradually decreases over the next 30 years until Year 40.

- Removal Efficiency: Incremental efficiency of Scenario 2A is 0.27 lbs/Mgal at the beginning of the cleanup period, 0.29 lbs\Mgal when the new extraction wells are started after 5 years, falls below 0.04 lbs/Mgal after 25 years of pumping (see Figure F.7-34) and decreases further from years 25 to 40. Scenario 1B shows a similar curve of efficiency over time only with slightly higher values. Cumulative system efficiency after 40 years is 0.127 lbs/Mgal for Scenario 2A and 0.146 lbs/Mgal for Scenario 2B.

113 - Maximum Concentration Reduction: Figures F.7-36A and F.7-37A show the uranium concentration over time for each aquifer zone for representative Model Layers 1, 3 and 6 for Scenarios 2A and 2B. Uranium concentrations in layers 2, 4, and 5 for Scenarios 2A and 2B are shown in Figures F.7-36B and F.7-37B, respectively. Scenarios 2A and 2B reduce the maximum uranium concentration for all aquifer zones below 20 μg/L in 27 and 33 years, respectively. For both these scenarios, model layer 2 took the longest time to remediate. As expected, Scenario 2A with the higher pumping rate reduces maximum concentration faster than Scenario 2B. For both scenarios, the reduction of Zone 4 maximum concentrations in Model Layer 2 takes the longest cleanup time while the other zones take somewhat less time. Lower model layers clean up in a shorter time although the solute is extracted at a slower rate; thus the curves are flatter. This is not only due to the pumps being placed in the shallow aquifer and preferentially extracting shallow groundwater, but also artificial vertical dispersion in the model (see Section F.7.7 for further discussion).

  Contamination contour plots for Model Layer 1 after 40 years are shown in Figures F.7-38 and F.7-39. The maximum concentrations at 40 years for Scenarios 2A and 2B are 6.1 and 9.2 μg/L respectively. Again this is the expected result with the higher pumping rate reducing the maximum concentration to a lower value. Plumes for each scenario have a similar shape although the footprint of the 3 μg/L contour is larger for the lower pumping rate case of Scenario 2B.

F.7.4.4 Extraction Scenario 3A and 3B

Description

110 Well locations, depths, screened intervals, and pumping rates of Scenario 3 wells are identified in Table F.7-10. The well locations are shown in Figure F.7-40. Scenario 3 is similar to Scenario 2, but does not include pumping from the two new off-property on System 4 wells. So that the total pumping rate remains at 7500 gpm and 6300 gpm for Scenarios 3A and 3B, this 600 gpm pumping from these Scenario 2 off-property wells is distributed to some Extraction System 2 wells. One purpose of Scenarios 2 and 3 is to determine if additional off-property wells can significantly improve overall system performance.

Scenario 3 Results

Scenario 3 results applied to the three measurement criteria are discussed below.

- Rate of Removal: Figures F.7-41 and F.7-42 present the system performance for these scenarios. After 40 years of pumping, Scenario 3A has removed 89.5 percent of the total uranium from the Great Miami Aquifer while Scenario 1B has removed 87.0 percent. The rate of uranium removal is relatively slow from 0 to 5 years when only the 5 Extraction System 4 wells are pumping, increases dramatically from years 5 to 10 after the installation of the new wells, and gradually decreases over the next 30 years until Year 40.

- Removal Efficiency: Incremental efficiency of Scenario 3A is 0.27 lbs/Mgal at the beginning of the cleanup period, 0.29 lbs\Mgal when the new extraction wells are started after 5 years, falls to approximately 0.04 lbs/Mgal after 25 years of pumping (see Figure F.7-41) and decreases further from years 25 to 40. Scenario 1B shows a similar curve of efficiency over time only with slightly higher values. Cumulative system efficiency after 40 years is 0.128 lbs/Mgal for Scenario 3A and 0.147 lbs/Mgal for Scenario 3B.

113 - Maximum Concentration Reduction: Figures F.7-43A and F.7-44A show the uranium concentration over time for each aquifer zone for representative model layers 1, 3 and 6 for Scenarios 3A and 3B. Uranium concentrations in layers 2, 4, and 5 for Scenarios 3A and 3B are shown in Figures F.7-43B and F.7-44B, respectively. Scenarios 3A and 3B reduce the maximum uranium concentration for all aquifer zones below 20 μg/L in 26 and 29 years, respectively. For both these scenarios, model layer 2 took the longest time to remediate. As expected, Scenario 3A with the higher pumping rate reduces maximum concentrations faster than Scenario 3B. For both scenarios, the reduction of Zone 2 maximum concentration takes the full cleanup time while the other zones take less time. Lower model layers clean up in a shorter time although the solute is extracted at a slower rate; thus the curves are flatter. This is not only due to the pumps being placed in the shallow aquifer and preferentially extracting shallow groundwater, but also artificial vertical dispersion in the model (see Section F.7.7 for further discussion).

  Contamination contour plots for Model Layer 1 after 40 years are shown in Figures F.7-45 and F.7-46. The maximum concentrations at 40 years for Scenarios 3A and 3B

are 5.9 and 8.1 μg/L, respectively. Again this is the expected result with the higher pumping rate reducing the maximum concentration to a lower value. Plumes for each scenario have a similar shape although the footprint of the 3 μg/L contour is larger for the lower pumping rate case of Scenario 3B.

F.7.4.5 Selection of Restoration to 20 μg/L Design

Table F.7-11 summarizes results from the six extraction scenarios. These scenarios removed from 86.2 to 89.5 percent of the uranium mass within 40 years at efficiencies ranging from 0.126 to 0.147 lbs/Mgal. The time to reduce the maximum concentration below 20 μg/L ranged from 25 to 35 years. After 40 years maximum concentrations ranged from 5.9 μg/L to 12.3 μg/L.

452 Figures F.7-47 and F.7-48 compare the incremental system efficiency over time and fraction of total mass remaining over time for the six scenarios. Each scenario shows similar shaped curves over time although there is some offset of the curves. These curves show that Scenario 3A and 3B have the highest efficiency and greatest mass removal when compared to their Scenario 1 and 2 counterparts. Based on a comparison of Scenarios 1, 2 and 3, additional off-property wells (No. 13 in Scenario 1 [see Figure F.7-26] and Nos. 24 and 25 in Scenario 2 [see Figure F.7-33]) did not significantly improve efficiency or remediation time.

454 The three "A" scenarios (7500 gpm pumping rate) removed greater mass but at a lower efficiency than their "B" counterparts. Although the differences were relatively small, Scenarios 3A and 3B removed the greatest mass at higher efficiencies and reduced the maximum concentrations to a lower value than their Scenario 1 and 2 counterparts. Scenario 3B performed at a higher efficiency than Scenario 3A. Although Scenario 3B removed less mass than 3A and took a longer time to restore the aquifer to 20 μg/L, nevertheless 3B was still able to clean up the aquifer in a reasonable amount of time (28 years for Scenario 3B versus 25 years for Scenario 3A). Therefore, based on these results, Scenario 3B was selected as the preferred scenario.

F.7.4.6 Modeling of Other Constituents and Process Support Data

The groundwater flow and solute transport modeling conducted for the 20 μg/L design was based on existing conditions and projected future loading conditions of uranium contamination. Only uranium was considered because, based on sampling, uranium is the predominant contaminant on site and in the Great Miami Aquifer, and typically has accounted for the large majority of the risk as predicted in the operable unit risk assessments (DOE 1993b, 1994a, 1995). Characterization efforts have also shown that uranium is present in most contaminated areas; thus, the uranium plume will typically occur in the same locations as the other constituents.

To check how effective the 20 μg/L design is at removing other constituent plumes and to determine mass and concentration removal to support GTF process design, plumes of additional constituents

identified in the Operable Unit 5 RI Report (DOE 1995) were also modeled with pumping according to the selected scenario (3B) over a 40-year period. These additional constituents could pose difficulties for a system based on uranium capture if the constituent plume lies outside the footprint of the uranium plume, or if the constituent's K_d is larger than that of uranium. Uranium is also included in this analysis from Scenario 3B to provide predicted process information for uranium.

For each simulation, the maximum concentration by aquifer zone and the average concentration by extraction system were graphed (see Figures F.7-50 to F.7-62). Initial conditions and distribution coefficients were previously presented and are shown in Figures F.7-9 through F.7-14, Table F.7-5 and Table F.7-6. The results are summarized on Table F.7-12. A description of the results of the modeling of each constituent is described in the following paragraphs:

- Uranium: Extraction system average uranium concentrations are graphed over the 40-year period on Figure F.7-50. System 2 initially sees a maximum concentration greater than 100 μg/L which reduces at 20 years to less than 20 μg/L. The other extraction systems follow similar patterns, but with lower concentrations.

113 - Neptunium-237: The neptunium-237 plume is generally at a similar location as the uranium plume (see Figure F.7-9). Neptunium has K_d of 15 L/kg and a retardation of 935 which is higher than uranium by a factor of more than 7, causing neptunium-237 to be significantly less mobile. Figure F.7-51A shows the maximum concentrations for Layers 1, 3 and 6 of the 5 model zones over time. This figure shows that the maximum concentration in the plume is reduced below the screening level (i.e., 10^{-6} ILCR) after about 10 years. Neptunium-237 concentrations in Layers 2, 4, and 5 are shown in Figure F.7-51B. The maximum Great Miami Aquifer concentration of neptunium-237 is almost two orders of magnitude less than the screening level at 40 years.

  System average concentrations for neptunium-237 are reported over the 35-year period in Figure F.7-52. System 2 extracts the highest average concentration, initially seeing an average concentration greater than 1.0×10^{-4} μg/L which reduces slightly over time.

113 - Radium-226: Radium-226 has a number of isolated plumes on and off property (see Figure F.7-10). These plumes are relatively immobile based on the relatively high K_d of 470 L/kg and R_d of 2899. Figures F.7-53A and F.7-53B show the maximum concentrations for all layers of the 5 model zones over time. This figure shows that the maximum concentration in the plume remains below the screening level over the 40 year period.

  System average concentrations for radium-226 are reported over the 35-year period on Figure F.7-54. Average concentrations extracted for all systems are below 1.0×10^{-6} μg/L.

113 - Technetium-99: Technetium-99 has identified plumes originating at the waste pit area
115 and South Field, based upon modeling (see Figure F.7-11). Groundwater monitoring results of technetium-99 were shown in Plate E-101 of the Operable Unit 5 RI Report (DOE 1995). The plumes originating from the waste pit area (Pit 4) and South Field were

clearly marked. In general, modeling results for technetium-99 match the measured concentration patterns with larger simulated plumes of concentrations below the detection limit. Technetium-99 is considerably more mobile than uranium with K_d of 0.2 L/kg and a retardation of 2.23. Figures F.7-55A and F.7-55B show the maximum concentrations for all layers of the 5 model zones over time. The maximum concentration reduces below the screening level in less than 25 years.

System averages for technetium-99 are reported over the 40-year pumping period in Figure F.7-56. Extraction System 2 initially has a concentration greater than 1.0×10^{-2} μg/L at Year 5, which reduces over time. Other extraction systems follow similar patterns over time although with lower concentrations.

113 • Antimony: Elevated concentrations of antimony have been identified in the waste pit area, in the South Field area, in the pa K_d of 1.4 L/kg and production area, and an isolated concentration was detected in the South Plume area (see Figure F.7-12). Antimony has similar mobility as uranium with a K_d of 1.4 L/kg and a retardation of 9.6. Figures F.7-57A and F.7-57B show the maximum concentrations for all layers of the 5 model zones over time. The maximum concentration reduces below the screening level in less than 10 years.

System averages for antimony are reported over the 40-year pumping period in Figure F.7-58. System 1 initially has a concentration of approximately 5.0×10^{-1} μg/L at Year 5, which reduces rapidly over time. Other extraction systems follow similar patterns over time although with lower concentrations.

113 • Arsenic: Elevated concentrations of arsenic have been identified in the South Plume area (as part of the Paddys Run Road Site plume) and at the northern property line (see Figure H.7-13). Arsenic is less mobile than uranium, with a K_d of 16 L/kg and a retardation of 99.7. Figures F.7-59A and F.7-59B show the maximum concentrations for all layers of the 5 model zones over time. The maximum concentration remains above the screening level over the entire 40-year period by one order of magnitude.

System averages for arsenic are reported over the 40-year pumping period in Figure F.7-60. System 4 (the South Plume extraction system) extracts the majority of the arsenic mass.

113 • Manganese: Elevated concentrations of manganese are scattered throughout the Great Miami Aquifer underlying the FEMP area (see Figure H.7-14). Manganese has a low mobility with a K_d of 30 L/kg and a retardation of 186. Figures F.7-61A and F.7-61B show the maximum concentrations for all layers of the 5 model zones over time. The maximum concentration remains above the screening level over the entire 40-year period by at least a factor of 2 or 3.

System averages for manganese are reported over the 40-year pumping period in Figure F.7-62. Average concentration are typically less than 3.0×10^{2} μg/L.

116 • Total VOCs: Elevated concentrations of total VOCs are scattered throughout the Great Miami Aquifer generally underlying the FEMP (see Table F.7-5). The most significant VOC is trichloroethene (TCE), which decomposes to other VOCs. Modeling was

conducted as if all VOCs were TCE using the risk-based screening levels for TCE. Figures F.7-63A and F.7-63B show the maximum concentrations for all layers of the 5 model zones over time. Being relatively mobile with a K_d of about 1 L/kg, maximum TCE concentrations are reduced from in excess of 1000 μg/L to below the MCL level of 5 μg/L within a period of 16 years. Because mobilities are similar, transformation products such as vinyl chloride are also expected to be removed by the system.

System averages for VOCs are reported over the 40-year pumping period in Figure F.7-64. Average concentrations are typically less than 3.0×10^{-3} μg/L.

117 In summary, the proposed extraction system, based on this modeling, will be effective for reducing maximum aquifer concentrations of neptunium-237, technetium-99, antimony, and total VOCs below MCL or 10^{-5} ILCR screening levels. Capture of the remaining constituents will be less effective, primarily due to the lower mobility of these compounds and, to a lesser degree, locations of the recovery wells (based on uranium concentrations). Certain relatively less mobile contaminants also have large initial groundwater plumes which were conservatively assigned using the maximum detected value in each monitoring well for groundwater modeling purposes. Some portions of these plumes are located far away or upgradient from known contaminant source areas such as the former production area, waste management areas, Paddys Run, and the SSOD and may not be due to FEMP releases considering the reasonable transport speeds of these contaminants in the aquifer. Examples of such situations include portions of the arsenic, manganese, and radium-226 plumes used in the modeling. Measured 1993 groundwater data presented in the Plates in the Operable Unit 5 RI Report (DOE 1995) show much smaller groundwater plumes of these contaminants.

453 F.7.4.7 Modeling of the Higher Desorption K_d Case

Following the approach outlined in Section F.7.2.8, simulations were also run for the upper limit uranium K_d (desorption) of 12 L/kg so that a range of cleanup times could be calculated. These simulations were run until clean up to the 20 μg/L concentration was achieved. Scenario 3B was used in this analysis.

The results of these simulations with higher desorption K_d of 12 L/kg are discussed below.

- Rate of Removal: Figure F.7-63 presents the system performance for this case. After 40 years of pumping, this case has removed approximately 52 percent of the total uranium from the Great Miami Aquifer. The rate of uranium removal is relatively slow from 0 to 5 years when only the original five South Plume extraction wells are pumping, increases dramatically from Years 5 to 10 after the installation of the new wells, and gradually decreases over the next 30 years until Year 40. Overall, as expected, the rate of removal is significantly slower for this higher K_d case than the baseline K_d case (compare Figures F.7-42 and F.7-65).

- Removal Efficiency: Incremental efficiency is 0.27 lbs/Mgal at the beginning of the cleanup period, drops rapidly to 0.04 lbs/Mgal at 5 years, recovers slightly to 0.06 lbs/Mgal and remains fairly constant through the remaining time. Cumulative system efficiency after 30 years is 0.10 lbs/Mgal.

113 453B

- Maximum Concentration Reduction: Figures F.7-66A and F.7-66B show the uranium concentration over time for each aquifer zone for all model layers for the high K_d Case. The maximum uranium concentration for all aquifer zones falls below 20 μg/L in approximately 57 years. Model layer 1 and aquifer Zone 2 take the longest time to remediate. The solute is extracted at a slower rate with the higher K_d; thus the curves are flatter when compared to the baseline K_d case (compare Figures F.7-44 and F.7-64).

  Contamination contour plots for Model Layer 1 after 40 and 57 years are shown in Figures F.7-67 and F.7-68. The maximum concentrations at 40 years for this case is 28.4 μg/L (compare to 8.1 μg/L for the baseline K_d case - Figure F.7-46). By Year 57, the plume has a similar shape but the maximum concentration is 19 μg/L.

- Average Concentration by Extraction System: Figure F.7-69 shows the average concentration of uranium by extraction system (consisting of all the wells assigned to a particular system). Similar to the maximum concentration and efficiency curves, the higher desorption K_d has resulted in less mass being extracted and therefore the average concentrations are also lower. Aquifer Zone 2 starts at approximately 100 μg/L and quickly reduces to approximately 10 μg/L at Year 10.

F.7.5 GROUNDWATER RESTORATION TO 3 μg/L DESIGN

F.7.5.1 Description

The primary objective of the groundwater restoration to 3 μg/L design modeling is to select and evaluate a system design that will reduce aquifer maximum uranium concentrations to 3 μg/L. The secondary objectives are to accomplish this restoration within a reasonable amount of time and at a reasonable extraction efficiency. The time and efficiency objectives are obviously more difficult for the restoration to the 3 μg/L design than the 20 μg/L design and more time and a lower efficiency will be required. Only a single scenario was developed for the 3 μg/L design because information obtained from the scenario modeling for the 20 μg/L design was used (see Section F.7.4).

118 The development of the restoration to 3 μg/L design consisted of several steps. Contour output from Year 25 from the restoration to 20 μg/L design, with the more aggressive 7500 gpm pumping rate (see Section F.7.4), was inspected to determine the locations of remaining plumes. Year 25 is five years after source loading from surface water and other operable units is terminated at Year 20. It was considered a reasonable time frame to change the pumping. At this stage of the analysis, it was desired to keep the pumping sequence simple, yet changing the pumping scheme at Year 25 allowed extraction efficiency to be increased in certain areas for achieving the lower cleanup goal. Based on the locations of these plumes, additional wells were added in the interior of the existing plumes. Pumping was modified at Year 25 to include these new wells and to adjust pumping rates at

other wells to maximize uranium removal. This pumping period was continued until the cleanup goal of 3 μg/L was achieved.

Once this design was defined, a more detailed evaluation was conducted. This detailed evaluation included more analysis of aquifer zone and extraction well concentrations, assessing the capture of other constituents found in the Great Miami Aquifer, and assessing the effect of a higher desorption K_d on system effectiveness.

F.7.5.2 Modeling Results

110 Well locations, depths, screened intervals, and pumping rates of the restoration to 3 μg/L design are shown in Table F.7-13. The well locations are shown in Figure F.7-70. The 3 μg/L design has three additional wells when compared to the restoration to 20 μg/L design; 1 shallow well and 2 deep wells (pumping Model Layers 5 and 6) in Aquifer Zone 2 . These additional wells are located adjacent to the southern property line. In addition, the locations of two shallow wells were adjusted to remove uranium more efficiently.

Results applied to the three measurement criteria are discussed below:

- Rate of Removal: Figure F.7-71 presents the system performance for these scenarios. After 40 years of pumping, this design has removed 90.0 percent of the total uranium from the Great Miami Aquifer. After 70 years of pumping, this design has removed almost 95 percent of the total uranium from the Great Miami Aquifer. The rate of uranium removal is relatively slow from 0 to 5 Years when only the original 5 South Plume Extraction wells are pumping, increases dramatically from Years 5 to 10 after the installation of the new wells, and gradually decreases over the next 30 years until Year 75. After approximately 40 years, the uranium removed curve becomes quite flat indicating that little uranium is being removed after that time.

- Removal Efficiency: Incremental efficiency of this design is 0.27 lbs/Mgal at 5 years, increases to 0.29 lbs/Mgal at 10 years and gradually decreases over the remaining time period. After 40 years, efficiencies are less than 0.02 lbs/Mgal as little uranium is being extracted. Because there is the lower target of 3 μg/L, more dilute groundwater will necessarily be extracted. Cumulative system efficiency after 30 years is 0.17 lbs/Mgal.

113 - Maximum Concentration Reduction: Figures F.7-72A and F.7-72B show the uranium concentration over time for each aquifer zone for all model layers for this case. The maximum uranium concentration for all aquifer zones falls below 3 μg/L in approximately 70 years. Model Layer 4 (i.e., clay interbed) took the longest time to remediate, probably because of the lower hydraulic conductivity.

  Contamination contour plots for Model Layer 1 after 40 and 70 years are shown in Figures F.7-73 and F.7-74. The maximum concentrations in Layer 1 at 40 and 70 years are 4.6 μg/L and 2.4 μg/L, respectively.

- Average Concentration by Extraction System: Figure F.7-75 shows the average concentration of uranium by extraction system (consisting of all the wells assigned to a particular system). These curves show a steadily reducing average concentration over time. Extraction System 2 with the highest concentration is approximately 100 μg/L at year 5 and reduces to approximately 3 μg/L at Year 35.

F.7.5.3 Modeling of Other Constituents

The groundwater flow and solute transport modeling conducted for the restore to 3 μg/L design was based on existing conditions and projected future loading conditions of uranium contamination. To check how effective this design is at removing other constituent plumes and to determine mass and concentration removal to support GTF process design, plumes of additional constituents identified in the Operable Unit 5 RI Report were also modeled with pumping according to the selected design over the same cleanup time (70 years) as uranium.

113 For each simulation, the maximum concentration by aquifer zone and the average concentration by extraction system were graphed (see Figures F.7-76 A and B to F.7-87 A and B). Initial conditions and distribution coefficients were previously presented and are shown in Figures F.7-9 through F.7-14, Table F.7-5 and Table F.7-6. Because more detailed descriptions of the initial conditions and results were previously included in Section F.7.4, this section only provides a summary.

A summary of the results is shown in Table F.7-14. The restore to 3 μg/L extraction design, based on this modeling, will be effective for reducing maximum aquifer concentrations of neptunium-237, technetium-99, antimony, and total VOCs below 10^{-6} ILCR screening levels. Capture of the remaining constituents will be less effective, primarily due to the lower mobility of these compounds and, to a lesser degree, locations of the recovery wells (based on uranium concentrations).

F.7.5.4 Modeling of the Higher Desorption K_d Case

Following the approach outlined in Section F.7.2.8, simulations were also run for the upper limit K_d (desorption) of 12 L/kg so that a range of cleanup times could be calculated. These simulations were run until cleanup to a concentration of 3 μg/L was achieved.

The results of these simulations with higher desorption K_d of 12 L/kg are discussed below:

- Rate of Removal: Figure F.7-88 presents the system performance for this case. After 40 years of pumping, this case has removed approximately 57 percent of the total uranium from the Great Miami Aquifer. After 70 years of pumping, this design has removed 72 percent (compared to 95 percent for the baseline K_d case). The rate of uranium removal is relatively slow from 0 to 5 years when only the South Plume Extraction wells are pumping, increases dramatically from years 5 to 10 after the installation of the new wells, and gradually decreas8es over the remainder of the

simulation. Overall, as expected, the rate of removal is significantly slower for this higher K_d case than the baseline K_d case (compare Figures F.7-71 and F.7-88).

- Removal Efficiency: Incremental efficiency is 0.27 lbs/Mgal at the beginning of the cleanup period, drops rapidly to 0.04 lbs/Mgal at 5 years, and recovers slightly to 0.06 lbs/Mgal at 20 years. This slight recovery in efficiency is caused by the change in K_d at Year 7. After 40 years efficiency is less the 0.06 lbs/Mgal and continues to decrease. Cumulative system efficiency after 30 years is 0.10 lbs/Mgal.

113 - Maximum Concentration Reduction: Figures F.7-89A and F.7-89B show the uranium concentration over time for each aquifer zone for all model layers for this case. The maximum uranium concentration for all aquifer zones fall below 3 μg/L in approximately 105 years. Model Layer 3 and aquifer Zone 2 take the longest time to remediate. The solute is extracted at a slower rate with the higher K_d; thus the curves are flatter when compared to the baseline K_d case (compare Figures F.7-72 and F.7-89).

  Contamination contour plots for Model Layer 1 after 40 and 100 years are shown in Figures F.7-90 and F.7-91. The maximum concentrations at 40 years for this case is 18.7 μg/L (compared to 4.6 μg/L for the baseline K_d case - Figure F.7-73). By year 100, the plume has a similar shape but the maximum concentration is 2.8 μg/L.

- Average Concentration by Extraction System: Figure F.7-92 shows the average concentration of uranium by extraction system (consisting of all the wells assigned to a particular system). Similar to the maximum concentration and efficiency curves, the higher desorption K_d has resulted in less mass being extracted and therefore the average concentrations are also lower. Aquifer Zone 2 starts at approximately 100 μg/L, quickly reduces to approximately 10 μg/L at Year 10, and gradually reduces to 3 μg/L at Year 50.

F.7.6 GROUNDWATER CONTAINMENT TO 20 μg/L DESIGN

F.7.6.1 Description

The primary objective of the groundwater containment to 20 μg/L design modeling is to select and evaluate a system design that will not allow concentrations greater than 20 μg/L to migrate off site and will clean up the uranium that has already migrated off site (the South Plume). This will be accomplished through the pumping of two groundwater extraction well systems. One of these systems, the South Plume recovery well system, was previously installed and is operational. The other system will be located along the southern perimeter of the site property and is developed under this task.

Only a single scenario was developed for the 20 μg/L groundwater containment design since information obtained from the scenario modeling for the 20 μg/L design was used (see Section F.7.4). The containment design will use the same initial conditions and contaminant loading rates established in Section F.7.2.

110 Modeled well locations, depths, screened intervals, and pumping rates of these well systems are shown in Table F.7-15. The well locations are shown in Figure F.7-93. The containment scenario uses two major well systems pumping at a combined rate of 2600 gpm. The existing South Plume extraction system was designed to contain and remove contamination which had already spread off property. A second system, consisting of five on-site wells, were placed along the southern perimeter of the FEMP property to contain and intercept the contamination plume as it travels southward with the regional groundwater flow. Discharge rates from the extraction wells were selected to efficiently intercept the contaminant plumes and minimize the further spread of contamination off property. Discharge rates for the existing South Plume recovery well system were selected to operate in conjunction with the on-site wells to provide for the efficient containment and removal of contamination, and minimize the impact on the Paddys Run Road Site plume.

F.7.6.2 Results

- Rate of Removal: Figure F.7-94 presents the system performance for this design. After 40 years of pumping, this design has removed 55.8 percent of the total uranium from the Great Miami Aquifer. After 60 years of pumping, this design has removed 70.6 percent of the total uranium. A relatively high rate of uranium removal is sustained from Years 0 to 70 and gradually decreases over the remainder of the simulation.

- Removal Efficiency: Incremental efficiency of this design is 0.27 lbs/Mgal at 5 years, increases to 0.29 lbs/Mgal at 10 years and gradually decreases over the remaining time period. After 100 years, efficiencies are less than 0.01 lbs/Mgal as little uranium is being extracted.

113 - Maximum Concentration Reduction: Figures F.7-95A and F.7-95Bshow the uranium concentration over time for each aquifer zone for all model layers for this design. The maximum uranium concentration for all aquifer zones falls below 20 μg/L in approximately 60 years. It takes 380 years for the maximum concentration in Model Layer 4 to fall below 3 μg/L. This long time frame is apparently caused by the lower conductivity in Model Layer 4 which represents the clay interbed in the aquifer.

  Contamination contour plots for Model Layer 1 after 40 and 60 years are shown in Figures F.7-96 and F.7-97. The maximum concentrations in layer 1 at 40 and 60 years are 38.8 μg/L and 15.6 μg/L, respectively. It can also be seen that this design is effective at presenting plume movement across the eastern property line. Figure F.7-95 shows the maximum concentration in aquifer Zone 5 remaining below 20 μg/L. The plume depictions in Figures F.7-96 and F.7-97 also show no eastern plume migration.

F.7.6.3 Modeling of the Higher Desorption K_d Case

Following the approach outlined in Section F.7.2.8, simulations were also run for the upper limit K_d (desorption) of 12 L/kg so that a range of cleanup times could be calculated. These simulations were run until cleanup to the 20 μg/L concentration was achieved.

The results of these simulations with higher desorption K_d of 12 L/kg are discussed below:

- Rate of Removal: Figure F.7-98 presents the system performance for this case. After 40 years of pumping, this case has removed approximately 26 percent of the total uranium from the Great Miami Aquifer. After 60 years of pumping, this design has removed 32 percent (compared to 70.6 percent for the baseline K_d case). The cumulative uranium removed curve is more gradually sloping than the baseline K_d case. Overall, as expected, the rate of removal is significantly slower for this higher K_d case than the baseline K_d case (compare Figures F.7-94 and F.7-98).

- Removal Efficiency: Incremental efficiency is 0.27 lbs/Mgal at the beginning of the cleanup period, drops rapidly to 0.04 lbs\Mgal at 5 years, and recovers slightly to 0.05 lbs/Mgal at 20 years. After 20 years efficiency slowly decreases. Cumulative system efficiency after 30 years is 0.26 lbs/Mgal.

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- Maximum Concentration Reduction: Figures F.7-99A and F.7-99B show the uranium concentration over time for each aquifer zone for all model layers for this case. The maximum uranium concentration for all aquifer zones falls below 20 μg/L in approximately 120 years and below 3 ppb in approximately 380 years. Model Layer 1 and aquifer Zone 2 take the longest time to remediate. The solute is extracted at a slower rate with the higher K_d thus the curves are flatter when compared to the baseline K_d case (compare Figures F.7-95 and F.7-99).

  Contamination contour plots for Model Layer 1 after 40 and 120 years are shown in Figures F.7-100 and F.7-101. The maximum concentrations at 40 years for this case is 85.2 μg/L (compare to 38.8 μg/L for the baseline K_d case - Figure F.7-96). By year 120, the plume has a similar shape but the maximum concentration is 19.4 μg/L.

F.7.7 UNCERTAINTY AND MODEL LIMITATIONS

F.7.7.1 Description

Modeling of heterogenous hydrogeologic systems necessarily contains uncertainties. Uncertainty in modeling results potentially affects the extraction system design and needs to be analyzed. In addition, effects caused by the high rate of pumping also need to be evaluated. Six of these issues are:

- Loss of contaminant mass in the pumping-induced vadose zone
- Artificial vertical dispersion in the model
- K_d values
- Uncertainty of other model input parameters
- Analysis of hydraulic effects
- Impact of solids removal.

These issues are discussed below.

F.7.7.2 Loss of Mass in SWIFT

The SWIFT code does not appropriately represent the mass in a model cell that has been dewatered due to pumping. When a model cell is partially dewatered, the SWIFT code no longer considers the mass in the dewatered segment even if the cell later resaturates. Under low or no-pumping conditions, the impact of this issue on results is negligible. However, when simulating large volume pumping systems with changes in pumping rate over time, this phenomenon can have a more significant impact.

An evaluation of this phenomenon requires consideration of the appropriate conceptual model needed to represent it. The SWIFT model considers equilibrium sorption/desorption controlled by K_d. Shifting of the water table in pump-down areas caused by the extraction disturbs that equilibrium. When an extraction well starts to desaturate an area, some amount of solute moves vertically with the decreasing water table, some amount remains adsorbed on soil, and some amount remains in residual water in the partially desaturated zone. This porewater may subsequently move vertically to the water table carrying some concentration of solute. The quantity of uranium that remains adsorbed on the soil will redissolve over time into infiltrating rainwater or into groundwater (if groundwater returns to its original level).

119 For this modeling study, an analysis of the impact of this phenomenon was performed. The impact of lost mass was evaluated in a sample case by continuously loading facilities that have a dewatered zone above (based on natural infiltration rate and estimated leachate concentrations) until the adsorbed contaminant mass was depleted. The adsorbed mass, mass loading rate with infiltration, and time of loading were estimated during the analysis. This analysis assumed that all contamination left in a dewatered model segment is reincorporated in the saturated zone directly beneath it distributing between sorbed and dissolved phases according to K_d. This analysis indicated that there was only a small impact on dissolved concentrations. Details and results of the analysis may be found in Appendix F.8. A pulsed pumping scheme could be used as part of the operating strategy to provide this adsorbed mass with an opportunity to redissolve over a relatively short period of time. Thus it was determined that the model could be used in its present state for FS comparisons. However, for preliminary design when more refined time scales and optimized pumping schemes will be developed, the phenomenon needs to be evaluated using an appropriate model and, if necessary, revisions made.

F.7.7.3 Artificial Vertical Dispersion in SWIFT

While performing solute transport modeling of groundwater extraction options for the Operable Unit 5 FS, it was discovered that, according to the model, a significant mass of uranium would migrate downward to the lower model layers after a reasonably short simulation time. This was an unexpected result because initially the large majority of uranium mass occurred in the upper layers of the model and the simulated and actual flow fields are essentially horizontal.

The characterization of dispersion within SWIFT caused this problem. In SWIFT, dispersion has two components, a longitudinal dispersivity and a transverse dispersivity. The longitudinal dispersivity functions parallel to the major flow direction while transverse operates in the two directions normal to the major flow. In the calibrated model with no significant vertical gradients, the longitudinal dispersivity is a relatively high number (100 feet). The transverse dispersivity is a much lower number (0.1 feet). Normally, and during calibration, the longitudinal dispersivity operates in a horizontal direction corresponding to the major flow in the Great Miami Aquifer. The transverse dispersivity operates in the other two directions. With the strong vertical gradients produced by shallow extraction pumping, the longitudinal dispersivity would operate in the vertical direction and this relatively high dispersivity would cause excessive dispersion vertically, resulting in vertical downward migration of solute. This is a four order-of-magnitude increase of the vertical dispersivity from the nonpumping conditions. This problem produces a condition in the model that is not consistent with conceptual pictures of real contaminant transport at the site.

For the relative comparison of alternatives in the FS, the model can be used in its present state with steady state flow assumptions and the approximate simulation of vertical dispersion. The vertical migration of some solute occurs in all simulations in this comparative analysis and generally makes solute extraction more difficult on all pumping designs. The vertical scale is relatively minor when compared to the horizontal scale; transport to Layer 6 is a relatively small distance when compared to the thousands of feet dealt with in the horizontal scale. For these reasons, it is not necessary to correct this problem for this comparative analysis. However, for preliminary design when more refined time scales and optimized pumping schemes are developed, the phenomenon needs to be corrected.

The effects associated with the anisotropic longitudinal dispersivity in the vertical and horizontal directions have been investigated. Results indicated that remediation time periods for cases with different longitudinal dispersivities in the vertical and horizontal directions were not significantly different from those for cases with isotropic longitudinal dispersivity. Details of the simulation results from cases with anisotropic longitudinal dispersivity are presented in Section F.8.6.2, Appendix F.8.

F.7.7.4 Further Sensitivity Analysis on K_d

The most sensitive parameter affecting a given extraction system is K_d. As discussed in previous sections, variation of K_d values from 1.78 to 12 L/kg in simulation runs helps bracket the cleanup time requirements for extraction systems. While a range of K_ds of 1.78 to 12 was used, it is possible that K_d values could be even higher (see Section F.2). In order to determine the effect of potential higher K_ds on cleanup times in the restoration to 20 μg/L design, additional simulations were conducted to determine the relationship between K_d and cleanup time of this design.

113 The various values of K_d used in the sensitivity runs for uranium range from the anticipated adsorption K_d value (1.78 L/kg) upward to 88 L/kg. Maximum concentration curves are given for K_d = 1.78 L/kg (Figures F.7-44A and F.7-44B), K_d = 12 L/kg (Figures F.7-66A and F.7-66B), K_d = 6 L/kg (Figures F.7-102A and F.7-102B), K_d = 30 L/kg (Figures F.7-103A and F.7-103B), K_d = 60 L/kg (Figures F.7-104A and F.7-104B), and K_d = 88 L/kg (Figures F.7-105A and F.7-105B). All curves are identical the first 5 years because it was assumed that the dissolved uranium already in the aquifer would be more mobile and a K_d of 1.78 L/kg was used. K_d was changed to the appropriate value of the simulation at 7 years. Seven years was chosen because this time period represents the approximate removal of a pore volume, i.e., the dissolved uranium (see Section F.7.2). The concentrations at 10 years are the groundwater concentrations corresponding to K_d of the applicable simulation as dissolved concentrations were reduced to conserve solid-phase mass.

It is apparent from Figure F.7-105 that if K_d were increased much above 88 L/kg, achievement of the 20 μg/L target does not appear feasible. Surface water loading was continued in all of these cases for 20 years, 13 years beyond the point at which the higher K_d was imposed. The higher K_d values were intended to simulate a higher desorption K_d after all the porewater was removed. However, according to the SWIFT algorithm, the continued loading from surface water would be immediately equilibrated between the dissolved and adsorbed phases. The adsorbed material would then be removed very slowly with extraction because of the high K_d, while in reality the more applicable K_d for surface water loading is the adsorption K_d (i.e., 1.78 L/kg).

To test this hypothesis, additional SWIFT runs were conducted with K_ds of 12 and 88 L/kg and no surface water loading (Approach 2). The times for the maximum groundwater concentrations to reach 20 μg/L are 40 and 8 years for K_ds of 12 and 88, respectively. Adding the pumping which occurs during the 20 years while surface water loading occurs and an additional 2 years to remove the pore-water gives total estimates of 62 and 30 years to clean up if the desorption K_d is 12 or 88 L/kg. These values compare with 55 and 71 years for the previous model. Increasing K_d without surface water loading while maintaining constant solid-phase mass reduces the dissolved concentrations and, therefore, cleanup time. Maximum concentrations were obtained at zero time and were 163 and 22.2 μg/L for K_ds of 12 and 88, respectively. Thus, ignoring surface water loading, if the desorption K_d is above about 98 L/kg and the total mass of uranium in the Great Miami Aquifer is conserved, the maximum equilibrium groundwater concentration (calculated by 88/98 x 22.2 or 12/98 x 163) would be below 20 μg/L. Thus, if the desorption K_d is sufficiently large, cleanup becomes a matter of simply removing the dissolved uranium. However, continued surface water uranium loading complicates this theory and becomes the major factor controlling cleanup time.

Cleanup times that correspond to the intersection of the highest maximum concentration curve (that of Zone 2, Layer 1) with the horizontal 20 μg/L target line are plotted versus K_d in Figure F.7-106. The results of the two cases using the alternate method (Approach 2) of simulating the higher desorption K_d are included. These times range from 30 to 71 years and indicate that for a reasonable range of variation of K_d cleanup of the Great Miami Aquifer is feasible.

While this alternate method (Approach 2) of simulating a higher desorption K_d is acceptable for the comparative analysis in the FS, a new or modified calculational model that treats the adsorption/desorption phenomenon in more detail with specific inputs for both sorption and desorption is needed for the more detailed analysis in preliminary design.

F.7.7.5 Uncertainty in Other Parameters

The Model Improvement Report (DOE 1994c) evaluated other important parameters such as hydraulic conductivity and dispersivity and their effect on risk assessment performance measures. Within reasonable ranges of variation, uncertainty in these other parameters is not expected to seriously impact cleanup time. Additional sensitivity analysis on these parameters will not be performed at this time.

F.7.7.6 Analysis of Hydraulic Effects

Hydraulic effects of the modeled designs are evaluated to determine the potential effects on the regional aquifer and the effects on the model boundaries. For this analysis, the effects of only two designs (the no-additional action design and restoration to 20 ppb designs) are evaluated. Results from the other designs may be extrapolated from this analysis.

Regional Aquifer Effects

Water table contours for the no-additional-action and Restoration to 20 ppb designs are shown in Figures F.7-107 and F.7-108. The no additional action contours show the familiar southward and eastward groundwater flow direction across the site. However, the pumping of 6300 gpm or an additional 4800 gpm (1500 gpm is pumped in extraction system 4 in the no-additional-action design) creates a major change in the pattern of water table contours. As expected, there is a general lowering of the water table on property in the proximity of the extraction wells. The most pronounced feature is the reversal of flow along the eastern site boundary. According to the model, advective groundwater flow (and contaminant transport) will no longer occur to the east.

Figure F.7-109 shows the additional drawdown caused by the restoration to 20 ppb design over the no-additional-action design; i.e., contours from Figure F.7-108 were subtracted from Figure F.7-107. The most pronounced drawdown occurs along a linear path from the Operable Unit 1 area to the Operable Unit 2 South Field. Impacts of more than an additional 1 foot of drawdown occur over the majority of the model area. Overall this figure shows a significant hydraulic impact to this portion of

the Great Miami Aquifer represented by the model. It should be noted that, based on an inspection of these drawdowns occurring close to the boundaries, these patterns of heads and drawdowns are constrained in the model by the constant-head boundaries. This issue will be discussed below.

Another approach to evaluating the hydraulic impact is through a simple water budget calculation (see Table F.7-16). The increased pumping of 4800 gpm of the restoration to 20 ppb design over the no-additional-action design is accounted for in two ways; 1) influx through boundaries increases by almost 20 percent and 2) efflux through boundaries decreases approximately 35 percent. Given an average recharge rate of 8.4 inches/year (averaged based on the 1500 gpm total recharge over the 7.5-square mile model grid) and assuming the only influx of water into the system is through recharge (infiltration from the Great Miami River would be another source), the pumping rates of the no-additional-action and restoration to 20 ppb designs would require 5.4 and 22.6 square miles of recharge areas respectively (see Table F.7-16). Because the model grid is 7.5 square miles in area, a recharge area smaller than the model grid could sustain pumping for the no-additional-action design. However, for the restoration to 20 ppb design, an area approximately three times the size of the model grid would be required.

Based on the water budget and the size of the potential recharge area, pumping at 6300 gpm is approaching practical limits of groundwater extraction in this area. This pumping rate equates to a recharge area similar to the upstream portions of the Shandon and the New Haven troughs. In the real hydrogeologic system, certain no-flow boundaries at the edge of the aquifer may be encountered and greater flow may occur from the Great Miami River to the east. Constant-head boundaries in the model are maintaining an artificially high gradient and increasing velocities and flux across certain boundaries. Seasonal changes (as much as 7 feet) may exacerbate the problem.

Two possible solutions are reinjection and improving extraction efficiency, allowing pumping at an overall lower rate. Reinjection obviously creates another term in the water budget and allows recycling of water, minimizing the overall hydraulic impact. Efficiency may be increased by methods that increase chemical mobility (e.g, sparging) or simply with additional wells. Adding extraction wells allows a more efficient system to be created by pumping only at the more concentrated plume areas. With a more efficient uranium extraction system, reductions in overall pumping rate will reduce the hydraulic impact. In addition, system design to this point has been simplified with constant pumping rates and no optimization. Optimization techniques should improve the design, to some degree, again allowing a higher efficiency to be maintained. Further discussion of these techniques are included in Section F.7.8.

Model Boundary Effects

A related problem to the hydraulic impacts discussed above is the issue of boundary effects. The model was constructed and calibrated with the only major pumping taking place in the eastern portion

of the grid by the SOWC wells. Constant-head boundary conditions were set at the four boundaries based on water elevation data. However, with the high rates of pumping projected for the extraction system designs, drawdown effects apparently intersect the boundaries (e.g., see Figure F.7-109). With constant-head conditions, the head at these boundary cells is maintained when in reality the drawdown area would extend outward beyond these boundaries. This would result in "flatter" contours of drawdown.

While this is an important effect, given the other uncertainties of the model and coarseness of the overall design at this stage, the model in its present state is acceptable for this analysis. When more detailed analysis occurs during system design, this issue will become more important and will need to be corrected for the actual design case.

Assignment of Mobility Fractions

457 For this analysis, constant mobility fractions were assigned to each layer. Fractions of 0.25, 0.50, and 0.25 were assigned to Layers 1, 2, and 3, respectively, for shallow wells completed in those layers. Fractions of 0.5 and 0.5 were assigned to Layers 5 and 6, respectively, for deep wells completed in those layers. These fractions correspond roughly to average saturated cell thicknesses before extraction pumping. This approach assumed that additional drawdown from extraction pumping was not significant, which was not the case in Layer 1 where significant additional dewatering occurred. However, this approach is considered adequate for the relative comparison of alternatives.

During optimization (see Appendix F.8) and design studies, an approach will be used which accounts for reduced cell transmissivity scaled by the final water elevation in the cell resulting from pumping. Cell transmissivity will vary from pumping sequence to pumping sequence depending on final water elevations for each sequence.

F.7.7.7 Solids Removal Impact

The high volume of groundwater pumped from the aquifer could impact the aquifer by removing suspended solids. The impact of the suspended solids removal on the aquifer is evaluated for the restoration to 20 ppb design to determine if significant recompaction of the matrix could occur.

123 Based on a total suspended solids concentration of 3 mg/L (Parsons 1994) and a pumping rate of 6300 gpm over 30 years, approximately 830 cubic yards of aquifer suspended solids would be removed. If one assumes pumping impacts an area of 2000 by 4000 feet (considerably smaller than the 20 ppb design's capture zone), then on average 0.003 feet of aquifer material would be removed over the impacted area. This very small number indicates that solids removal will not cause significant recompaction of the aquifer. Because of the small volume of solids removed by pumping, there will be insignificant effects on adsorbed concentrations or degree of retardation of contaminants in the

aquifer. Proper well construction will decrease turbulent flow and help maintain a low rate of solids removal over time.

F.7.8 DESIGN, OPERATION, AND MONITORING OF THE EXTRACTION SYSTEMS

A strategy to maintain design conservatism and provide for future design and operational flexibility will be followed. This strategy includes centralized and instrumented control of groundwater extraction systems and allows individual control of the elements of the extraction systems. Because of the inherent uncertainties in the hydrogeologic system, flexibility of pumping rates and pumping sequences will be built into the instrumentation system. In addition, because of the temporal and spatial changes and inherent difficulties of predictions in the hydrogeological environment, it is possible that future changes or enhancements to the system may be necessary to meet the overall extraction system goals.

F.7.8.1 Design of Extraction System

The overall design/construction process is controlled by DOE Administrative Orders. These orders require a sequenced design process made up of:

- Title I - Preliminary design
- Title II - Detailed design
- Title III - Construction

This sequenced approach allows an efficient process of obtaining the quality final constructed product. Integration of the design disciplines products is key to a successful constructed product. The FS effort is conducted before Title I or preliminary design and focuses on the screening and selection of the appropriate technology for remediation. While some amount of detail is necessary to answer FS questions, the sequence of design phases necessarily move from the general to detailed analysis.

The following paragraphs summarize the specific steps that will be conducted relating to the extraction system design:

124 - Pumping Test - A pumping test will be conducted in the South Field area. This is the one main area of the proposed extraction system where a pumping test has not been performed. Results from this test will be used to define site-specific parameters for this portion of the Great Miami Aquifer where the most active groundwater withdrawal takes place. Analytical techniques and numeric transient analysis will be used to establish aquifer hydraulic conductivities, storativity and porosity from the pumping test. The model will also be used in a transient mode to match pumping test results and obtain a
124 transient calibration. A pumping test was performed in the area of the waste pits (another main area of the extraction system) in 1962 by the U.S. Geological Survey (Spieker and Norris 1962).

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- Desorption K_d Investigation - The K_d for uranium in the Great Miami Aquifer material will be studied by removing archived samples from areas of high concentration plumes and analyzing these samples for solid uranium concentration so that desorption K_d can be calculated by performing desorption batch tests. This study will help refine the possible range of K_d in the aquifer for extraction system design.

- Model Calibration - The new pumping test results will be input into the model to check the original calibration. This checking process will consist of replacing the calculated local hydraulic parameters in the South Field area in the original model, running this new model, and comparing the results to the original calibration criteria. If the model successfully meets the calibration criteria, then the preliminary design will proceed with this new adjusted model. If the model results fall outside the calibration criteria, then the model will be calibrated. Following calibration, the model will be ready for use for preliminary design to finalize the location and capacity of the wells.

- Extraction System Design Modeling - A groundwater modeling study will be performed to design the Great Miami Aquifer extraction systems. The recalibrated model will be applied with the latest available data from the K_d investigation and other monitoring results. The starting point of this design modeling will be the selected design from the Operable Unit 5 FS. The latest modeling constraints and design criteria will be incorporated in the modeling process. The design modeling process will use optimization techniques to iteratively refine well locations and well pumping rates based on maximizing the performance of the extraction system. Either commercially available computer codes will be used and linked to the current model or a new optimization algorithm will be developed to perform this optimization.

  The SWIFT model will be prepared for this modeling by including code refinements so that important processes are appropriately represented with the model. The three issues which were described in Section F.7.7 may require modifications to SWIFT. These issues include lost mass in the pumping-induced vadose zone, artificial vertical dispersion, and greater capability for handling adsorption and desorption. In addition, representations of pulsed pumping in the model will be considered.

F.7.8.2 Operation and Monitoring of Extraction System

A Design, Monitoring, and Evaluation Program Plan (DMEPP) will be prepared to delineate a program of operation, monitoring, evaluation and potential additional design activities associated with the new groundwater recovery systems. The DMEPP is needed to effectively operate and monitor the groundwater recovery system over a period of time and to respond with potential system changes. The DMEPP requirement is called out in DOE 1994a. The DMEPP will describe monitoring and evaluation/response programs which will be used to ensure system objectives are achieved.

The following paragraphs summarize the steps, which will be defined in the DMEPP, that will be conducted relating to the extraction system operation:

- Pulsed Pumping - Heavy pumping causes drawdown in the vicinity of the extraction wells. The increased drawdown desaturates a portion of the Great Miami Aquifer

containing uranium and does not allow that mass to be extracted. This potential problem may be alleviated through the use of a pulsed pumping technique, whereby the groundwater extraction would be intermittently interrupted to allow the water table to rise. The new extraction systems will be operated using such a pulsed pumping scheme.

The resaturation of the materials above the water table would allow the groundwater to reequilibrate with the previously immobile uranium. Based on a previous pumping test conducted at the site (DOE 1993c), the recovery of the water table after the cessation of pumping normally takes less than a few hours. The new chemical equilibrium for many ions is established within a few minutes (deMarsily 1986). Therefore, because of these short hydraulic and chemical equilibrium recovery periods, a pulsed pumping procedure could be designed that only effects the long-term intended extraction rate to a small degree.

An additional benefit will be obtained from pulsed pumping. Intermittent pumping will allow the stagnation zones to regain the prepumping groundwater velocity, thereby forcing the contaminants trapped in the stagnation zones to move away from the stagnation zones.

- Monitoring Program - The purpose of the monitoring program is to take environmental samples and measurements over time to provide data for assessing the performance of the system. Monitoring well locations for sampling and measurements will be established to help assess the effectiveness of capture of the system. This program will consist of routine monitoring of water levels to confirm the hydraulics and indicator analyses at specified intervals.

  Operation of the extraction systems allows an opportunity to obtain real-time data on the performance of the system and the aquifer parameters. For example, the adsorption/desorption of uranium between the liquid and solid states has a profound effect on the effectiveness of uranium removal. Because of the possibility of this parameter varying spatially and because of difficulties in sampling for this parameter, this phenomenon can best be estimated while the system is going through dynamic changes during pumping. The data collected will be fed into the evaluation/response program.

- Evaluation/Response Program - The purpose of this program is to analyze whether the system is meeting its objectives and to respond accordingly. This program consists of periodic system evaluation reports; development of system modifications; and implementation of either design, operation, or monitoring program changes (as needed).

  Three possible design enhancements are described below:

  - Upgradient Reinjection - Treated groundwater would be forced under pressure through injection wells into the Great Miami Aquifer upstream of extraction wells to increase hydraulic gradients and therefore flow velocities toward the extraction wells. These reinjection wells then could induce flow reversals and other hydraulic gradient changes to increase extraction rates. Injection wells are a conventional technique to enhance migration of contaminants downgradient toward extraction wells.

Reinjection of treated groundwater avoids the possibility of allowing accidental releases to the Great Miami River should the treatment facility go off-line and/or exceed regulatory limits. The addition of dissolved oxygen before discharge to the river would no longer be required.

125 If not properly designed and operated, groundwater reinjection could have undesirable effects that will reduce contaminant recovery efficiency. However, a properly designed groundwater recovery/reinjection well system can increase groundwater flushing rates through contaminated zones and still maintain hydraulic capture of all the contaminated groundwater. The higher flushing rate can achieve aquifer restoration in a shorter time frame. The use of groundwater reinjection wells will be further evaluated as a supporting technology during the engineering design stage of aquifer restoration and carefully designed and operated if implemented.

- In Situ Sparging- Sparging consists of forcing a gaseous medium into groundwater. Sparging could be done in conjunction with reinjection using reinjection wells. Vapor entrainment ensues and some chemical species are preferentially mobilized. Efficiency is maximized in permeable sand and gravel similar to the Great Miami Aquifer because less pressure is required to sustain gas injection than would be required in less permeable sediment. The technique has been widely used in flushing soil of volatile organic species. An analogous technique has been employed for in situ mining of uranium. Sparging through injection wells in groundwater associated with unconsolidated uranium deposits with CO_2, air, or O_2 may accelerate uranium extraction rates.

- Additional Extraction Wells - Based on monitoring results, it may be cost effective to add wells in the future to remove specific plumes. These wells could be located to attack a plume at a specific depth or location.

- Model Postaudit Program - A groundwater model postaudit program will be conducted in accordance with the provisions outlined in the DOE 1994c. This program will periodically assess the veracity of the groundwater model based on the latest results from the extraction system monitoring.

- Shutdown of Extraction Systems - The extraction design will be divided into separate extraction systems. As portions of the plume are remediated, the applicable extraction systems will be shut down. Based on monitoring and periodic evaluations, pumping rates of individual wells within an extraction system may change or be turned off either permanently or temporarily. To ensure that correct decisions have been made, the monitoring and evaluation program will continue for a particular system even after it has been turned off.

  Final shut down of the entire extraction program will occur when it has been determined that the cleanup objectives have been met. To ensure that correct decisions have been made, the entire monitoring and evaluation program will continue for a period determined by the permit/agreement. At the end of the monitoring period, wells will be removed or secured in a manner acceptable to the regulatory authorities.

F.7.9 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

F.7.9.1 Summary and Comparison of Designs

Groundwater modeling was conducted to support the analysis of groundwater extraction options of the Great Miami Aquifer for the Operable Unit 5 FS. This analysis for all extraction designs assumes remediation of the other operable units and contaminated soil. This modeling evaluated groundwater restoration or on-site containment of uranium contamination in the Great Miami Aquifer to the 20 and 3 μg/L uranium concentrations (representing the MCL 10^{-5} and 10^{-6} ILCR risk levels). After defining modeling constraints and initial conditions, four groundwater remediation system designs were evaluated with different remediation objectives:

- No-Additional-Action Design - continue pumping the existing South Plume recovery wells with no additional wells to determine the time required to reduce the maximum uranium concentration below 20 μg/L and 3 μg/L.

- Groundwater Restoration to 20 μg/L Design - remediate the groundwater below the FEMP property and beyond so that the maximum remaining uranium concentration in the Great Miami Aquifer is 20 μg/L.

- Groundwater Restoration to 3 μg/L Design - remediate groundwater below the FEMP property and beyond so that the maximum remaining uranium concentration in the Great Miami Aquifer is 3 μg/L.

- Groundwater Containment to 20 μg/L Design - prevent concentrations greater than 20 μg/L to migrate off property. Remediate off groundwater so that the maximum uranium concentration in the Great Miami Aquifer is 20 μg/L.

These designs were modeled with unique well configurations and pumping rates to determine the time necessary to meet the stated cleanup level. The extraction of other COCs was simulated for only the two more aggressive designs; the restoration to 20 μg/L design and the restoration to 3 μg/L design. Each design was simulated with a higher desorption K_d to determine an upper bound cleanup time.

Table F.7-18 summarizes results from the simulations of the four designs. Results include uranium removal quantities, incremental and cumulative system efficiencies, and cleanup times for the different designs. This table includes results from both the baseline K_d of 1.78 L/kg and the sensitivity K_d of 12 L/kg of each design. Cleanup time for the restoration to 20 μg/L design ranges from 30 to 55 years while the restoration to 3 μg/L design ranges from 70 to 105 years. The no-additional-action and containment to 20 μg/L designs both take considerably longer.

Within the time determined by the uranium simulation, the two aggressive designs (restoration to 20 μg/L and restoration to 3 μg/L) are effective in reducing the maximum concentration below MCL and 10^{-6} standards of four of seven other constituents with contaminant plumes. Capture of the

remaining constituents will be less effective primarily due to the lower mobility of these compounds (i.e., higher K_d).

F.7.9.2 Conclusions and Recommendations

The following bullets summarize the conclusions and recommendations:

- These designs provide a reasonable and conservative estimate of the size (number of wells, pumping rate, and cleanup time) of groundwater extraction systems that will remediate the Great Miami Aquifer to the defined concentrations, and thus provide reasonable basis for cost estimates of such designs. While a simple system was modeled and design optimization could improve system performance, nevertheless cost estimates based upon a simple system will be conservative. Given the heterogeneity and unknowns in hydrogeologic systems, this added conservatism seems appropriate at this stage of the project.

- Based on the modeling, a groundwater extraction system can effectively remediate groundwater under the defined system constraints. Given the time frames for extraction outlined above, the current design capacity of the GTF of 7500 gpm is adequate for the cleanup of the Great Miami Aquifer through groundwater extraction.

- The predicted ranges of time required for groundwater extraction for the different designs based on a K_d range of 1.78 to 12 L/kg (desorption only) vary according to the following:

  - Cleanup to 20 μg/L
    - no-additional-action design - 90 to 170 years
    - Restoration to 20 μg/L design - 30 to 55 years
    - Containment to 20 μg/L design - 60 to 120 years

  - Cleanup to 3 μg/L
    - no-additional-action design - 290 to greater than 405 years
    - Restoration to 3 μg/L design - 70 to 105 years
    - Containment to 20 μg/L design - 330 to 380 years.

  Because the actual value of desorption K_d could be higher than 12, cleanup times could also change. A sensitivity study varying K_d for the restoration to 20 μg/L design showed that higher K_ds could increase the 55-year time (for desorption $K_d = 12$) to 71 years or more than 25 percent. It was also found that, except for future surface-water loading, K_d above certain values (e.g., 98 L/kg for the restoration to 20 μg/L design) results in decreasing the cleanup time because solute desorbs at a rate that produces liquid concentrations less than 20 μg/L. In this case, surface water loading becomes the major factor controlling cleanup time, which is about 22 years.

- Groundwater extraction of other COC plumes should be integrated with overall site remediation. Plumes beneath the production area cannot be effectively remediated during the large scale construction and/or demolition operations in this area. Future monitoring efforts should continue to assess whether additional extraction wells should be constructed for isolating and remediating other constituent plumes.

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- Design enhancements that affect the hydraulics (such as reinjection wells) or the chemical mobility (such as sparging systems) could result in a system that reduces the maximum concentration in a shorter period of time. While these enhancements were not considered in this analysis for costing in the FS, they should be analyzed in more detail for preliminary and final design. Based on the value and distribution of desorption K_d that actually occurs during operation, these enhancements may be necessary to achieve projected cleanup times.

448 - Optimization of the design could be conducted to better define well locations, pumping rates, and pumping sequences. These optimization techniques should provide some increase in the performance and efficiency of the extraction system. Given the scale of the project, even small gains in efficiency can mean large cost savings, so an optimization study should be cost effective. It is recommended that refinement of the selected design be conducted with optimization techniques during preliminary design. This optimization process will include adjustment of well numbers, locations, depth, pumping rate, etc..

461 - Because of the problem associated with the potentially immobile uranium above the pumping-lowered water table, and to a lesser extent, contamination trapped in stagnation zones, it is recommended that pulse pumping be included in the operational strategy of the system. This will maximize the ability of the system to remove the uranium remaining above the depressed water table quickly through regular flushing. Additionally, it will remove contaminants trapped in stagnation zones. Sufficient conservatism exists in the restoration to 20 μg/L design to allow the reduction in effective pumping rate that a pulsed pumping scheme will cause. The 6300 gpm extraction rate is approximately 84 percent of the projected GTF capacity allowing some flexibility in sequencing pumps and wells. Detailed analysis of pulsed pumping should be conducted during design.

- Pumping capacities of the restoration to 20 μg/L and restoration to the 3 μg/L designs approach the practical limits of sustainable yield of the aquifer in this area. Further design and operation need to consider this limit. Reinjection and methods to increase efficiency will reduce this impact.

- Well locations and projected pumping rates and durations are preliminary, based on the constraints and analysis approach defined herein. The final design should be modeled based on the most recent constraints and initial conditions.

- Three significant issues affect the performance of the SWIFT Great Miami Aquifer model: 1) artificial vertical dispersion occurs especially under heavy pumping because the larger longitudinal dispersion operates in the vertical direction, causing greater concentrations to occur at lower model layers than actually should; 2) mass in the pumping-induced vadose zone is not accounted for in the model; 3) constant-head boundary conditions under heavy pumping artificially constrain the extent of the area drawn down by pumping. It is felt that these issues did not affect results sufficiently to cause changes in decisions made in the FS. However, the model should be corrected before the more detailed modeling for preliminary design.

- Because of heterogeneities in the hydrogeological system and uncertainties in the model, an operation, monitoring and response program needs to control the extraction system to

allow response to changes found in the field. This program should be similar to program defined in the Design, Monitoring and Evaluation Program Plan for the South Plume Recovery System.

F.7.10 REFERENCES

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TABLE F.7-1

104 URANIUM SURFACE WATER LOADINGS

	Loading With Retention Basin in Operation for Modeled Years 0-20	
Surface Water Reach[a]	(lb/yr)	(lbs/period)
OU1 Area	12.95	259.0
OU2 Area	50.68	1013.60
Plants 6 and 9 area	2.19	43.80
Paddys Run C-D	25.07	501.36
Paddys Run D-E	10.32	206.44
Paddys Run E-F	3.96	79.20
Storm sewer outfall ditch	100.87	2017.43
Total		4120.83

[a] See Operable Unit 5 RI Report (DOE 1995) for definition of Paddys Run and storm sewer outfall ditch reaches.

TABLE F.7-2

SWIFT GREAT MIAMI AQUIFER MODEL PARAMETERS

Parameter	Value
Distribution coefficient (K_d) - Uranium 238	1.78 L/kg
Grain density	2.6 g/cc
Porosity	0.3
Retardation Factor (R)	12
Longitudinal dispersivity	100 feet
Transverse dispersivity	0.1 feet
Horizontal hydraulic conductivity range	200 to 638 ft/day
Infiltration rate range	6 to 176 in./yr

TABLE F.7-3

INITIAL GREAT MIAMI AQUIFER RESIDENT URANIUM MASS (LBS)[a]

Layer	Zone 1[b]	Zone 2[b]	Zone 3[b]	Zone 4[b]	Zone 5[b]	Outside Zones	Total
1	521.2	2779	245.4	566.9	222.4	124.0	4458
2	1233	6680	483.8	1737	370.9	240.9	10,750
3	294.9	236.0	53.65	155.6	0.9499	24.26	765.3
4	0.1576	0	1.067	0.09137	0.02109	0	1.337
5	3.018	0	16.92	0.9091	0.3732	0	21.22
6	0	0	7.011	0.5893	0.2425	0	7.843
Total	2052	9695	807.8	2461	594.9	389.2	16,000

[a] Including liquid and solid-phase mass
[b] See Figure F.7-8 for zone definition

TABLE F.7-4

INITIAL CONCENTRATION OF TOTAL VOLATILE ORGANIC COMPOUNDS FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

SWIFT Cell Nos.[a]		Conc.
I	J	(μg/L)
39	98	83.4
43	93	33
47	91	10
44	90	58
51	90	11
48	86	8
66	65	35
36	90	278
37	71	16
48	60	20
34	66	26
28	67	26
38	58	10
30	56	31
45	44	108
26	49	12
28	46	11
21	40	24.8
22	37	1035
7	3	12.3
12	8	351
8	3	23
5	5	24

[a] See Figure F.7-8 for cell locations

TABLE F.7-5

PARAMETERS FOR OTHER CONSTITUENTS IN THE GREAT MIAMI AQUIFER

Constituent	Distribution Coefficient K_d (mL/g)	Retardation Factor R	Loading from Paddys Run Section C-D[a] (kg/yr)	Loading from Paddys Run Section D-E[a] (kg/yr)	Loading from Paddys Run Section E-F[a] (kg/yr)	Loading from Storm Sewer Outfall Ditch (kg/yr)	OU1 Area (kg/yr)	OU2 Area (kg/yr)	OU3 Area (kg/yr)
Neptunium-237	15	93.5	9.96×10^{-5}	3.75×10^{-5}	4.00×10^{-6}	0	0	0	0
Radium-226	470	2899	2.91×10^{-7}	1.09×10^{-7}	1.15×10^{-8}	4.20×10^{-8}	0	0	0
Technetium-99	0.2	2.23	5.42×10^{-3}	1.1×10^{-2}	1.26×10^{-3}	9.10×10^{-3}	2.77×10^{-6}	0	9.45×10^{-7}
Antimony	1.4	9.63	2.21×10^{-1}	9.2×10^{-2}	1.76×10^{-2}	2.56×10^{-1}	0	0	0
Arsenic	16	99.7	5.23×10^{-1}	2.67×10^{-1}	5.12×10^{-2}	7.45×10^{-1}	0	0	0
Manganese	30	186	3.16×10^{1}	2.41×10^{1}	6.33×10^{0}	1.51×10^{2}	0	0	0
Total volatile organic compounds	1	7.16	0	0	0	0	0	0	0

[a] See Operable Unit 5 RI Report (DOE 1995) for definition of Paddys Run reaches

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TABLE F.7-6

NO-ADDITIONAL-ACTION PUMPING SCHEDULE

Extraction System	Well Number	Screened Interval Layer	SWIFT Cell Number (I,J)[a]	Well Pumping Rate (gpm) from Year 0 until Year 1000
4	1	1 - 3[b]	19,36	300
	2	1 - 3[b]	21,35	300
	3	1 - 3[b]	24,35	300
	4	1 - 3[b]	26,35	300
	5	1 - 3[b]	28,34	300
System Total	5			1500

[a] See Figure F.7-8 for cell locations
[b] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.

TABLE F.7-7

SUMMARY OF GROUNDWATER NO-ADDITIONAL-ACTION SCENARIO - RESULTS FOR OTHER CONSTITUENTS OF CONCERN

Constituent	Maximum Concentration (ppb)	Location	Time (yr)	MCL[a] Screening Level (ppb)	Maximum Conc. Below Screening Level
Neptunium-237	8.66×10^{-4}	On-Site	910	1.42×10^{-3}	Yes
Radium-226	1.62×10^{-5}	On-Site	1000	2.02×10^{-5}	Yes
Technetium-99	4.01×10^{-1}	On-Site	90	5.53×10^{-2}	No
Antimony	4.65×10^{1}	On-Site	10	6.0×10^{0}	No
Arsenic	1.36×10^{2}	On-Site	10	5.0×10^{1}	No
Manganese	2.38×10^{3}	On-Site	10	9.04×10^{2}	No

[a] Where maximum contaminant level was not available, an incremental lifetime cancer risk of 10^{-5} or a hazard quotient of 0.2 was used.

TABLE F.7-8

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GROUNDWATER RESTORATION TO 20 μg/L DESIGN, SCENARIO 1, PUMPING SCHEDULE

Extraction System	Well Number	SWIFT Cell Number (I,J)[a]	Screened Interval Layer	Scenarios 1A and 1B Well Pumping Rate 0 to 5 Years (gpm)	Scenario 1A Well Pumping Rate 5 to 40 Years (gpm)	Scenario 1B Well Pumping Rate 5 to 40 Years (gpm)
1	1	31,80	1 - 3[b]	0	400	320
	2	34,83	1 - 3[b]	0	400	320
	3	38,85	1 - 3[b]	0	500	400
	4	42,88	1 - 3[b]	0	400	320
	5	46,89	1 - 3[b]	0	400	320
2	6	28,50	1 - 3[b]	0	500	400
	7	33,47	1 - 3[b]	0	500	400
	8	37,47	1 - 3[b]	0	500	400
	9	31,54	1 - 3[b]	0	500	400
	10	36,54	1 - 3[b]	0	500	400
	11	33,61	1 - 3[b]	0	500	400
3	12	59,69	1 - 3[b]	0	400	320
4	13	23,43	1 - 3[b]	0	500	400
	14	19,36	1 - 3[b]	300	300	300
	15	21,35	1 - 3[b]	300	300	300
	16	24,35	1 - 3[b]	300	300	300
	17	26,35	1 - 3[b]	300	300	300
	18	28,34	1 - 3[b]	300	300	300
System Total	18		1 - 3[b]	1500	7500	6300

[a] See Figure F.7-8 for cell locations
[b] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.

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TABLE F.7-9

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GROUNDWATER RESTORATION TO 20 μg/L DESIGN, SCENARIO 2, PUMPING SCHEDULE

Extraction System	Well Number	SWIFT Cell Number (I,J)[a]	Screened Interval Layer	Scenarios 2A and 2B Well Pumping Rate 0 to 5 Years (gpm)	Scenario 2A Well Pumping Rate 5 to 40 Years (gpm)	Scenario 2B Well Pumping Rate 5 to 40 Years (gpm)
1	1	38,89	1 - 3[b]	0	300	240
	2	31,80	1 - 3[b]	0	200	160
	3	36,81	1 - 3[b]	0	200	160
	4	39,84	1 - 3[b]	0	200	160
	5	42,86	1 - 3[b]	0	200	160
	6	44,89	1 - 3[b]	0	200	160
	7	46,92	1 - 3[b]	0	200	160
2	8	27,50	1 - 3[b]	0	400	320
	9	30,48	1 - 3[b]	0	300	240
	10	33,47	1 - 3[b]	0	300	240
	11	36,46	1 - 3[b]	0	300	240
	12	39,46	1 - 3[b]	0	300	240
	13	29,63	1 - 3[b]	0	200	160
	14	28,58	1 - 3[b]	0	200	160
	15	32,59	1 - 3[b]	0	200	160
	16	31,54	1 - 3[b]	0	200	160
	17	33,50	1 - 3[b]	0	200	160
	18	34,53	1 - 3[b]	0	200	160
	19	36,54	1 - 3[b]	0	200	160
	20	39,56	1 - 3[b]	0	200	160
	21	42,57	1 - 3[b]	0	200	160
	22	47,53	1 - 3[b]	0	200	160
3	23	59,68	1 - 3[b]	0	300	240
4	24	27,45	1 - 3[b]	0	300	240
	25	22,43	1 - 3[b]	0	300	240
	26	19,36	1 - 3[b]	300	300	300
	27	21,35	1 - 3[b]	300	300	300
	28	24,35	1 - 3[b]	300	300	300
	29	26,35	1 - 3[b]	300	300	300
	30	28,34	1 - 3[b]	300	300	300
System Total	30			1500	7500	6300

[a] See Figure F.7-8 for cell locations
[b] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.

TABLE F.7-10

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GROUNDWATER RESTORATION TO 20 μg/L DESIGN, SCENARIO 3, PUMPING SCHEDULE

Extraction System	Well Number	SWIFT Cell Number (I,J)[a]	Screened Interval Layer	Scenarios 3A and 3B Well Pumping Rate 0 to 5 Years (gpm)	Scenario 3A Well Pumping Rate 5 to 40 Years (gpm)	Scenario 3B Well Pumping Rate 5 to 40 Years (gpm)
1	1	38,89	1 - 3[b]	0	300	240
	2	31,80	1 - 3[b]	0	200	160
	3	36,81	1 - 3[b]	0	200	160
	4	39,84	1 - 3[b]	0	200	160
	5	42,86	1 - 3[b]	0	300	240
	6	44,89	1 - 3[b]	0	200	160
	7	46,92	1 - 3[b]	0	200	160
2	8	27,50	1 - 3[b]	0	500	400
	9	30,48	1 - 3[b]	0	400	320
	10	33,47	1 - 3[b]	0	400	320
	11	36,46	1 - 3[b]	0	400	320
	12	39,46	1 - 3[b]	0	400	320
	13	29,63	1 - 3[b]	0	200	160
	14	28,58	1 - 3[b]	0	200	160
	15	32,59	1 - 3[b]	0	200	160
	16	31,54	1 - 3[b]	0	200	160
	17	33,50	1 - 3[b]	0	200	160
	18	34,53	1 - 3[b]	0	200	160
	19	36,54	1 - 3[b]	0	200	160
	20	39,56	1 - 3[b]	0	200	160
	21	42,57	1 - 3[b]	0	200	160
	22	47,53	1 - 3[b]	0	200	160
3	23	55,68	1 - 3[b]	0	300	240
4	24	19,36	1 - 3[b]	300	300	300
	25	21,35	1 - 3[b]	300	300	300
	26	24,35	1 - 3[b]	300	300	300
	27	26,35	1 - 3[b]	300	300	300
	28	28,34	1 - 3[b]	300	300	300
System Total	28			1500	7500	6300

[a] See Figure F.7-8 for cell locations
[b] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.

TABLE F.7-11

SUMMARY OF SCENARIO RESULTS

Extraction Case	Total Uranium Mass Removed after 40 Years (lbs)	Uranium Removed after 40 Years (percent)	Cumulative System Efficiency after 40 Years (lbs/Mgal)	Time to Reduce Maximum Concentration Below 20 μg/L (years)	Maximum Concentration after 40 Years (ppb)
Scenario 1A	17,884	88.4	0.126	30.0	9.0
Scenario 1B	17,436	86.2	0.145	35.0	12.3
Scenario 2A	18,021	89.0	0.127	25.5	6.1
Scenario 2B	17,484	86.4	0.146	30.0	9.2
Scenario 3A	18,108	89.5	0.128	25.0	5.9
Scenario 3B	17,598	87.0	0.147	28.0	8.1

Note: Uranium removed includes both mass withdrawn with pumped groundwater and mass left in the pumping-induced vadose zone. It is assumed that the operation program (pulsed pumping) and natural infiltration will redissolve material left in the pumping-induced vadose zone and this mass will be recovered.

TABLE F.7-12

SUMMARY OF GROUNDWATER RESTORATION TO 20 μg/L DESIGN - RESULTS FOR OTHER CONSTITUENTS OF CONCERN

Constituent	Maximum Conc. at 30 Years (ppb)	Location of Maximum	MCL[a] Screening Level (ppb)	Maximum Conc. Reduced Below Screening Level
Neptunium-237	1.31×10^{-4}	Zone 1, Layer 1	1.42×10^{-3}	Yes
Radium-226	1.21×10^{-5}	Zone 1, Layer 1	2.02×10^{-5}	Yes
Technetium-99	1.22×10^{-3}	Zone 2, Layer 5	5.53×10^{-2}	Yes
Antimony	9.96×10^{-2}	Zone 1, Layer 1	6.0×10^{0}	Yes
Arsenic	9.64×10^{1}	Zone 3, Layer 3	5.0×10^{1}	No
Manganese	1.60×10^{3}	Zone 4, Layer 1	9.04×10^{2}	No
Total volatile organic compounds	2.64×10^{-1}	Zone 3, Layer 3	5.0×10^{0}	Yes

[a] Where maximum contaminant level was not available, an incremental lifetime cancer risk of 10^{-5} or a hazard quotient of 0.2 was used.

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TABLE F.7-13

GROUNDWATER RESTORATION TO 3 μg/L DESIGN PUMPING SCHEDULE

Extraction System	Well Number	Well Depth[a]	Screened Interval Layer	SWIFT Cell Number (I,J)	Well Pumping Rate 0 to 5 Years (gpm)	Well Pumping Rate 5 to 25 Years (gpm)	Well Pumping Rate 25 to 75 Years[b] (gpm)
1	1	Shallow	1 - 3[c]	38,89	0	300	0
	2	Shallow	1 - 3[c]	31,80	0	200	0
	3	Shallow	1 - 3[c]	36,81	0	200	0
	4	Shallow	1 - 3[c]	39,84	0	200	300
	5	Shallow	1 - 3[c]	42,86	0	300	300
	6	Shallow	1 - 3[c]	44,89	0	200	0
	7	Shallow	1 - 3[c]	46,92	0	200	0
2	8	Shallow	1 - 3[c]	27,50	0	500	500
	9	Shallow	1 - 3[c]	30,48	0	400	500
	10	Shallow	1 - 3[c]	33,47	0	400	500
	11	Shallow	1 - 3[c]	36,46	0	400	500
	12	Shallow	1 - 3[c]	39,46	0	400	500
	13	Shallow	1 - 3[c]	29,63	0	200	0
	14	Shallow	1 - 3[c]	28,58	0	200	0
	15	Shallow	1 - 3[c]	32,59	0	200	300
	16	Shallow	1 - 3[c]	31,54	0	200	300
	17	Shallow	1 - 3[c]	33,50	0	200	300
	18	Shallow	1 - 3[c]	34,53	0	200	300
	19	Shallow	1 - 3[c]	36,54	0	200	300
	20	Shallow	1 - 3[c]	39,56	0	200	0
	21	Shallow	1 - 3[c]	42,57	0	200	0
	22	Shallow	1 - 3[c]	47,53	0	200	400
	23	Shallow	1 - 3[c]	41,53	0	0	400
	24	Deep	5 - 6[d]	34,48	0	0	300
	25	Deep	5 - 6[d]	33,48	0	0	300
3	26	Shallow	1 - 3[c]	55,68	0	300	0
4	27	Shallow	1 - 3[c]	19,36	300	300	300
	28	Shallow	1 - 3[c]	21,35	300	300	300
	29	Shallow	1 - 3[c]	24,35	300	300	300
	30	Shallow	1 - 3[c]	26,35	300	300	300
	31	Shallow	1 - 3[c]	28,34	300	300	300
System Total	31				1500	7500	7500

[a] Shallow indicates that the well is screened in the upper Great Miami Aquifer or Model Layers 1, 2, and 3 and Deep indicates that the well is screened in the lower Great Miami Aquifer or Model Layers 5 and 6.
[b] The total pumping rate is redistributed among the recovery wells to maintain efficiency.
[c] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.
[d] Elevation of the top of Layer 5 is approximately 438-442 feet AMSL. Elevation of the bottom of Layer 6 (the top of bedrock) is approximately 380-396 feet AMSL.

TABLE F.7-14

SUMMARY OF GROUNDWATER RESTORATION TO 3 μg/L DESIGN - RESULTS FOR OTHER CONSTITUENTS OF CONCERN

Constituent	Maximum Concentration at 70 Years (μg/L)	Location of Maximum	10^{-6} Screening Level[a] (μg/L)	Maximum Conc. Reduced Below Screening Level
Neptunium-237	2.06×10^{-5}	Zone 1, Layer 1	7.9×10^{-4}	Yes
Radium-226	1.12×10^{-5}	Zone 1, Layer 4	1.52×10^{-6}	No
Technetium-99	2.33×10^{-5}	Zone 1, Layer 4	1.71×10^{-3}	Yes
Antimony	1.27×10^{-2}	Zone 2, Layer 3	2.0×10^{0}	Yes
Arsenic	$7.69 \times 10^{+1}$	Zone 3, Layer 4	2.9×10^{1}	No
Manganese	$8.37 \times 10^{+2}$	Zone 1, Layer 2	9.04×10^{2}	Yes
Total volatile organic compounds	3.02×10^{-2}	Zone 2, Layer 6	1.0×10^{1}	Yes

[a] Where a 10^{-6} incremental lifetime cancer risk was not available, a hazard quotient of 0.2 was used (as presented in Table 2-16).

TABLE F.7-15

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445 GROUNDWATER CONTAINMENT TO 20 μg/L PUMPING SCHEDULE

Subsystem	Well Number	SWIFT Cell Number (I, J)[a]	Screened Interval Layer	Well Pumping Rate 0 to 5 Years (gpm)	Well Pumping Rate 5-75 years (gpm)
2	1	27,50	1 - 3[b]	0	300
	2	30,48	1 - 3[b]	0	200
	3	33,47	1 - 3[b]	0	200
	4	36,46	1 - 3[b]	0	200
	5	39,46	1 - 3[b]	0	200
4	6	19,36	1 - 3[b]	300	300
	7	21,35	1 - 3[b]	300	300
	8	24,35	1 - 3[b]	300	300
	9	26,35	1 - 3[b]	300	300
	10	28,34	1 - 3[b]	300	300
System Total	10			1500	2600

[a] See Figure F.7-8 for cell locations
[b] Elevation of the water table in Layer 1 is approximately 523-526 feet above mean sea level (AMSL). Elevation of the bottom of Layer 3 is approximately 442-444 feet AMSL.

TABLE F.7-16

GREAT MIAMI AQUIFER EXTRACTION WATER BUDGET

	No Additional Action Design	Restoration to 20 μg/L Design
Inflow to Model (gpm)		
Recharge	2100	2100
Influx through boundaries	20,666	24,425
Total inflow	22,765	26,525
Outflow from Model (gpm)		
FEMP extraction pumping	1500	6300
Other pumping	17,368	17,368
Efflux through boundaries	3890	2857
Total outflow	22,758	26,525
Recharge Area Determination		
FEMP extraction pumping (gpm)	1500	6300
Average infiltration rate (in/yr)	8.4	8.4
Area required to sustain pumping rate (sq. miles)	5.4	22.6

TABLE F.7-17

SUMMARY OF GROUNDWATER EXTRACTION DESIGN RESULTS

Extraction Design	Case	Uranium Mass Removed after 30 Years (lbs)	Uranium Mass Removed after 30 Years (percent)	Uranium Mass Removed after 70 Years (lbs)	Uranium Mass Removed after 70 Years (percent)	Cumulative System Efficiency Over 30 Years (lbs/Mgal)	Total Water Pumped Over 30 Years (x 10^6 gallons)	Clean-Up Time to 20 μg/L (years)	Clean-Up Time to 3 μg/L (years)
No-Additional Action	$K_d = 1.78$	5465	27.1	11,000	54.5	0.23	23,652	90	290
No-Additional Action	$K_d = 12$	3130	16.3	4250	22.1	0.13	23,652	170	>405
Restoration to 20 μg/L	$K_d = 1.78$	16,500	81.7	-	-	0.19	86,724	30	-
Restoration to 20 μg/L	$K_d = 12$	8720	44.0	-	-	0.10	86,724	55	-
Restoration to 3 μg/L	$K_d = 1.78$	17,300	85.6	19,100	94.6	0.17	102,492	-	70
Restoration to 3 μg/L	$K_d = 12$	9820	49.6	14,200	71.7	0.10	102,492	-	105
Containment to 20 μg/L	$K_d = 1.78$	9785	48.4	15,200	75.2	0.26	38,106	60	380
Containment to 20 μg/L	$K_d = 12$	4510	22.8	6990	35.3	0.12	38,106	120	330

*\ILLUS\OU-5\PO-113\F-GMA RESTORE.EPS

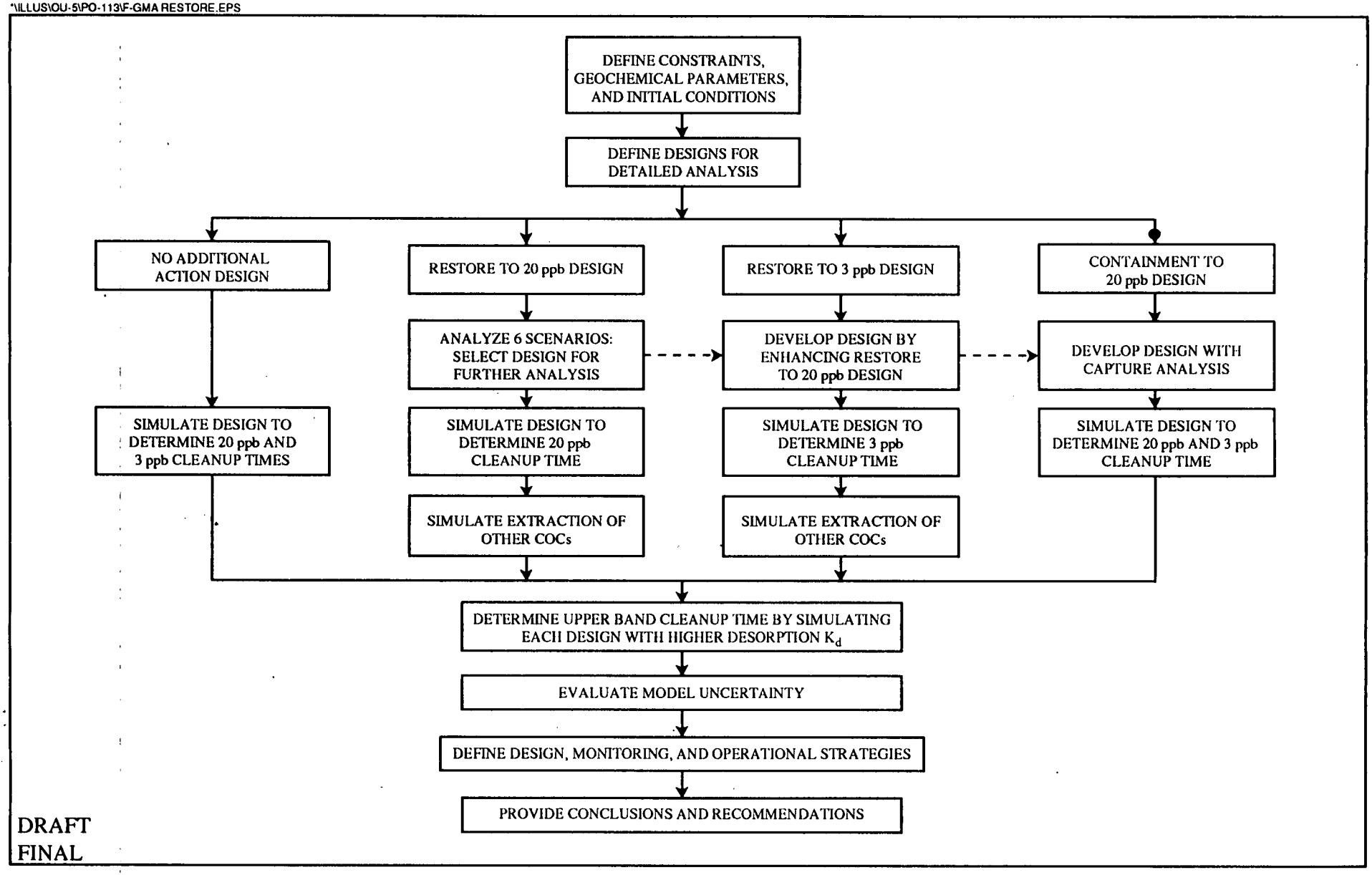

FIGURE F.7-1. FLOWCHART OF GREAT MIAMI AQUIFER RESTORATION/CONTAINMENT MODELING APPROACH

*\ILLUS\OU-5\PO-113\LOAD SCENARIO-A.EPS

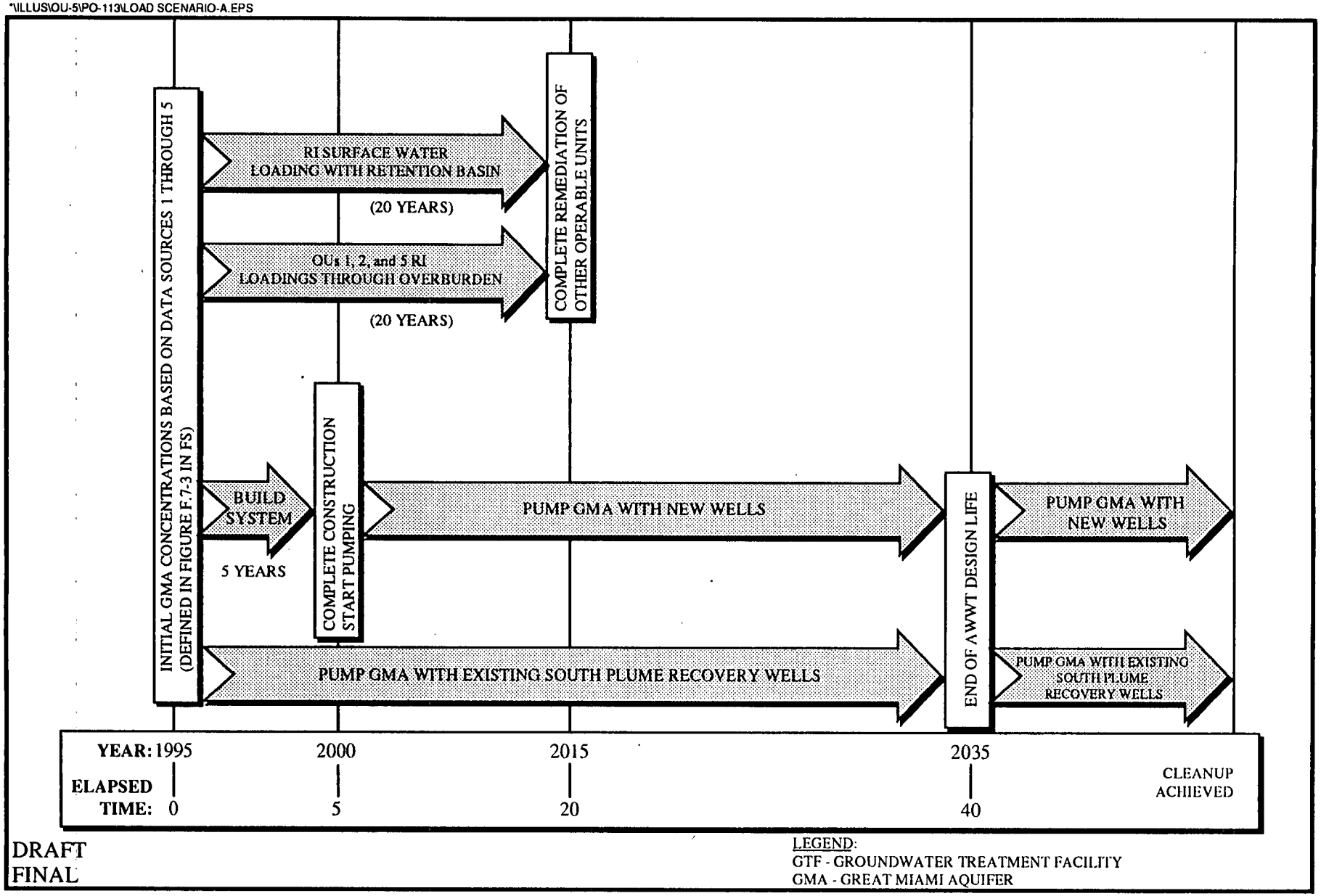

FIGURE F.7-2. TIMELINE OF REMEDIATION AND GROUNDWATER EXTRACTION PRESENTED IN THE FS

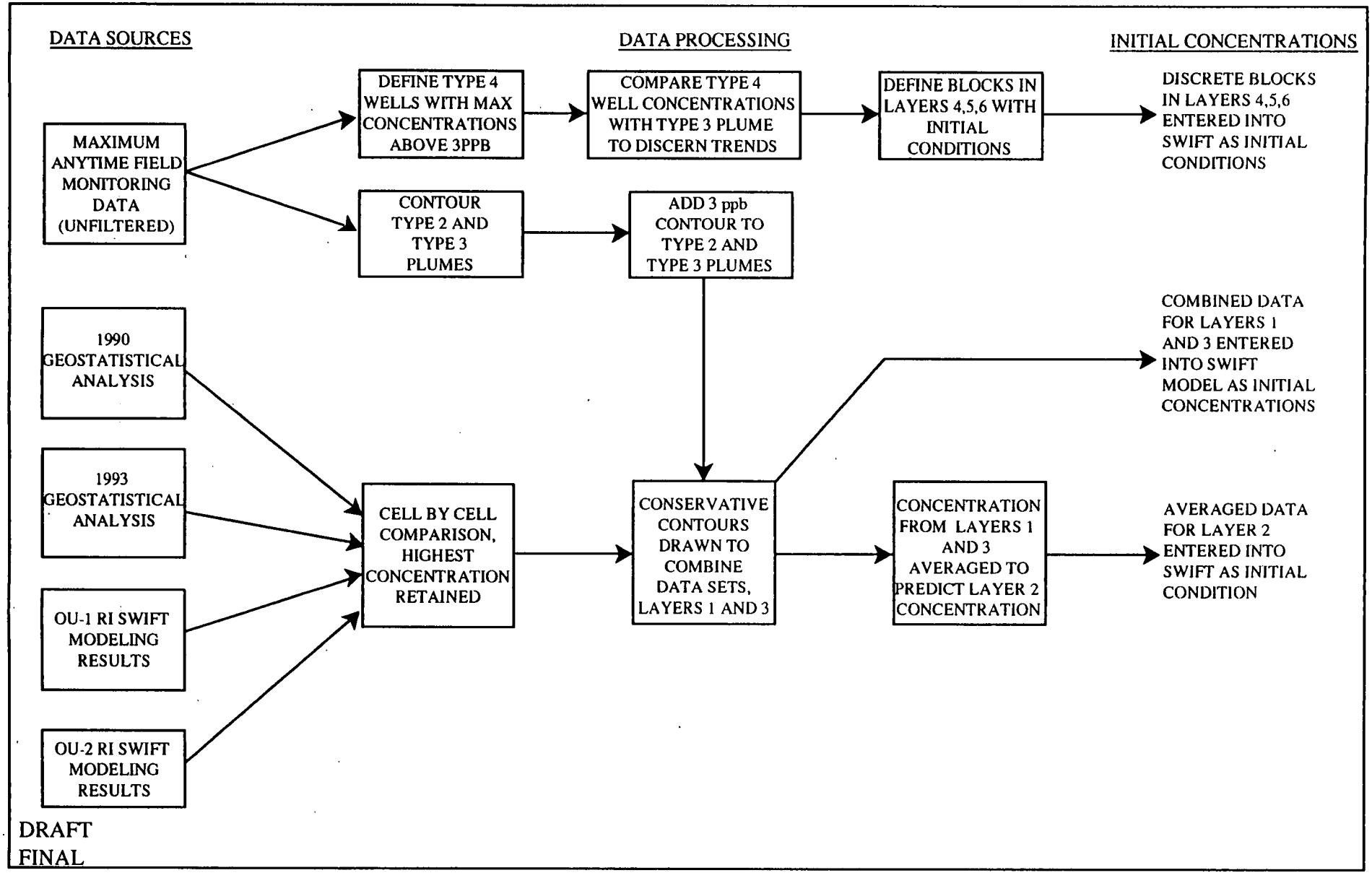

FIGURE F.7-3. DEVELOPMENT OF CONSERVATIVE INITIAL GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS

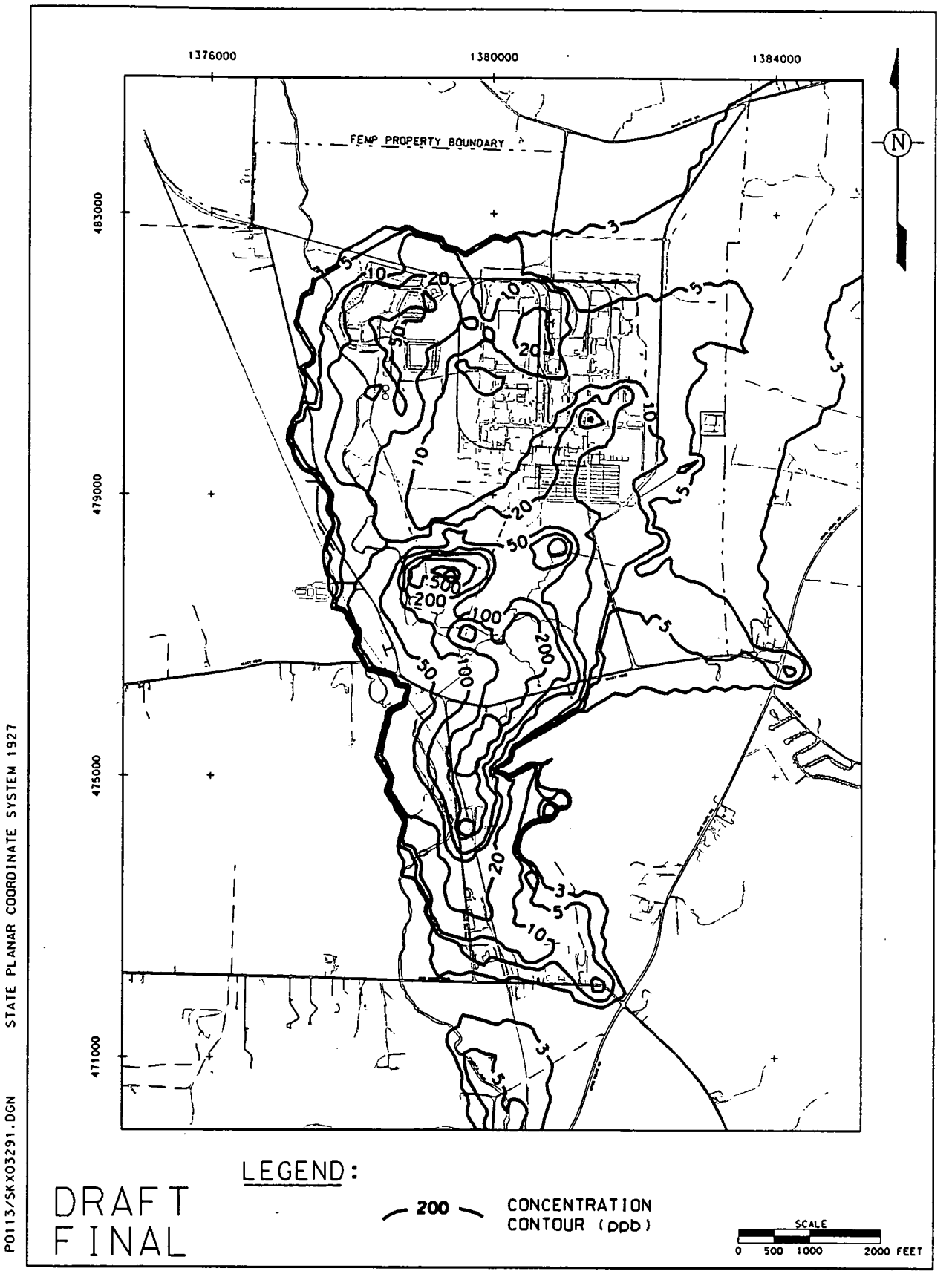

FIGURE F.7-4. CONSERVATIVE INITIAL GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS. LAYER 1

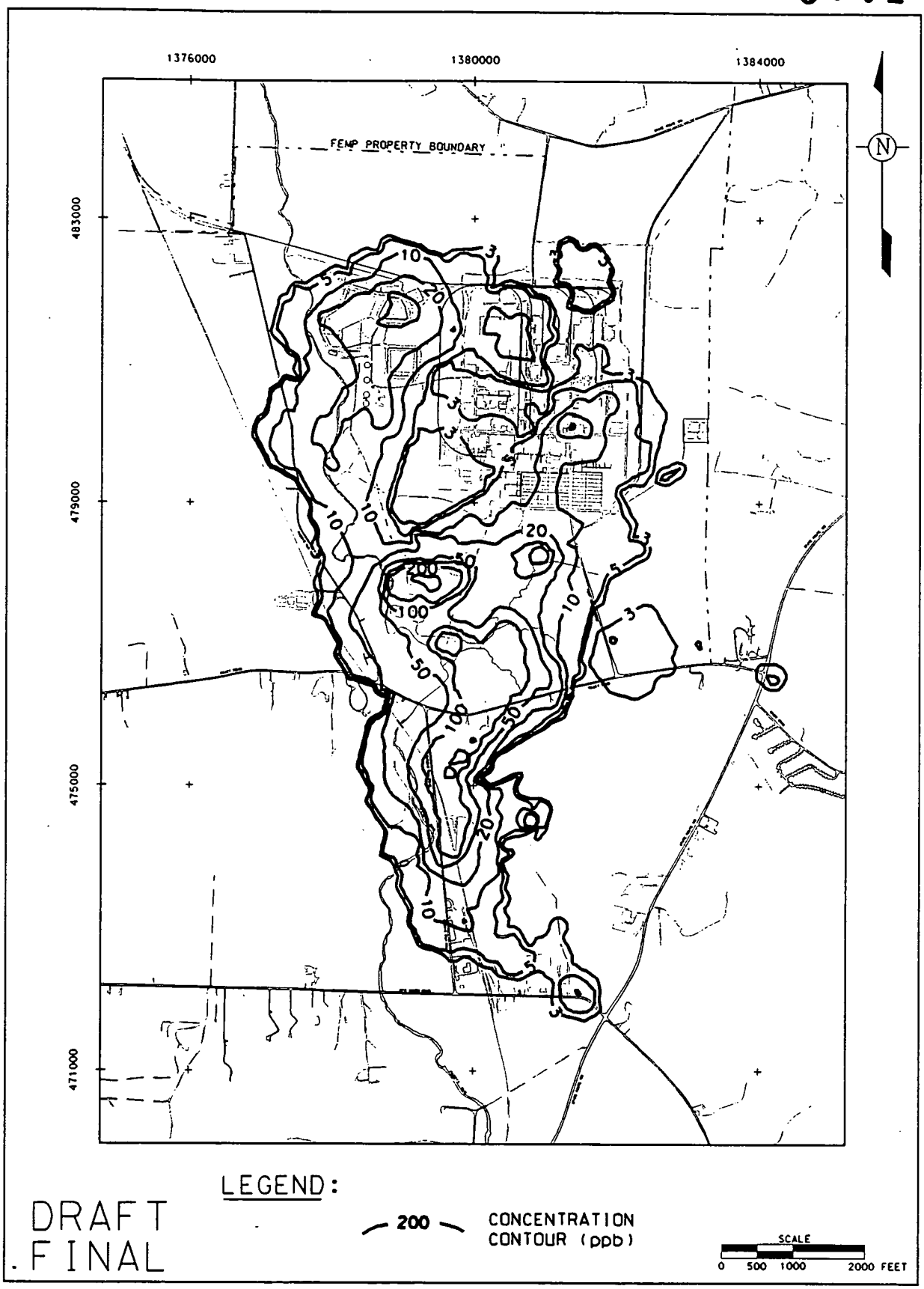

FIGURE F.7-5 CONSERVATIVE INITIAL GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS. LAYER 2

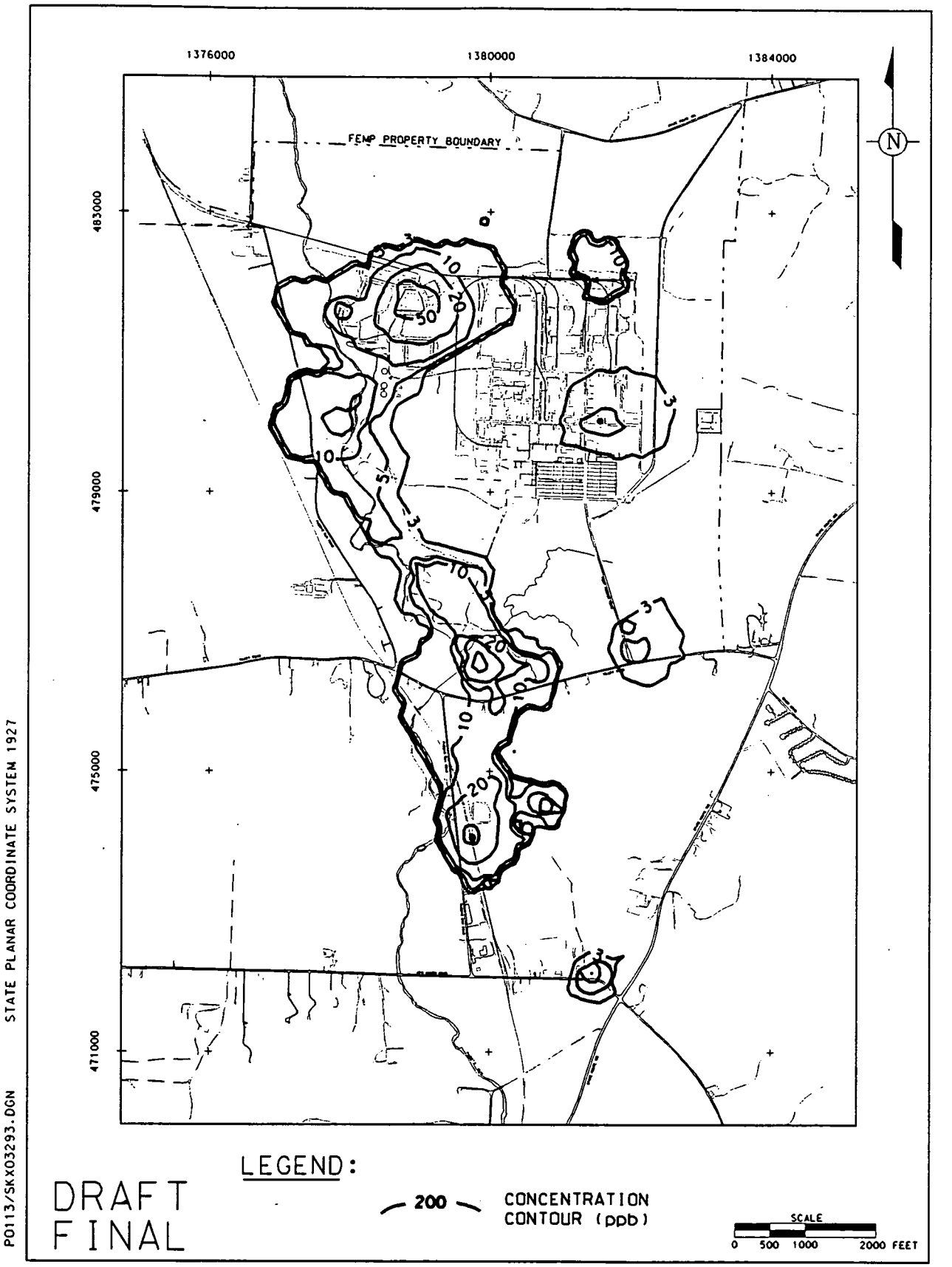

FIGURE F.7-6. CONSERVATIVE INITIAL GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS. LAYER 3

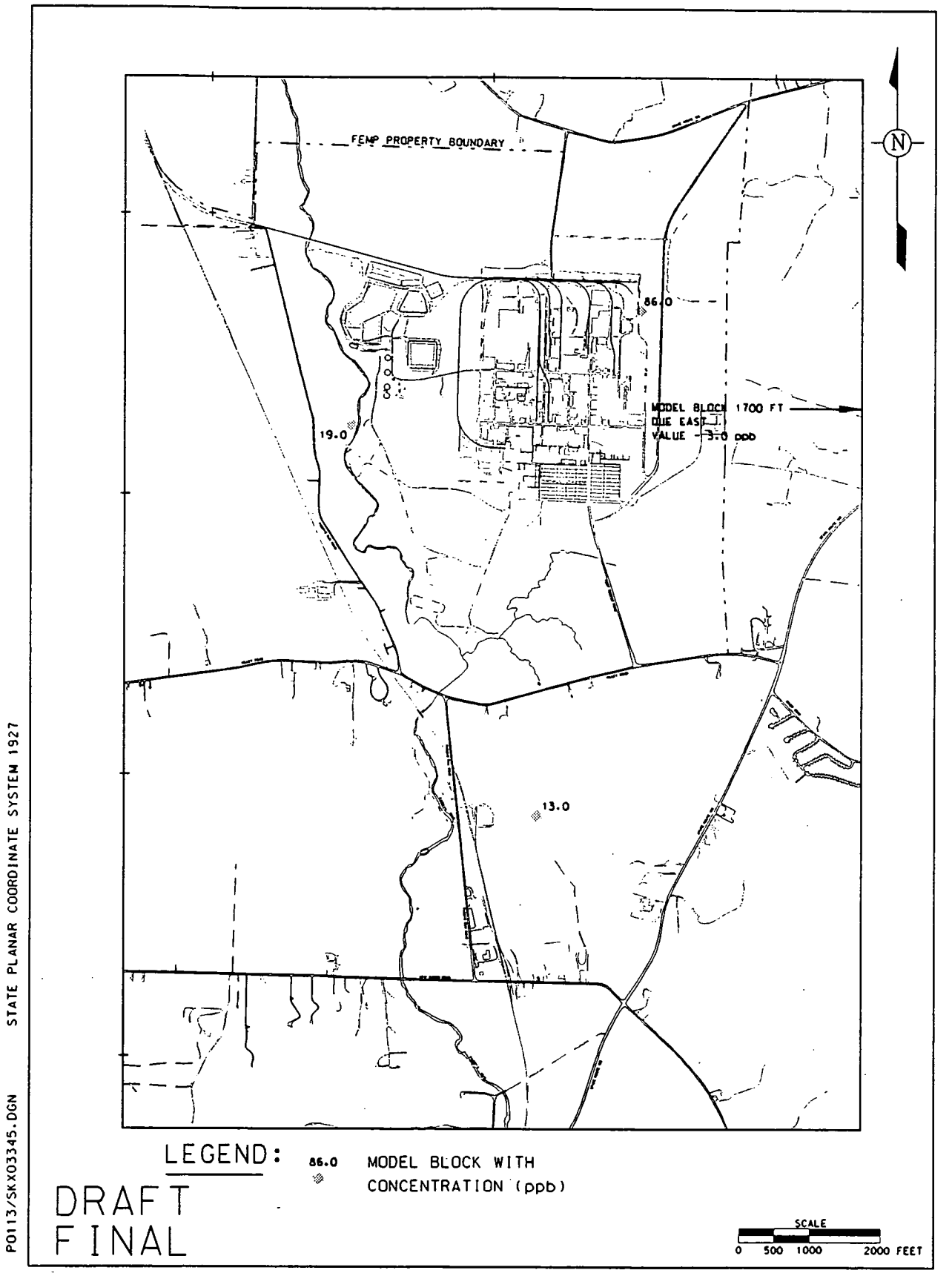

FIGURE F.7-7. CONSERVATIVE INITIAL GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS. LAYERS 4, 5 AND 6

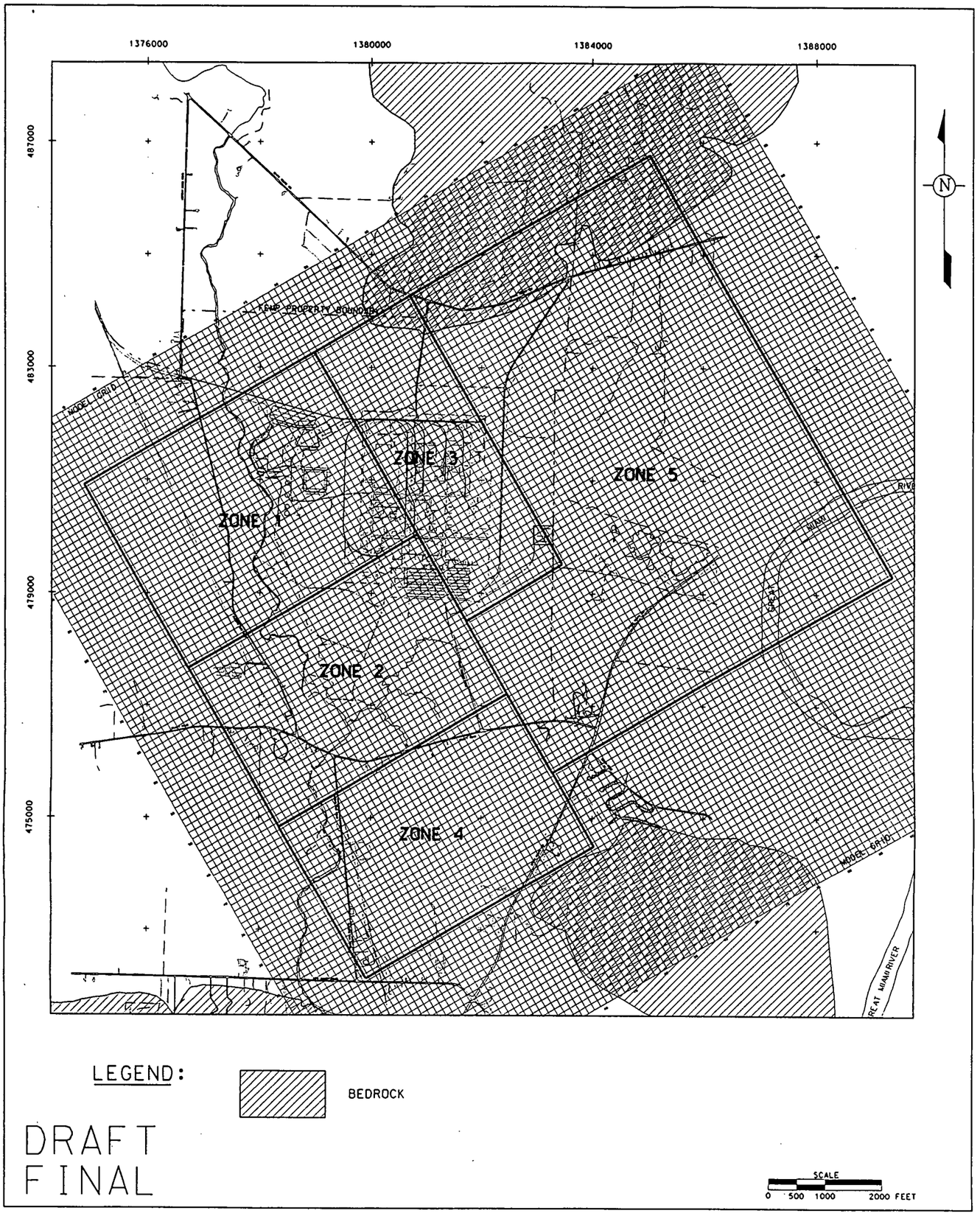

FIGURE F.7-8. MODEL GRID, AQUIFER ZONES AND EXTRACTION SYSTEMS

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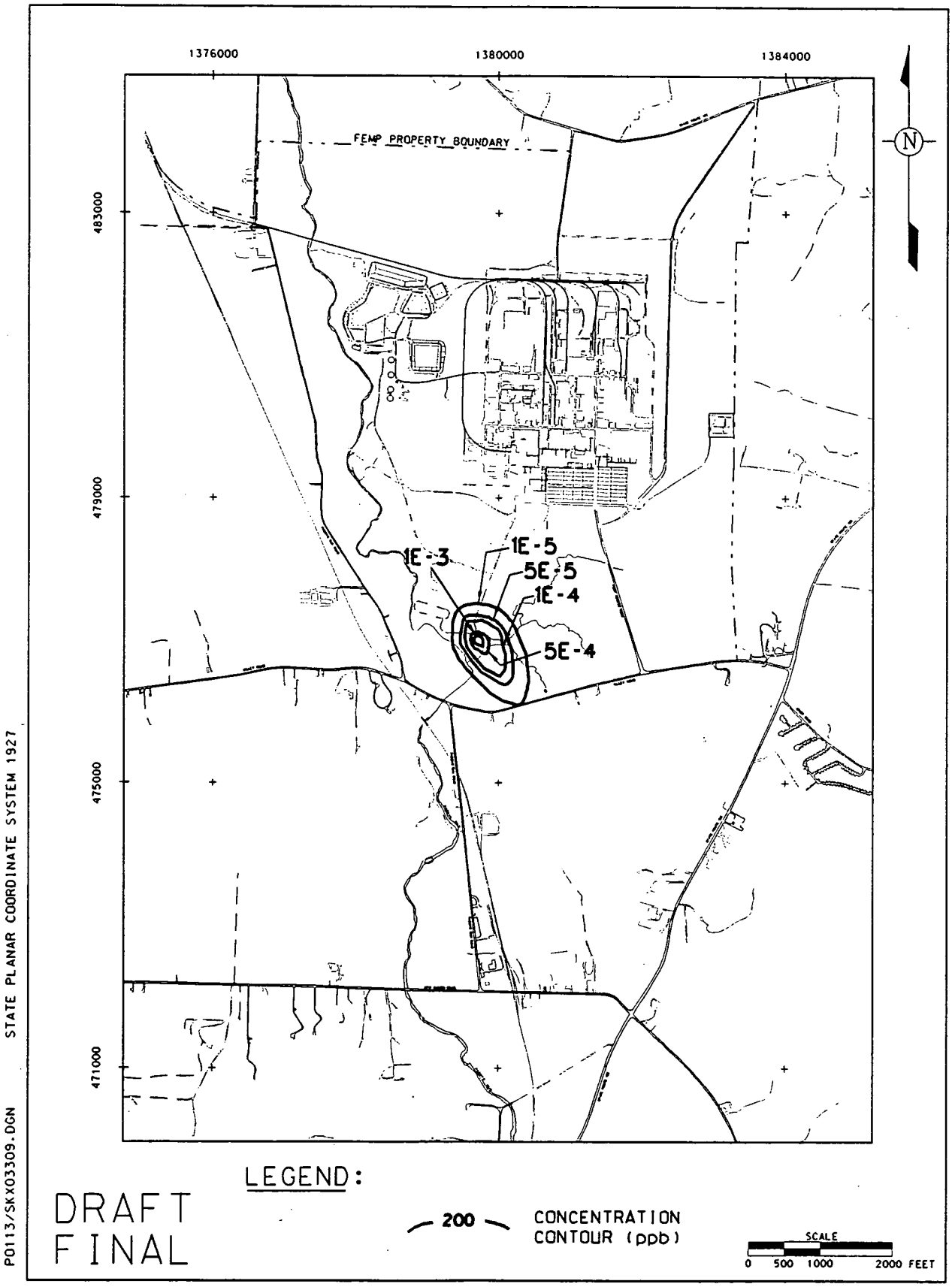

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FIGURE F.7-9. INITIAL CONCENTRATION OF NP-237 FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

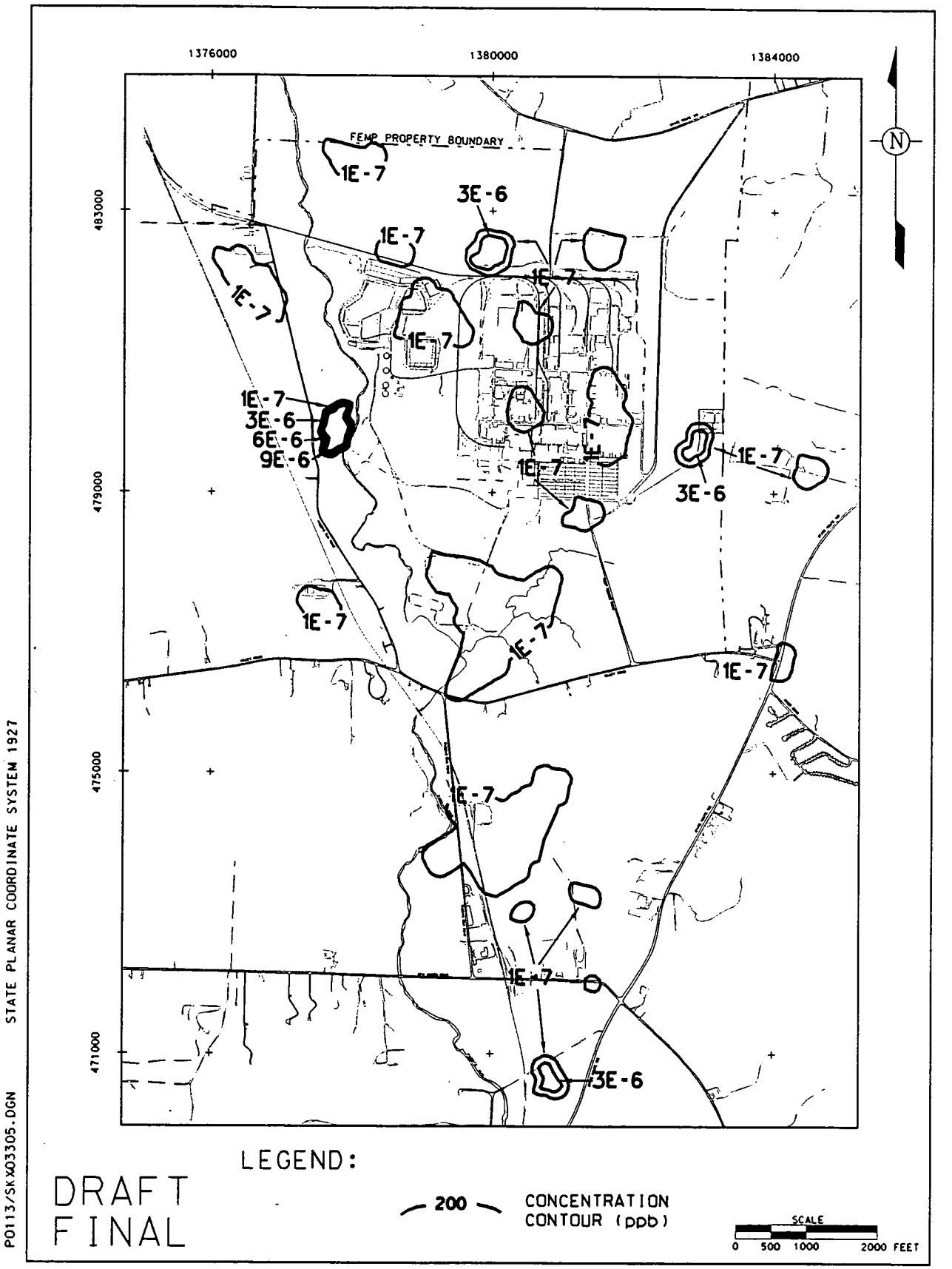


FIGURE F.7-10. INITIAL CONCENTRATION OF RA-226 FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

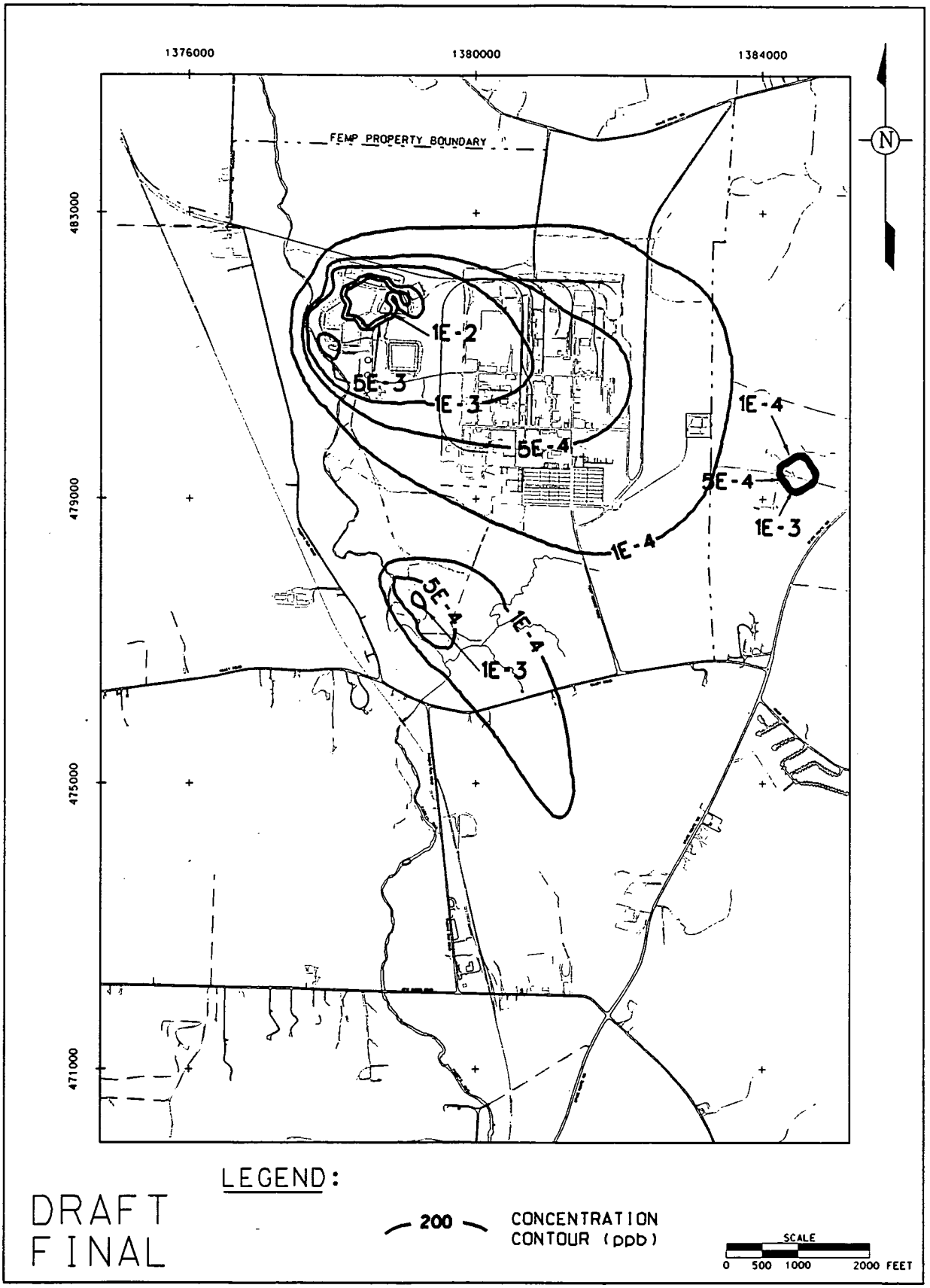
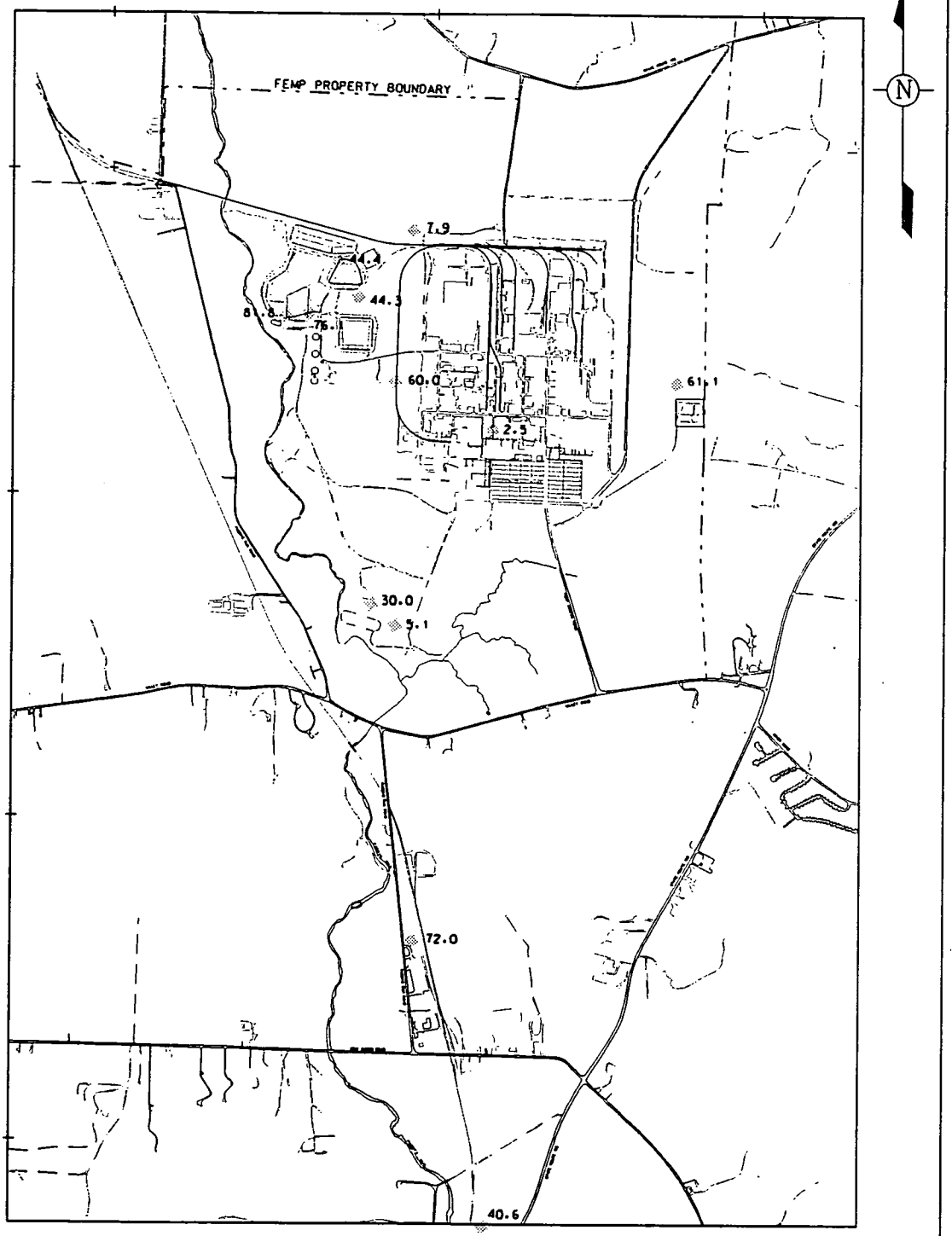


FIGURE F.7-11. INITIAL CONCENTRATION OF TC-99 FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1



LEGEND: 72.0 MODEL BLOCK WITH CONCENTRATION (ppb)

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SCALE
0 500 1000 2000 FEET

STATE PLANAR COORDINATE SYSTEM 1927

P0113/SKX03344.DGN

FIGURE F.7-12. INITIAL CONCENTRATION OF ANTIMONY FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

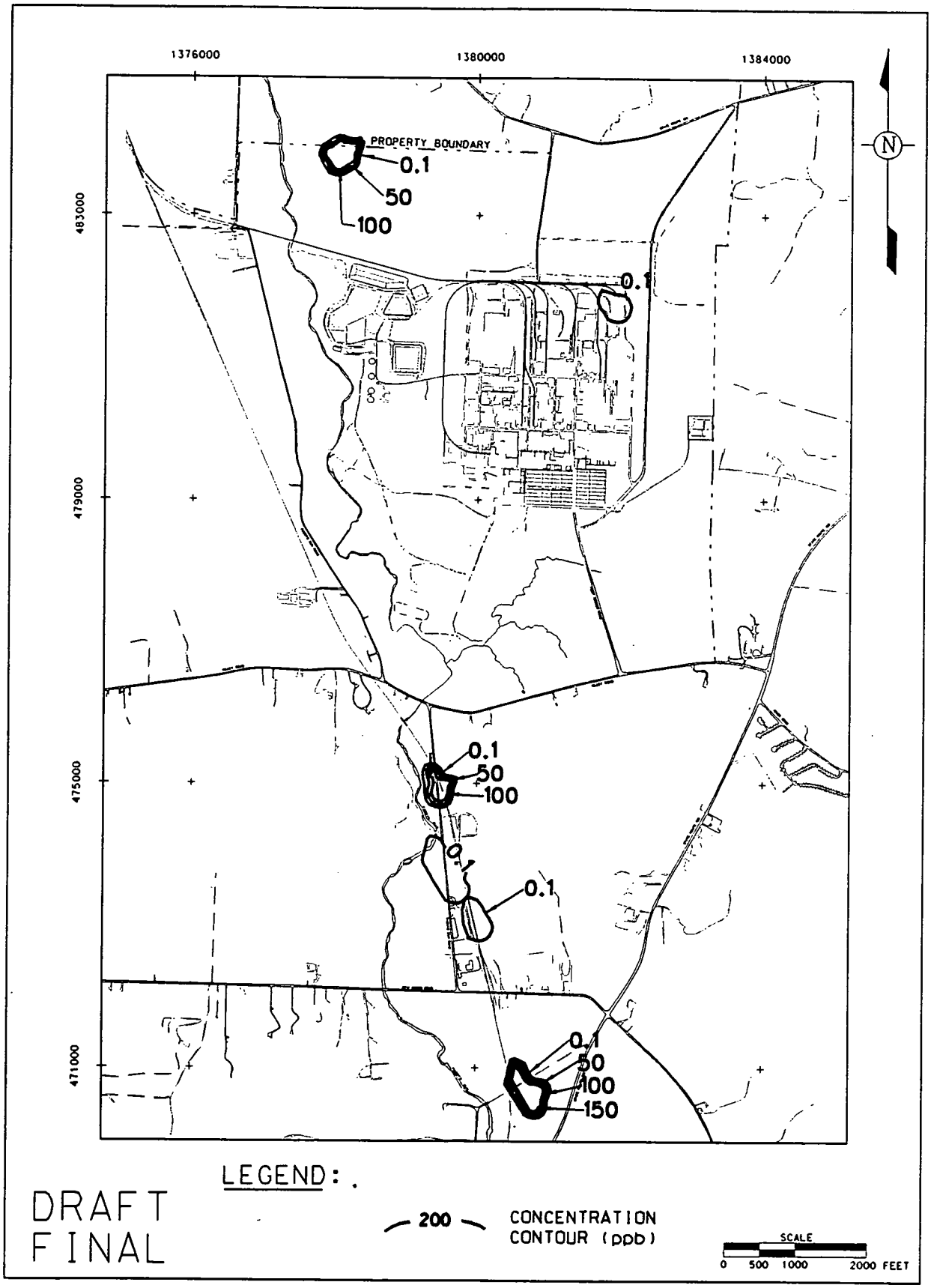

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FIGURE F.7-13. INITIAL CONCENTRATION OF ARSENIC FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

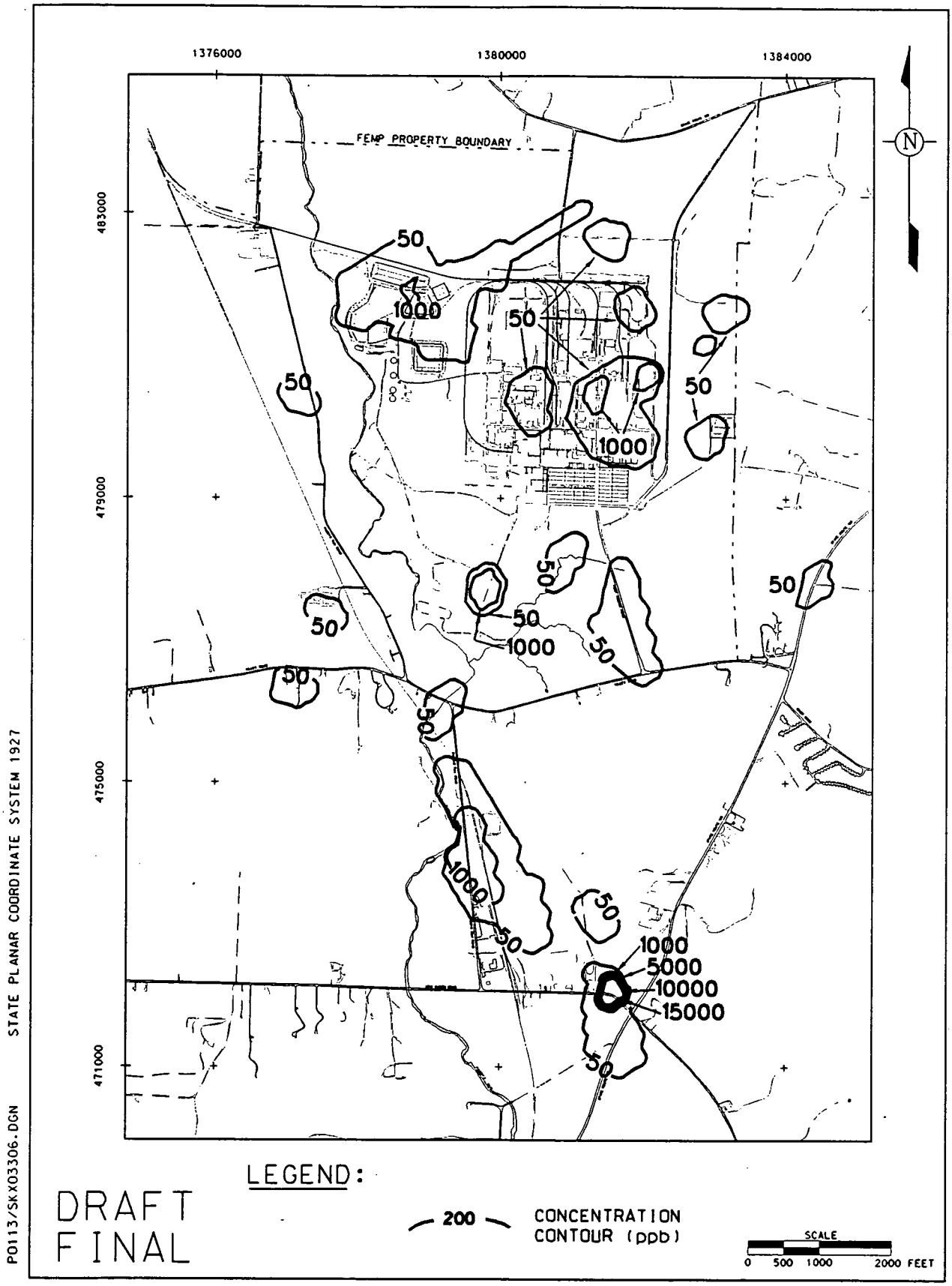


FIGURE F.7-14. INITIAL CONCENTRATION OF MANGANESE FOR SWIFT GREAT MIAMI AQUIFER MODELING, LAYER 1

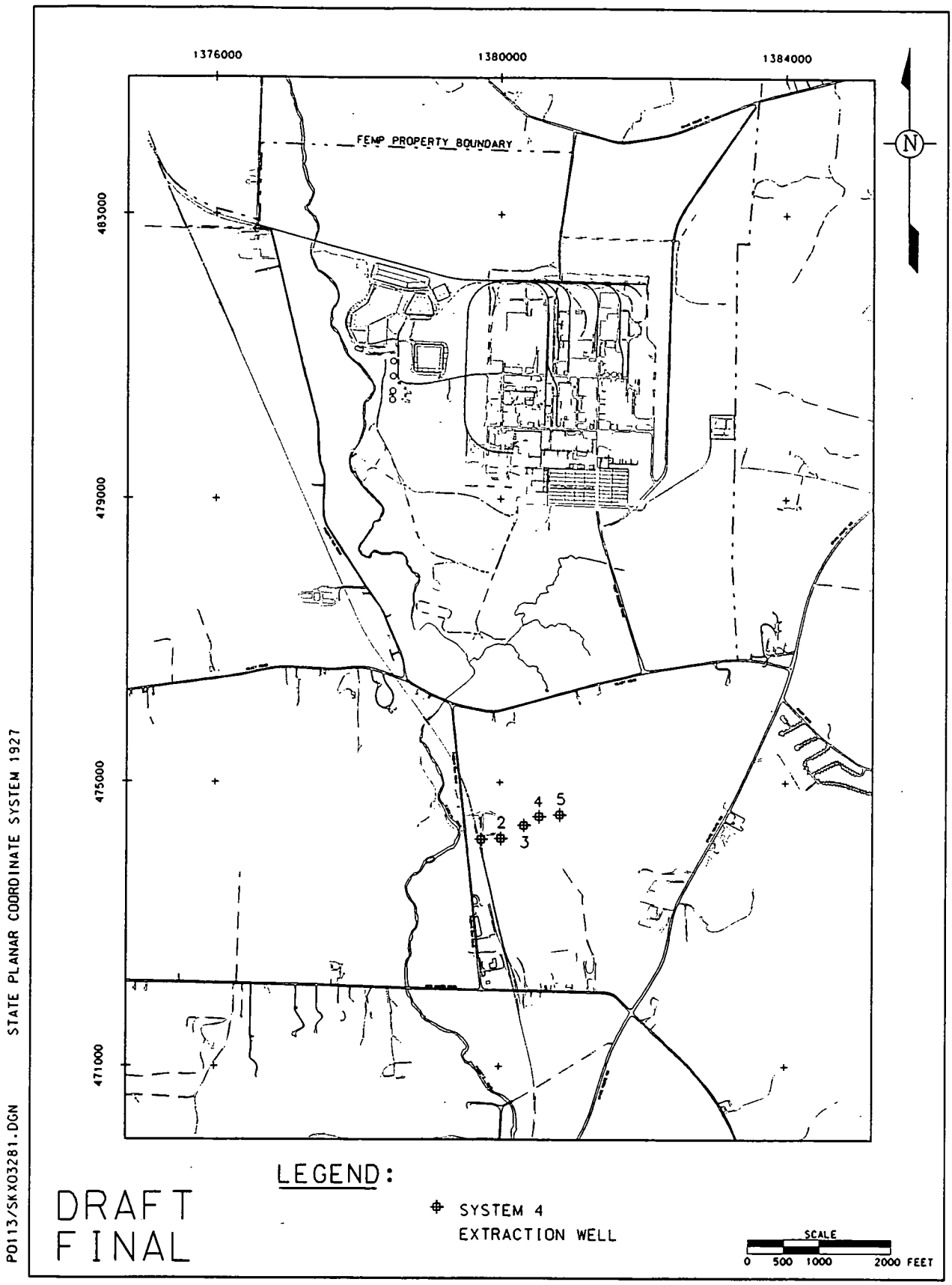
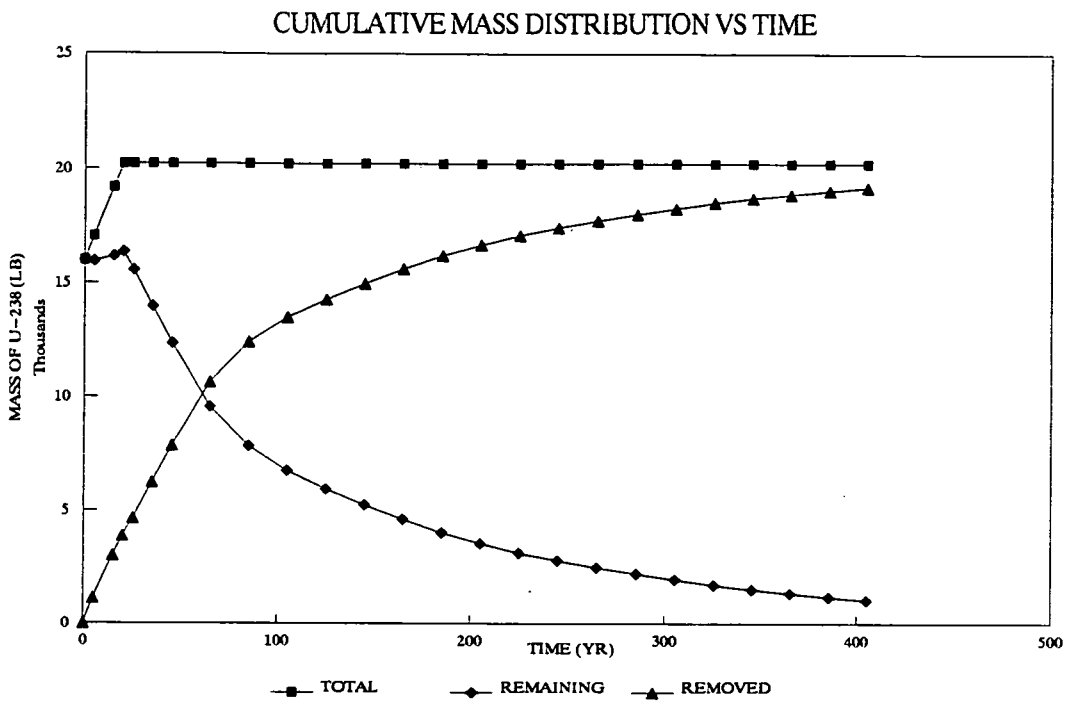


FIGURE F.7-15. NO-ADDITIONAL-ACTION, WELL LOCATIONS



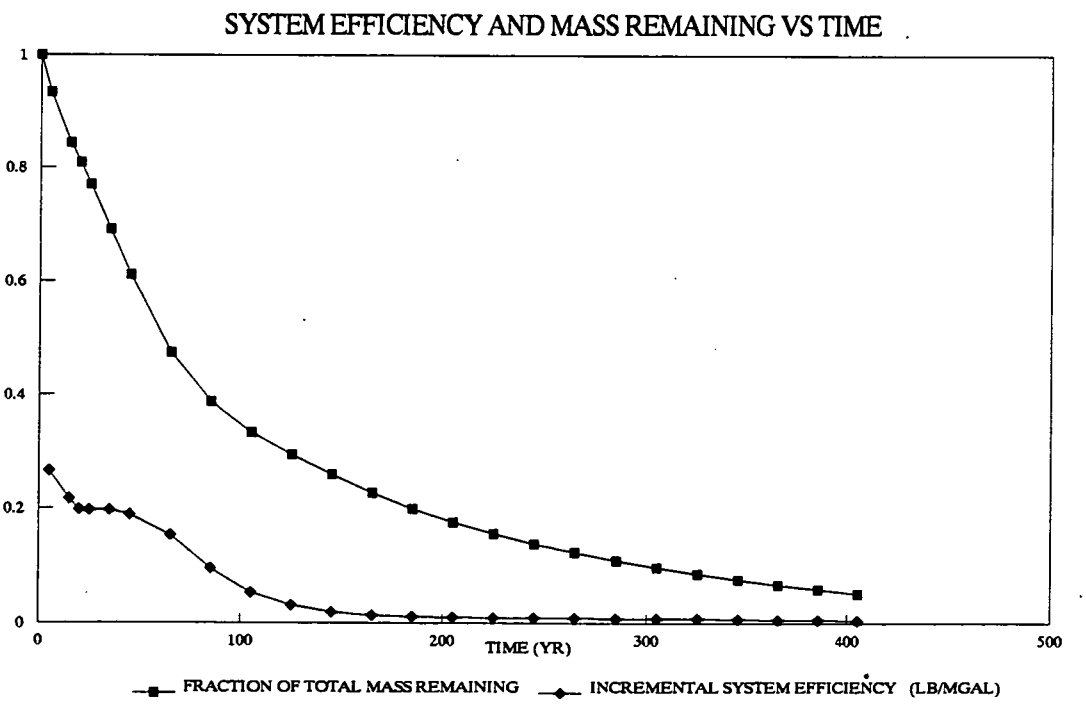


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FIGURE F.7-16. NO-ADDITIONAL-ACTION SYSTEM PERFORMANCE CURVES

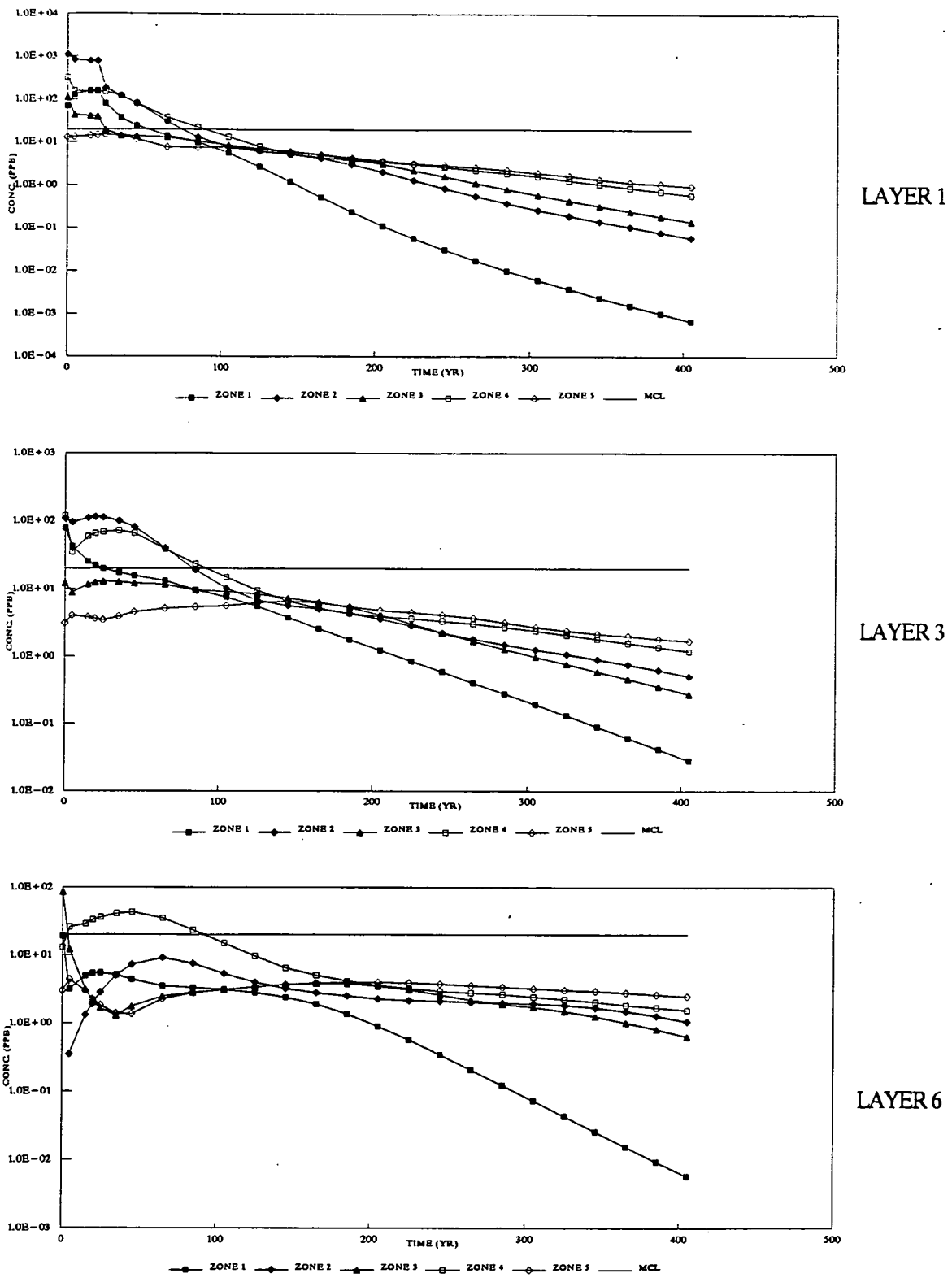

FIGURE F.7-17A. NO-ADDITIONAL-ACTION, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

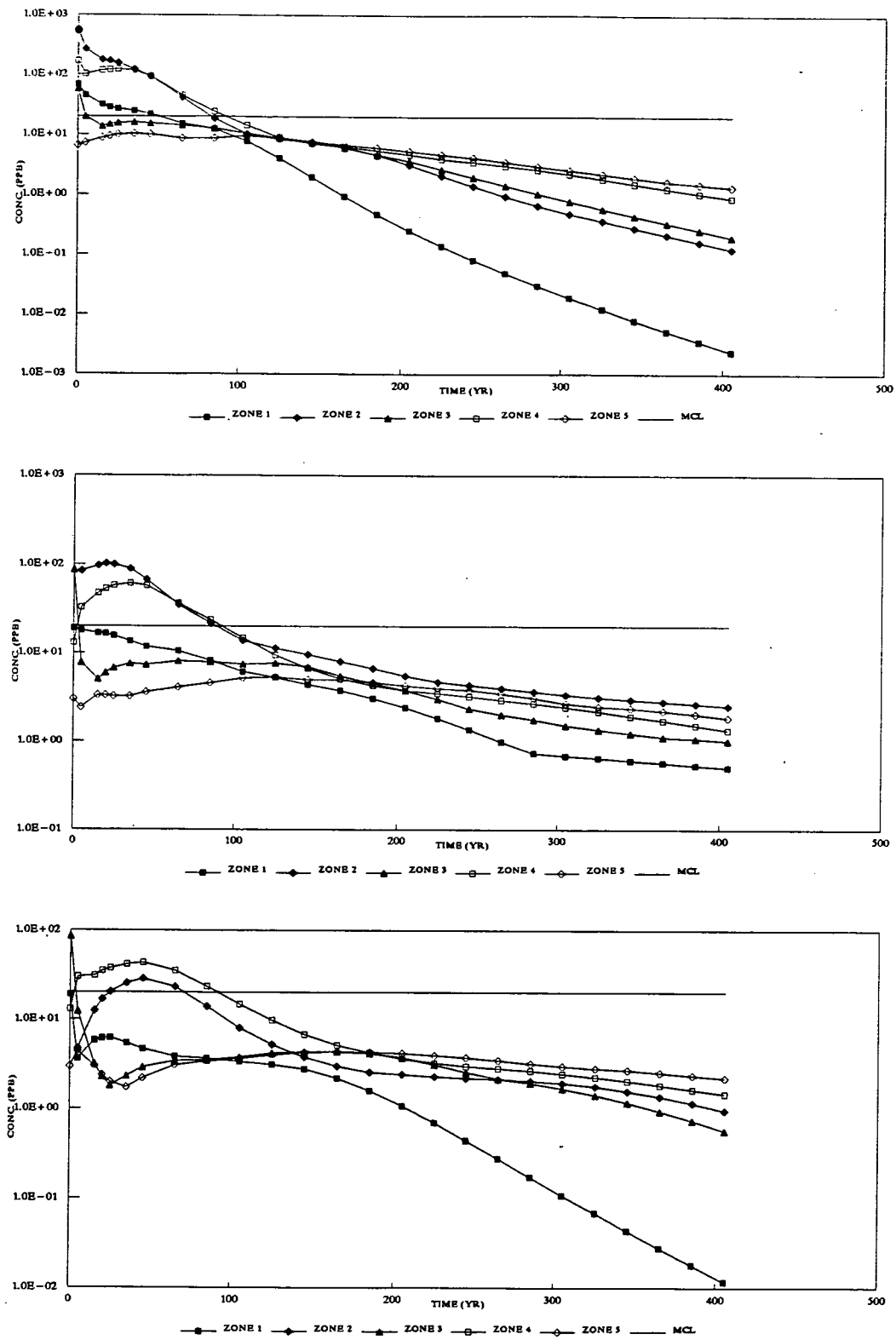

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FIGURE F.7-17B. NO-ADDITIONAL-ACTION, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

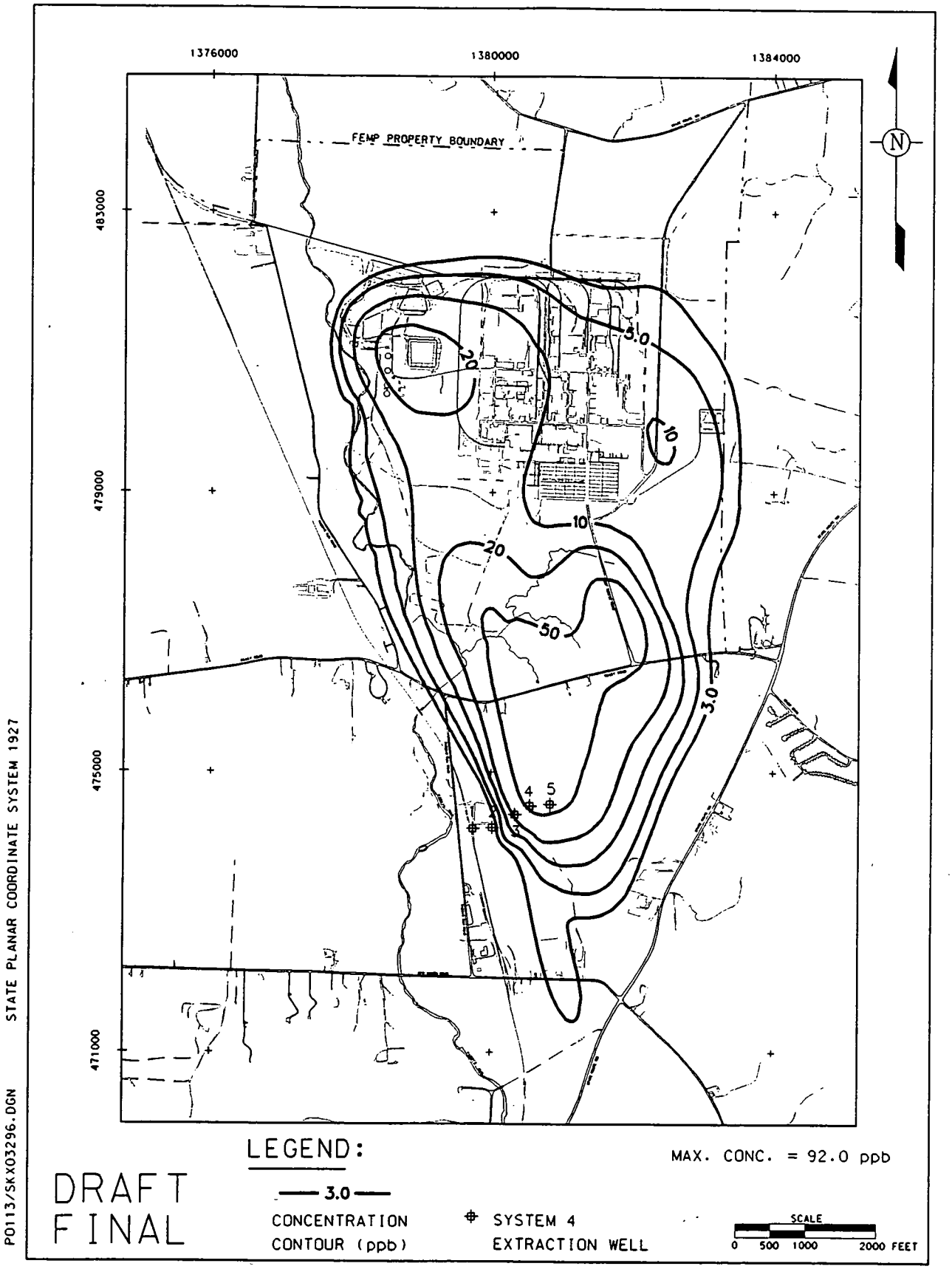


FIGURE F.7-18. NO-ADDITIONAL-ACTION. URANIUM CONCENTRATION CONTOURS. YEAR 45. LAYER 1

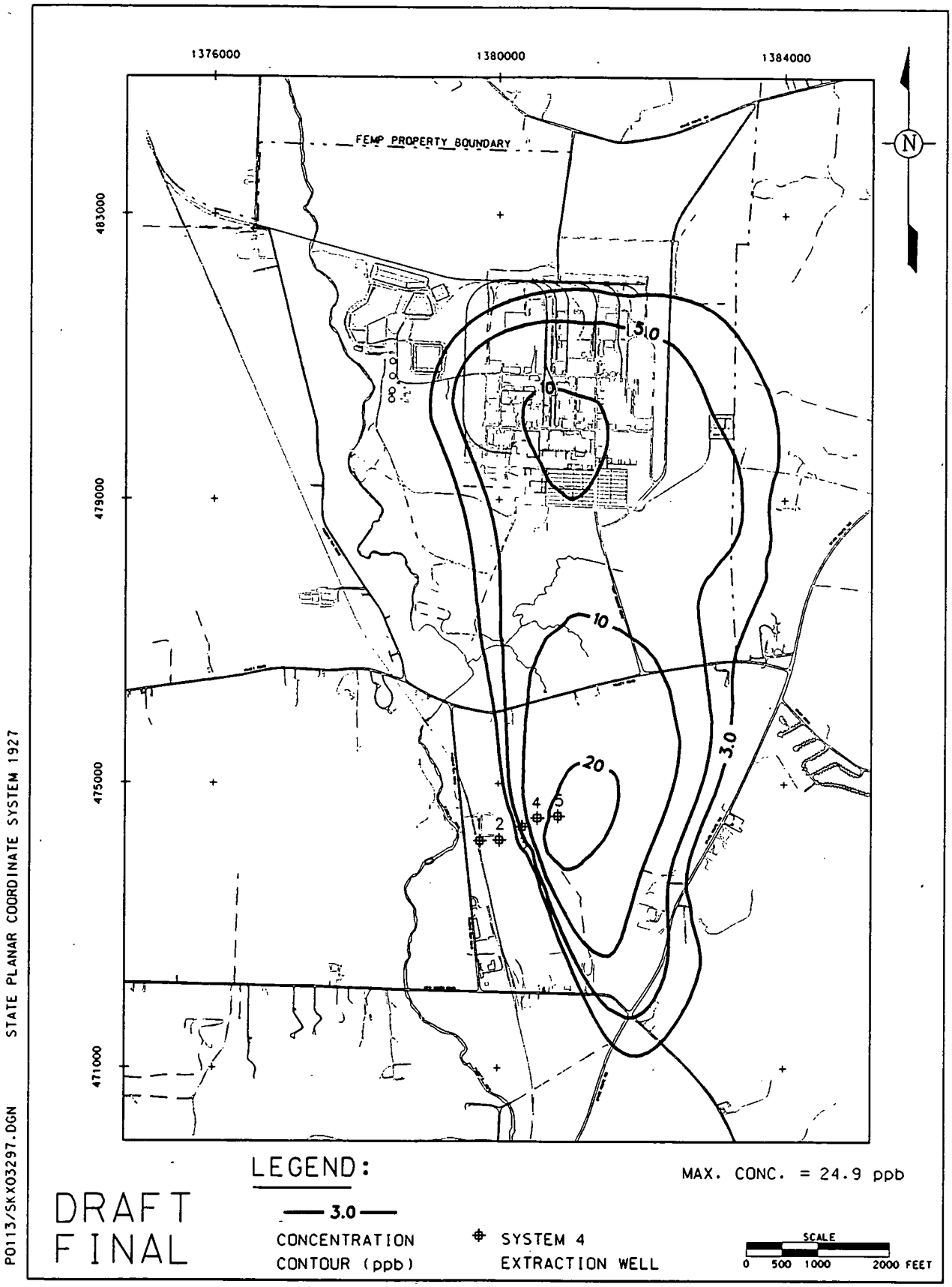


FIGURE F.7-19. NO-ADDITIONAL-ACTION. URANIUM CONCENTRATION CONTOURS. YEAR 85. LAYER 1

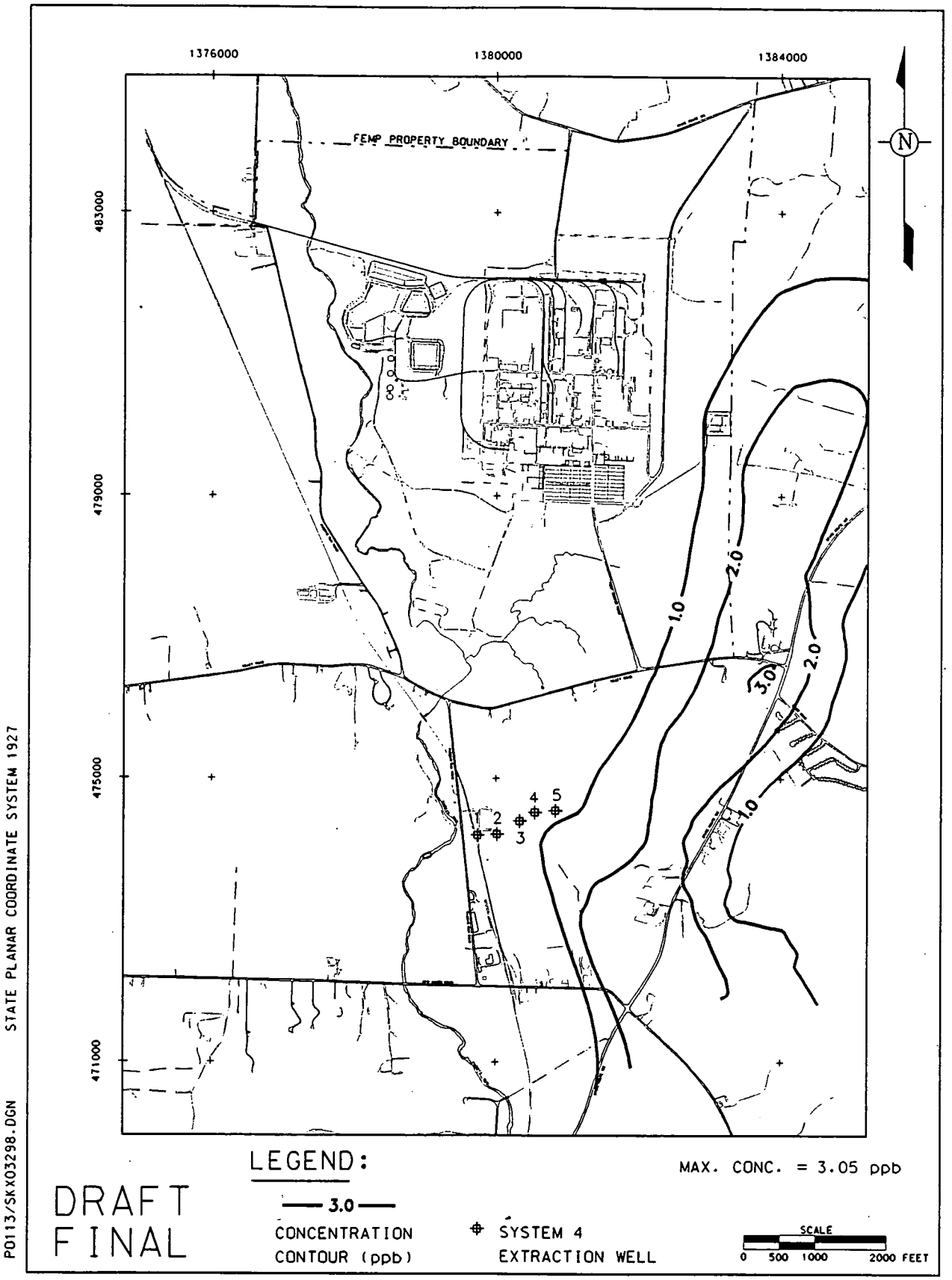
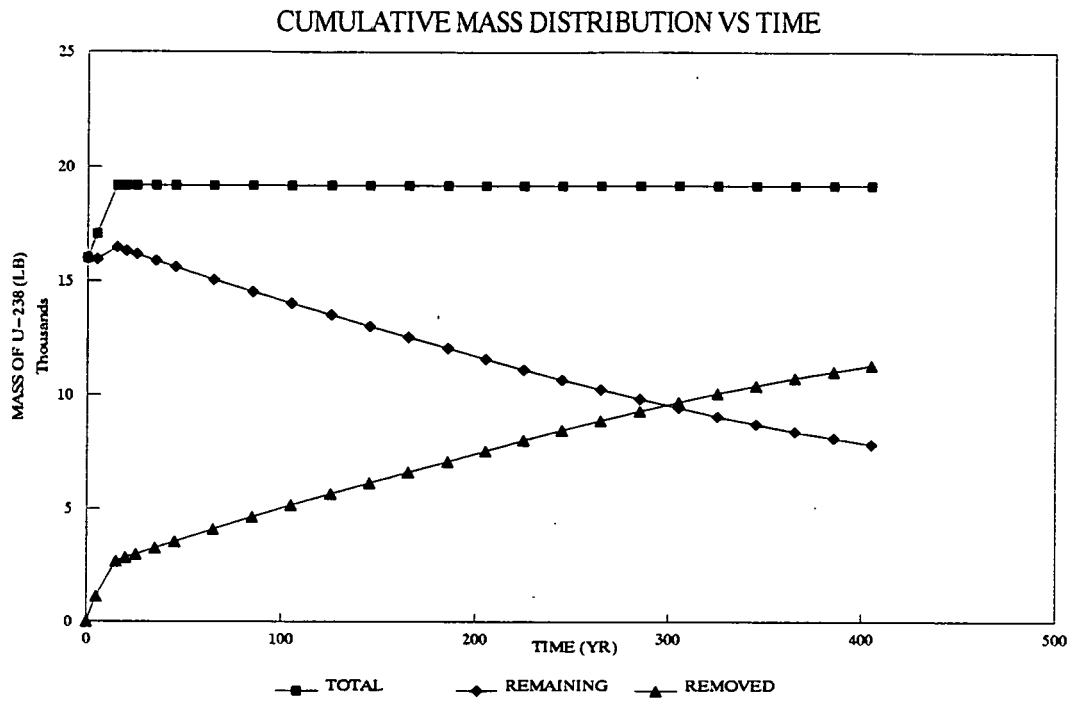


FIGURE F.7-20. NO-ADDITIONAL-ACTION, URANIUM CONCENTRATION CONTOURS, YEAR 345, LAYER 1



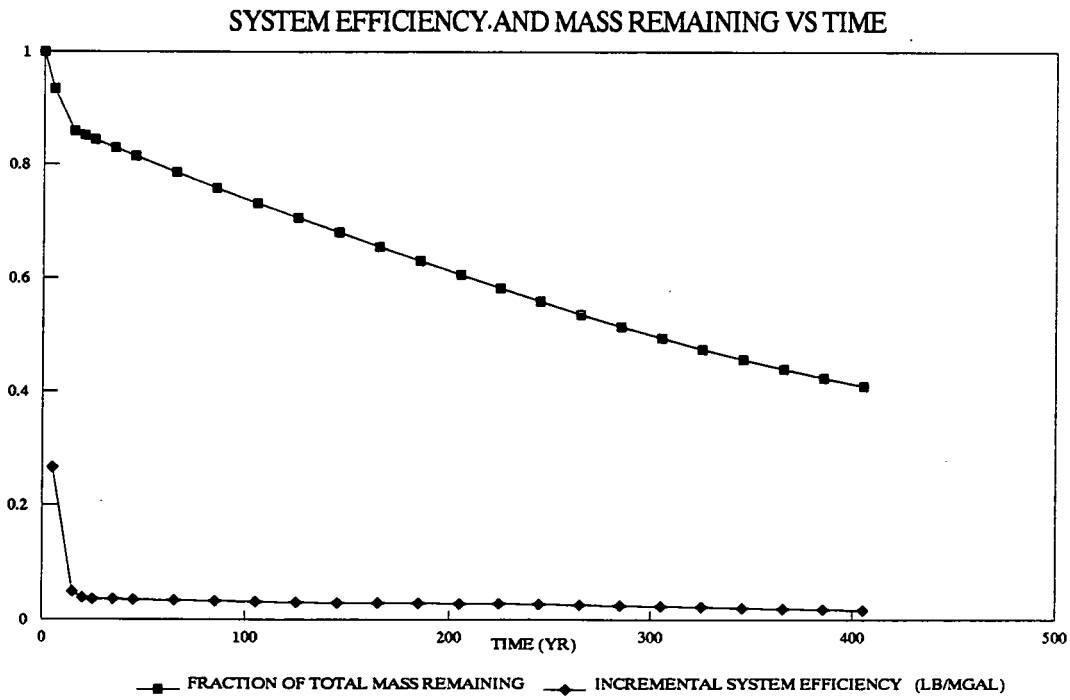


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FIGURE F.7-21. NO ADDITIONAL ACTION – HIGH Kd, SYSTEM PERFORMANCE CURVES

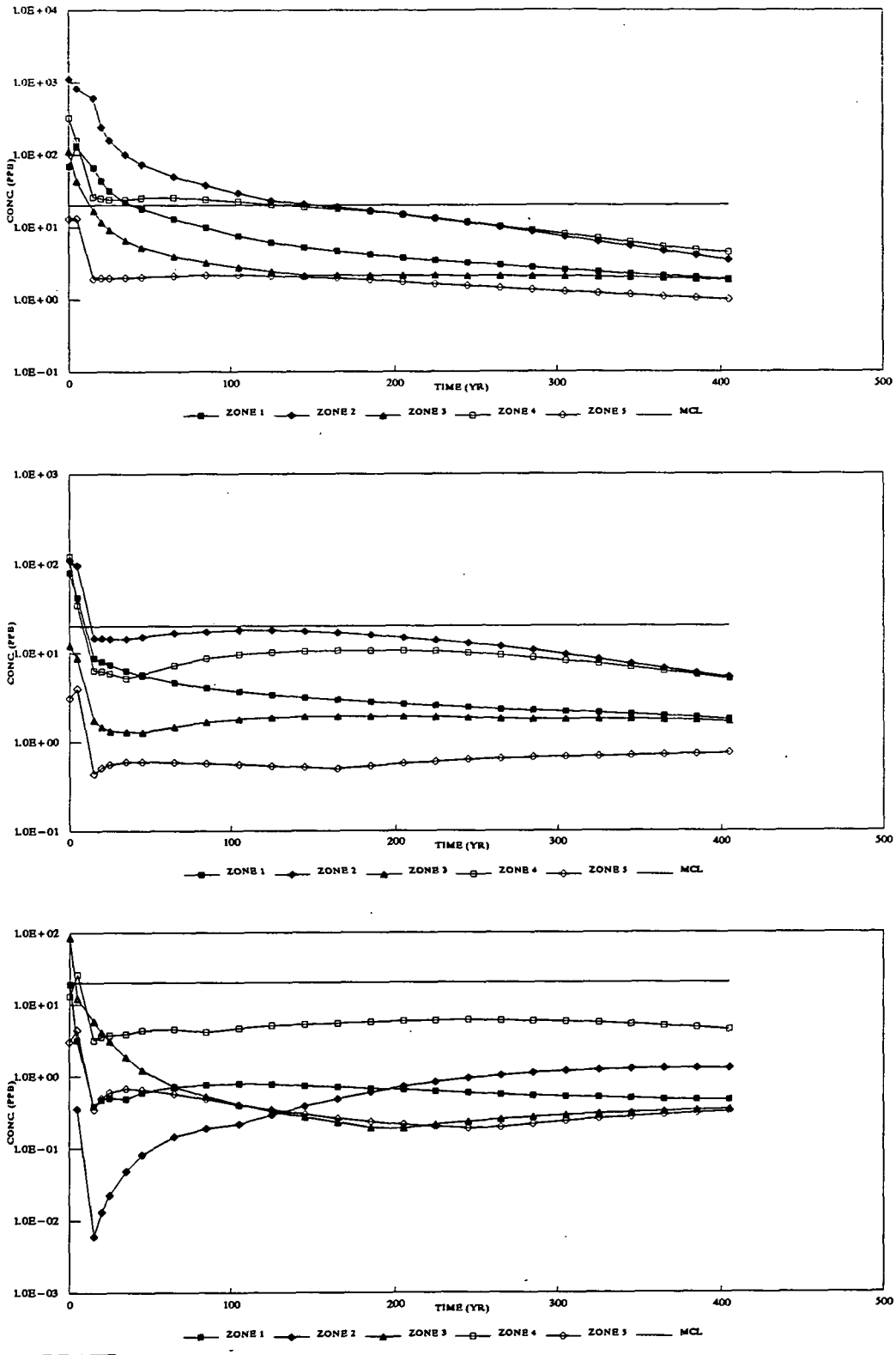

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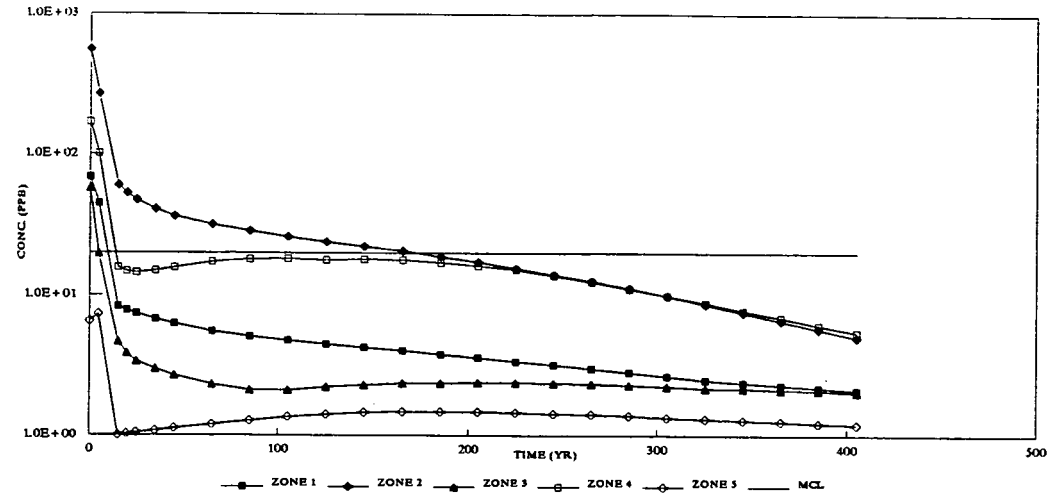
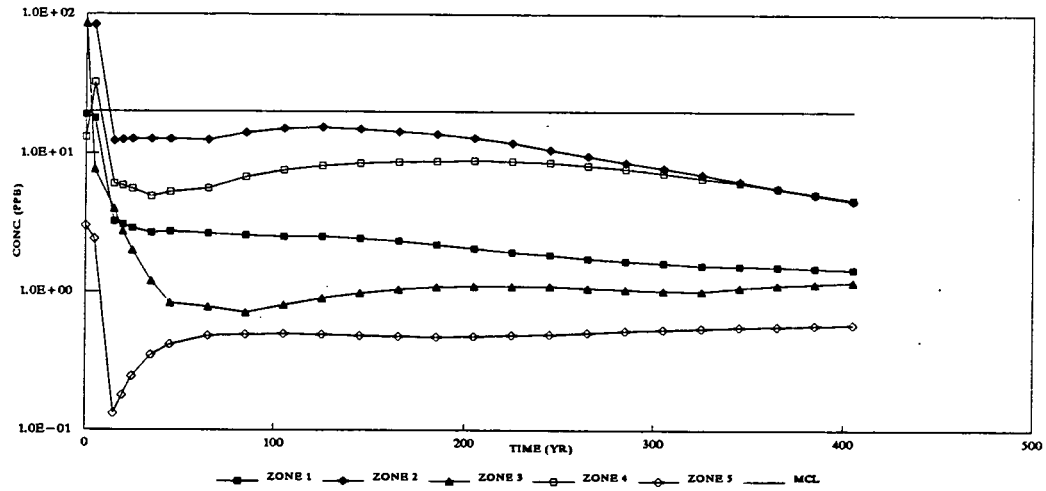
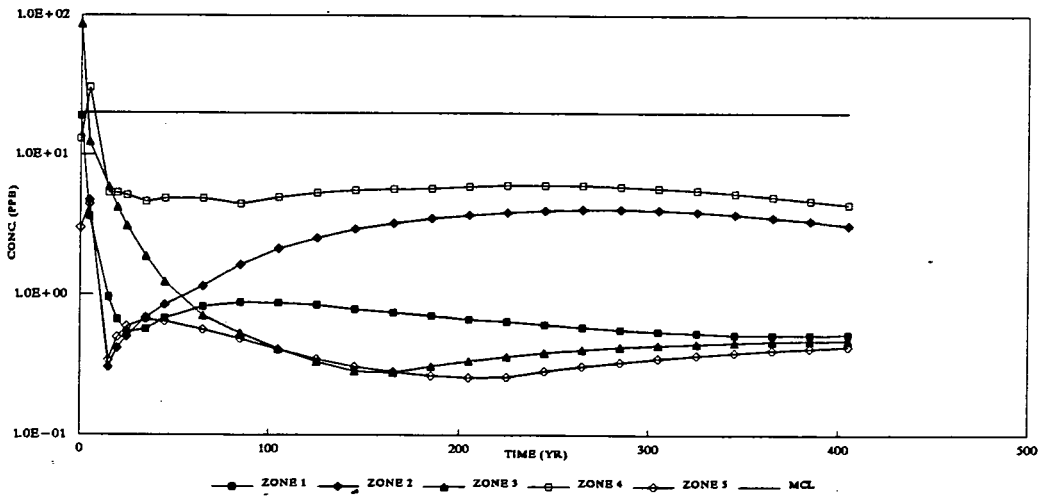
FIGURE F.7-22A. NO ADDITIONAL ACTION – HIGH Kd, MAXIMUM URANIUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.



LAYER 2



LAYER 4



LAYER 5

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FIGURE F.7-22B. NO ADDITIONAL ACTION – HIGH Kd, MAXIMUM URANIUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

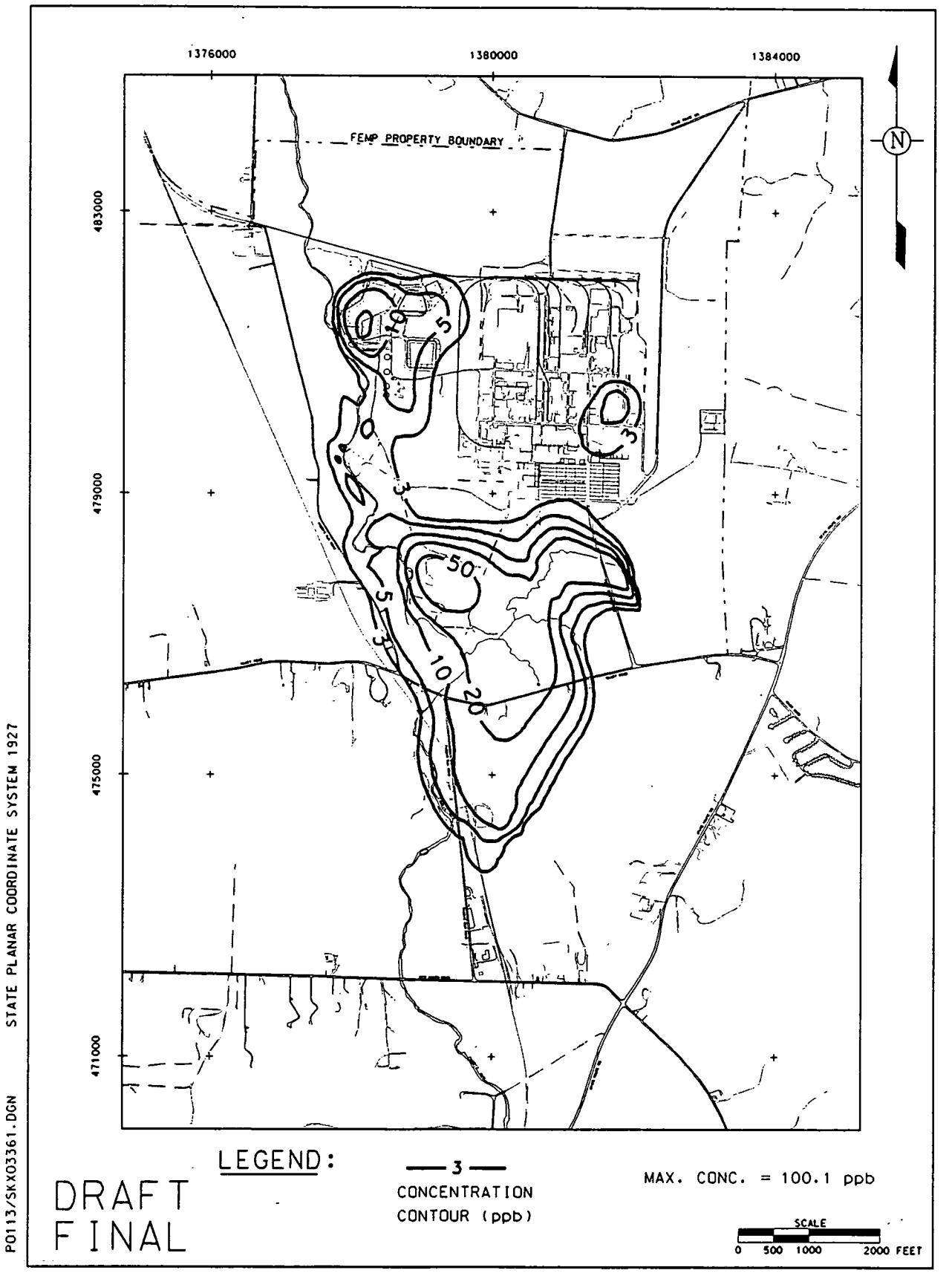


FIGURE F.7-23. NO-ADDITIONAL-ACTION - HIGH Kd. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

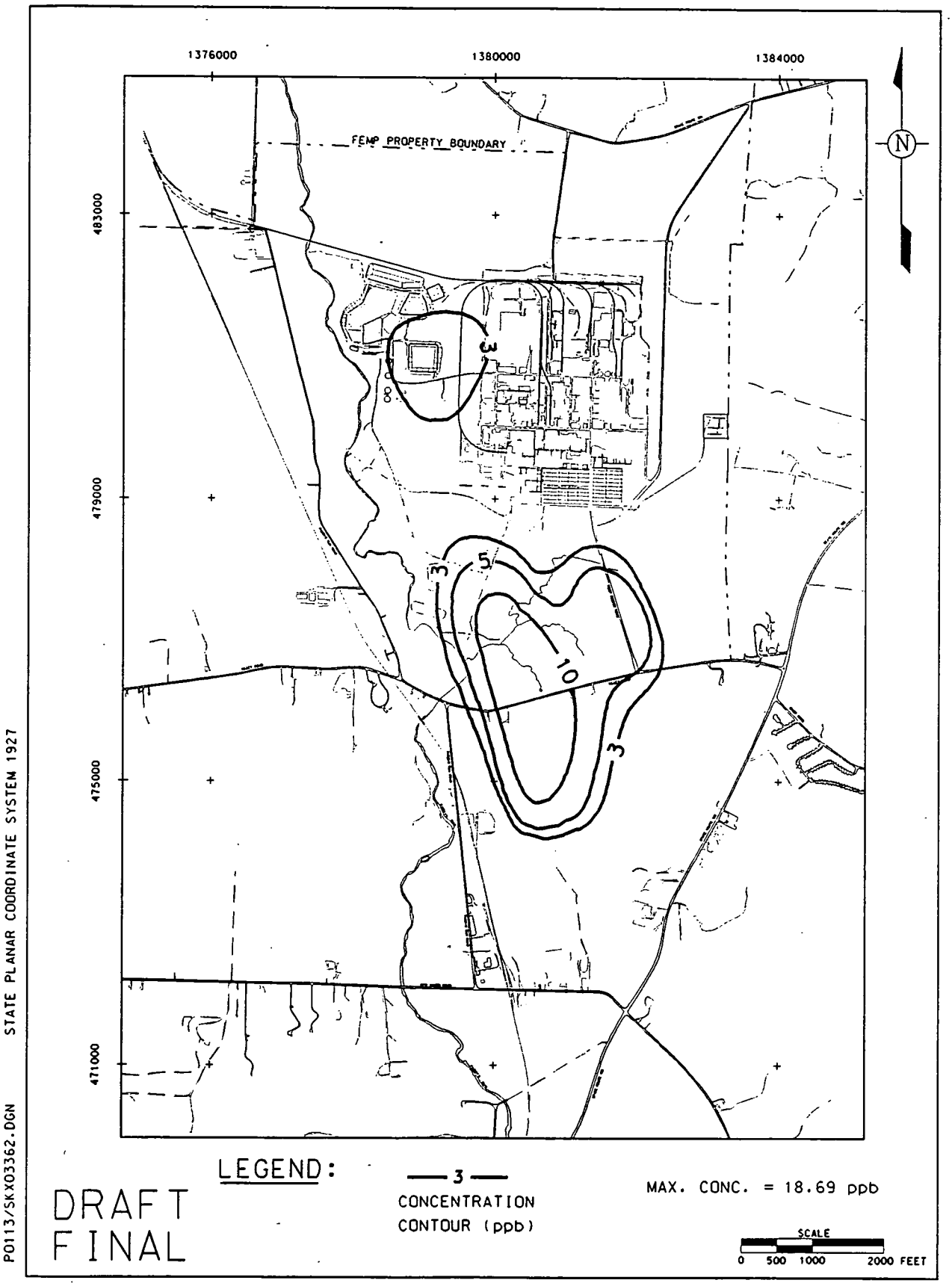


FIGURE F.7-24. NO-ADDITIONAL-ACTION - HIGH Kd. CONCENTRATION CONTOURS. YEAR 150. LAYER 1

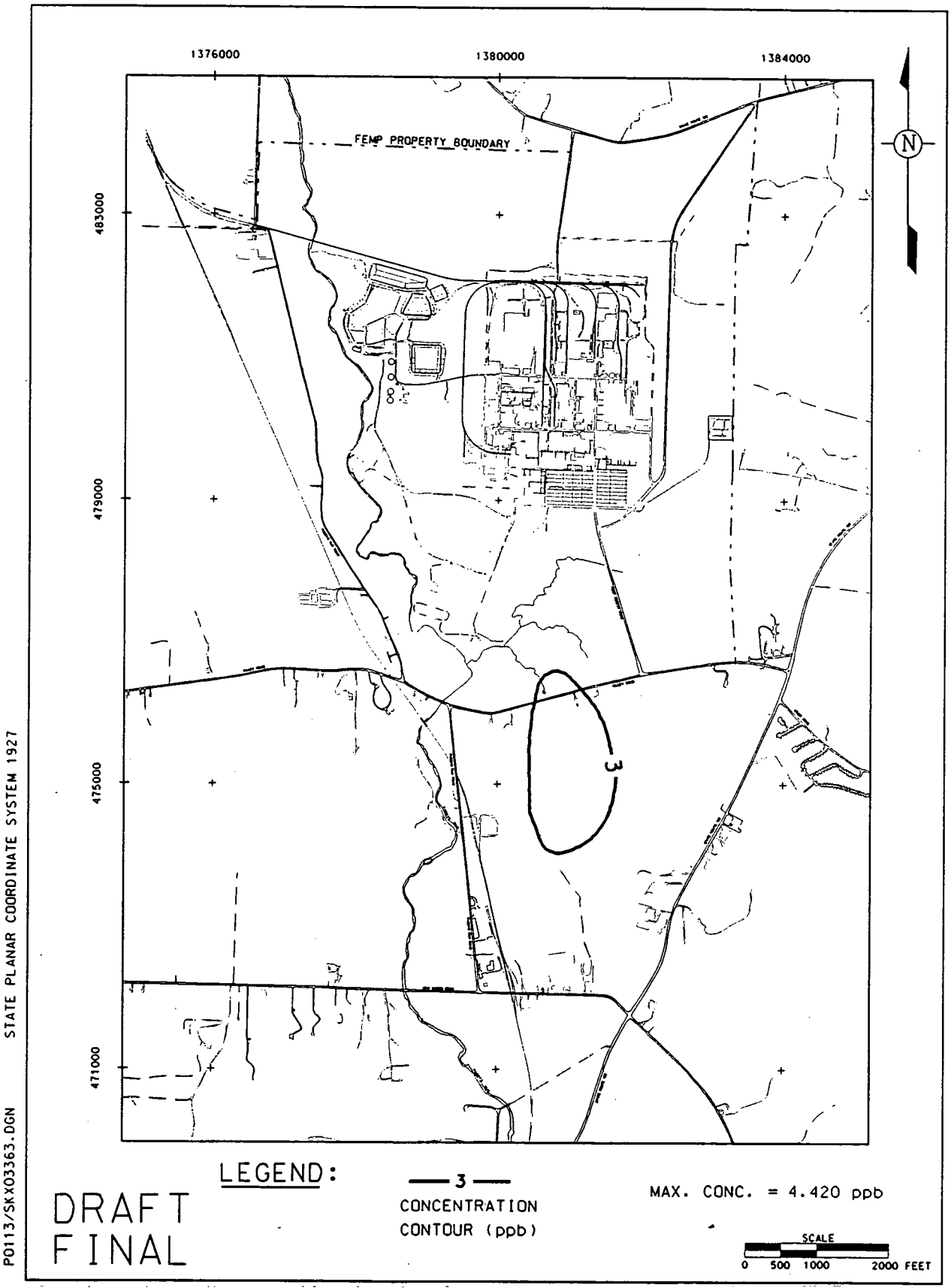


FIGURE F.7-25. NO-ADDITIONAL-ACTION - HIGH Kd, CONCENTRATION CONTOURS, YEAR 400, LAYER 1

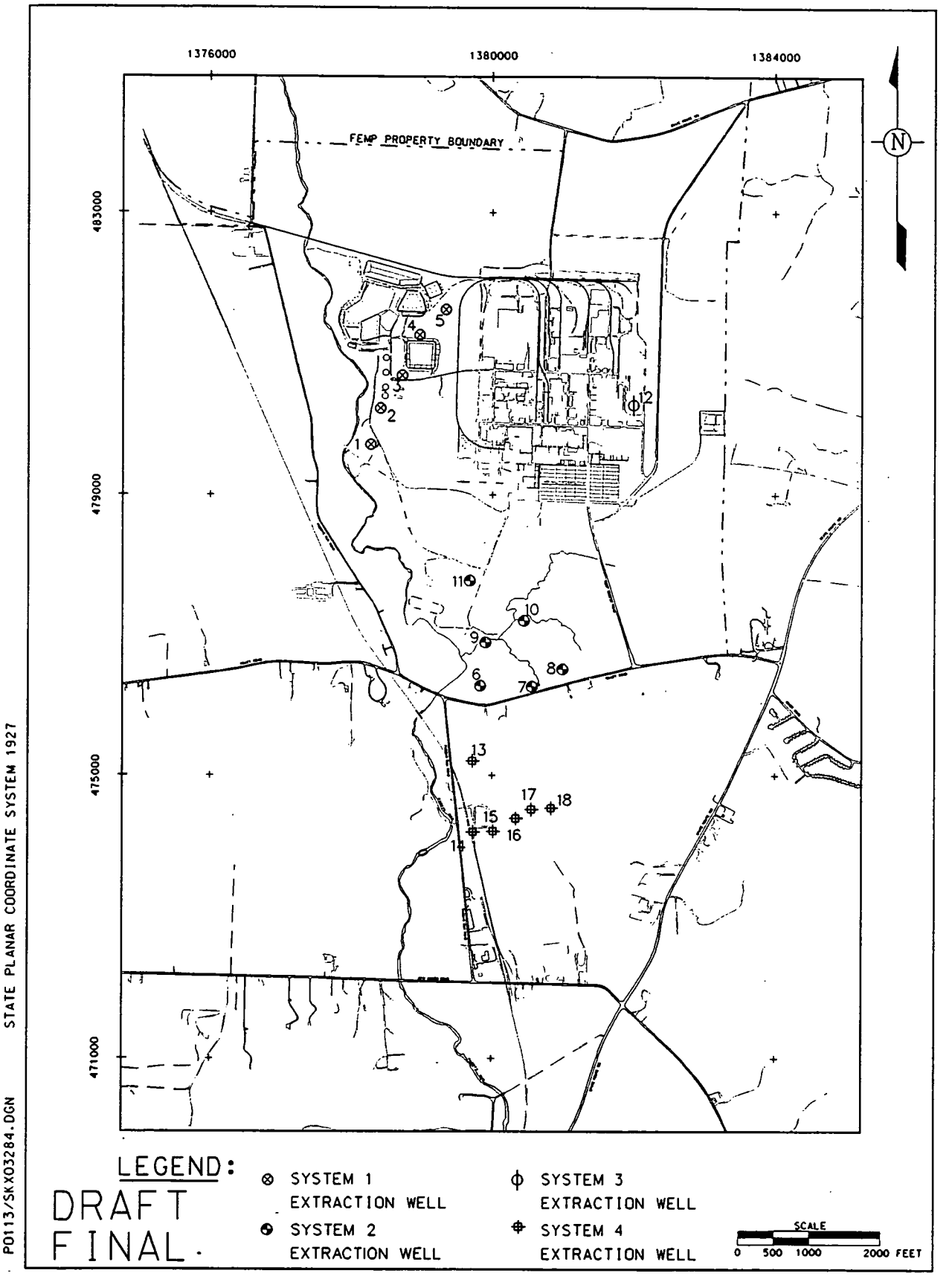
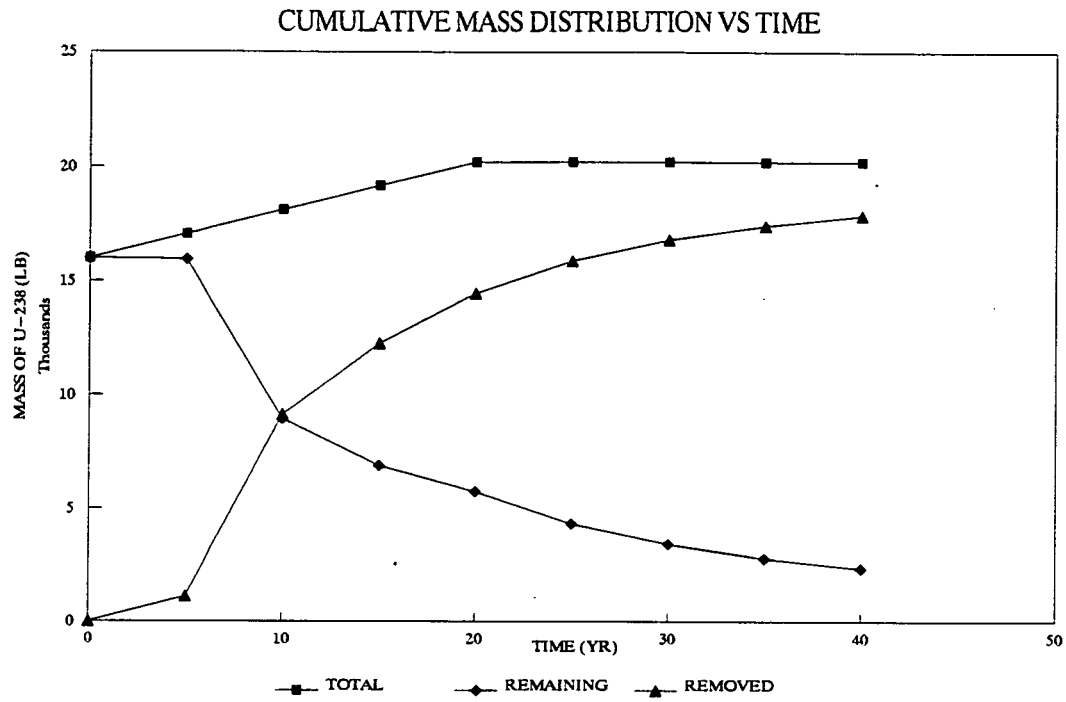


FIGURE F.7-26. SCENARIO 1 (RESTORATION TO 20 ppb). WELL LOCATIONS



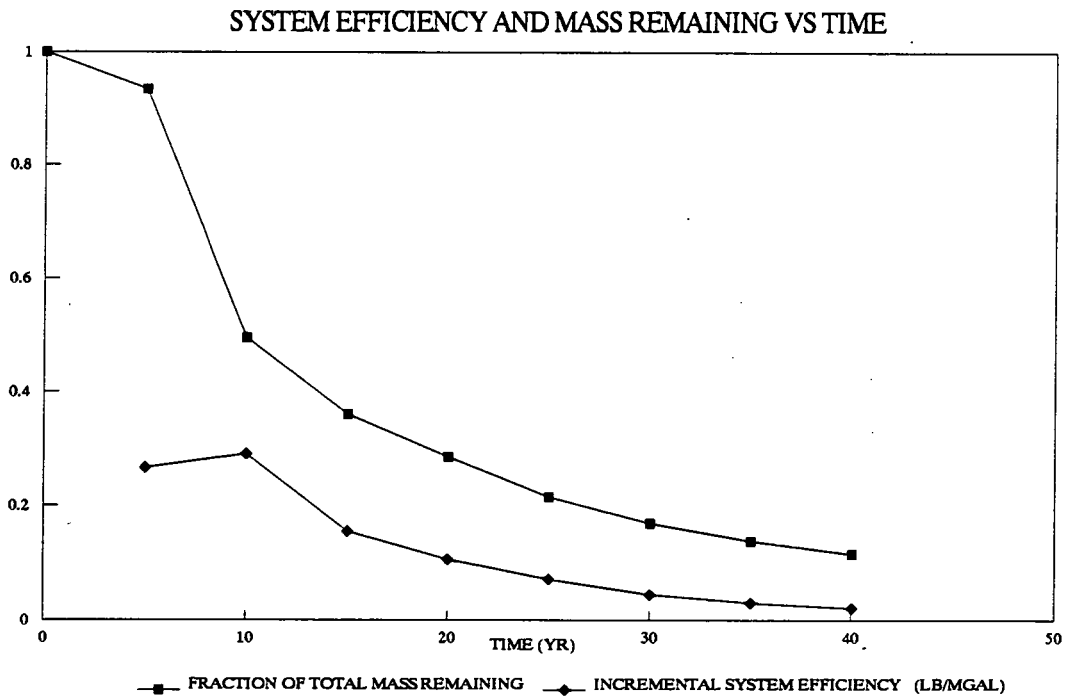


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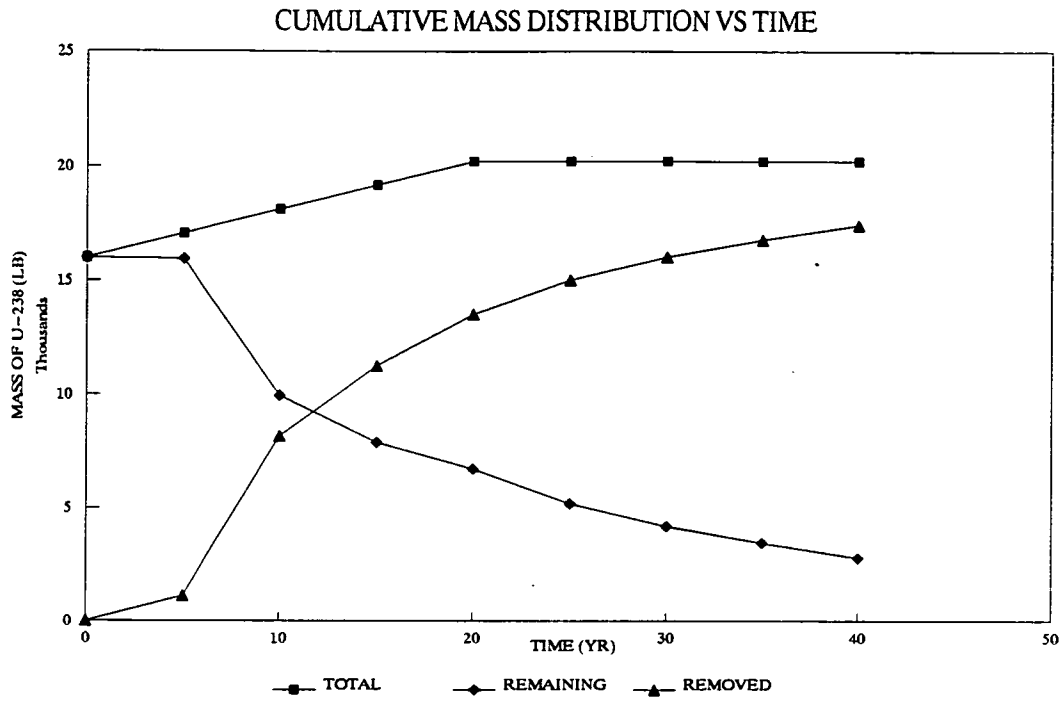
FIGURE F.7-27. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1A, SYSTEM PERFORMANCE CURVES



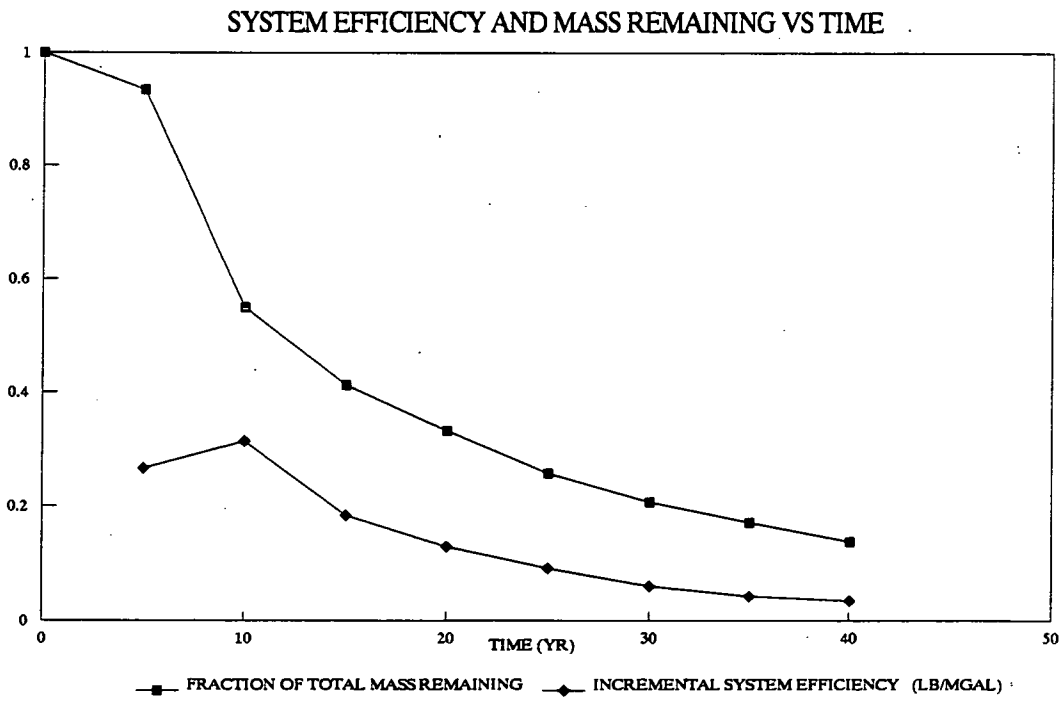


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FIGURE F.7-28. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1B, SYSTEM PERFORMANCE CURVES

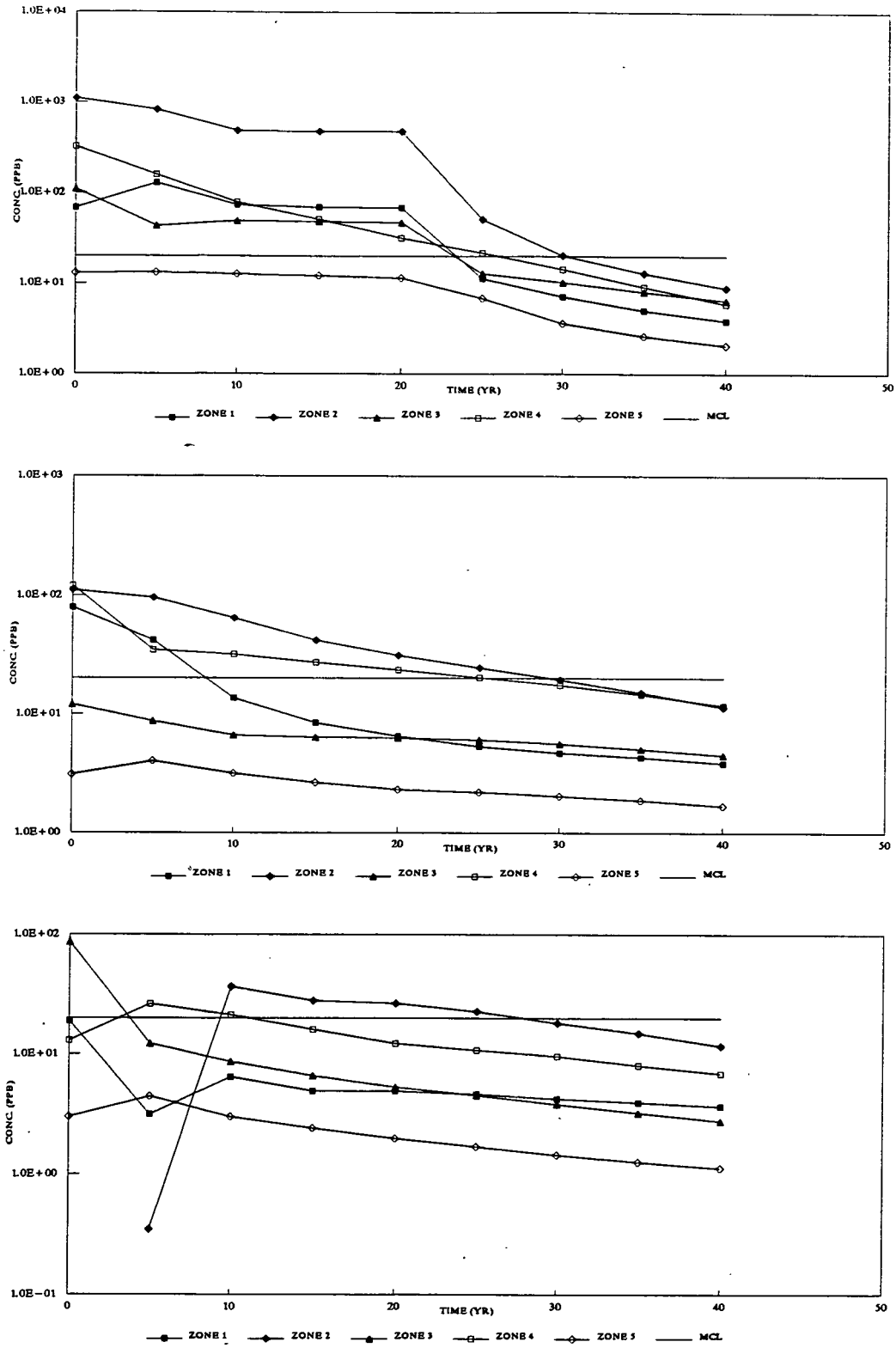

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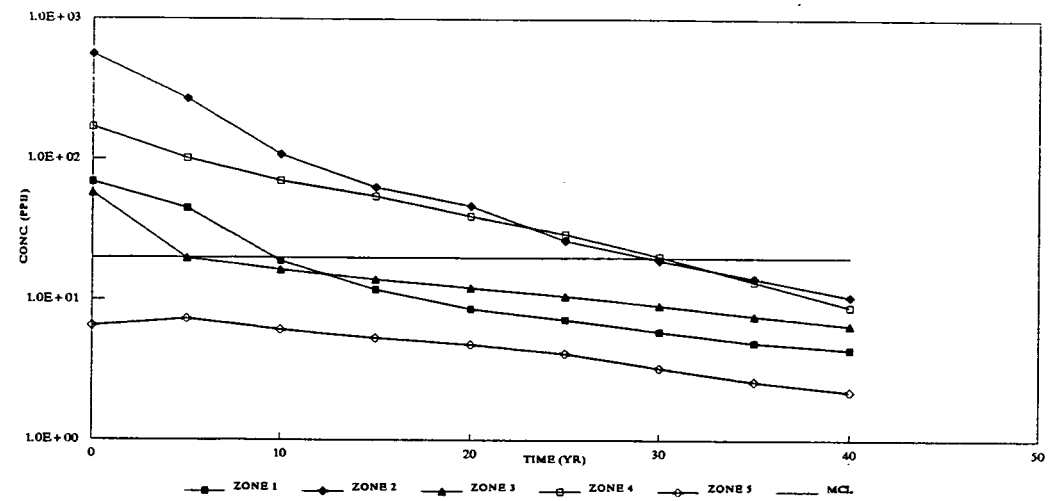
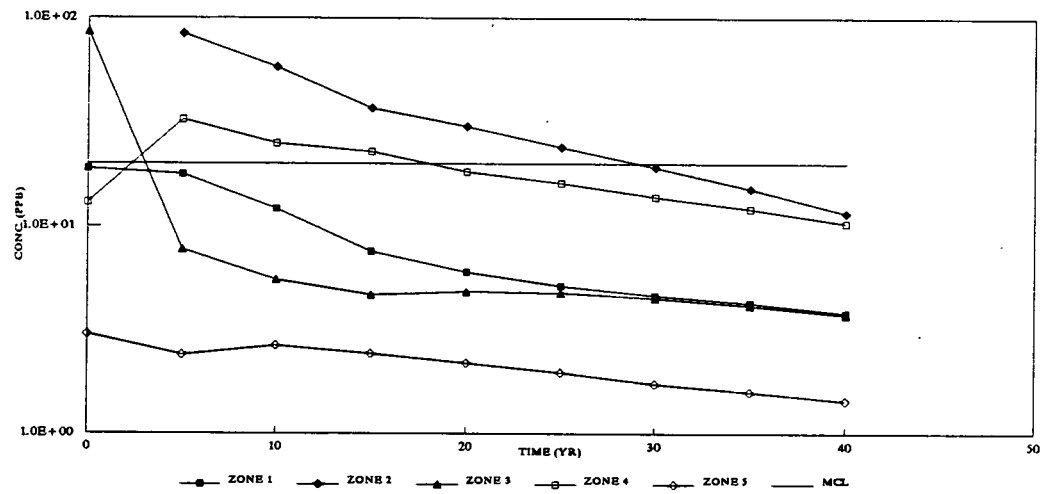
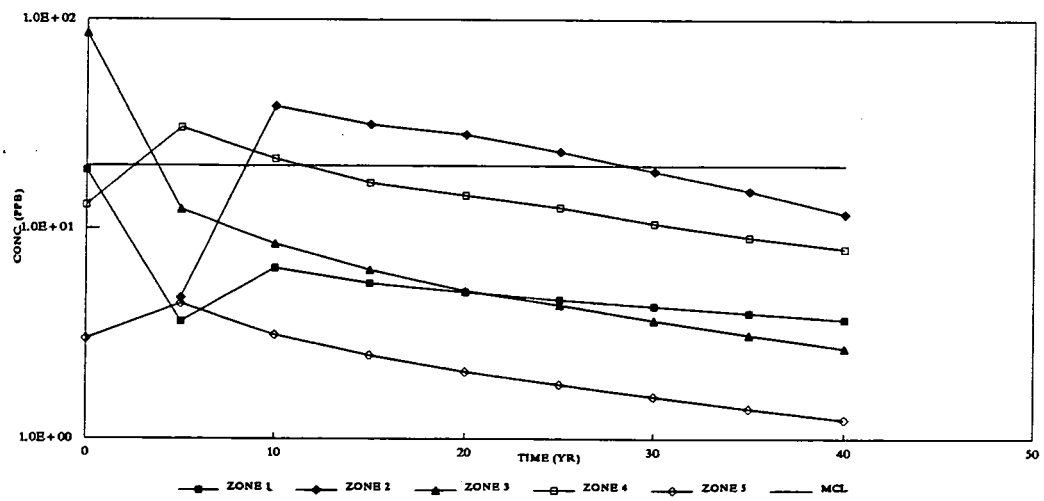
FIGURE F.7-29A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1A, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.



LAYER 2



LAYER 4



LAYER 5

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FIGURE F.7–29B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1A, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

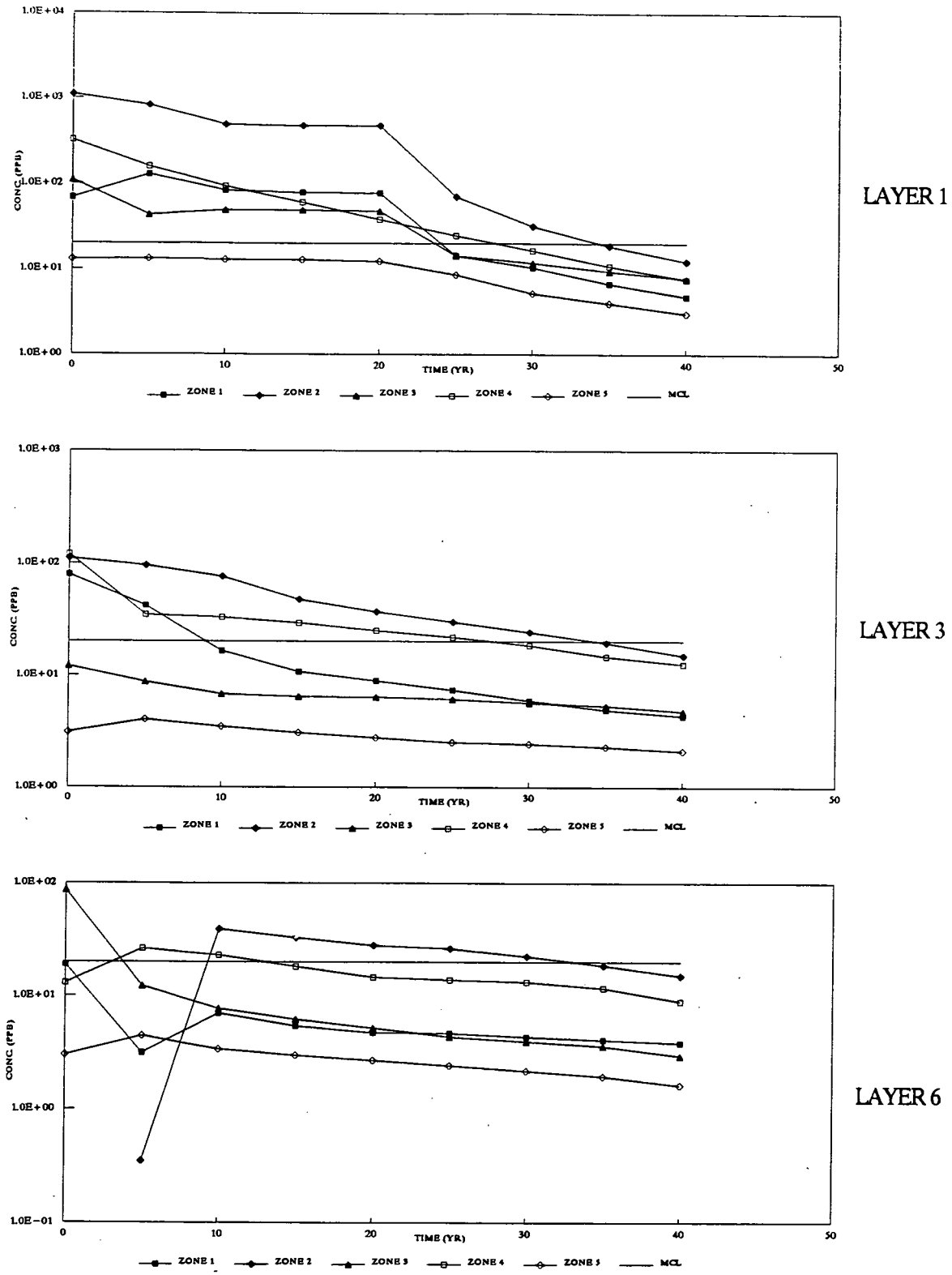

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FIGURE F.7-30A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1B, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

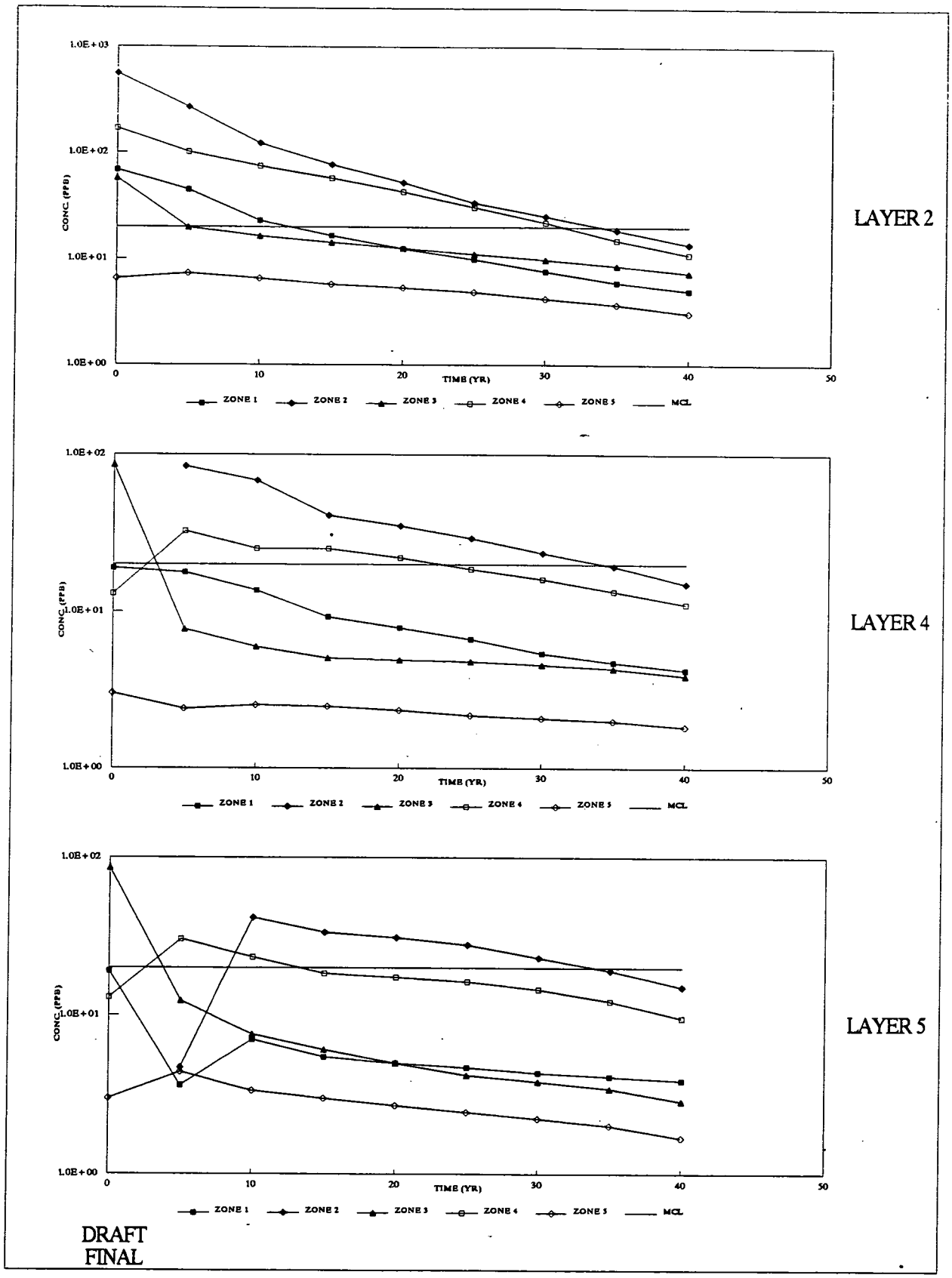


FIGURE F.7-30B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 1B, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

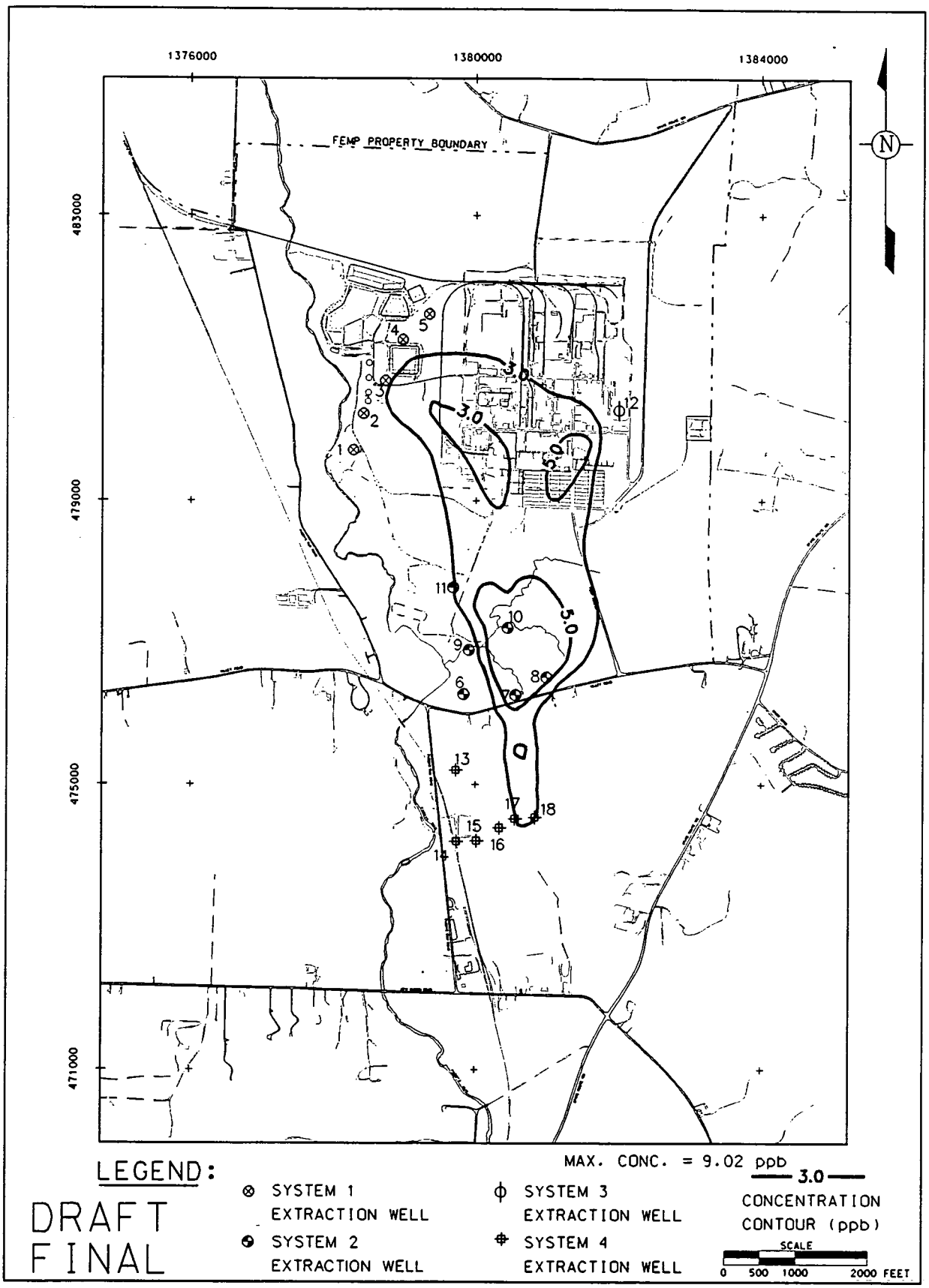


FIGURE F.7-31. SCENARIO 1A, URANIUM CONCENTRATION CONTOURS, YEAR 40, LAYER 1

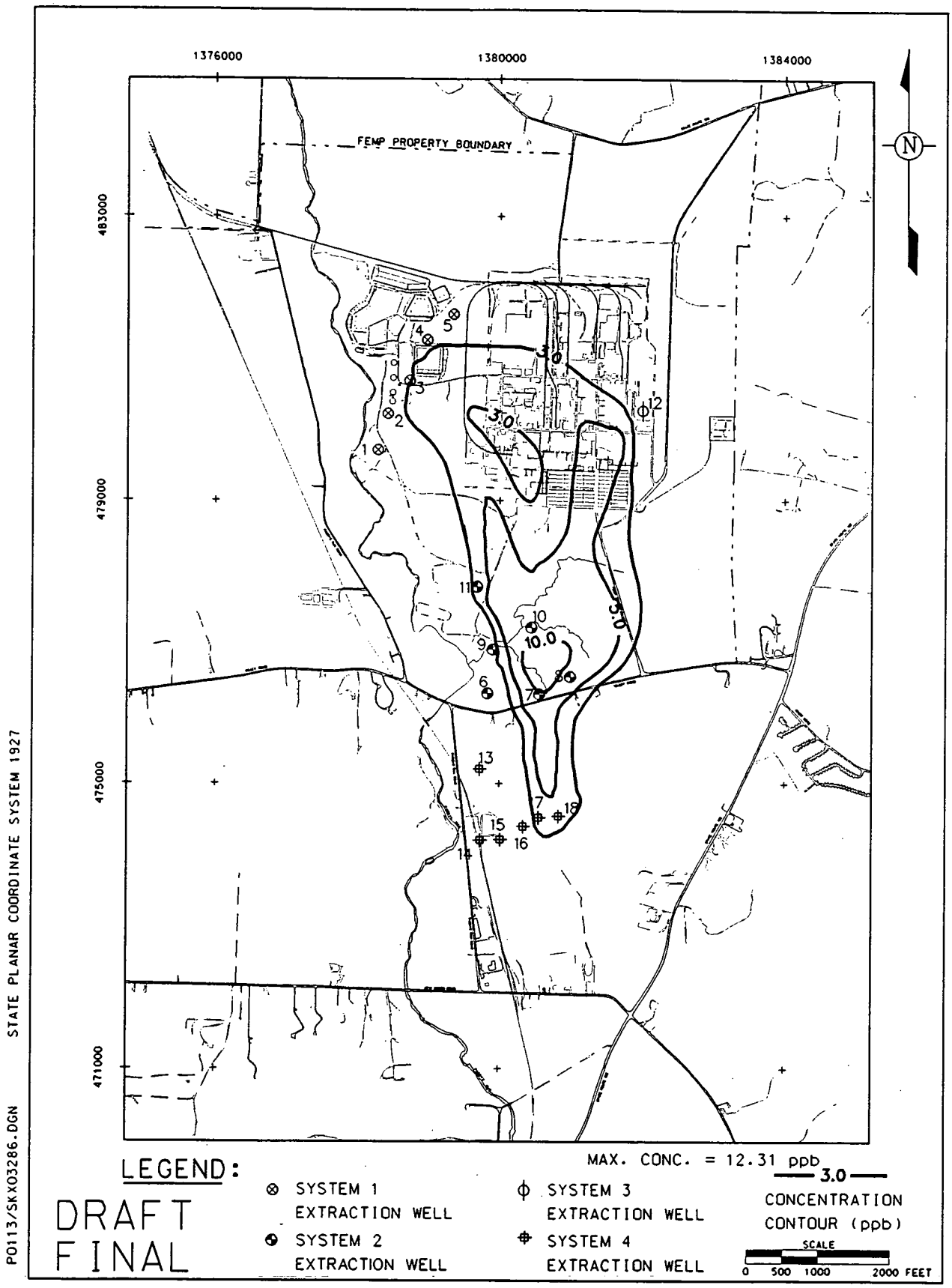


FIGURE F.7-32. SCENARIO 1B, URANIUM CONCENTRATION CONTOURS, YEAR 40, LAYER 1

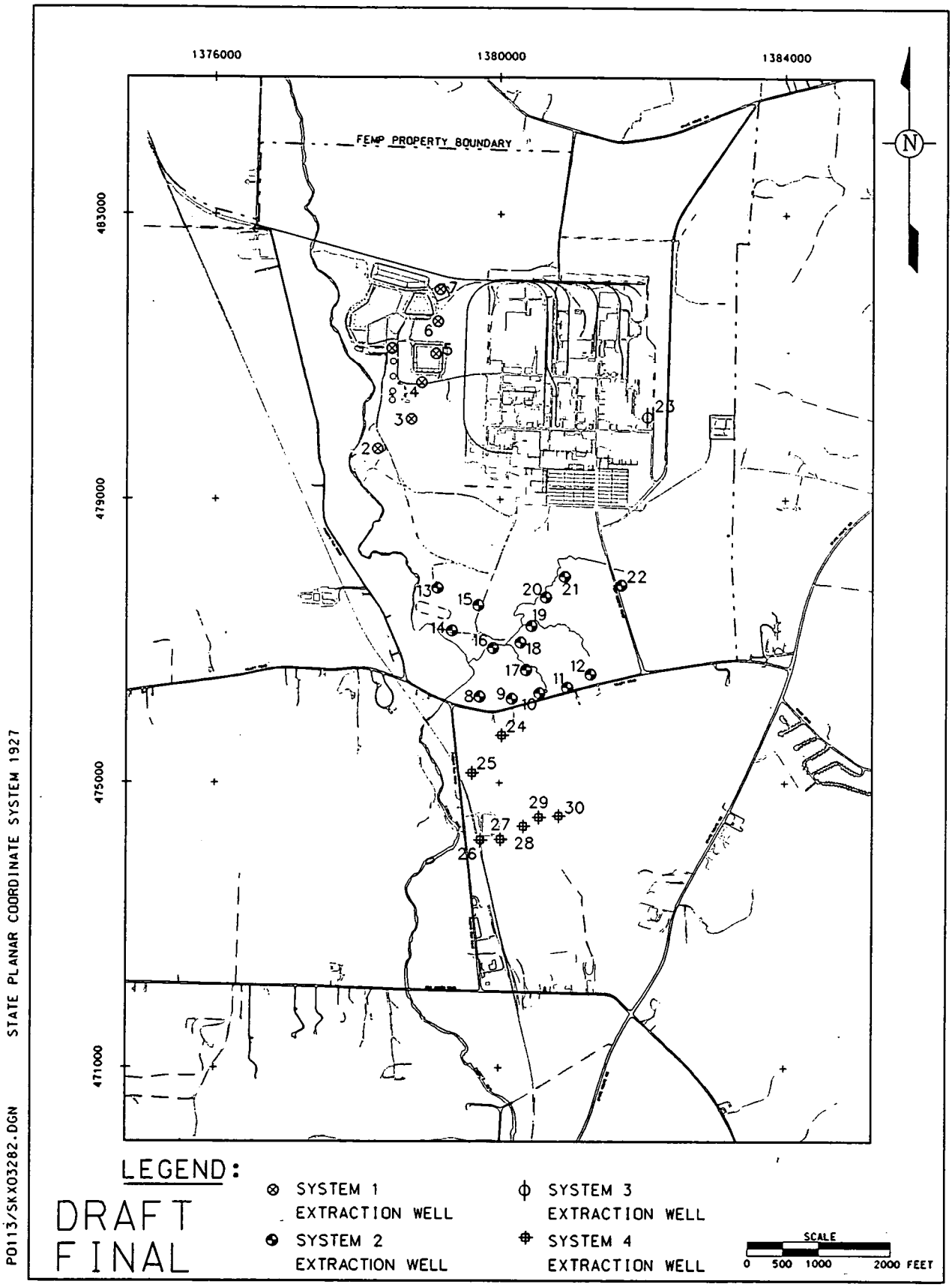
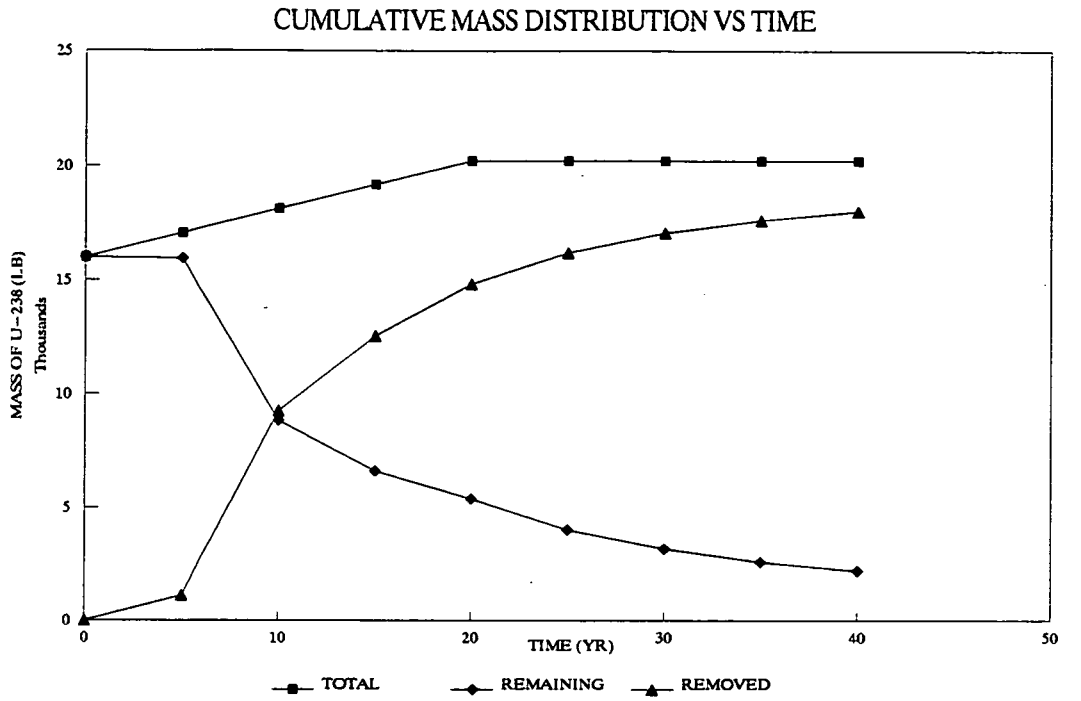


FIGURE F.7-33. SCENARIO 2 (RESTORATION TO 20 ppb). WELL LOCATIONS



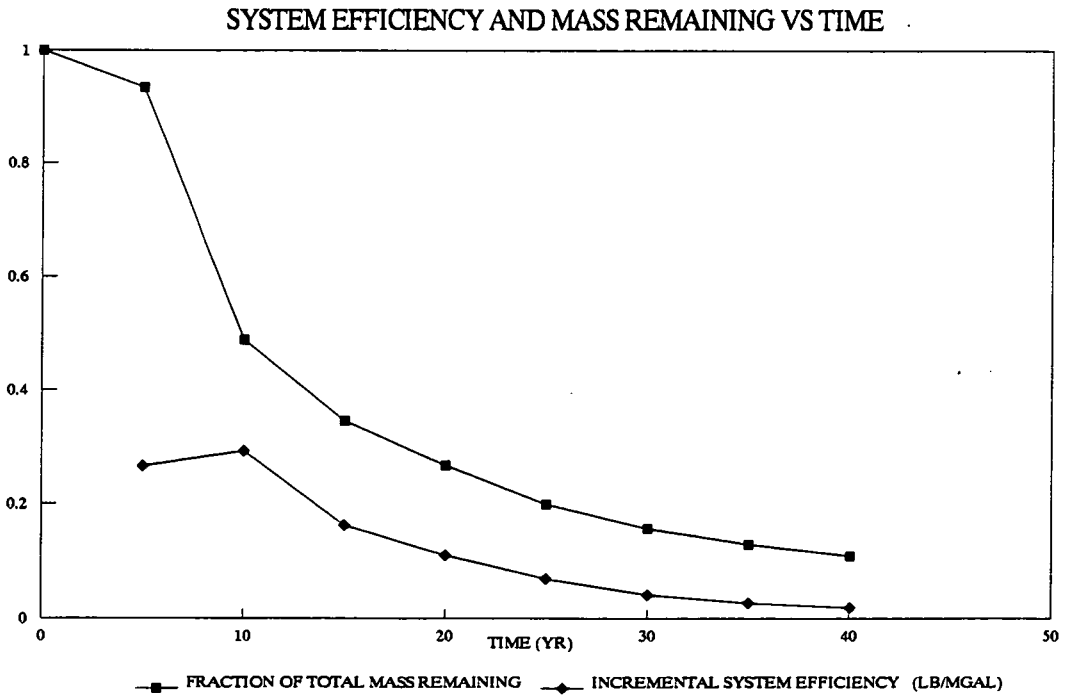


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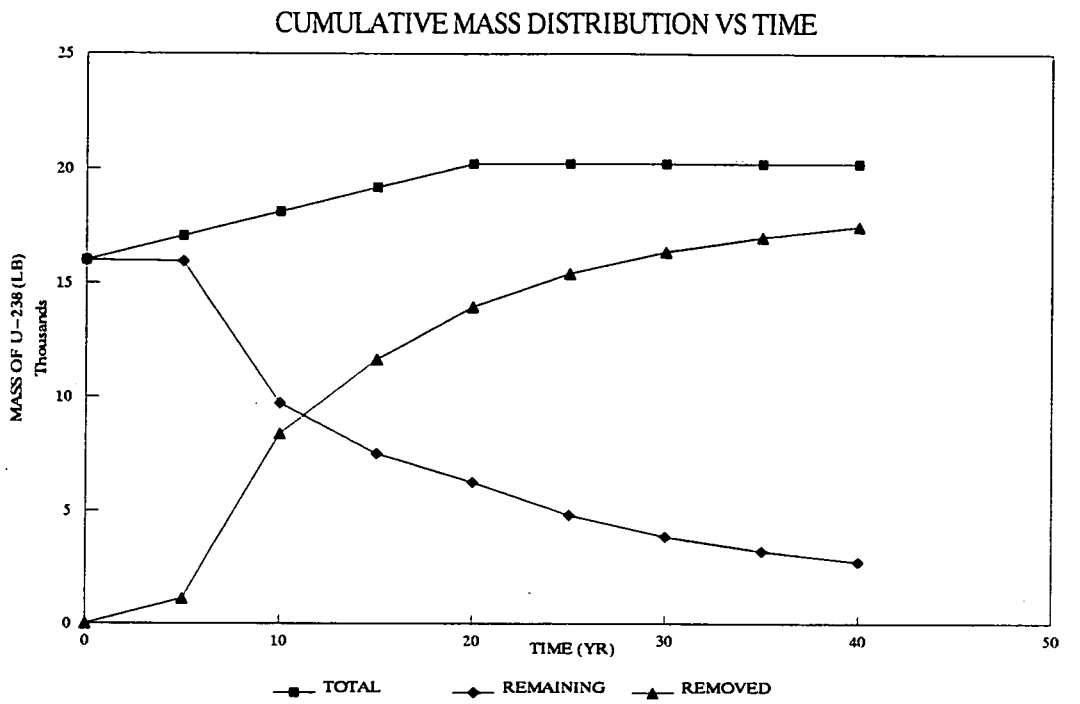
FIGURE F.7-34. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2A, SYSTEM PERFORMANCE CURVES



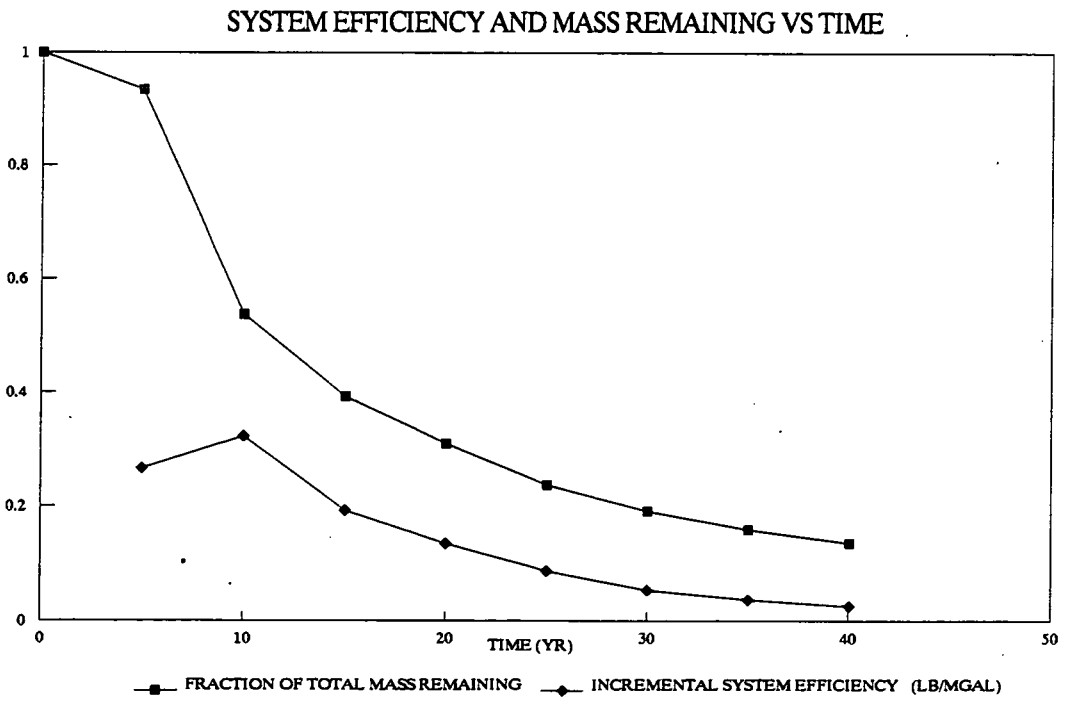


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FIGURE F.7-35. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2B, SYSTEM PERFORMANCE CURVES

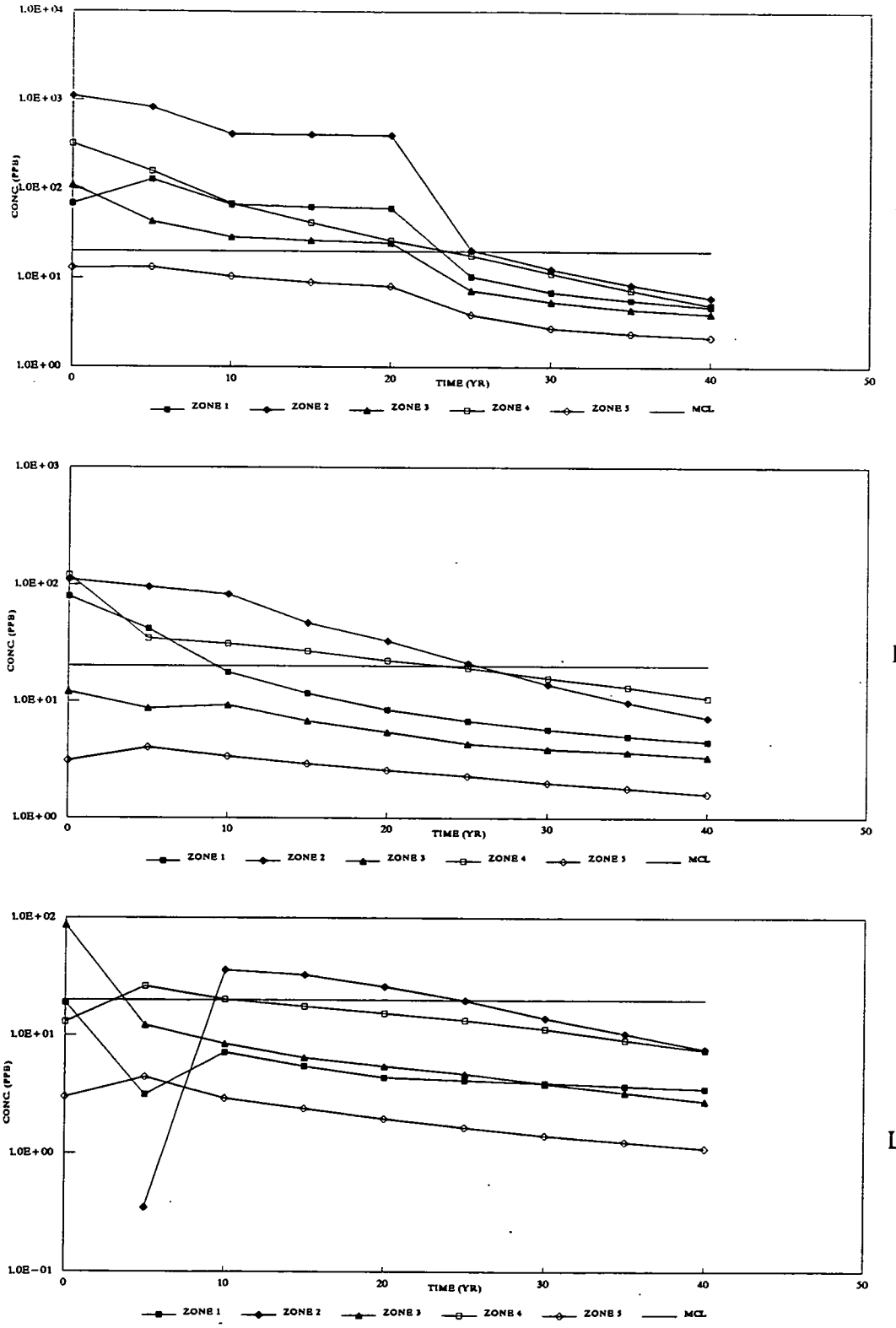

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FIGURE F.7-36A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2A, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

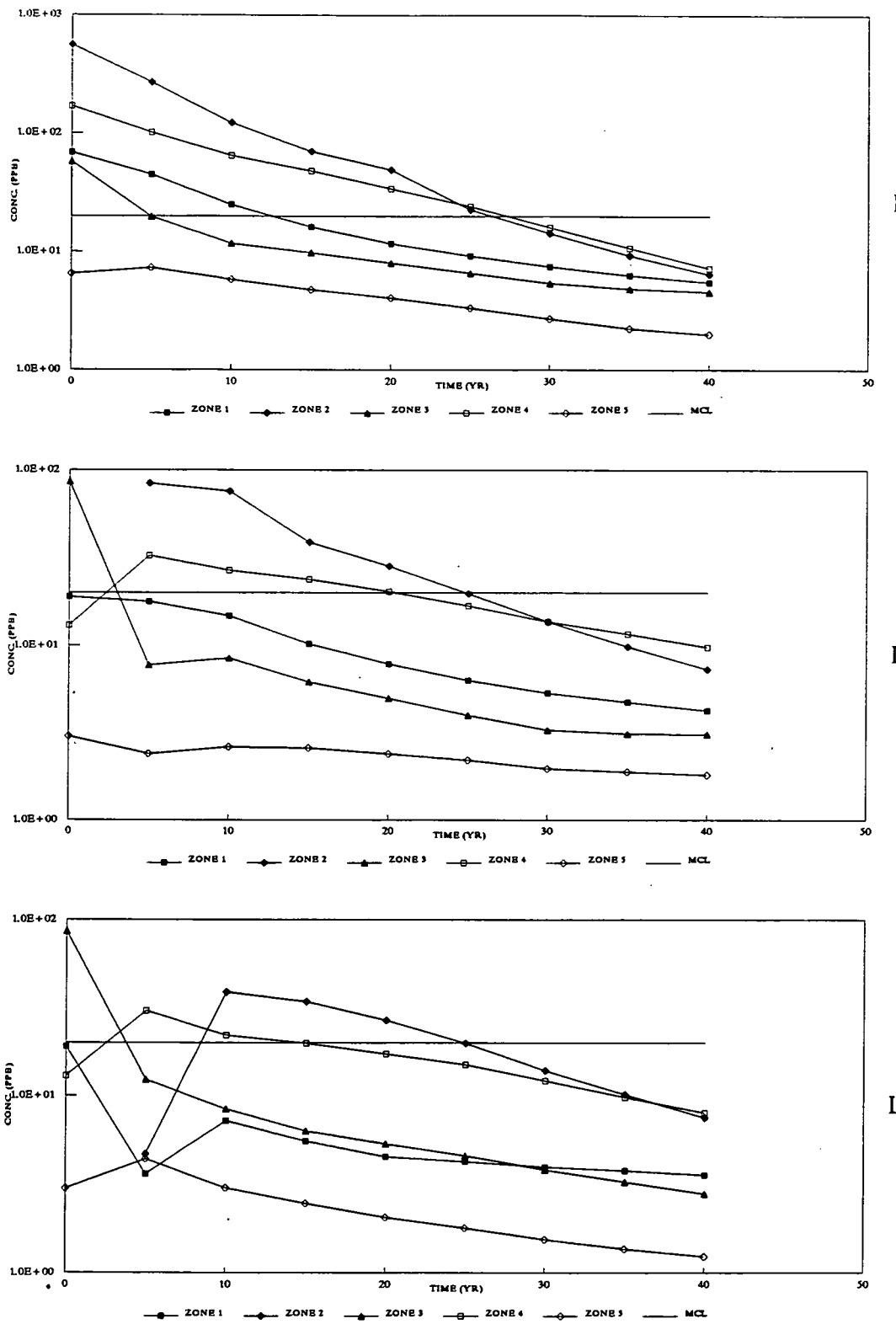

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FIGURE F.7–36B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2A, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

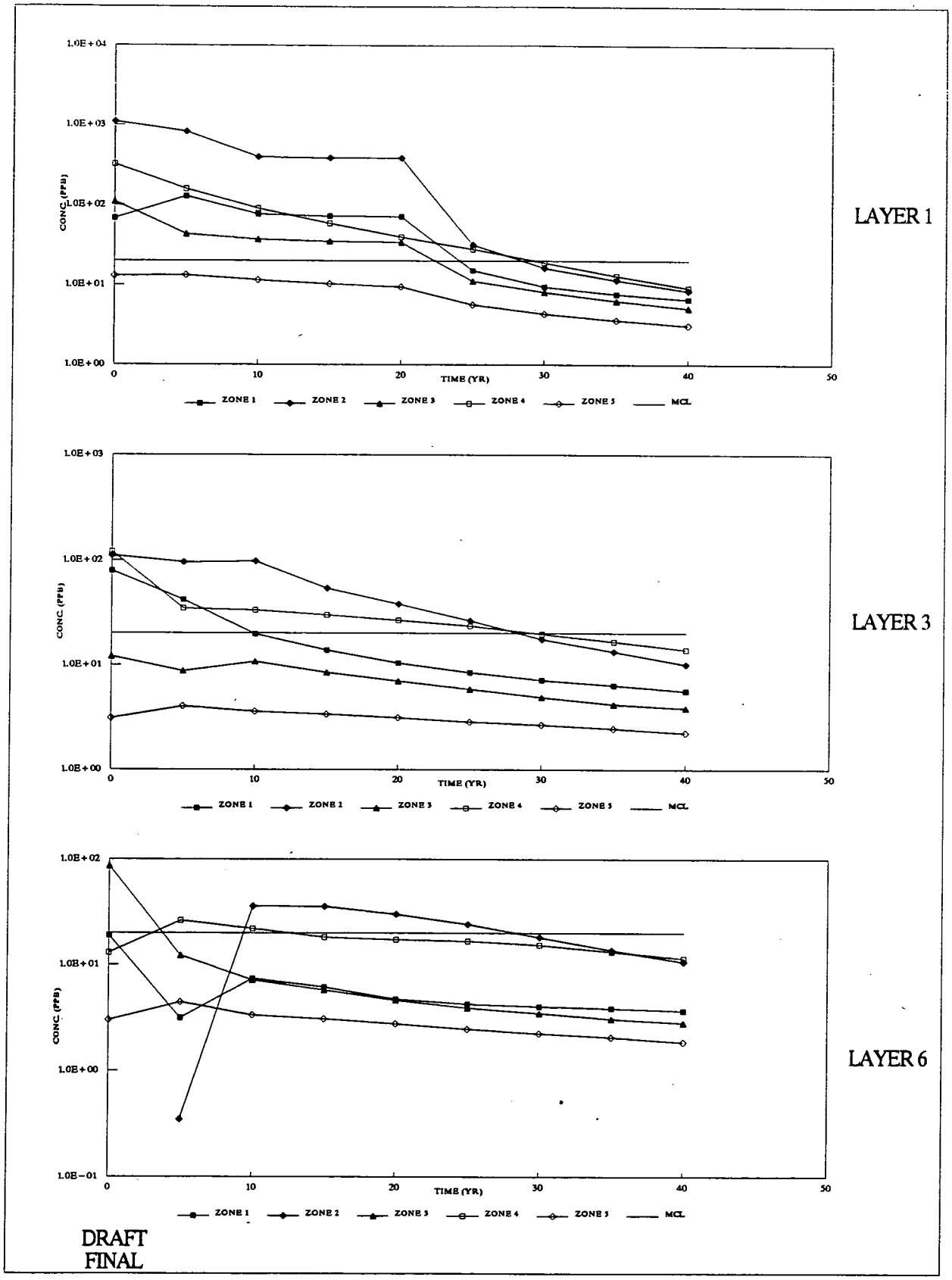

FIGURE F.7-37A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2B, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

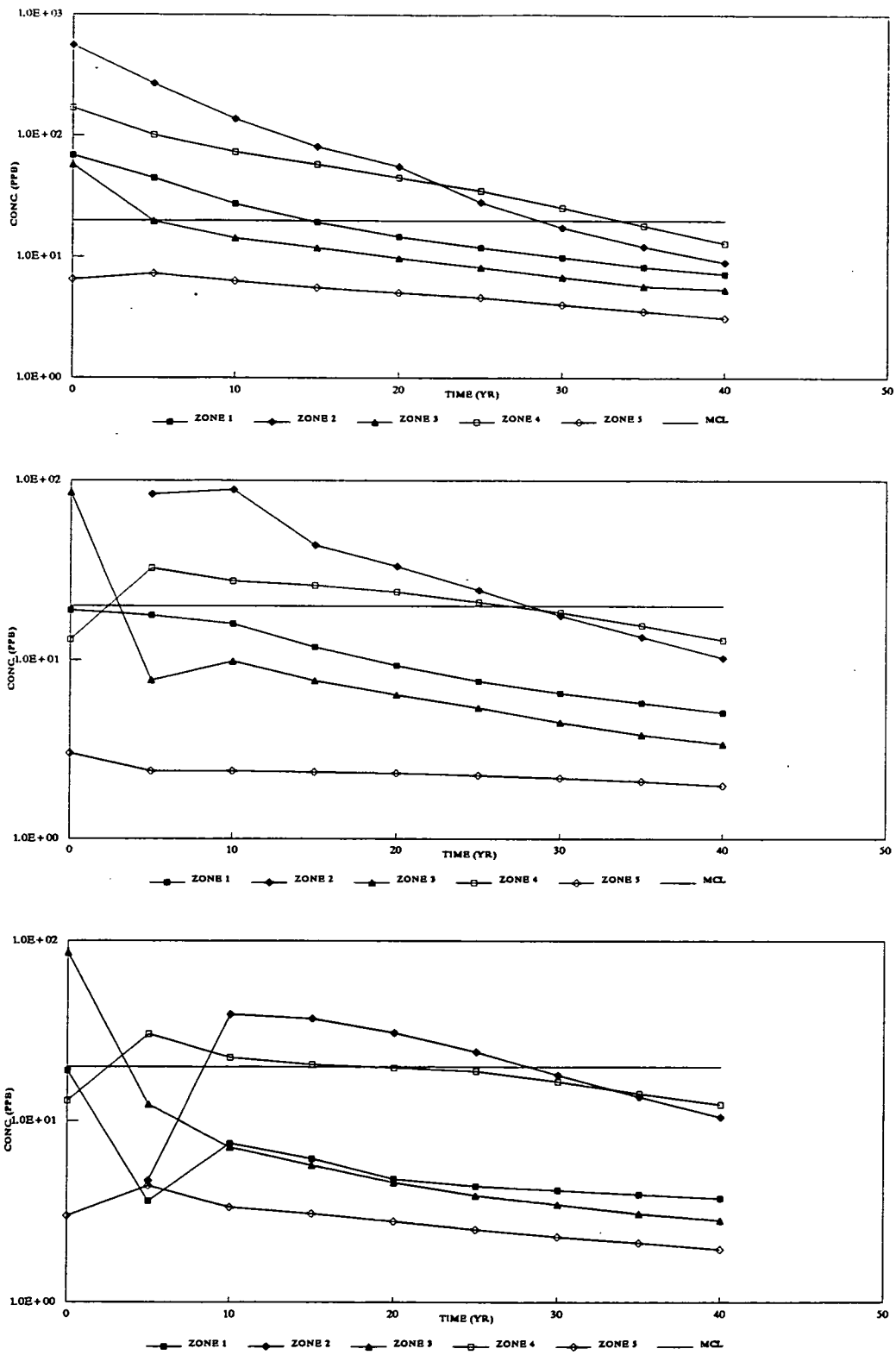

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FIGURE F.7-37B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 2B, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

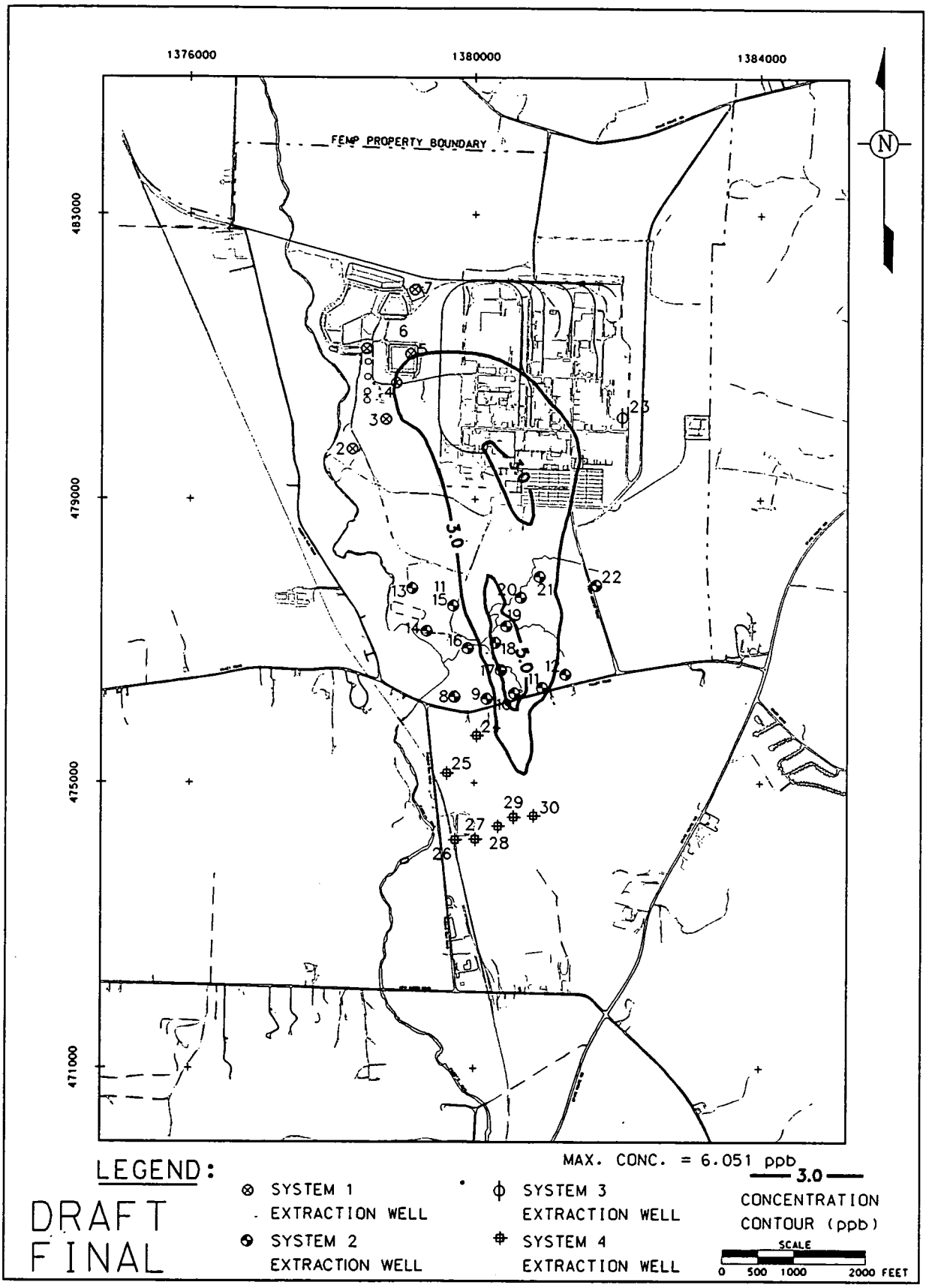

FIGURE F.7-38. SCENARIO 2A. URANIUM CONCENTRATION CONTOURS. YEAR 40. LAYER 1

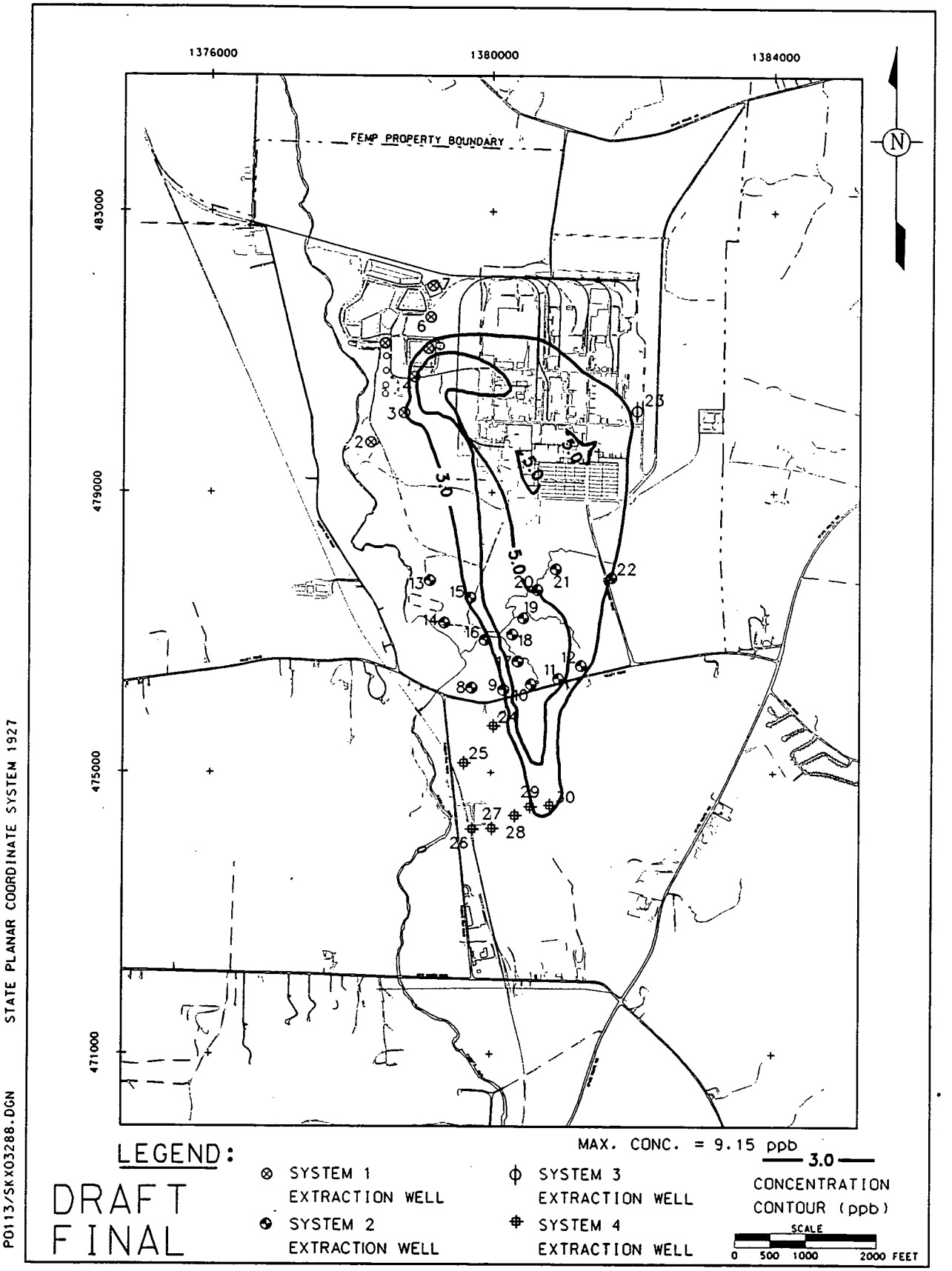

FIGURE F.7-39. SCENARIO 2B. URANIUM CONCENTRATION CONTOURS. YEAR 40. LAYER 1

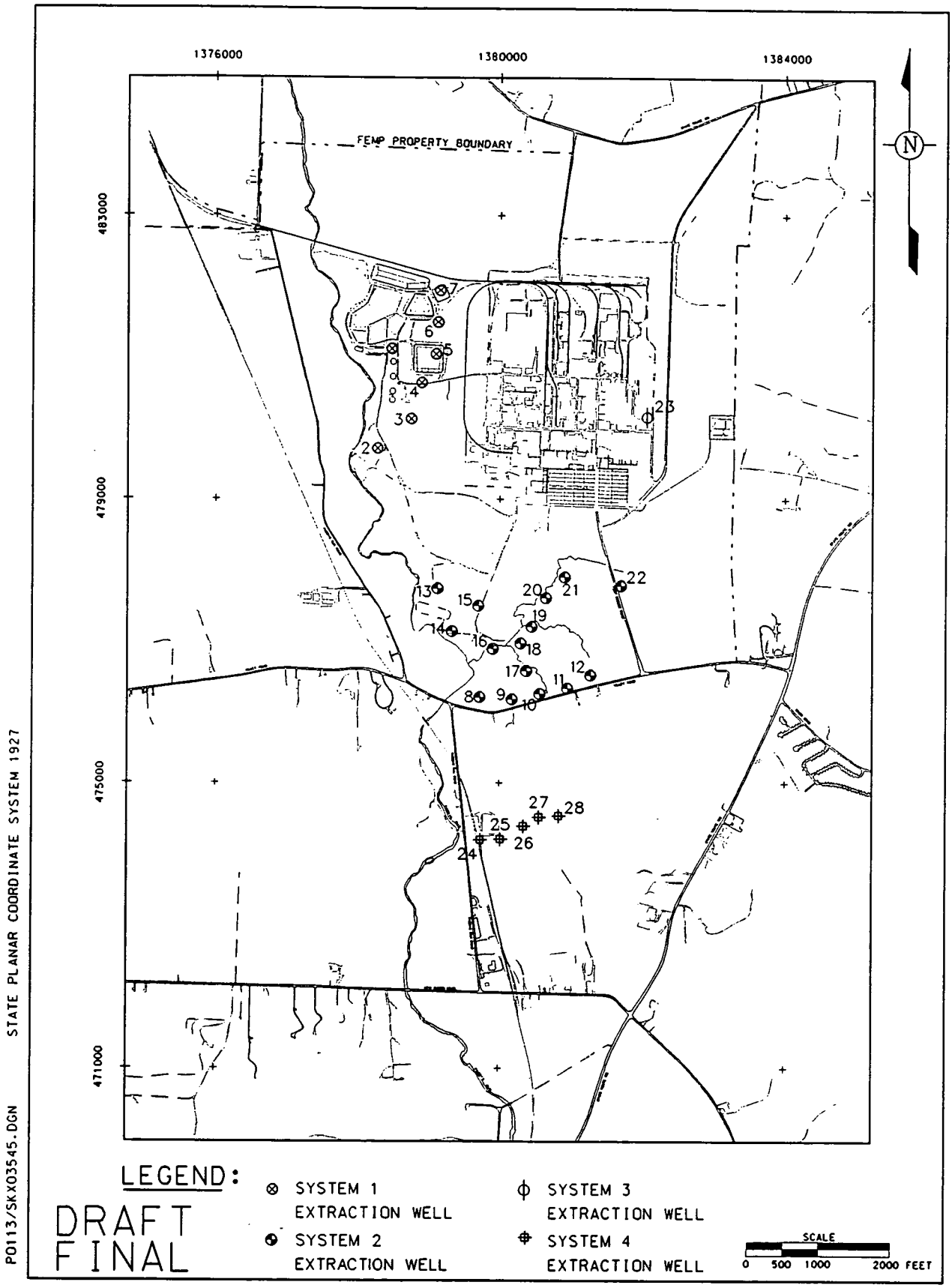

FIGURE F.7-40. SCENARIO 3 (RESTORATION TO 20 ppb). WELL LOCATIONS

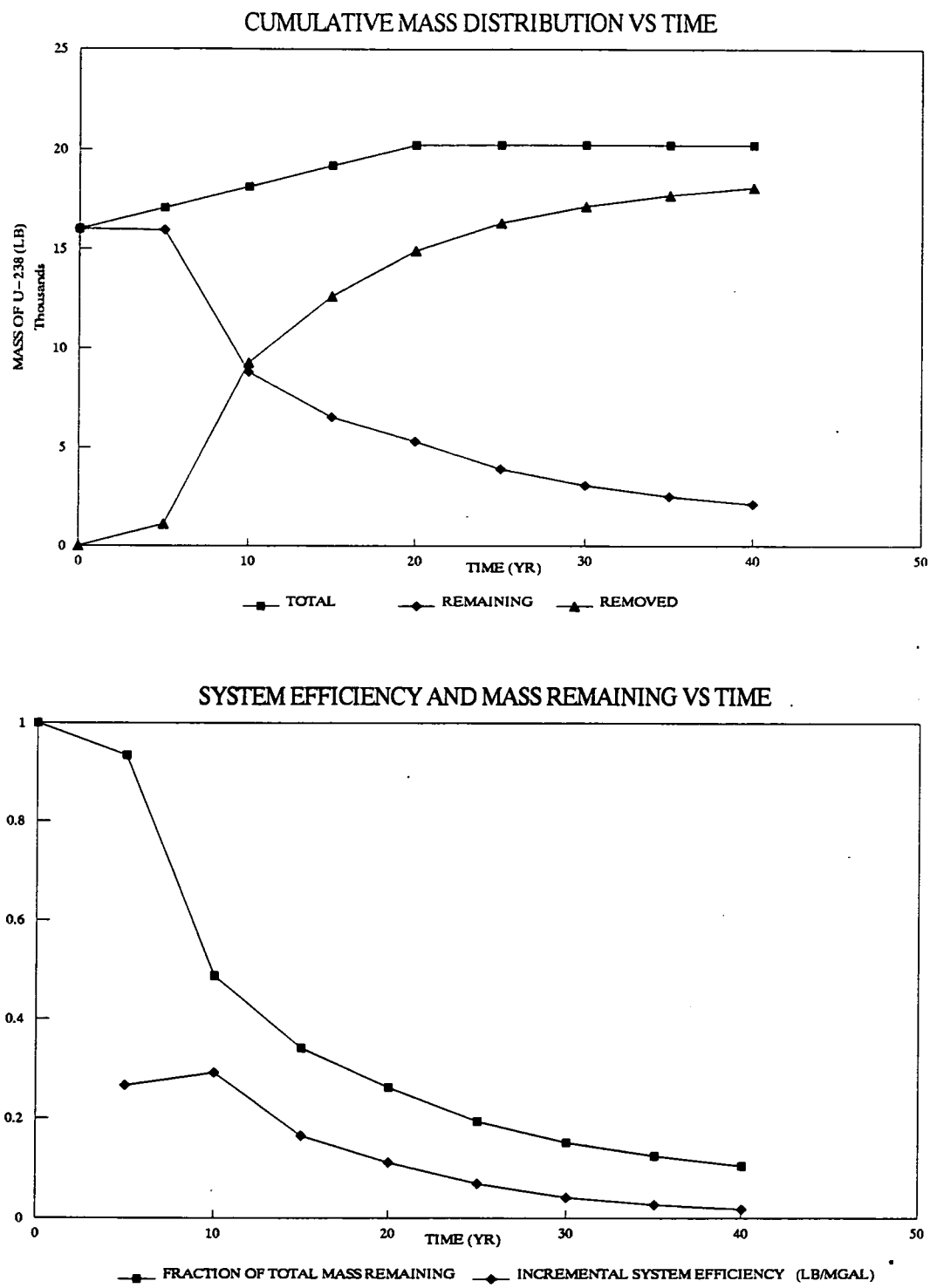

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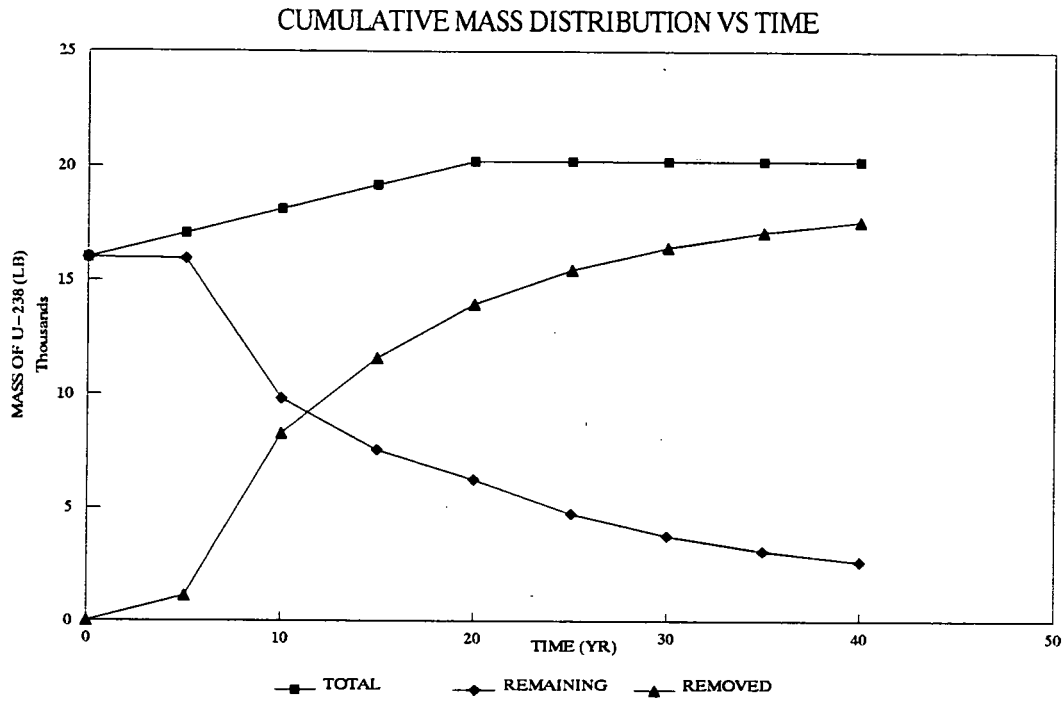
FIGURE F.7-41. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3A, SYSTEM PERFORMANCE CURVES



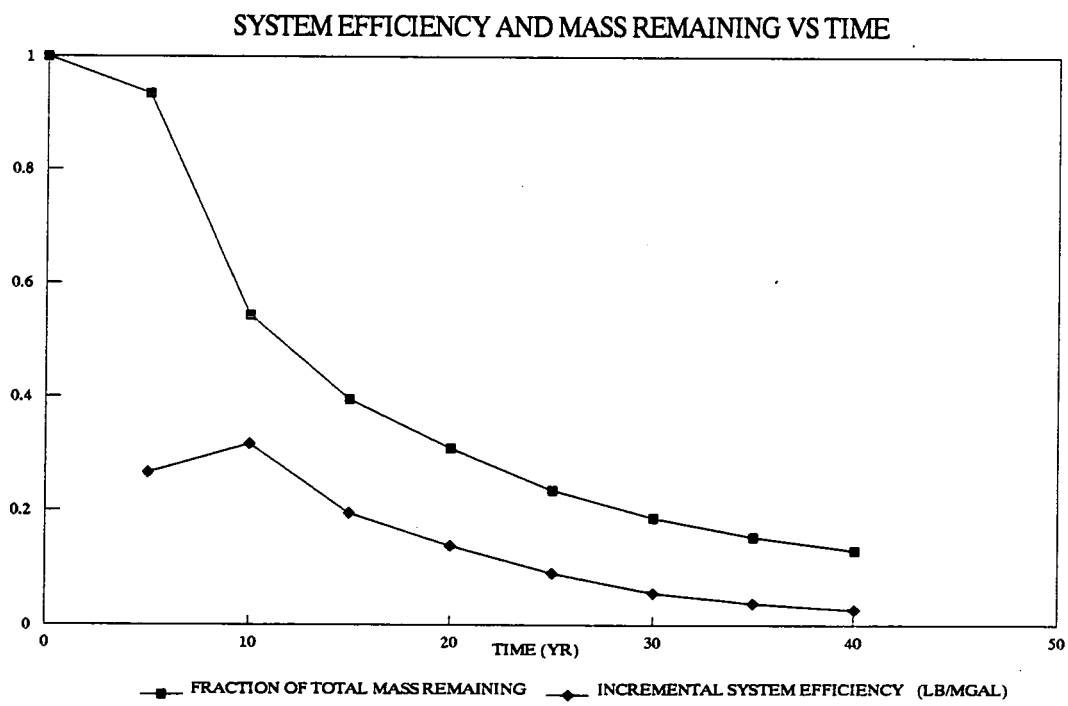


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FIGURE F.7-42. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3B, SYSTEM PERFORMANCE CURVES

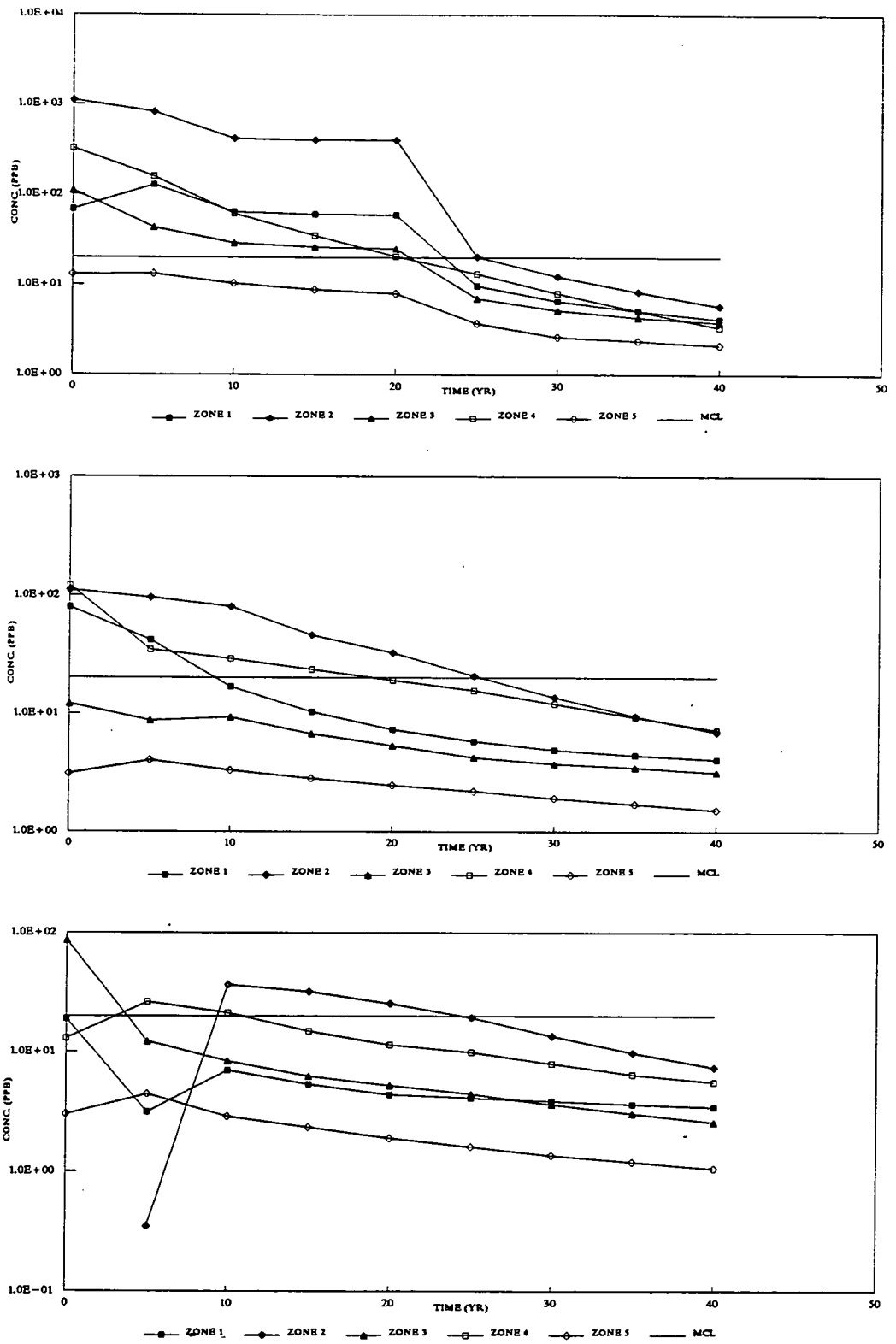

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FIGURE F.7-43A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3A, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

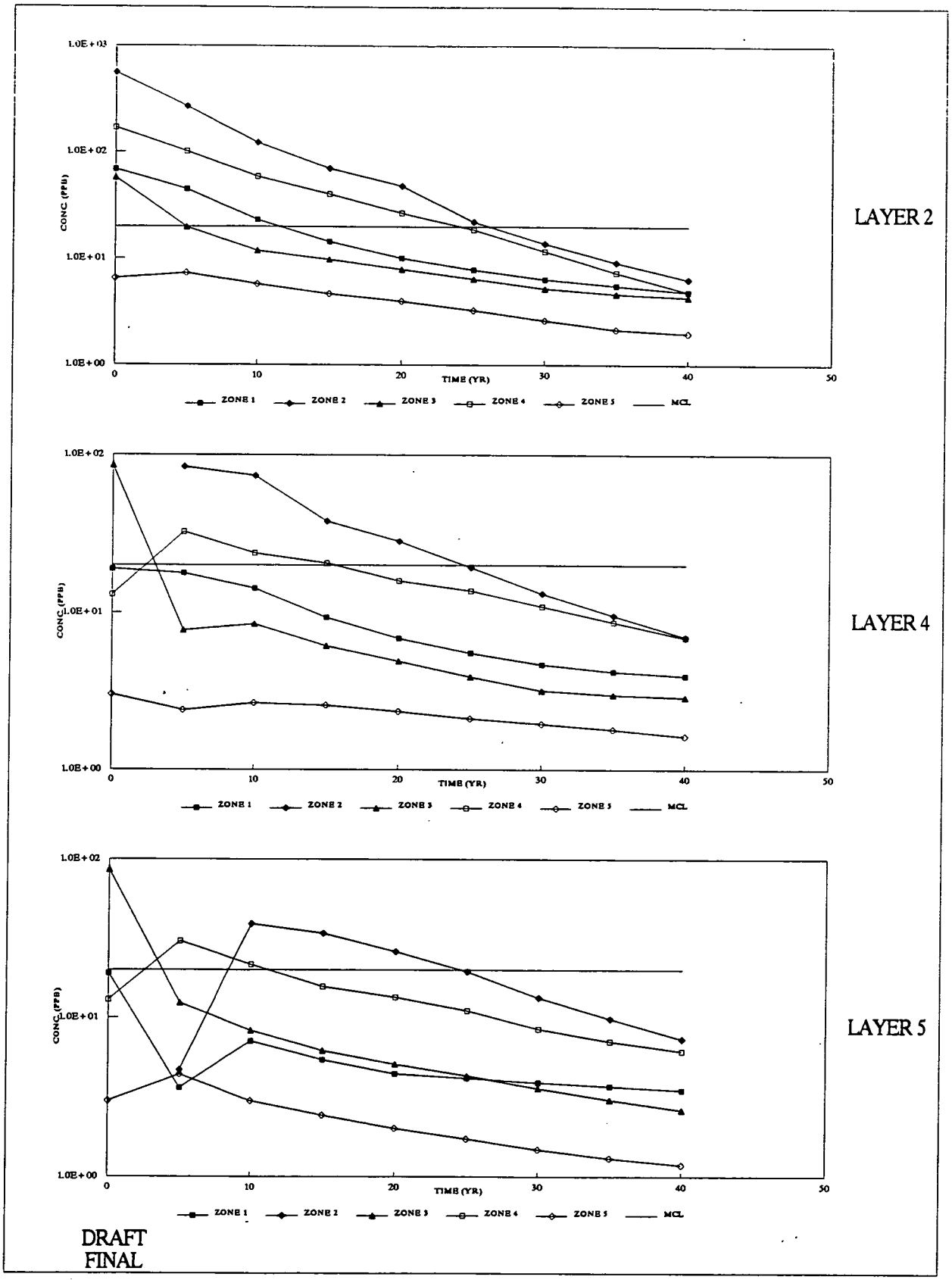

FIGURE F.7-43B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3A, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

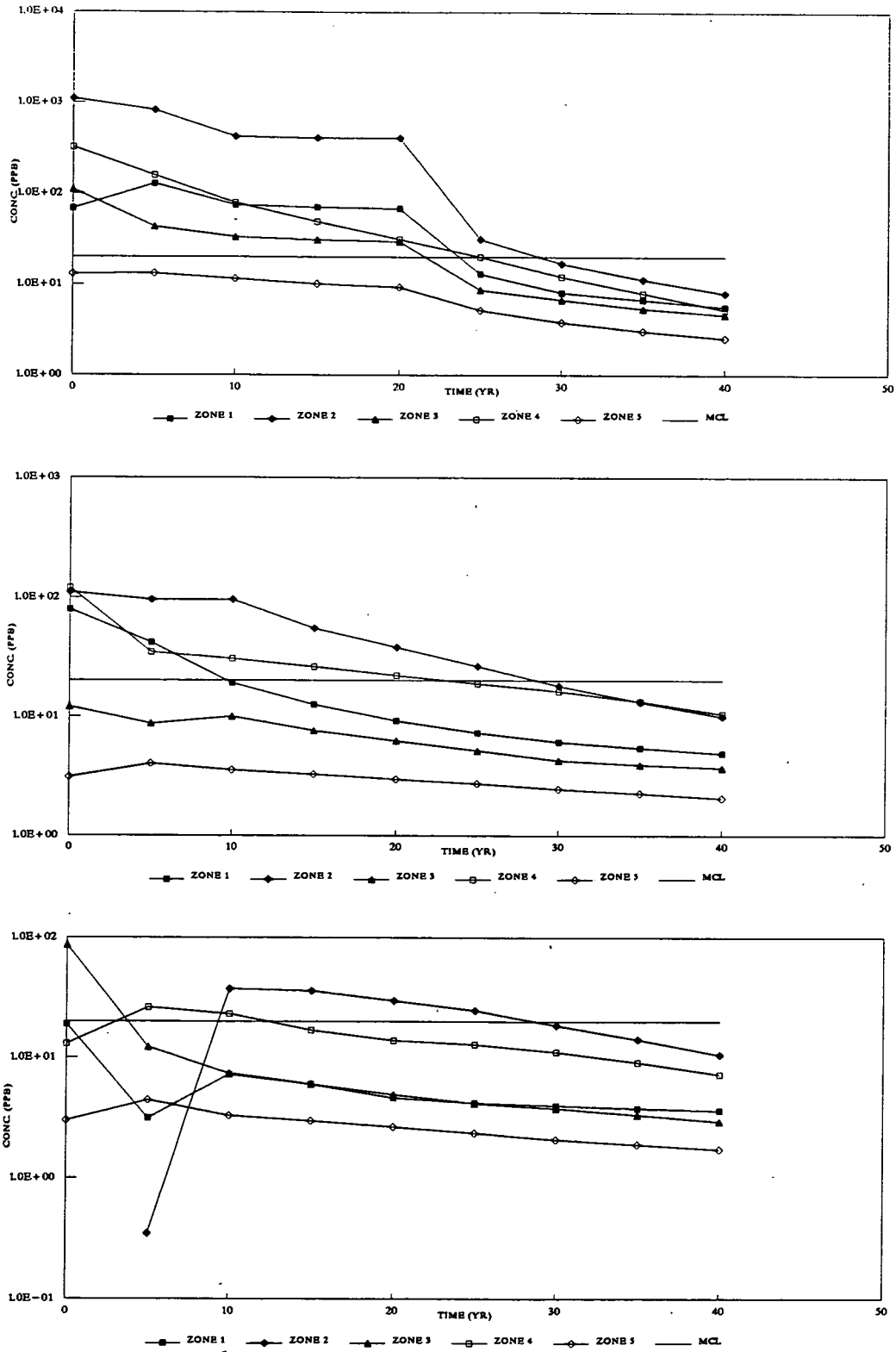

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FIGURE F.7-44A. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3B, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

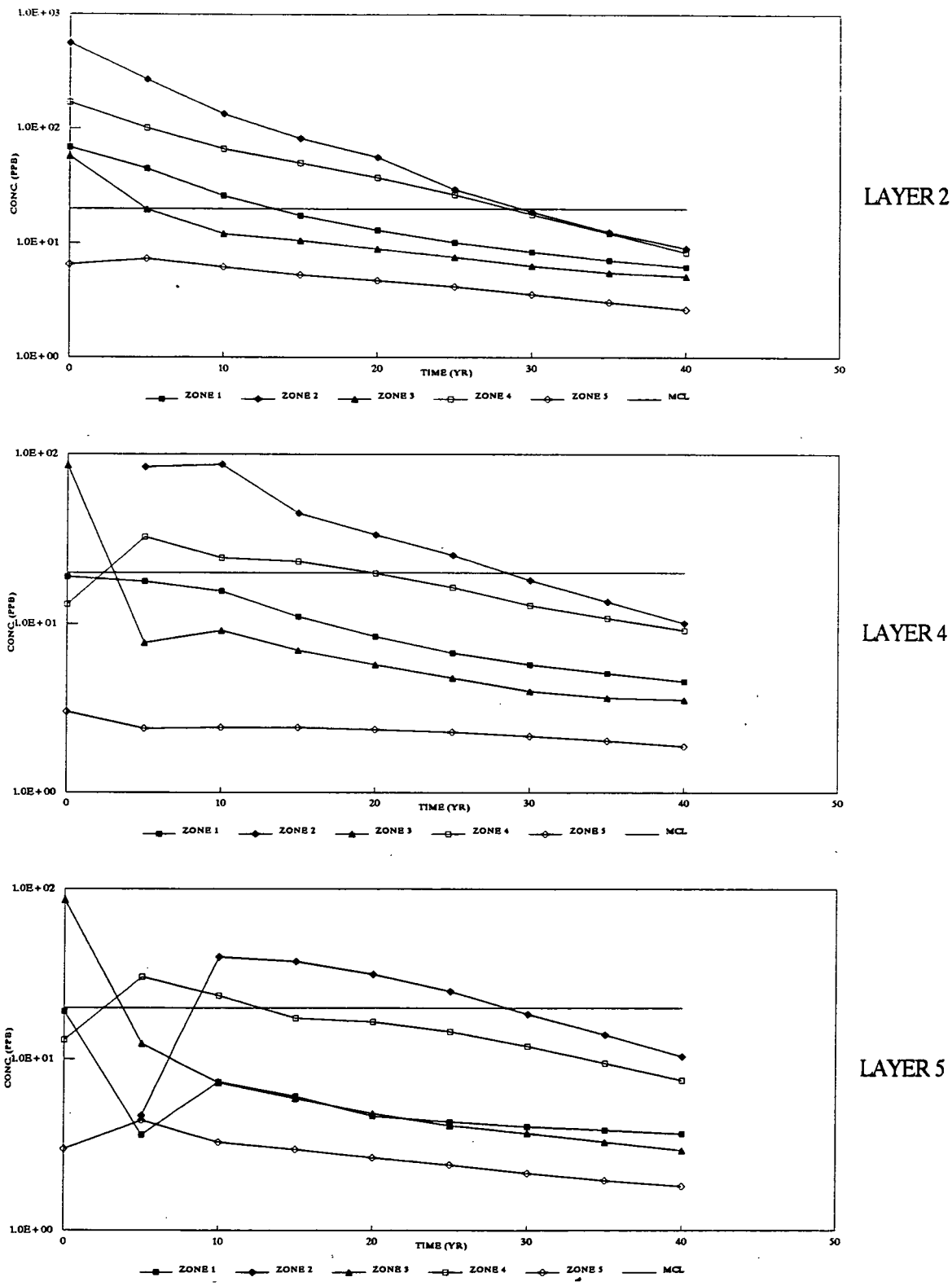

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FIGURE F.7–44B. GROUNDWATER RESTORATION TO 20 PPB, SCENARIO 3B, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

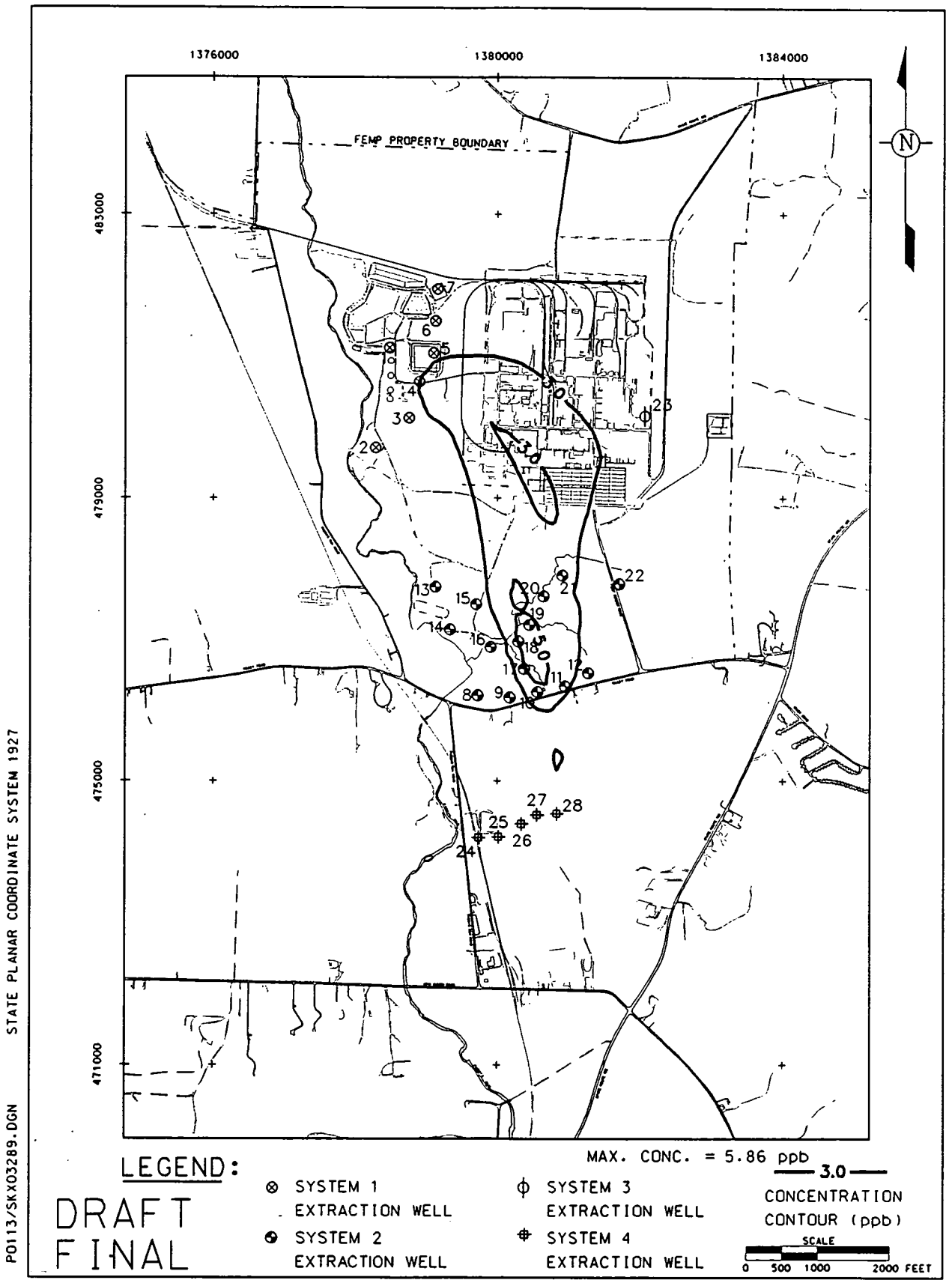

FIGURE F.7-45. SCENARIO 3A. URANIUM CONCENTRATION CONTOURS. YEAR 40. LAYER 1

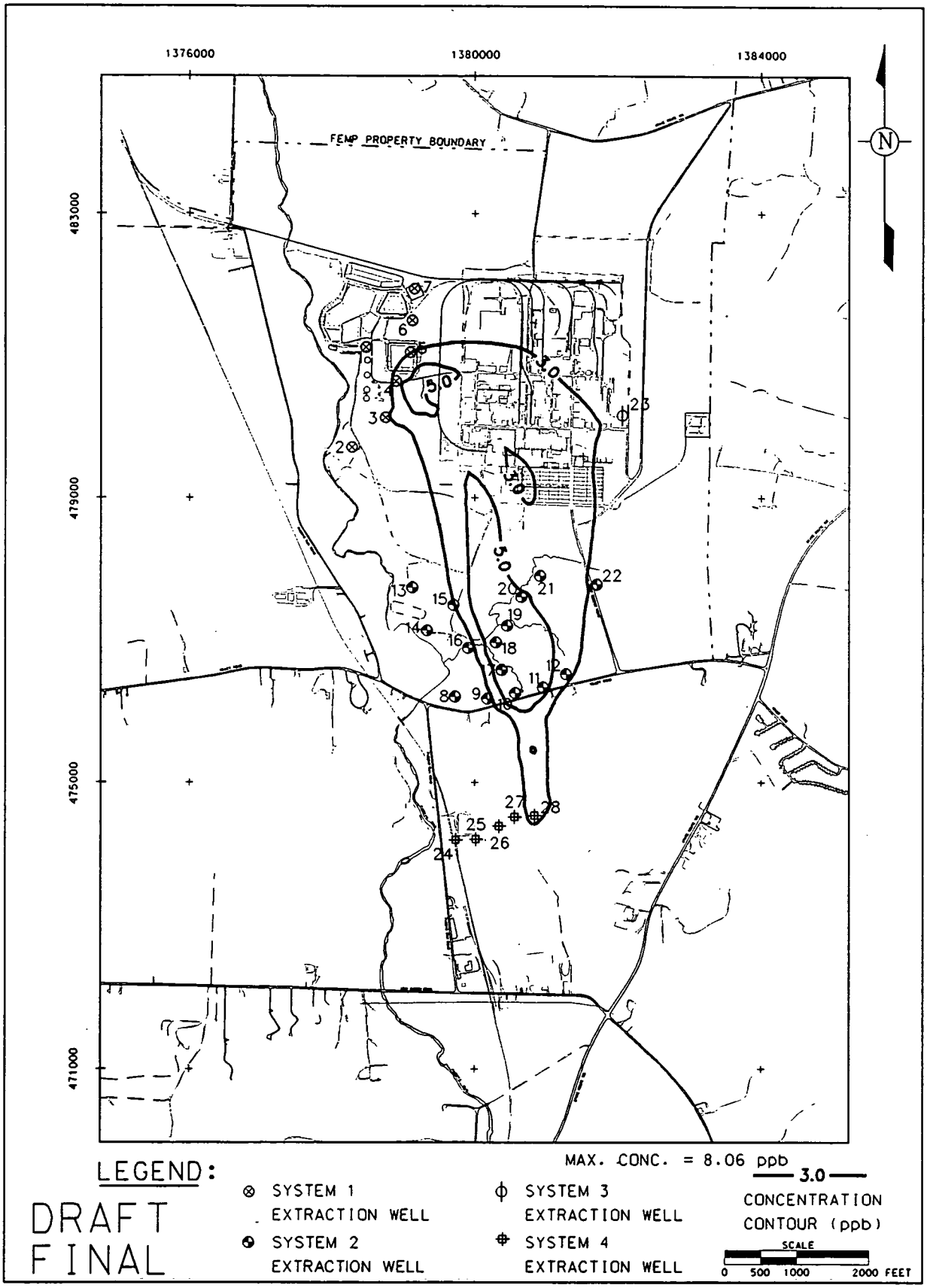

FIGURE F.7-46. SCENARIO 3B. URANIUM CONCENTRATION CONTOURS. YEAR 40. LAYER 1

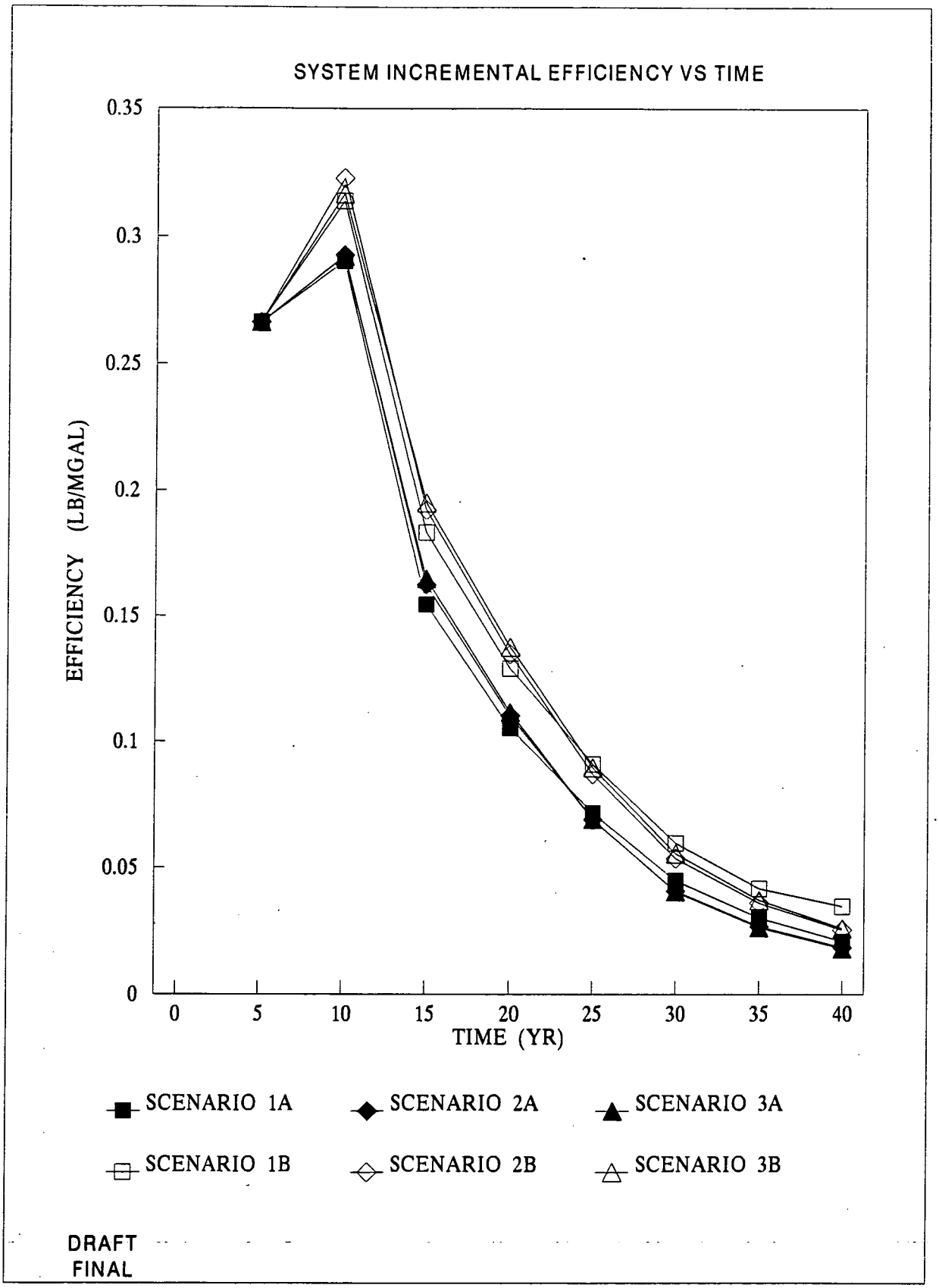

FIGURE F.7-47 – COMPARISON OF SCENARIOS, SYSTEM EFFICIENCY

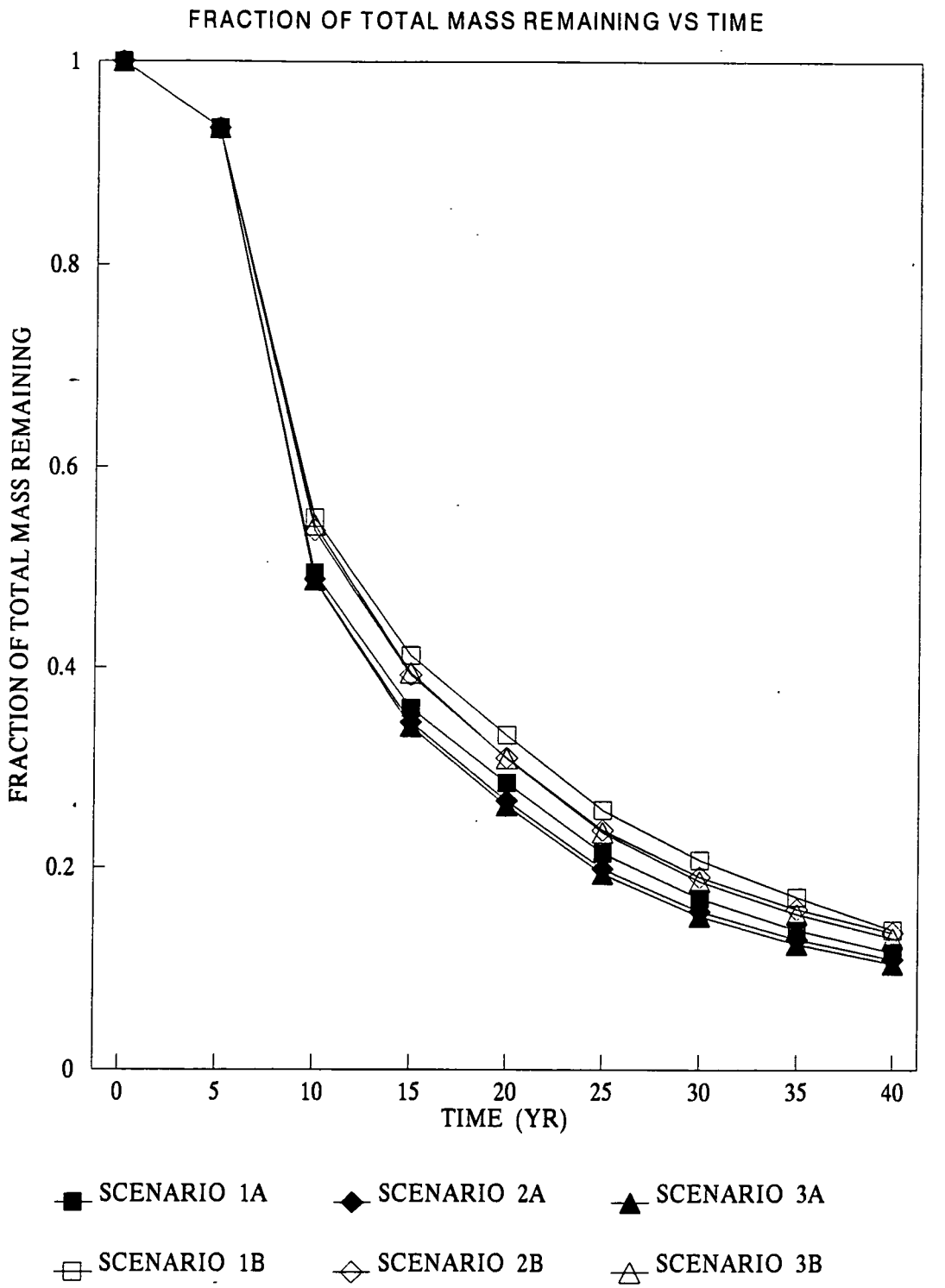

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FIGURE F.7-48 – COMPARISON OF SCENARIOS, MASS REMAINING

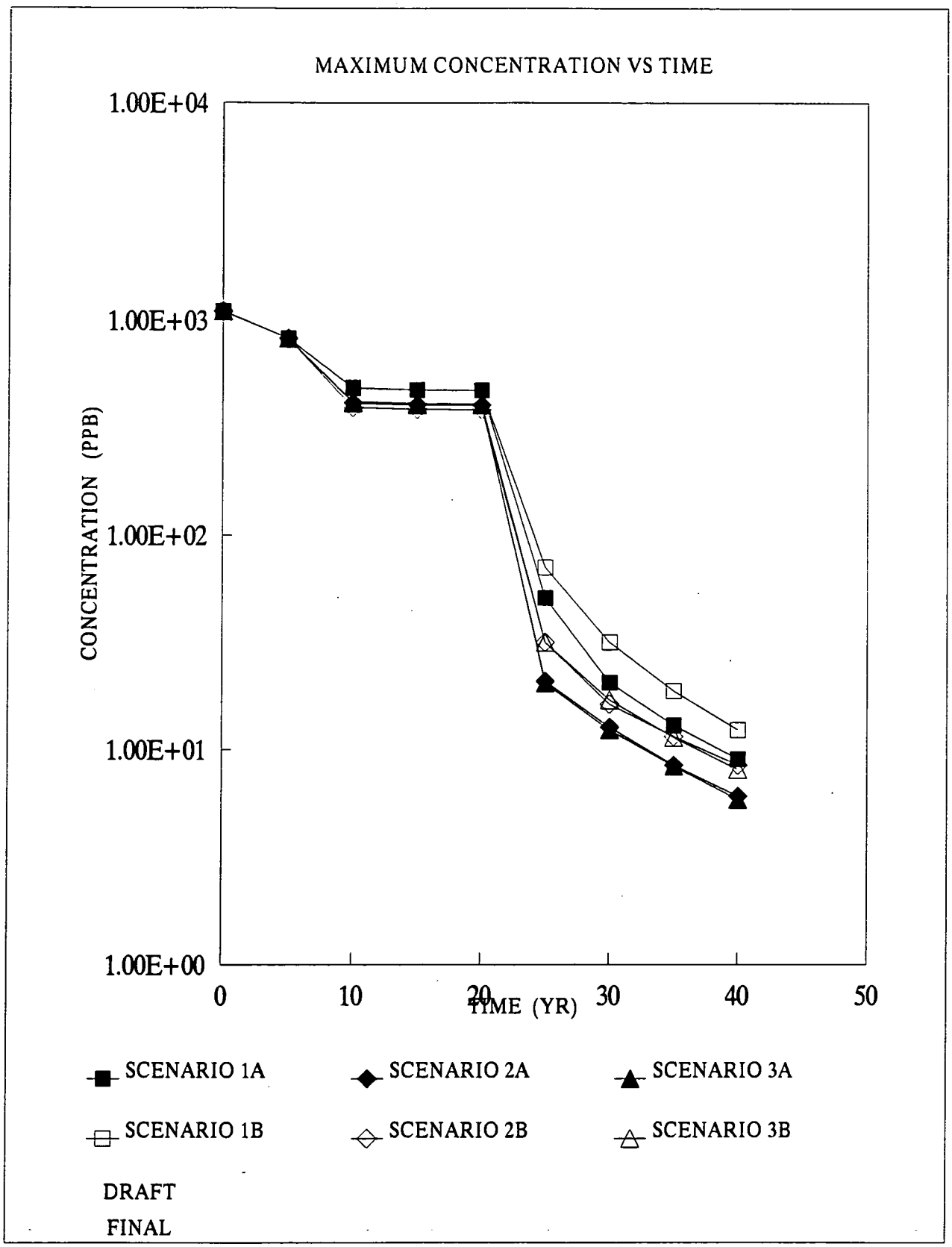

FIGURE F.7-49 COMPARISON OF SCENARIOS, MAXIMUM CONCENTRATION CURVES

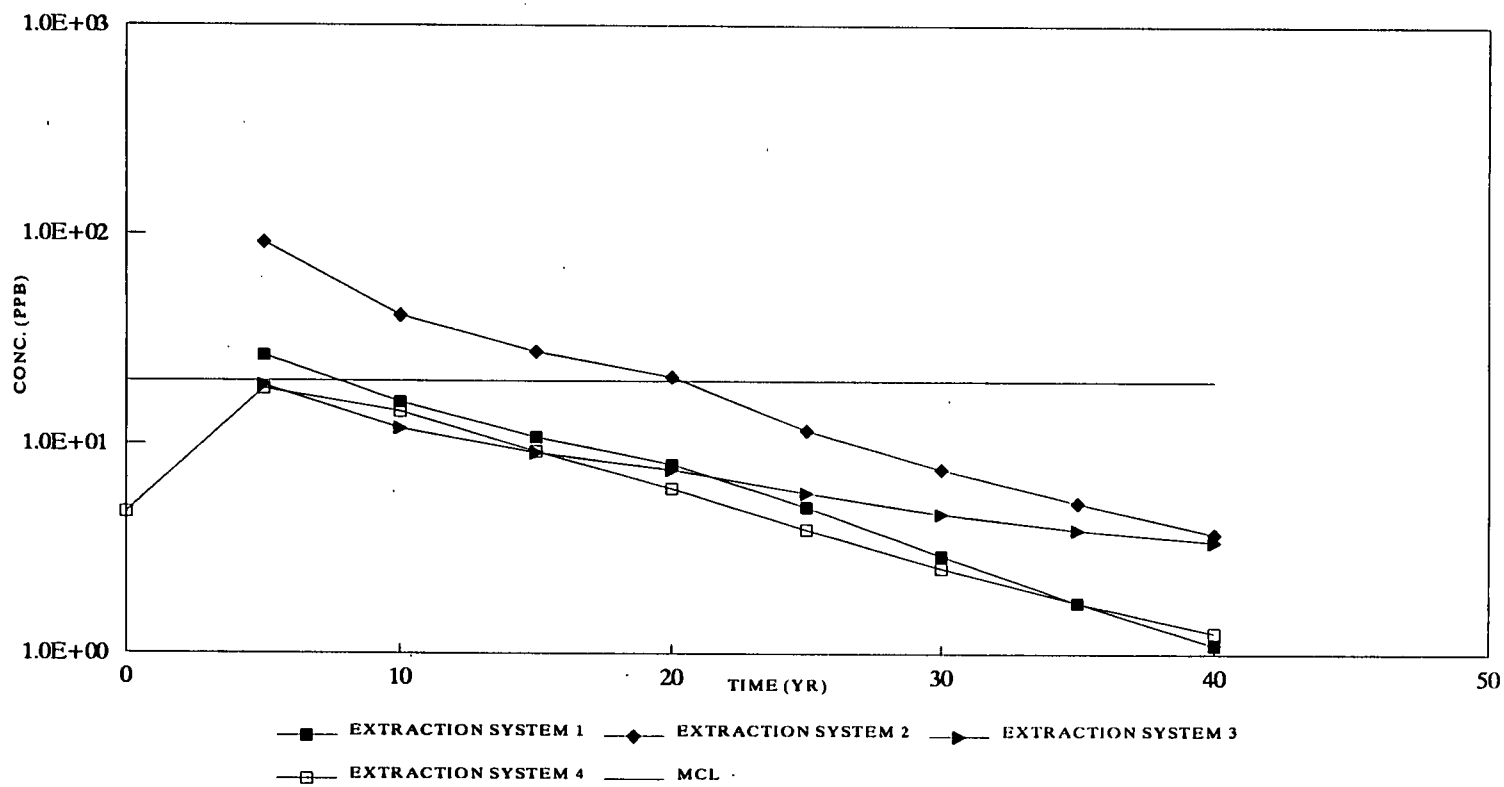

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FIGURE F.7-50. GROUNDWATER RESTORATION TO 20 PPB, URANIUM, AVERAGE CONCENTRATION CURVES

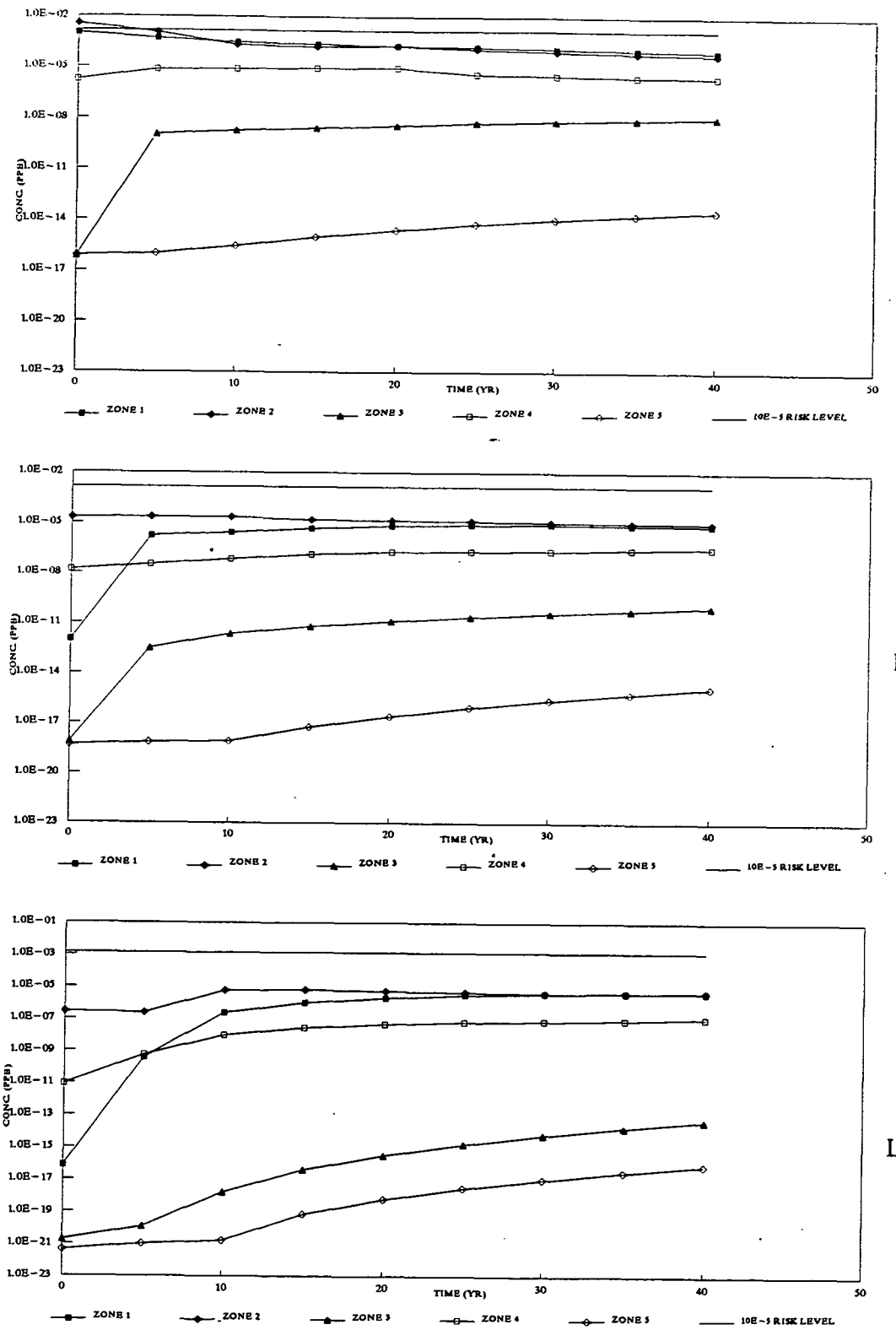

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FIGURE F.7-51A. GROUNDWATER RESTORATION TO 20 PPB, NEPTUNIUM-237, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

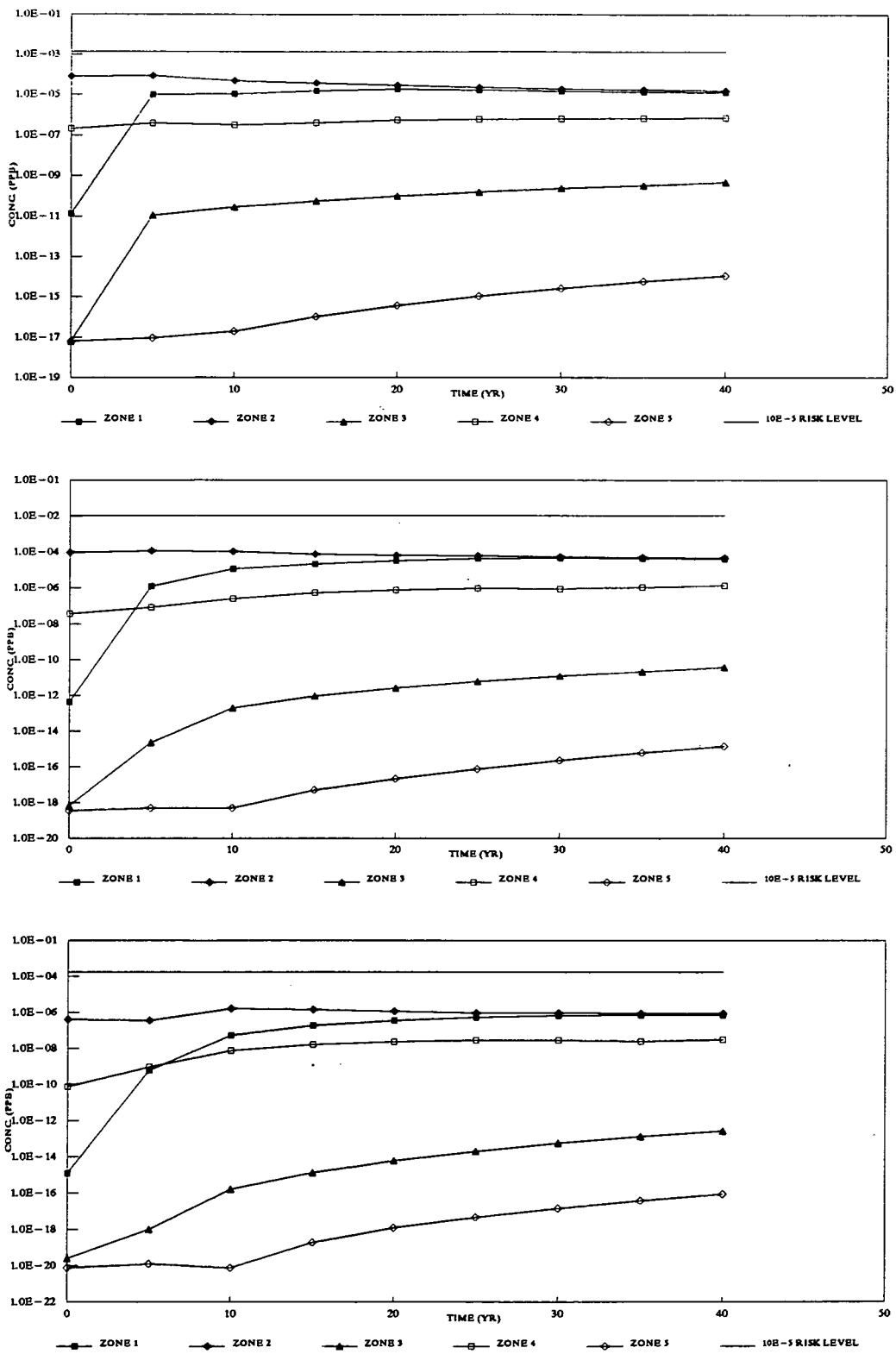

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FIGURE F.7-51B. GROUNDWATER RESTORATION TO 20 PPB, NEPTUNIUM-237, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

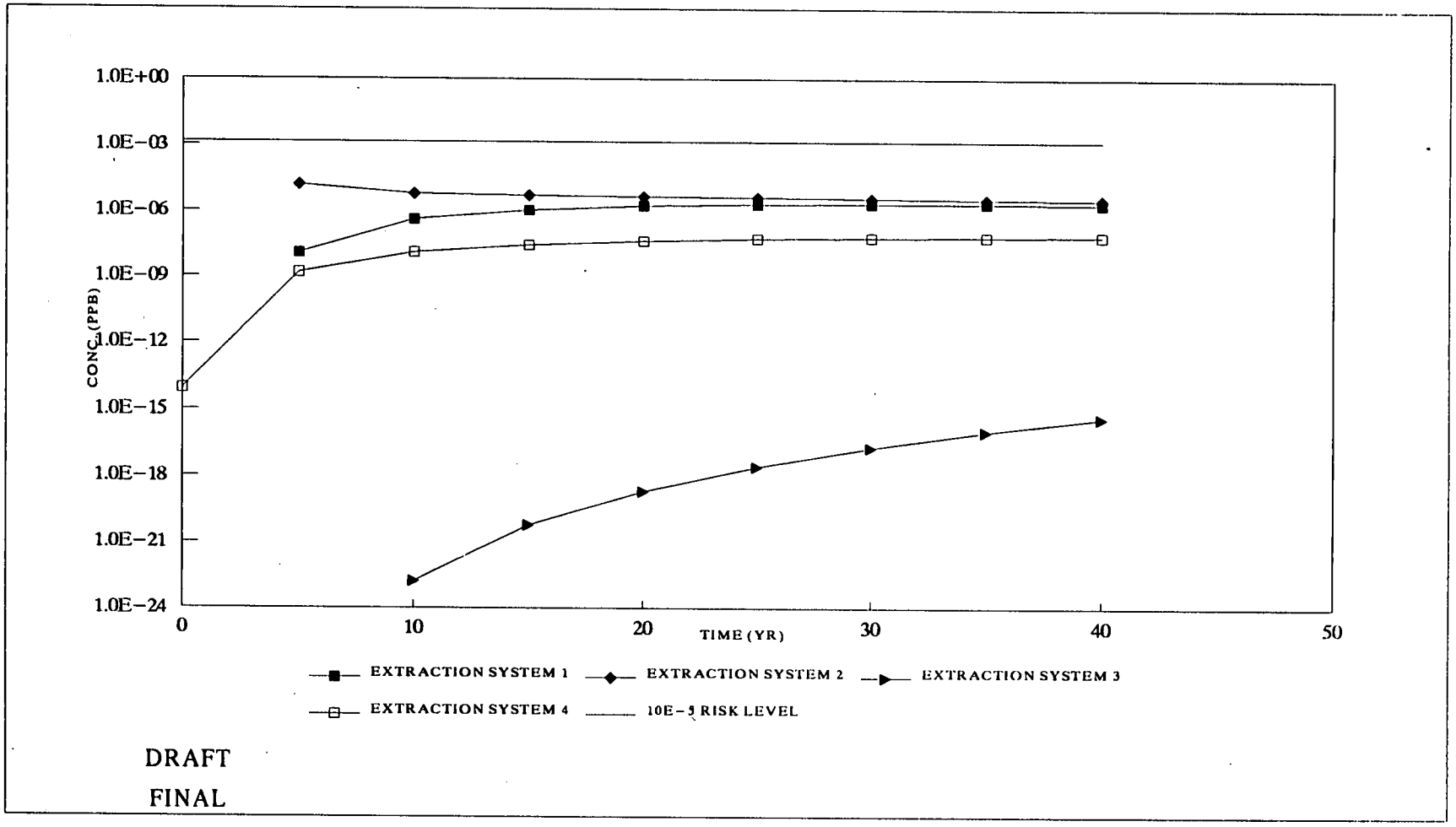

FIGURE F.7-52. GROUNDWATER RESTORATION TO 20 PPB, NEPTUNIUM-237, AVERAGE CONCENTRATION CURVES

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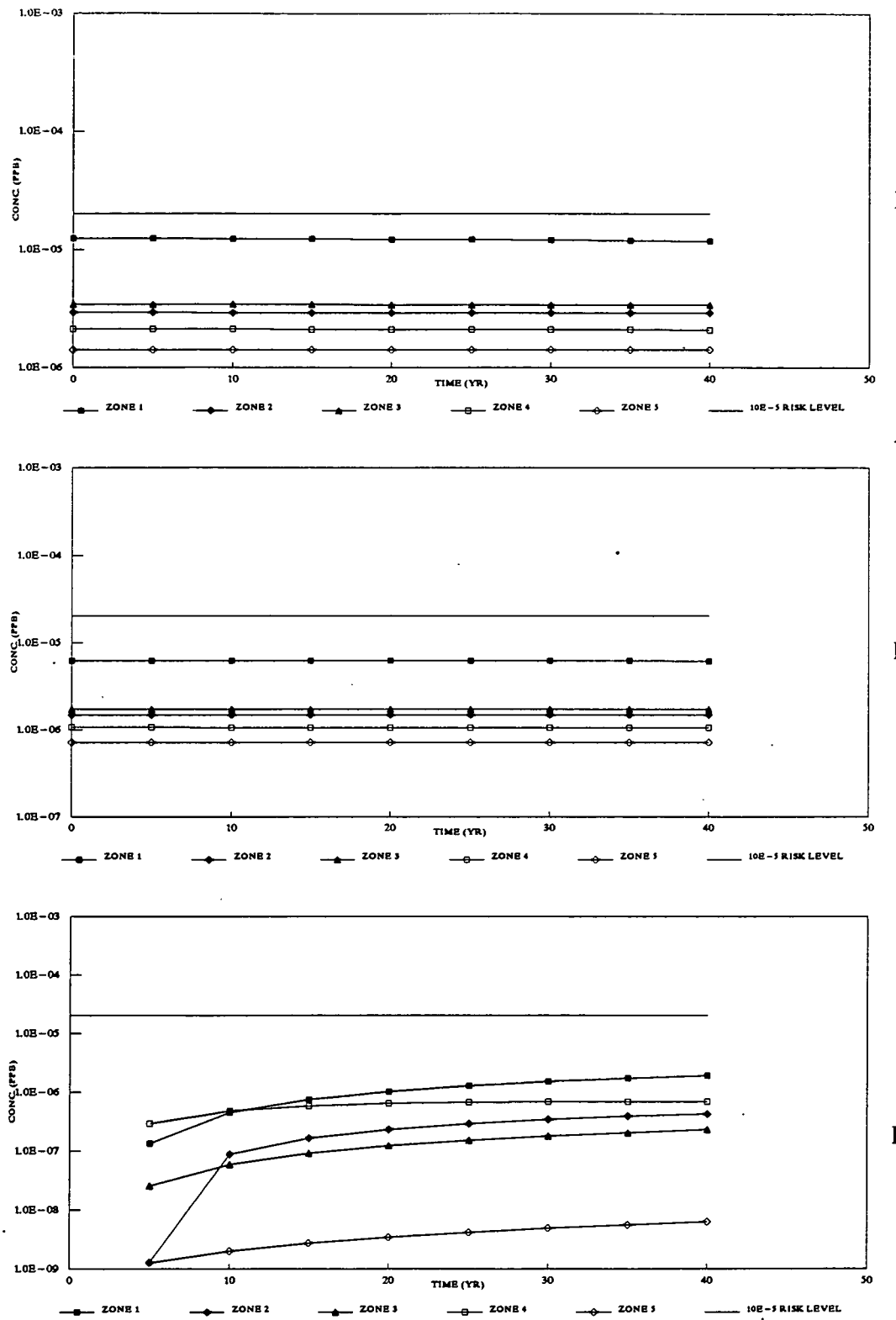

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FIGURE F.7-53A. GROUNDWATER RESTORATION TO 20 PPB, RADIUM-226, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

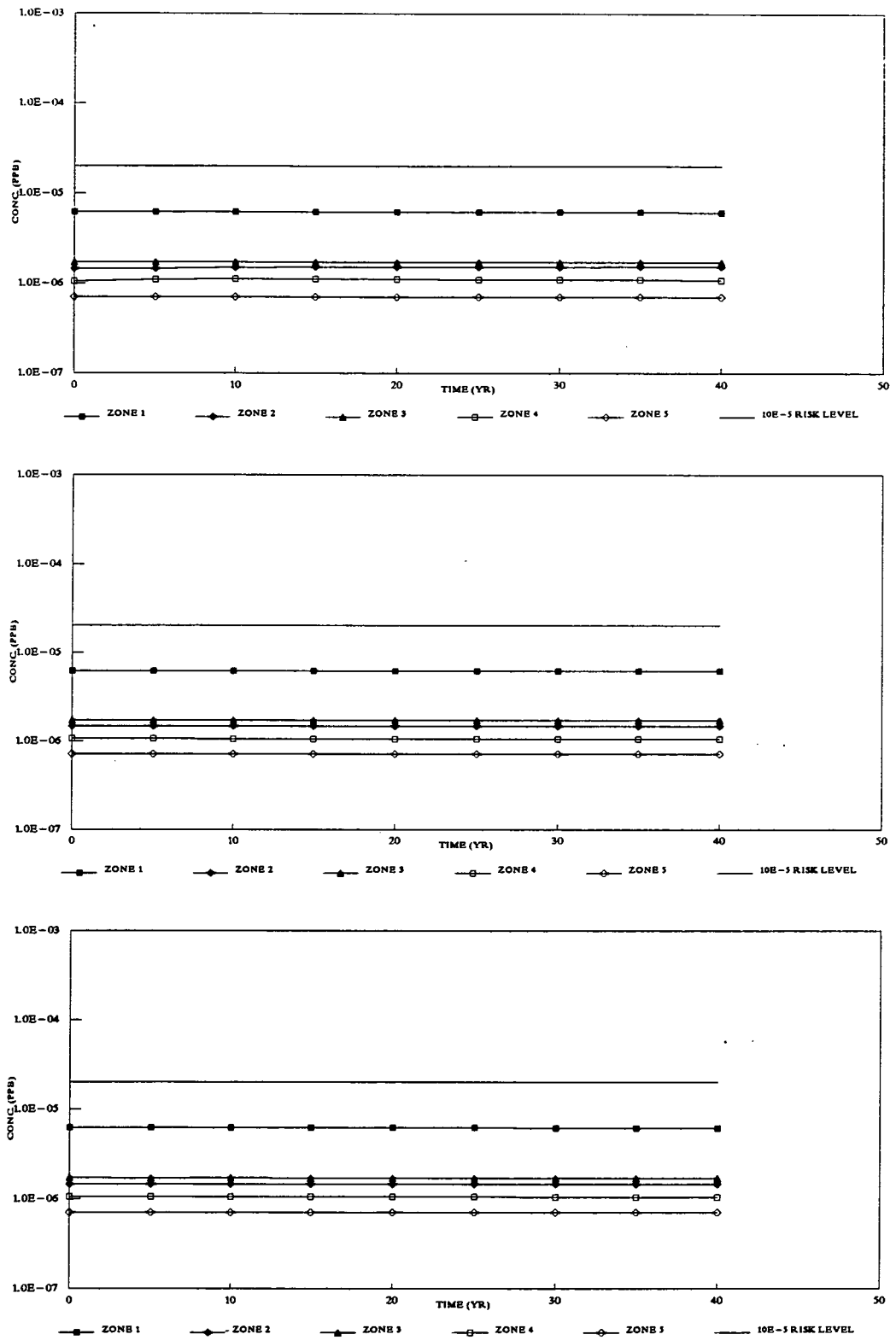

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FIGURE F.7-53B. GROUNDWATER RESTORATION TO 20 PPB, RADIUM-226, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

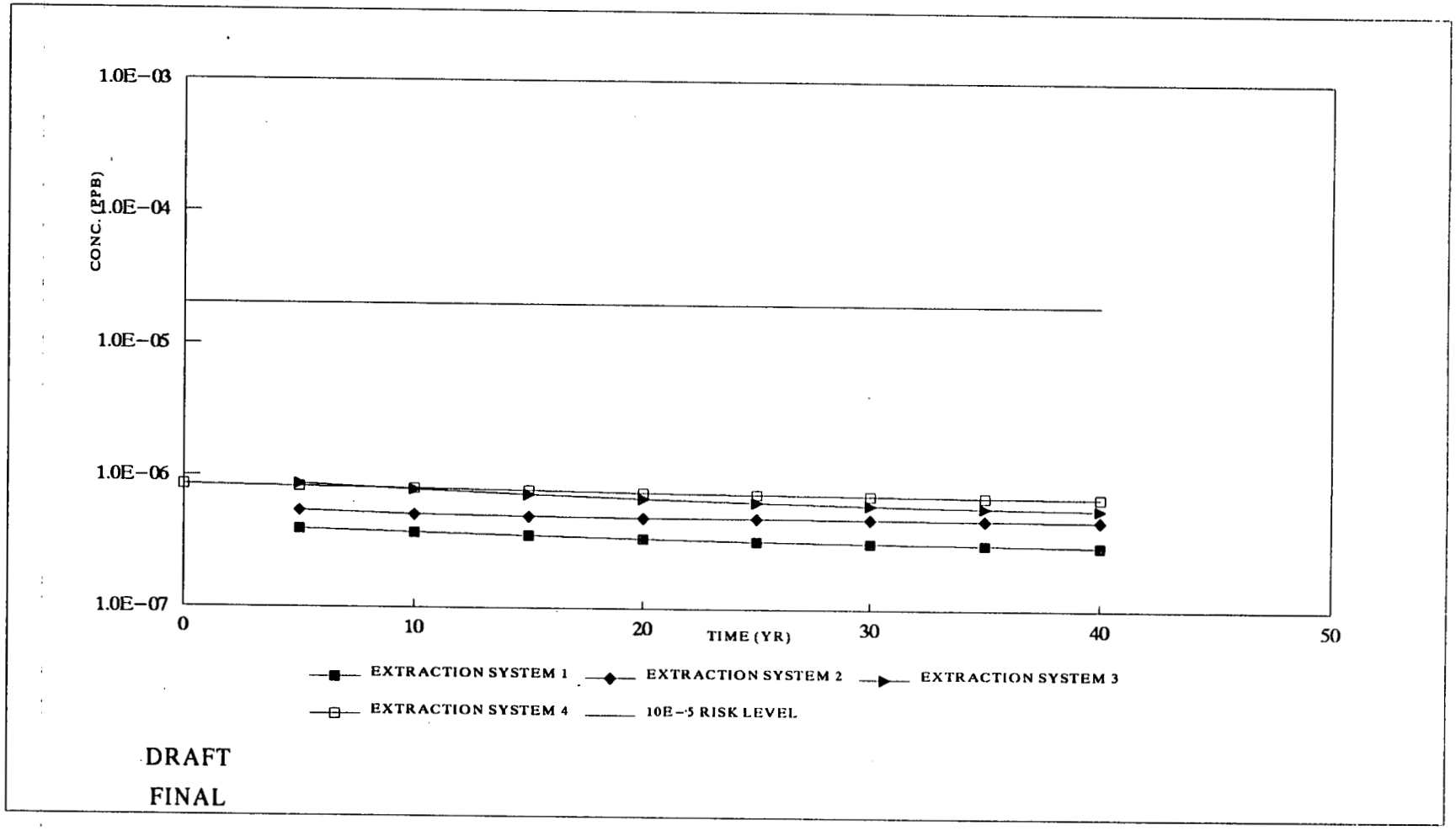

FIGURE F.7-54. GROUNDWATER RESTORATION TO 20 PPB, RADIUM-226, AVERAGE CONCENTRATION CURVES

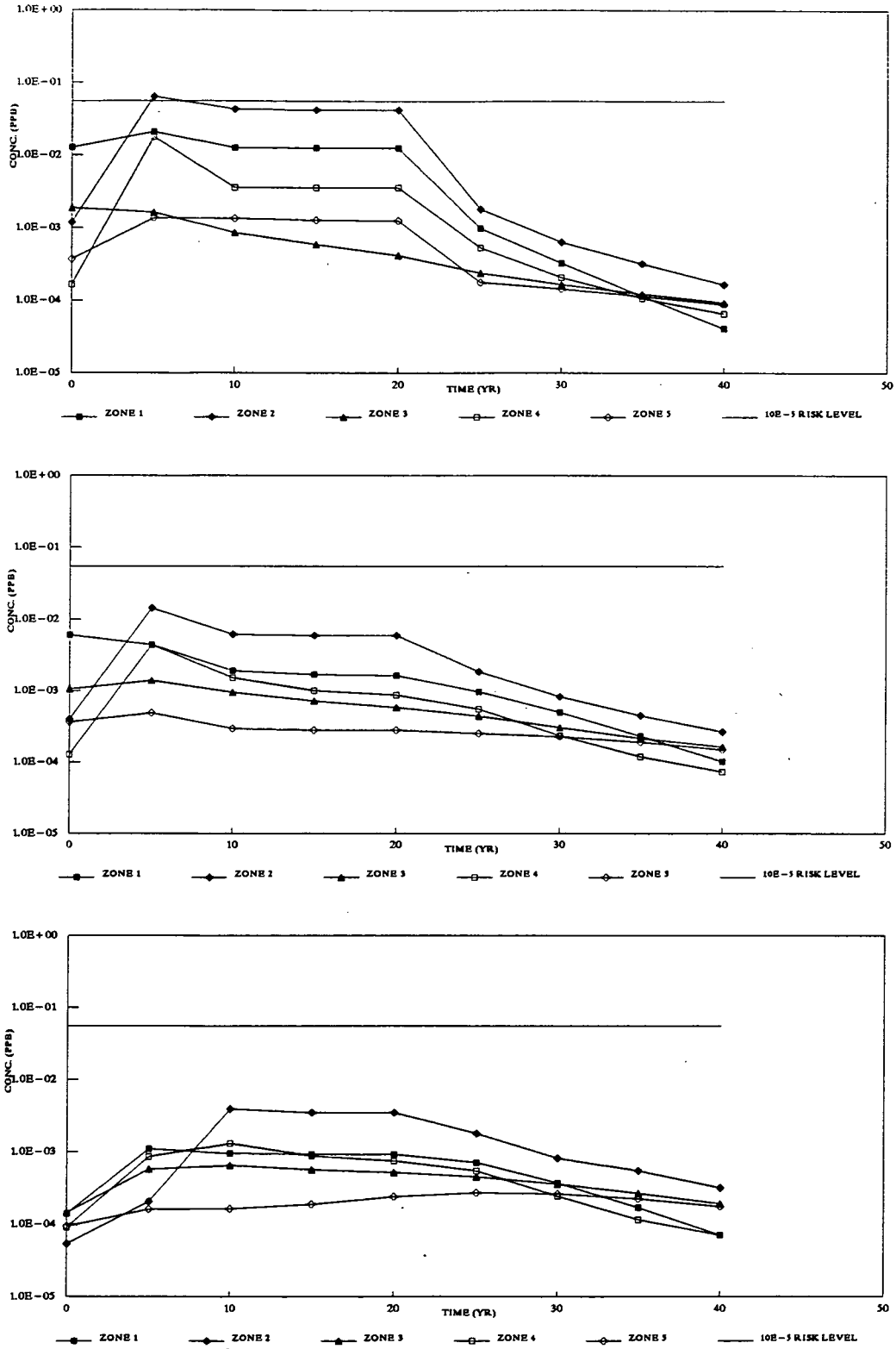

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FIGURE F.7-55A. GROUNDWATER RESTORATION TO 20 PPB, TECHNETIUM-99, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

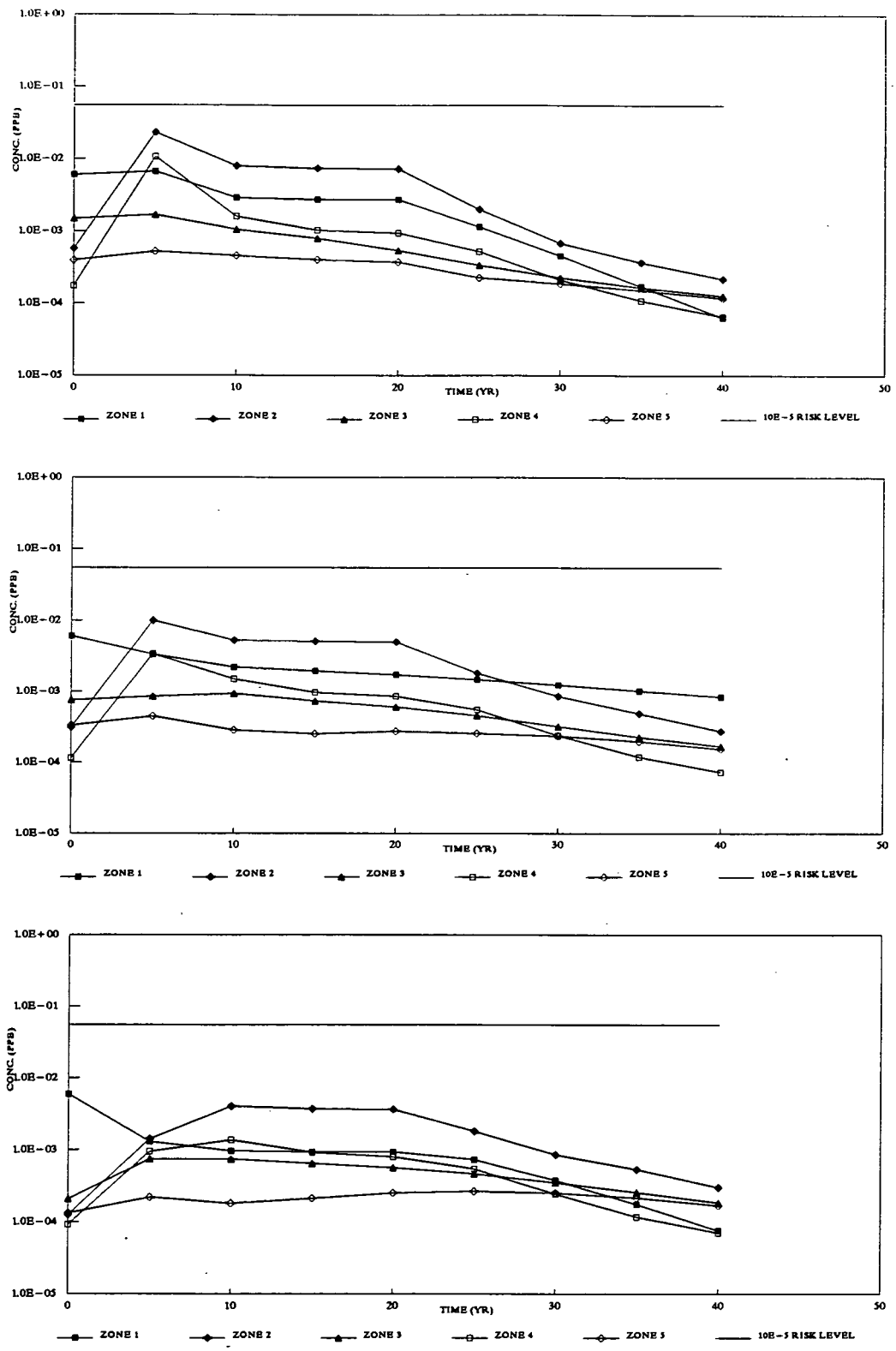

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FIGURE F.7-55B. GROUNDWATER RESTORATION TO 20 PPB, TECHNETIUM-99, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

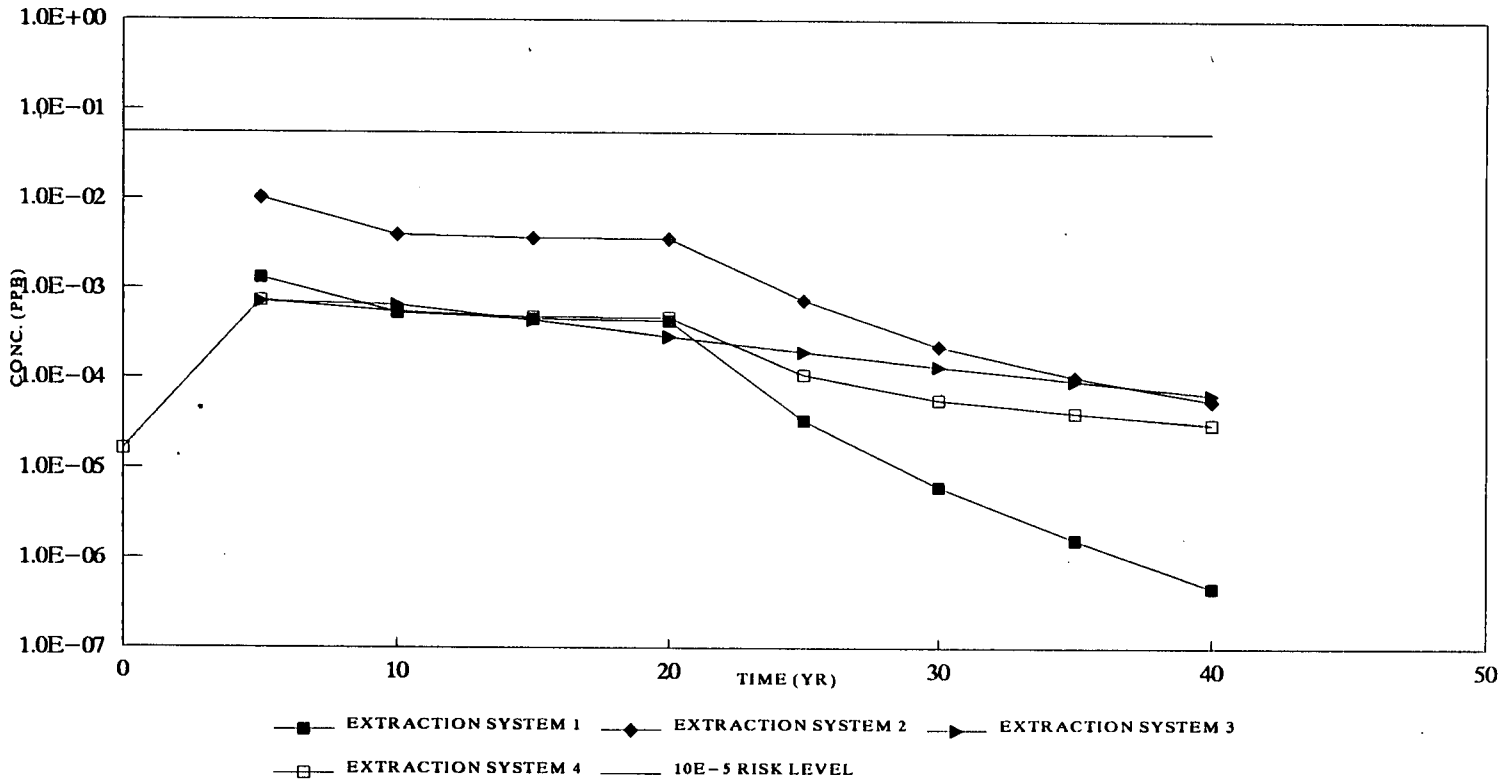

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FIGURE F.7-56. GROUNDWATER RESTORATION TO 20 PPB, TECHNETIUM-99, AVERAGE CONCENTRATION CURVES

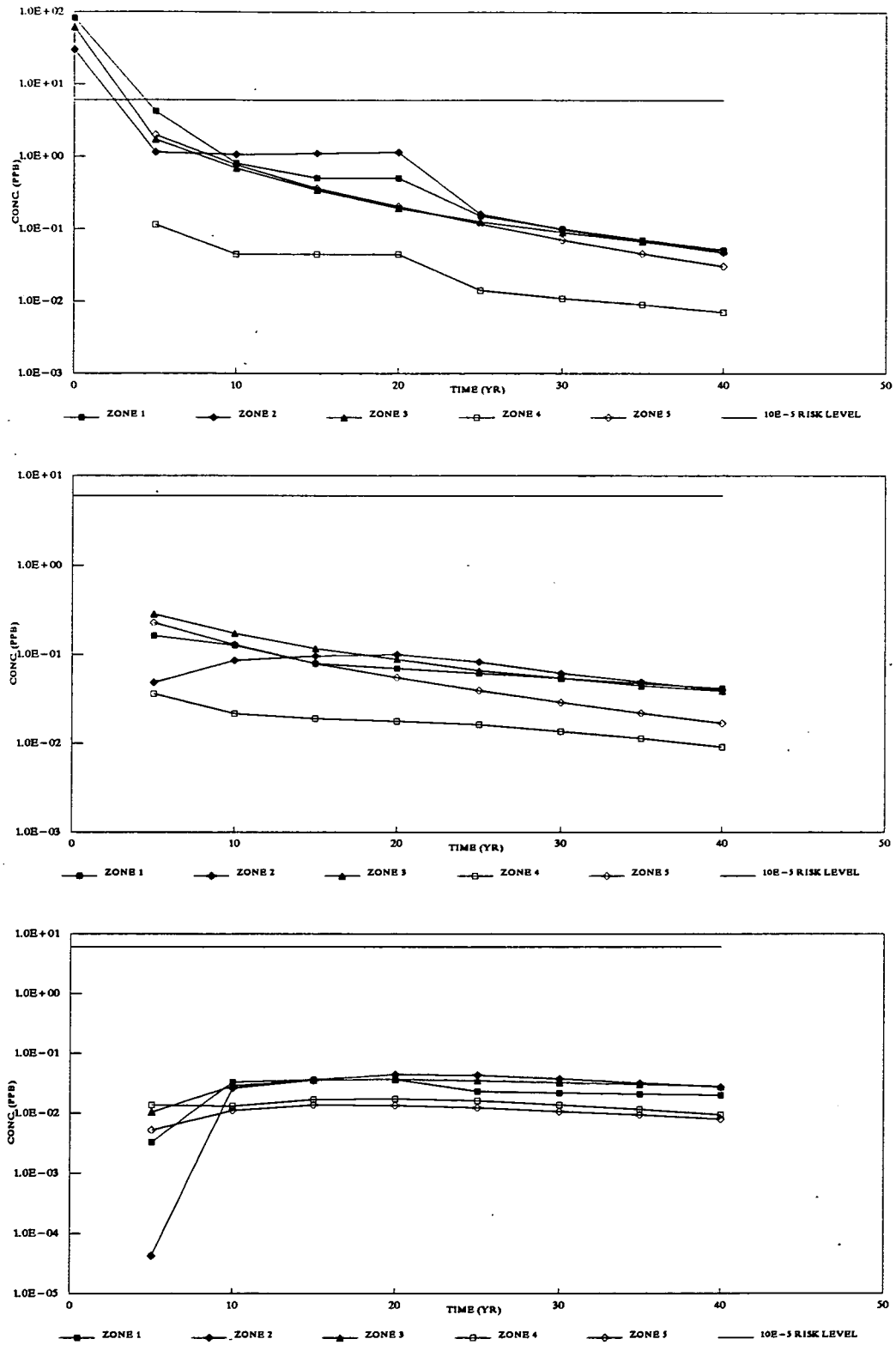

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FIGURE F.7-57A. GROUNDWATER RESTORATION TO 20 PPB, ANTIMONY, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

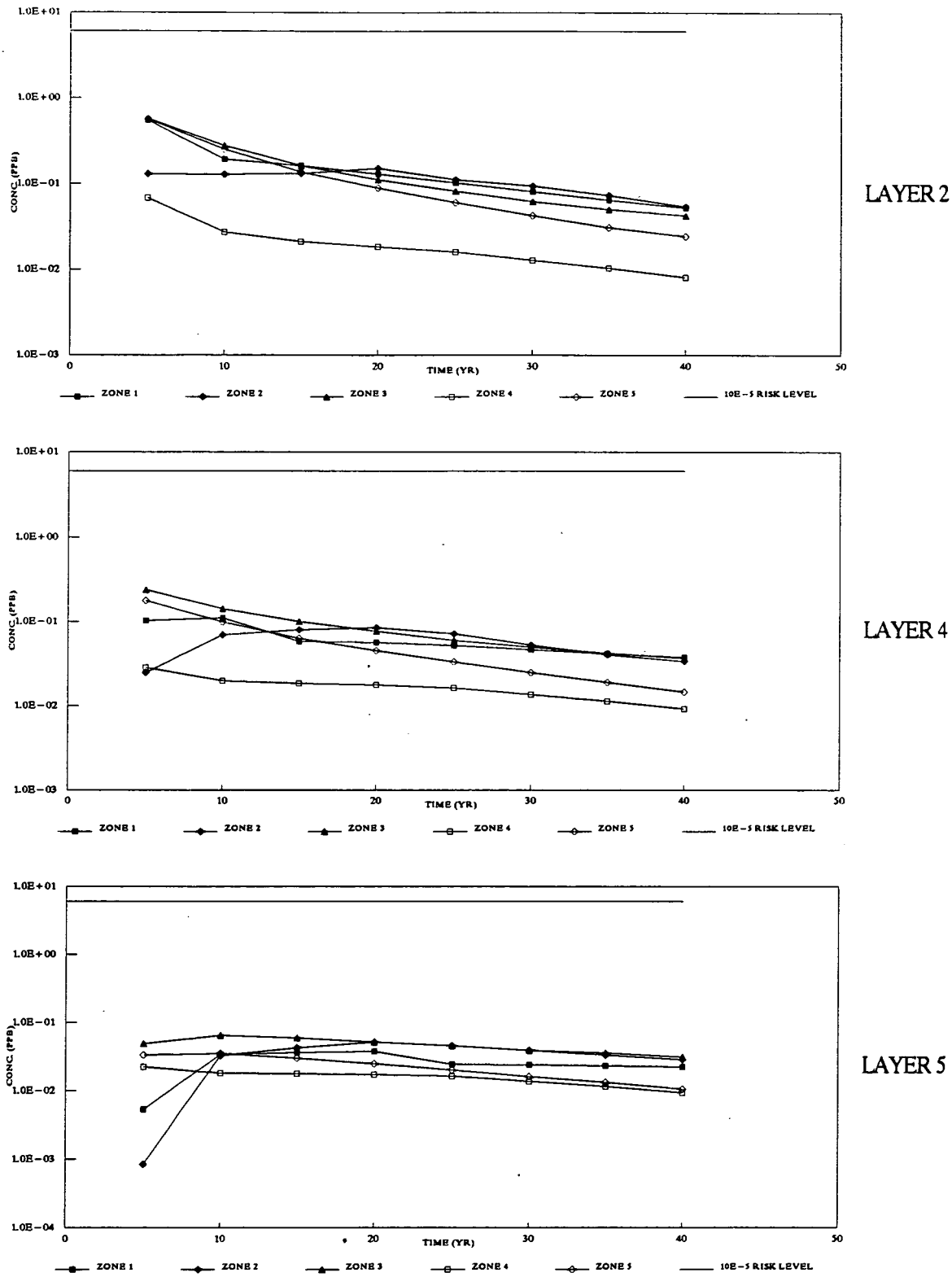

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FIGURE F.7-57B. GROUNDWATER RESTORATION TO 20 PPB, ANTIMONY, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

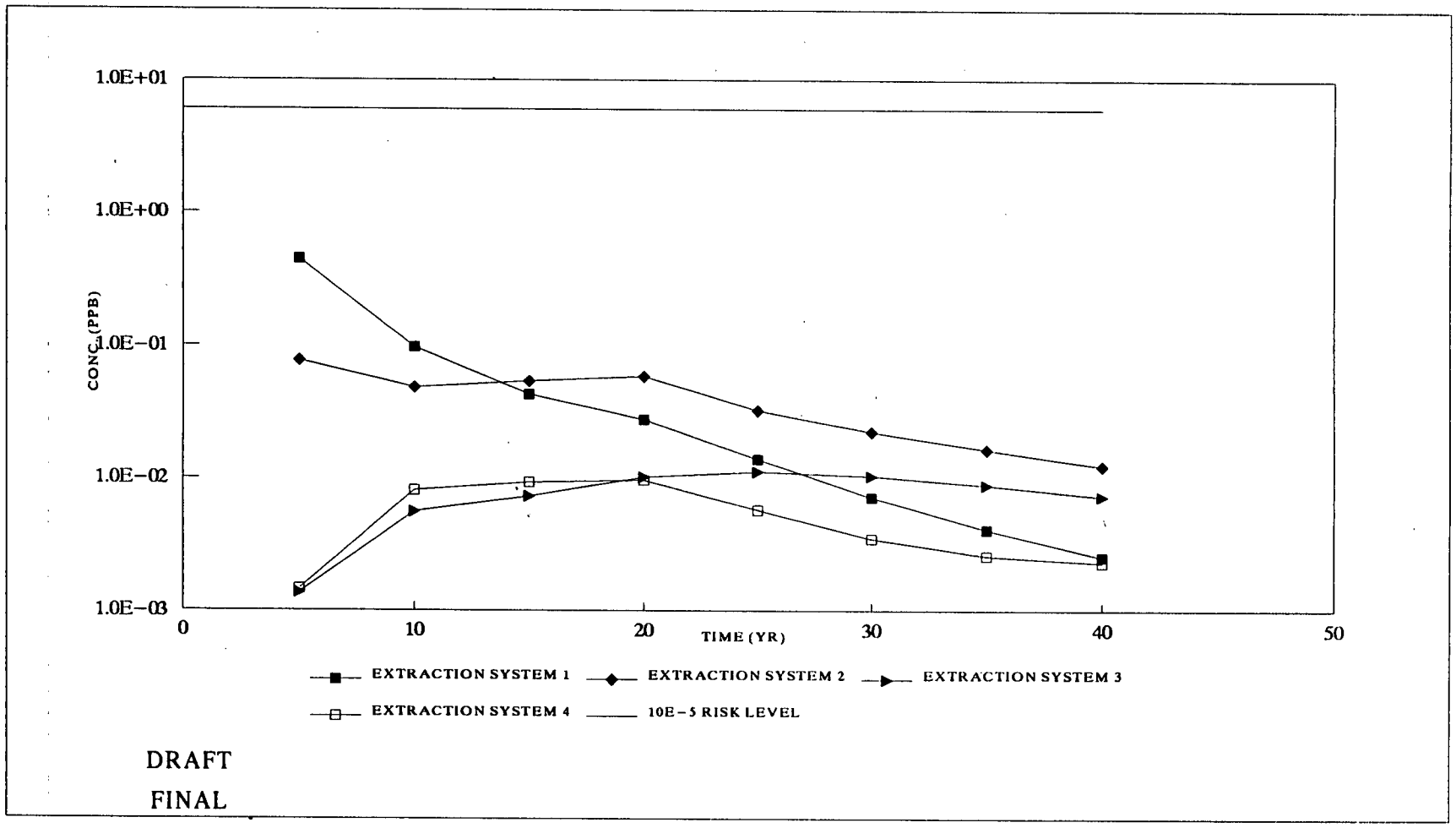

FIGURE F.7-58. GROUNDWATER RESTORATION TO 20 PPB, ANTIMONY, AVERAGE CONCENTRATION CURVES

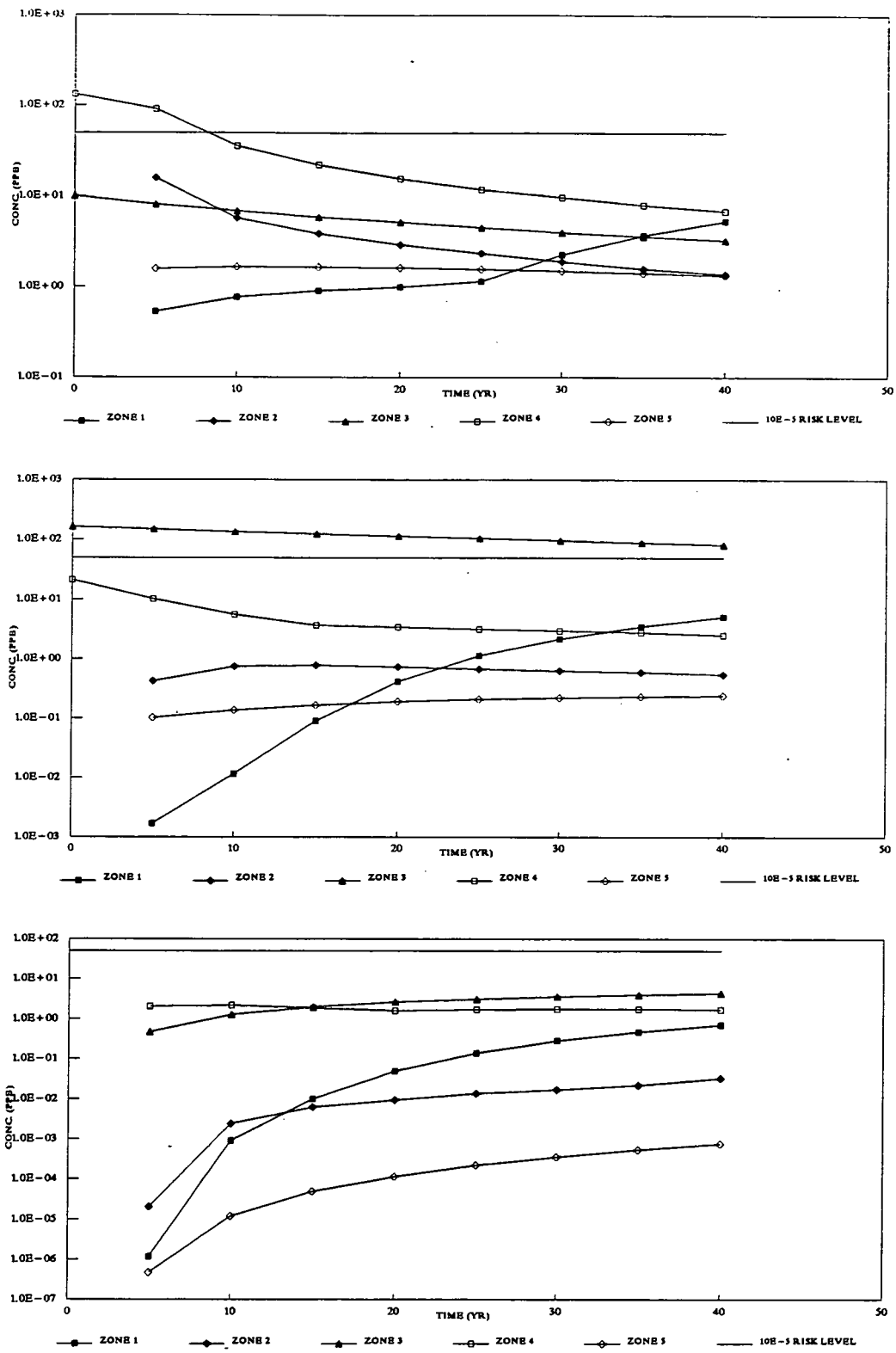

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FIGURE F.7-59A. GROUNDWATER RESTORATION TO 20 PPB, ARSENIC, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

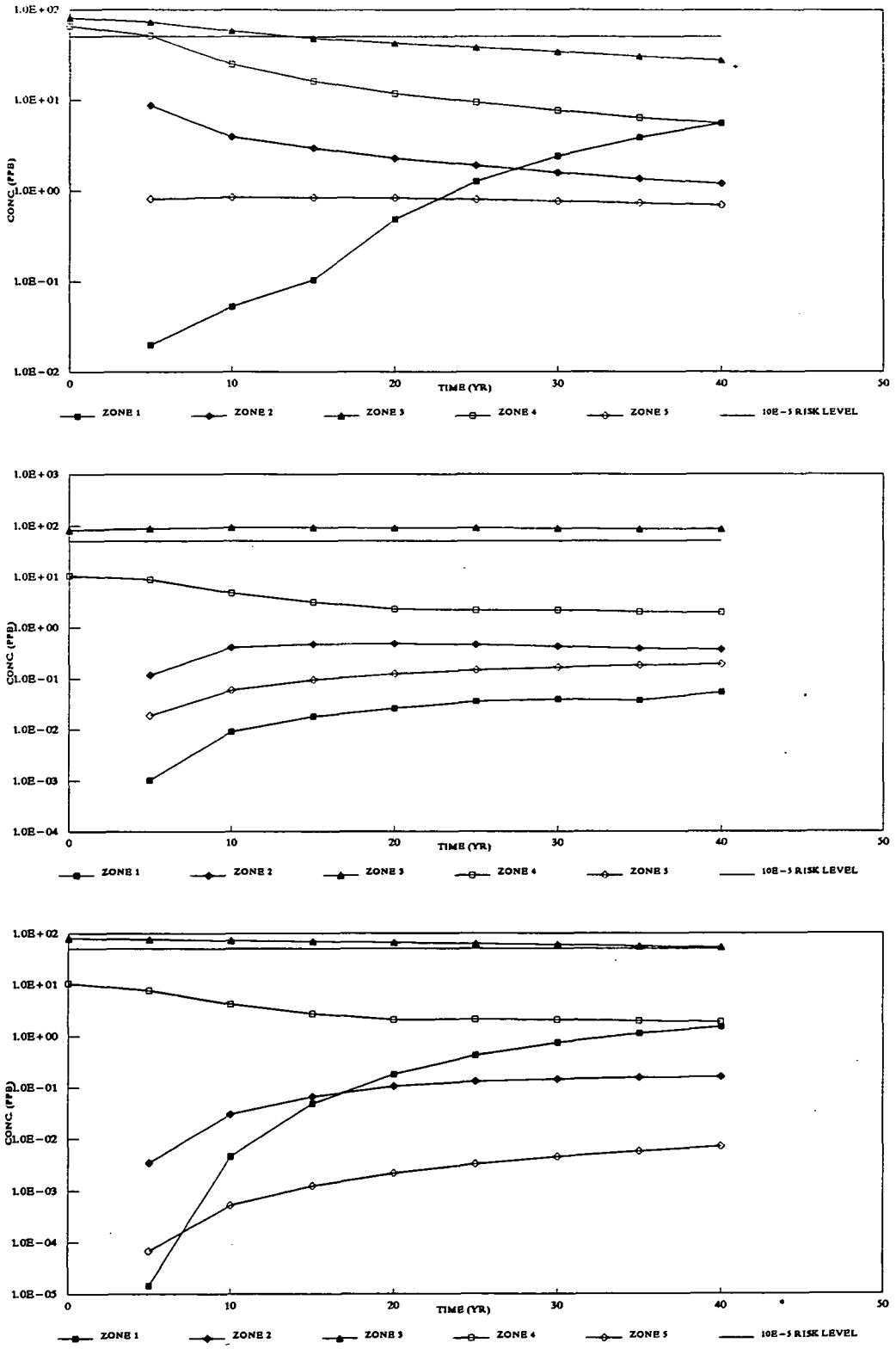

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FIGURE F.7-59B. GROUNDWATER RESTORATION TO 20 PPB, ARSENIC, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

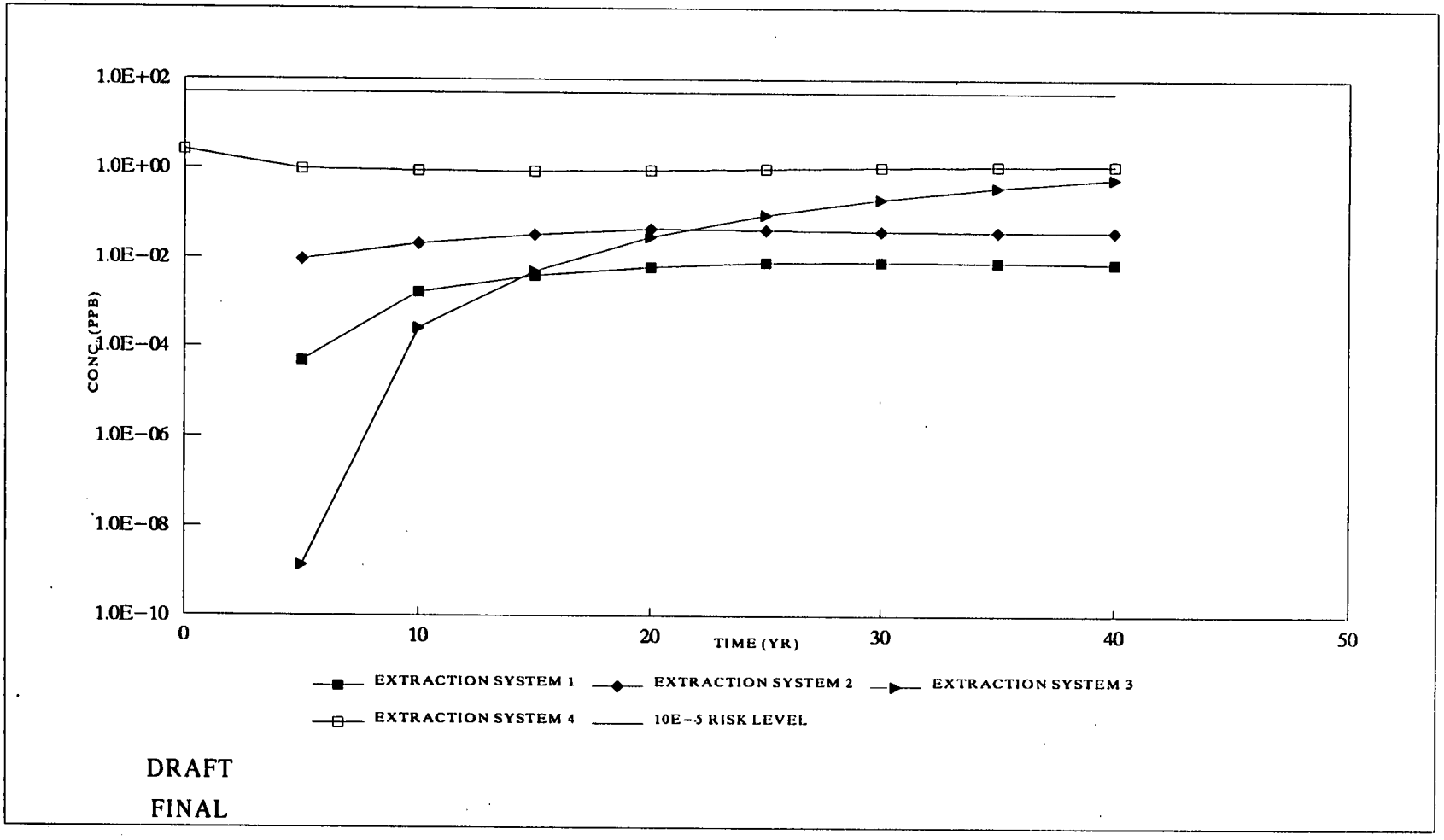

FIGURE F.7-60. GROUNDWATER RESTORATION TO 20 PPB, ARSENIC, AVERAGE CONCENTRATION CURVES

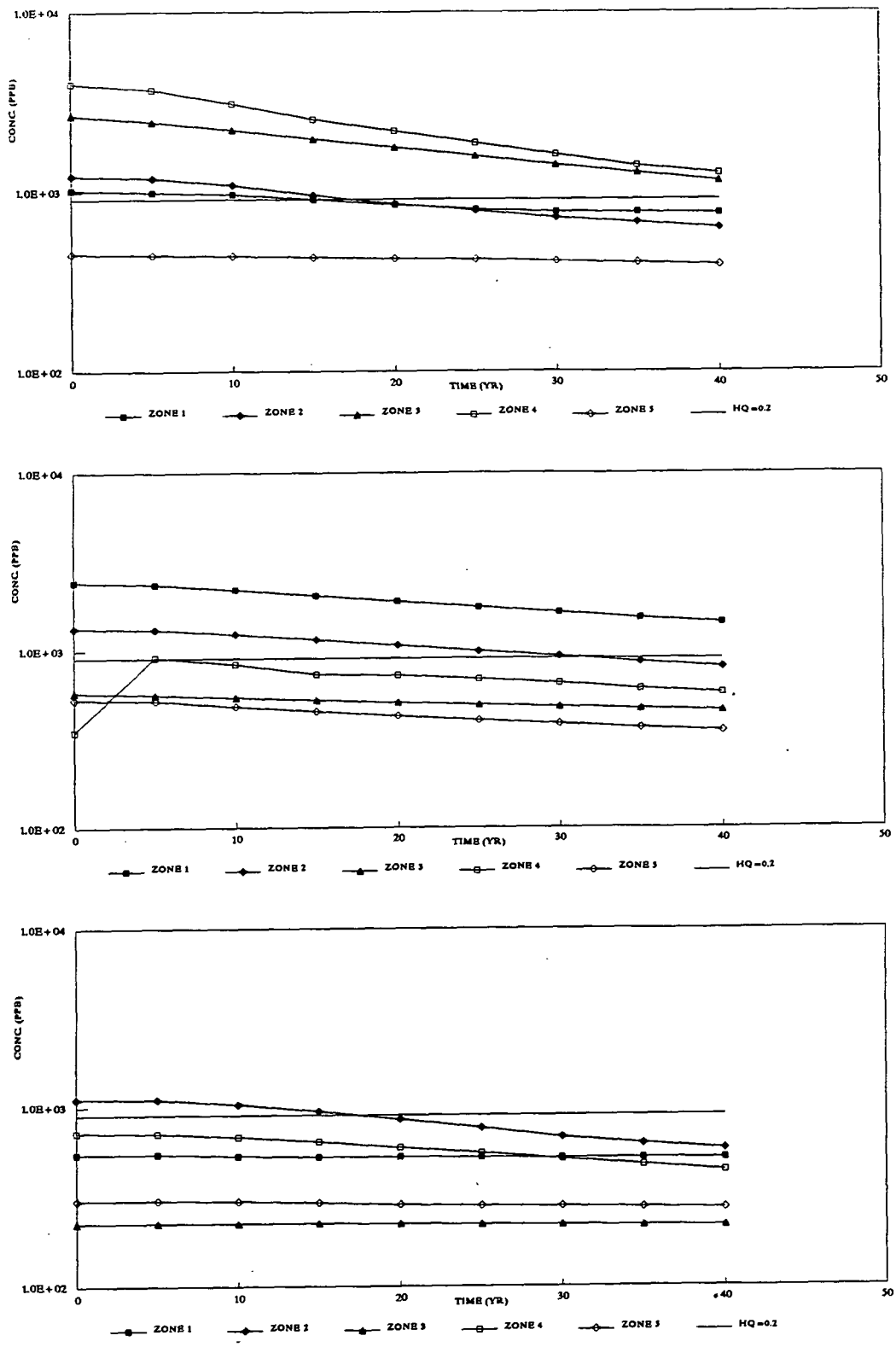

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FIGURE F.7–61A. GROUNDWATER RESTORATION TO 20 PPB, MANGANESE, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

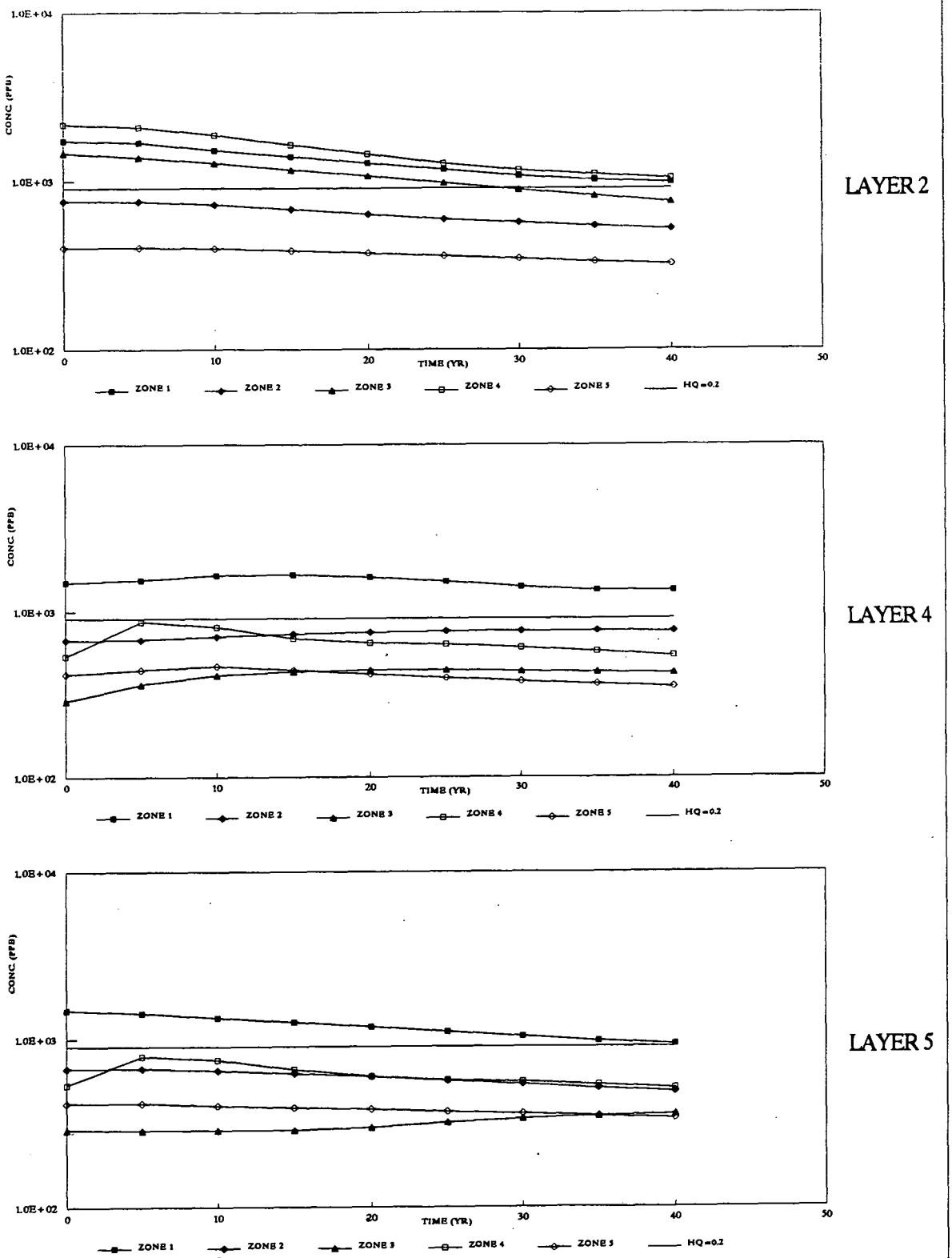

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FIGURE F.7-61B. GROUNDWATER RESTORATION TO 20 PPB, MANGANESE, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

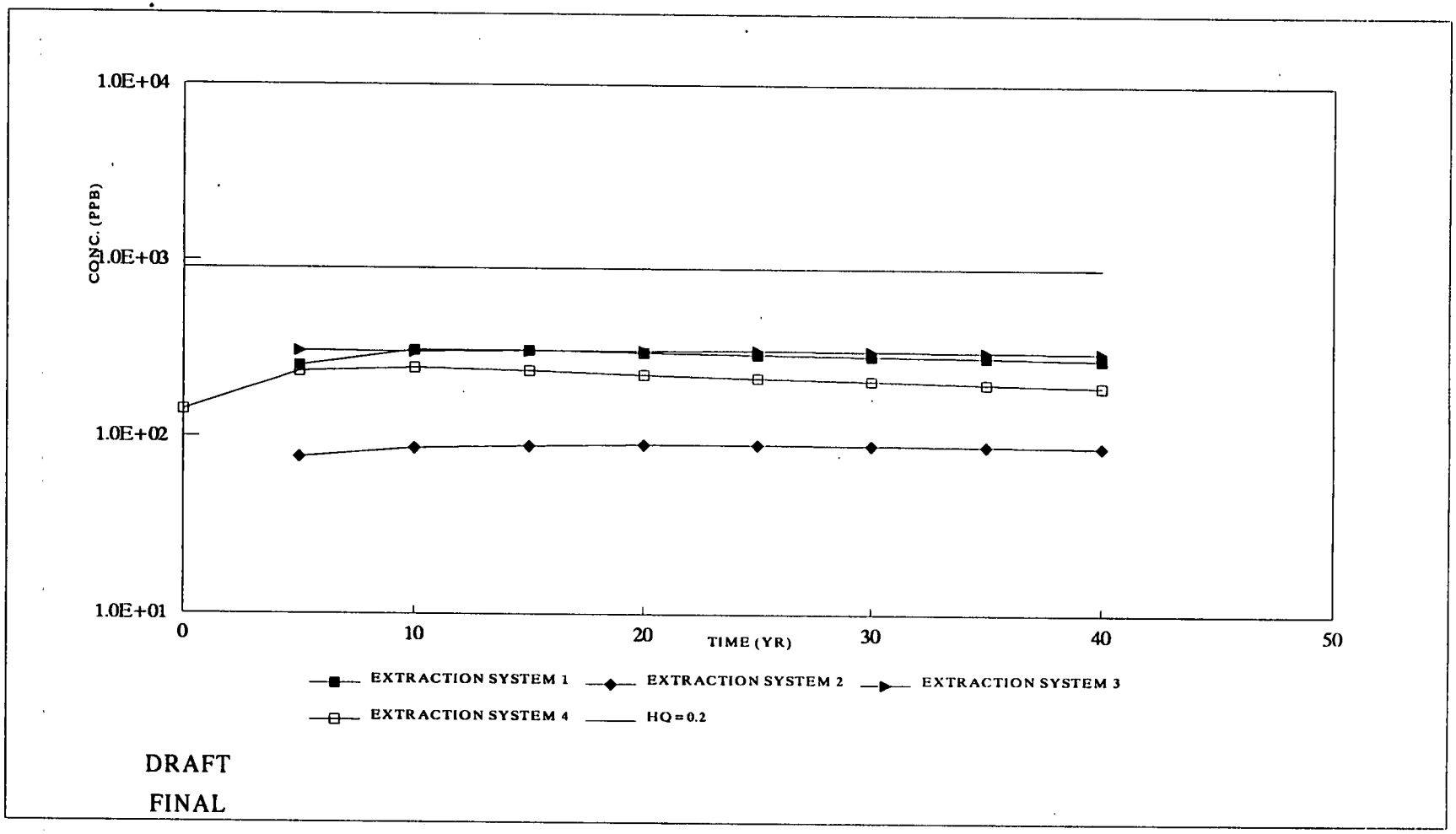

FIGURE F.7-62. GROUNDWATER RESTORATION TO 20 PPB, MANGANESE, AVERAGE CONCENTRATION CURVES

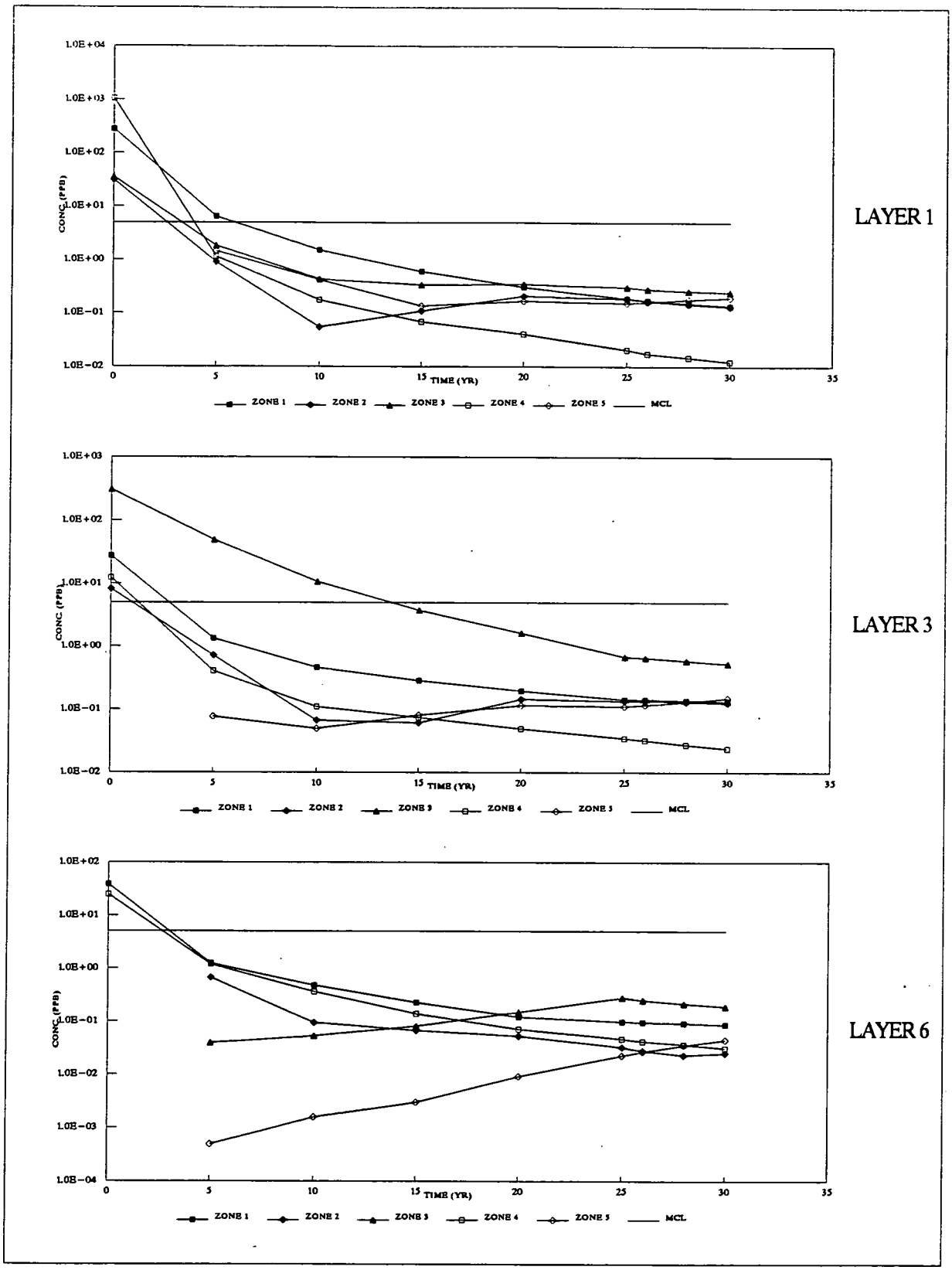

FIGURE F.7–63A. GROUNDWATER RESTORATION TO 20 PPB, TOTAL VOC, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

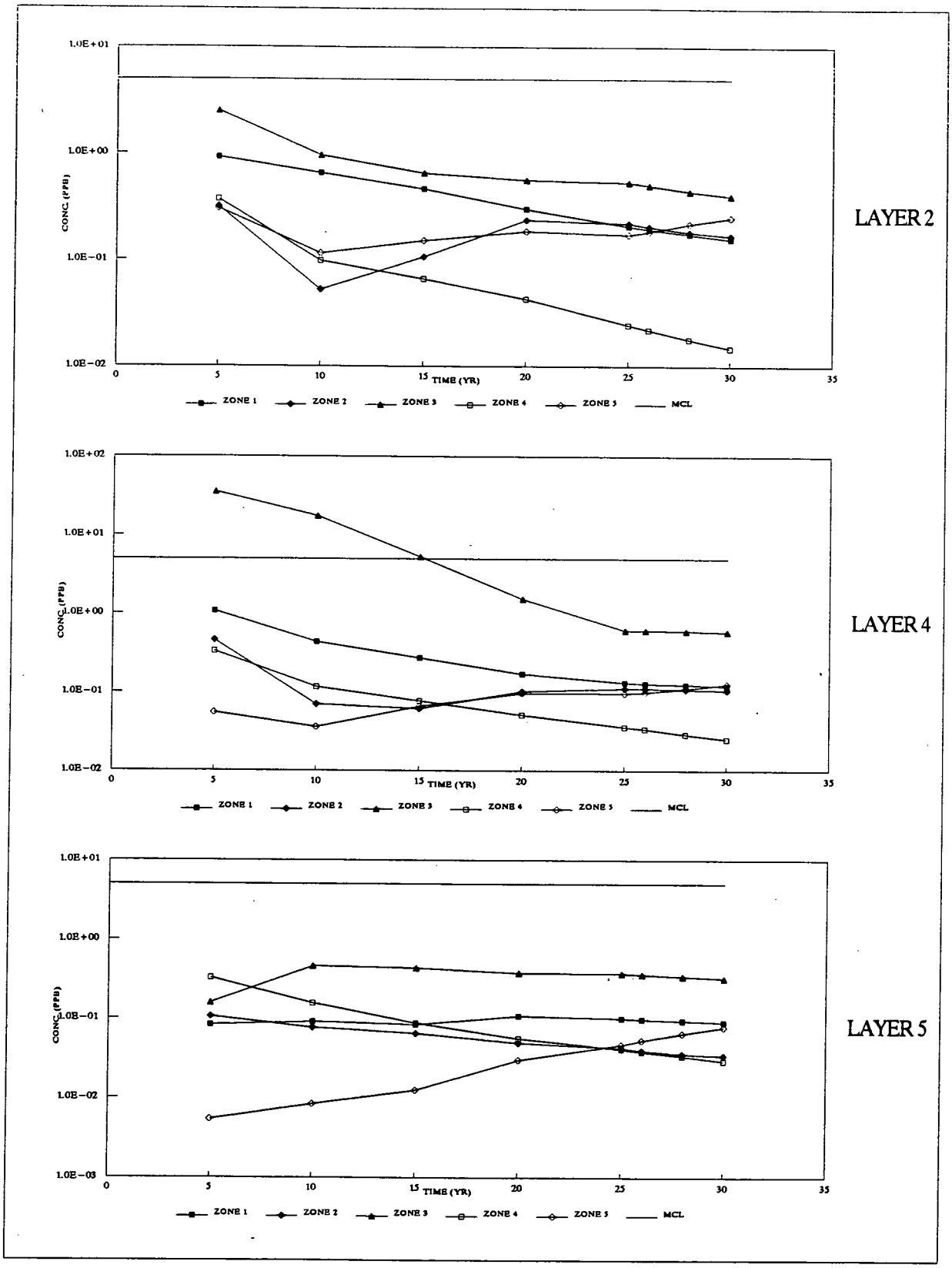

FIGURE F.7-63B. GROUNDWATER RESTORATION TO 20 PPB, TOTAL VOC, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

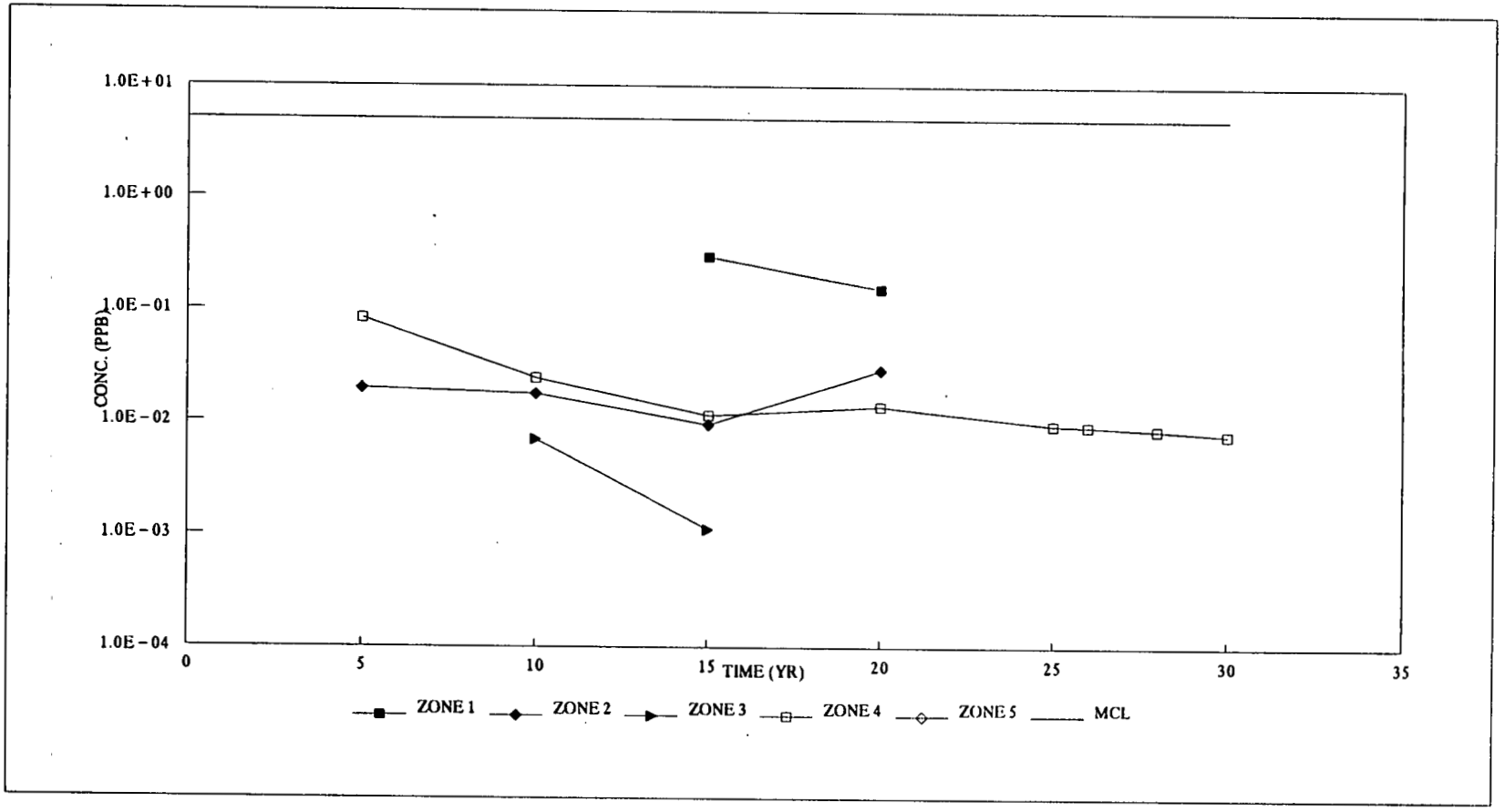

FIGURE F.7-64. GROUNDWATER RESTORATION TO 20 PPB, TOTAL VOCS, AVERAGE CONCENTRATION CURVES.

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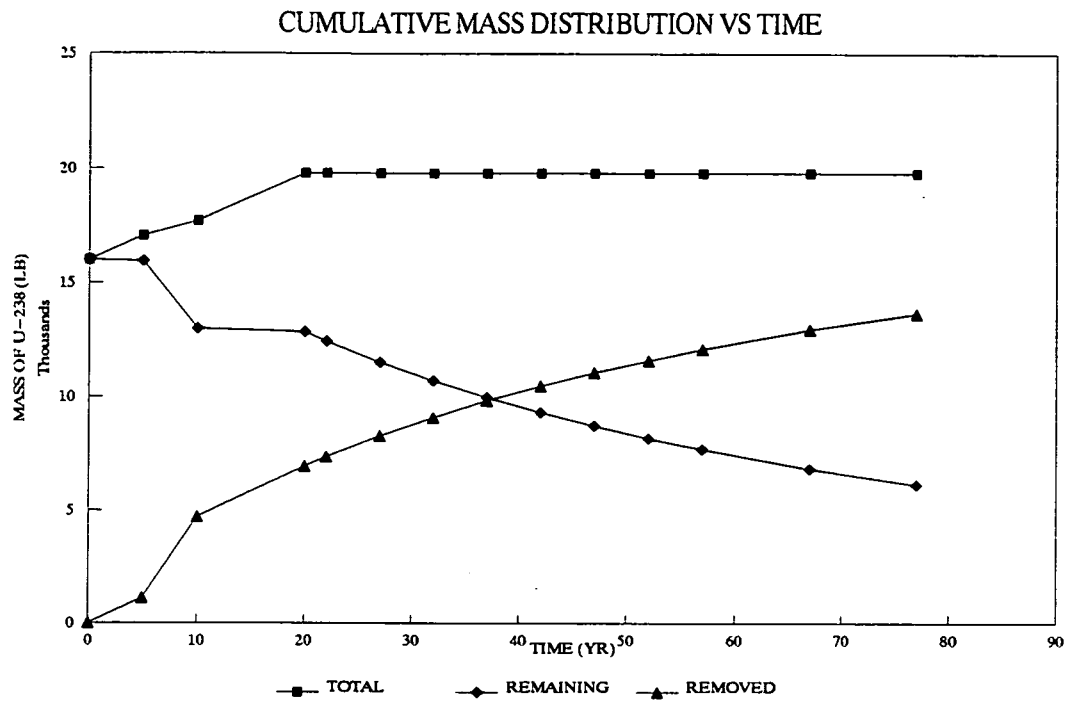

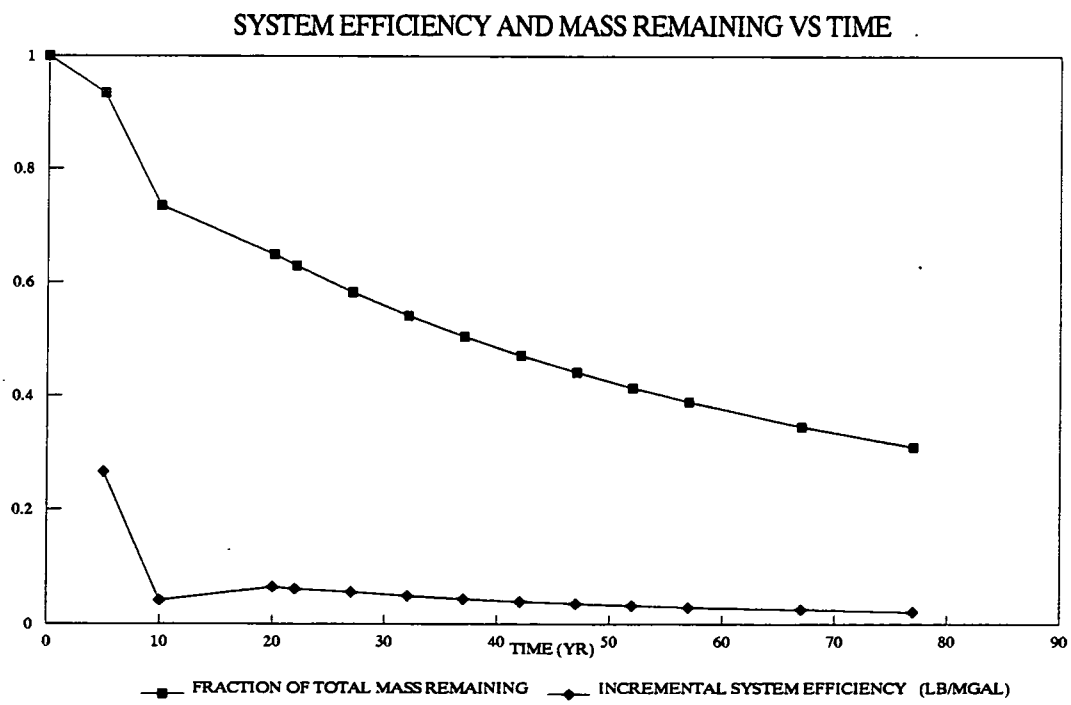

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FIGURE F.7-65. GROUNDWATER RESTORATION TO 20 PPB – HIGH Kd, SYSTEM PERFORMANCE CURVES

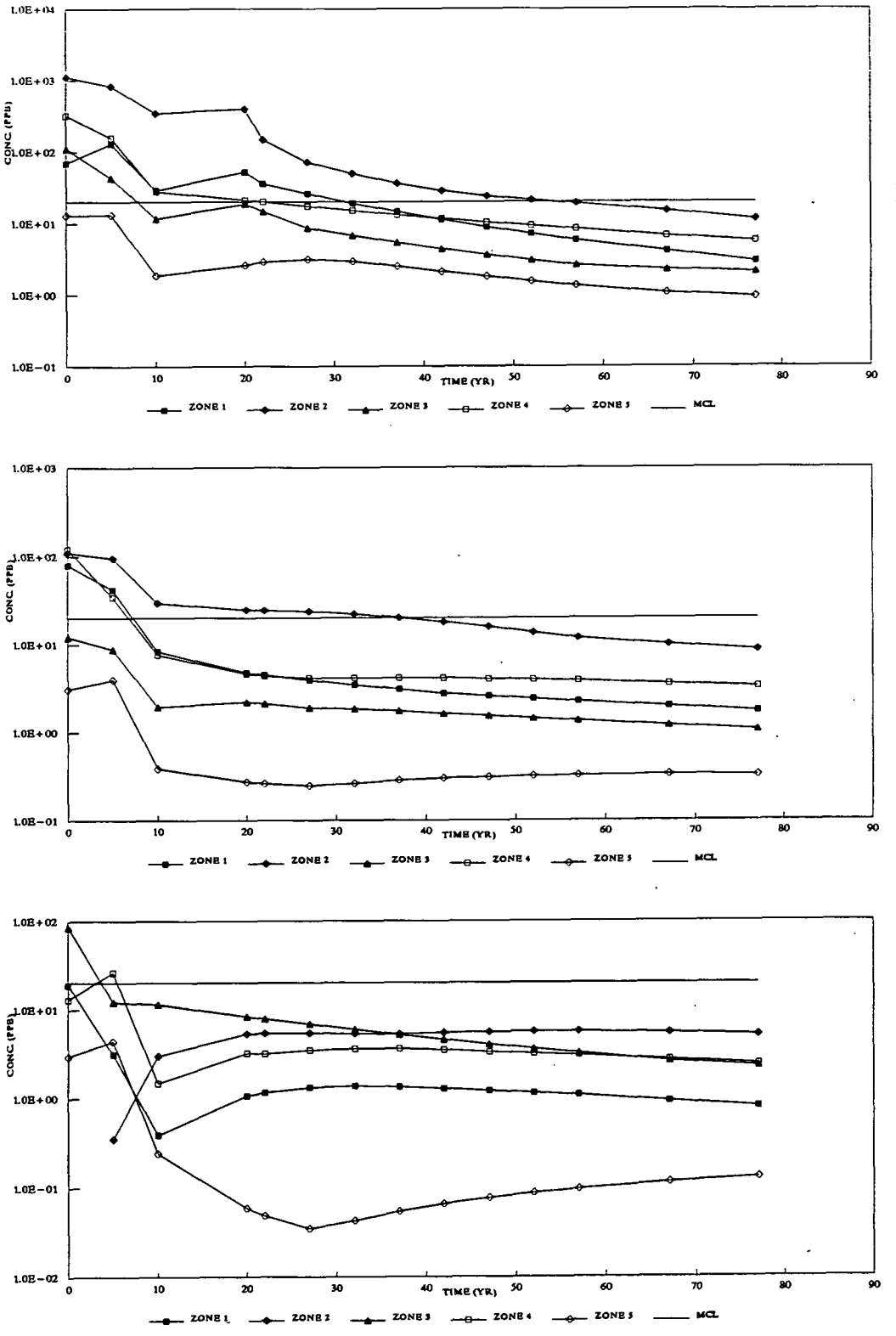

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FIGURE F.7-66A. GROUNDWATER RESTORATION TO 20 PPB – HIGH Kd, MAXIMUM URANIUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6

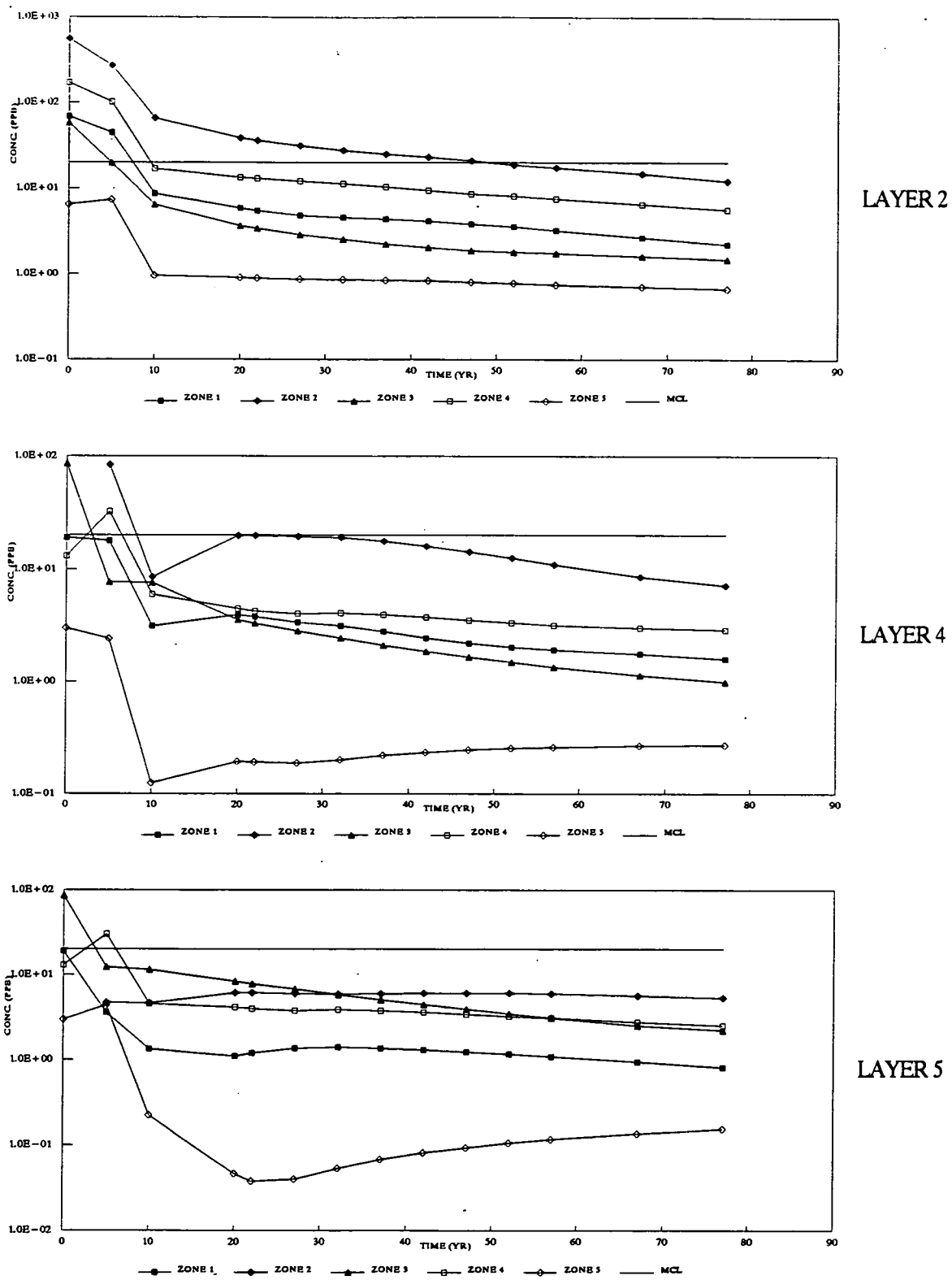

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FIGURE F.7-66B. GROUNDWATER RESTORATION TO 20 PPB – HIGH Kd, MAXIMUM URANIUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

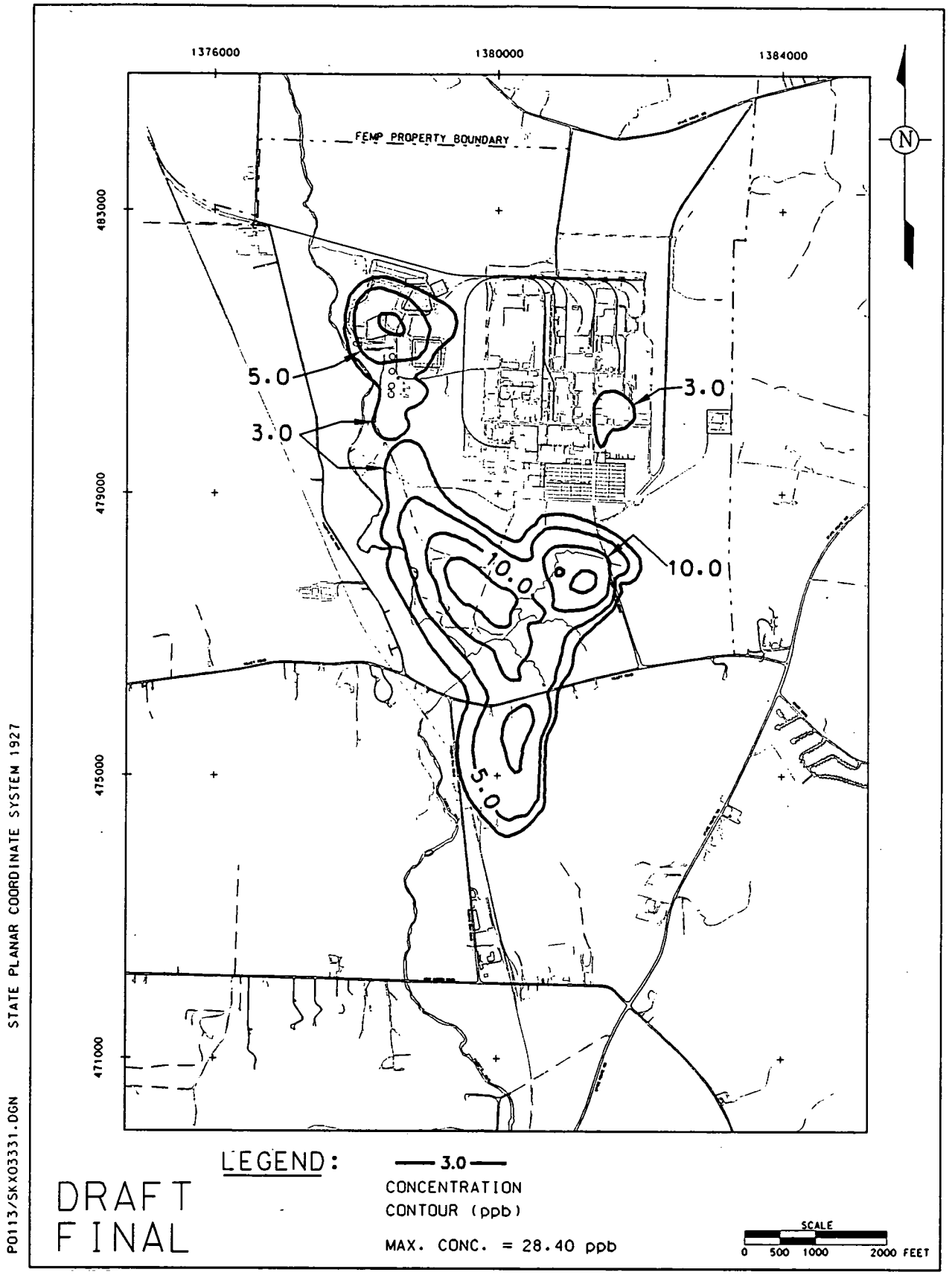

FIGURE F.7-67. GROUNDWATER RESTORATION TO 20 ppb - HIGH Kd. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

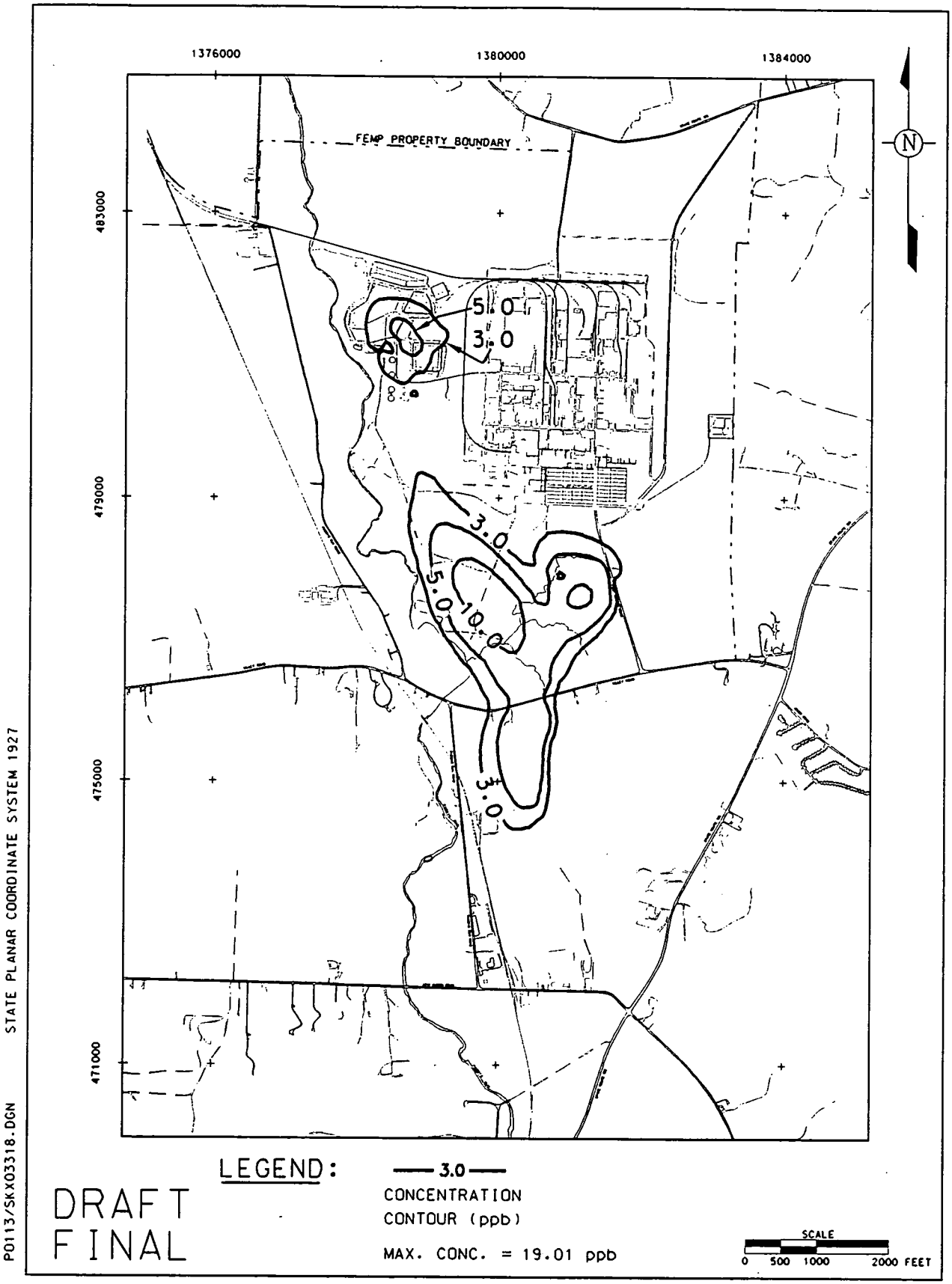

FIGURE F.7-68. GROUNDWATER RESTORATION TO 20 ppb - HIGH Kd. CONCENTRATION CONTOURS. YEAR 57. LAYER 1

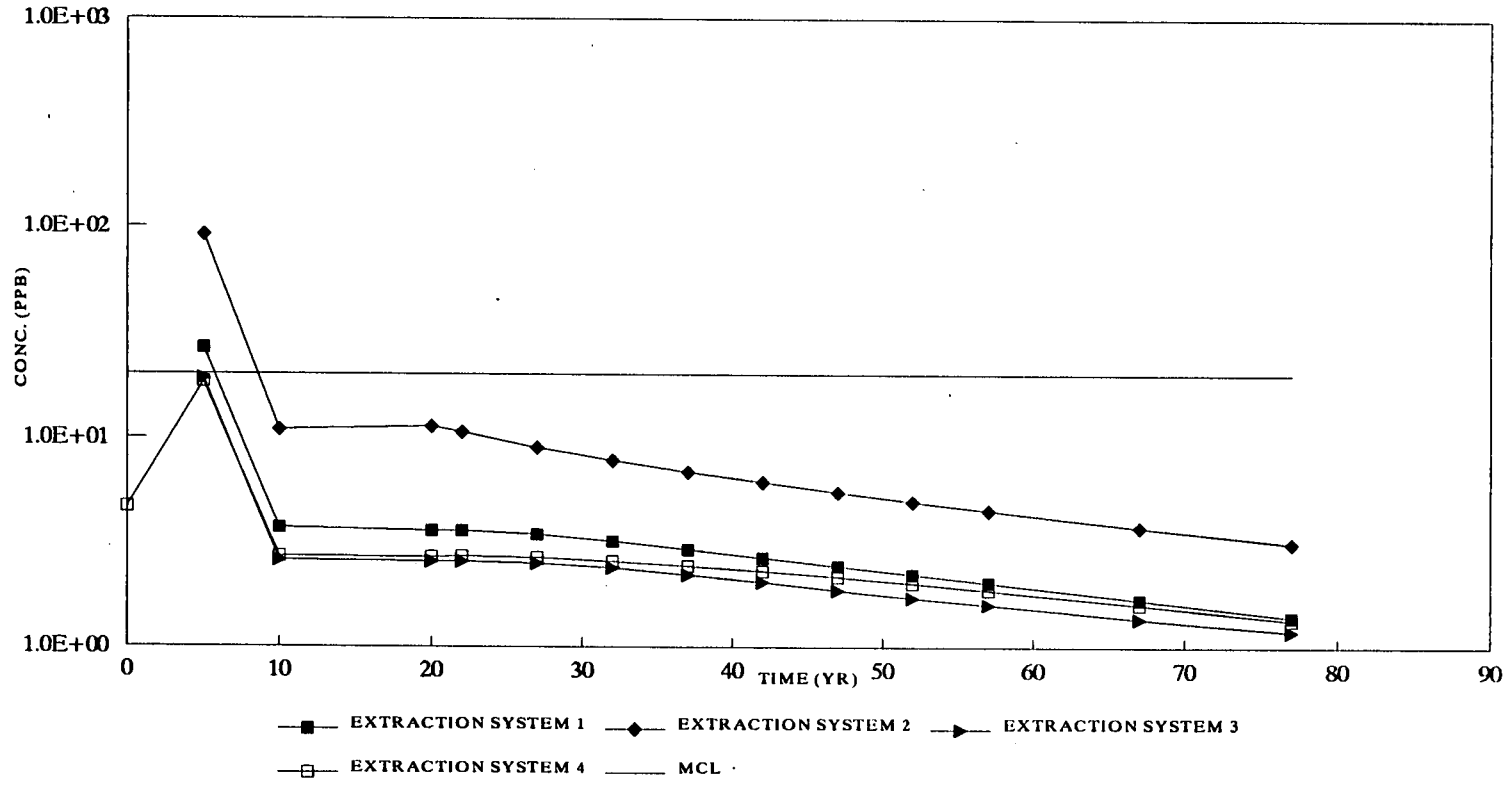

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FIGURE F.7-69. GROUNDWATER RESTORATION TO 20 PPB – HIGH Kd, AVERAGE CONCENTRATION CURVES

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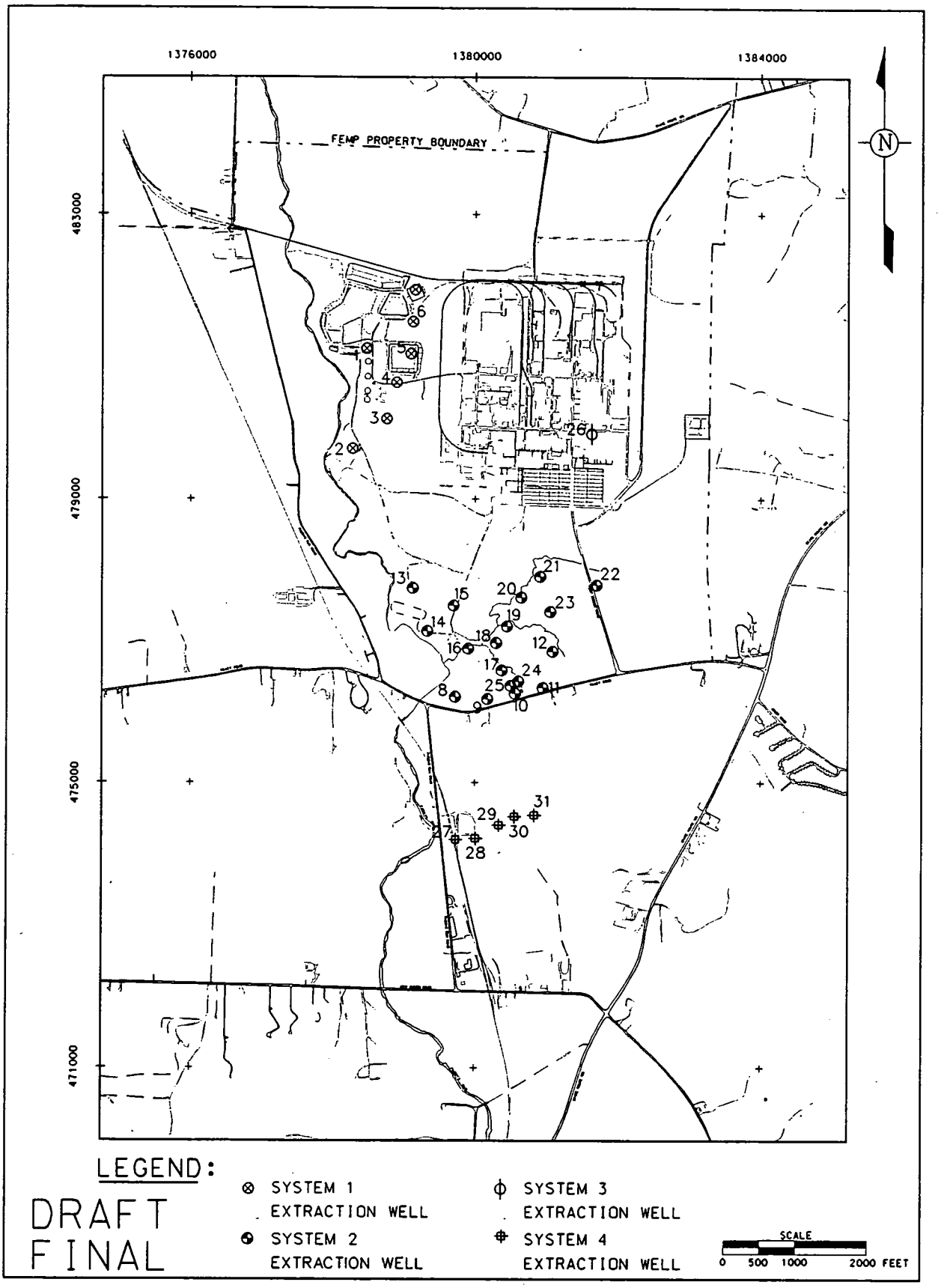
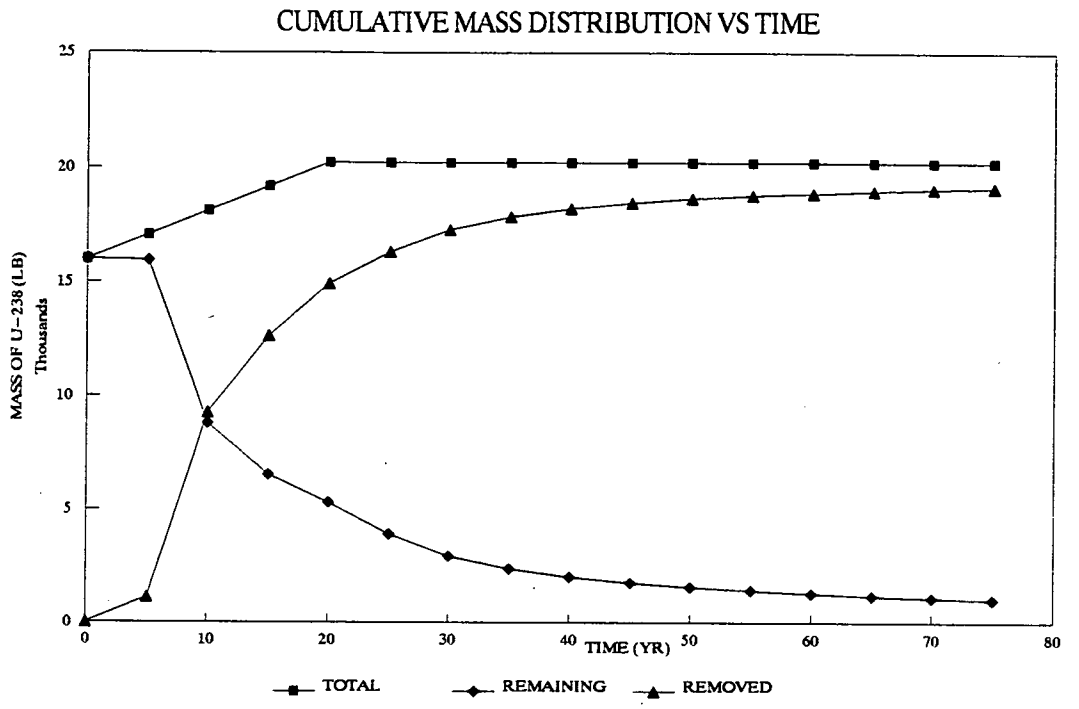


FIGURE F.7-70. GROUNDWATER RESTORATION TO 3 PPB. WELL LOCATIONS



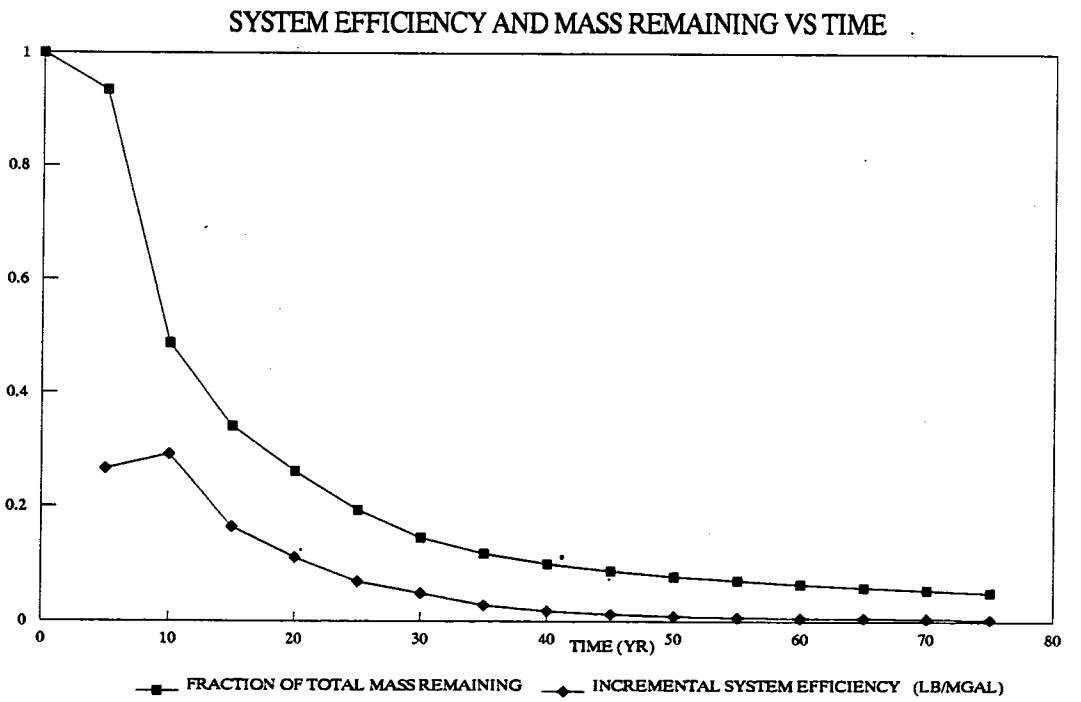


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FIGURE F.7-71. GROUNDWATER RESTORATION TO 3 PPB, SYSTEM PERFORMANCE CURVES

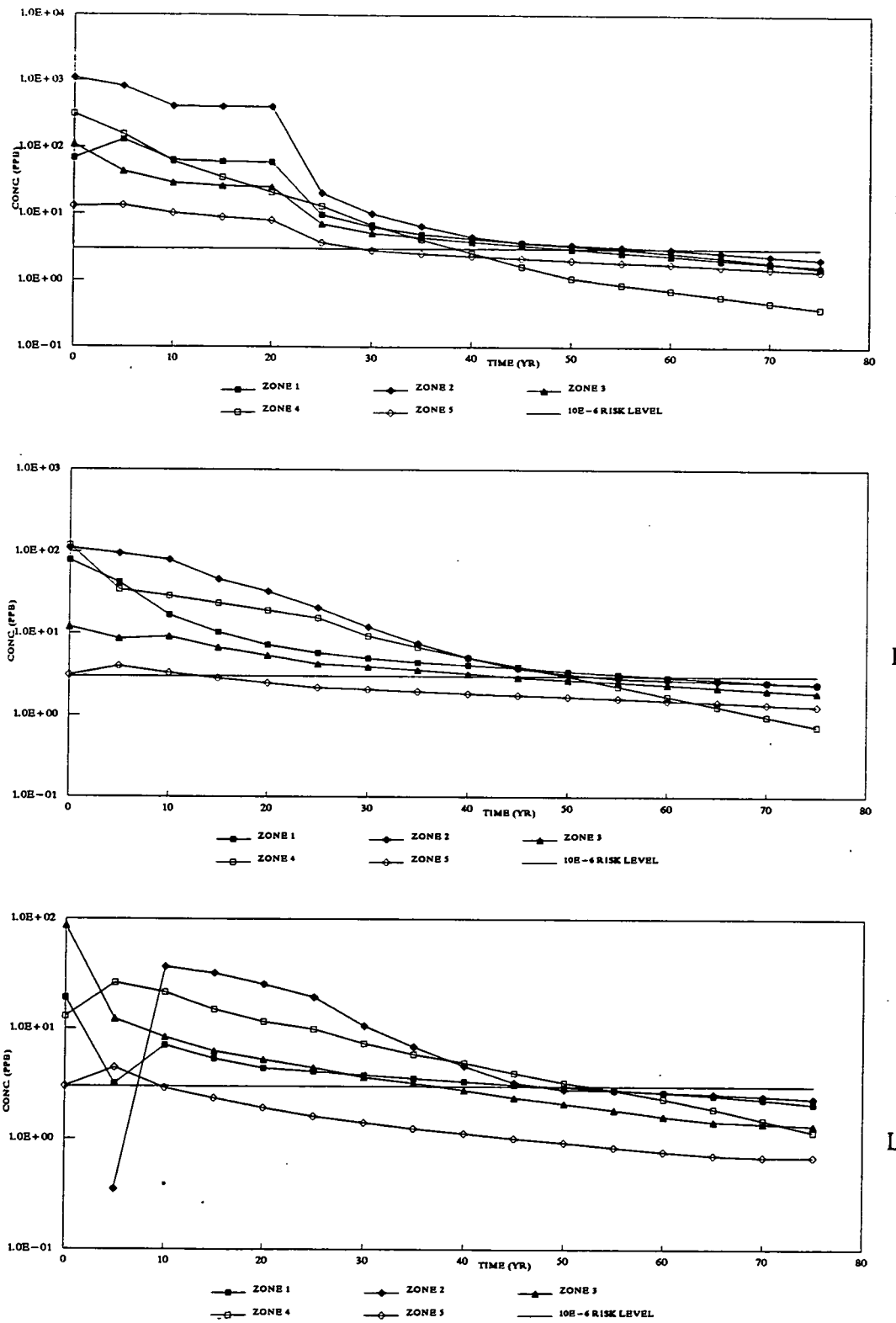

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FIGURE F.7-72A. GROUNDWATER RESTORATION TO 3 PPB, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

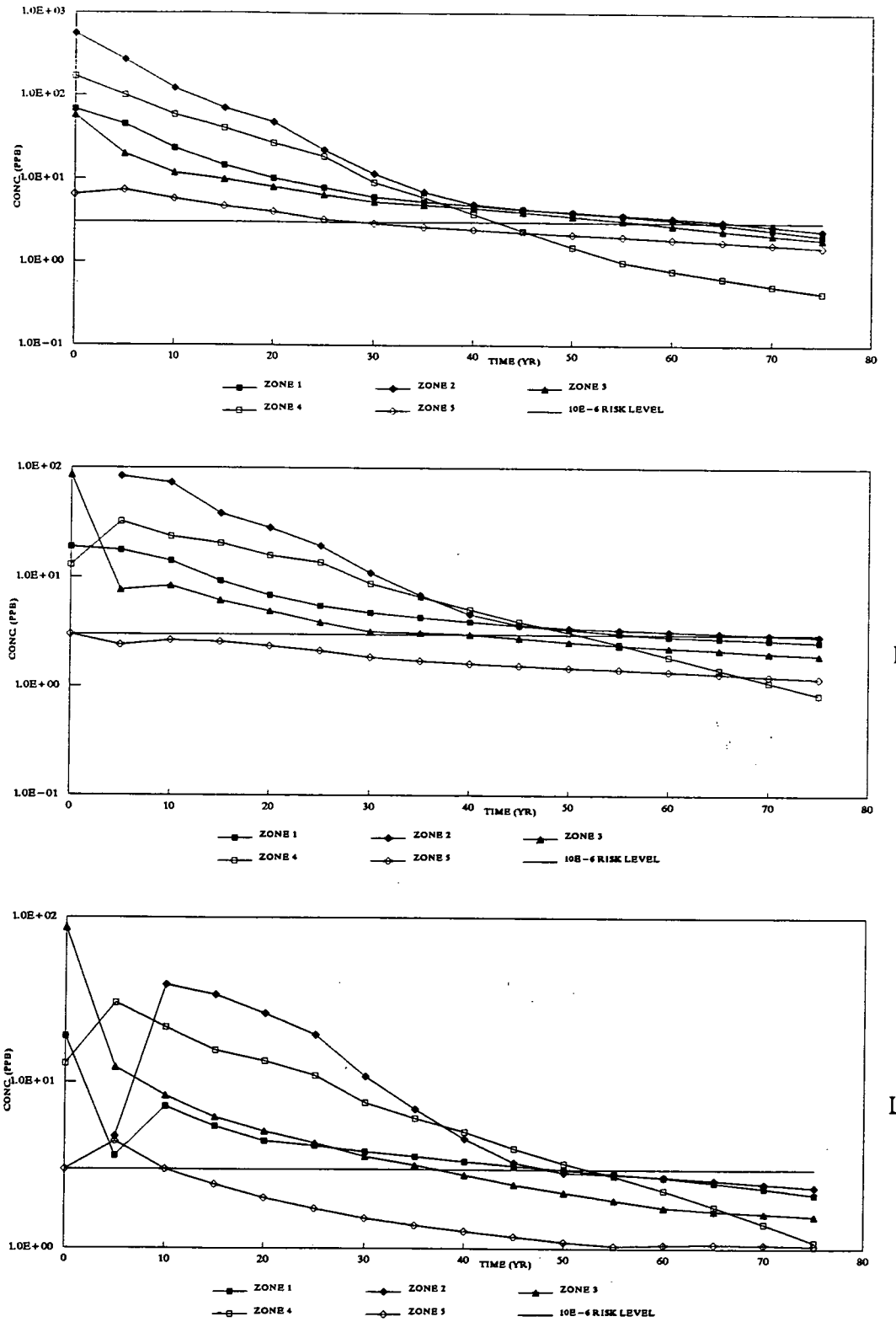

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FIGURE F.7-72B. GROUNDWATER RESTORATION TO 3 PPB, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

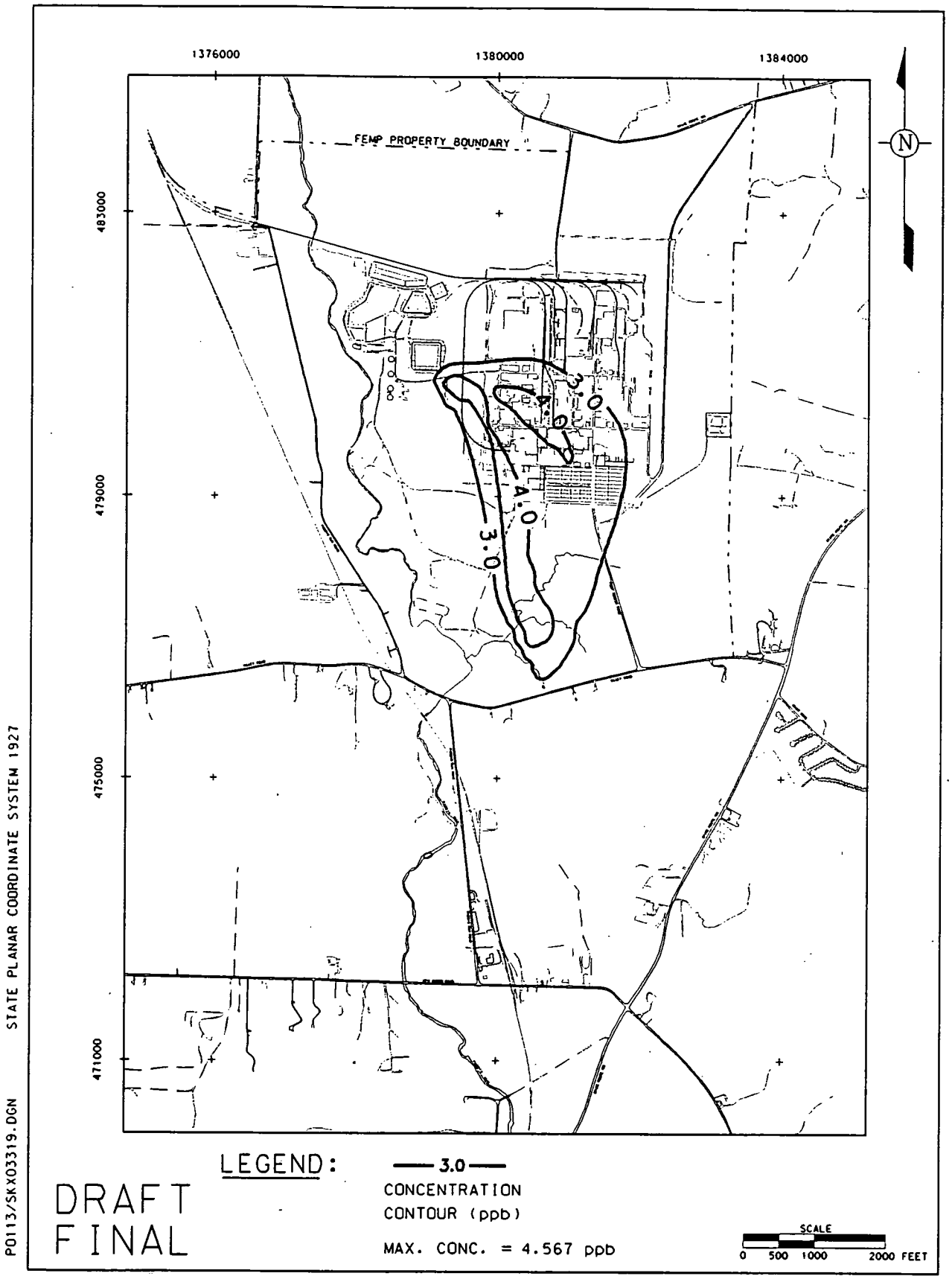

FIGURE F.7-73. GROUNDWATER RESTORATION TO 3 ppb. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

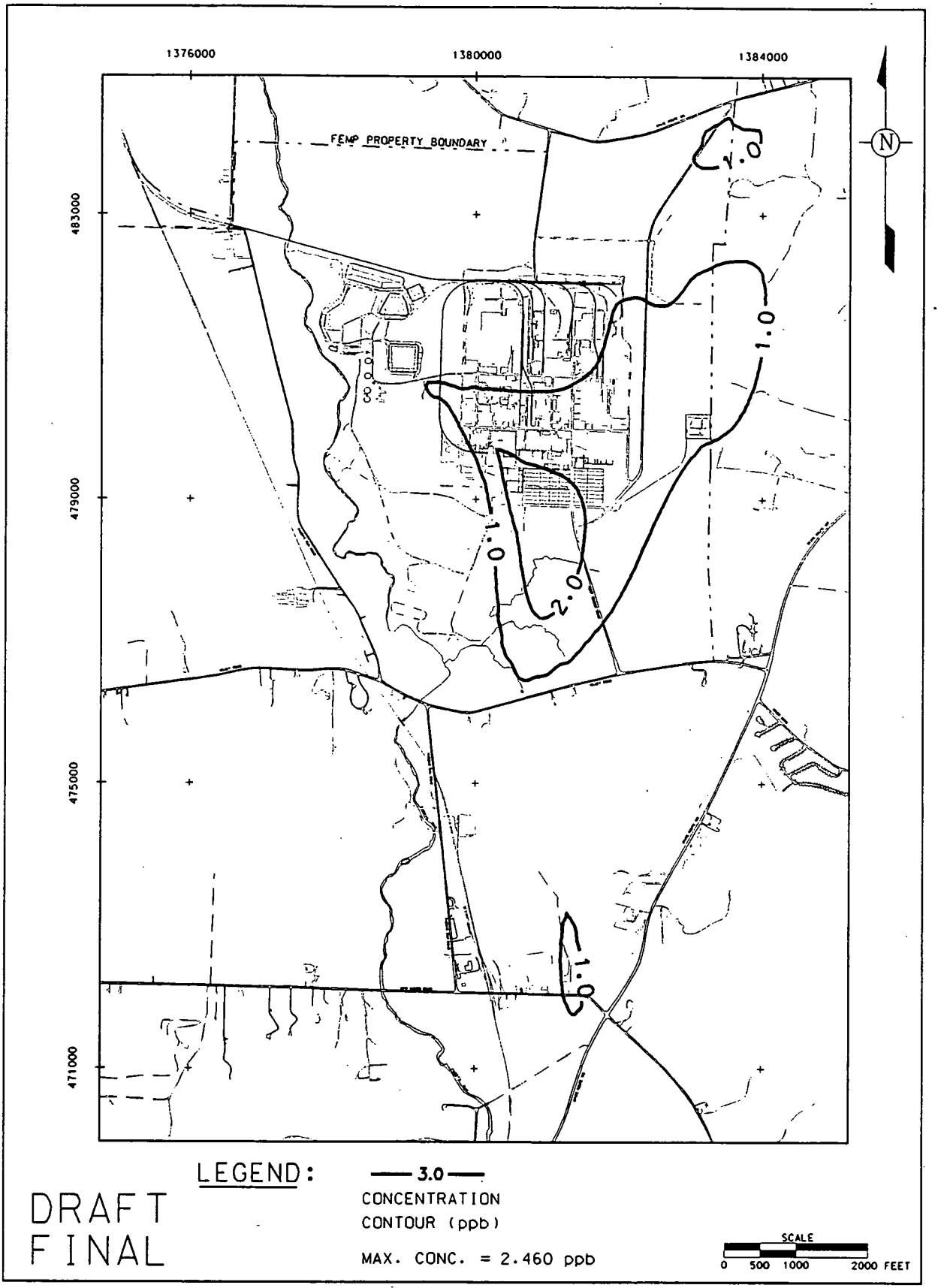

FIGURE F.7-74. GROUNDWATER RESTORATION TO 3 ppb. CONCENTRATION CONTOURS. YEAR 70. LAYER 1

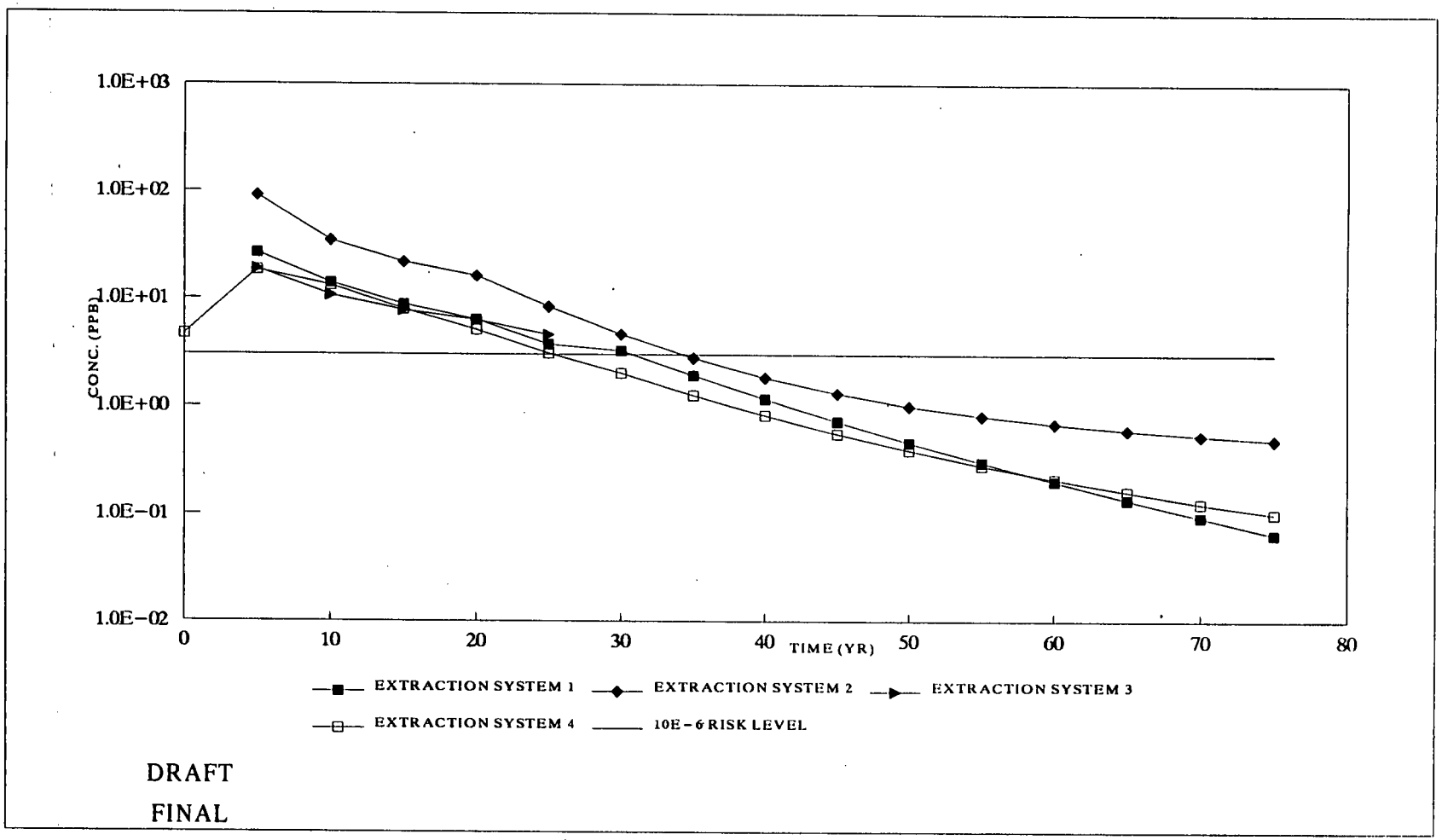

FIGURE F.7-75. GROUNDWATER RESTORATION TO 3 PPB,URANIUM, AVERAGE CONCENTRATION CURVES

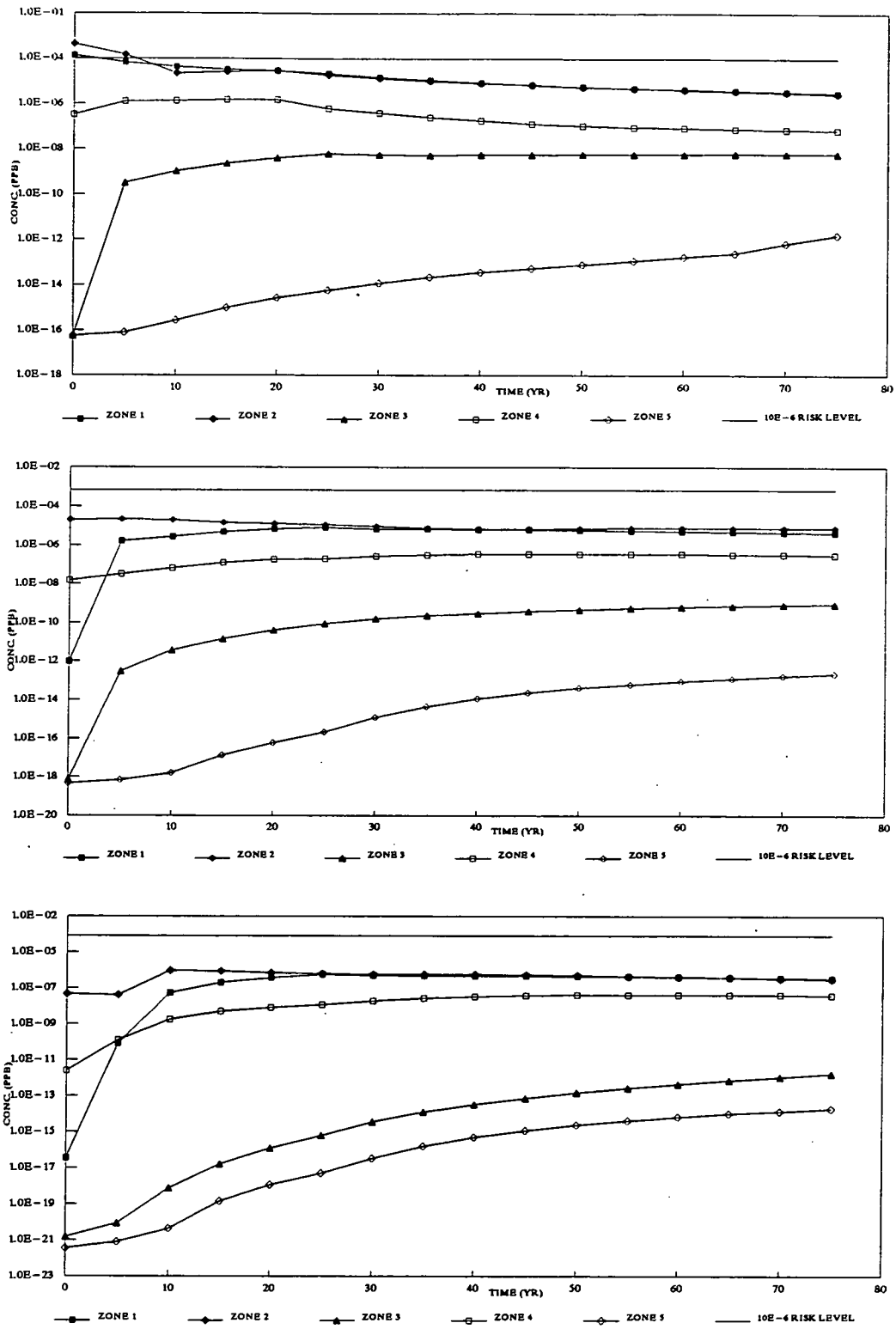

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FIGURE F.7-76A. GROUNDWATER RESTORATION TO 3 PPB, NEPTUNIUM-237, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

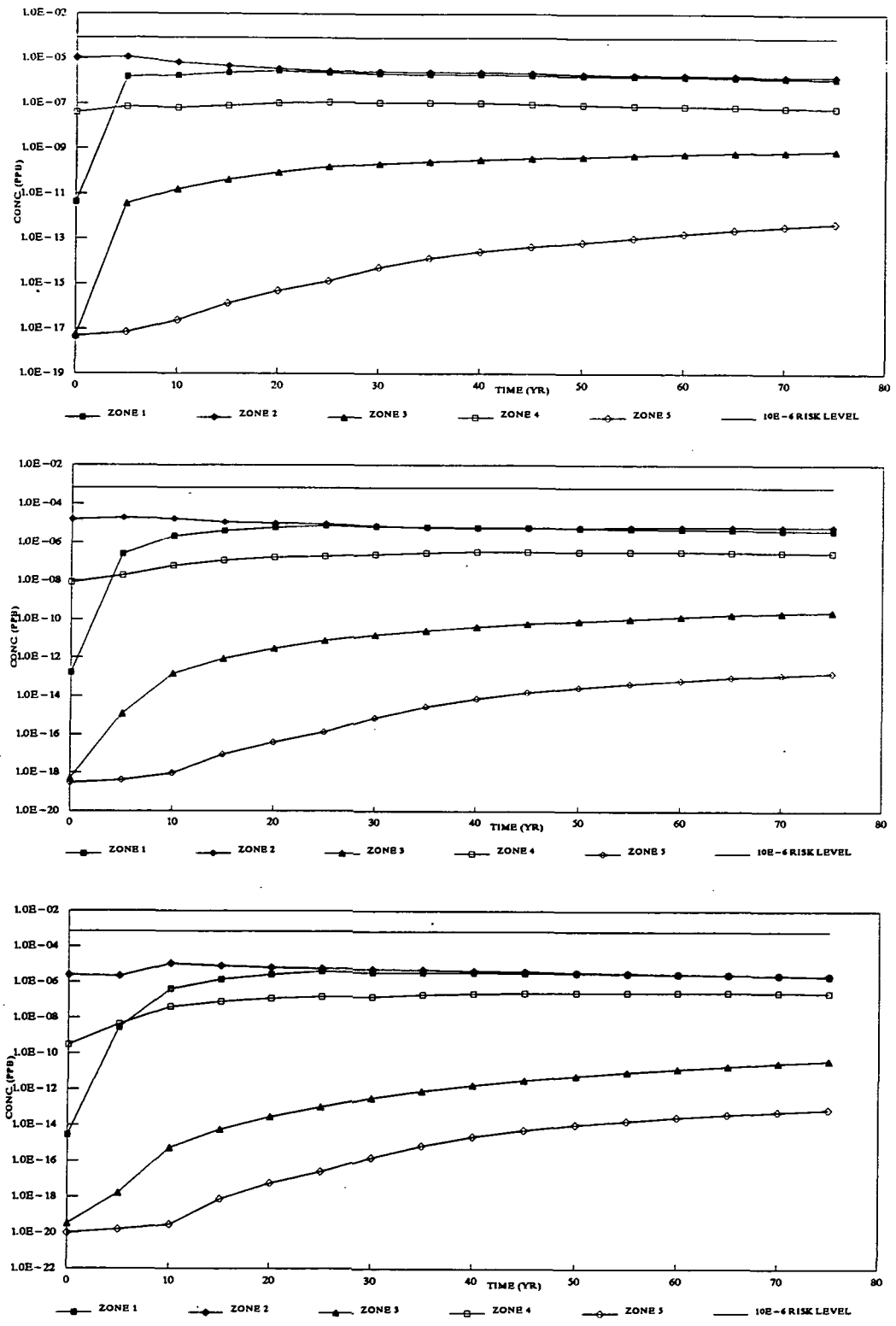

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FIGURE F.7-76B. GROUNDWATER RESTORATION TO 3 PPB, NEPTUNIUM-237, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

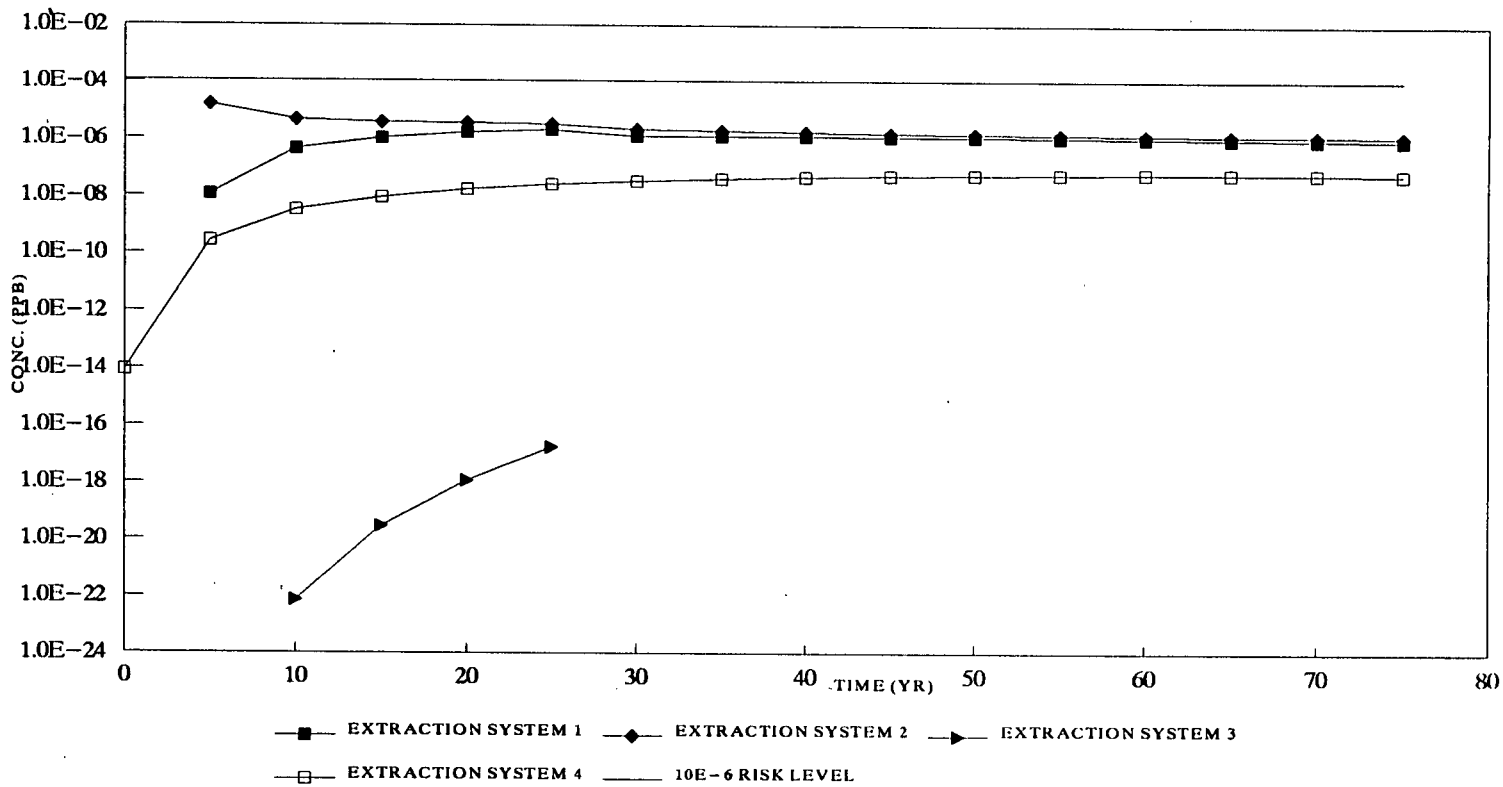

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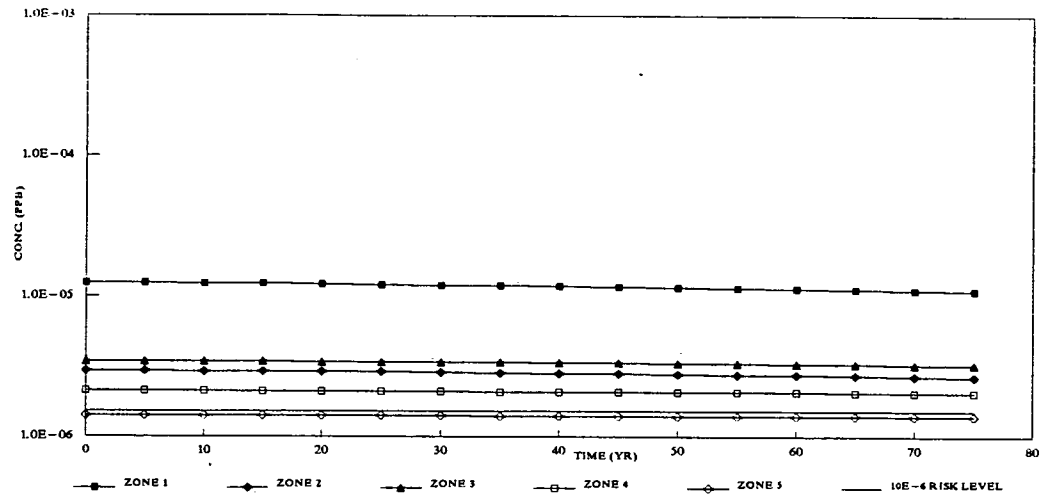
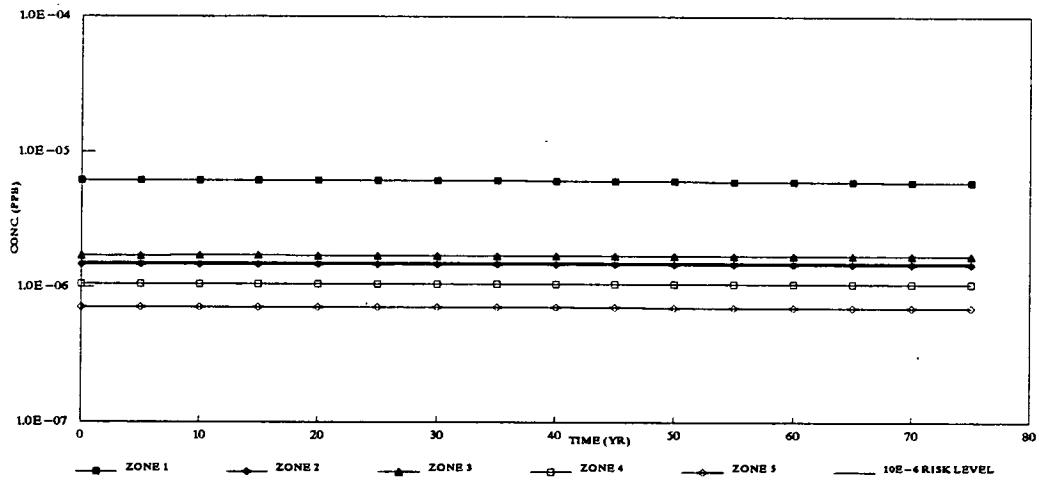
FIGURE F.7−77. GROUNDWATER RESTORATION TO 3 PPB, NEPTUNIUM−237, AVERAGE CONCENTRATION CURVES



LAYER 1



LAYER 3

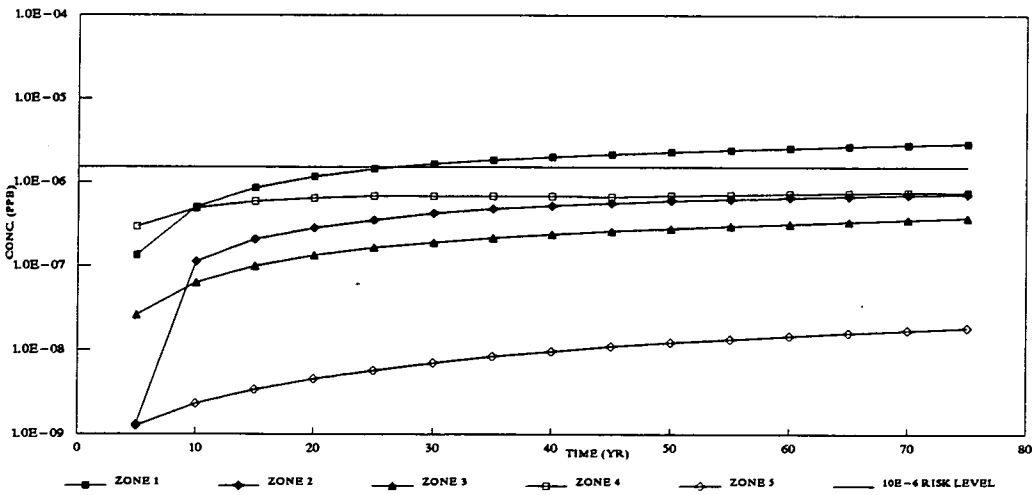


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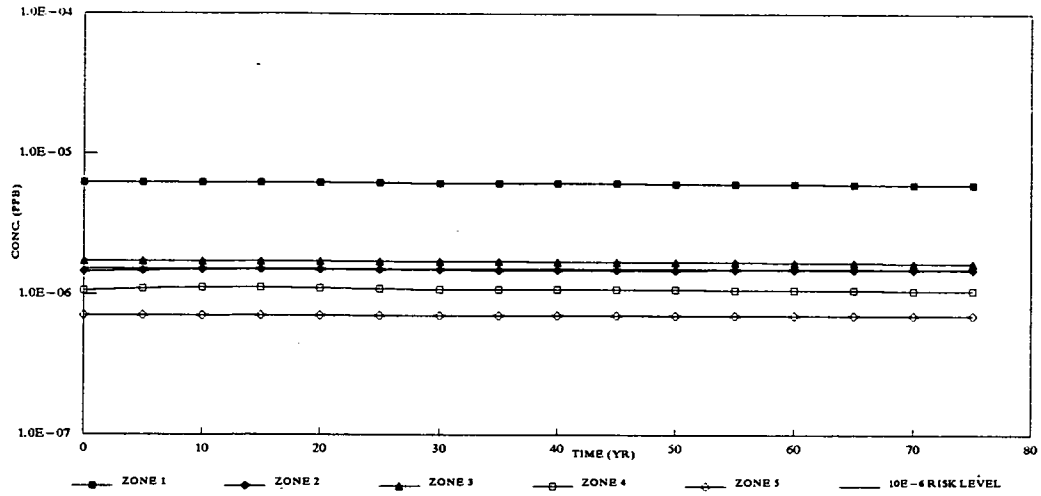
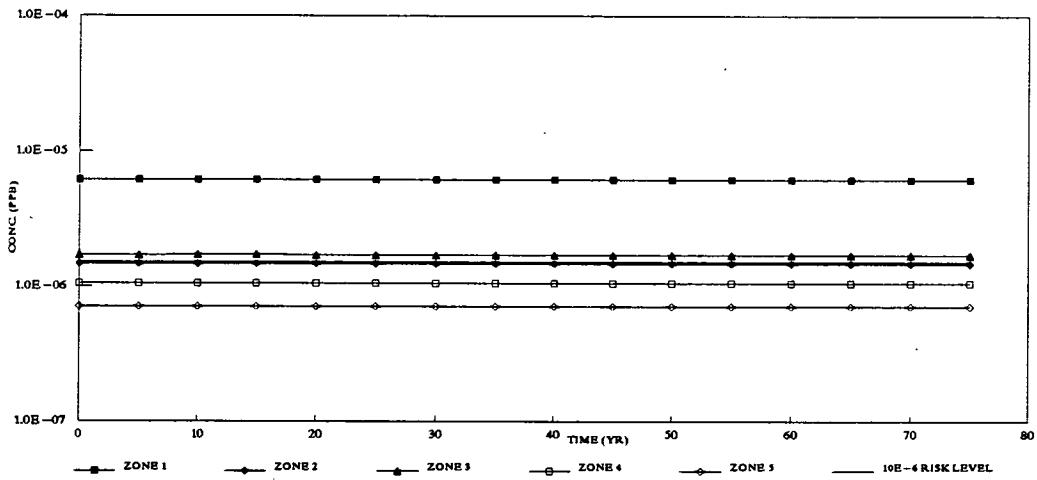
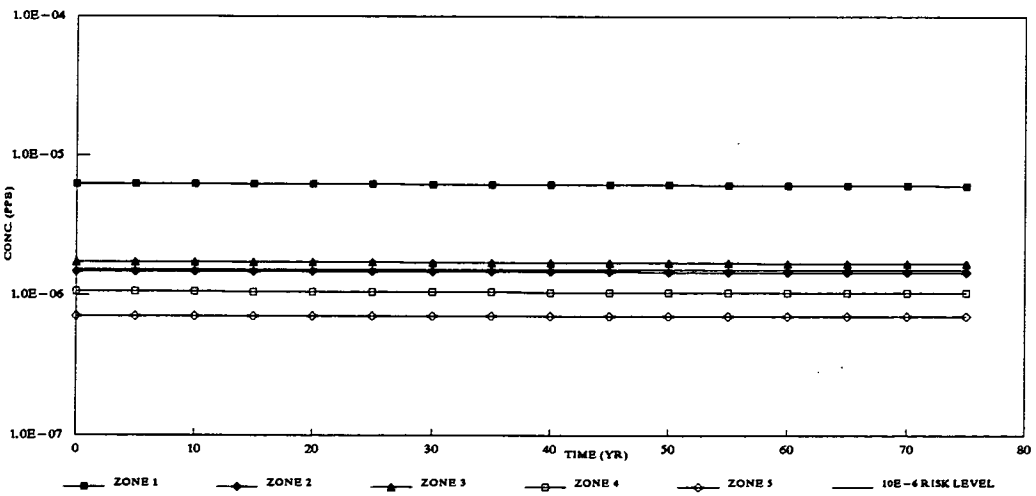
FIGURE F.7-78A. GROUNDWATER RESTORATION TO 3 PPB, RADIUM-226, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.



LAYER 2



LAYER 4



LAYER 5

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FIGURE F.7-78B. GROUNDWATER RESTORATION TO 3 PPB, RADIUM-226, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

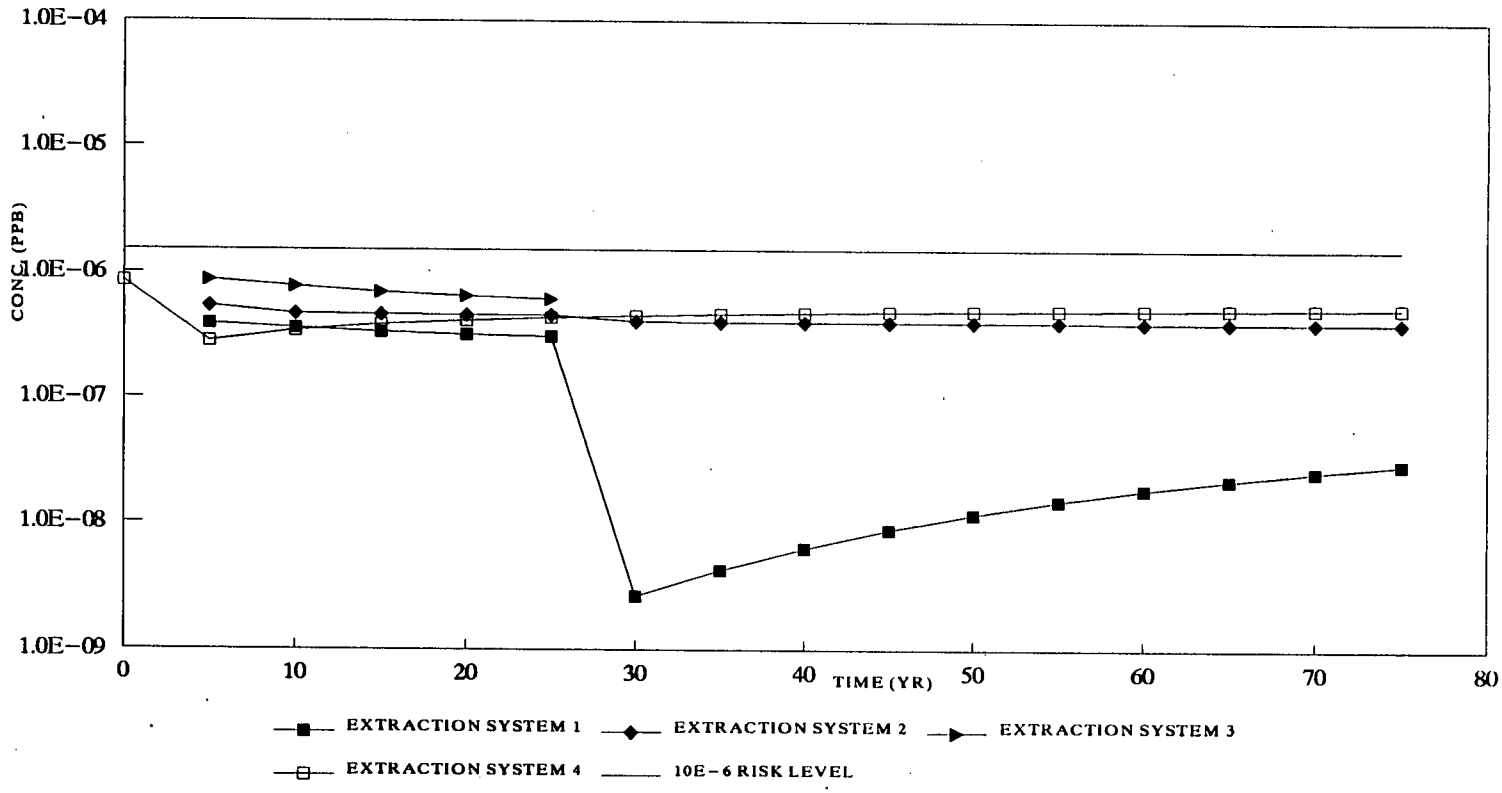

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FIGURE F.7-79. GROUNDWATER RESTORATION TO 3 PPB, RADIUM-226, AVERAGE CONCENTRATION CURVES

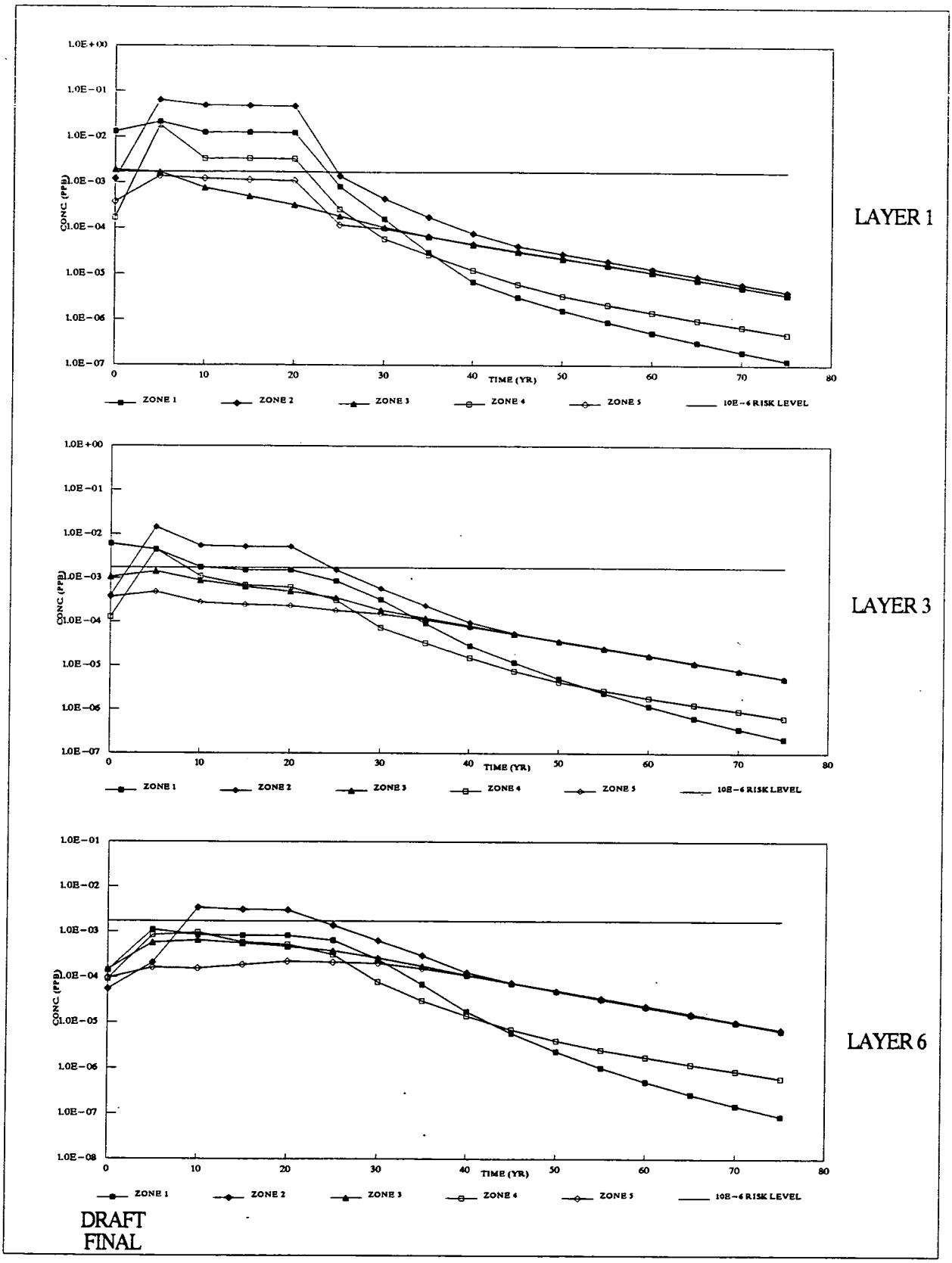

FIGURE F.7-80A. GROUNDWATER RESTORATION TO 3 PPB, TECHNETIUM-99, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

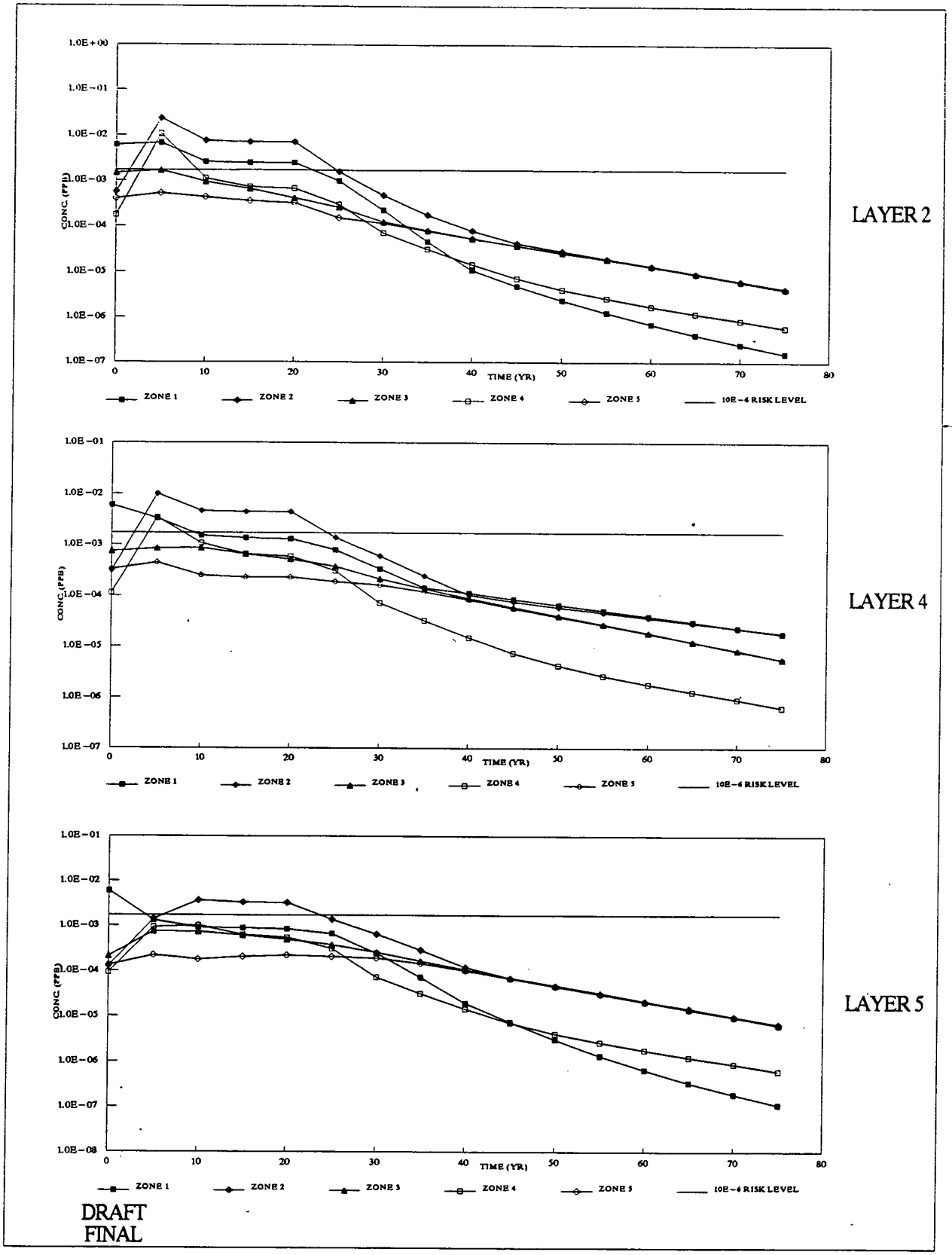

FIGURE F.7-80B. GROUNDWATER RESTORATION TO 3 PPB, TECHNETIUM-99, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

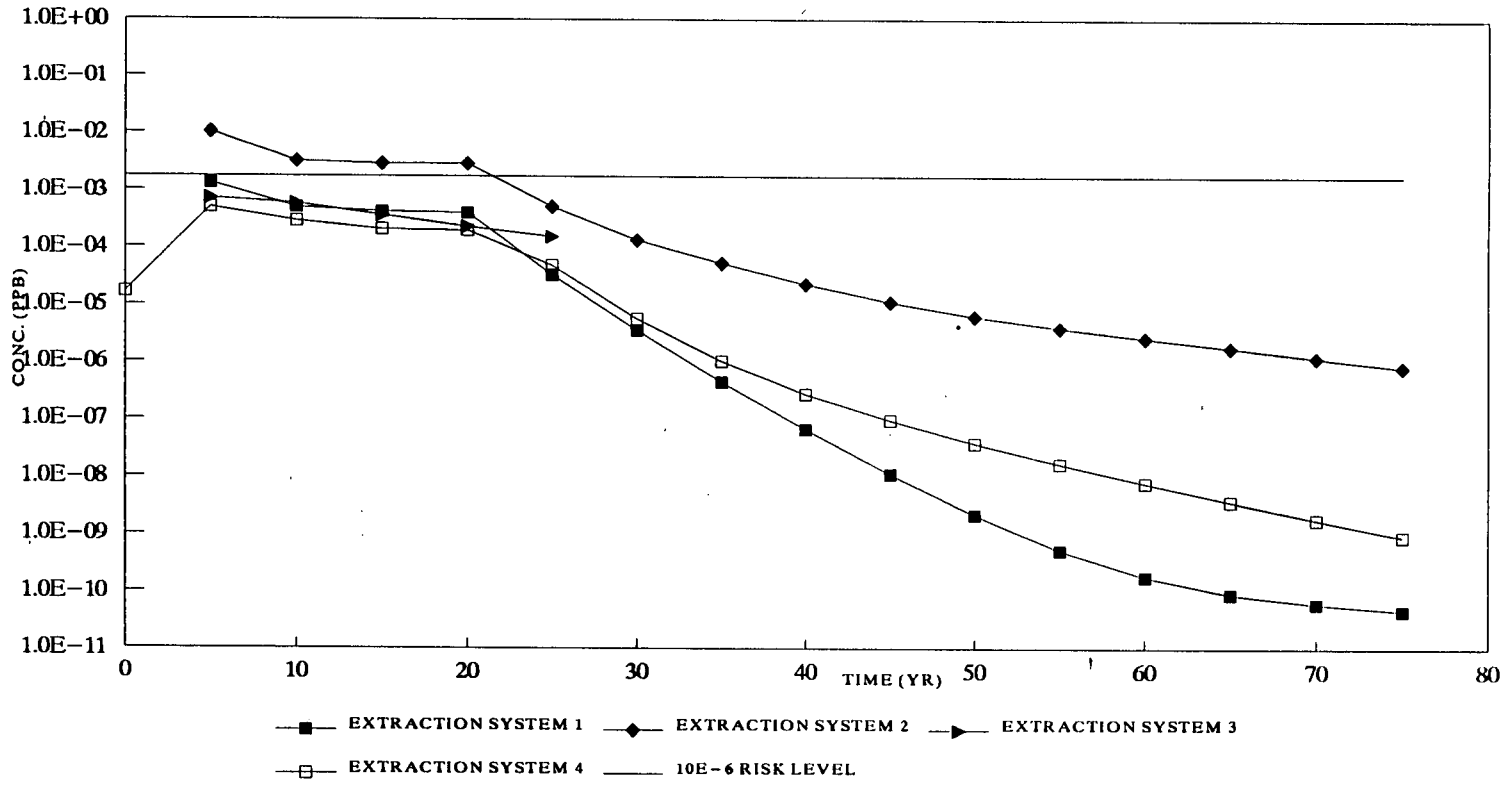

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FIGURE F.7-81. GROUNDWATER RESTORATION TO 3 PPB, TECHNETIUM-99, AVERAGE CONCENTRATION CURVES

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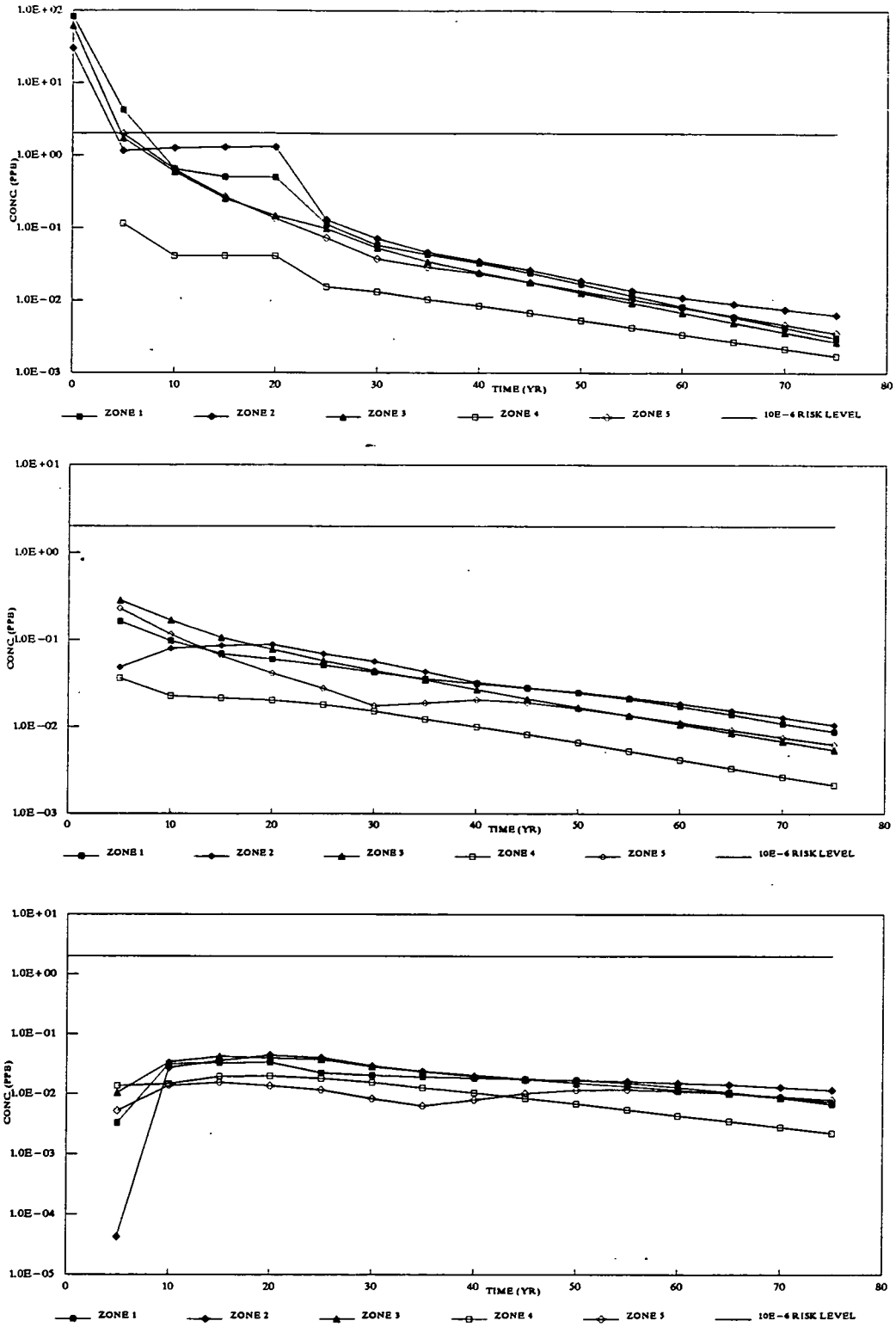

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FIGURE F.7-82A. GROUNDWATER RESTORATION TO 3 PPB, ANTIMONY, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

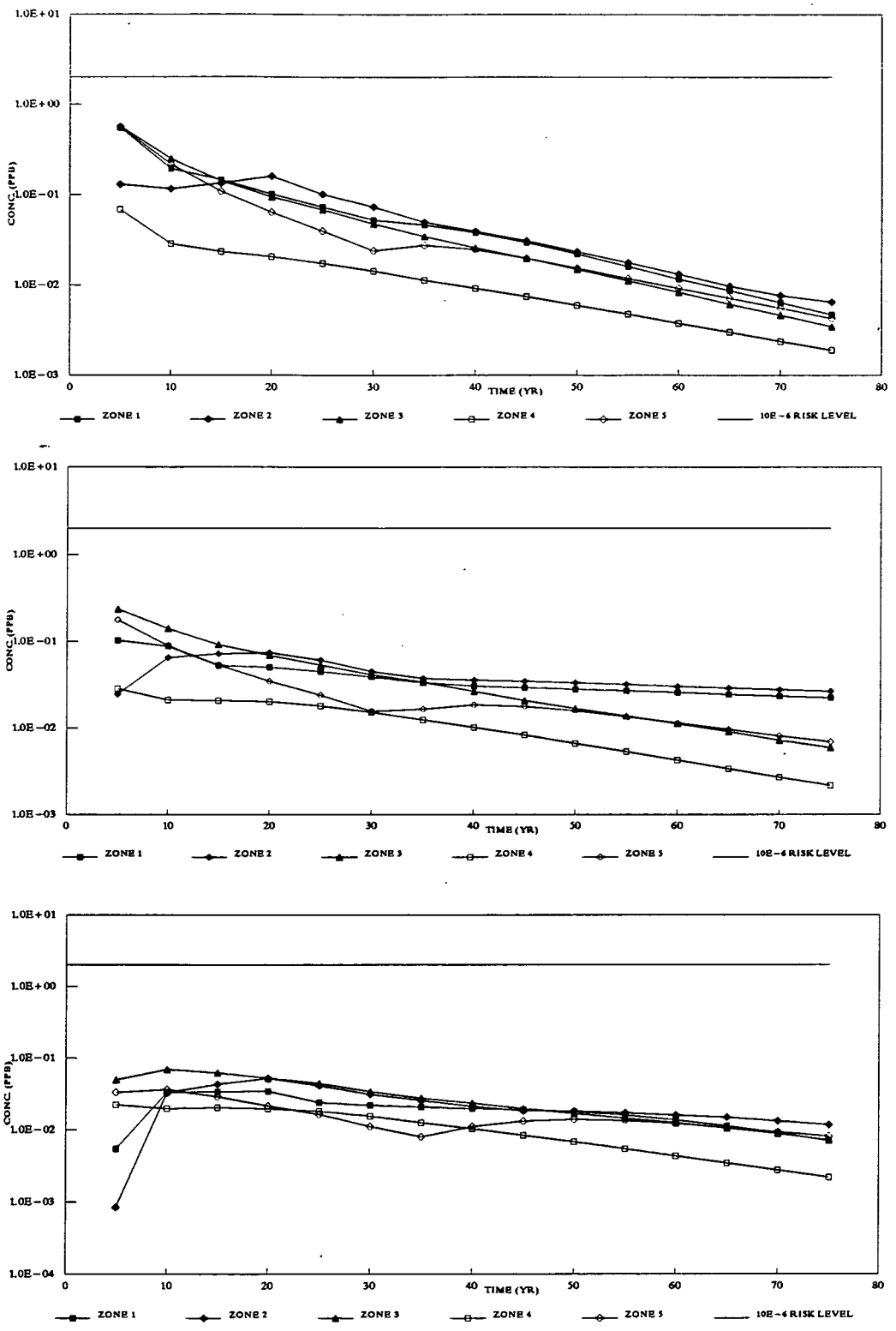

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FIGURE F.7-82B. GROUNDWATER RESTORATION TO 3 PPB, ANTIMONY, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

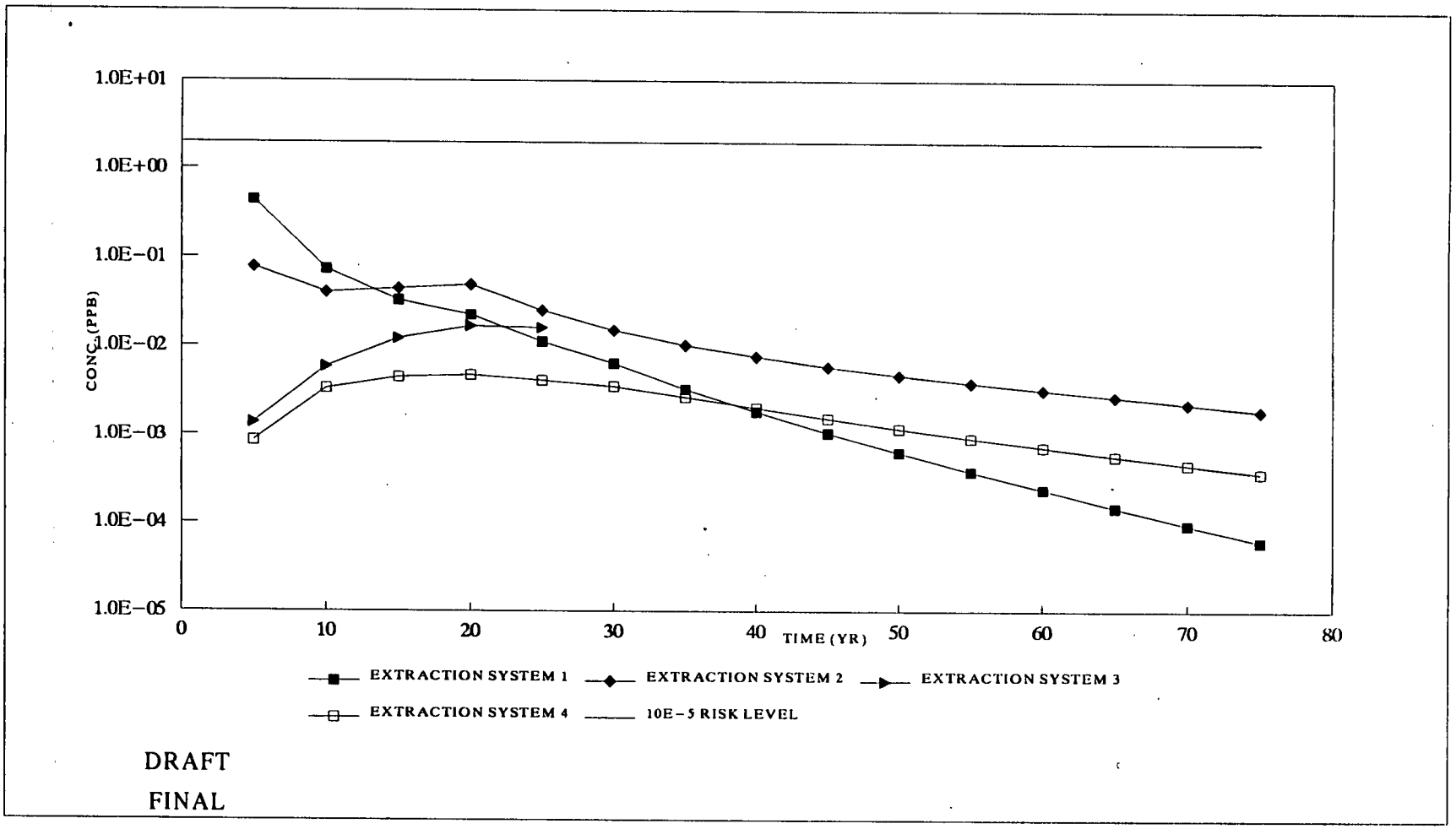

FIGURE F.7-83. GROUNDWATER RESTORATION TO 3 PPB, ANTIMONY, AVERAGE CONCENTRATION CURVES

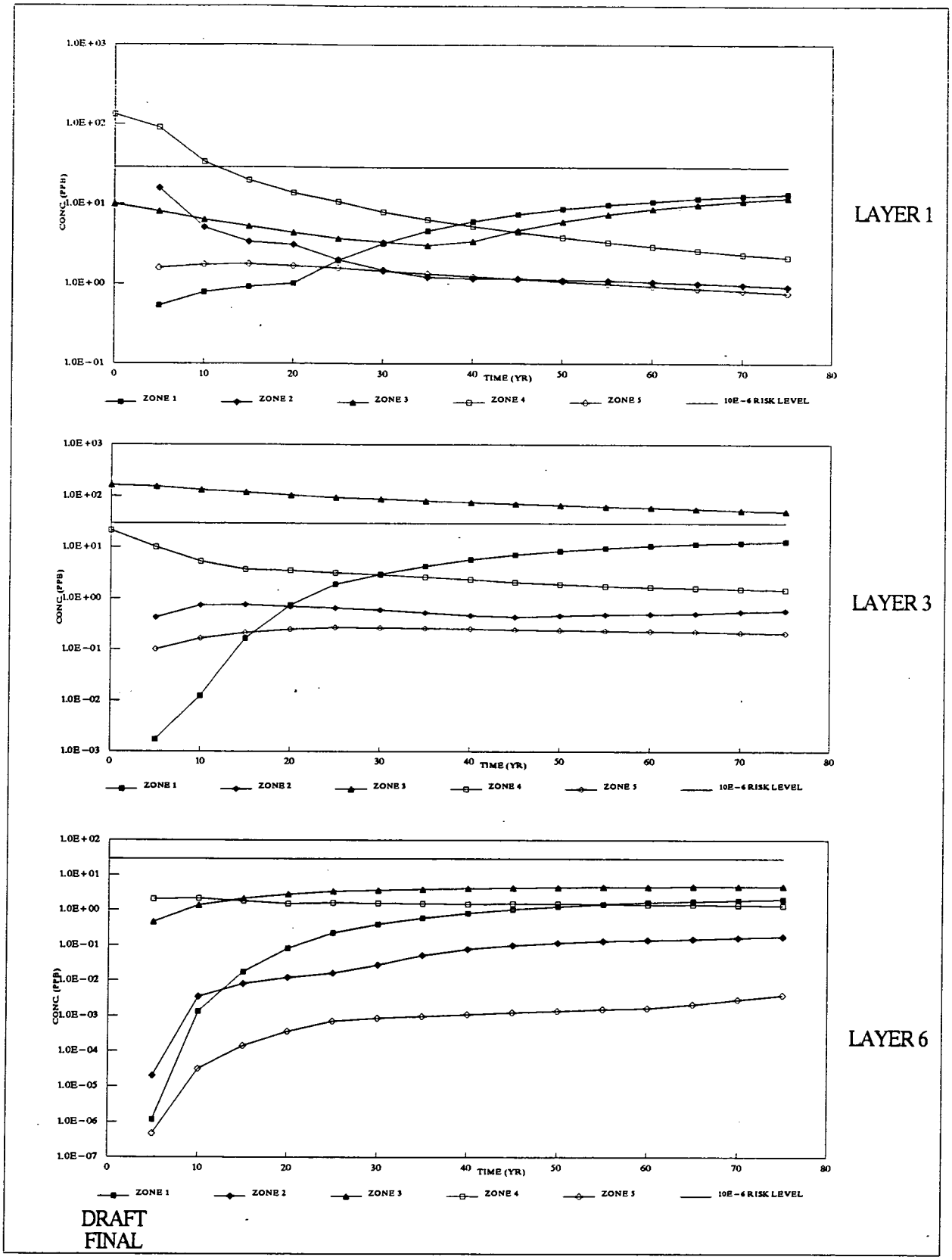

FIGURE F.7-84A. GROUNDWATER RESTORATION TO 3 PPB, ARSENIC, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

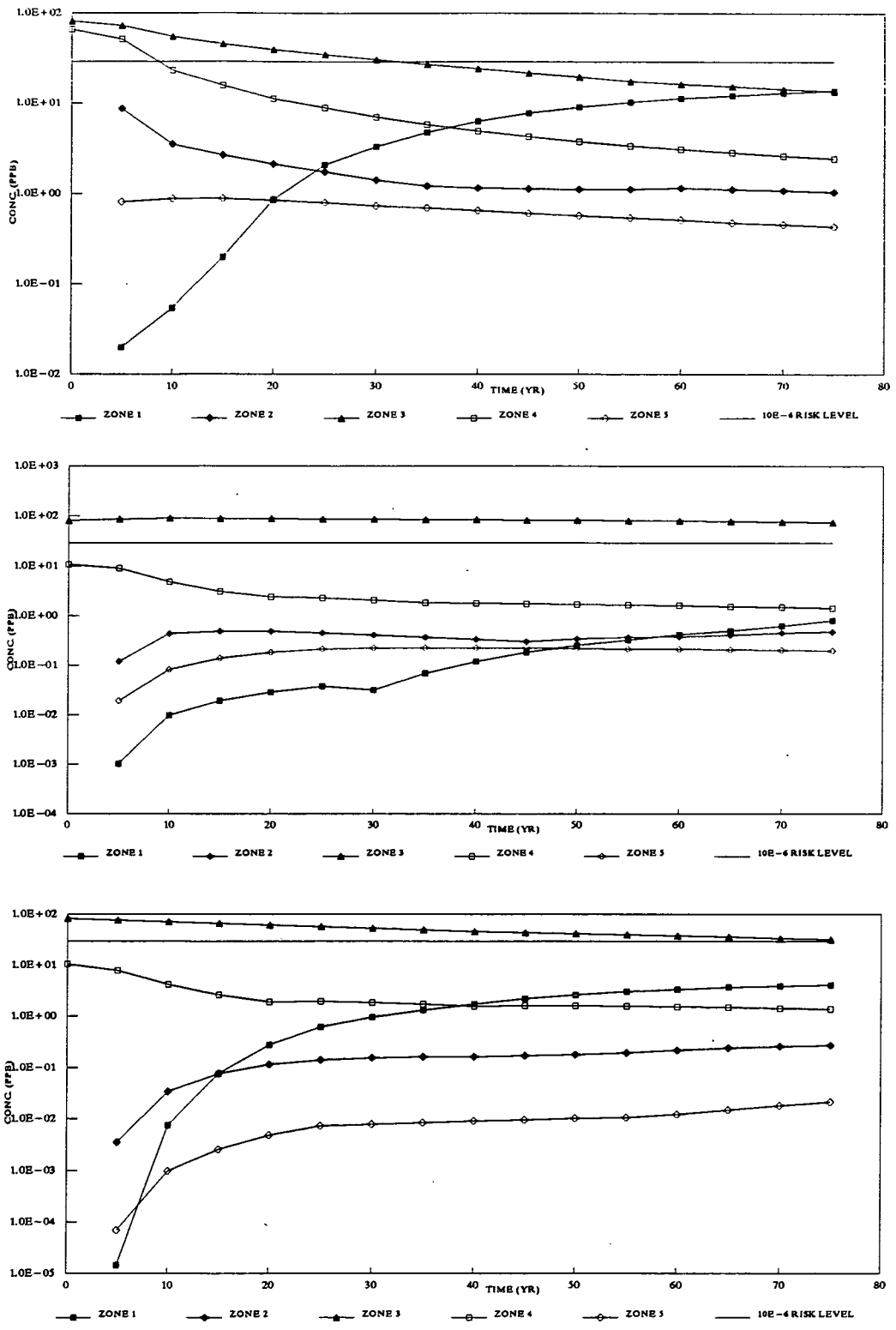

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FIGURE F.7-84B. GROUNDWATER RESTORATION TO 3 PPB, ARSENIC, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

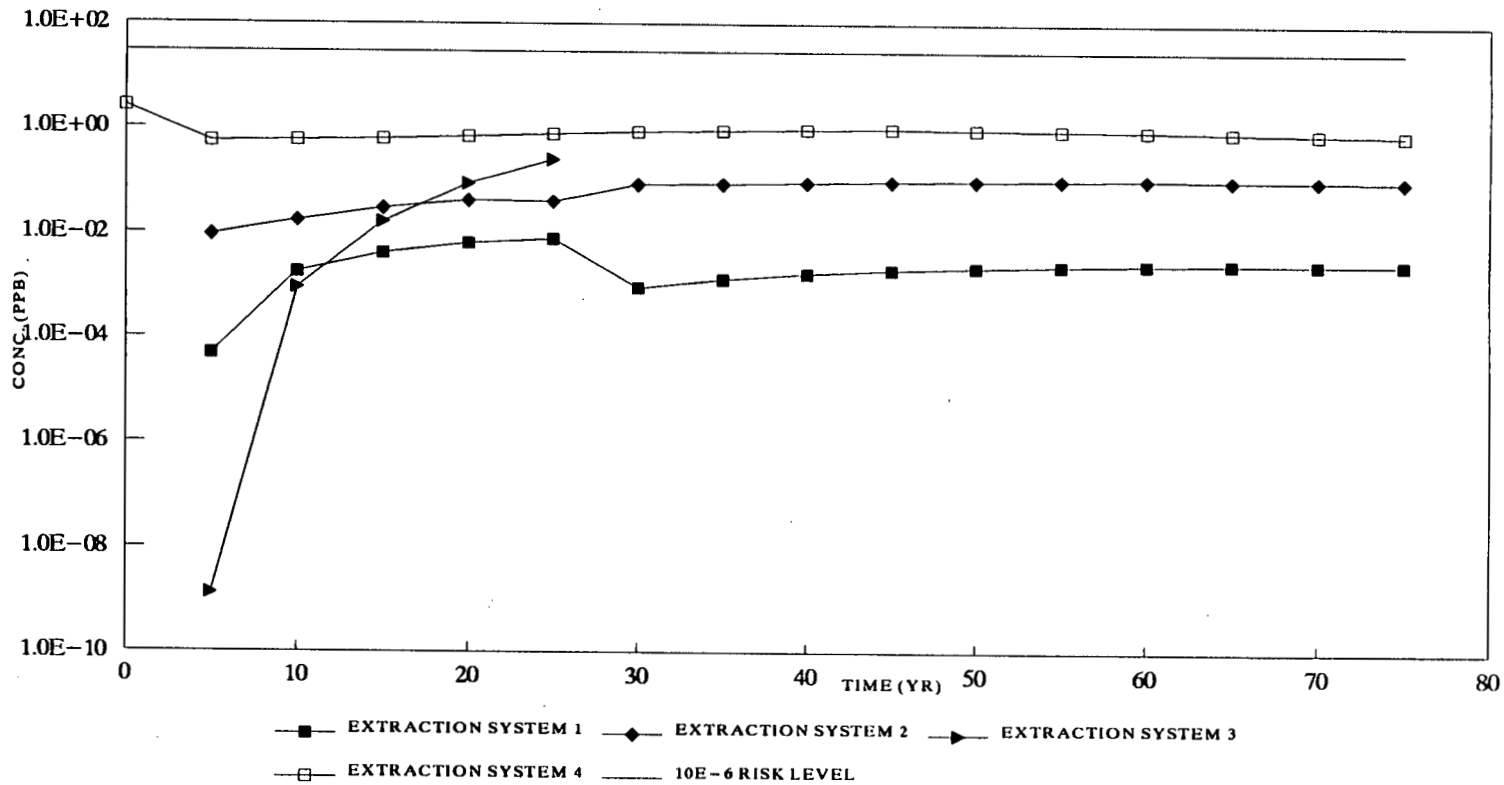

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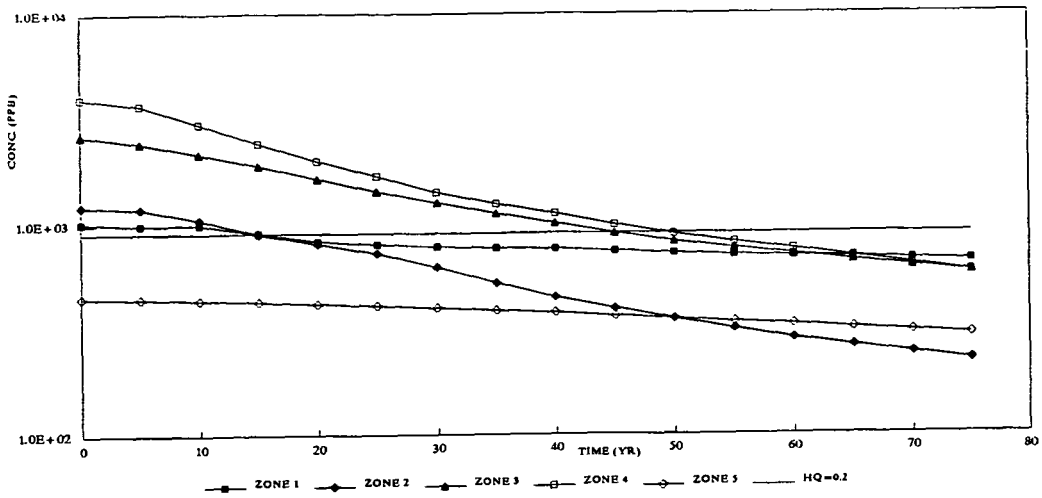
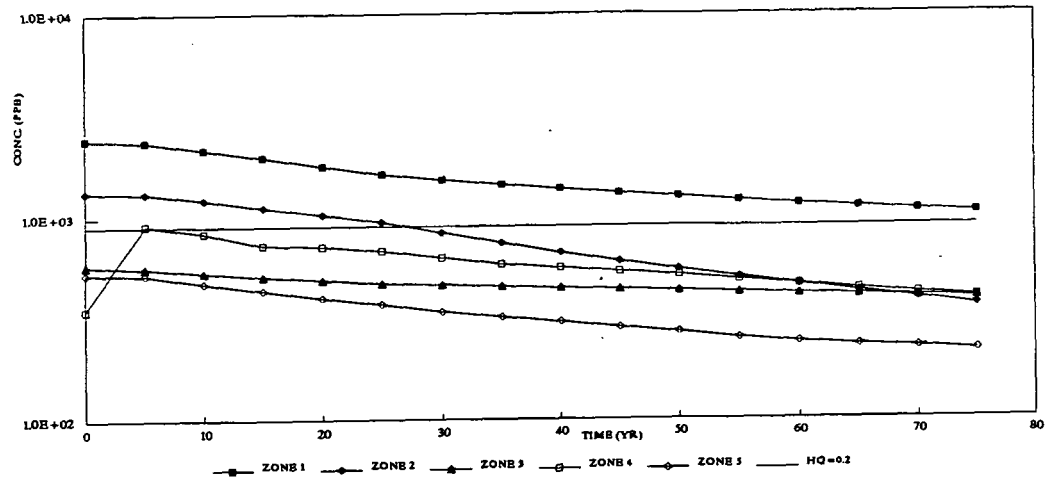
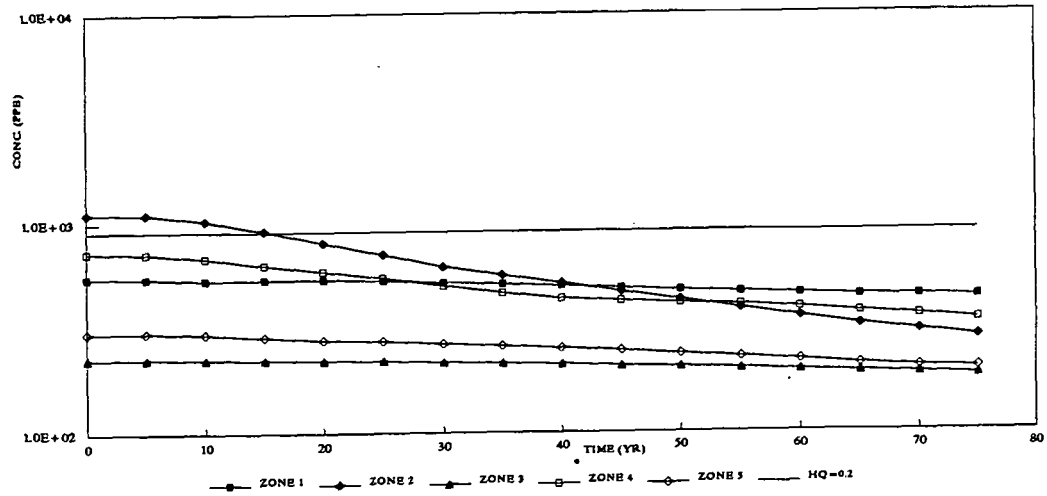
FIGURE F.7-85. GROUNDWATER RESTORATION TO 3 PPB, ARSENIC, AVERAGE CONCENTRATION CURVES



LAYER 1



LAYER 3



LAYER 6

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FIGURE F.7-86A. GROUNDWATER RESTORATION TO 3 PPB, MANGANESE, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

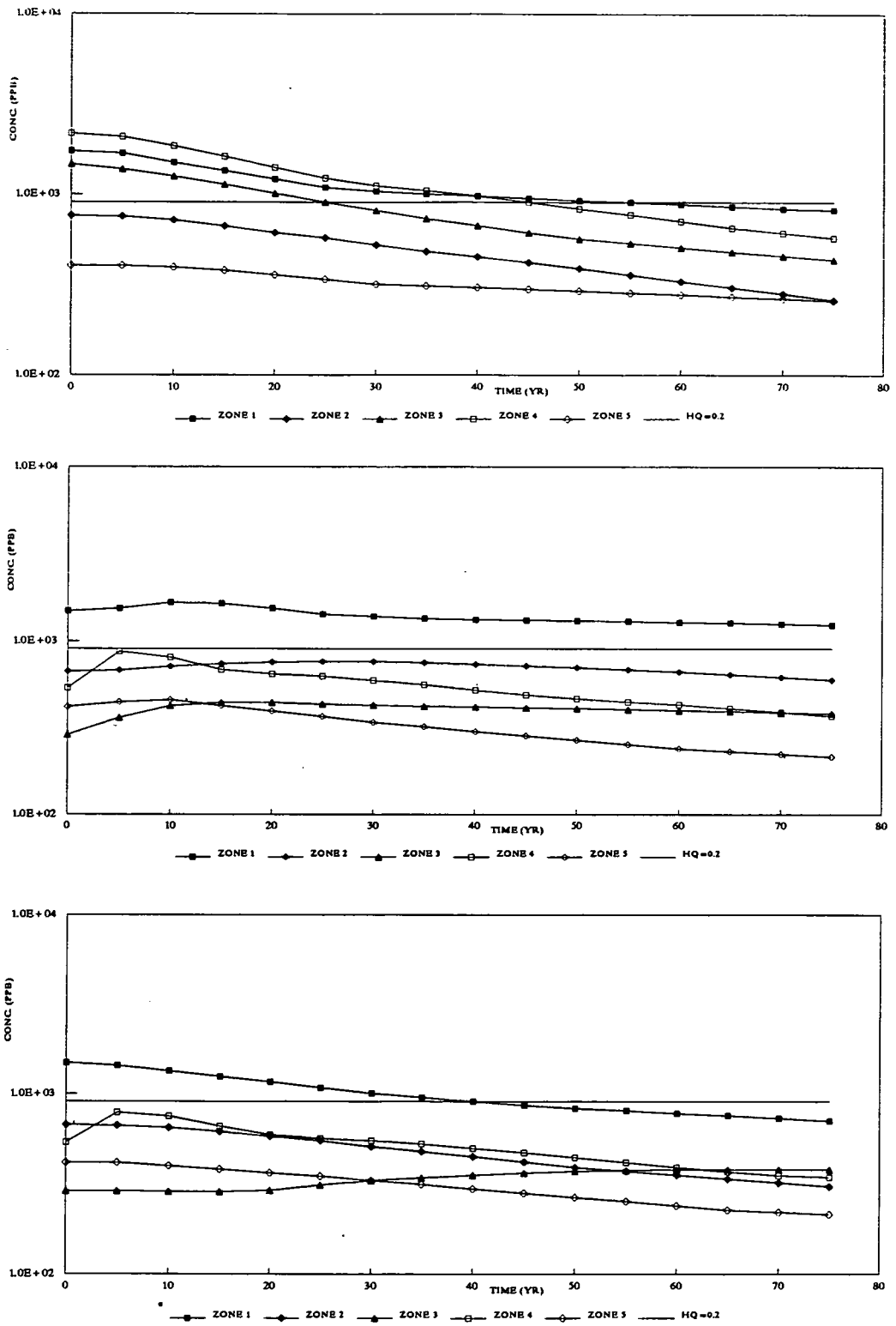

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FIGURE F.7–86B. GROUNDWATER RESTORATION TO 3 PPB, MANGANESE, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

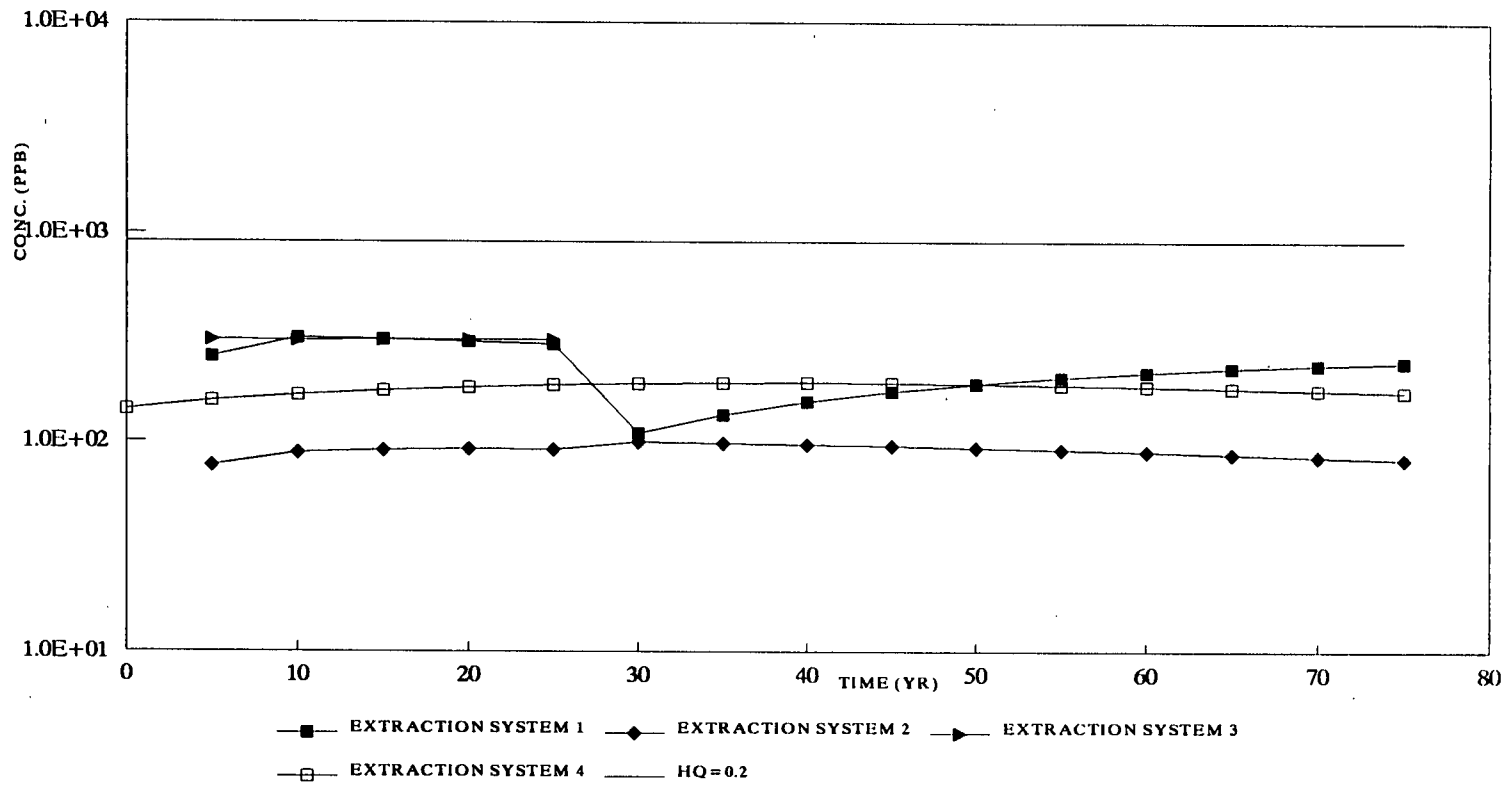

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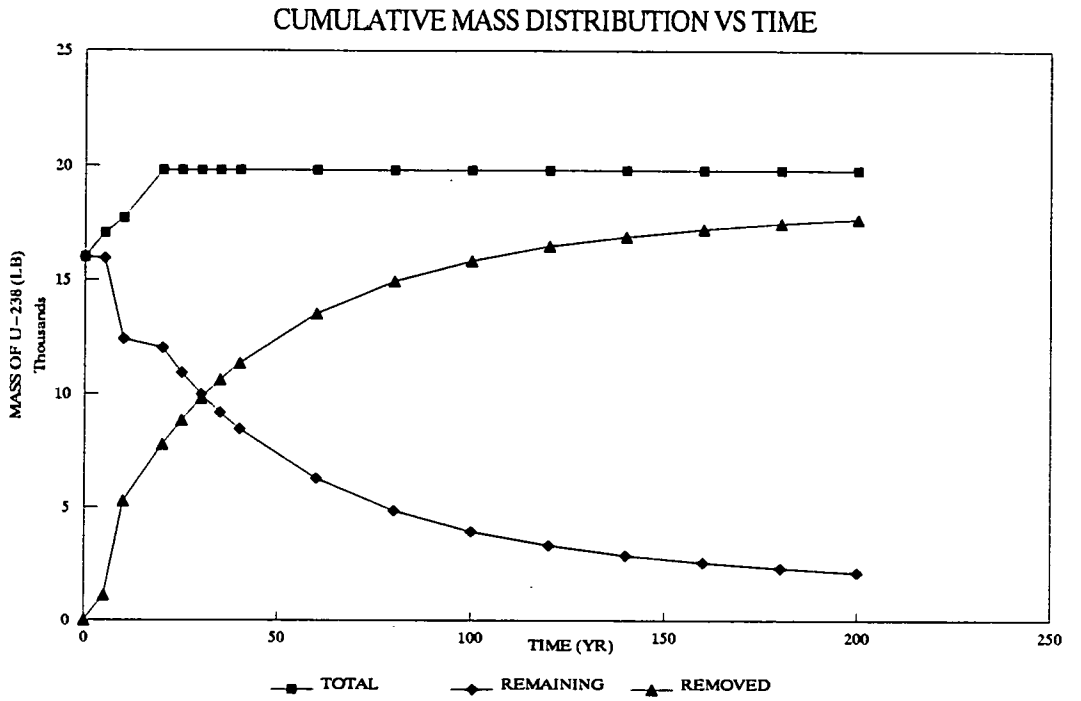
FIGURE F.7-87. GROUNDWATER RESTORATION TO 3 PPB, MANGANESE, AVERAGE CONCENTRATION CURVES



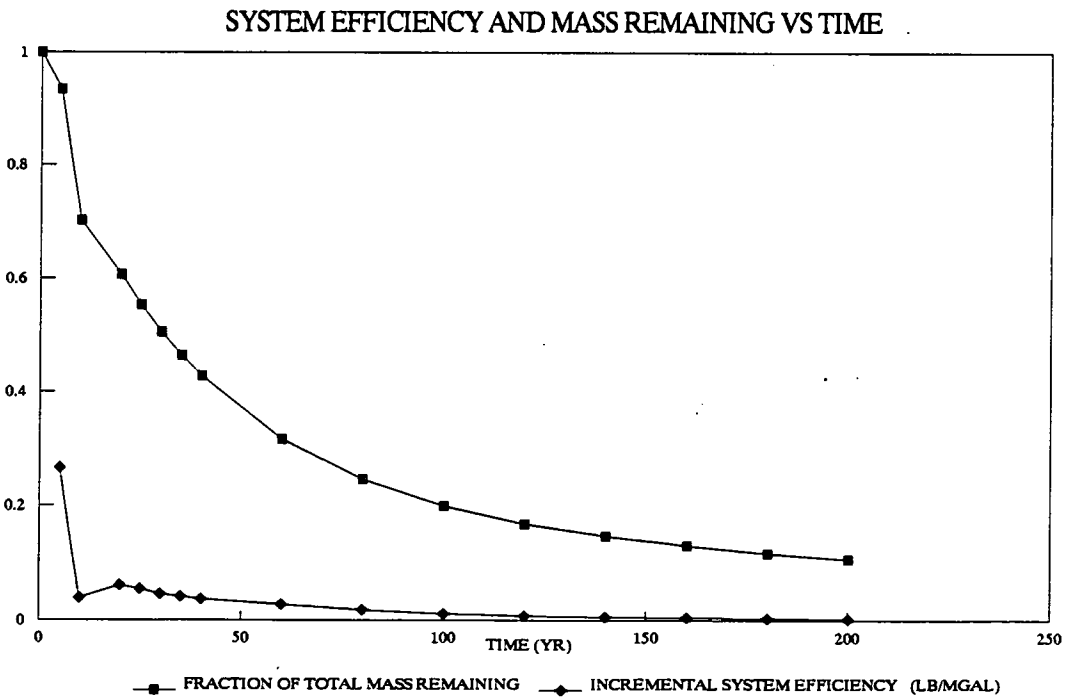


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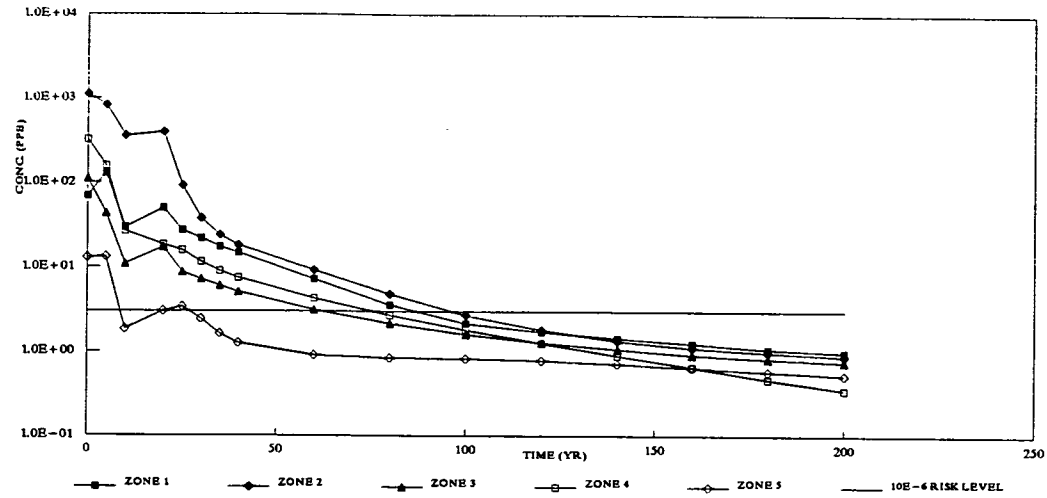
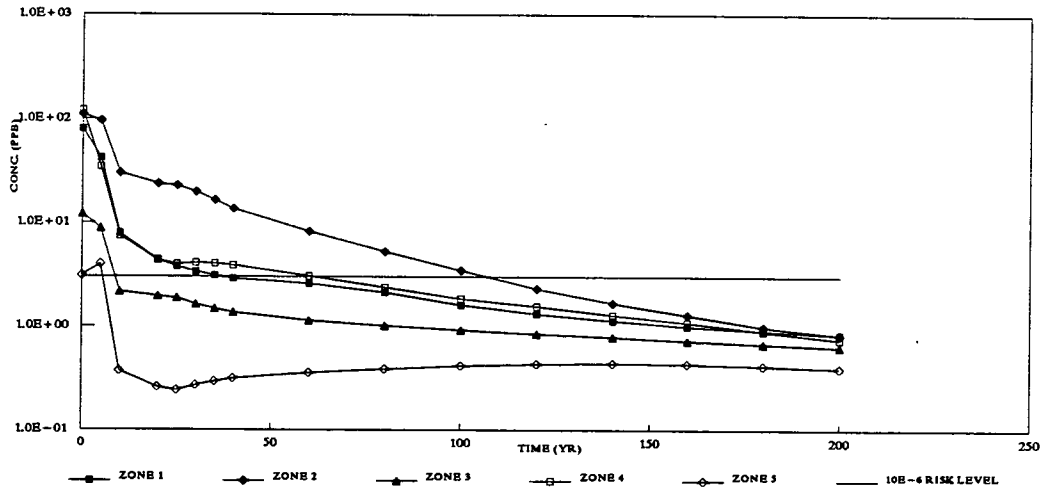
FIGURE F.7-88. GROUNDWATER RESTORATION TO 3 PPB – HIGH Kd, SYSTEM PERFORMANCE CURVES



LAYER 1



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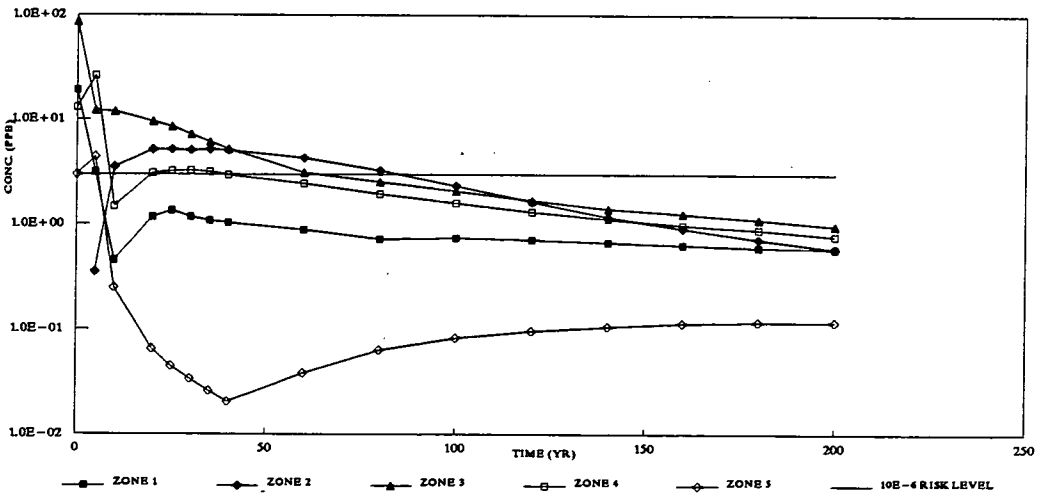

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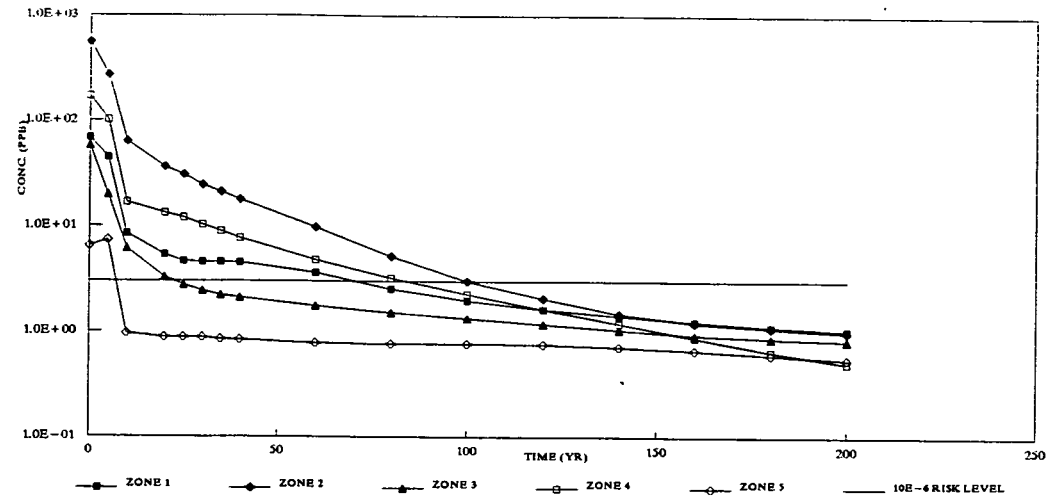
FIGURE F.7-89A. GROUNDWATER RESTORATION TO 3 PPB – HIGH Kd, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.



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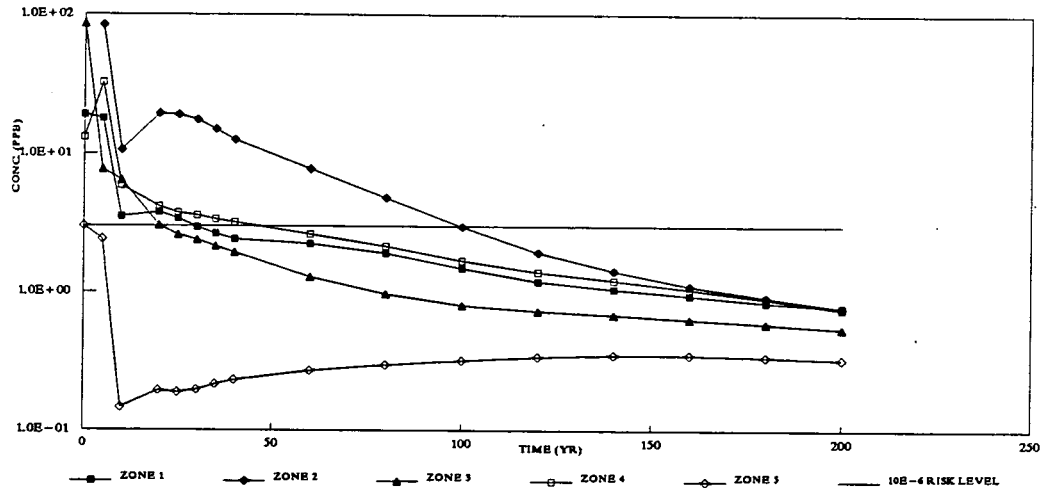

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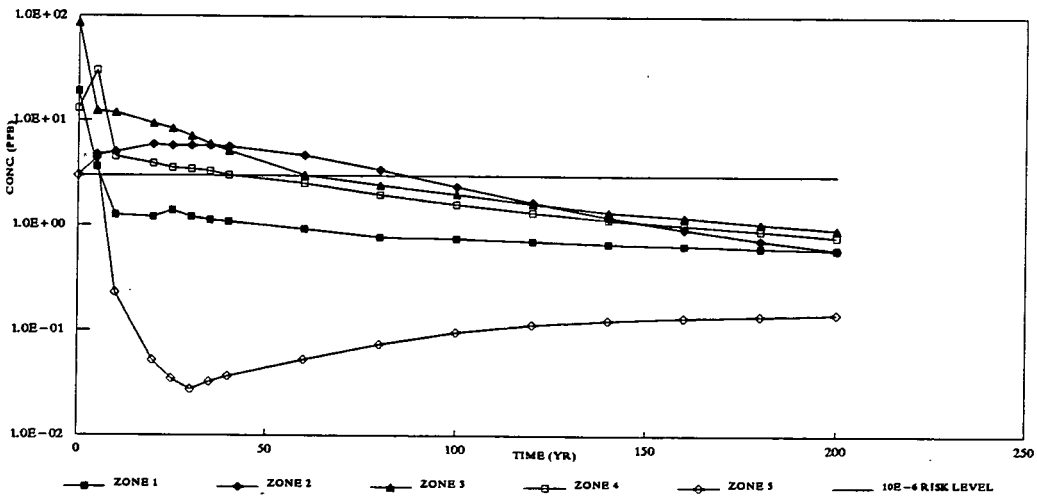

LAYER 5

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FIGURE F.7-89B. GROUNDWATER RESTORATION TO 3 PPB – HIGH Kd, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

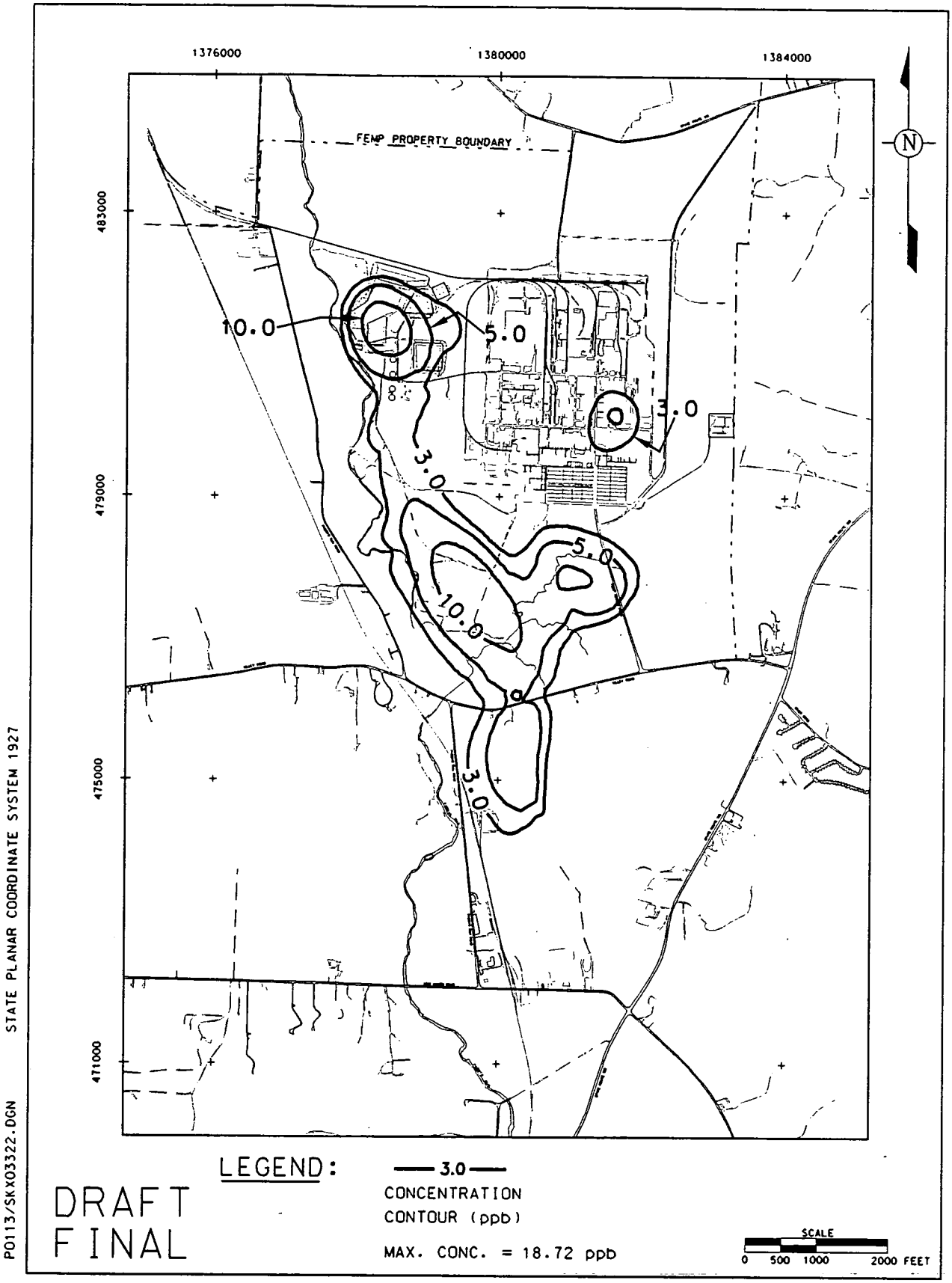


FIGURE F.7-90. GROUNDWATER RESTORATION TO 3 ppb. HIGH Kd. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

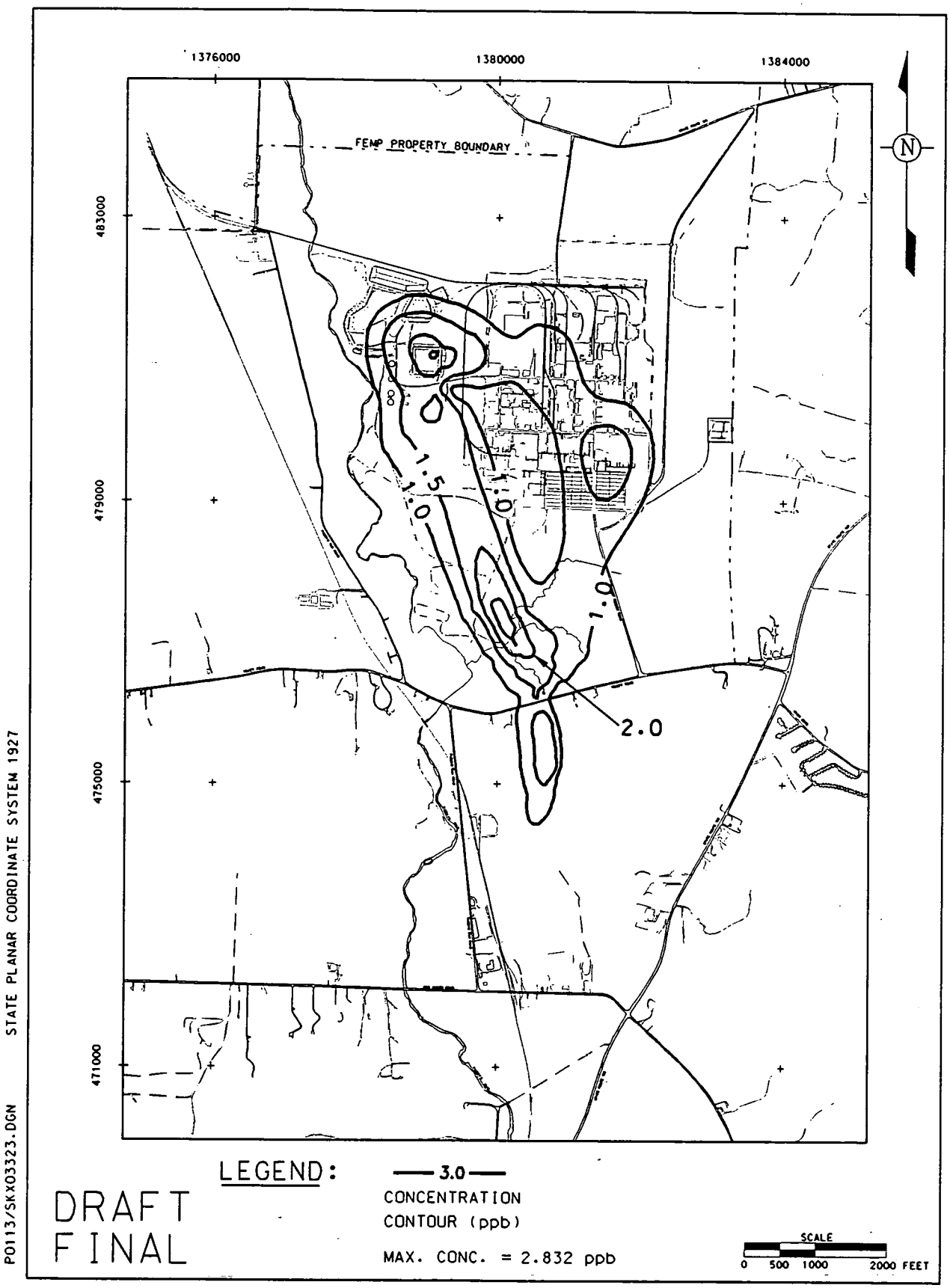


FIGURE F.7-91. GROUNDWATER RESTORATION TO 3 ppb. HIGH Kd. CONCENTRATION CONTOURS. YEAR 100. LAYER 1

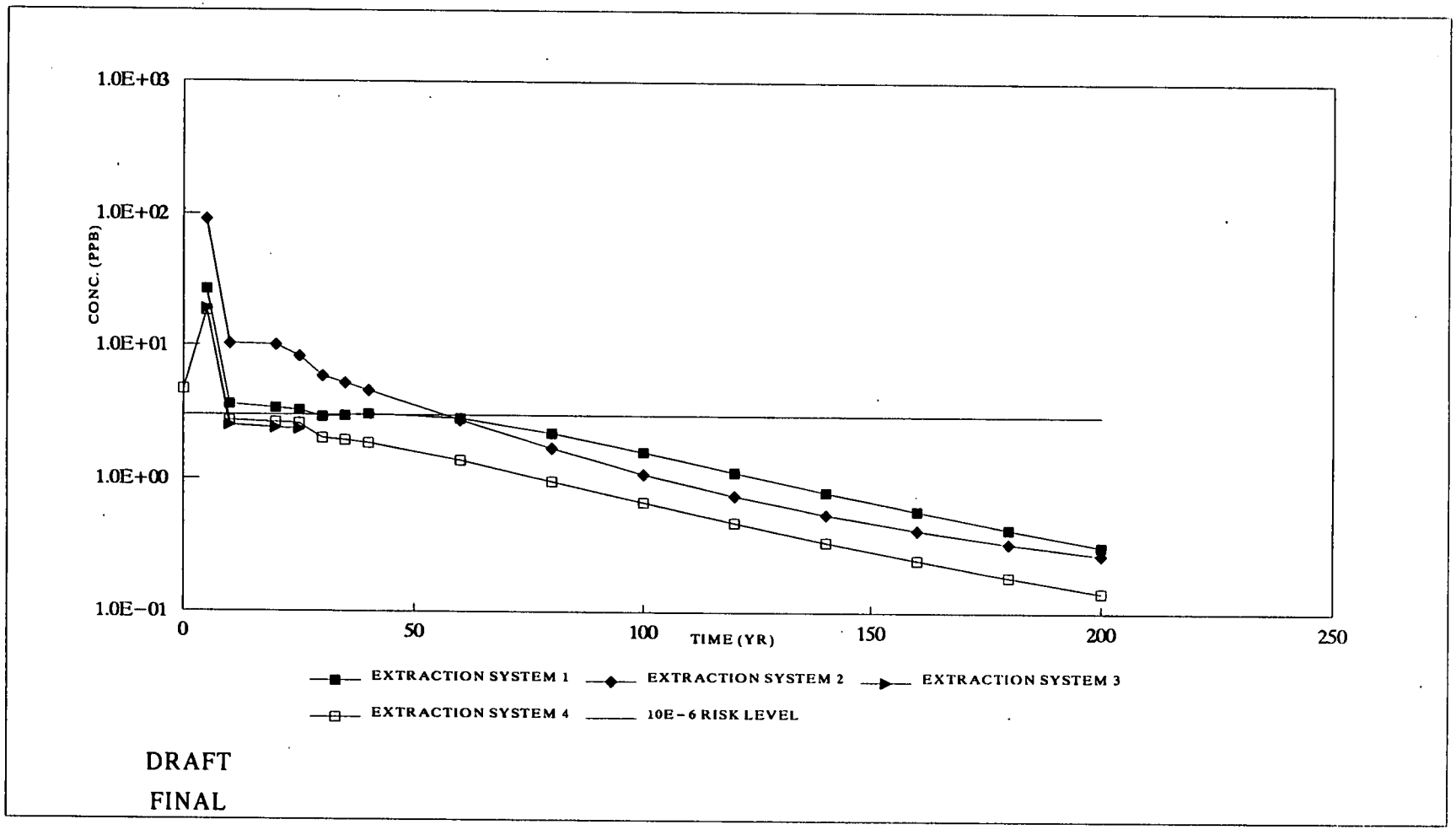


FIGURE F.7-92. GROUNDWATER RESTORATION TO 3 PPB – HIGH Kd, AVERAGE CONCENTRATION CURVES

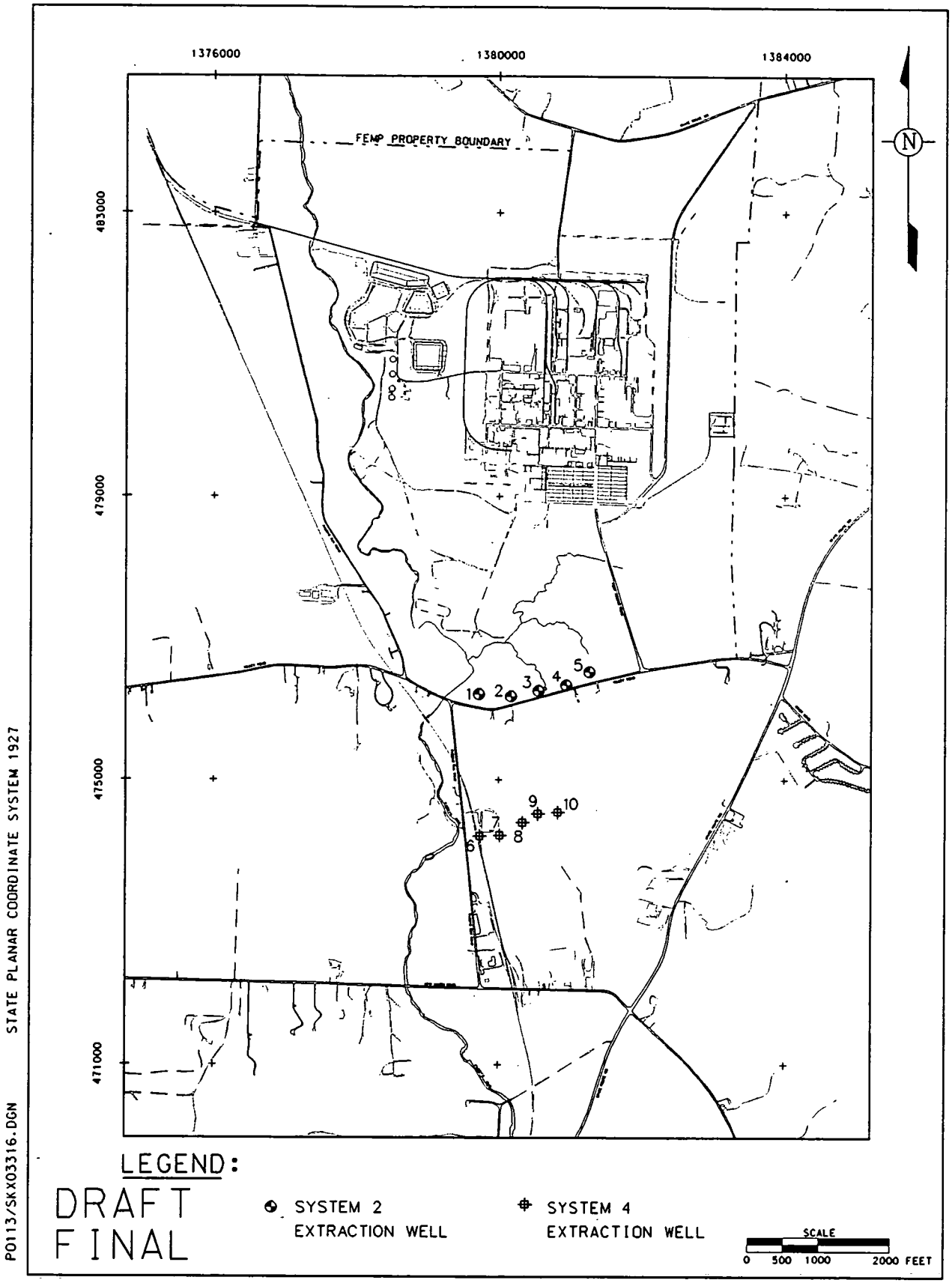
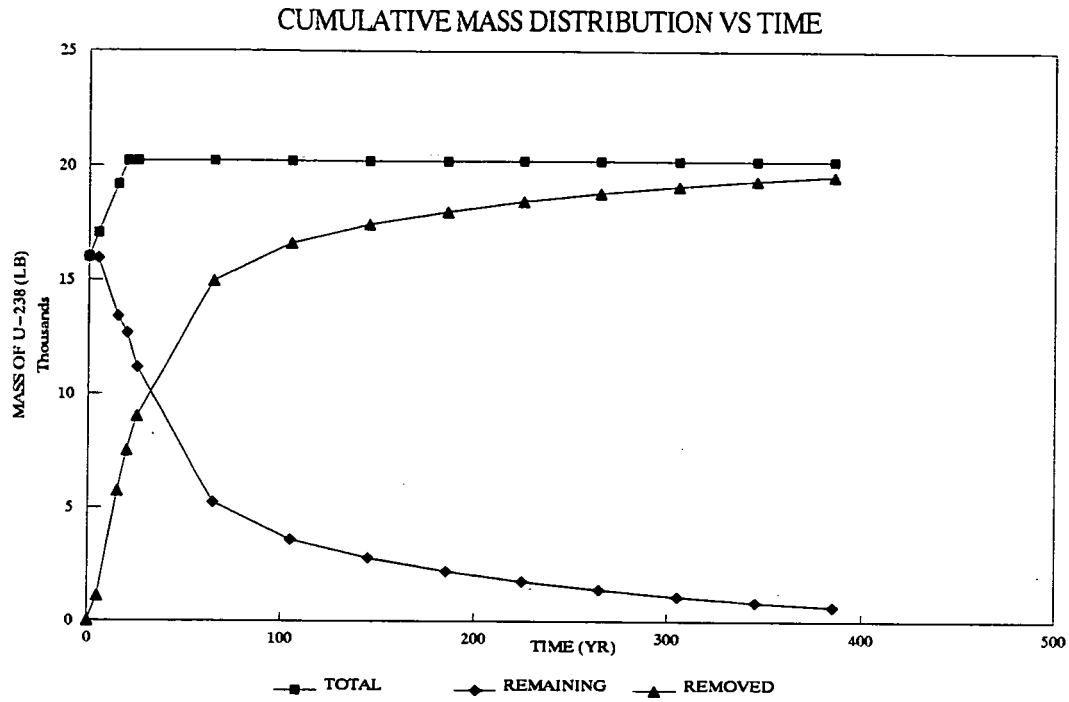


FIGURE F.7-93. GROUNDWATER CONTAINMENT TO 20 PPB WELL LOCATIONS



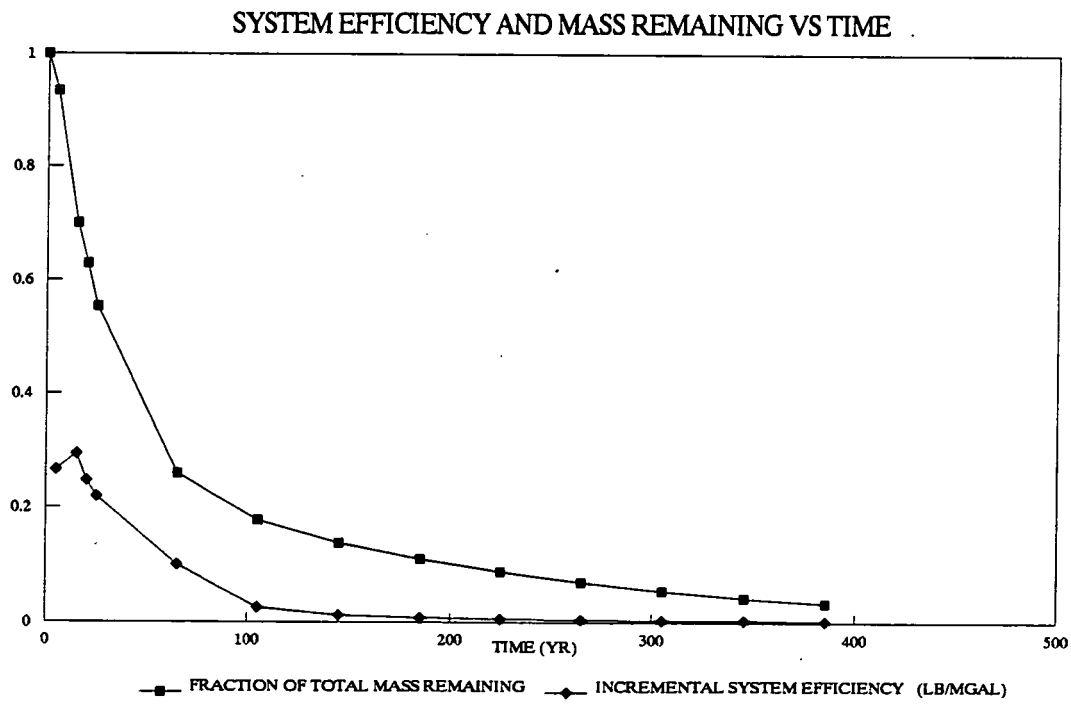


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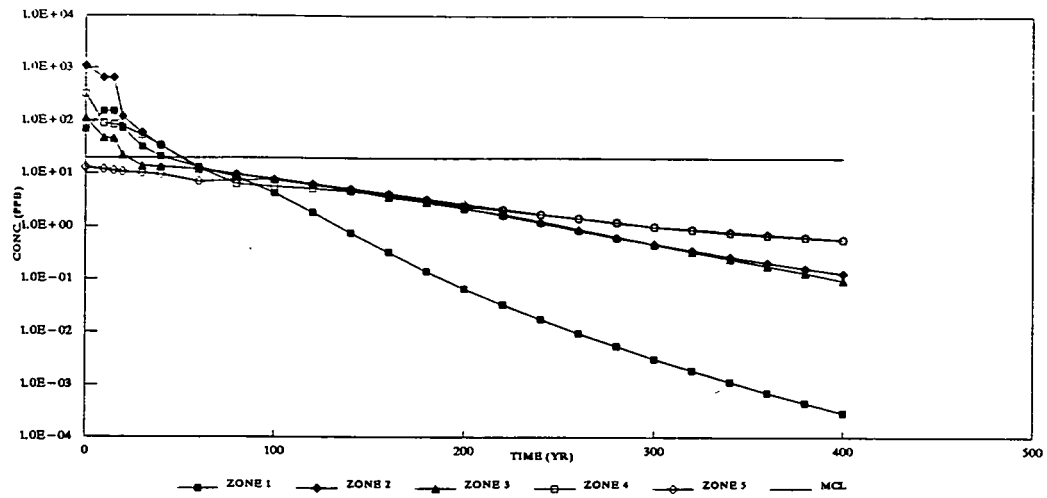
FIGURE F.7-94. GROUNDWATER RESTORATION TO 20 PPB, SYSTEM PERFORMANCE CURVES



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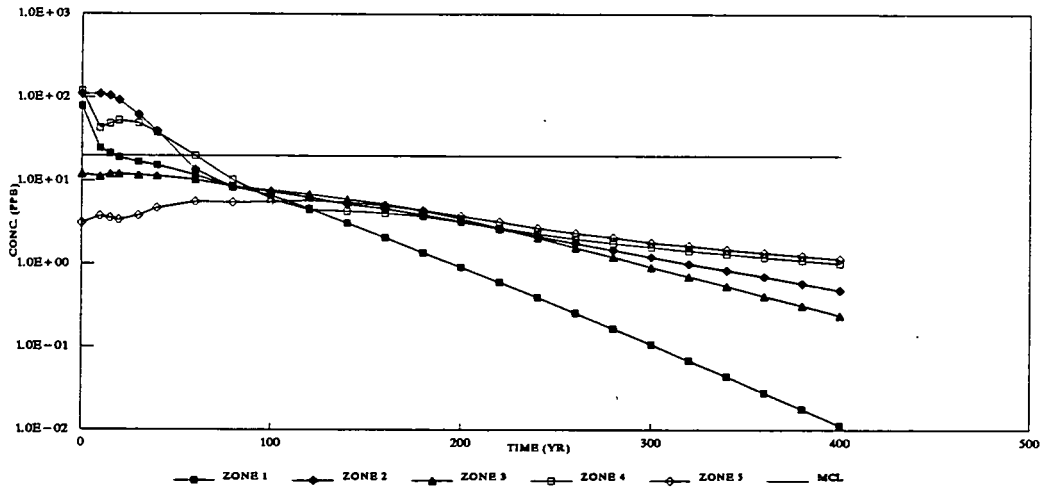

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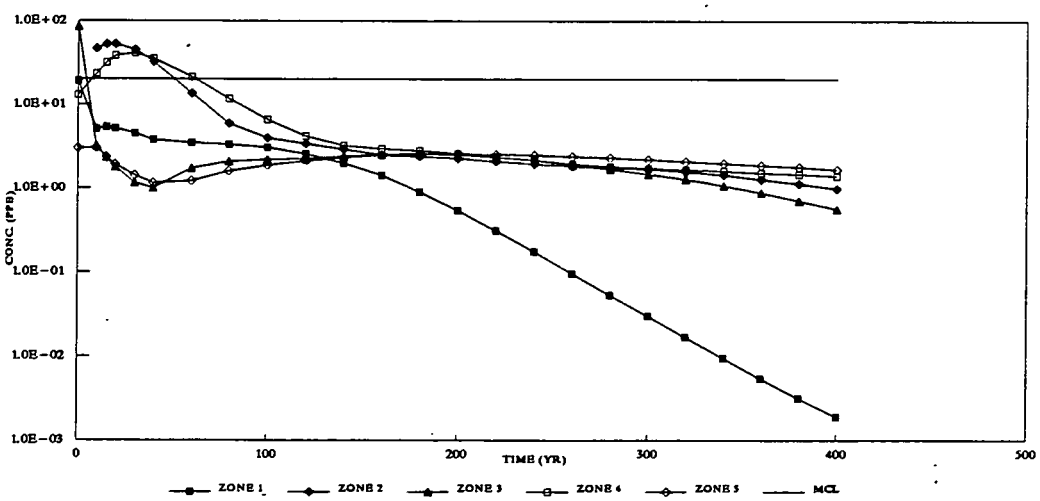

LAYER 6

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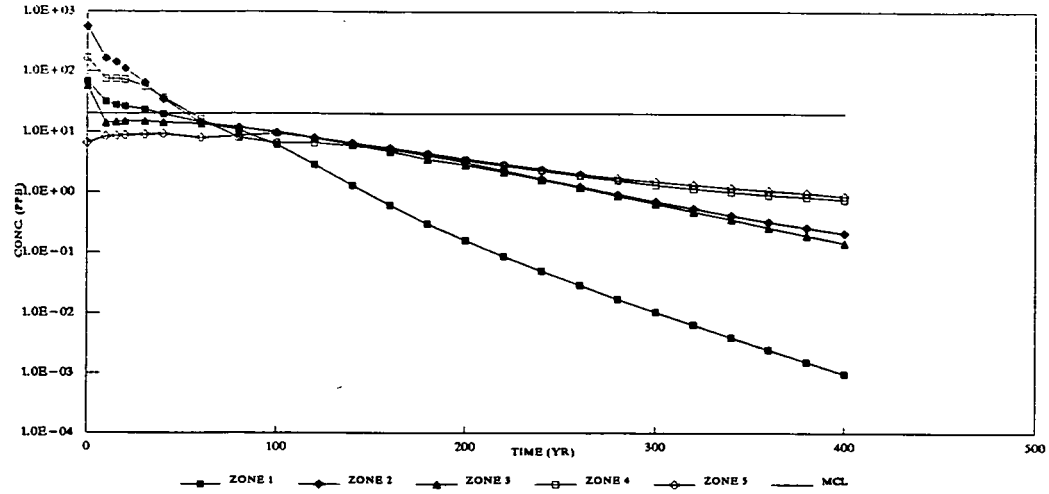
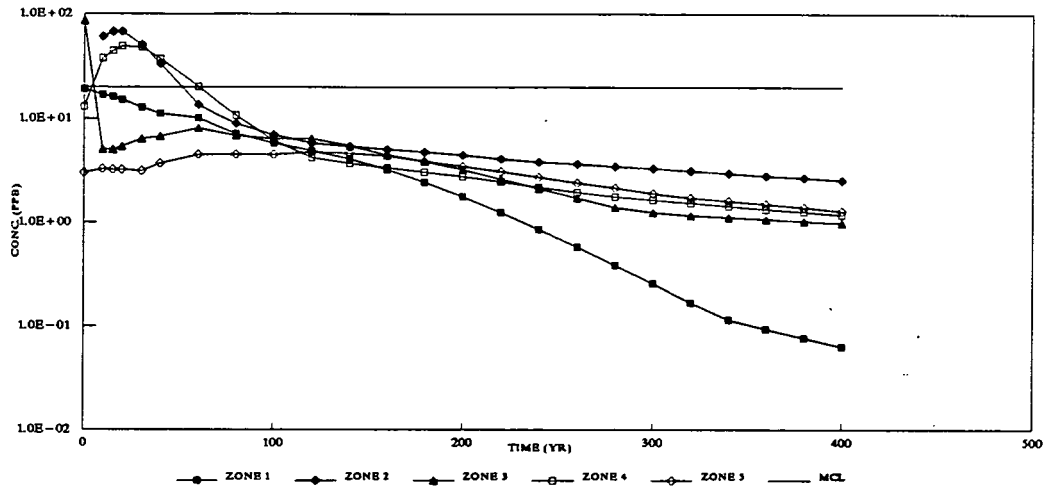
FIGURE F.7-95A. GROUNDWATER CONTAINMENT TO 20 PPB, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.



LAYER 2



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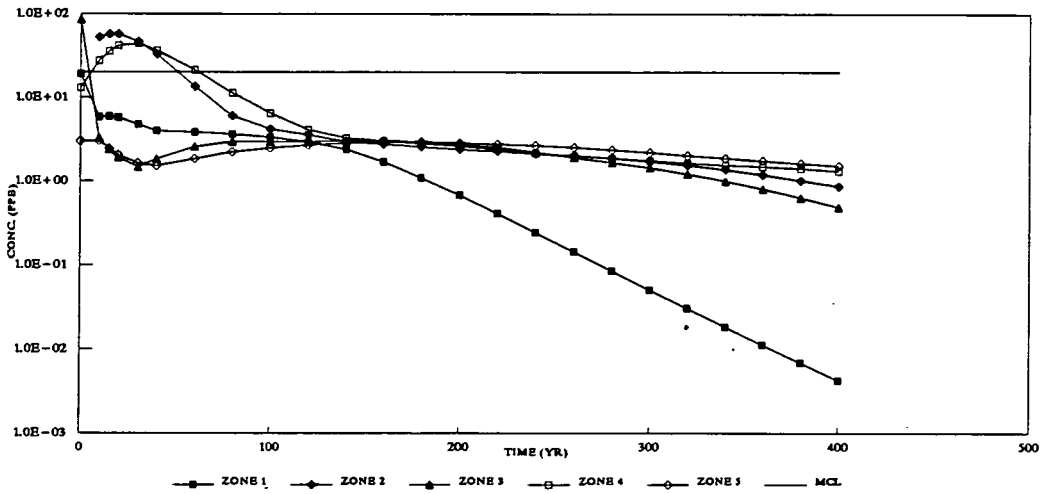

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FIGURE F.7-95B. GROUNDWATER CONTAINMENT TO 20 PPB, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

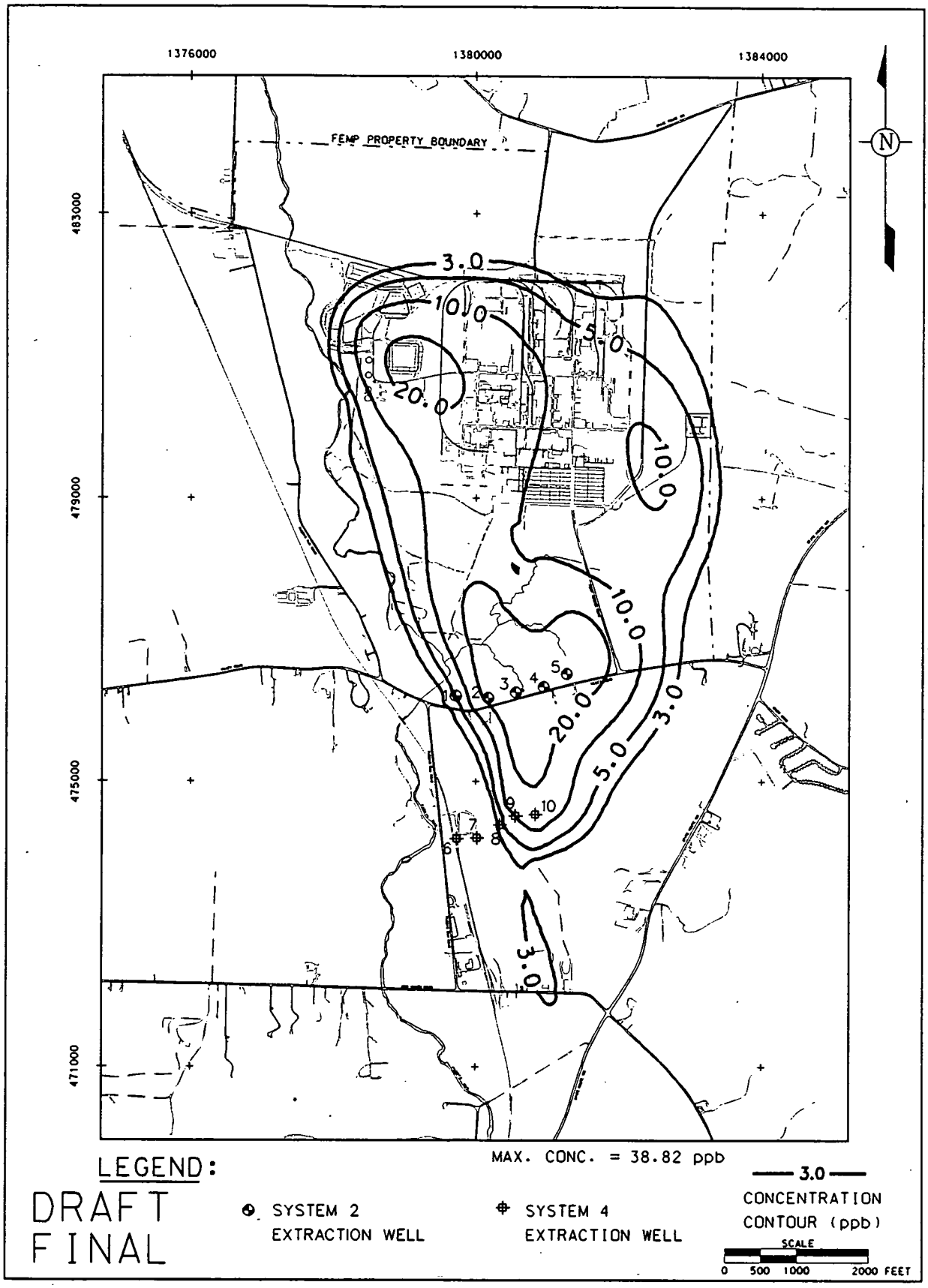


FIGURE F.7-96. GROUNDWATER CONTAINMENT TO 20 PPB. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

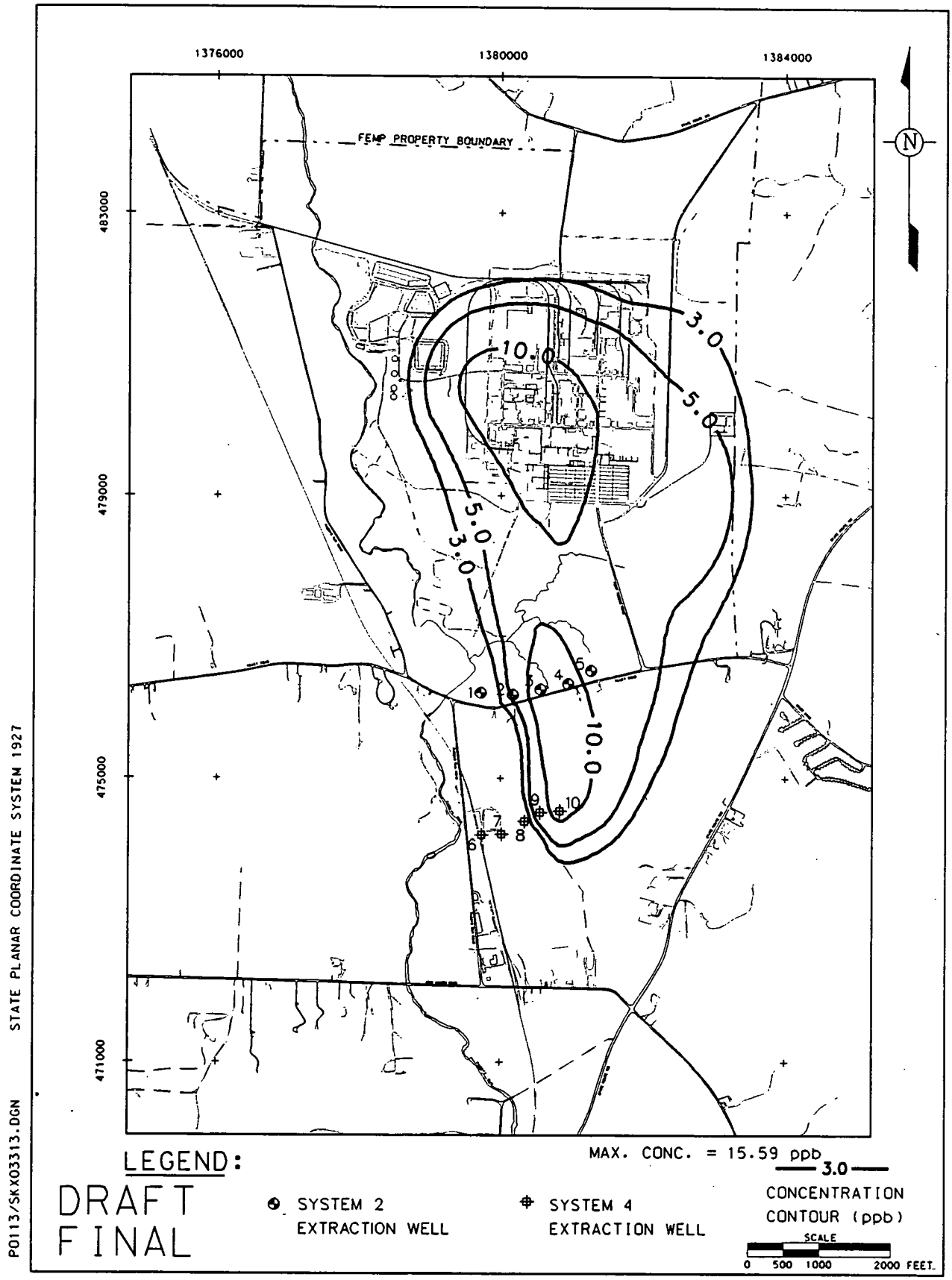
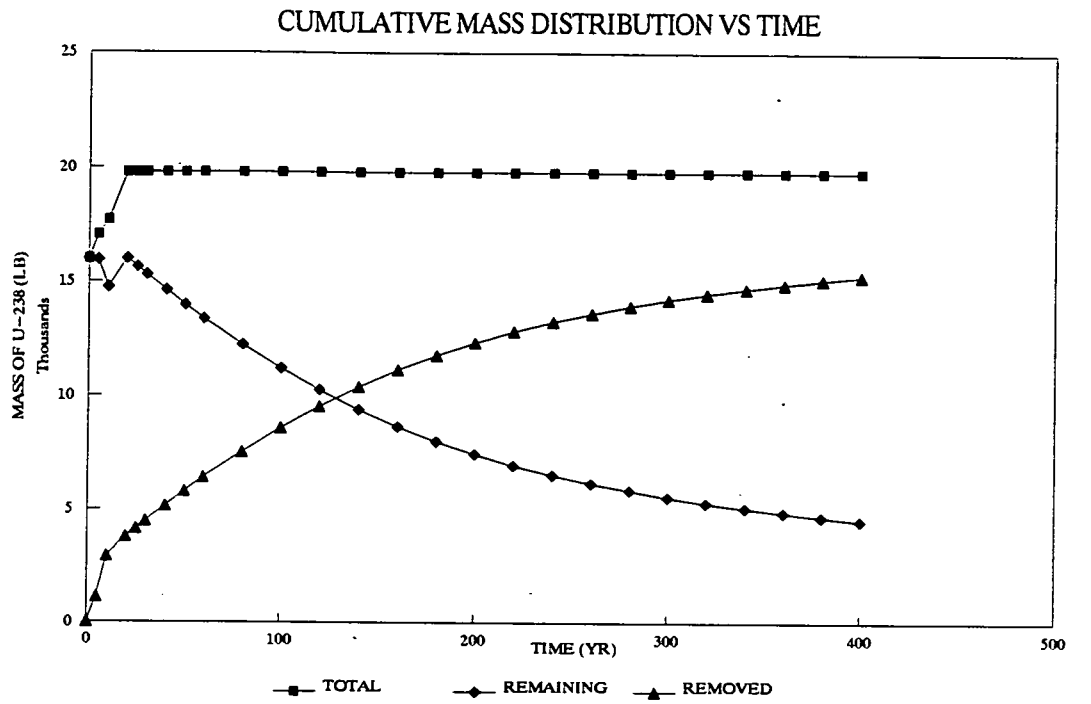


FIGURE F.7-97. GROUNDWATER CONTAINMENT TO 20 PPB. CONCENTRATION CONTOURS. YEAR 60. LAYER 1



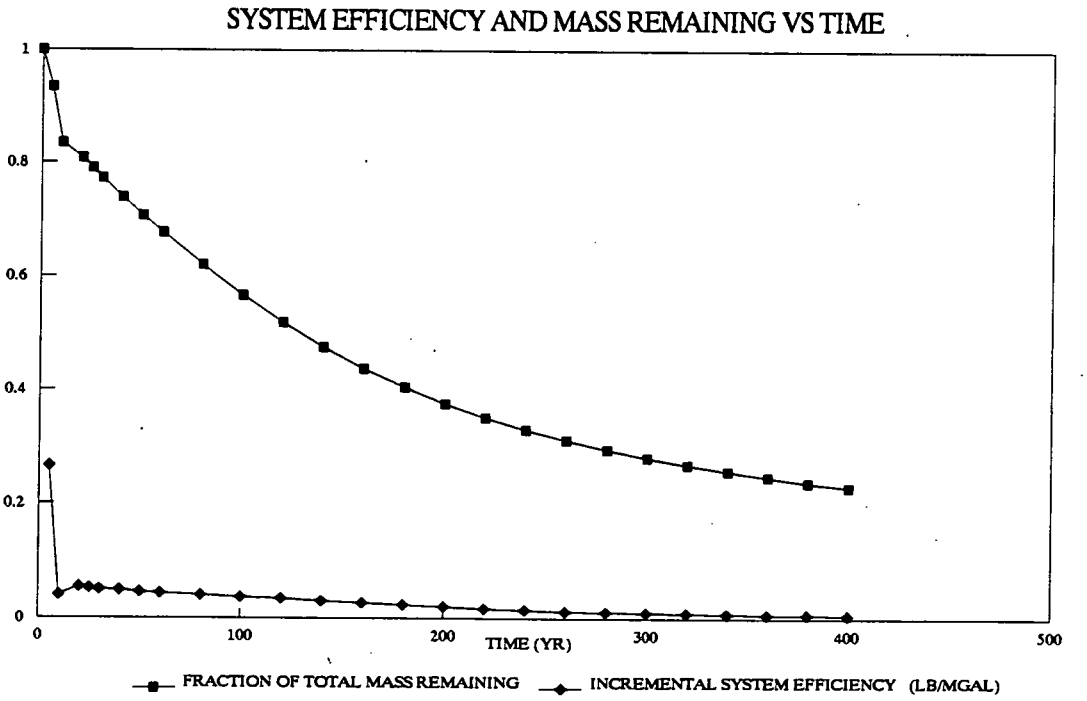


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FIGURE F.7-98. GROUNDWATER CONTAINMENT TO 20 PPB – HIGH Kd, SYSTEM PERFORMANCE CURVES

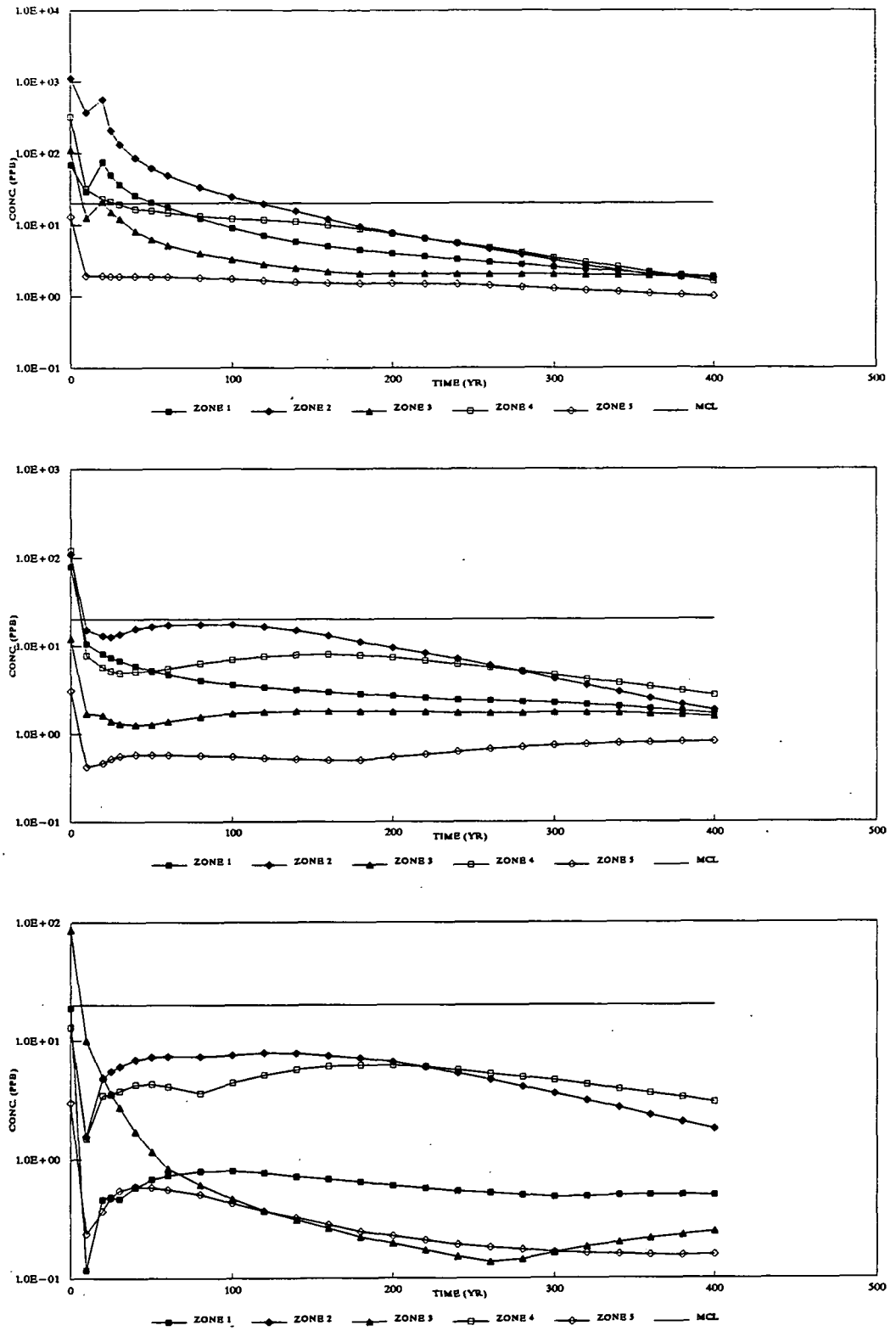

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FIGURE F.7-99A. GROUNDWATER CONTAINMENT TO 20 PPB – HIGH Kd, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

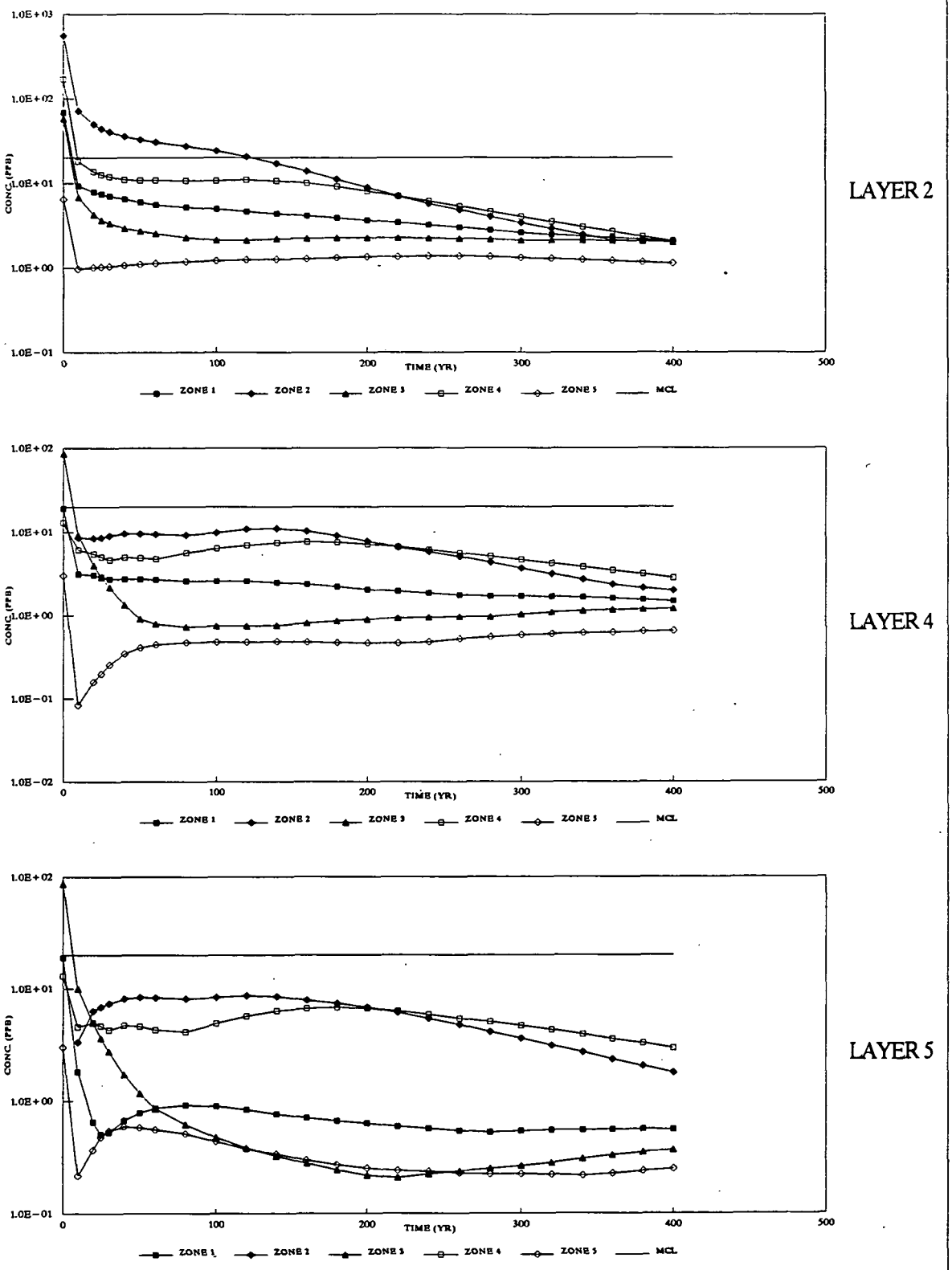

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FIGURE F.7-99B. GROUNDWATER CONTAINMENT TO 20 PPB – HIGH Kd, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

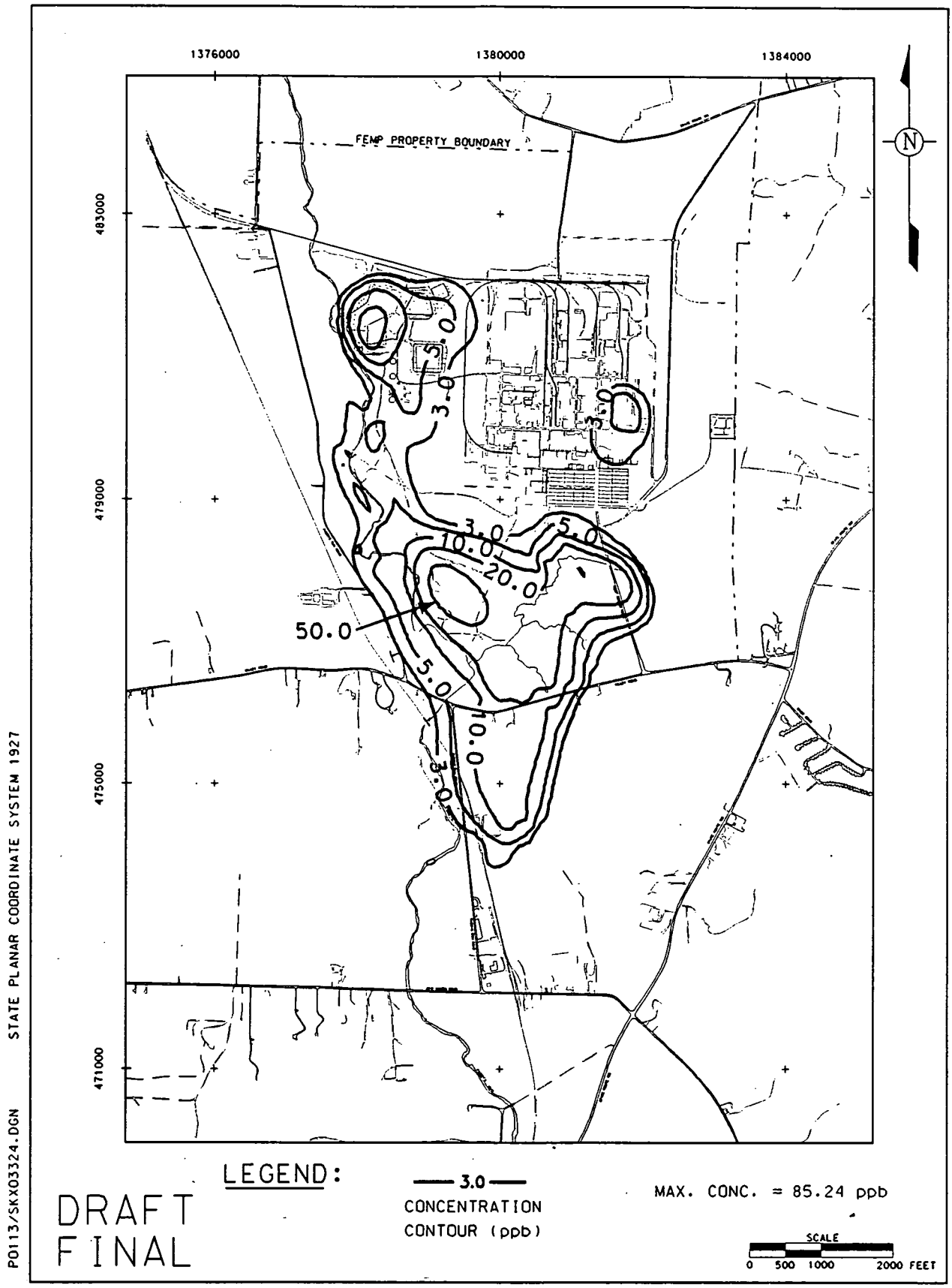


FIGURE F.7-100. GROUNDWATER CONTAINMENT TO 20 ppb - HIGH Kd. CONCENTRATION CONTOURS. YEAR 40. LAYER 1

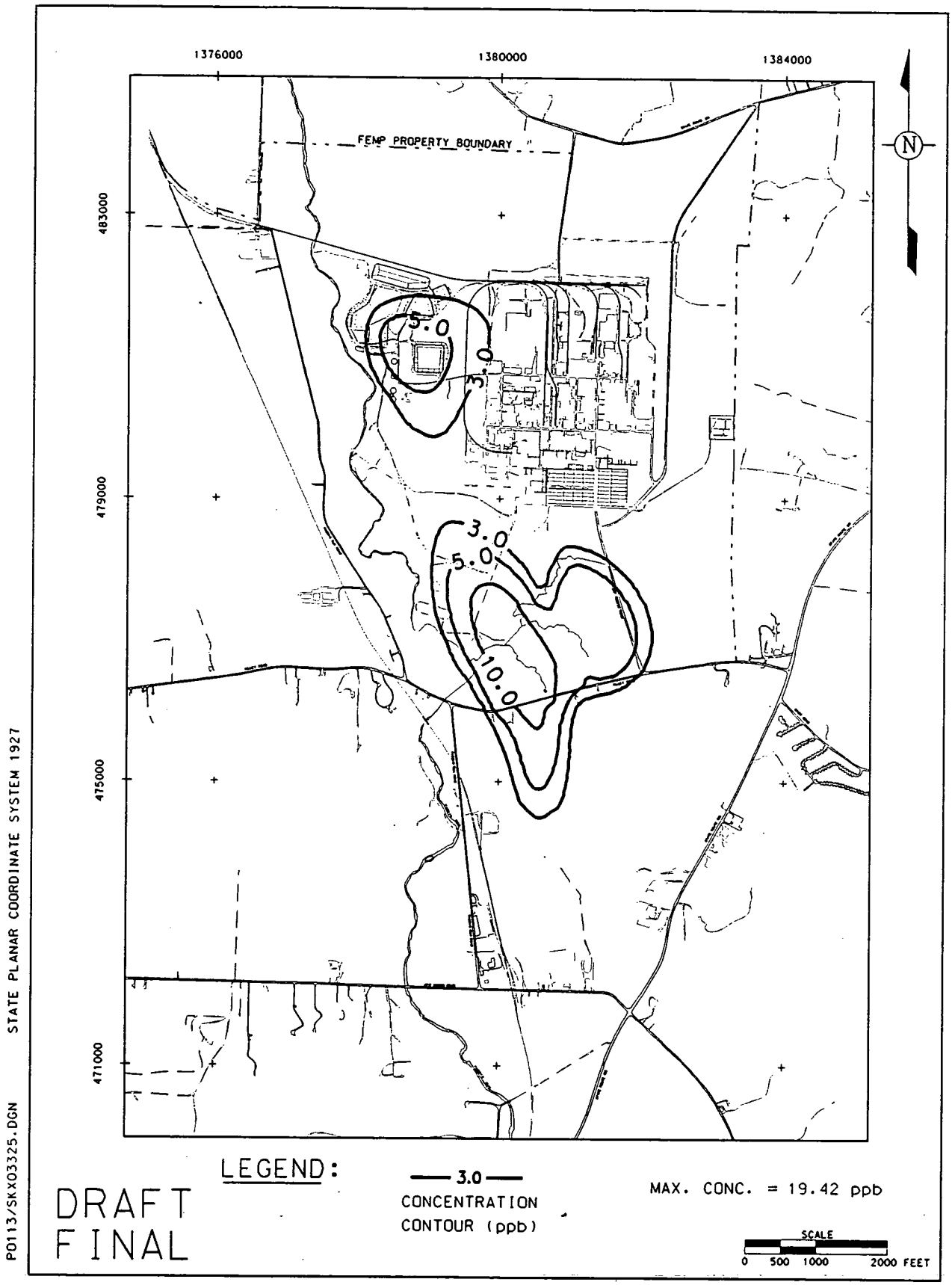
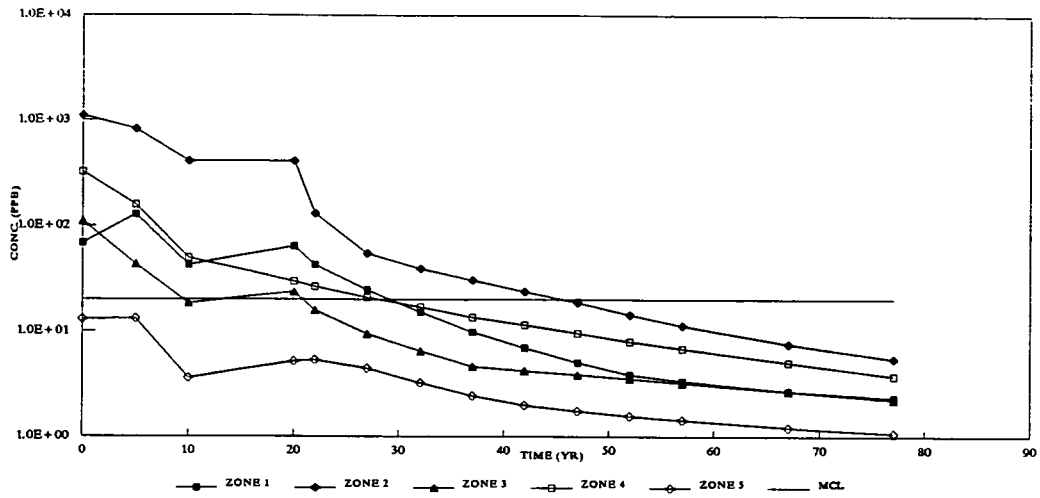
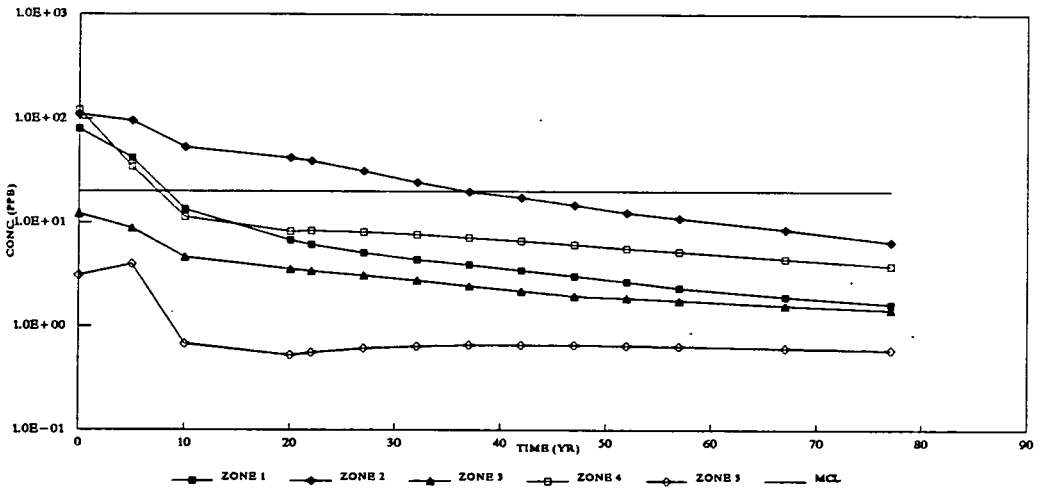


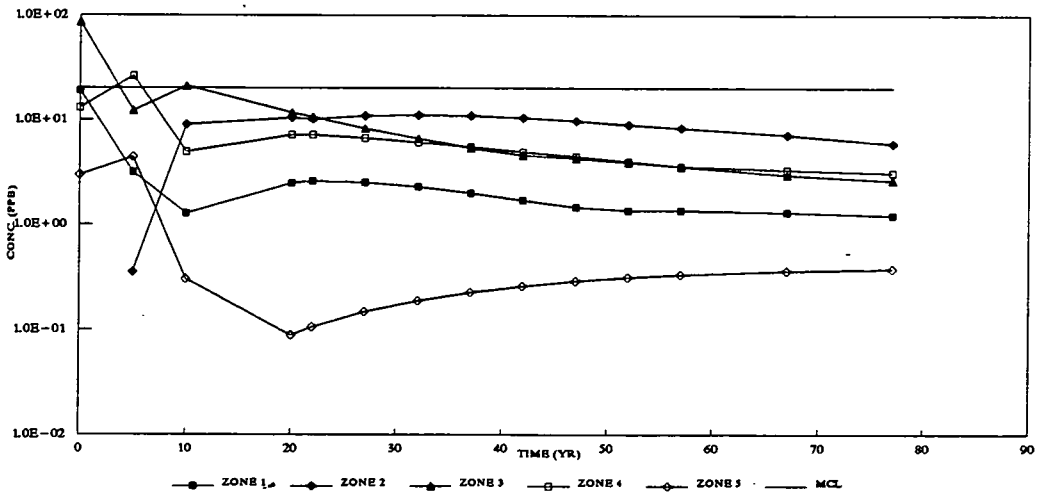
FIGURE F.7-101. GROUNDWATER CONTAINMENT TO 20 ppb - HIGH Kd, CONCENTRATION CONTOURS, YEAR 120, LAYER 1



LAYER 1



LAYER 3



LAYER 6

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FIGURE F.7-102A. Kd SENSITIVITY STUDY, Kd=6 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

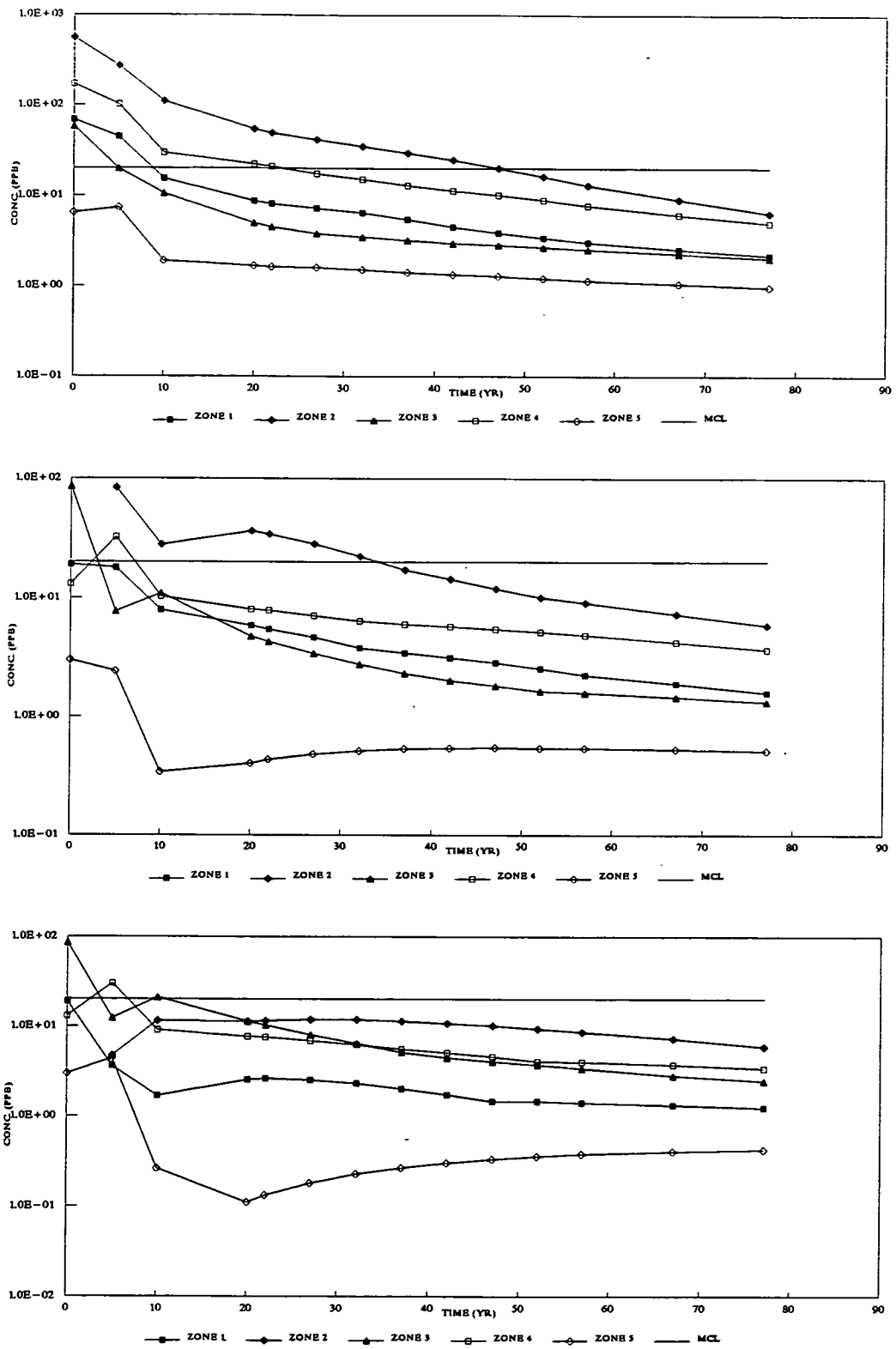

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FIGURE F.7-102B. Kd SENSITIVITY STUDY, Kd=6 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

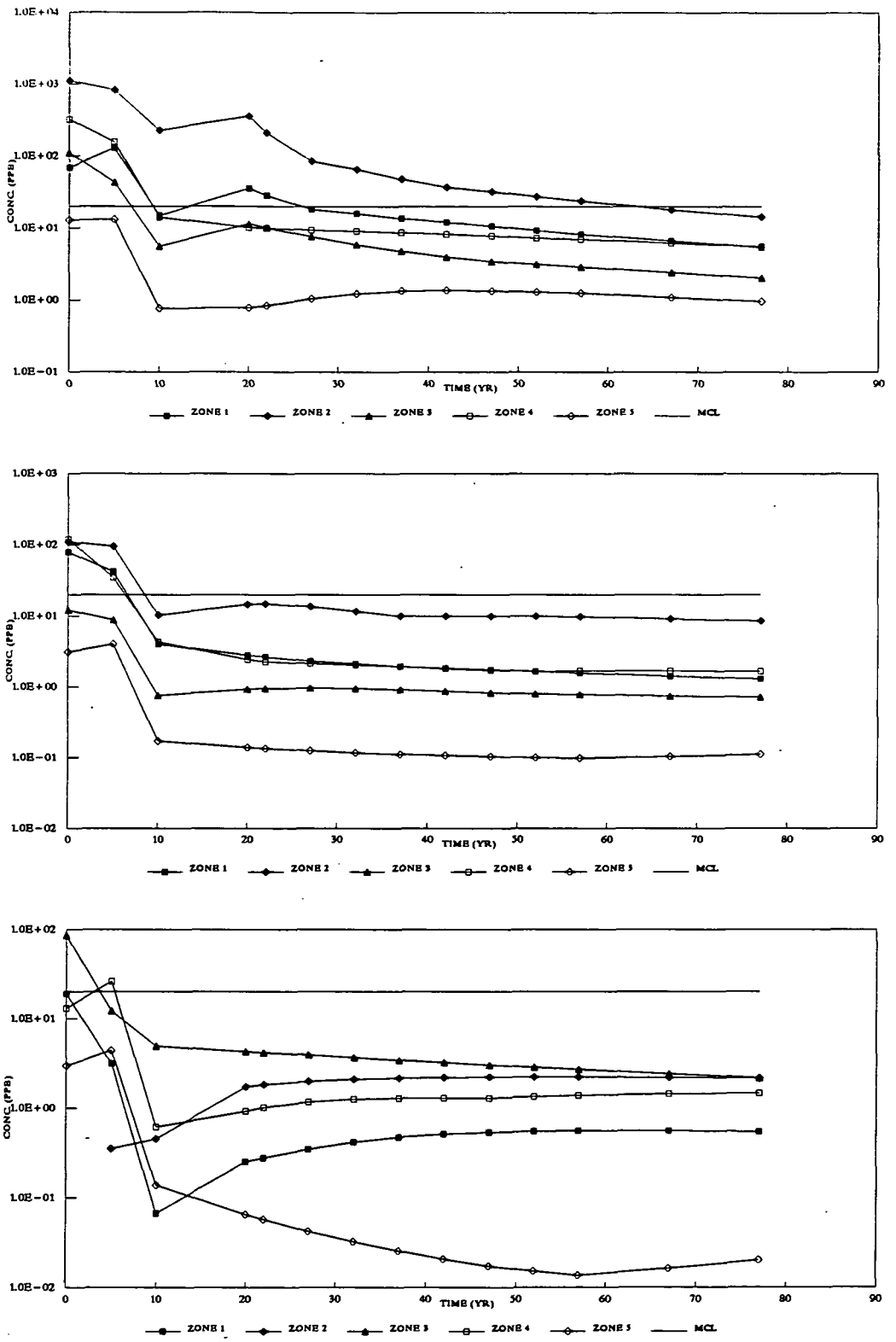

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FIGURE F.7-103A. Kd SENSITIVITY STUDY, Kd=30 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

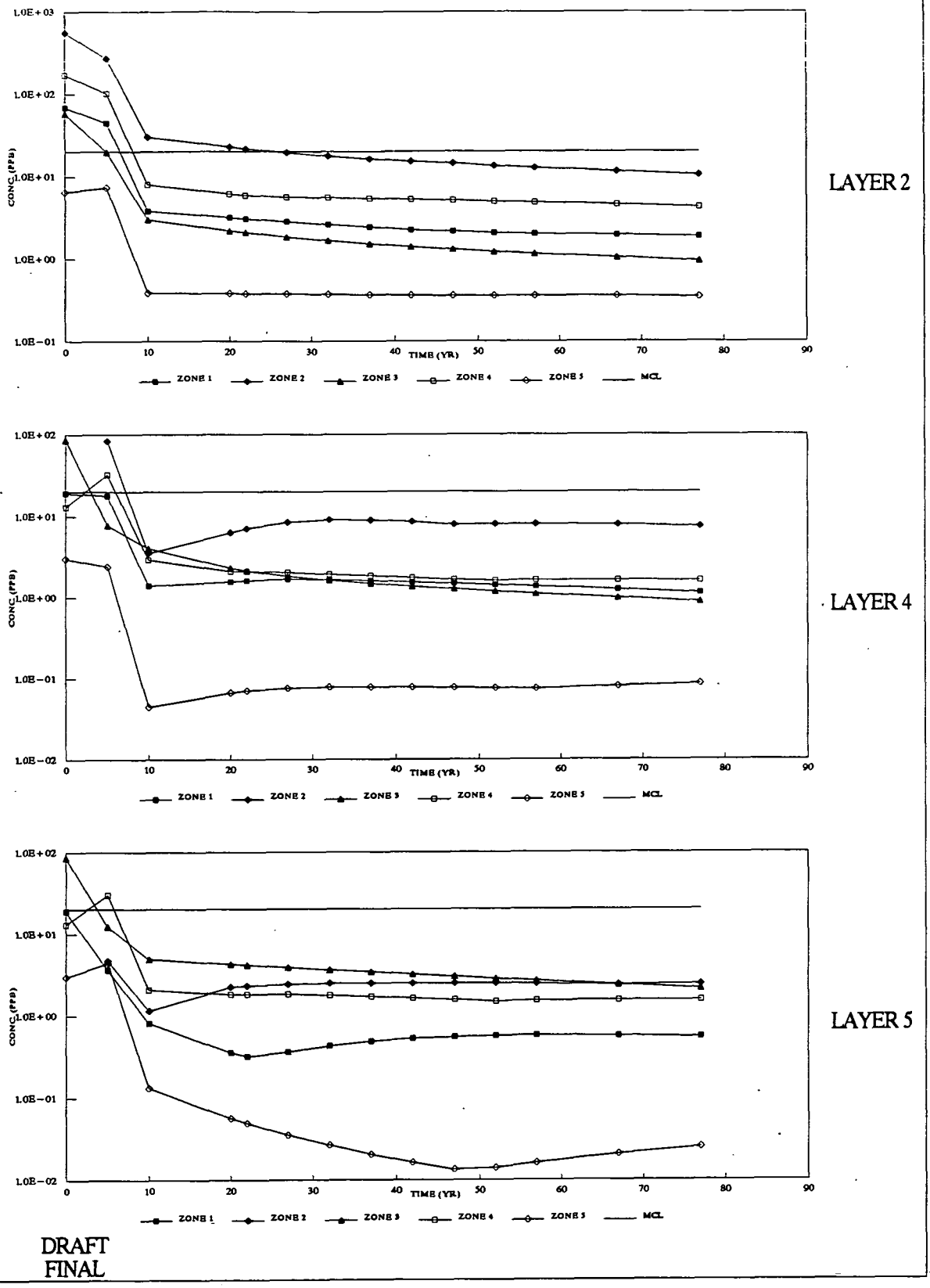

FIGURE F.7-103B. Kd SENSITIVITY STUDY, Kd=30 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

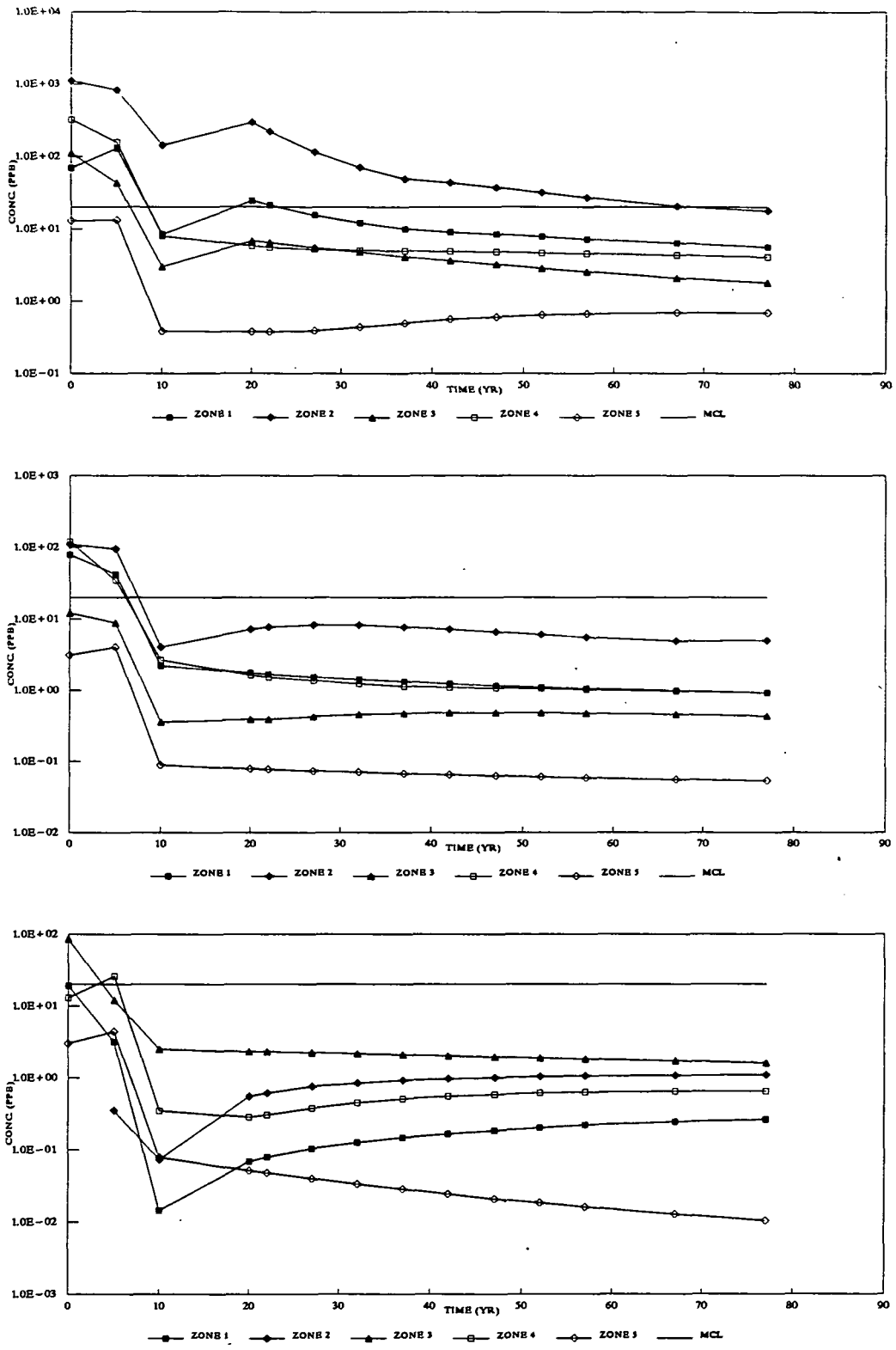

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FIGURE F.7-104A. Kd SENSITIVITY STUDY, Kd=60 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

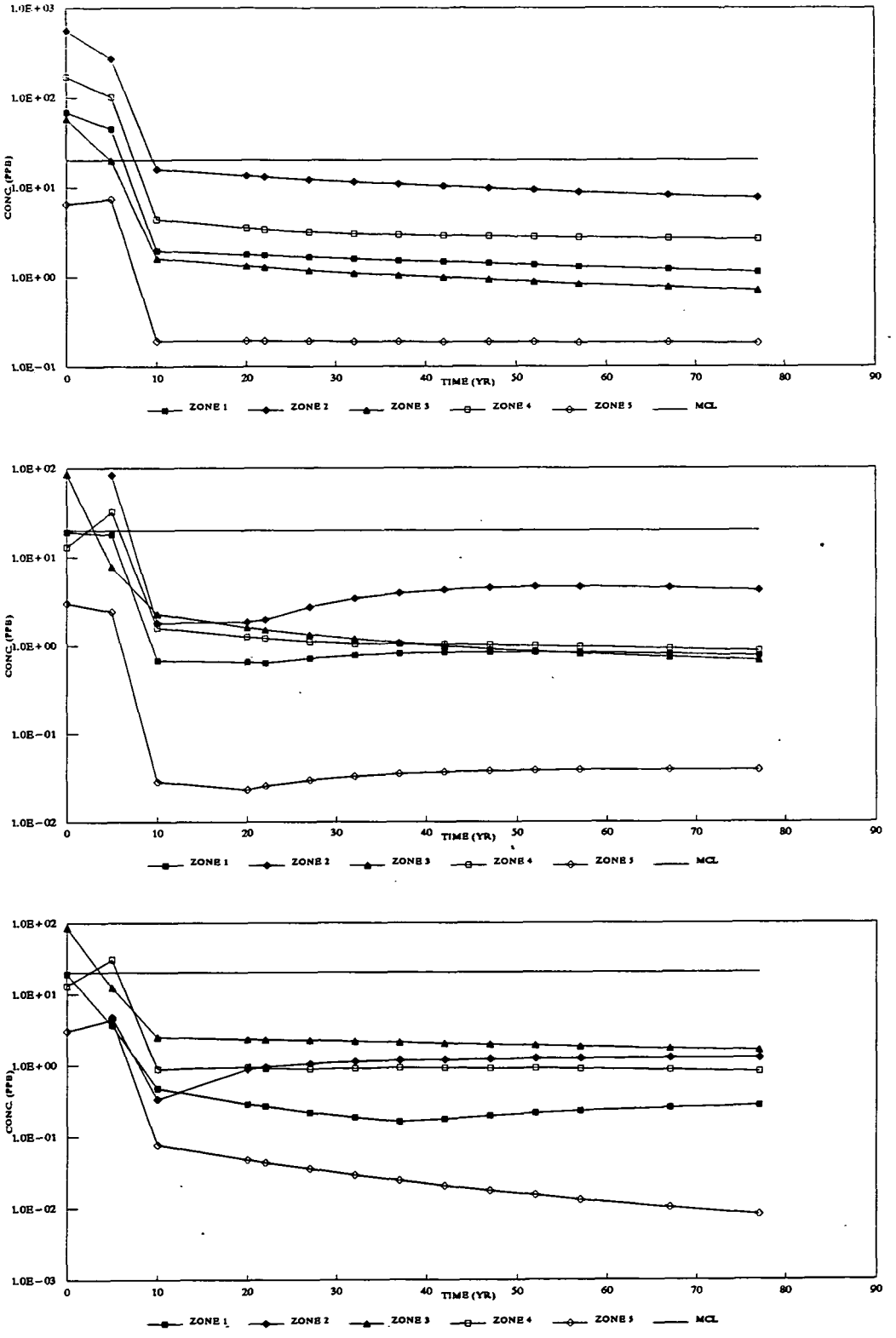

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FIGURE F.7-104B. Kd SENSITIVITY STUDY, Kd=60 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

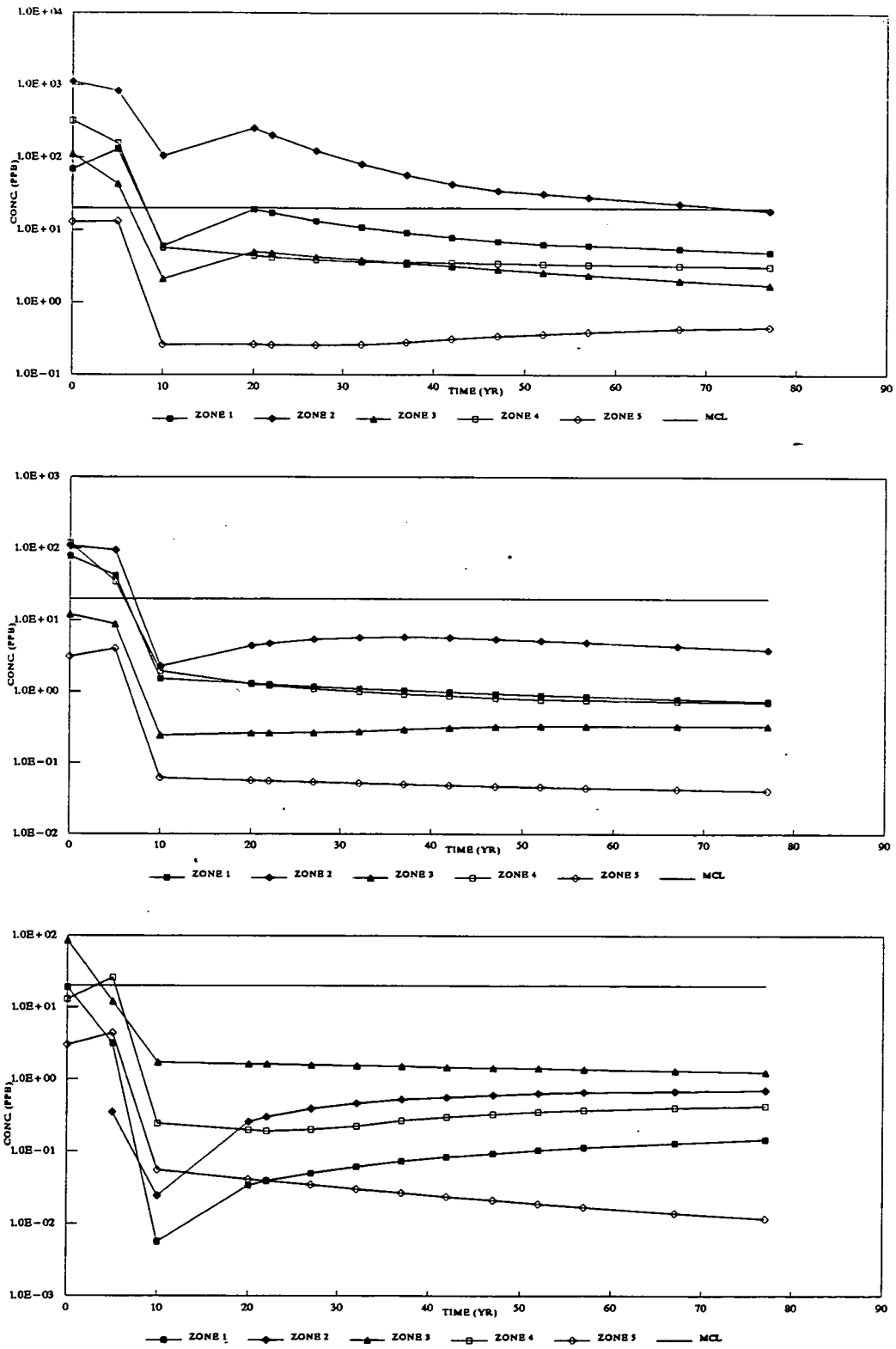

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FIGURE F.7-105A. Kd SENSITIVITY STUDY, Kd=88 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 1, 3, AND 6.

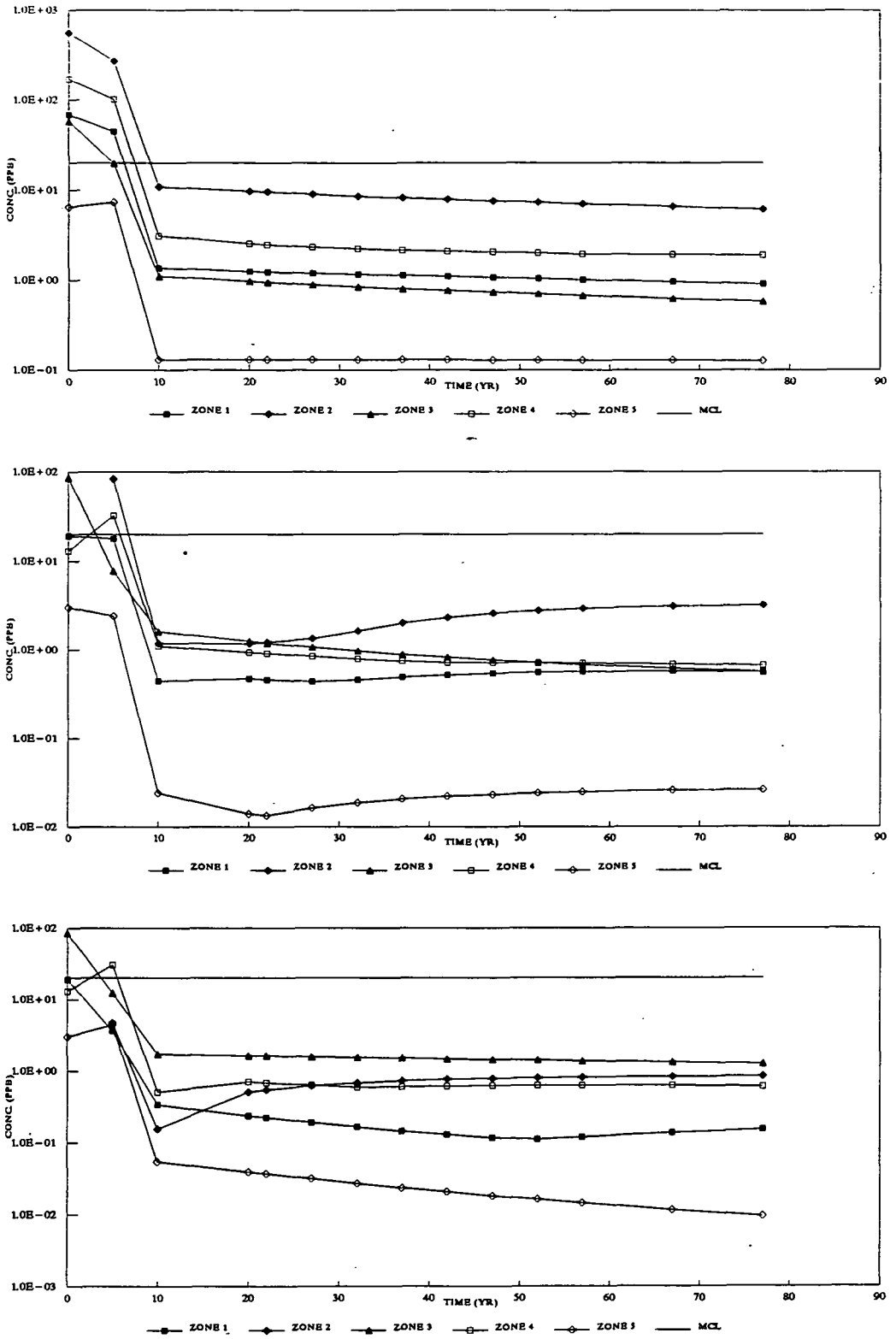

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FIGURE F.7-105B. Kd SENSITIVITY STUDY, Kd=88 L/KG, MAXIMUM CONCENTRATION CURVES. LAYERS 2, 4, AND 5.

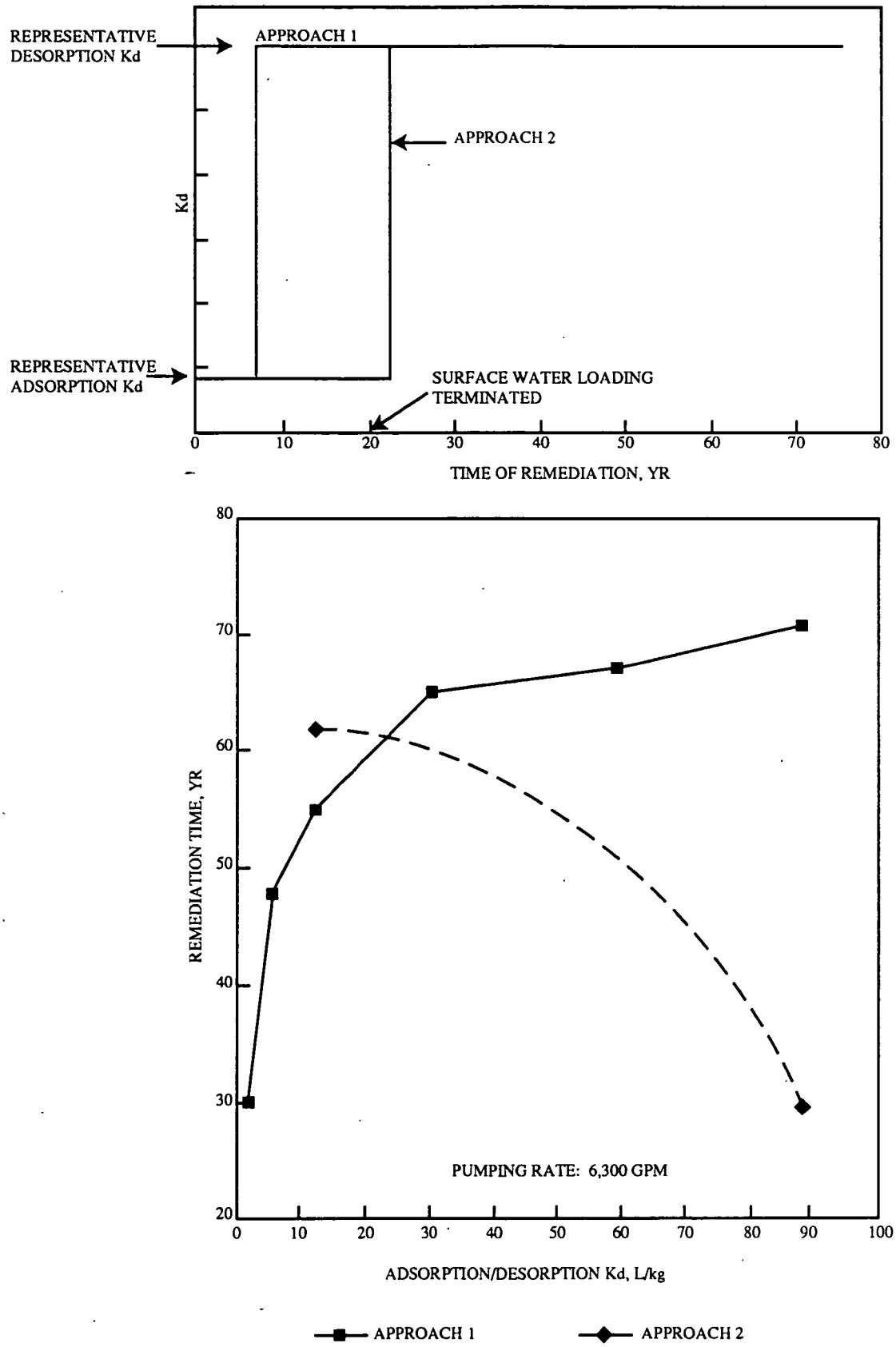

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FIGURE F.7-106. Kd SENSITIVITY STUDY, Kd VERSUS CLEANUP TIME FOR DIFFERENT APPROACHES

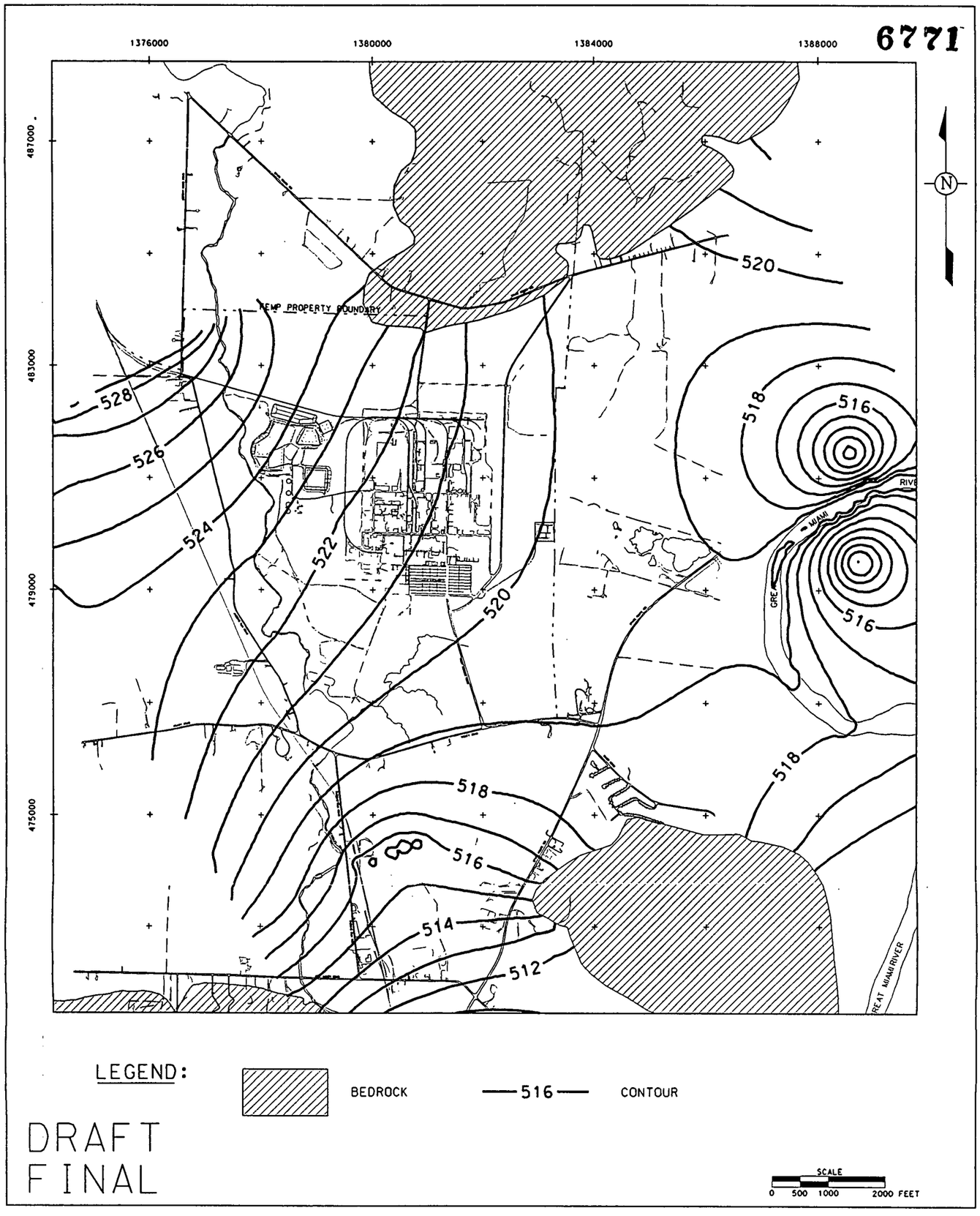

FIGURE F.7-107. NO ADDITIONAL ACTION DESIGN - WATER TABLE CONTOURS

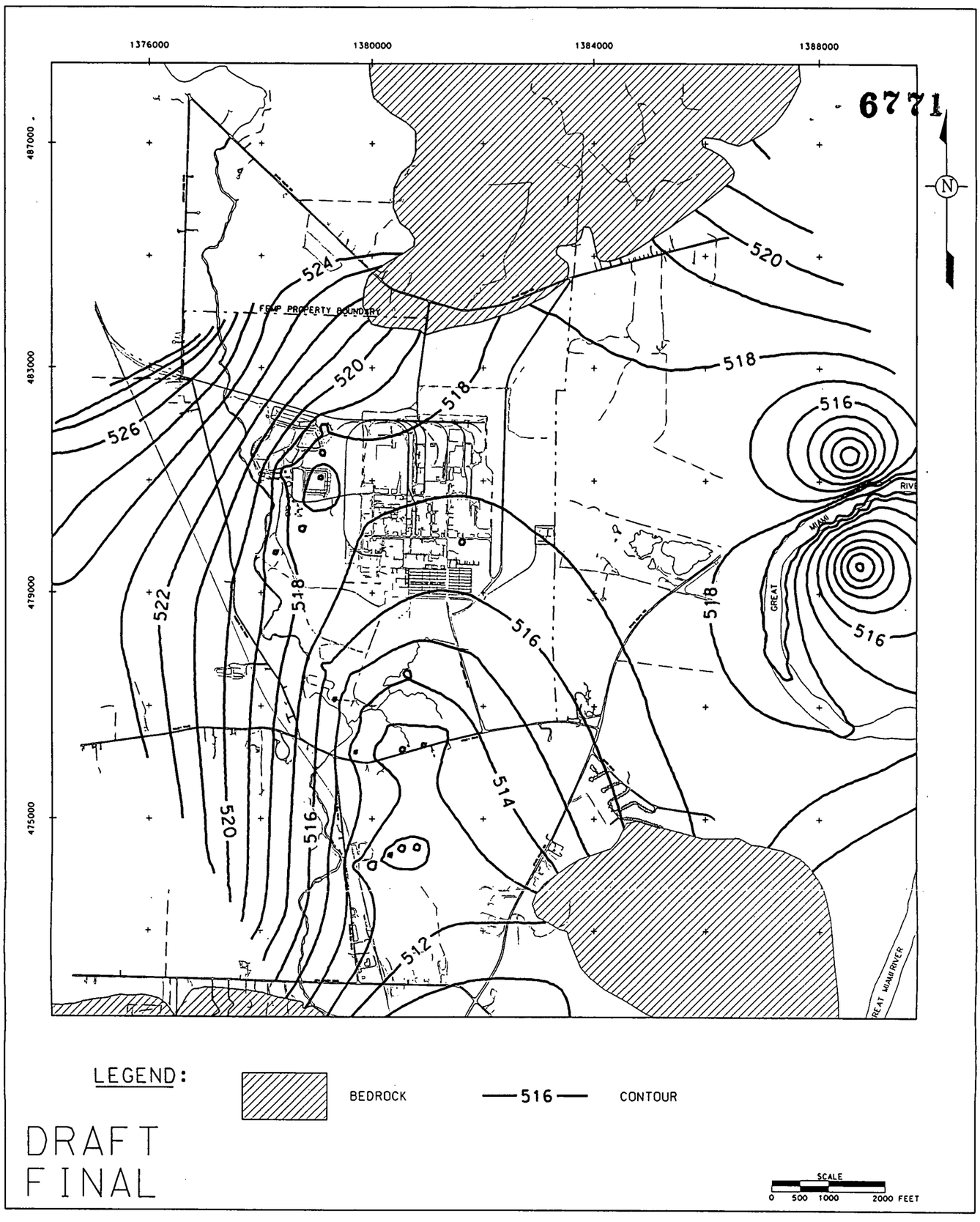

FIGURE F.7-108. RESTORATION TO 20 ppb DESIGN - WATER TABLE CONTOURS

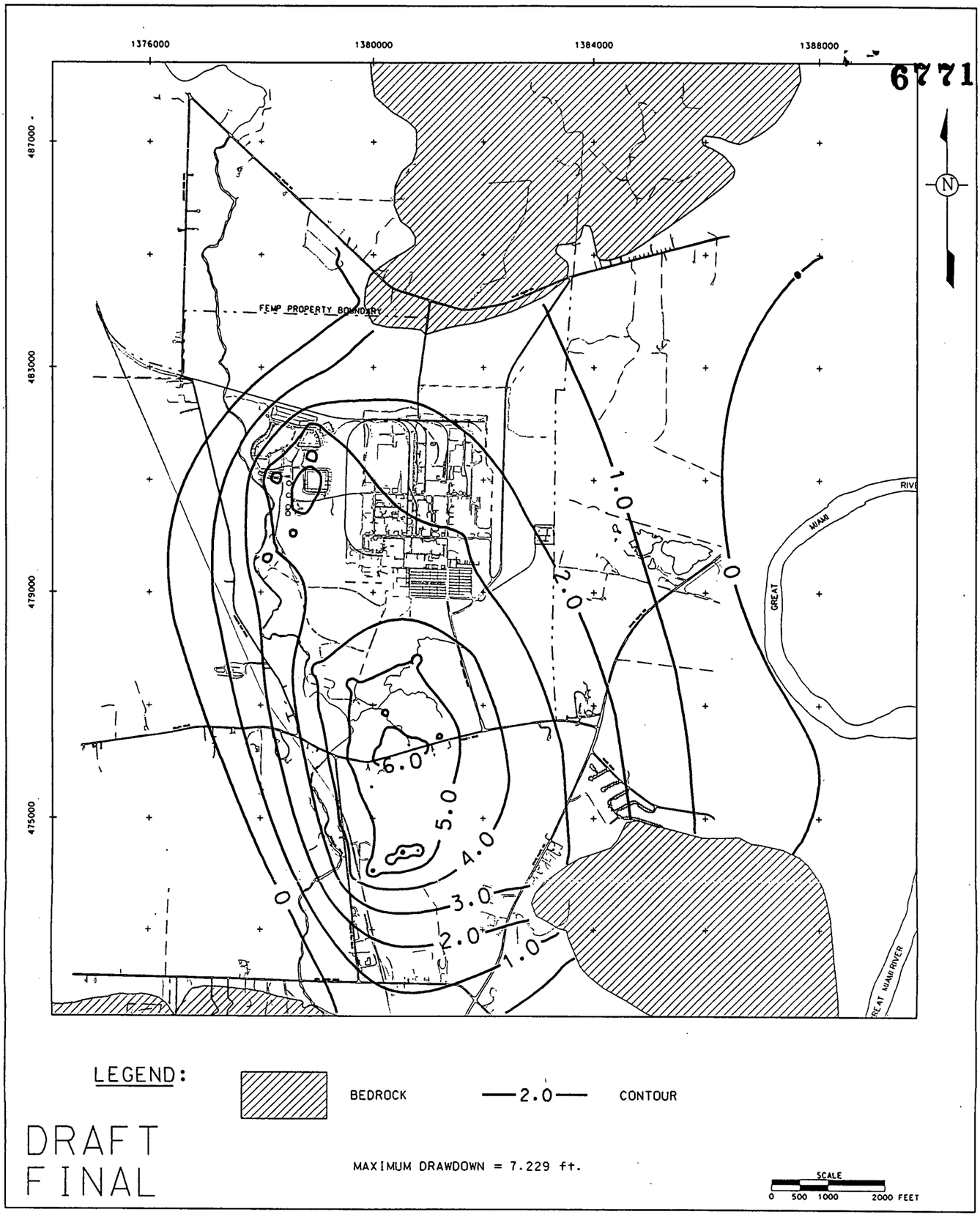

FIGURE F.7-109. ADDITIONAL DRAWDOWN CAUSED BY GROUNDWATER RESTORATION TO 20 ppb DESIGN PUMPING

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F.8.IV	Great Miami Aquifer Desorption K_d

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LIST OF ACRONYMS

AWWT	Advanced Wastewater Treatment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
COC	Contaminant of Concern
DCG	Derived Concentration Guide
DOE	United States Department of Energy
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FS	Feasibility Study
gpm	gallons per minute
MCL	Maximum Contaminant Level
OEPA	Ohio Environmental Protection Agency
ppb	parts per billion
PRL	Preliminary Remediation Level
ROD	Record of Decision

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F.8 PREDESIGN OPTIMIZATION OF THE GREAT MIAMI AQUIFER GROUNDWATER EXTRACTION AND TREATMENT STRATEGY

F.8.1 INTRODUCTION

F.8.1.1 Scope of the Optimization Study

In general, Appendix F.7 has demonstrated that hydraulic extraction of contaminated groundwater is a feasible approach for the Great Miami Aquifer remediation. An aquifer restoration optimization study was conducted on the extraction program presented in Appendix F.7 to identify and support revised treatment strategies that could accomplish EPA's intended protectiveness goals and satisfy regulatory requirements.

Before developing the additional cases for evaluation, a revised FS baseline case was evaluated that considered updated hydraulic boundary conditions, revised well locations mobility fractions, the latest site-wide soil remediation schedule, and surface water loading rate.

F.8.1.2 Objective

The primary objective of this study is to optimize the selected groundwater extraction alternative presented in Appendix F.7 and to evaluate treatment strategies for extracted groundwater. The goals of the optimization process include:

- Reducing predicted cleanup time
- Reducing predicted hydraulic impacts
- Maintaining regulatory compliance
- Increasing overall cost-effectiveness.

F.8.1.3 Regulatory Requirements

Great Miami Aquifer groundwater remediation is driven by the regulatory-based requirements defined under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These requirements include:

- Restoring the site-contaminated portion of the Great Miami Aquifer to MCLs or equivalent protective requirements (as presented in Table 2-16 of the FS) within a reasonable time frame (i.e., 30 years)

- Compliance with all the regulations promulgated and permits granted by EPA and OEPA regarding risk-based concentration levels and discharge limits for the Great Miami River during the site remediation.

- Compliance with all the negotiated discharge limits (e.g., 702 lbs/yr of uranium and less than 20 ppb blended effluent concentration) to the Great Miami River and continuously reduce the mass discharge rate during the course of the site remediation

- Compliance with all the other relevant DOE Orders (e.g., derived concentration guide, DOE Order 5400.5).

F.8.1.4 Evaluation Criteria

Each remediation strategy evaluated in this optimization study was compared against the following criteria:

- Remediation Period - A minimum remediation time is desirable from cost and risk reduction perspectives. An upper limit of remediation time has been set at 30 years, based on the selected alternative in Appendix F.7 and because this time frame falls within the postclosure care period. All things being equal, a reduction in remediation time is desirable to expedite release of the site and reduce operating costs.

- Regulatory Compliance - The selected case must comply with applicable laws and regulations, described in Section F.8.1.3.

- Hydraulic Impacts - The baseline groundwater remediation alternative with a constant 6300 gpm extraction rate is near the limit of the hydraulic capacity of the aquifer in the site area. Model uncertainty, seasonal effects, long-term rainfall trends, and increases in water withdrawal by area water producers could cause an exceedance of capacity at some point during the remediation period. A lower extraction rate would create a larger safety factor in the operation of the system.

- Treatment Capacity and Efficiency - Each extraction and treatment option results in a need for treatment capacity over time (variable or constant), resulting in capital and operating costs. Steep reductions in needed treatment capacity over time are inefficient (from a cost perspective) because facilities are not used to their design life. In the order of increasing cost, the following three scenarios of obtaining treatment capacity are possible: using only available excess capacity of the Advanced Wastewater Treatment (AWWT) facility (estimated as 800 gpm); expansion of existing facilities (estimated as up to 700 gpm for a total of 1500 gpm); and building a new facility (necessary if treatment needs are greater than 1500 gpm).

- Impacts to the Great Miami River - It is desirable to have the least impact (lowest uranium concentrations and least overall mass) on the river as possible. The river, through the outfall, will receive groundwater with residual uranium concentrations directly from wells (with concentration based on the treatment criteria) and treated effluent with a residual concentration of uranium (assumed to be 5 ppb). Based on the extraction case and treatment approach, different concentrations of uranium are discharged through the outfall over time.

- Cost - Each alternative will have a total cost consisting of capital and operating costs. Obviously, a preference is given to cases with lower total cost. Certain criteria (e.g., treatment capacity and remediation time) may be translated to cost. Other criteria (e.g., the impact to the Great Miami River) may be incrementally traded versus costs. Overall, it is important to get the greatest reduction in risk possible for each dollar spent.

F.8.1.5 Optimization Approach

The groundwater modeling conducted for the screening and selection of a feasible approach for extraction of the Great Miami Aquifer plume defined extraction wells based on the estimated plume and pumped each well at a constant rate until cleanup to the desired level was achieved (see Figure F.8-1 for well configuration). However, in the actual operation of such a system, control would be exerted over pumping rates, allowing decreases in pumping and treatment rates and/or a more efficient distribution of pumping over time, and treatment strategies, which have a large impact on cost, were not evaluated in Appendix F.7. Reducing cleanup time or treatment capacity has a large impact on cost and the mass rate of discharge to the Great Miami River. Figure F.8-2 shows a flowchart of the approach followed in this study. The flowchart represents (from top to bottom) assumptions, extraction strategies including the revised baseline, treatment strategies, and evaluation of each case to the stated evaluation criteria. Each extraction strategy plus a treatment strategy produces an individual case for evaluation.

To understand the relationship between capital costs (primarily related to the size of the treatment plant) and operating costs (primarily related to remediation time), a separate hypothetical analysis of costs was conducted. Several hypothetical scenarios were developed, using data from actual simulations to develop curves of remediation time versus extraction rate and assuming the total mass removed would be the same as the revised baseline case to achieve aquifer restoration. The objective of this analysis is to direct design efforts toward an optimum (based on cost) relationship among extraction rate, treatment capacity, and remediation time.

The model used in Appendix F.7 was updated to incorporate revised hydraulic boundary conditions, to include revised well mobility fractions from different model layers to reflect the dewatered model Layer 1, to create a minimum 10-foot mixing zone for determining exposure concentrations below the groundwater table when model Layer 1 blocks are dewatered, and to include revised loading terms more reflective of the latest data and soil remediation strategy. Then a revised baseline case was modeled to provide a basis for comparison. Extraction and treatment strategies remain the same as in the selected alternative for the revised baseline and two additional groundwater extraction strategies (with the revised assumptions) were modeled:

- Time-varying pumping rates - several cases were modeled varying the distribution of pumping over time with fixed well locations. Optimization cases were simulated with a reduction in overall pumping rate over time as areas were cleaned up or a constant overall pumping rate redistributing pumping as areas were cleaned up. Optimization cases were simulated as system (i.e., a group of wells) or well based.

- Sequential operation of systems - two cases were modeled that fixed a lower overall pumping rate and then sequentially extracted groundwater from different areas of the site, considering the soil remediation schedule.

One case from each of the two extraction strategies (time-varying and sequential) was selected for more detailed analysis. Particle tracking was used to define horizontal and vertical capture zones for these two extraction strategies to aid in analyzing hydraulic impacts and assess vertical capture. Revised approaches for groundwater treatment included no treatment, treating groundwater above 5 ppb uranium concentration, treating groundwater above 20 ppb uranium concentration at the well head, treating groundwater above 20 ppb uranium concentration at the well head up to a fixed flow rate of 800 gpm, and treating groundwater above 20 ppb uranium concentration at the well head up to a fixed flow rate of 1500 gpm. The two selected extraction options were combined with the five treatment options to create 10 cases for detailed analysis with the defined evaluation criteria.

The different extraction/treatment cases were evaluated against the five identified criteria and a case was selected. With the selected extraction strategy, pumping was simulated with initial conditions and loadings of other groundwater COCs to determine this system's effectiveness for cleaning up these other COCs within the given time frame.

In Appendix F.7- the issue of artificial vertical dispersion was evaluated to determine the potential impact on extraction system effectiveness. Results of a sensitivity simulation using a test model with a revised dispersivity approach were compared with the selected system simulation.

To assess the impact of uncertainty in geochemical conditions, sensitivity analysis was conducted to evaluate impacts of different uranium desorption characteristics (i.e., lower desorption rates than the baseline condition) during aquifer restoration. A uniform uranium solid/liquid partition coefficient (K_d) value of 1.78 L/kg and the assumption of a fully reversible adsorption/desorption process were used in all the previously described simulations of the groundwater extraction strategies.

F.8.2 SENSITIVITY ANALYSIS OF COST COMPONENTS

This section provides a sensitivity analysis of the costs of hypothetical extraction and treatment scenarios. Results from this analysis provided information regarding the ranges of optimal costs of groundwater extraction and treatment strategies. This information is useful when developing evaluating the performance of the potential extraction and treatment strategies.

F.8.2.1 Sensitivity Analysis Approach

Cost analysis of groundwater remediation options becomes an exercise in trading off capital costs versus operating costs. For the removal of a fixed mass of extracted groundwater, lower extraction/treatment rates (smaller capital costs) result in longer remediation times (greater operating costs). To understand the relationship of these fluctuating capital and operating costs, a series of hypothetical cases were costed with the objective of determining an optimum extraction rate and remediation time. The sensitivity of the total cost to the extraction and treatment components was also evaluated.

Based on inspection of the treatment demand versus time curves, typically there is a steep drop off in needed capacity after the first few years followed by a more gradual decrease. Satisfying this peak in demand is not cost-effective because treatment capacity is used for only a few years (i.e., less than its design life). However, if some portion of this peak treatment demand is not treated, then there will be greater mass discharged to the river. To determine potential cost savings of not treating this peak in demand, two cases of fixed treatment capacity were also costed.

Hypothetical cases were created by first estimating cleanup time for different extraction rates. In Appendix F.7, three extraction rates were simulated and remediation times were determined:

- No additional action at 1500 gpm (System 4) - remediation in 90 years
- Containment at 2600 gpm - remediation in 60 years
- Revised baseline at 6300 gpm - remediation in 30 years.

With these three cases, an estimated curve of extraction rate versus cleanup time was created and values of cleanup time for any hypothetical extraction rate could be estimated (see Figure HYP-1 in Attachment F.8.II). These cleanup times were only estimates, because the lower pumping rates are only extracting groundwater at limited locations. Total mass to be extracted and treated was the second parameter used to constrain the solution; this was estimated from a simulation of the revised baseline extraction of 6300 gpm with groundwater containing greater than 20 ppb of uranium sent to treatment. The hypothetical cases cover a wide range of extraction rates (as low as 2000 gpm) and cleanup times (as high as 65 years) (see Figure HYP-2 in Attachment F.8.II).

With treatment time and total treatment mass, treatment capacity over time could be estimated as a first order decay curve. These curves were used to estimate costs based on different extraction and treatment rates. As discussed above, two other cases were created which pumped 4500 gpm and treated groundwater above 20 ppb of uranium up to a maximum of 1500 gpm and 800 gpm.

F.8.2.2 Sensitivity Analysis Results

Table F.8-1 summarizes the costs (in 1994 dollars) of these hypothetical scenarios and Figure F.8-3 breaks the extraction and treatment costs into capital and operation and maintenance (O&M) components. From simply an extraction perspective, Case H4 with an extraction rate of 4500 gpm and a remediation period of 30 years is slightly lower in cost than the other options. For all of the cases (except H9), total extraction costs are approximately 25 to 30 percent of the total while treatment costs make up the remainder. As remediation time increases, O&M costs comprise a greater percentage of the total cost with percentages ranging from approximately 60 percent (for Case H2) to 75 percent (for Case H7). Case H1, with 6300 gpm extraction, 4500 gpm treatment, and the shortest remediation time of 26 years, results in the least cost of $143 million, while the greatest cost option is Case H7 (with the lowest extraction rate and longest remediation time) at $171 million. In

Cases H2 through H6, the total costs are very similar. Cases H8 and H9, representing a different approach with a fixed treatment capacity as described above, show a substantial reduction in total cost, especially in capital and O&M costs for treatment . Case H9 shows no treatment costs because excess treatment capacity of 800 gpm presently exists. The sharp reduction in costs for H8 and H9 from the other cases shows the extreme sensitivity of total cost to reduction in maximum treatment capacity.

F.8.3 SIMULATION RESULTS

Model simulation results for potential groundwater extraction and treatment strategies developed and evaluated in this study are summarized in this section. Because it is the most significant groundwater contaminant at the FEMP, uranium was used as the indicating contaminant in these simulations. Additional detailed results are provided in Attachment F.8.II.

F.8.3.1 Extraction Strategy

All the extraction strategies evaluated in this report were simulated with the following revisions from the model used in Appendix F.7:

- The constant-head model boundary conditions on the west and north grid boundary were adjusted to reflect the hydraulic effects of pumping. These boundaries were adjusted by simulating pumping at the desired rate for each case using the original regional grid (IT 1993) and adjusting the boundary of the revised smaller grid based on drawdown at the same location in the regional grid. At the maximum pumping rate of 6300 gpm, drawdown effects up to 7 feet were seen at the nearest (western) boundary with proportionally less effect at lower pumping rates and at boundaries that were farther away.

- For the analysis conducted in Appendix F.7, constant mobility fractions were assigned to each layer. Fractions of 0.25, 0.50, and 0.25 were assigned to Layers 1, 2, and 3 respectively for shallow wells. Fractions of 0.5 and 0.5 were assigned to Layers 5 and 6 respectively for deep wells. During this optimization study, an approach was used which accounted for reduced cell transmissivity scaled by the final water elevation in the cell resulting from pumping. Cell transmissivity varied from pumping sequence to pumping sequence depending on final water elevations for each sequence.

- Surface water loading rates of uranium during the remediation period were revised based on the latest operable unit remediation schedules. The Surface Water Flow and Infiltration Model (DOE 1993) was simulated with these latest data and two loading rates (from years 0 to 10 and 10 to 20) were established based on these modeling results. Postremedial surface water loading of uranium after 20 years was also included in the loading terms. This loading continued until the completion of the simulation. Table F.8-2 shows the revised surface water loading rates (see Attachment F.8.I for detailed surface water modeling results).

- Uranium loading rates from existing Operable Units 1 and 2 areas were loaded for only 10 years (instead of 20 years as in Appendix F.7) based on the latest remediation schedule showing remediation of Operable Units 1, 2, and 4, and other areas outside of the production area within 10 years. Uranium loading from Operable Unit 3 remained at 20 years since the production area will be remediated last. Table F.8-2 shows the revised operable unit loading rates.

- Due to the high rate of pumping, many model Layer 1 blocks become partially or fully dewatered. Concentrations in these dewatered blocks may be artificially high if direct loading is occurring at the same location because very little dilution occurs in the model. To correct this situation, model output files are post processed redefining Layer 1 at a minimum thickness of 10 feet from the water table and correcting concentrations as the weighted average between modeled Layer 1 and Layer 2 concentrations. Ten feet has been used as a minimum mixing depth considered to be a minimum well screen length of groundwater production wells through which future exposures to groundwater contaminants may occur (see mixing depth used in the WAC development presented in Appendix F.5).

F.8.3.1.1 Revised Baseline Case

Except for the above revisions, the revised baseline case used the same conditions and assumptions used in the restore to 20 ppb design (the selected alternative) and employed the following two pumping periods:

- 0 through 5 years - only System 4 (South Plume system) pumping
- 5 through 26 years - all systems pumping.

Revised baseline well pumping rates are the same as for the selected alternative (i.e., 6300 gpm), with individual well pumping rates varying from 160 to 400 gpm, and cleanup time (when treating groundwater with uranium concentrations above 20 ppb) has been reduced to 26 years (year 0 is 1995) from 30 years. This reduction in remediation time is apparently due to the reductions in loading terms and time of loading from the Operable Unit 2 South Field area and surface water. Zone 4 (South Plume) now takes the longest time to remediate; (Zone 2 (South Field and the SSOD area) took the longest in the selected alternative). This reduction also appears to be due to the decrease in Operable Unit 2 South Field area and surface water loading. In essence, Zone 4 maintained the same remediation time while Zone 2's was reduced to 24 years. Therefore, Zone 4 is now the limiting area.

F.8.3.1.2 Time-Varying Pumping Rate Results

The first type of optimization simulation used the same 6300 gpm total extraction rate as in the revised baseline case, but varied system and individual well pumping rates over time to reduce total remediation time, treatment capacity, and treatment time. Well locations were fixed for all simulations based on the selected alternative (see Figure F.8-1).

Four cases were modeled with time-varying pumping rates. While individual well pumping rates vary in all cases, time-varying cases employ variable and constant total pumping rates. Two system-based (V1 and V2) and two well-based (V3 and V4) cases were simulated. Variable pumping rate cases (V1 and V3) have a reduction in pumping rate over time resulting from turned-off well systems or individual wells that have concentrations below the cleanup level. Constant pumping rate cases (V2 and V4) have a constant total extraction rate over time resulting from cleaned up systems' or wells' pumping rates being redistributed among those wells or systems still requiring cleanup. However, the redistribution is limited by a maximum pumping rate of 500 gpm in any well and a maximum pumping rate of 1500 gpm for wells in Zone 4 (due to potential impacts on the Paddys Run Road Site). Therefore, when there are limited wells still pumping, the total extraction rate may actually decrease to meet these conditions.

Table F.8-2 summarizes the results of these simulations. Cleanup times ranged from 24 to 30 years, with Case V2 taking the least amount of time; Case V3 required 30 years to remediate. Because the logic used in turning off wells was based on well contaminant concentrations (not on aquifer concentrations), all V3 wells were turned off at year 28 even though there was still a maximum uranium concentration in the aquifer greater than 20 ppb (i.e., this maximum was not located at a well block). An additional 2 years was required to reduce this Zone 2 concentration below 20 ppb with natural dilution processes. This shows that turning off wells with concentrations below 20 ppb is overly simplistic because wells pull contaminated groundwater from adjacent areas.

Table F.8-2 also shows the uranium mass extracted, the total water pumped, and the efficiency (lbs/million gallons pumped). The extracted masses for the revised baseline and Cases V1 through V3 were fairly close. Case V4, however, extracted significantly more mass. This additional extracted mass was caused by aggressive pumping in the vicinity of the highest contaminant levels in the Operable Unit 2 South Field area. Removal efficiency increases quite dramatically as the logic in simulating the cases becomes more sophisticated (i.e., the well-based cases (V3 and V4) are more efficient because individual wells with low concentrations can be turned off).

F.8.3.1.3 Sequential Pumping Results

Two additional optimization cases were simulated with a lower fixed flow rate (approximately 4000 gpm), and aquifer zones were sequentially remediated. The same well locations (see Figure F.8-1) as the other simulations were used but the pumping from these wells was sequenced by attacking plumes in different areas at different times. To minimize hydraulic impacts, the extraction rate in any particular aquifer zone did not exceed the revised baseline extraction rate for that particular area.

The following sequence of pumping was observed for both cases:

- 0 to 5 years - pumped a total of 2000 gpm from existing South Plume wells and wells near the high concentration area in the South Field

- 5 to 10 years - pumped a total of 4000 gpm from existing South Plume wells and wells near the SSOD

- 10 to 15 years - Pumped a total of 4000 gpm from existing South Plume wells, wells near the SSOD, and wells near the fence line

- 15 to 20 years - Pumped a total of 4000 gpm from existing South Plume wells, wells near Operable Unit 1, wells near the fence line, and the South Field.

For Case S1, the South Field, Operable Unit 1, the production area, and the fence line were pumped from year 20 until cleanup. For Case S2, the South Plume wells, Operable Unit 1, and the production area were pumped from year 20 until cleanup. The only difference between Cases S1 and S2 is the operation of either the fence line (South Field) or the South Plume wells after year 20.

Table F.8-4 summarizes the results of the sequential pumping cases. Case S1 required 34 years, or 8 more years than the baseline case, and Zone 4 required the longest time to remediate. Case S2 required considerably less time, with cleanup occurring after 27 years, and showed a significantly higher removal efficiency than Case S1, although Case S2 extracted less uranium.

F.8.3.1.4 Screening of Extraction Strategies

Because several treatment/disposal options need to be combined with each extraction case for analysis, the extraction cases above are screened to reduce the number of cases for further analysis. A single case is selected from each of the variable pumping rate simulations and the sequential pumping simulations.

- Variable Pumping Rate - Case V4 is selected for further analysis. Case V4 extracted the greatest amount of uranium mass at the highest efficiency (see Table F.8-3). While Case V2 cleaned up the aquifer a year earlier, the extraction efficiency was 40 percent better in Case V4. Since greater mass was extracted with V4, further optimization efforts should be able to reduce Case V4 remediation time.

- Sequential Pumping Rate - Case S2 is selected for further analysis. Case S2 extracted the greatest amount of uranium mass at the highest efficiency and remediated the aquifer 7 years sooner than did Case S1 (see Table F.8-4).

F.8.3.2 Capture Zone Analysis

For the revised baseline and the two selected extraction strategies (i.e., V4 and S2), capture zone analysis was conducted to show hydraulic capture zones for the different pumping schemes.

Capture zone plots were defined over the time frames of the applicable period for each extraction case. Both a plan view capture zone and a vertical (roughly north-south) cross section are presented for each pumping period. All particles are projected onto each of these planar surfaces.

Attachment F.8.II shows all of these capture zone plots. As an example, the capture zone plots for Case S2, Years 0 to 27, are presented in Figures F.8-4 and F.8-5. Two sets of horizontal projections of the capture zones, arising from two different values of retardation factors (11.8 for uranium-238 and 2.23 for technetium-99), for Case S2 are shown in Figure F.8-4. In the Figure, horizontal projections of pathlines of captured fluid particles moving with the retardation factor of 11.8 are presented. For comparison purposes, an outline showing the extent of the movement of captured fluid particles with the retardation factor of 2.23 is also shown in the figure. As expected, the spatial extents of the capture zones with the smaller retardation factor are greater than those associated with the larger retardation factor. In comparing the spatial extents of the capture zones depicted by Figure F.8-4 and the initial distribution of uranium concentration in the Great Miami Aquifer in Figure F.7-4, Appendix F.7, one can see that the capture zones cover areas with the bulk of uranium. In Figure F.8-5, vertical projections of captured fluid particle pathlines, due to the retardation factor of 11.8 (uranium-238), along an approximately North-South oriented vertical plane are shown. As can be seen in the figure, the majority of the pathlines depict the major movement in the top three layers of the model where the bulk of uranium has been detected. The figure also shows upward movement of fluid particles from lower layers, which is indicative of the presence of a relatively strong upward vertical hydraulic gradient induced by groundwater extraction. For comparison purposes, an outline showing the extent of the movement of captured fluid particles with the retardation factor of 2.23 is also shown in the figure. Similar to the results presented in Figure F.8-4, the spatial extents of the capture zones with the smaller retardation factor is greater than those associated with the larger retardation factor. In general, the revised baseline and Case V4 have more extensive capture zones than Case S2; however, Case S2 is sufficient for aquifer remediation purposes as shown in the simulated capture zones.

F.8.3.3 Treatment and Disposal Strategies

For the two selected extraction strategies, five treatment and disposal strategies were evaluated. Each extraction strategy combined with a treatment and disposal strategy results in a unique design with a specific treatment capacity over time, treatment duration, river outfall concentration over time, and river mass loading over time.

The five treatment and disposal strategies are:

- I - No treatment - all extracted groundwater is directly discharged to the Great Miami River.

- II - Treat above 20 ppb - extracted groundwater with uranium concentrations greater than 20 ppb at the well head is sent to treatment; 20 ppb is approximately the proposed drinking water MCL of uranium. Extracted groundwater with concentrations below 20 ppb is sent to the Great Miami River. 20

- III - Treat above 5 ppb - extracted groundwater with uranium concentrations greater than 5 ppb at the well head is sent to treatment; 5 ppb represents an estimate of the technological limits of uranium removal (i.e., treatment plant effluent concentrations are estimated at 5 ppb). Extracted groundwater with concentrations below 5 ppb is sent to the Great Miami River.

- IV - Treat above 20 ppb up to a fixed rate of 800 gpm - extracted groundwater with uranium concentrations greater than 20 ppb is sent to treatment, up to a maximum treatment capacity of 800 gpm. The remaining groundwater is sent to the Great Miami River.

- V - Treat above 20 ppb up to a fixed rate of 1500 gpm - extracted groundwater with uranium concentrations greater than 20 ppb is sent to treatment, up to a maximum treatment capacity of 1500 gpm. The remaining groundwater is sent to the Great Miami River.

As described above, all the treated and untreated groundwater is assumed to be discharged to the Great Miami River to determine the maximum impacts to the surface water under each treatment strategy. Other disposal options, such as reinjection of groundwater with concentrations lower than the cleanup level, will be continually evaluated during the engineering design and system operation.

F.8.3.3.1 Treatment Strategy Results

Two extraction and five new treatment strategies together result in a matrix of 10 different options for analysis. In addition, the revised baseline case, which simply treats all groundwater regardless of concentration, was also evaluated. Each of these options requires a certain treatment capacity over time and results in a certain impact to the river over time by the blended treatment plant effluent and untreated groundwater.

Table F.8-5 summarizes the treatment results and Table F.8-6 shows the disposal to the Great Miami River results for the 11 cases evaluated. These tables show the loadings and concentrations that are predicted to be sent to the treatment plant and to the river. These values are described in more detail in the evaluation section of this study (see Section F.8.4).

F.8.4 PERFORMANCE EVALUATION

This section compares the performance of each of the 11 groundwater remediation options (revised baseline, V4-I through V4-V, and S2-I through S2-V) described in the previous section, using the following evaluation criteria:

- Remediation period
- Aquifer hydraulic impacts
- Impacts to the Great Miami River
- Regulatory compliance
- Cost.

Because of the nature of these criteria, this evaluation is qualitative. Remediation period and regulatory compliance are threshold type criteria; an option must meet minimum requirements to be considered further. Impacts to the aquifer and river change more gradually and, therefore, are ranked rather than rejected. Relative cost is a secondary criterion. If options are comparable regarding the other criteria, then the option with the least cost would be selected. Incremental cost to change (reduce the impact) of another criterion provides a method to determine trade-off of cost versus risk reduction.

Based on this comparison, a strategy will be recommended as the starting point for remedial design. It is important to note that this comparison is intended to define an overall approach and philosophy to groundwater remediation, but not necessarily to settle on an actual design at this stage. Using the information obtained in Section F.8.3, Table F.8-7 summarizes all the major performance factors (except the cost) of the 11 cases evaluated as well as the selected case. The recommended strategy is further described in Section F.8.7.1.

F.8.4.1 Remediation Period

The maximum remediation period is set at 30 years. While a minimum amount of remediation time is desirable (primarily from a cost point of view), even 30 years is acceptable because it is within the postclosure care period. Hypothetically, reduction in remediation time could have a small impact on reduction in risk. All things being equal, a reduction in remediation time is desirable to expedite release of the site.

The time to remediate for the revised baseline and two extraction cases varies only from 25 to 27 years. It is somewhat surprising that the sequential lower extraction rate case (4000 gpm maximum extraction rate) only needed to pump groundwater two years longer (and 17,574 million gallons less groundwater) than the variable pumping rate case. There are probably two reasons for this. First, the sequential philosophy is typically more efficient since it creates fewer stagnation zones caused by competing pumping. Secondly, the pumping rate of 6300 gpm appears overly aggressive, resulting in inefficiencies because excessive clean water is extracted.

F.8.4.2 Aquifer Hydraulic Impacts

The selected alternative with a constant 6300 gpm extraction rate is near the limit of the hydraulic capacity of the aquifer in this area. Model uncertainty, seasonal effects, long-term rainfall trends, and increases in water withdrawal by water producers could cause an exceedance of capacity at some

point during the remediation period. A lower extraction rate would create a larger safety factor. In addition, greater pumping results in greater drawdown, which may create desaturated zones with adsorbed concentrations of uranium which will be more difficult to remediate.

Hydraulic impact is roughly proportional to the total extraction rate. The maximum extraction rate for the revised baseline and the variable pumping rate case (Case V4) is 6300 gpm, while the sequential pumping case (Case S2) has a maximum total pumping rate of approximately 4000 gpm. Therefore, the sequential pumping case has approximately 37 percent less hydraulic impact. Resultant groundwater drawdown contours for these three cases are shown in Figures RB-9, V4-18, and S2-18 in Attachment F.8.II.

F.8.4.3 Impacts to the Great Miami River

It is desirable to have the least impact (lowest uranium concentrations and least mass) on the river as possible. The river, through the outfall, will receive groundwater with residual uranium concentrations directly from wells (with concentration based on the treatment criteria) and treated effluent with a residual concentration of uranium (assumed to be 5 ppb). Based on the extraction case and treatment approach, different concentrations of uranium are discharged through the outfall over time.

Table F.8-6 compares the mass discharged to the river for the 11 cases. The total mass over the remediation period, the peak loading rate, and the average annual mass (total mass divided by the remediation period) are shown. These measures reflect the overall impact to the river over time. The total mass discharged to the river varies from 1916 lbs for Case S2 with treatment to 5 ppb residual concentration of uranium, to 13,029 lbs for Case V4 with no treatment. The sequential pumping case had lower mass numbers than the variable pumping rate cases due to the fact that less mass was extracted from the aquifer with the sequential cases (see Tables F.8-3 and F.8-4). Table F.8-6 also shows the peak and average mass loading rates to the river. These numbers range from 87 to 1111 lbs/year for the peak loading and 71 to 521 lbs/year for the average loading. Again, these numbers are greatest for the no-treatment cases and least for the treat to 5 ppb of uranium cases.

Finally, the maximum blended and average concentrations of water entering the river from the outfall line are reported (see Figures V4-17 and S2-17 in Attachment F.8.II). The maximum blended concentration is 71 ppb in the Case S2 no-treatment case. For the other cases, the maximum concentration varies from 5 to 51 ppb. Time-averaged uranium concentrations to the river vary from 5 to 26 ppb.

The impact to the river of the different modeled cases varies significantly depending on the treatment strategy. Six cases fall below the maximum blended concentration standard for the outfall of 20 ppb.

Only Cases V4-I and V4-IV had peak mass loadings above the 702 lbs/year discharge to the river provision.

F.8.4.4 Regulatory Compliance

The selected case must comply with applicable laws and regulations described in Section F.8.1.3.

All 11 cases comply with applicable laws and permits. As shown in Table F.8-7 and Figures F.8-6, F.8-7, and F.8-8, except for the no-treatment cases (i.e., Cases V4-I and S2-I), the calculated maximum concentration (single-well based) is less than 77 ppb and the time-averaged uranium concentrations in the combined discharge flow with treated and untreated groundwater are less than 18 ppb. However, for the no-treatment cases the maximum uranium concentrations (single-well based) can exceed 240 ppb during the first few years of operation. With the 7-day, 10-year low flow rate (7Q10) and average flow rate of 280 and 3460 cubic feet per second (cfs), respectively, in the Great Miami River, a minimum dilution factor of 20 (using the 7Q10 flow and a discharge flow rate of 6300 gpm) can be expected when the discharge flow completely mixes with the river flow. With this dilution factor, the uranium concentrations in the river will be at least 20 times lower than concentrations measured in the discharge flow. Therefore, the impacts on water quality in the Great Miami River due to the discharge are insignificant (i.e., within the background level, which is about 3 to 4 ppb) for all the cases with groundwater treatment. The highest surface water concentration without groundwater treatment is about 12 ppb. The surface water PRL is 540 ppb (see Table 2-14).

The long-term impacts on the Great Miami River sediment can be evaluated by comparing the predicted mass loading rates and the past discharge records. The average annual uranium mass loading rate to the Great Miami River between 1952 and 1993 is about (1910 kg/yr) 4210 lbs/yr (see Table 1-5 of the Operable Unit 5 RI Report). The average rate in the last 10 years has decreased to about 1535 lbs/yr (697 kg/yr). Under these past uranium mass loadings, the measured sediment concentrations (i.e., Operable Unit 5 RI and Environmental Monitoring data) in the Great Miami River between the discharge outfall and Paddys Run are all less than 5 mg/kg. As shown in Table F.8-6, the calculated annual uranium mass loading rates range from 87 lbs/yr (Case S2-III) to 1111 lbs/yr (Case V4-I) for the evaluated extraction and treatment strategies. If it is assumed that other discharges from the site equal 150 lbs/yr, then 552 lbs/yr are available for loading to the Great Miami River. Cases V4-I, V4-IV, V4-V, and S2-I then will exceed this 552 lbs/yr. These loading rates are less than the past discharge rates. Therefore, it can be concluded that mass loading from all the evaluated extraction and treatment strategies will not cause sediment concentration in the Great Miami River to exceed 5 mg/kg. The risk-based (HQ = 0.2) sediment criteria for the expanded trespasser is 210 mg/kg as presented in Table C.2-12 in Appendix C.

F.8.4.5 Cost

Each alternative will have a total cost consisting of capital and operating costs. Obviously a preference is given to cases with lower total cost. The other criteria of treatment capacity and remediation time may be reduced to cost. Other criteria (e.g., the impact to the Great Miami River) may be incrementally traded versus costs. Overall, it is important to get the greatest reduction in risk possible for each dollar spent.

Based on the results of the sensitivity analysis of cost components presented in Section F.8.2, the cost for groundwater extraction will be very close among all the evaluated strategies. Significant differences in cost will be due to the various treatment strategies. Obviously the no-treatment strategy has the lowest overall cost while the revised baseline (i.e., treat all groundwater) has the highest overall cost. Among the strategies that can satisfy all the regulatory requirements and more importantly the outfall uranium concentration limit at 20 ppb (i.e., revised baseline, V4-II, V4-III, S2-II, S2-III, and S2-V), Case S2-V should have the lowest cost due to its less aggressive treatment strategy.

F.8.5 MODELING OF OTHER CONSTITUENTS OF CONCERN

Based on the performance evaluation described in previous section, Case S2-V is the most favorable strategy for Great Miami Aquifer remediation. However, this selection is based on simulations of uranium only. With the selected strategy, additional model simulations were conducted with initial conditions and future loadings of other groundwater COCs to determine this system's effectiveness for cleaning up these other COCs.

F.8.5.1 Initial Conditions and Loading Terms for Other COCS

The modeling input parameters for other COCs are shown on Table F.8-8. The distribution coefficient and the retardation factor are the same as the values used in Appendix F.7 (see discussion of selection of these values in Appendix F.7). As are the surface water loading terms for the first 10 years. However, after year 10, revised values from the residual modeling (see Appendix H) were used until the end of simulations. The same aquifer initial conditions that were utilized for Appendix F.7 were assigned for the modeling of the other COCs (see Appendix F.7, Figures F.7-9 through F.7-14).

F.8.5.2 Simulation Results

Table F.8-9 summarizes the results of modeling the other groundwater COCs. The detailed results are plotted in Attachment F.8.II. Five of the constituents (antimony, neptunium-237, radium-226, technetium-99 and total [VOCs] are reduced below the PRLs within the 27-year remediation period of uranium. Arsenic and manganese concentrations are effected by groundwater extraction only to a small degree due to their high distribution coefficient (which allows a continual source desorbing from solid to the liquid state) and the high retardation coefficient (which prevents solute movement to

extraction wells). However, the remaining areas that have concentrations higher than the PRLs of arsenic and manganese are small and isolated. The only on-property plumes of these two COCs are between Plant 6 and Plant 9 in the former production area and under the waste pit area. Off-property arsenic concentrations are lower than the PRL. The remaining off-property plumes of manganese are south of the Paddys Run Road Site and may not be FEMP related. Figures H.I-2 and H.I-4 show the arsenic and manganese plumes at the end of pumping.

Table F.8-9 also shows the predicted concentrations and loadings to the treatment plant and to the river. These values are plotted over time in Attachment F.8.II.

F.8.6 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted to improve the understanding of the impact of changes in K_d and of the artificial vertical dispersion in the model.

F.8.6.1 Sensitivity Analysis of Geochemical Conditions

Contaminant mass exists in both dissolved and adsorbed phases in the aquifer. Only dissolved contamination can be readily recovered by groundwater extraction. However, adsorbed contaminant mass can continuously and usually slowly desorb into dissolved phases. Therefore, the aquifer restoration system needs to recover contaminant mass in both forms until groundwater concentrations caused by prolonged desorption of contaminants from soil particles will no longer exceed the desired cleanup level. A uniform uranium K_d value of 1.78 L/kg and the assumption of fully reversible adsorption/desorption processes were used in all the previously described simulations. Due to the limited ability to predict the tendency of the soil particles composing the aquifer system to release the contaminants to groundwater for extraction, there is considerable uncertainty in the long-term efficiency of the extraction system and the amount of time required to attain remediation levels for uranium and several other contaminants.

A sensitivity analysis was conducted to evaluate the impacts of different uranium desorption characteristics (i.e., lower desorption rates than the baseline condition) during aquifer restoration (see Attachment F.8.III). The first part of this sensitivity analysis was used to evaluate the size and location of the plume that may have prolonged desorption of uranium mass, causing future groundwater concentrations to exceed the cleanup level. Using the results of recently completed laboratory desorption batch tests for uranium-contaminated aquifer soil in the South Field area (see Attachment F.8.IV), the second part of the sensitivity analysis consisted of analytical model simulations to determine the relationship between the groundwater flushing rate and the time required to reach the aquifer cleanup level in the potential problem area.

Figure F.8.III-2 summarizes these sensitivity analysis results, showing the cleanup time for different desorption K_d values and pumping rates in the South Field area (see Attachment F.8.III for details).

In general, the overall time frame and cost of extraction and treatment to restore the aquifer will not change significantly due to higher desorption K_d values because higher desorption K_d values will also result in smaller groundwater plumes during remediation. By adjusting the extraction operation, a larger portion of the available extraction and treatment capacities can be focused in this smaller area to achieve higher groundwater flushing rates and, therefore, maintain the same cleanup time.

Because of the uncertainty associated with contaminant desorption characteristics, the FEMP should continue to investigate supporting technologies, such as reinjection and pulsed pumping, to enhance contaminant recovery and hydraulic flushing efficiencies and reduce the time needed to restore the aquifer. Reinjection would potentially involve pumping of extracted groundwater with concentrations below the cleanup level back into the aquifer to increase the rate of flow and create an enhanced local flushing effect in order to speed contaminant removal.

The uncertainties associated with the desorption characteristics of contaminants and hydraulic efficiency of groundwater extraction also indicate the importance of performance evaluation during the aquifer restoration. A monitoring and evaluation program should be in place to assess progress of the remediation effort.

F.8.6.2 Artificial Vertical Dispersion in Swift

While performing solute transport modeling of groundwater extraction options (Appendix F.7), it was discovered that, according to the model, a significant mass of uranium would migrate downward to the lower model layers after a reasonably short simulation time. This was an unexpected result because initially the large majority of uranium mass occurred in the upper layers of the model and the simulated and actual flow fields are essentially horizontal.

Appendix F.7 discusses the cause of this problem (see Section F.7.7.3). It was concluded in Appendix F.7 that, for the relative comparison of alternatives in the FS, the model can be used in its present state with steady-state flow assumptions and the approximate simulation of vertical dispersion. However, for preliminary design when more refined time scales and optimized pumping schemes are developed, the phenomenon needs to be evaluated further and corrected if deemed necessary.

To assess the impact at this stage, a sensitivity simulation was conducted using a modified version of the dispersion algorithm in the SWIFT code. The modified dispersion algorithm uses a different dispersivity value in the vertical direction. The Case S2 simulated pumping was modeled with both the original code and a modified code so that results could be compared and the impact of this vertical dispersion effect on the selected extraction case could be assessed. In the corrected code, a more realistic vertical dispersivity of 10 feet was used (instead of the 0.1 feet value used in the original model). The original 0.1 foot vertical (transverse) dispersivity value was set artificially low to compensate for the model-induced vertical dispersivity.

Detailed results from the new simulation are contained in Attachment F.8.II. Table F.8-10 compares the maximum concentrations at different time periods from the two simulations. At year 10, as expected, the revised algorithm prevents some of the vertical movement of the contaminant to the lower model Layers and consequently keeps greater concentrations in Layer 1. The effects diminish after year 10, although the revised model now has a higher Layer 3 concentration than the original simulation. At year 26, the revised model has a greater concentration in Layer 3 (still greater than 20 ppb) than the original case; however, both Layer 1 and Layer 6 are lower than the original case.

With the revised model, remediation time increased from 27 to almost 30 years due to a small residual plume with concentrations slightly above 20 ppb remained at the edge of Zone II extending the remediation time. A modified pumping approach in this area over the last few years of the simulation would likely bring concentrations below the 20 ppb standard earlier.

Overall, the results from simulating Case S2 with the revised dispersivity algorithm are comparable to the original case results. Although total remediation time was three years more, the concentration causing this additional time was barely above the standard. With a slightly different pumping scheme over the last pumping period, it is believed that results could be comparable to the original simulation of this extraction case.

F.8.6.3 Resaturation of the Dewatered Zone

When groundwater extraction is carried out in the Great Miami Aquifer, partial desaturation will occur above the receding water table. Owing to the presence of capillary forces in the granular materials of the Great Miami Aquifer, a certain amount of moisture will be held against drainage by gravitational forces in the desaturated zone. In the capillary-retained moisture, there exists contaminant mass in two phases: the dissolved phase; and the sorbed phase on the surfaces of the granular materials, similar to the existence of contaminant mass in the saturated zone below the water table. The concentration of the contaminant in the desaturated zone tends to diminish over time due to radioactive decay (for radioactive contaminants), biodegradation, and volatilization (for VOCs), as well as dilution/washing by infiltration. However, the concentrations in the saturated zone will decrease at a much faster rate due to pumping-induced groundwater flushing through the contaminant plumes. At the cessation of groundwater extraction, the water table will gradually return to its original elevation. If the contaminant concentration in the rising groundwater is different from that in the desaturated zone, re-equilibration of the contaminant between the sorbed and dissolved phases will occur. In the event that the concentration of contaminant in the rising groundwater is lower than that in the desaturated zone, the groundwater will be adversely impacted by the desorption of contaminant mass in the sorbed phase to achieve a new equilibrium, thereby increasing the contaminant concentration in the groundwater. The possibility that the contaminant mass retained in the desaturated zone may adversely affect the groundwater once the groundwater pumping has ceased was analyzed.

Based on the simulation results from Case S2, it was found that the amount of uranium retained in the desaturated zone is approximately 10 percent and that the maximum concentration of uranium in the desaturated zone at the end of the groundwater remedial extraction period (i.e., 27 years) is somewhat greater than that in the groundwater immediately below (in Model Layer 1). In the analysis, it was conservatively assumed that the saturation in the desaturated zone is unity so as to provide a conservative value of uranium concentration in Model Layer 1 after resaturation. The resulting concentration in Model Layer 1 due to mixing between the uranium concentration in the groundwater in Model Layer 1 and uranium concentration in the moisture in the desaturated zone was the depth-weighted average of the two concentrations. It was found that the maximum uranium concentration in Model Layer 1 resulting from mixing between the moisture and the rising groundwater in Model Layer 1 is always smaller than 20 ppb.

F.8.7 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

F.8.7.1 Recommended Groundwater Remediation

Based on the strategies evaluation of Section F.8.4, Case S2 with treatment of groundwater containing uranium concentrations greater than 20 ppb up to a fixed rate of 1500 gpm (Case S2-V) was selected as the recommended groundwater remediation option. Table F.8-7 summarizes the performance of the 11 cases evaluated.

This case consists of four extraction systems (a total of 28 extraction wells) pumping 2000 gpm from years 1995 to 2000 and approximately 4000 gpm of Great Miami Aquifer groundwater from the year 2000 through the year 2022. This case uses an approach with sequenced pumping of different plume areas. As areas of the aquifer are cleaned to the 20 ppb cleanup level, extraction systems are turned off and pumping rates redistributed to other systems. During the later stages of remediation, the extraction rate reduces. Individual well pumping rates vary from 160 gpm to 500 gpm. Recovered groundwater with uranium concentrations exceeding 20 ppb up to a maximum of 1500 gpm will be treated for uranium removal before being discharged to the Great Miami River. All other recovered groundwater will be discharged directly to the Great Miami River. Existing excess treatment capacity will be supplemented with additional capacity in the existing AWWT structure. The blended treatment effluent and untreated groundwater discharges to the Great Miami River will contain less than 20 ppb uranium concentrations. The peak annual mass loading rate of 273 lbs/yr is well within the current negotiated limit (i.e., 702 lbs/yr) even with the estimated 150 lbs/yr from other waste water treatment flows.

Figure F.8-9 summarizes the extraction rates from the different extraction systems over the simulation. Figure F.8-10 summarizes the flow rates that are sent to treatment and the river for the recommended Case S2-V. This curve shows that extraction is 2000 gpm for the first 5 years, 4000 gpm from year 5 to year 20, and then steps down until year 27 as wells that are not effectively

extracting uranium are turned off. Modeling results predicted that treatment of extracted groundwater needs to occur for 20 years.

Figure F.8-11 summarizes the mass loading rate of uranium to the river over time produced by Case S2-V. Mass loading to treatment is initially at its greatest rate of approximately 600 lbs/yr and reduces until year 5. At year 6 when the additional wells are turned on the mass discharged increases again. From this point, the loading gradually decreases until year 20, at which point loading is less than 50 lbs/yr. Mass loading to the river is approximately 50 lbs/yr initially, spikes to it's peak of 273 lbs/yr at year 6 when the new wells are turned on, reduces gradually to year 15, increases slightly at year 20 and decreases over the remainder of the remediation period.

F.8.7.2 Summary of Major Factors Considered

Five major factors that affect the conceptual design of the Great Miami Aquifer remediation strategy considered in this optimization study are discussed below in an estimated relative order of importance. Rationale of the recommended aquifer remediation strategy presented in the previous section as well as potential improvements related to each factor, which can be incorporated during the engineering design, are also described.

F.8.7.2.1 Regulatory Requirements

COC-specific groundwater cleanup goals, which are to be approved by the regulatory agencies (i.e., final remedial levels) and will directly impact required groundwater extraction time frame and cost, are the most important factors in the selection of suitable aquifer remediation approaches. Currently the proposed groundwater cleanup levels are the MCLs or 10^{-5} incremental risk-based criteria for site-related contamination. Based on simulations, the uranium cleanup goal (i.e., a MCL of 20 ppb) can be achieved by groundwater extraction. For two immobile contaminants (arsenic and manganese), the current groundwater extraction system may not be totally effective and residual concentrations in small portions of the aquifer may reach asymptotic conditions. A small number of additional extraction wells in these isolated areas (e.g., between Plant 6 and Plant 9 in the former production area) where these contaminants still have concentrations higher than the final remediation levels may need to be installed and operated during the remediation.

A minimum remediation time is desirable from both cost and risk reduction perspectives. An upper limit of remediation time has been set at 30 years. Most of the simulated extraction strategies can achieve aquifer cleanup within this time frame. With this time frame, a simple hydraulic containment approach which will need to be maintained for more than 100 years is not acceptable.

Discharge limits developed based on the promulgated surface water and sediment quality criteria for the Great Miami River will determine what are the acceptable treatment strategies for extracted groundwater. Currently the recreational user or meat/milk consumer are proposed as the exposure

scenario for developing the surface water and sediment quality criteria in the Great Miami River. The existing negotiated discharge limit of uranium mass (i.e., 702 lbs/yr) should also apply. The recommended treatment strategy from this optimization study complies with these discharge limits at the outfall without dilution in the river.

Reinjecting a portion of the extracted groundwater as one of the suitable groundwater disposal alternatives and a way of improving hydraulic efficiency of the extraction system will need to be evaluated further the acceptable quality of groundwater to be reinjected and the optimal locations and rates of reinjection need to be determined. However, the need and effectiveness of a large-scale groundwater reinjection system as a part of the aquifer remediation strategy has not been determined at this time, due to lack of regulatory guidelines and uncertainty about the aquifer geochemical conditions. It is also important to point out that dilution or further spreading of groundwater plumes caused by reinjection are undesirable and should be avoided by proper design of the extraction/injection well arrangement.

F.8.7.2.2 Schedule of Soil Remediation

Continuous loading of contaminant mass into the Great Miami Aquifer through overburden under the Operable Units 1, 2, and 4, and streambeds of the SSOD and Paddys Run will significantly lengthen the required aquifer remediation time. The revised assumptions used in the optimization study propose a more aggressive schedule for soil remediation of these contaminant sources outside the former production area in order to reduce the amount of mass that eventually needs to be recovered by aquifer remediation. Instead of 20 years as assumed in Appendix F.7, a 10-year remediation time was assumed for these contaminant sources. This shorter soil remediation schedule will also make less aggressive pumping and treatment strategies practical for achieving aquifer restoration in a reasonable time frame.

F.8.7.2.3 Aquifer Geochemical Conditions

The actual contaminant desorption characteristics will affect the optimal aquifer remediation approach. The baseline geochemical conditions in the optimization study assumed an uniform uranium K_d value of 1.78 L/kg and fully reversible adsorption/desorption processes. These assumptions allow the maximum extent of the aquifer that may require continuous pumping, the maximum amount of uranium mass that needs to be recovered, and the potentially longest aquifer restoration time (due to the larger extent and mass need to be remediated with a limited extraction capacity) to be determined. Therefore, a conservative overall cost of aquifer restoration can be estimated for planning purposes.

However, the adsorption process is partially irreversible and the desorption process is usually slower as shown by the desorption batch tests for the South Field area aquifer soil samples. Based on results of the geochemical sensitivity analysis, higher desorption K_d values (i.e., slower desorption) will require higher groundwater flushing rates in some localized areas which have significant solid-phase

contaminant concentrations, in order to achieve cleanup in a reasonable time frame. When a K_d significantly higher than 1.78 L/kg is encountered, the extraction strategy will need to be adjusted during aquifer remediation. Because of the smaller residual plumes that will remain after extraction of the initial pore volume of the contaminated aquifer due to higher K_d values, available extraction capacity can then be concentrated in smaller areas to achieve higher groundwater flushing rates and achieve the same cleanup time frame (as demonstrated in the sensitivity analysis). Reinjection and pulsed pumping will also be considered to improve the mass removal efficiency. Therefore, the overall cost and remediation time frame for aquifer restoration will not be significantly affected when properly managed.

F.8.7.2.4 Hydraulic Impacts and Efficiency

The FS baseline extraction approach with a 6300 gpm extraction rate is near the limit of the hydraulic capacity of the aquifer in this area. Model uncertainty, seasonal effects, long-term rainfall trends, and increases in water withdrawal by area water producers could cause an exceedance of capacity at some point during the remediation period. A lower extraction rate would create a larger safety factor in the operation of the system.

Groundwater stagnation zones (created by adjacent extraction wells), desaturated zones above the drawn-down groundwater table, and natural preferential flow paths existing in the aquifer will reduce the overall long-term mass removal efficiency of the groundwater extraction system. The recommended sequential pumping strategy with lower maximum pumping rate (i.e., 4000 gpm) will reduce hydraulic impacts and greatly improve the hydraulic and mass removal efficiencies of the extraction system. Reinjection and pulsed pumping will also be considered to further improve the efficiency of the groundwater extraction system. Model simulations and field demonstrations of reinjection will be conducted to support the system design.

F.8.7.2.5 Limitations of the Predicting Tools

A groundwater model can only simulate homogenous or simple zoning of aquifer hydraulic characteristics and a reversible adsorption/desorption K_d value. The natural hydraulic and geochemical processes in the aquifer are obviously much more complex. Nevertheless, groundwater models remain the most effective tool when designing or planning aquifer remediation strategies. Any use of long-term predictions obtained by modeling needs to consider the limitations and uncertainties of the model. Continuous improvements, recalibrations, and applications of the groundwater model are integrated parts of the operation and management of the aquifer remediation system.

F.8.7.3 RECOMMENDATIONS

The groundwater remediation system at the FEMP needs to achieve regulatory compliance in the Great Miami Aquifer cost-effective. Based on the current conceptual model of the Great Miami

Aquifer and the groundwater flow and contaminant fate and transport model simulations, effectiveness of various pump-and-treat systems was evaluated in this FS. The recommended groundwater extraction and treatment strategies from this optimization study will be the basis of cost estimation and engineering design for the remediation system. The design, operation, and monitoring programs that will be conducted to support the aquifer remediation are described in Section F.7.8. Results of negotiations with the regulatory agencies regarding cleanup goals and discharge limits as parts of the FS/ROD process will also be reflected in the final design of the system. As described previously, these regulatory requirements are the most important factors to be considered in the remediation approach.

Industrial experiences have shown low efficiency and limitations of the traditional pump-and-treat approach. However, pump and treat remains the most viable option for aquifer remediation of uranium. It is also indicated by the literature that efficiency can be improved by incorporating reinjection, pulsed pumping, and continuous monitoring and system adjustments. These supporting methods will be considered during design and operation of the system as described in Section F.7.8.

Aquifer geochemical and pumping test data will be collected before operation of each of the four proposed recovery well systems. Performance of the system will also be continuously monitored during operation. System adjustments to improve hydraulic and mass removal efficiencies can then be made based on this collected data. A two-step extraction operation for high desorption K_d conditions would be implemented when deemed necessary. The first step will quickly extract the larger extent of dissolved contamination, while the second step will then focus higher flushing rates on the smaller residual plumes that have significant solid-phase concentrations. The monitoring information, continuous improvements, and recalibrations and applications of the groundwater model will be integrated parts of the operation and management of the aquifer remediation system.

TABLE F.8-1

SUMMARY OF ESTIMATED GROUNDWATER REMEDIATION COSTS OF HYPOTHETICAL CASES

Case	Extraction Rate[a] (gpm)	Maximum Treatment Rate[b] (gpm)	Remediation Period (years)	Extraction Capital (million $)	Extraction O&M (million $)	Extraction Total (million $)	Treatment Capital (million $)	Treatment O&M (million $)	Treatment Total (million $)	Total Costs[c] (million $)
H1	6300	4500	26	12.06	23.56	35.62	47.48	60.09	107.57	$143.19
H2	5500	4500	28	12.05	23.79	35.84	47.40	67.06	114.46	$150.30
H3	5000	4500	29	12.06	23.44	35.50	47.38	68.78	116.16	$151.66
H4	4500	4500	30	12.06	22.93	34.99	47.37	69.58	116.95	$151.94
H5	4000	4000	32	12.06	23.07	35.13	44.07	71.80	115.87	$151.01
H6	3000	3000	44	12.04	27.99	40.02	36.93	82.08	119.00	$159.02
H7	2000	2000	65	12.01	33.69	45.71	28.82	96.21	125.02	$170.73
H8	4500	1500	30	12.06	22.93	34.99	5.00	56.22	61.22	$96.21
H9	4500	800	30	12.06	22.93	34.99	0	40.00	40.00	$74.99

[a] Constant extraction rate.

[b] Treat groundwater > 20 ppb uranium concentration at well head.

[c] Not a formal cost estimate and for comparison purposes only.

TABLE F.8-2

SOURCES AND RATES OF URANIUM MASS LOADING TO SURFACE WATER

Source[a]	Mass Loading 0-10 yrs lb/day	Mass Loading 11-20 yrs lb/day	Mass Loading after 20 yrs lb/day
Operable Unit 1	4.900×10^{-02}	----	----
Operable Unit 2	1.388×10^{-01}	----	----
Process Area	6.000×10^{-03}	6.000×10^{-03}	----
Paddys Run C-D	1.335×10^{-02}	1.921×10^{-03}	2.006×10^{-03}
Paddys Run D-E	5.975×10^{-03}	1.486×10^{-03}	1.534×10^{-03}
Paddys Run E-F	1.655×10^{-03}	2.199×10^{-04}	2.356×10^{-04}
Storm sewer outfall ditch	3.643×10^{-02}	2.628×10^{-03}	4.362×10^{-03}

[a] See map in Attachment F.8.I.

TABLE F.8-3

SUMMARY OF VARIABLE PUMPING RATE SIMULATIONS

Case	Description	Cleanup Time (yrs)	Last Zone to Clean Up	Uranium Mass Extracted (lbs)	Total Water Pumped (Mgal)	Removal Efficiency (lb/Mgal)
Revised baseline		26	4	10078	73283	0.14
V1	System based, variable	26	4	9806	64728	0.15
V2	System based, constant	24	4	9783	66678	0.15
V3	Well based, variable	30	2	9482	51392	0.18
V4	Well based, constant	25	4	13029	61869	0.21

TABLE F.8-4

SUMMARY OF SEQUENTIAL PUMPING SIMULATIONS

Case	Cleanup Time (yrs)	Last Zone to Clean Up	Uranium Mass Extracted (lbs)	Total Water Pumped (Mgal)	Removal Efficiency (lb/Mgal)
Revised baseline	26	4	10078	73283	0.14
S1	34	4	9479	60551	0.16
S2	27	4	9426	44295	0.21

TABLE F.8-5

SUMMARY OF URANIUM TREATMENT RESULTS

Extraction Strategy	Treatment Strategy	Case Designation	Cleanup Time (yrs)	Mass To Treatment (lbs)	Water To Treatment (Mgal)	Max Conc. To Treatment (ppb)	Avg. Conc. Treatment (ppb)	Peak Loading Treatment (lbs/yr)	Avg. Loading Treatment (lbs/yr)
Revised baseline	Treat all	RB	26	10078	73283	242	16	1047	388
Variable pumping	No treatment	V4(I)	25	0	0	NA	NA	NA	NA
	Treat > 20 ppb	V4(II)	25	9901	26941	242	44	1056	396
	Treat > 5 ppb	V4(III)	25	12947	59192	242	26	1111	518
	800 gpm fixed treatment > 20 ppb	V4(IV)	25	4139	7569	242	66	363	166
	1500 gpm fixed treatment > 20 ppb	V4(V)	25	6024	12082	242	60	560	241
Sequential pumping	No treatment	S2(I)	27	0	0	NA	NA	NA	NA
	Treat > 20 ppb	S2(II)	27	6785	16067	242	51	616	251
	Treat > 5 ppb	S2(III)	27	9378	42984	242	26	656	347
	800 gpm fixed treatment > 20 ppb	S2(IV)	27	3971	7225	242	66	483	147
	1500 gpm fixed treatment > 20 ppb	S2(V)	27	5768	11685	242	59	595	214

6271
000888

TABLE F.8-6

SUMMARY OF URANIUM DISPOSAL TO THE GREAT MIAMI RIVER RESULTS

Extraction Strategy	Treatment Strategy	Case Designation	Cleanup Time (yrs)	Mass To River (lbs)	Water To River (Mgal)	Max Blended Conc To River (ppb)	Avg Conc River (ppb)	Peak Loading River (lbs/yr)	Avg Loading River (lbs/yr)
Revised baseline	Treat all	RB	26	3000	73283	5	5	138	115
Variable pumping	No treatment	V4(I)	25	13029	61869	51	25	1111	521
	Treat > 20 ppb	V4(II)	25	4310	61869	10	8	288	172
	Treat > 5 ppb	V4(III)	25	2570	61869	5	5	138	103
	800 gpm fixed treatment > 20 ppb	V4(IV)	25	9244	61869	31	18	845	370
	1500 gpm fixed treatment > 20 ppb	V4(V)	25	7555	61869	24	15	647	302
Sequential pumping	No treatment	S2(I)	27	9426	44295	71	26	656	349
	Treat > 20 ppb	S2(II)	27	3414	44295	12	9	211	126
	Treat > 5 ppb	S2(III)	27	1916	44295	5	5	87	71
	800 gpm fixed treatment > 20 ppb	S2(IV)	27	5808	44295	23	16	405	215
	1500 gpm fixed treatment > 20 ppb	S2(V)	27	4248	44295	16	11	273	157

TABLE F.8-7

SUMMARY OF PERFORMANCE OF EVALUATED STRATEGIES

Option	Cleanup Time (years)	Max. Pumping Rate (gpm)	Removal Efficiency Aquifer (lbs/Mgal)	Max. Req. Treatment Capacity (gpm)	Time Treat. Required (yrs)	Peak Loading Treatment (lbs/yr)	Peak Loading River[a] (lbs/yr)	Max. Blended Conc. to River[b] (ppb)
Appendix F.7 Selected alternative	30	6300	0.19[c]	6300	30	1047	138	5
Revised baseline	26	6300	0.14	6300	26	1047	138	5
V4 (I)	25	6300	0.21	0	0	0	1111	51
V4 (II)	25	6300	0.21	5300	18	1056	288	10
V4 (III)	25	6300	0.21	6300	25	1111	138	5
V4 (IV)	25	6300	0.21	800	18	363	845	31
V4(V)	25	6300	0.21	1500	18	560	647	24
S2 (I)	27	4000	0.21	0	0	0	656	71
S2 (II)	27	4000	0.21	3000	20	616	211	12
S2 (III)	27	4000	0.21	4000	27	656	87	5
S2 (IV)	27	4000	0.21	800	20	483	405	23
S2(V)	27	4000	0.21	1500	20	595	273	16

[a] Values do not include potential discharge to the Great Miami River of about 150 lbs/yr of uranium resulting from the collection, treatment, and discharge of surface water and process wastewater.

[b] Reflects highest blended treatment plant effluent and direct discharged groundwater concentration.

[c] Appendix F.7 selected alternative includes additional surface water and operable unit loading.

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TABLE F.8-8

PARAMETERS FOR OTHER CONSTITUENTS IN THE GREAT MIAMI AQUIFER

Constituent	Distribution Coefficient K_d (mL/g)	Retardation Factor R	Loading from Paddys Run Section C-D[a] 0-10 Years (kg/yr)	Loading from Paddys Run Section C-D 10 Years-EOS[b] (kg/yr)	Loading from Paddys Run Section D-E[a] 0-10 Years (kg/yr)	Loading from Paddys Run Section D-E 10 Years-EOS[b] (kg/yr)	Loading from Paddys Run Section E-F[a] 0-10 Years (kg/yr)	Loading from Paddys Run Section E-F[a] 10 Years-EOS[b] (kg/yr)	Loading from Storm Sewer Outfall Ditch 0-10 Years (kg/yr)	Loading from Storm Sewer Outfall Ditch 10 Years-EOS[b] (kg/yr)
Neptunium-237	15	93.5	9.96×10^{-5}	6.21×10^{-7}	3.75×10^{-5}	2.58×10^{-7}	4.00×10^{-6}	4.17×10^{-8}	0	7.43×10^{-7}
Radium-226	470	2899	2.91×10^{-7}	0.00×10^{0}	1.09×10^{-7}	0	1.15×10^{-8}	2.50×10^{-11}	4.20×10^{-8}	1.12×10^{-9}
Technetium-99	0.2	2.23	5.42×10^{-3}	1.14×10^{-3}	1.1×10^{-2}	4.16×10^{-4}	1.26×10^{-3}	3.33×10^{-5}	9.10×10^{-3}	0
Antimony	1.4	9.63	2.21×10^{-1}	6.31×10^{-2}	9.2×10^{-2}	2.92×10^{-2}	1.76×10^{-2}	3.95×10^{-3}	2.56×10^{-1}	6.91×10^{-2}
Arsenic	16	99.7	5.23×10^{-1}	3.50×10^{-1}	2.67×10^{-1}	1.95×10^{-1}	5.12×10^{-2}	3.35×10^{-2}	7.45×10^{-1}	7.27×10^{-1}
Manganese	30	186	3.16×10^{1}	3.55×10^{1}	2.41×10^{1}	2.64×10^{1}	6.33×10^{0}	4.27×10^{0}	1.51×10^{2}	8.73×10^{1}
Total volatile organic compounds	1	7.16	0	0	0	0	0	0	0	0

[a] See Operable Unit 5 RI Report for definition of Paddys Run reaches
[b] EOS - End of simulation

TABLE F.8-9

SUMMARY OF OTHER COCS: TREATMENT AND DISPOSAL RESULTS

	MCL[a] Screening Level (ppb)	Cleanup Time (yrs)	Mass to Treat (lbs)	Water to Treat (Mgal)	Max. Conc. to Treat (ppb)	Avg. Conc. to Treat (ppb)	Peak Load to Treat (lb/yr)	Avg. Load to Treat (lb/yr)
Antimony	6.0×10^{0}	5	2.76×10^{0}	7225	1.28×10^{-1}	4.58×10^{-2}	2.20×10^{-1}	1.02×10^{-1}
Arsenic	5.0×10^{1}	>27	3.83×10^{1}	7225	8.48×10^{0}	6.35×10^{-1}	1.11×10^{1}	1.42×10^{0}
Manganese	9.04×10^{2}	>27	1.36×10^{4}	7225	2.52×10^{3}	2.26×10^{2}	3.30×10^{3}	5.04×10^{2}
Neptunium-237	1.42×10^{-3}	5	5.56×10^{-4}	7225	3.27×10^{-5}	9.23×10^{-6}	5.74×10^{-5}	2.06×10^{-5}
Radium-226	2.02×10^{-5}	0	5.33×10^{-5}	7225	1.58×10^{-6}	8.84×10^{-7}	4.14×10^{-6}	1.97×10^{-6}
Technetium-99	5.53×10^{-2}	10	3.02×10^{-1}	7225	1.75×10^{-2}	5.02×10^{-3}	3.01×10^{-2}	1.12×10^{-2}
Total volatile organic compounds	5.0×10^{0}	15	1.89×10^{0}	7225	1.74×10^{-1}	3.13×10^{-2}	2.64×10^{-1}	6.98×10^{-2}

	MCL[a] Screening Level (ppb)	Cleanup Time (yrs)	Mass to River (lbs)	Water to River (Mgal)	Max Conc to River (ppb)	Avg Conc to River (ppb)	Peak Load to River (lb/yr)	Avg Load to River (lb/yr)
Antimony	6.0×10^{0}	5	1.15×10^{1}	44,295	1.28×10^{-1}	3.11×10^{-2}	7.92×10^{-1}	4.26×10^{-1}
Arsenic	5.0×10^{1}	>27	1.45×10^{2}	44,295	8.48×10^{0}	3.93×10^{-1}	1.11×10^{1}	5.38×10^{0}
Manganese	9.04×10^{2}	>27	6.98×10^{4}	44,295	2.52×10^{3}	1.89×10^{2}	3.93×10^{3}	2.58×10^{3}
Neptunium-237	1.42×10^{-3}	5	1.00×10^{-3}	44,295	3.27×10^{-5}	2.71×10^{-6}	6.78×10^{-5}	3.71×10^{-5}
Radium-226	2.02×10^{-5}	0	3.29×10^{-4}	44,295	1.60×10^{-6}	8.89×10^{-7}	1.74×10^{-5}	1.22×10^{-5}
Technetium-99	5.53×10^{-2}	10	6.06×10^{-1}	44,295	1.75×10^{-2}	1.64×10^{-3}	6.11×10^{-2}	2.24×10^{-2}
Total volatile	5.0×10^{0}	15	9.53×10^{0}	44,295	1.74×10^{-1}	2.58×10^{-2}	5.79×10^{-1}	3.53×10^{-1}

[a] Where maximum contaminant level was not available, an incremental lifetime cancer risk of 10^{-5} or a hazard quotient of 0.2 was used (see Table 2-16).

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TABLE F.8-10

COMPARISON OF RESULTS FROM ORIGINAL MODEL AND DISPERSION CORRECTED MODEL

	Maximum Groundwater Concentration (ppb)					
	Year 10		Year 20		Year 26	
Layer	Original Model	Dispersion Corrected Model	Original Model	Dispersion Corrected Model	Original Model	Dispersion Corrected Model
1	406	425	50.1	51.6	19.5	17.0
3	55.1	49.9	26.3	28.3	20.0	22.1
6	37.1	20.0	21.3	14.3	18.9	12.3

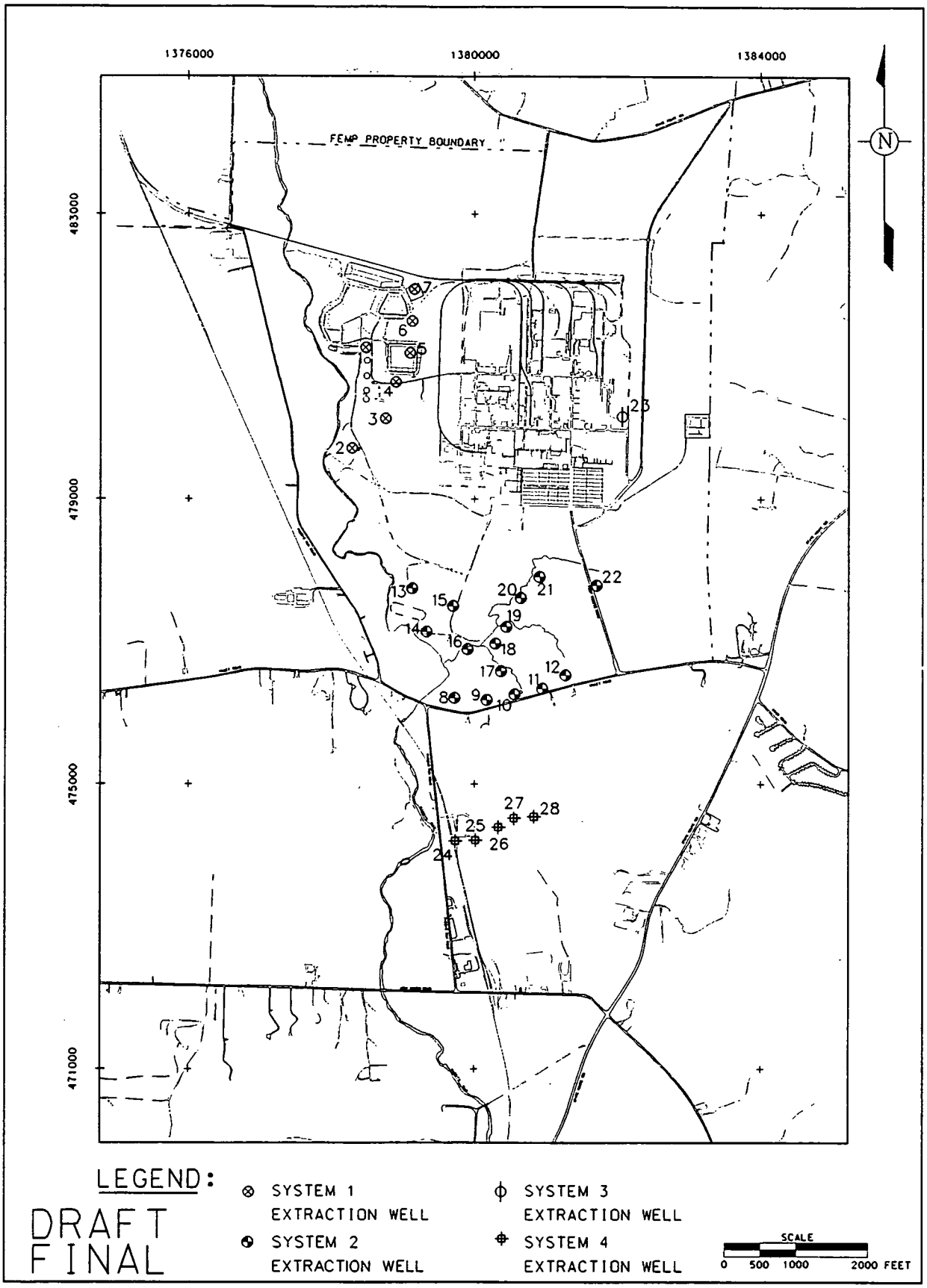


FIGURE F.8-1 - WELL CONFIGURATION FOR GROUNDWATER REMEDIATION OPTIMIZATION

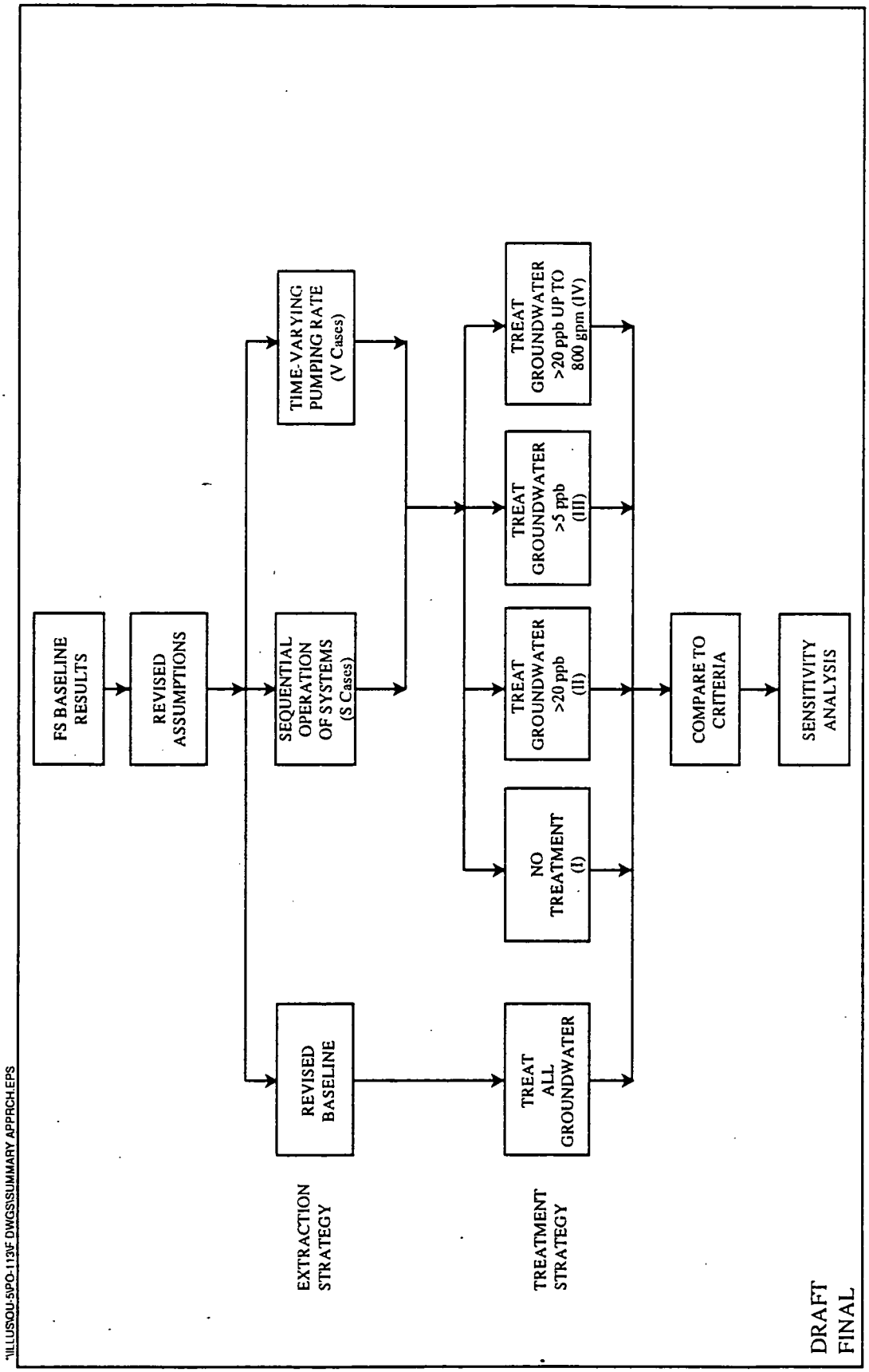


FIGURE F.8-2 - SUMMARY OF APPROACH TO PERFORM PRELIMINARY OPTIMIZATION

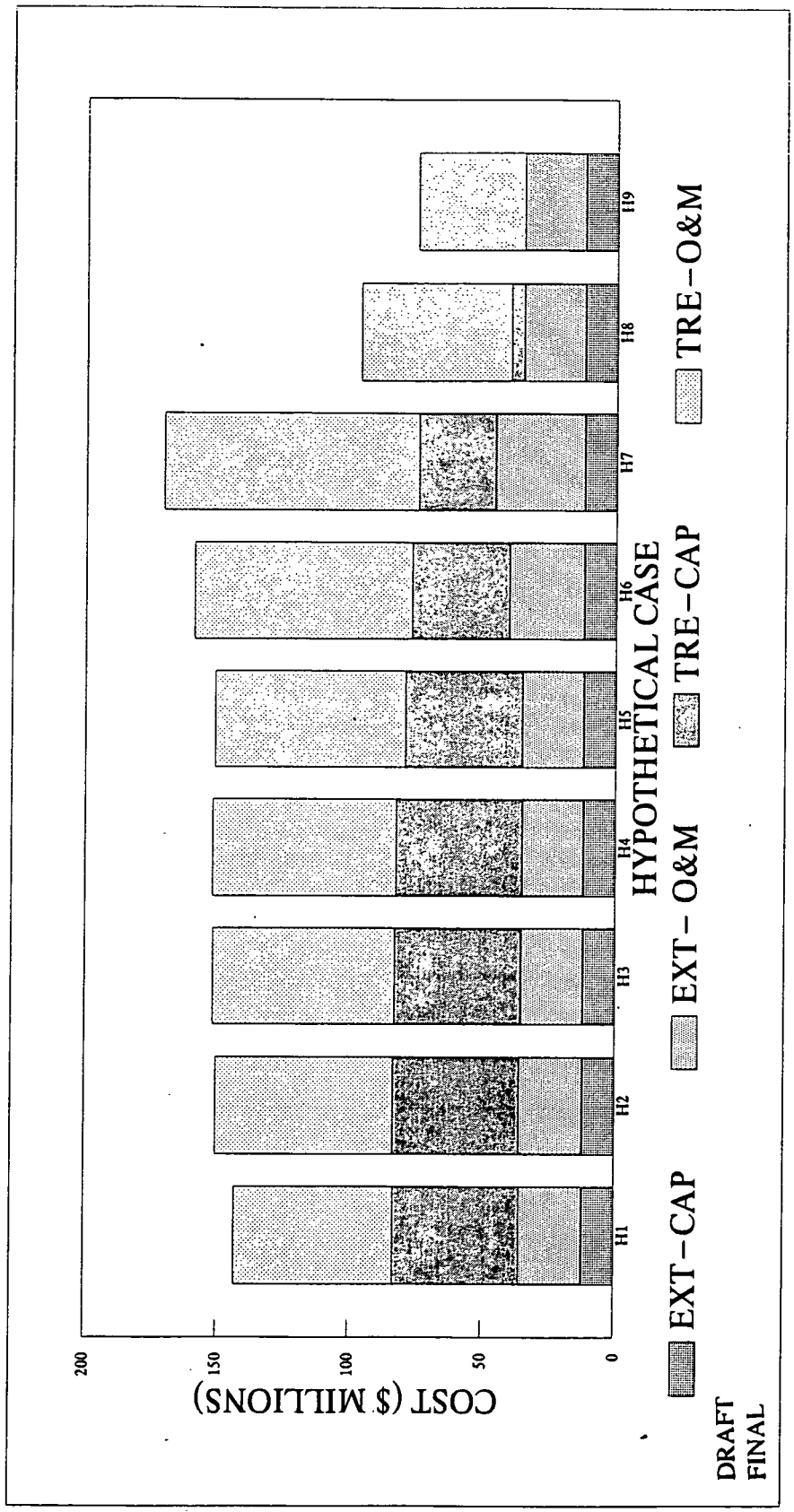


FIGURE F.8-3 - COST COMPARISON OF HYPOTHETICAL CASES

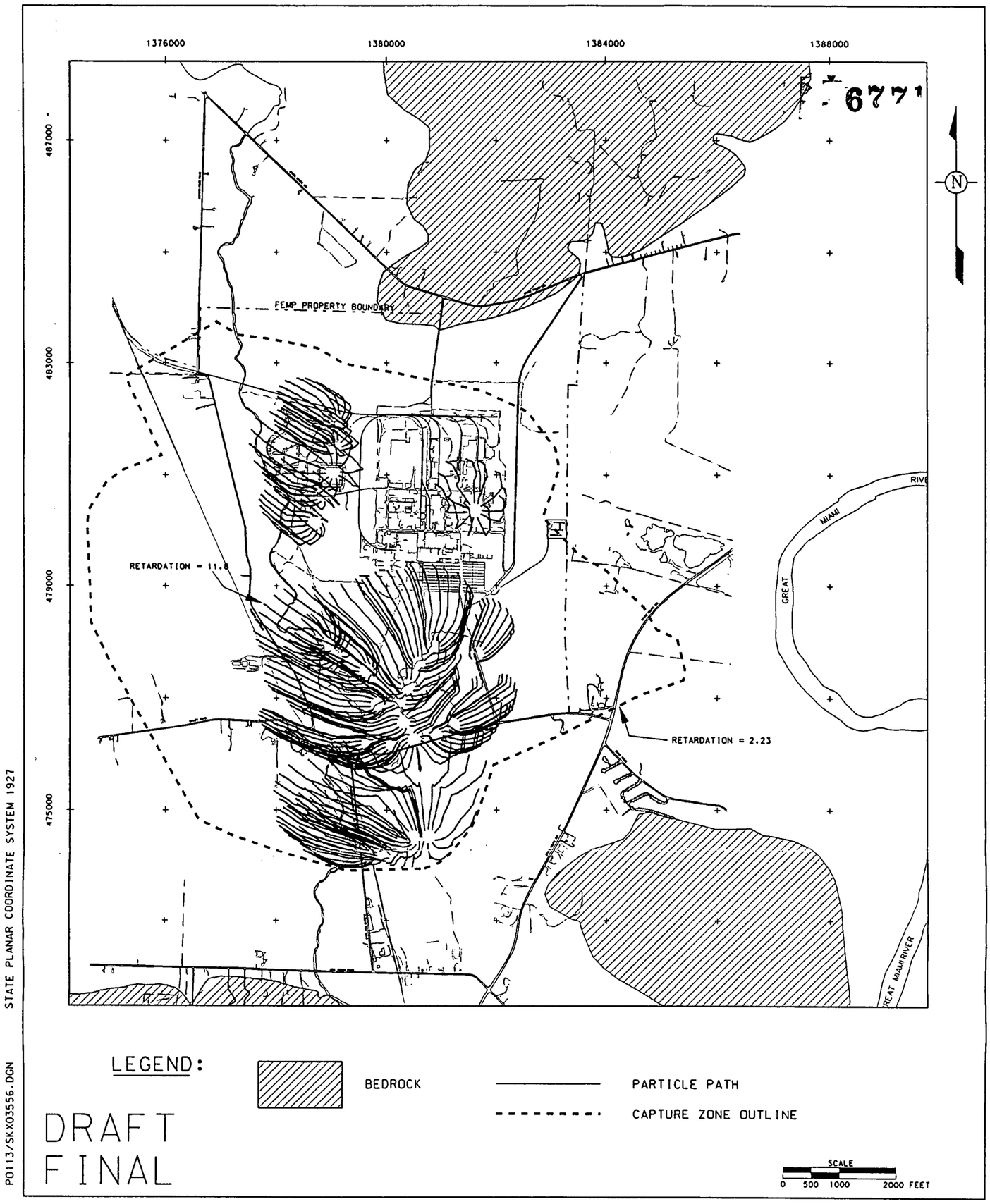
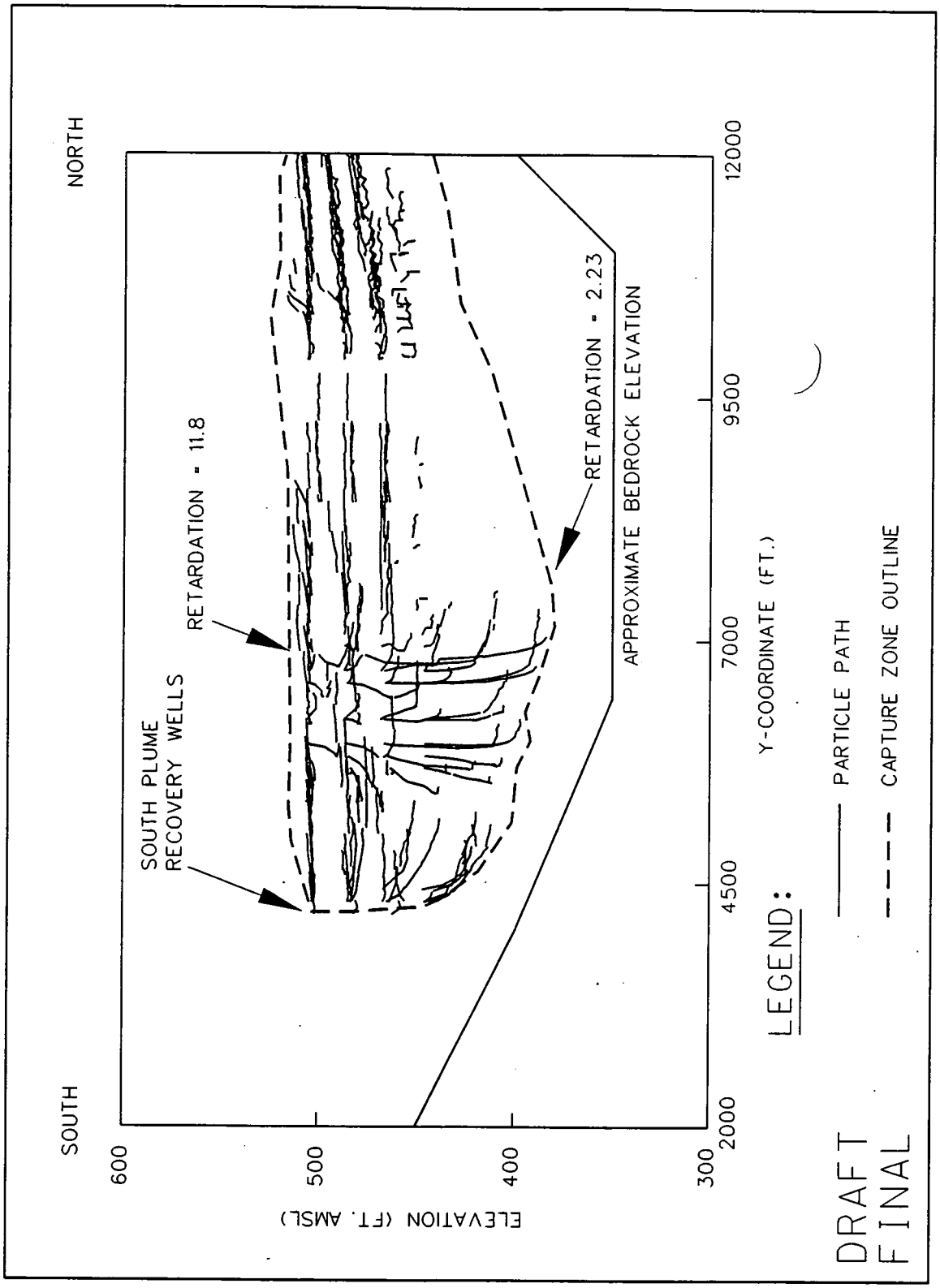


FIGURE F.8-4. CAPTURE ZONE PLOT FOR CASE S2, YEARS 0 THROUGH 27 (PLANAR VIEW)



P0113/SKX03560.DGN

FIGURE F.8-5 - CAPTURE ZONE PLOT FOR CASE S2, YEARS 0 THROUGH 27 (N-S CROSS SECTION)

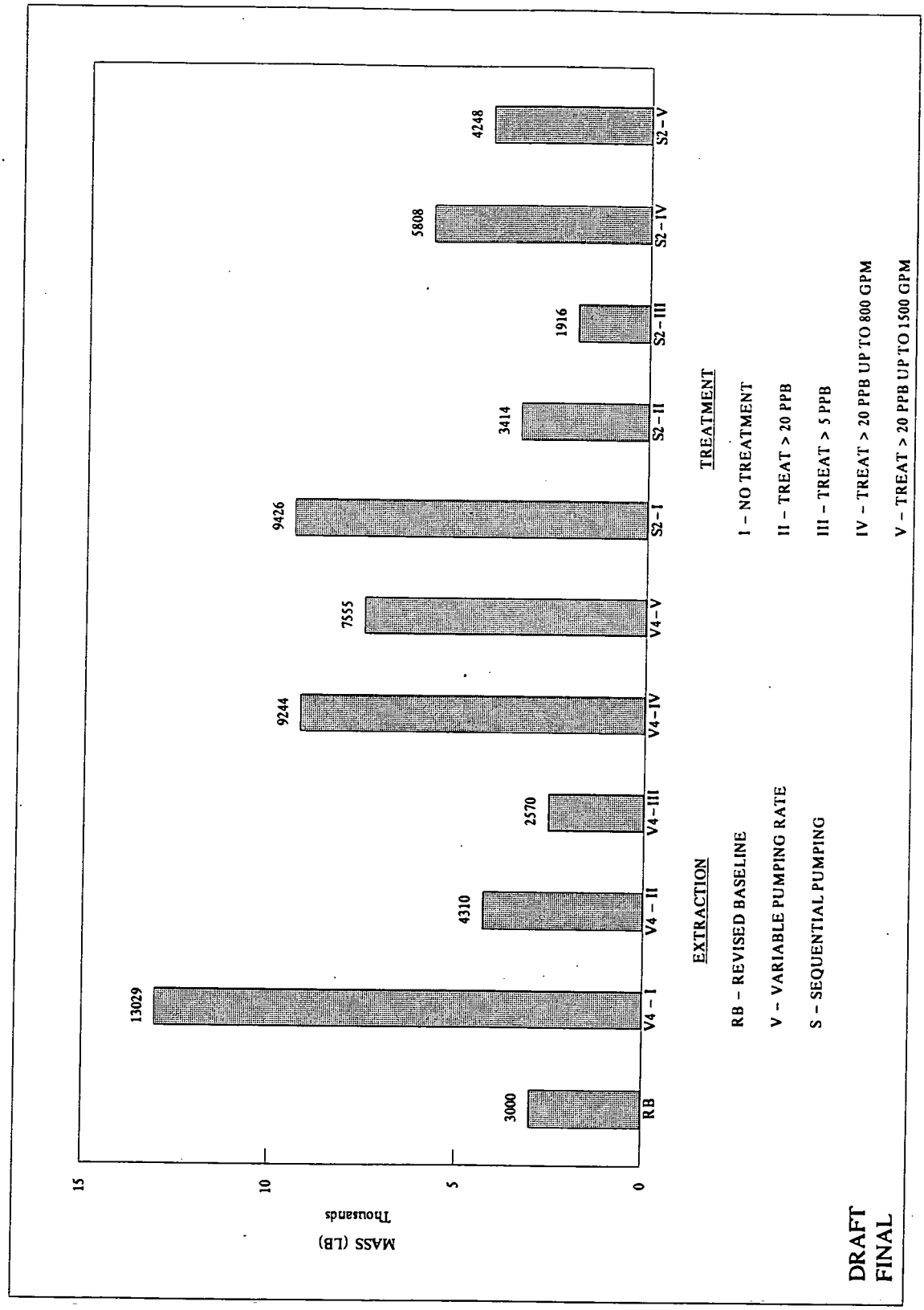
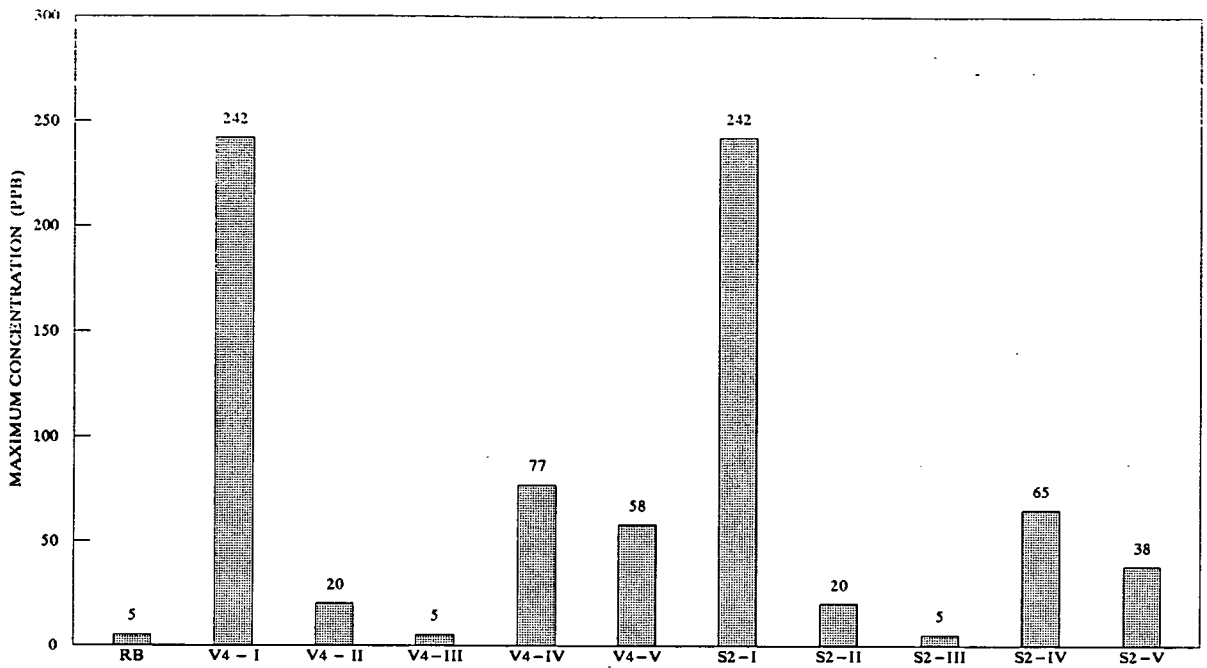
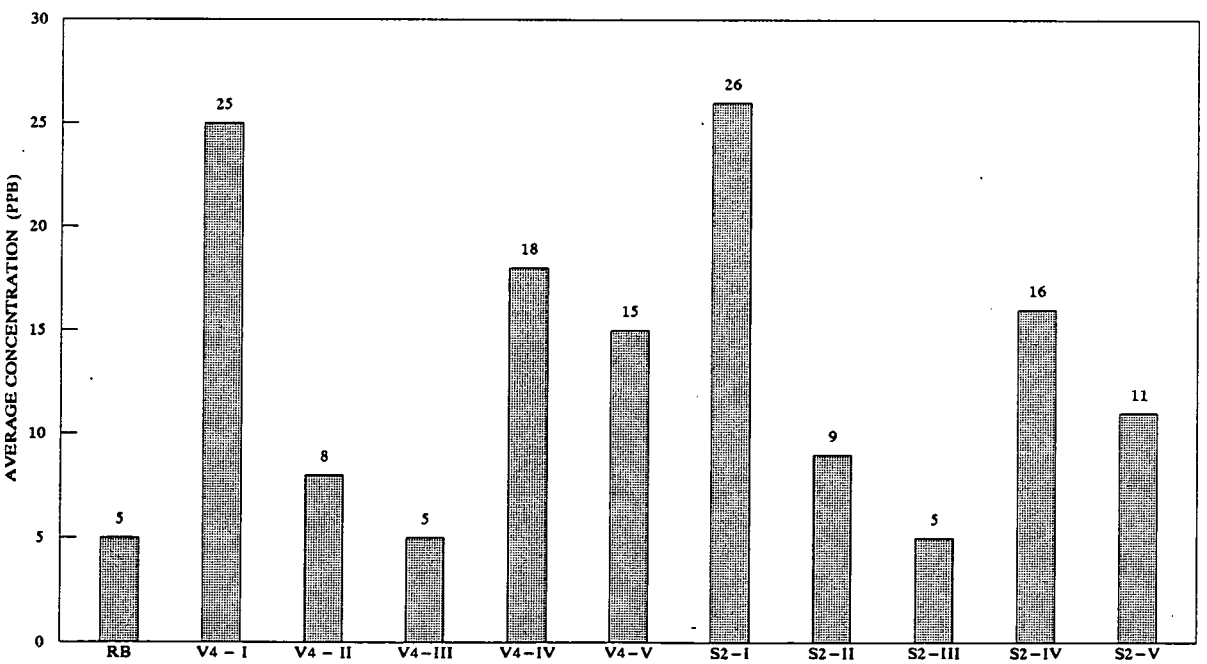


FIGURE F.8-6 - TOTAL MASS TO THE RIVER, BY CASE





EXTRACTION

RB – REVISED BASELINE

V – VARIABLE PUMPING RATE

S – SEQUENTIAL PUMPING

TREATMENT

I – NO TREATMENT

II – TREAT > 20 PPB

III – TREAT > 5 PPB

IV – TREAT > 20 PPB UP TO 800 GPM

V – TREAT > 20 PPB UP TO 1500 GPM

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FINAL

FIGURE F.8-7 - MAXIMUM AND AVERAGE CONCENTRATIONS TO THE RIVER, BY CASE

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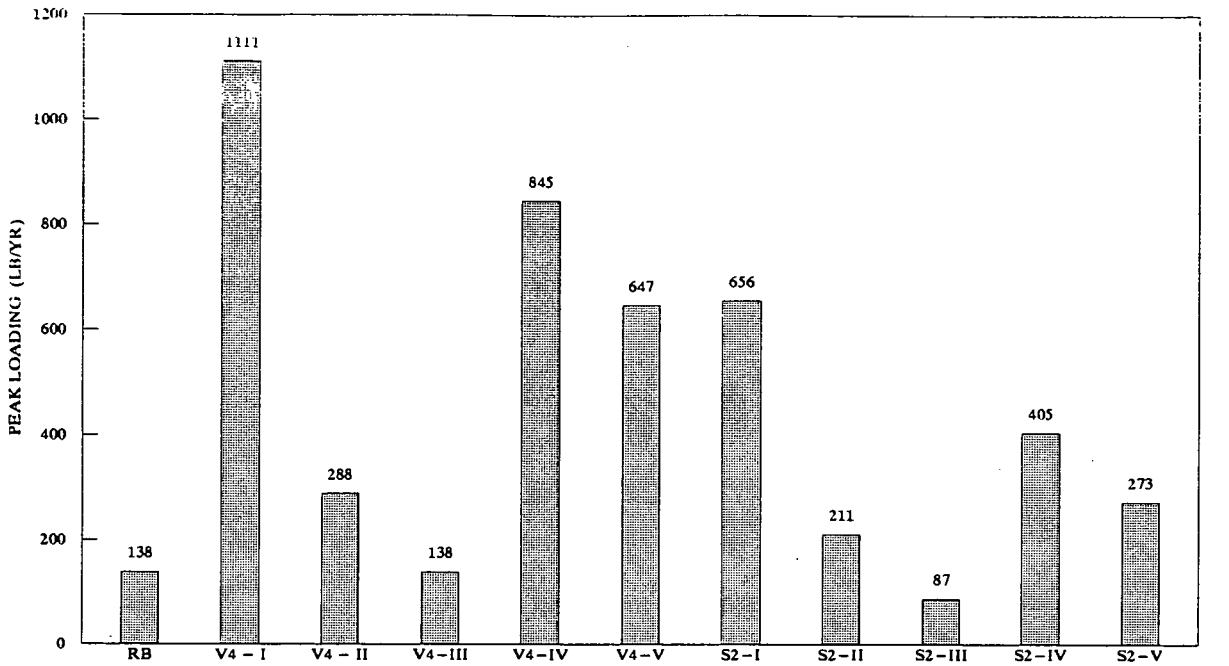

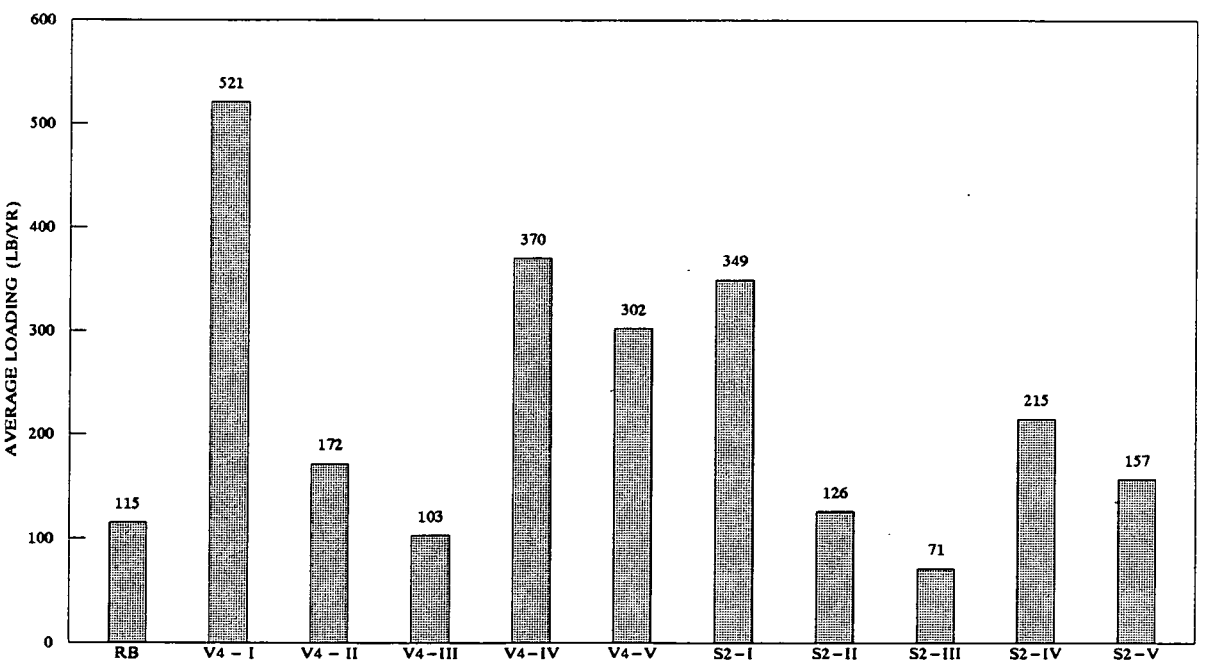

EXTRACTION

RB – REVISED BASELINE

V – VARIABLE PUMPING RATE

S – SEQUENTIAL PUMPING

TREATMENT

I – NO TREATMENT

II – TREAT > 20 PPB

III – TREAT > 5 PPB

IV – TREAT > 20 PPB UP TO 800 GPM

V – TREAT > 20 PPB UP TO 1500 GPM

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FINAL

FIGURE F.8-8 - PEAK AND AVERAGE LOADING TO THE RIVER, BY CASE

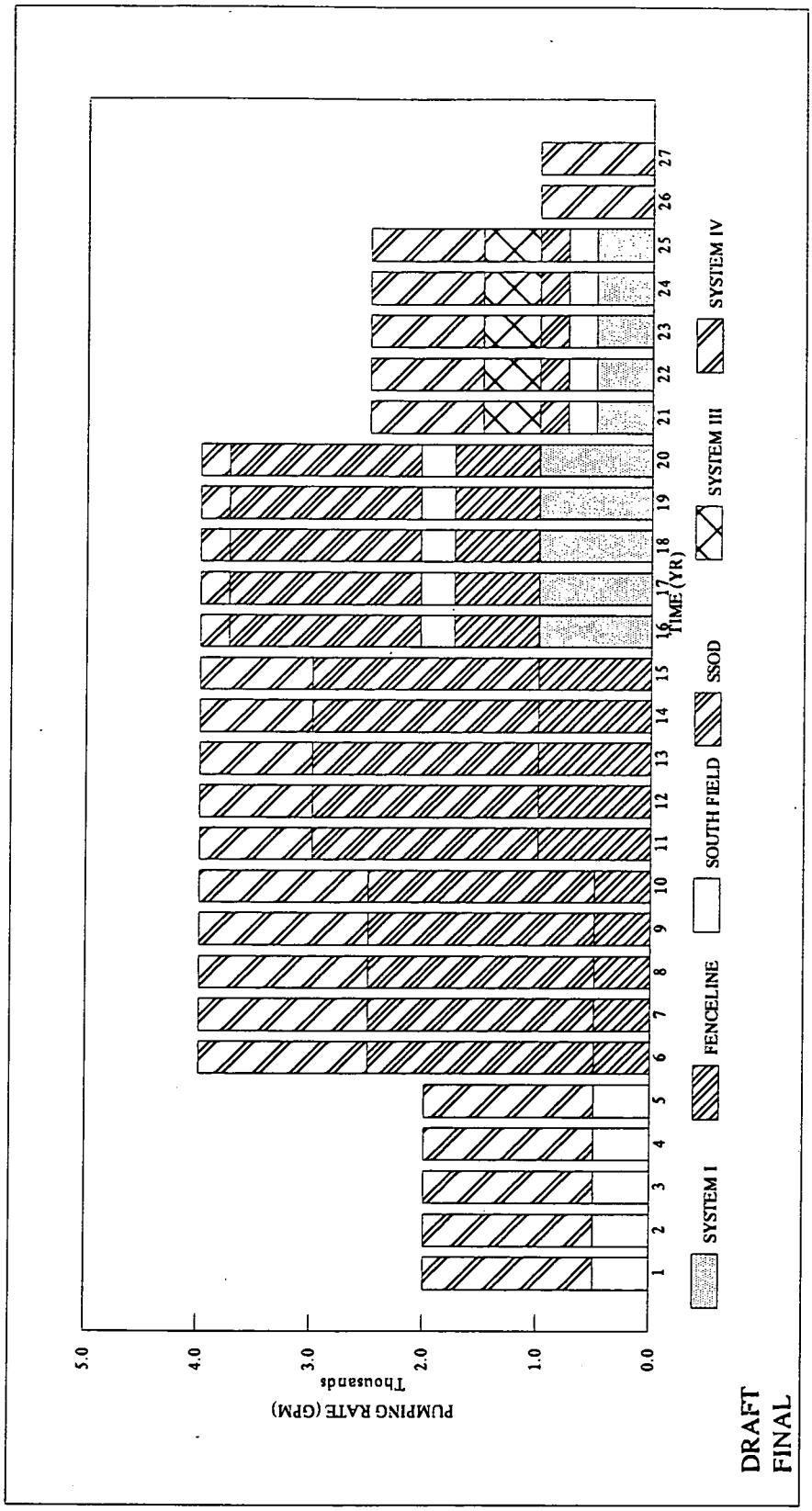

FIGURE F.8-9 - SEQUENTIAL PUMPING CASE S2-V, EXTRACTION RATE VERSUS TIME

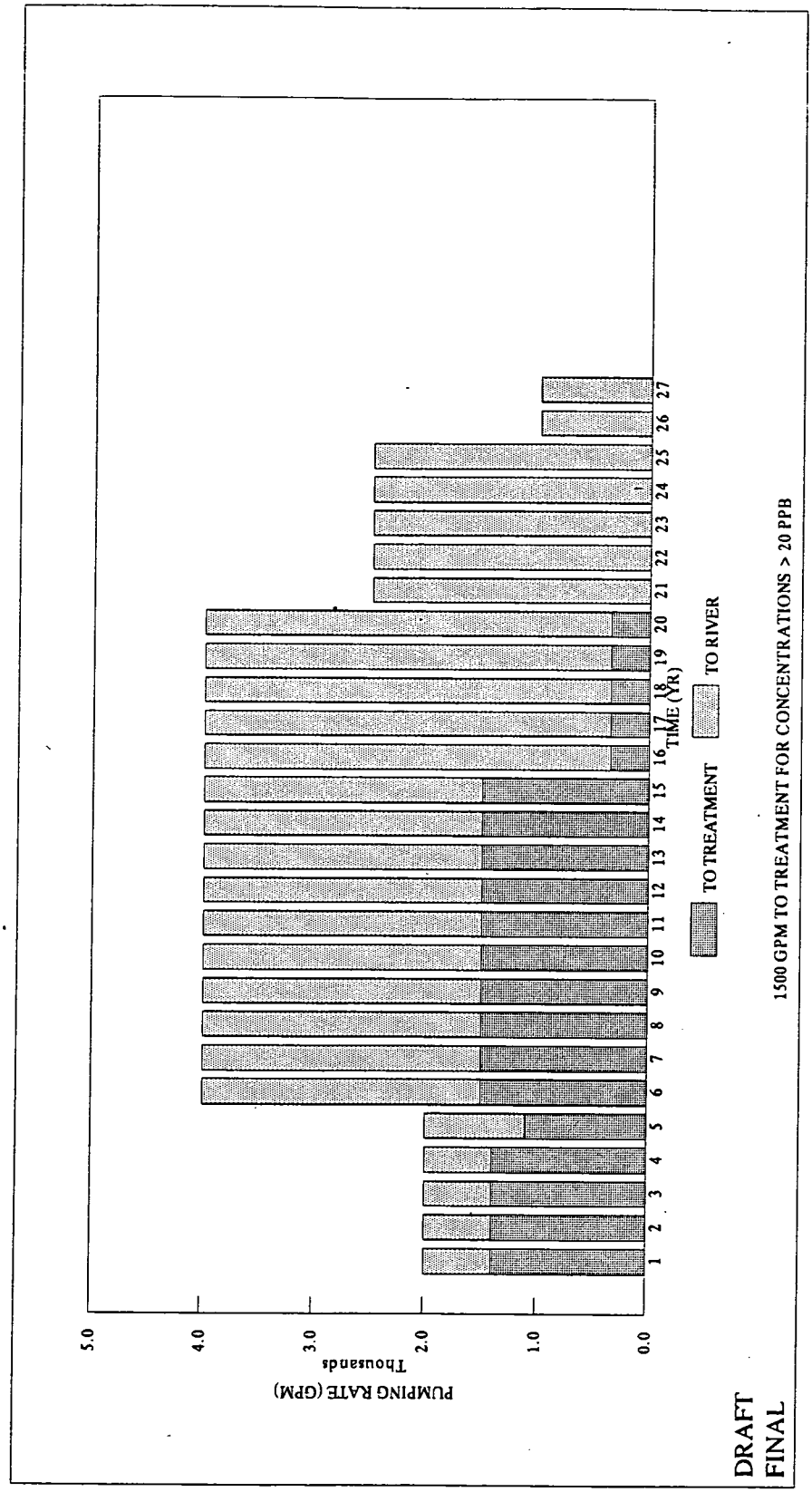

FIGURE F.8-10 - SEQUENTIAL PUMPING CASE S2-V, TREATMENT RATE VERSUS TIME

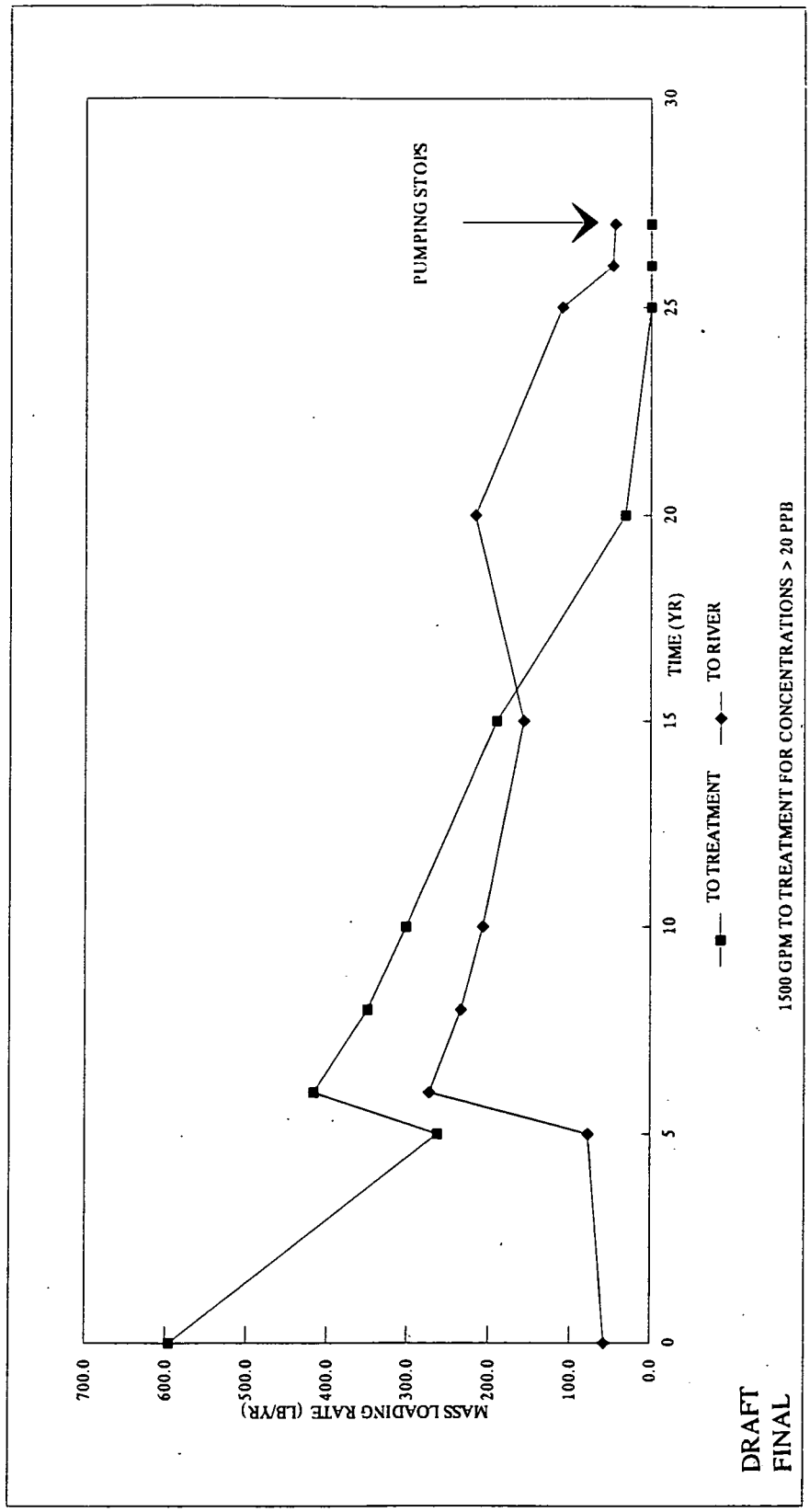

FIGURE F.8-11 - SEQUENTIAL PUMPING CASE S2-V, MASS LOADING RATE VERSUS TIME

ATTACHMENT F.1.I
MODIFICATION OF ECTran MODEL AND RECALIBRATION OF LYSIMETER DATA

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F.1.I MODIFICATION OF ECTran MODEL AND RECALIBRATION OF LYSIMETER DATA

F.1.I.1.0 INTRODUCTION

In previous applications of the ECTran model, only two model layers (one for gray clay and the other for unsaturated sand and gravel) were used to simulate the entire overburden regardless of the actual thickness. Although no dispersion coefficient is required in the ECTran model, overburden layer thickness used in the ECTran model has similar effects as created by the dispersion coefficient used in the ODAST model. Because the ECTran model assumes instantaneous mixing of contaminant mass in an entire model layer, a larger layer thickness corresponds to a higher dispersion coefficient. As a result, the ECTran model can underestimate the arrival time of contaminant (i.e., faster than actual contaminant migration) through the clay layer specially under low infiltration rates with large layer thicknesses.

To simulate contaminant migration through the clay layer (i.e., clay liner in the disposal cell and gray clay layer in the glacial overburden) more realistically under low infiltration rates, a reasonable model layer thickness is selected for the ECTran model by matching the ODAST model's predicted concentration through a hypothetical clay layer under a low infiltration rate. A cross-verification study was conducted between the ECTran and ODAST model using a low infiltration rate. Results of this study is presented in this attachment. In summary, a 3-foot sublayer structure was determined appropriate for the ECTran model.

The ECTran model with modified layer structure was recalibrated against the lysimeter data (i.e., Wells 11130 and 11131). A uranium K_d value of 3.1 L/Kg was determined for the gray clay layer. The ODAST model was also applied to match the lysimeter data with this K_d value as a verification of the dispersion coefficient used in the model. The procedure and results of this calibration are also presented in this attachment. The overall gray clay layer is simulated as multiple 3-foot sublayers with identical hydrogeological characteristics in the modified ECTran model to support CPRG and WAC developments. It is important to note that this modification will only create significant differences under low infiltration rates.

F.1.I.2.0 CROSS-VERIFICATION BETWEEN ODAST AND ECTran MODELS

The ODAST model has been used during the Operable Unit 5 RI to conduct fate and transport modeling through the vadose zone to determine loading rates of predominant COCs to the SWIFT Great Miami Aquifer model. The ECTran model, on the other hand, has been used to conduct fate and transport modeling (RI) and CPRG and WAC development modeling (FS) for both predominant and secondary COCs. Overall contaminant migration through the overburden is controlled by both

advection and dispersion. When advection is the dominant factor in the contaminant migration the

- results of ODAST and the original ECTran model match fairly well. However, when infiltration rate is low and dispersion is the dominant factor, differences between ODAST and the original ECTran become significant.

Based on comparisons between the ODAST and ECTran models' results, it was determined that the ECTran model was overly conservative in estimating the speed of contaminant migration and leachate concentration from the source to the Great Miami Aquifer as compared to ODAST under low infiltration rate conditions (i.e., capping scenarios). The two major reasons for the conservative estimate were model layer thickness and the inherent vertical dispersion effects. The original ECTran model, which was developed, included only one model layer for each material type (i.e., clay liner, gray clay or unsaturated Great Miami Aquifer). By using only one layer, an average leachate concentration from the layer is estimated and leaches to the underlying layer. This average concentration is higher than the actual concentration exiting the layer. This approach is acceptable for RI applications and for the condition when the infiltration rate is relatively high. However, this is too conservative for the development of WACs for disposal facilities with cap. The differences between WACs developed by using ODAST and original ECTran model can be as high as two orders of magnitude.

For example results from ODAST show that approximately 3 percent of the initial loading concentration of uranium will penetrate the clay layer. In comparison, ECTran allows approximately 22 percent of the initial loading concentration of uranium to penetrate a 10 foot hypothetical clay layer over a 1000 year period. These results were determined assuming a uranium K_d value of 24 L/kg and an infiltration rate of 1.22 inches per year. Because the vertical fate and transport results of ODAST are considered to be more realistic, modifications were made to ECTran to allow its results to be more similar to ODAST. The major modification to ECTran was to divide the clay layer into several thinner sublayers, giving a better estimation of the exiting leachate concentration from the bottom of the clay layer. The goal was to have ECTran allow approximately the same ratio of initial concentration to penetrate and pass through the clay layer as predicted by ODAST under low infiltration rate conditions.

F.1.I.2.1 Limit of Layer Thickness for ECTran Model

A limit on the model layer thicknesses used to define the overburden in ECTran was necessary to approximate the effects of vertical dispersion which are directly calculated and accounted for in ODAST. By using the limited thicknesses, the ECTran model better approximates (i.e., better accounts for dispersion) the actual loading concentrations through the overburden to the Great Miami Aquifer under low infiltration rate conditions. The overburden simulated in contaminant fate and transport modeling includes the gray clay layer and unsaturated sand and gravel of the Great Miami

Aquifer. To determine the appropriate gray clay sublayer thickness, the total gray clay layer was divided into a variety of sublayers to determine the best model sublayer thickness to give the most accurate representation of the contaminant loading. The unsaturated Great Miami Aquifer layer was held constant at one layer. Rationale for both decisions are discussed below. The modifications to ECTran were incorporated and used for both CPRG and WAC development in Operable Unit 5 FS.

Gray Clay Layer

Using the example described above, approximately 3 percent of the loaded concentration exits the clay layer using the ODAST model, which uses calculated vertical dispersion, while 22 percent of the loaded concentration exists the clay layer using the ECTran model and one single model layer for the entire 10-foot clay layer. To more accurately model the leachate concentration from the gray clay layer, the number of sublayers used to represent the clay layer within the ECTran model were increased to find the appropriate layer thickness. To test the effects of layer thickness in the ECTran model, a single 10-foot clay layer was divided into both 3 and 4 equal thickness sublayers. Figures F.1.I-1 and F.1.I-2 graphically show the results of the ECTran modeling. Figure F.1.I-1 shows the leachate results for 3 sublayers and the original leachate curve for the single 10 foot clay layer. The leachate leaving layer 3 at 1000 years is approximately 3 percent of the original loading concentration, which closely approximates the ODAST results. Figure F.1.I-2 shows the results for 4 sublayers. The leachate leaving layer 4 at 1000 years is approximately 1 percent of the original loading concentration which is lower than the ODAST results. Therefore, the 3 layer representation with a maximum thickness of approximately 3 feet gave the best results when compared to ODAST output and was selected for modeling.

Once the 3-foot sublayer structure was selected for the ECTran model, other parameters such as infiltration rate and source loading duration were investigated to determine their impact on the leachate concentration from the ECTran model. Figures F.1.I-3 through F.1.I-6 show the effects of infiltration rate on the leachate concentration curve. Figure F.1.I-3 shows the identical curve as shown in Figure F.1.I-1 except the duration is 10,000 years instead of 1000 years. The infiltration rate for this simulation was 1.22 inches per year. From the figure it can be seen that the third sublayer leachate concentration eventually becomes higher than the single 10 foot layer approximation around 5000 years. The reason for this occurrence is due to the constant source which is assumed in the model. With a constant source and sublayer model structure, the upper layers will become saturated and the lower layer's concentration will increase to a maximum (i.e., the constant source concentration) with enough time. In the single layer approach, because contaminant migrates and exists model boundary faster, saturation is difficult to reach. Figures F.1.I-4, F.1.I-5, and F.1.I-6 show that with increasing the infiltration to 5 inches per year, 8.4 inches per year, and 24 inches per year, respectively, the time required for the third layer leachate concentration to exceed the single 10 foot layer simulation decreases significantly. For example for an infiltration rate of 1.22 inches per

year the time was approximately 5000 years while if the infiltration rate is 24 inches per year the time is approximately 220 years.

In addition to infiltration rates, the source loading curve was varied to determine the impact on the leachate concentration. Figures F.1.I-1 through F.1.I-6 show leachate concentrations for a constant loading concentration of 1 μg/L for the modeling period. Figures F.1.I-7 through F.1.I-9 show leachate concentrations for a constant loading concentration of 1 μg/L for only the first 100 years of the modeling period. Figure F.1.I-7 through F.1.I-9 are for infiltration rates of 1.22 inches per year, 8.4 inches per year, and 12 inches per year, respectively. The figures show that for this loading scenario, the leachate from the single 10-foot layer and the leachate from sublayer 3 are distinctly different for a majority of the modeling period, but the two concentrations become similar towards the end of the modeling period. It is also noticeable that infiltration rate reduces the time in which it takes for these two loading curves to become similar.

Unsaturated Great Miami Aquifer Layer

Although the overall mass flow rate determined by HELP is correctly conserved, it is determined that the speed of vertical groundwater and contaminant migration through unsaturated sand and gravel in the Great Miami Aquifer can be underestimated by the original ODAST model especially when developing WACs for the disposal facilities with cap. ODAST uses a traditional conceptual model of a uniform front of soil moisture migration and does not consider the potential of preferential flow created by localized saturated conditions and heterogeneity of permeability created by various depositional phases or environments in the Great Miami Aquifer. This assumption is reasonable for gray clay layer, but it may not be conservative for the sand and gravel layer which has very high permeability. As a result, the simulated groundwater vertical seepage velocity in the unsaturated sand and gravel layer is in the same order of magnitude as in the gray clay layer when developing WACs for the disposal facility.

Localized saturated conditions and heterogeneity may create fingering effects in the unsaturated sand and gravel where water can migrate in small "streams" at higher rates instead of a uniform front at lower rates. In reality, the groundwater vertical seepage velocity in the unsaturated sand and gravel layer can be as high as the vertical hydraulic conductivity of the sand and gravel layer and independent of the overall infiltration rate. The differences between the simulated and potential seepage velocities is significant under a low infiltration rate (i.e., below 1 inch per year) created by the cap of the disposal facility.

The potential error of ODAST in seepage velocity calculation through the unsaturated sand and gravel layer is significant only when the overall infiltration rate is low. However to account for this error it was determined that the unsaturated sand and gravel layer will not be included whenever the ODAST

model is applied in Operable Unit 5 FS fate and transport modeling. A similar modification in the ECTran model is not necessary because the ECTran model only uses mass flow rate (instead of seepage velocity as in the ODAST model) in the calculation and assumes instantaneous mixing of contaminant mass in the entire unsaturated sand and gravel thickness as one single model layer. When simulated as a single model layer (i.e., not divided into smaller sublayers as for the gray clay layer described previously), the approach used in the ECTran model is still very conservative for the sand and gravel layer under low infiltration rate conditions.

Within ECTran, as a contaminant travels vertically through the vadose zone, instantaneous mixing of a contaminant occurs within a layer and travel time is not directly accounted for within the model. As discussed before, a one layer representation also conservatively estimates the contaminant leachate concentration from a layer. This representation best accounts for possible hydrogeological conditions in the unsaturated Great Miami Aquifer, which would allow contaminants to migrate unattenuated through the layer. The typical unsaturated Great Miami Aquifer layer thickness was 20 feet, however, the layer ranged in thickness from 20 feet to 35 feet for the various zones covering the FEMP as shown in Figures F.2-11 and F.2-12. Figure F.2-12 shows the typical cross-sections for each zone.

F.1.I.2.2 Modifications to the ECTran Model to Account for Sublayers

Modifications to the formulas used in ECTran were made to account for separating a single model layer into sublayers and to allow for a time varying source loading due to time varying infiltration rates or sources with limited initial contaminant mass. The original model development is presented in "Development and Application of the ECTran Model to Support RI/FS at the FEMP," (DOE, 1993). The following information presents the details of the modifications which were incorporated into the model for CPRG and WAC development.

For the modified version of ECTran, Equation 1 was used to predict leachate concentrations in the clay liner sublayers, gray clay sublayers and the unsaturated Great Miami Aquifer layer. In the original development, the liner sublayers were not considered and a different equation, Equation 3, was used for the unsaturated Great Miami Aquifer. Equation 1 uses a mass-balance analysis with solid- and dissolved-phase partitioning for the contaminants from the source area, assuming that the infiltrating precipitation contains residual source leachate or background contamination and that

dispersion in the layer is negligible to give the following expression for the time-dependent leachate concentration for the layer

$$\frac{dC_A}{dt} = \left[\frac{Q_1}{S_A V_{wA} + K_{dA} W_{sA}}\right] [CU_1 - C_A] - \lambda_A C_A \qquad (1)$$

In the original development this equation was solved by direct integration to yield the following solution:

$$C_A = \frac{CU_1 - \{CU_1 - [1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]C_{Ao}\} \exp\left[-\frac{Q_1 + (S_A V_{WA} + K_{dA} W_{sA})\lambda_A}{S_A V_{WA} + K_{dA} W_{sA}} \Delta t\right]}{[1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]} \qquad (2)$$

In Equation 2 CU_1 is a constant source loading concentration and C_{Ao} is the initial concentration. For increased flexibility, CU_1 was modified from a constant source to a time-dependent leachate concentration, $CU_1(t)$. As a result, Equation 1 cannot be directly integrated to yield Equation 2. Therefore, to solve this problem, the time- dependent continuous function, CU_1 (t), is approximated by a staircase function. In each small time interval, CU_1 is assumed to be constant, $CU_1(I\Delta t)$, therefore, the analytical solution, via direct integration, used previously (Equation 2), can be directly used to obtain $C_A((I+1)\Delta t)$ at each current time step by giving $C_A(I\Delta t)$ at the previous time step. With this approach, the previous solution for Equation 1, Equation 2, is slightly modified to yield in Equation 3

$$C_A((I+1)\Delta t) = \frac{CU_1(I\Delta t) - \{CU_1(I\Delta t) - [1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]C_A(I\Delta t)\} \exp\left[-\frac{Q_1 + (S_A V_{WA} + K_{dA} W_{sA})\lambda_A}{S_A V_{WA} + K_{dA} W_{sA}} \Delta t\right]}{[1 + (S_A V_{WA} + K_{dA} W_{sA})(\lambda_A/Q_1)]} \qquad (3)$$

where: $CU_1(I\Delta t)$ is the contaminant concentration in infiltrating precipitation at the previous time step (mg/L)

Q_1 is the infiltration rate (L/day)

$C_A((I+1)\Delta t)$ is the aqueous concentration in the layer at the current time step (mg/L)

$C_A(I\Delta t)$ is the aqueous concentration in the layer at the previous time step (mg/L)

S_A is the soil saturation fraction in the layer (dimensionless)

V_{wA} is the void volume in the layer (L)

K_{dA} is the aqueous/solid phase distribution coefficients in the layer (L/kg)

W_{sA} is the dry weight of soil in the layer (kg)

λ_A is the first-order chemical decay rate in the layer (day^{-1})

I is the number of time steps, starting from I = 0 (unitless)

Δt is the time step (day)

Required assumptions for applying Equations 2 and 3 include the following:

- A constant or depleting source leachate loading to the top liner or gray clay sublayer can be used.
- For subsequent liner sublayers or gray clay sublayers, the loading to the sublayer is the computed concentration of the overlying sublayer.
- For the unsaturated Great Miami Aquifer layer, the loading to the layer is the computed concentration of the bottom sublayer in the gray clay.

Instead of using the Summer's model which does not consider mass-partition as in the original ECTran, a similar mass-balance/mass-partitioning approach, which includes a time-dependent source loading term and a secondary source were used for the saturated Great Miami Aquifer under the source area and is presented in Equation 4.

$$\frac{dC_B}{dt} + \frac{K_2}{K_1}C_B = \frac{K_3}{K_1} + \frac{K_4}{K_1}\exp^{(-K_5 t)} \tag{4}$$

Equation 4 can be solved using an integrating factor approach or the method of undetermined coefficients (DOE 1993b) to yield Equation 5.

$$C_B = \frac{K_3}{K_2} + \frac{K_4}{K_2 - K_1 K_5}\exp(-K_5 t) + \left[C_{Bo} - \frac{K_3}{K_2} - \frac{K_4}{K_2 - K_1 K_5}\right]\exp\left(-\frac{K_2 t}{K_1}\right) \tag{5}$$

A similar assumption, as the one used to solve Equation 1, of using a staircase function to approximate time-dependent concentrations was also made for directly using Equation 4 to obtain C_B with a time-varying source loading concentration. As before, in each small time interval, the time-dependent concentrations are assumed to be constant, which allows for an analytical solution for C_B. The secondary source, CU_2, is assumed to be constant for this derivation. With the staircase function assumption, Equation 5 can be modified to yield Equation 6

$$C_B((I+1)\Delta t) = \frac{K_3(I\Delta t)}{K_2} + \frac{K_4(I\Delta t)}{K_2 - K_1 K_5}\exp(-K_5 \Delta t) + \left[C_B(I\Delta t) - \frac{K_3(I\Delta t)}{K_2} - \frac{K_4(I\Delta t)}{K_2 - K_1 K_5}\right]\exp\left(-\frac{K_2 \Delta t}{K_1}\right) \tag{6}$$

In which:

$$K_1 = S_B V_{wB} + K_{dB} W_{sB}$$

$$K_2 = Q_1 + Q_2 + (S_B V_{wB} + K_{dB} W_{sB}) \lambda_B$$

$$K_3(I\Delta t) = Q_1 CU_1 (I\Delta t) / [1 + (S_A V_{wA} + K_{dA} W_{sA})(\lambda_A / Q_1)] + Q_2 CU_2$$

$$K_4(I\Delta t) = Q_1 C_A(I\Delta t) - Q_1 CU_1(I\Delta t) / [1 + (S_A V_{wA} + K_{dA} W_{sA})(\lambda_A / Q_1)]$$

$$K_5 = [Q_1 + (S_A V_{wA} + K_{dA} W_{sA})\lambda_A] / (S_A V_{wA} + K_{dA} W_{sA})$$

And where:

CU_2 is the constant contaminant leachate concentration of the secondary source (mg/L)

$C_B((I+1)\Delta t)$ is the aqueous concentration at the current time interval in the layer (mg/L)

$C_B(I\Delta t)$ is the aqueous concentration at the previous time interval in the layer (mg/L)

Q_2 is the perched water inflow rate of the secondary source (L/day)

S_B is the soil saturation fraction in the layer (dimensionless)

V_{wB} is the void volume in the layer (L)

K_{dB} is the aqueous/solid phase distribution coefficients in the layer (L/kg)

W_{sB} is the dry weight of soil in the layer (kg)

λ_B is the first-order chemical decay rate in the layer (day^{-1})

I = Number of time steps, starting from I = 0 (unitless)

Δt = time step (day)

Required assumptions for applying Equations 4 and 6 include the following:

- The depth of aquifer that is available to dilute contaminant loading from overburden in the Great Miami Aquifer is the calculated mixing depth.
- A minimum of 10-foot mixing depth in the Great Miami Aquifer is appropriate for both CPRG and WAC development under low infiltration rate conditions.

F.1.I.3.0 RECALIBRATION OF LYSIMETER DATA

As presented in Attachment F.3.II of the Operable Unit 5 Draft RI, calibration of the uranium K_d value was performed so that the ECTran model's results matched the lysimeter data collected from Lysimeter Test Wells 11130 and 11131. The results of the calibration showed that a K_d value of 4 L/Kg for uranium in gray clay allowed the model to most accurately predict the lysimeter measurements. The model structure for this calibration was a single layer for both the gray clay and the unsaturated Great Miami Aquifer. Due to the modifications (i.e., increased number of model sublayers for the gray clay layer) in the modified ECTran model, a recalibration of the model was performed to verify the correct K_d value. A similar procedure as the one used in the Operable Unit 5 Draft RI was also used for this calibration.

For the recalibration the gray clay layer within ECTran was restructured to include multiple sublayers. Based on matching the vertical dispersion used in the ODAST model, the maximum thickness for each gray clay sublayer or liner within ECTran is approximately 3 feet. The rationale for determining this thickness was previously discussed in Section F.1.I.2. During the calibration the sublayers also allowed the model to better match the location where samples were collected with the lysimeters. Lysimeter samples were collected from the top 1 foot of both the gray clay and the unsaturated Great Miami Aquifer layers. Therefore, for the two calibration simulations, a 1-foot layer thickness was used for the top of the gray clay and the unsaturated Great Miami Aquifer, respectively, within the ECTran model. Table F.1.I-1 summarizes the model layering structure and parameters for the ECTran simulation to match Lysimeter Test Well 11130, while Table F.1.I-2 presents the same information for the ECTran simulation to match Lysimeter Test Well 11131.

The results of the calibration are summarized in Figures F.1.I-10 and F.1.I-11. Tables F.1.I-3 and F.1.I-4 present the output from the two ECTran models which were used to create Figures F.1.I-10 and F.1.I-11, respectively. As can be seen in Figure F.1.I-10, by using a K_d value of 3.1 L/kg in gray clay and a source loading concentration of 1140 ug/L for the first five years, a perched water concentration of 7.25 ug/L results at 40 years. This value compares well with the measured concentrations (i.e., ranging from 2.8 to 13 ug/L with an average about 5 ug/L) in Lysimeter Test Well 11130. Figure F.1.I-11 shows that the model predicts an unsaturated Great Miami Aquifer leachate concentration of 10.4 ug/L using a K_d value of 3.1 L/Kg in gray clay, and a K_d value of 1.78 L/Kg in unsaturated Great Miami Aquifer, and a source loading term of 1140 ug/L for the first five years. The predicted leachate concentration (10.4 ug/L) matches the measured concentrations (i.e., ranging from 3.4 to 12 ug/L with an average about 10 ug/L) from Lysimeter Test Well 11131 quite well. These calibration results are consistent with those presented in the Operable Unit 5 Draft, because they also match the range of measured results very well. As expected the change between the two uranium K_d values (i.e., 4 and 3.1 L/Kg) in gray clay is relatively small. This indicates that under the normal infiltration rate conditions the modified model layer structure in ECTran model does not create significant impacts to the modeling results. ODAST was also applied with the same layer thickness, source loading, and K_d value to verify the ECTran calibration results. Both models compare vary well with the measured data.

F.1.I.4.0 URANIUM K_d VALUE FOR GRAY CLAY AND CLAY LINER

As described in the Operable Unit 5 Draft RI, vertical contaminant fate and transport modeling through the glacial overburden only include the gray clay layer. Vertical migration of contaminant through the weathered overburden was assumed to be instantaneous. Based on measured data and model calibrations presented in the Attachments F.3.I and F.3.II of Operable Unit 5 Draft RI, K_d values of uranium in the gray clay layer range between 4 L/Kg (i.e., from lysimeter calibration) to higher than 2000 L/Kg. A calculated K_d value of 15 L/Kg was used to represent the baseline

conditions in the Plant 2/3, Plant 6, and Plant 9 areas for fate and transport modeling. This K_d value was also verified by previous model calibration using ECTran model which was summarized in Attachment F.3.II of the Operable Unit 5 Draft RI. Relative breakthrough times between source areas also provided information for prioritizing the cleanup efforts.

As information presented in the Operable Unit 5 Draft RI indicated, a K_d value of 15 L/Kg is conservative but not the minimum value. The retardation factor in the gray clay layer calculated using a K_d value of 15 L/Kg is about 165. In other words, uranium migrates 165 times slower than the groundwater seepage velocity which is about 1 to 2 feet per year. These low migration rates in the overburden resulted in the long breakthrough times presented in the RI baseline conditions. For the purpose of baseline risk assessment, these long breakthrough times did not change the conclusions regarding the maximum level and sources of future Great Miami Aquifer groundwater contamination. Based on modeling results, Great Miami Aquifer uranium concentration can reach 9 mg/L in about 200 years due to future surface water loading.

Based on the calibration results described above, a uranium K_d value of 3.1 L/Kg for the gray clay layer throughout the FEMP is selected for Operable Unit 5 FS to develop soil CPRGs and WACs for disposal facilities. This K_d represents the natural adsorption conditions which occur within the gray clay. This value was determined by model calibrations with both ODAST and ECTran models and is representative for conditions observed at the southeast lysimeter location. This lower K_d value could be the result of a small "short circuit" pathway through the clay, (i.e., a sand lense or fracture). Such pathways, while hard to identify in the field, can be accounted for in the model by lowering K_d. This low uranium K_d value is used in the FS fate and transport modeling and is independent of the source K_l values as suggested by the geochemical conditions in the glacial overburden at the FEMP. Selection of this lower K_d value to represent the whole site allows the combined geochemical and hydrogeological uncertainties in the natural environment which control the migration rate of uranium through overburden be better enveloped in the Operable Unit 5 remedial alternatives. With this lower K_d value the breakthrough time is about 5 times shorter than the baseline cases presented in the Operable Unit 5 Draft RI.

In comparison, a clay liner will be used as part of the disposal cell which is proposed for storage of residual waste and contaminated soil. This clay liner will be homogeneous and placed and compacted to specifications unlike the natural clay. The natural clay is more heterogeneous and was placed randomly due to natural deposition processes. It is reasonable to assume that this engineered clay liner will not have the same hydrogeological uncertainty and high degree of heterogeneity as in the natural "gray clay" layer encountered in the lysimeter test areas. Therefore, a higher K_d value which is closer to reported capacity of real clay material under general subsurface geochemical conditions (i.e, high carbonate content) expected in the FEMP is reasonable. An uranium K_d value of 24 L/Kg

is selected for the clay liner. This value is also justified by results of laboratory adsorption tests conducted with clay materials from the potential location of the cell east of the former production area. This information was also presented in the Attachment F.3.I of the Operable Unit 5 Draft RI.

TABLE F.1.I-1

SUMMARY OF ECTran INPUT PARAMETERS FOR CALIBRATION OF K_d USING LYSIMETER TEST WELL 11130

Model Parameters	Lysimeter Test Well 11130
Source Loading Area Size (ft x ft)	125 x 125
Gray Clay Thickness (ft)	5 (5 x 1 foot sublayers)
Unsaturated GMA Thickness (ft)	1
Source Material K_l (L/kg)	325
Gray Clay K_d (L/kg)	3.1
Unsaturated GMA Thickness (ft)	1.78
Infiltration Rate (in/yr)	8.34
Source Leachate Concentration (ug/L)	1140

TABLE F.1.I-2

SUMMARY OF ECTran INPUT PARAMETERS FOR CALIBRATION OF K_d USING LYSIMETER TEST WELL 11131

Model Parameters	Lysimeter Test Well 11131
Source Loading Area Size (ft x ft)	125 x 125
Gray Clay Thickness (ft)	15 (5 x 3 foot sublayers)
Unsaturated GMA Thickness (ft)	1
Source Material K_l (L/kg)	325
Gray Clay K_d (L/kg)	3.1
Unsaturated GMA K_d (L/kg)	1.78
Infiltration Rate (in/yr)	8.34
Source Leachate Concentration (ug/L)	1140

TABLE F.1.I-3

CALIBRATION OF K_d USING LYSIMETER TEST WELL 1130

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE: 5 SUBLAYERS IN LAYER 1
INVESTIGATOR: WYU
DATE: 10/10/94

CONTAMINANT: U238		SPECIFIC ACTIVITY:	3.35E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	2.00E+01
HALF LIFE (YRS):		SOURCE LEACHATE CONC. (UG/L)	1.14E+03
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	3.25E+02
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
INFILT(FT/YR):	0.698						B (FT):	64	Vzo (FT/YR):	0.3899
LENGTH (FT):	125	FOC (KG/KG):	0	THICKNESS (FT)	FOC (KG/KG):	0.0000	GW Q3 (L/DAY):	1.25E+04	CU2 (PPB):	0.00E+00
WIDTH (FT):	125	Kd (L/KG):	3.10	15	Kd (L/KG):	1.780	GW V.(FT/YR):	369.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	1.00	SUBLAYERS	SATURATION:	0.17	H (FT):	13.0741	RETARDATION:	13.6736
POROSITY 2:	0.3	S.L. TH (FT):	3.00	5	THICKNESS (FT):	1.00	EFF. POROSITY:	0.25	q (FT/YR) :	0
DENSITY 1 (G/CM3):	1.78	DECAY (1/DA	4.25E-13		DECAY (1/DAY):	4.25E-13	Q2 (L/DAY):	1.17E+04	DECAY (1/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00	Azi(FT):	0.67	CU3 (PPB):	0
Ts(YEARS):	5	D.F.(1/YR):	0				Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0	Q1 (L/DAY):	8.46E+02				Av (FT):	33.33	DISTANCE TO F.L	4800

TIME INTERVAL (YRS)	1	LAYER 1 LEACHATE CONC. (UG/L)						LAYER 2	SOURCE AREA CONC.	FENCE LINE CONC.
ELAPSED TIME - YRS	CU1(PPB)	SUBLAYER 1	SUBLAYER 2	SUBLAYER 3	SUBLAYER 4		SUBLAYER 5	(UG/L)	(UG/L)	(UG/L)
0	1.14E+03	0.0	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00		
1	1.14E+03	45.5	1.81E+00	7.24E-02	2.89E-03		1.15E-04	2.47E-05		
2	1.14E+03	89.1	5.30E+00	2.81E-01	1.40E-02		6.68E-04	1.62E-04		
3	1.14E+03	131.1	1.03E+01	6.81E-01	4.06E-02		2.26E-03	6.12E-04		
4	1.14E+03	171.3	1.67E+01	1.32E+00	9.17E-02		5.83E-03	1.73E-03		
5	1.14E+03	210.0	2.44E+01	2.24E+00	1.78E-01		1.27E-02	4.07E-03		
6	0.00E+00	201.6	3.15E+01	3.41E+00	3.07E-01		2.44E-02	8.43E-03		
7	0.00E+00	193.5	3.80E+01	4.79E+00	4.86E-01		4.28E-02	1.58E-02		
8	0.00E+00	185.8	4.39E+01	6.35E+00	7.20E-01		6.98E-02	2.74E-02		
9	0.00E+00	178.4	4.92E+01	8.06E+00	1.01E+00		1.07E-01	4.45E-02		
10	0.00E+00	171.3	5.41E+01	9.90E+00	1.37E+00		1.58E-01	6.87E-02		
11	0.00E+00	164.5	5.85E+01	1.18E+01	1.78E+00		2.23E-01	1.02E-01		
12	0.00E+00	157.9	6.25E+01	1.39E+01	2.27E+00		3.04E-01	1.45E-01		
13	0.00E+00	151.6	6.60E+01	1.59E+01	2.81E+00		4.04E-01	2.00E-01		
14	0.00E+00	145.6	6.92E+01	1.81E+01	3.42E+00		5.25E-01	2.70E-01		
15	0.00E+00	139.7	7.20E+01	2.02E+01	4.09E+00		6.67E-01	3.55E-01		
16	0.00E+00	134.2	7.45E+01	2.24E+01	4.82E+00		8.33E-01	4.57E-01		
17	0.00E+00	128.8	7.67E+01	2.45E+01	5.61E+00		1.02E+00	5.78E-01		
18	0.00E+00	123.7	7.85E+01	2.67E+01	6.45E+00		1.24E+00	7.20E-01		
19	0.00E+00	118.7	8.01E+01	2.88E+01	7.34E+00		1.48E+00	8.83E-01		
20	0.00E+00	114.0	8.15E+01	3.09E+01	8.28E+00		1.75E+00	1.07E+00		
21	0.00E+00	109.5	8.26E+01	3.30E+01	9.27E+00		2.05E+00	1.28E+00		
22	0.00E+00	105.1	8.35E+01	3.50E+01	1.03E+01		2.38E+00	1.52E+00		
23	0.00E+00	100.9	8.42E+01	3.70E+01	1.14E+01		2.74E+00	1.78E+00		
24	0.00E+00	96.9	8.47E+01	3.89E+01	1.25E+01		3.13E+00	2.07E+00		
25	0.00E+00	93.0	8.50E+01	4.07E+01	1.36E+01		3.55E+00	2.38E+00		
26	0.00E+00	89.3	8.52E+01	4.25E+01	1.47E+01		3.99E+00	2.73E+00		
27	0.00E+00	85.7	8.52E+01	4.42E+01	1.59E+01		4.47E+00	3.10E+00		
28	0.00E+00	82.3	8.51E+01	4.58E+01	1.71E+01		4.97E+00	3.50E+00		
29	0.00E+00	79.0	8.49E+01	4.74E+01	1.83E+01		5.50E+00	3.93E+00		
30	0.00E+00	75.9	8.45E+01	4.89E+01	1.95E+01		6.06E+00	4.39E+00		
31	0.00E+00	72.9	8.40E+01	5.03E+01	2.08E+01		6.65E+00	4.87E+00		
32	0.00E+00	69.9	8.35E+01	5.16E+01	2.20E+01		7.26E+00	5.38E+00		
33	0.00E+00	67.2	8.28E+01	5.28E+01	2.32E+01		7.90E+00	5.92E+00		
34	0.00E+00	64.5	8.21E+01	5.40E+01	2.45E+01		8.56E+00	6.49E+00		
35	0.00E+00	61.9	8.13E+01	5.51E+01	2.57E+01		9.24E+00	7.08E+00		
36	0.00E+00	59.4	8.04E+01	5.61E+01	2.69E+01		9.95E+00	7.69E+00		
37	0.00E+00	57.1	7.95E+01	5.70E+01	2.81E+01		1.07E+01	8.33E+00		
38	0.00E+00	54.8	7.85E+01	5.79E+01	2.93E+01		1.14E+01	8.99E+00		
39	0.00E+00	52.6	7.75E+01	5.87E+01	3.05E+01		1.22E+01	9.67E+00		
40	0.00E+00	50.5	7.64E+01	5.94E+01	3.16E+01		1.29E+01	1.04E+01		
41	0.00E+00	48.5	7.53E+01	6.00E+01	3.27E+01		1.37E+01	1.11E+01		
42	0.00E+00	46.6	7.41E+01	6.06E+01	3.39E+01		1.45E+01	1.18E+01		
43	0.00E+00	44.7	7.30E+01	6.11E+01	3.49E+01		1.54E+01	1.26E+01		
44	0.00E+00	42.9	7.18E+01	6.15E+01	3.60E+01		1.62E+01	1.34E+01		
45	0.00E+00	41.2	7.05E+01	6.19E+01	3.70E+01		1.70E+01	1.41E+01		
46	0.00E+00	39.6	6.93E+01	6.22E+01	3.80E+01		1.78E+01	1.49E+01		
47	0.00E+00	38.0	6.81E+01	6.24E+01	3.90E+01		1.87E+01	1.57E+01		
48	0.00E+00	36.5	6.68E+01	6.26E+01	3.99E+01		1.95E+01	1.66E+01		
49	0.00E+00	35.0	6.55E+01	6.27E+01	4.09E+01		2.04E+01	1.74E+01		
50	0.00E+00	33.6	6.43E+01	6.28E+01	4.17E+01		2.12E+01	1.82E+01		
MAXIMUM:	1.14E+03	2.10E-02	8.52E+01	6.28E+01	4.17E+01		2.12E+01	1.82E+01		

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	1.14E+03	3.71E+02	3.82E+02	1.24E+02
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TABLE F.1.I-4

CALIBRATION OF K_d USING LYSIMETER TEST WELL 1131

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrns) MODEL

SITE:

INVESTIGATOR: WYU
DATE: 10/10/94

CONTAMINANT: U238		SPECIFIC ACTIVITY:	3.35E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	2.00E+01
HALF LIFE (YRS):		SOURCE LEACHATE CONC. (UG/L)	1.14E+03
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	3.25E+02
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)		LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
INFILT(FT/YR):	0.698					B (FT):	64	Vzo (FT/YR):	0.3899
LENGTH (FT):	125	FOC (KG/KG):	0	FOC (KG/KG):	0.0000	GW Q3 (L/DAY):	1.25E+04	CU2 (PPB):	0.00E+00
WIDTH (FT):	125	Kd (L/KG):	3.10	Kd (L/KG):	1.780	GW V.(FT/YR):	369.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	1.00	SATURATION:	0.17	H (FT):	13.0741	RETARDATION:	13.6736
POROSITY 2:	0.3	THICKNESS (FT)	1.00	THICKNESS (FT):	1.00	EFF. POROSITY:	0.25	q (FT/YR) :	0
DENSITY 1 (G/CM3):	1.78	DECAY (I/DAY):	4.25E-13	DECAY (I/DAY):	4.25E-13	Q2 (L/DAY):	1.17E+04	DECAY (I/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00	CBo (PPB):	0.00E+00	AzFT):	0.67	CU3 (PPB):	0
Ts(YEARS):	5	D.F.(I/YR):	0			Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0	Q1 (L/DAY):	8.46E+02			Ay (FT):	33.33	DISTANCE TO F.L	4800

TIME INTERVAL (YRS)	1	LAYER 1 LEACHATE CONC. (UG/L)						
ELAPSED TIME - YRS	CU1(PPB)	SUBLAYER 1						
0	1.14E+03	0.00E+00						
1	1.14E+03	1.31E+02						
2	1.14E+03	2.47E+02						
3	1.14E+03	3.50E+02						
4	1.14E+03	4.41E+02						
5	1.14E+03	5.21E+02						
6	0.00E+00	4.61E+02						
7	0.00E+00	4.08E+02						
8	0.00E+00	3.61E+02						
9	0.00E+00	3.20E+02						
10	0.00E+00	2.83E+02						
11	0.00E+00	2.50E+02						
12	0.00E+00	2.22E+02						
13	0.00E+00	1.96E+02						
14	0.00E+00	1.74E+02						
15	0.00E+00	1.54E+02						
16	0.00E+00	1.36E+02						
17	0.00E+00	1.20E+02						
18	0.00E+00	1.06E+02						
19	0.00E+00	9.42E+01						
20	0.00E+00	8.34E+01						
21	0.00E+00	7.38E+01						
22	0.00E+00	6.53E+01						
23	0.00E+00	5.78E+01						
24	0.00E+00	5.12E+01						
25	0.00E+00	4.53E+01						
26	0.00E+00	4.01E+01						
27	0.00E+00	3.55E+01						
28	0.00E+00	3.14E+01						
29	0.00E+00	2.78E+01						
30	0.00E+00	2.46E+01						
31	0.00E+00	2.18E+01						
32	0.00E+00	1.93E+01						
33	0.00E+00	1.70E+01						
34	0.00E+00	1.51E+01						
35	0.00E+00	1.34E+01						
36	0.00E+00	1.18E+01						
37	0.00E+00	1.05E+01						
38	0.00E+00	9.26E+00						
39	0.00E+00	8.19E+00						
40	0.00E+00	7.25E+00						
41	0.00E+00	6.42E+00						
42	0.00E+00	5.68E+00						
43	0.00E+00	5.03E+00						
44	0.00E+00	4.45E+00						
45	0.00E+00	3.94E+00						
46	0.00E+00	3.48E+00						
47	0.00E+00	3.08E+00						
48	0.00E+00	2.73E+00						
49	0.00E+00	2.42E+00						
50	0.00E+00	2.14E+00						
MAXIMUM:	1.14E+03	5.21E+02						

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	1.14E+03	3.71E+02	3.82E+02	1.24E+02
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

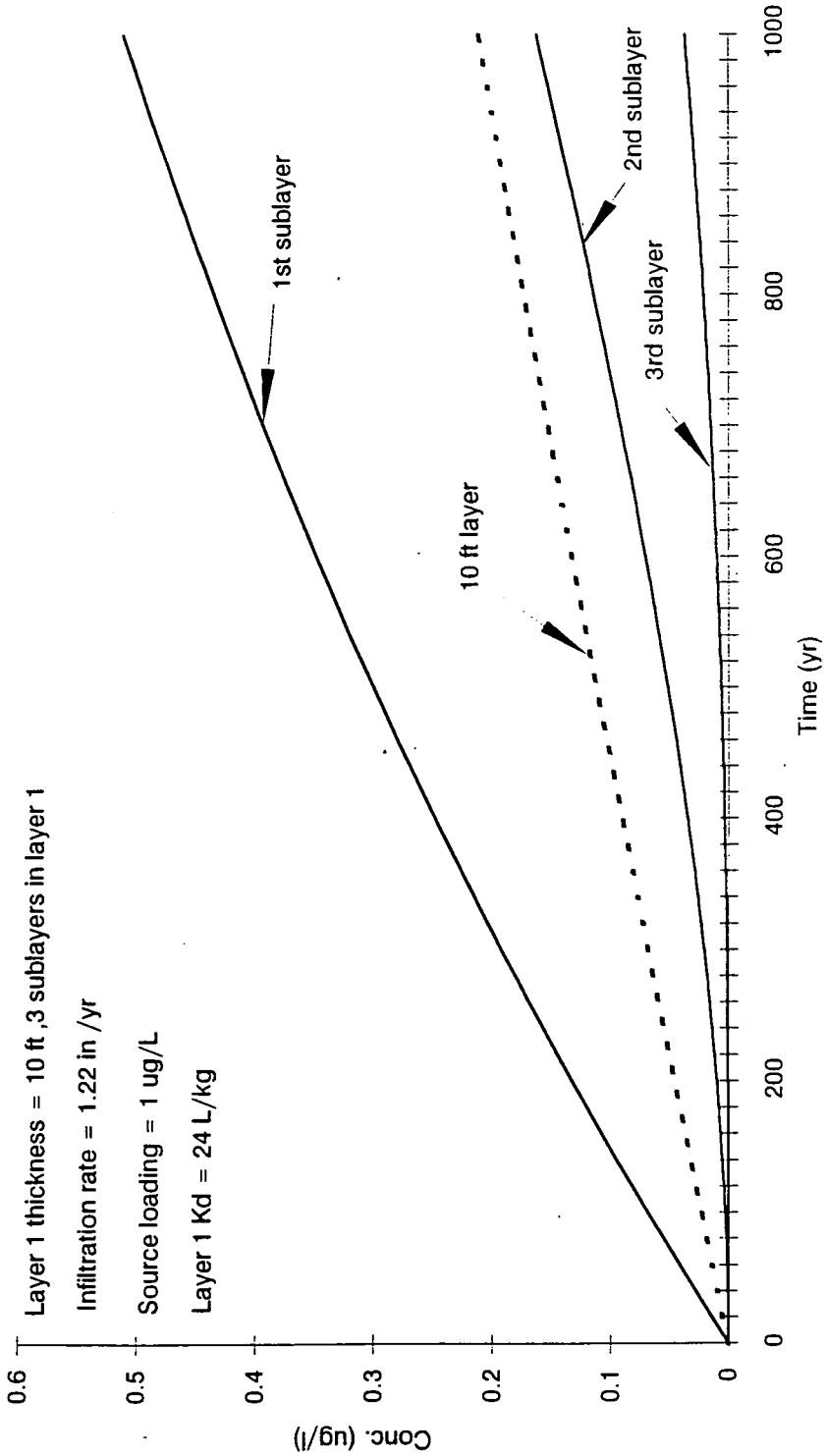

FIGURE F.1.I-1 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS

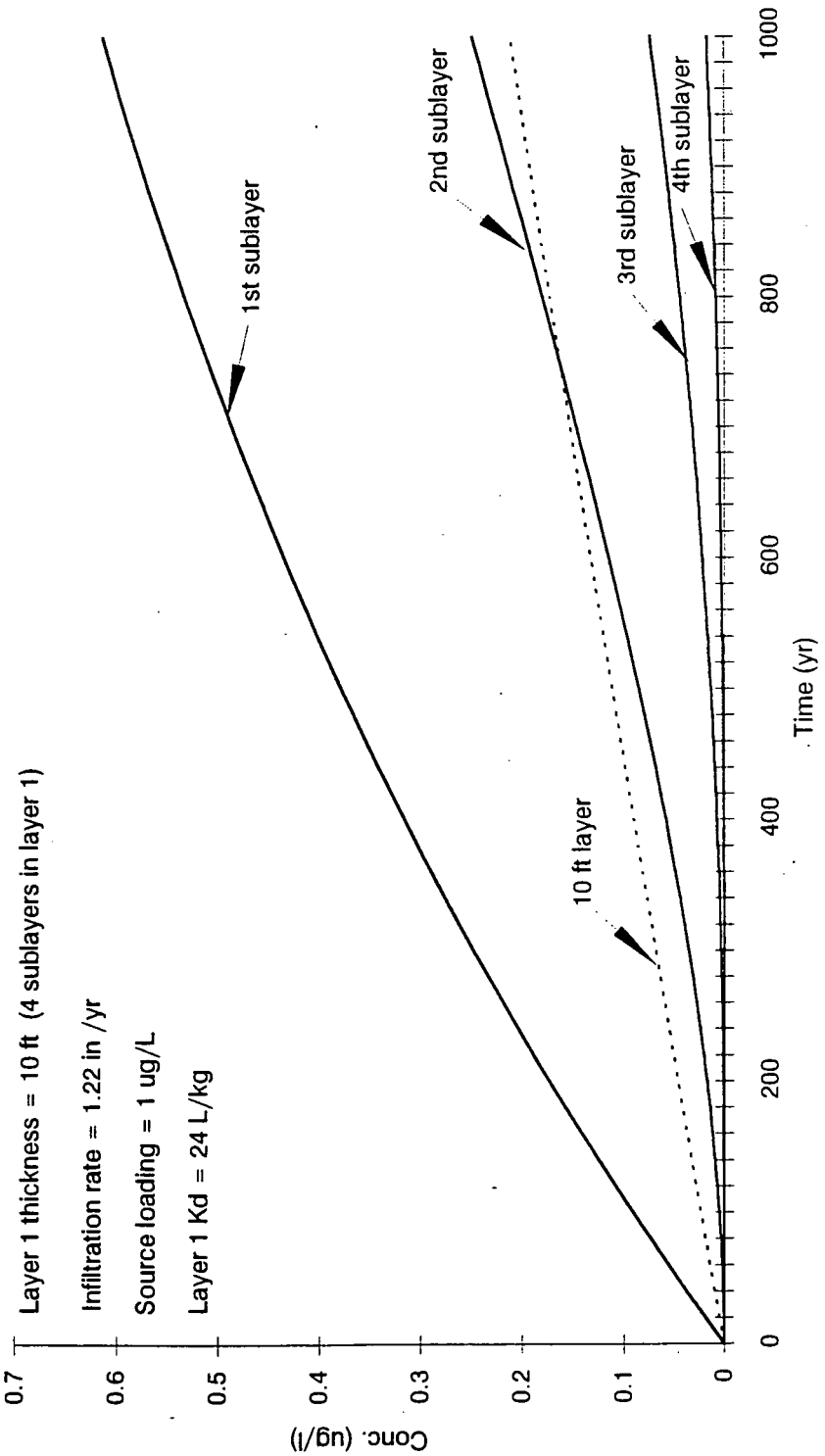

FIGURE F.1.I-2 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYER USING 4 SUBLAYERS

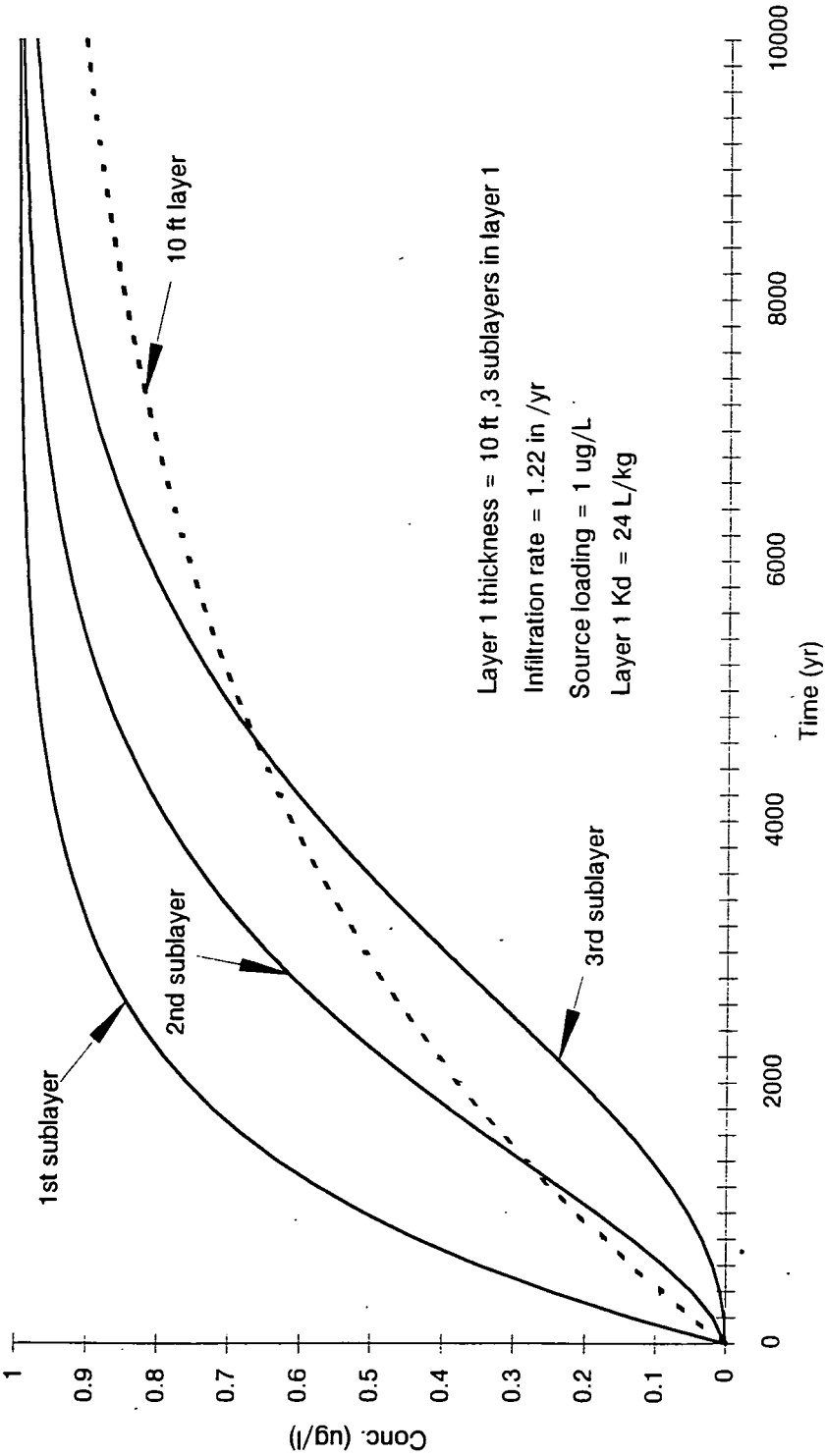

FIGURE F.1.I-3 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS AND 10,000-YEAR MODELING PERIOD

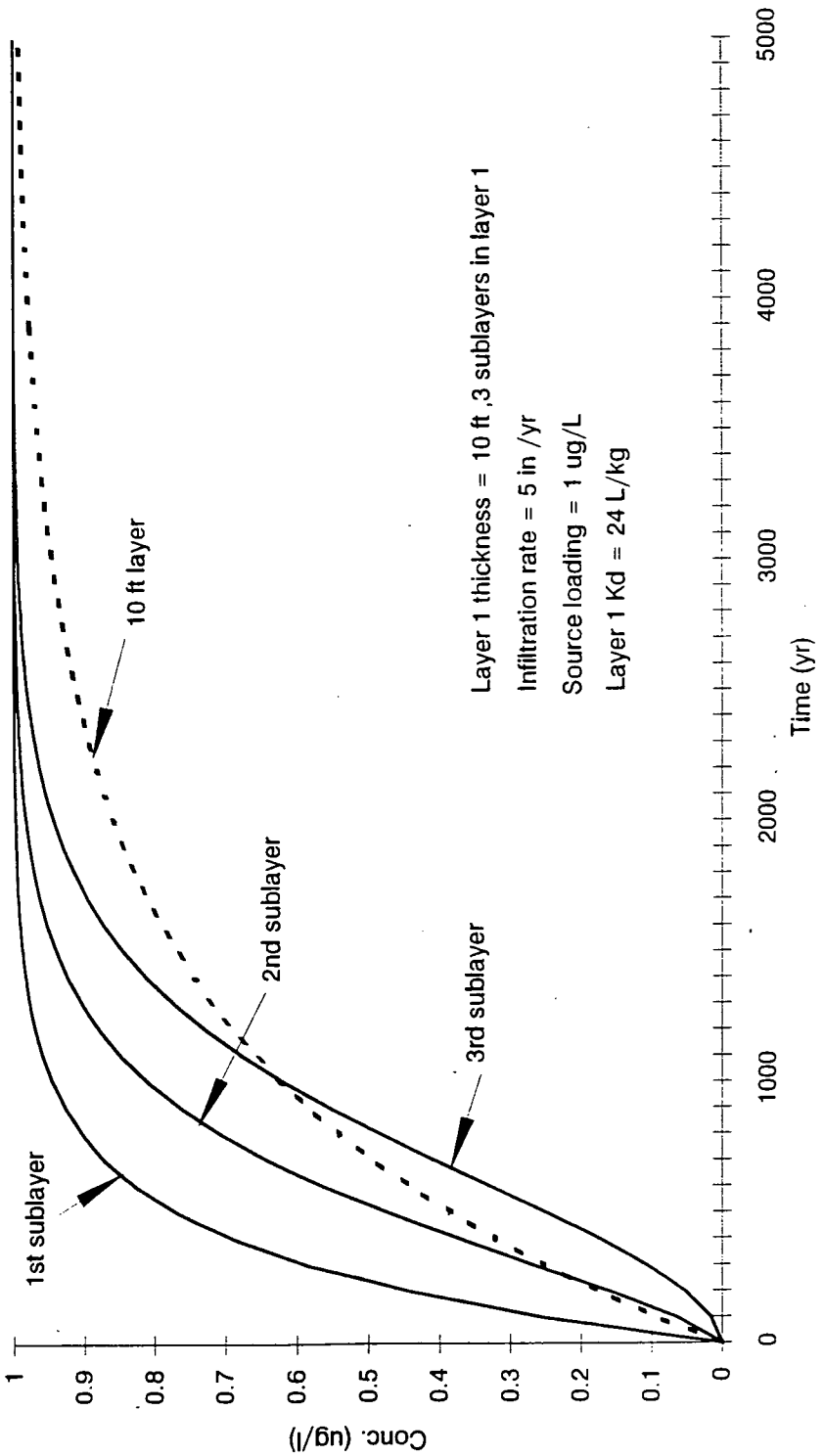

FIGURE F.1.I-4 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS AND 5000-YEAR MODELING PERIOD

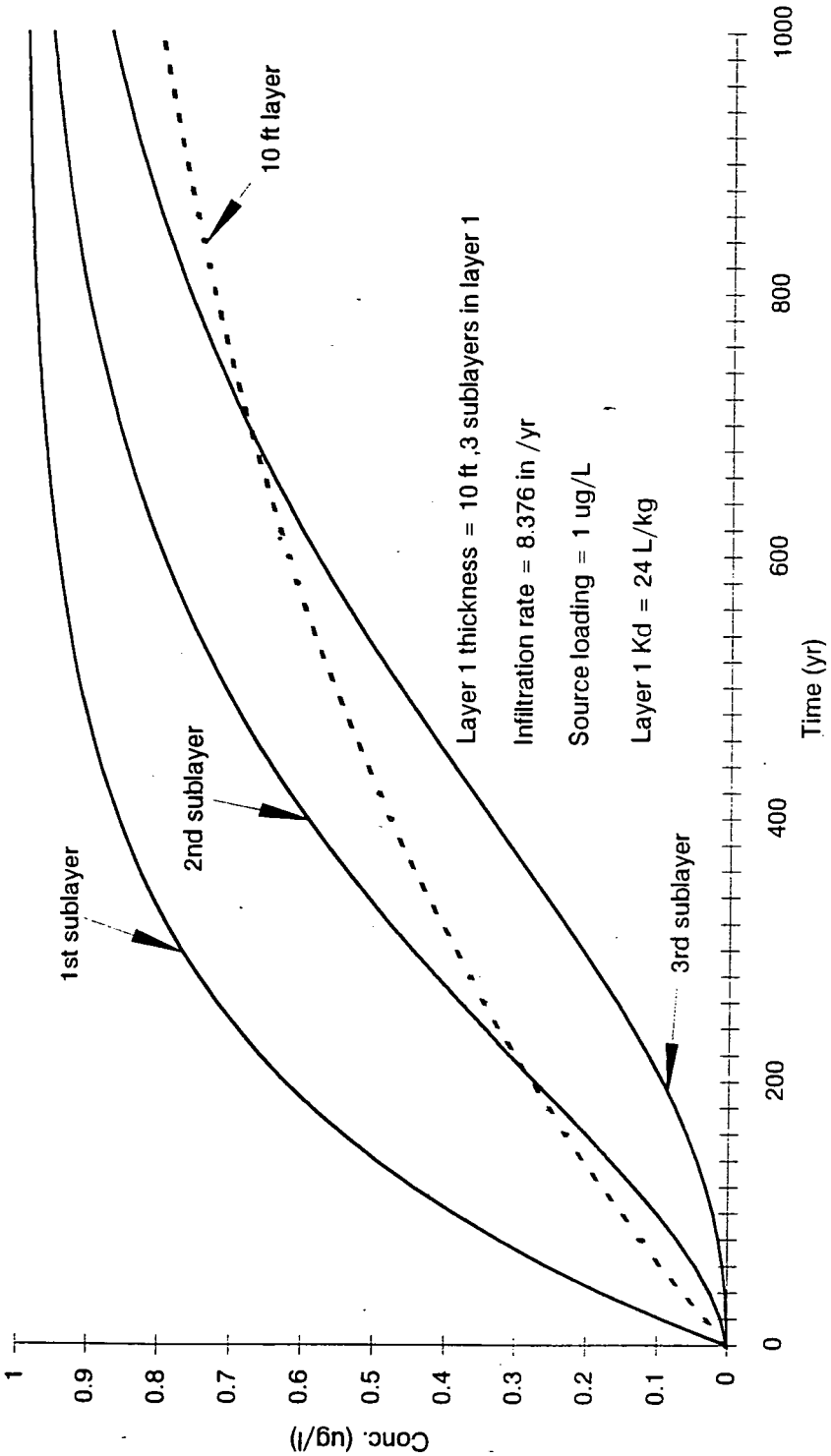

FIGURE F.1.I-5 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS, 1000-YEAR MODELING PERIOD, AND 8.4 IN/YR INFILTRATION RATE

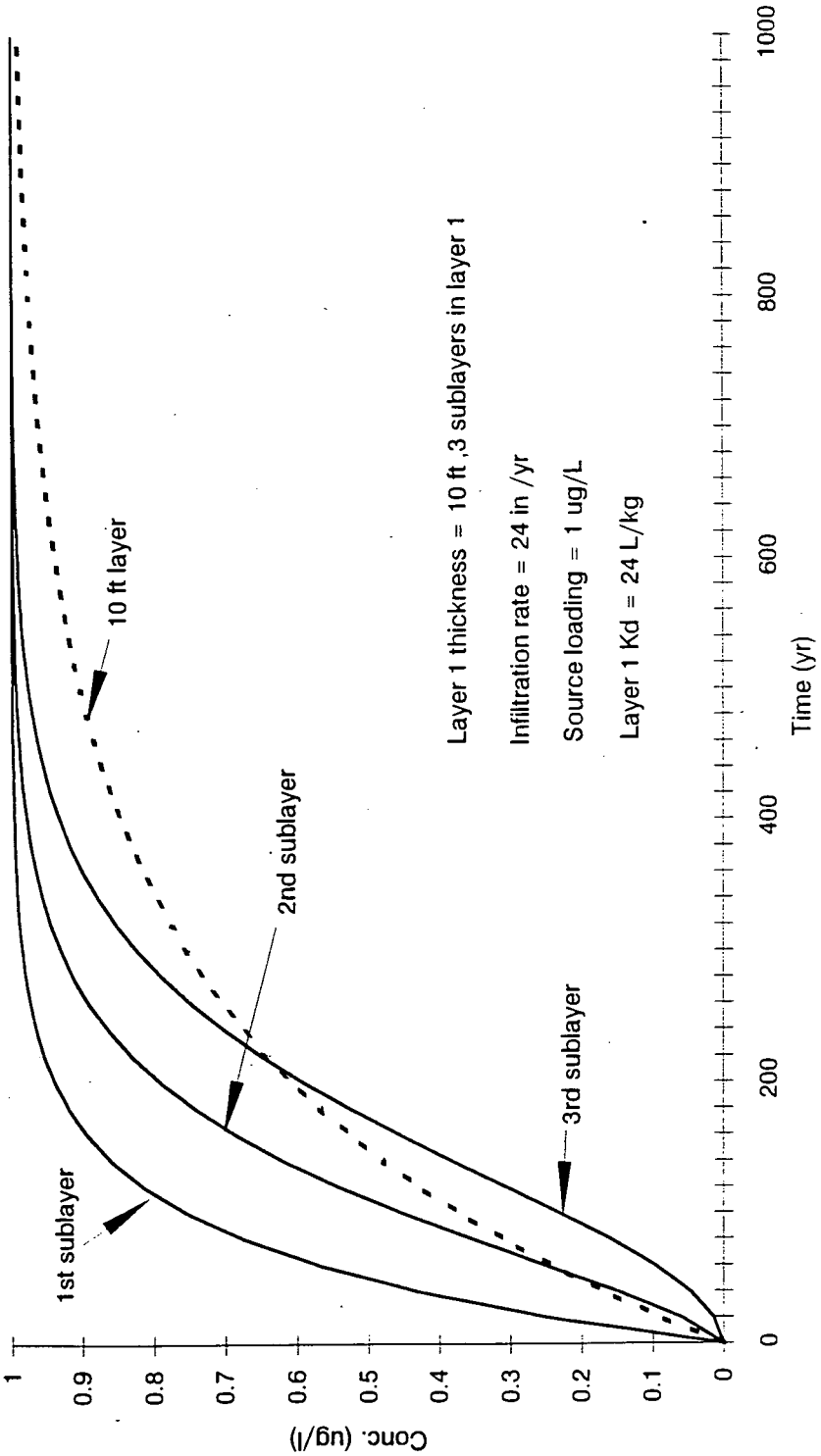

FIGURE F.1.I-6 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS, 1000-YEAR MODELING PERIOD, AND 24 IN/YR INFILTRATION RATE

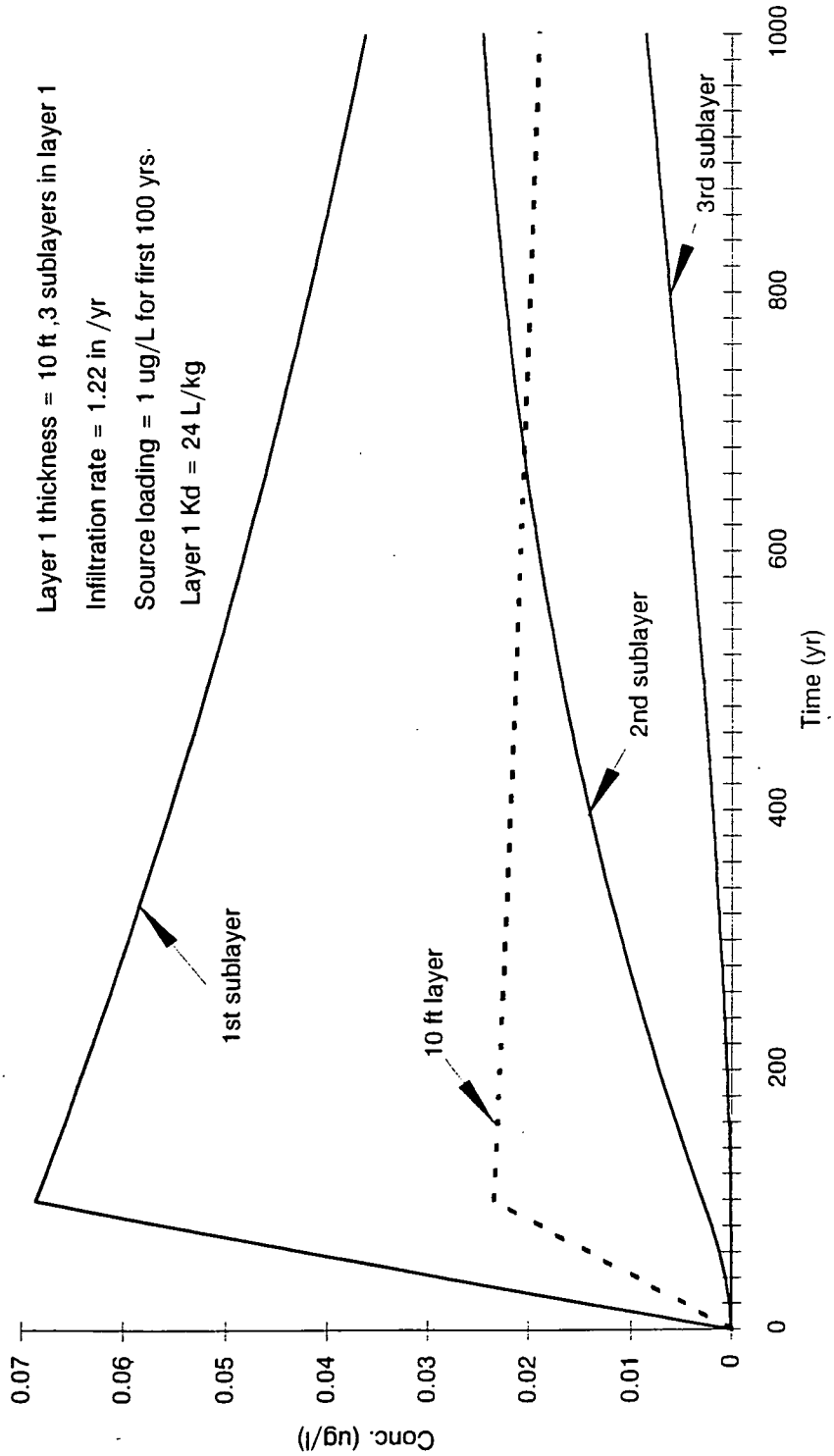

FIGURE F.1.I-7 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS, 1000-YEAR MODELING PERIOD, 100-YEAR LOADING PERIOD, AND 1.22 IN/YR INFILTRATION RATE

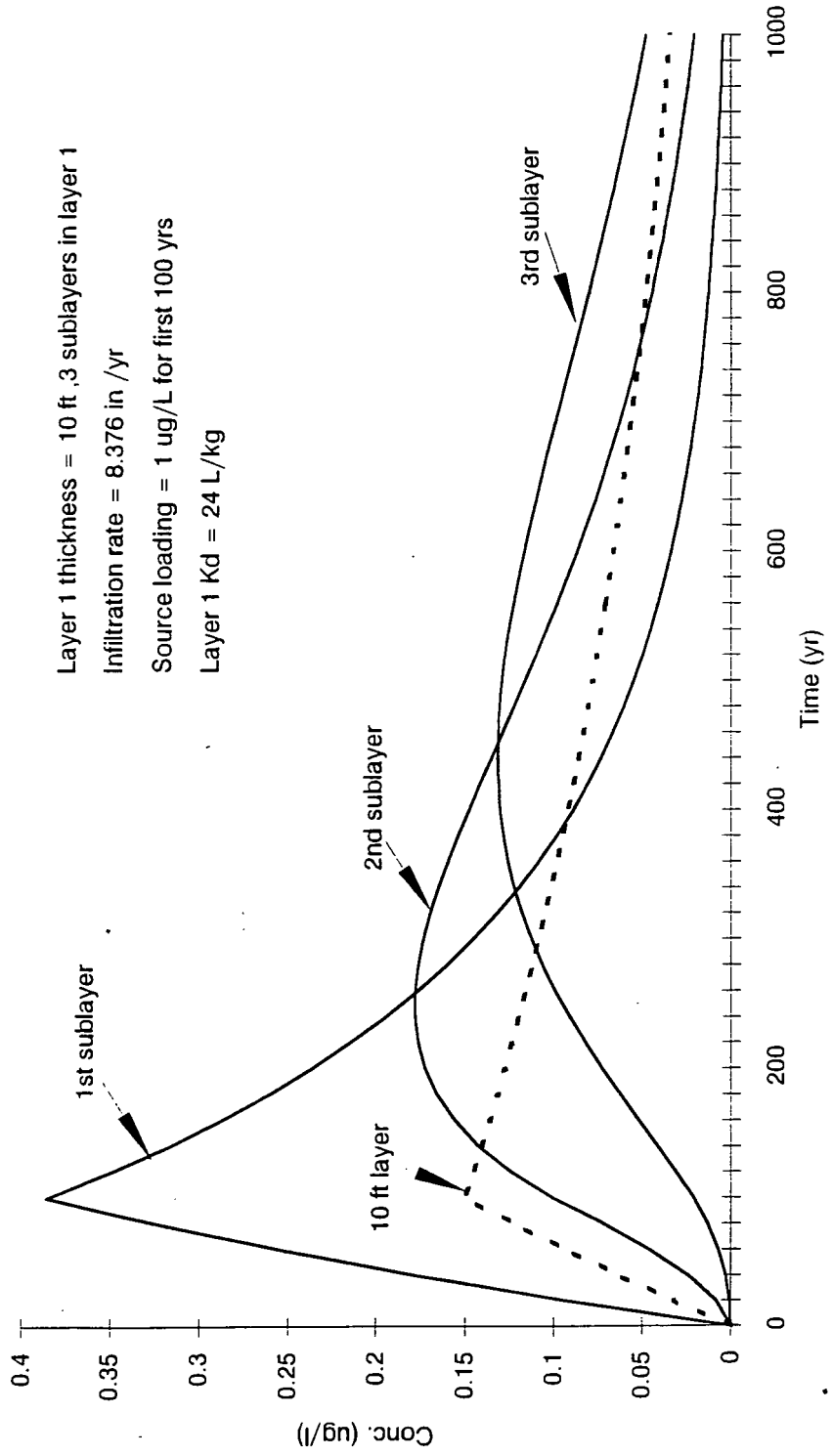

FIGURE F.1.I-8 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS, 100-YEAR MODELING PERIOD, 100-YEAR LOADING PERIOD, AND 8.4 IN/YEAR INFILTRATION RATE

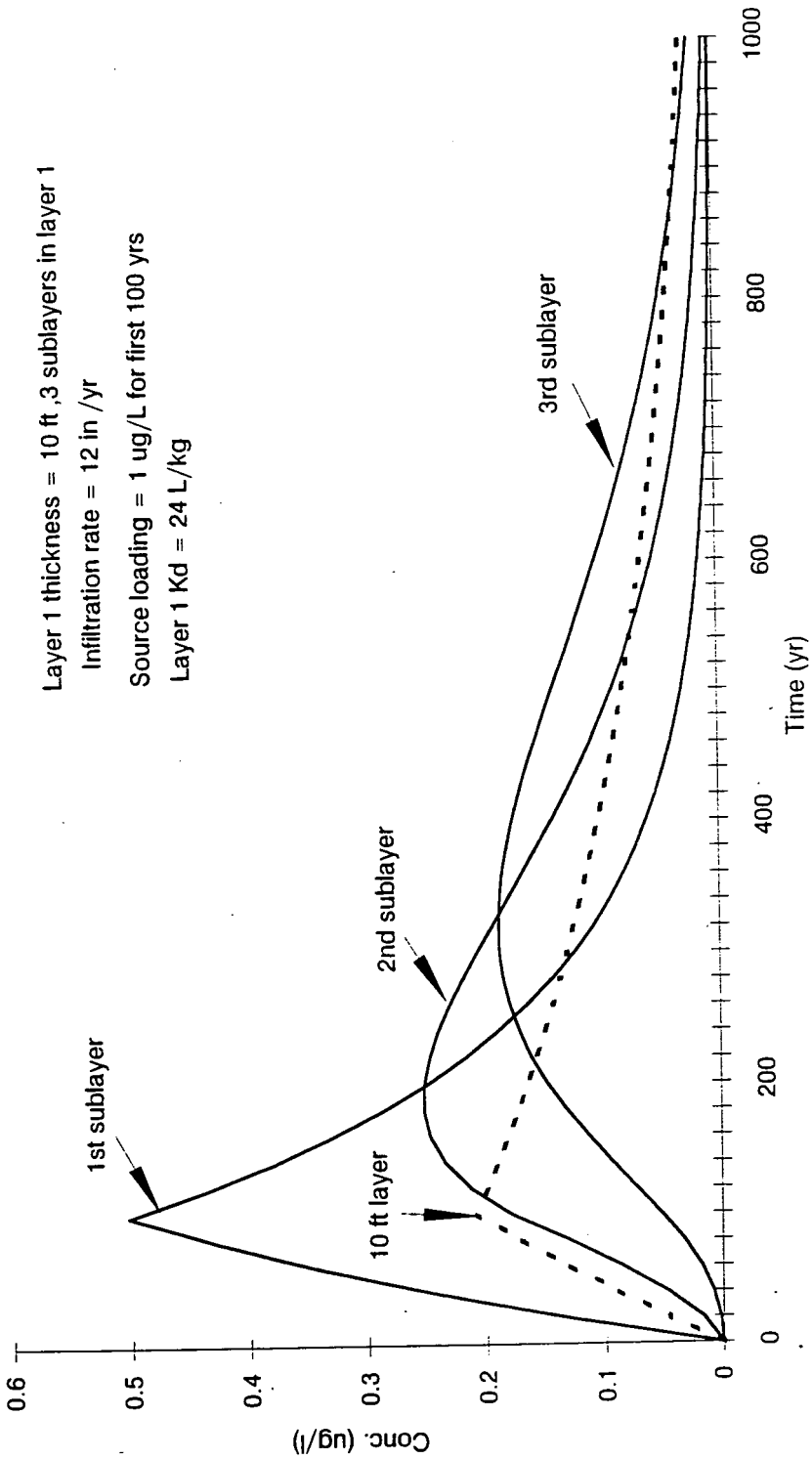

FIGURE F.1.I-9 PREDICTED URANIUM CONCENTRATION IN GRAY CLAY SUBLAYERS USING 3 SUBLAYERS, 1000-YEAR MODELING PERIOD, 100-YEAR LOADING PERIOD, AND 12 IN/YEAR INFILTRATION RATE

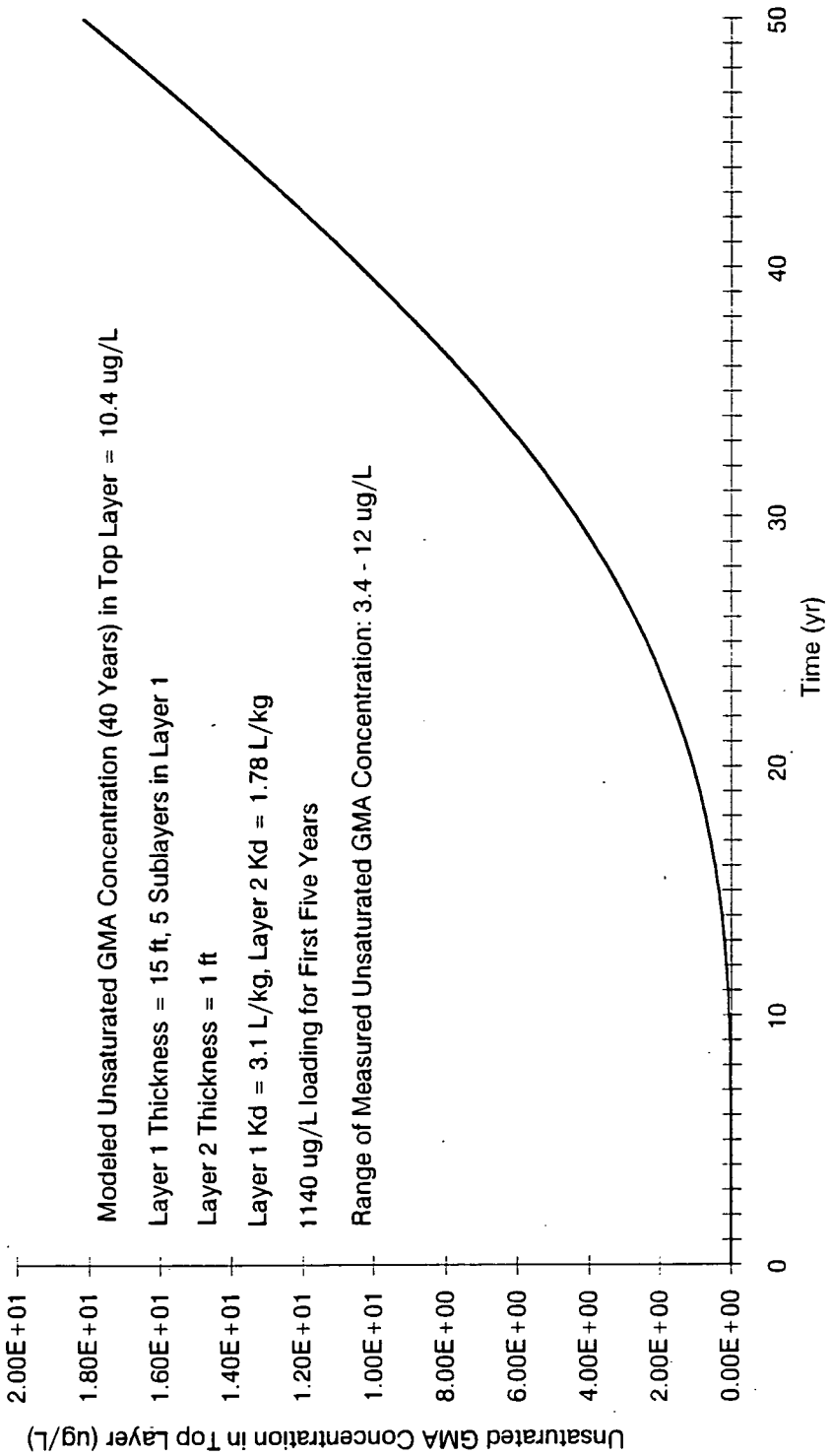

FIGURE F.1.I-10 PREDICTED URANIUM CONCENTRATION IN PERCHED GROUNDWATER AT LYSIMETER TEST WELL 11130

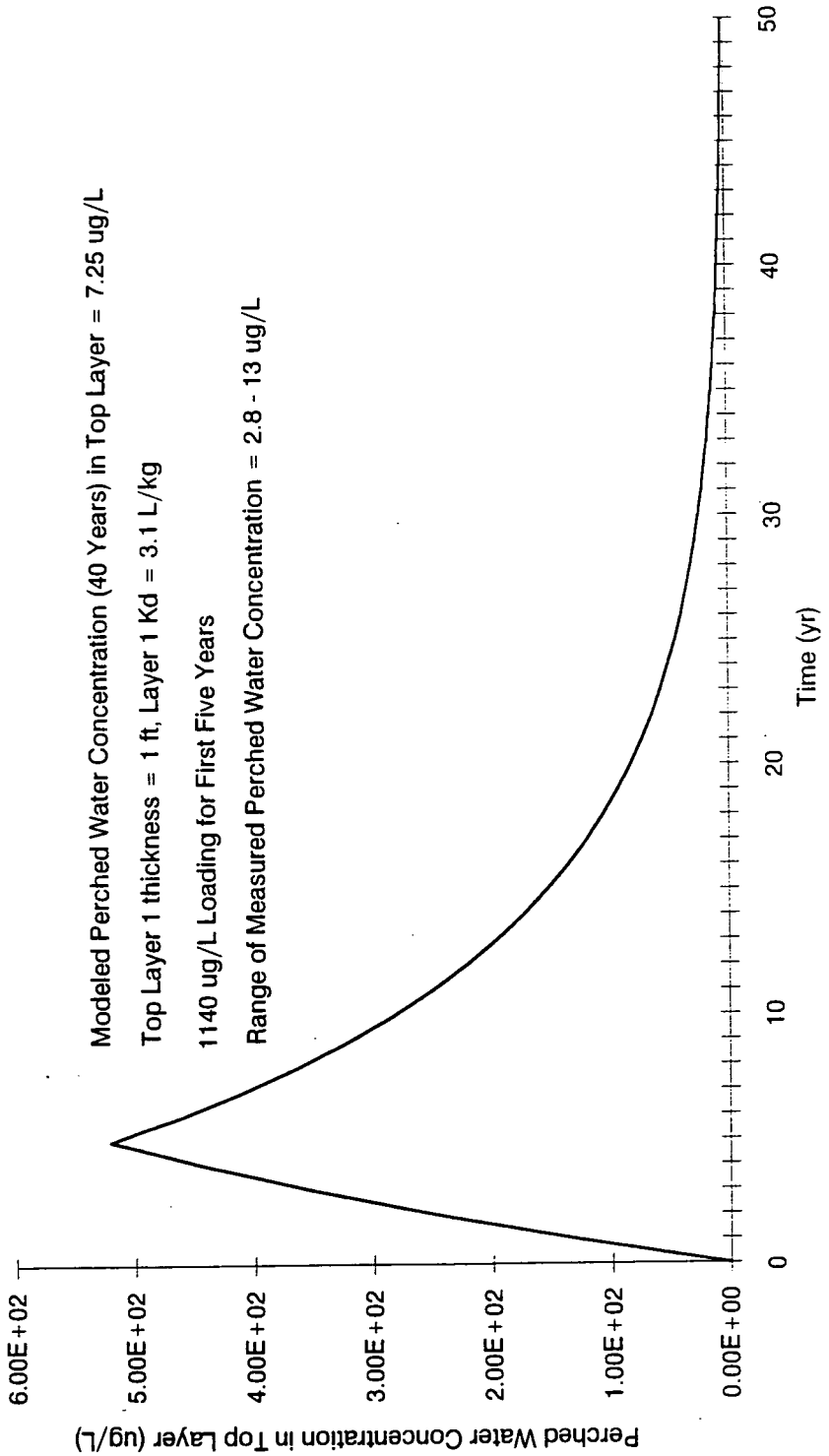

FIGURE F.1.I-11 PREDICTED URANIUM CONCENTRATION IN PERCHED GROUNDWATER AT LYSIMETER TEST WELL 11131

ATTACHMENT F.1.II
DESCRIPTION OF THE ODAST CODE

F.1.II.1 INTRODUCTION

To estimate the flux of contaminants through the vadose zone overlying the Great Miami Aquifer, the vadose zone is assumed to consist of a homogeneous, isotropic clay layer (representing glacial till) overlying a homogeneous, isotropic sand layer (unsaturated aquifer). Flow in the vadose zone is assumed to be unsaturated, steady-state, and one-dimensional (vertical). Mass transport is transient and is assumed to be one-dimensional. These assumptions are made to perform one-dimensional modeling (with vertical transport) with HELP and ODAST; otherwise, a saturated condition would require two- or three-dimensional modeling to handle the lateral components of flow and transport.

The modeling of contaminant transport through the vadose zone is accomplished by means of uncoupled flow and mass transport calculations. The vertical seepage flow velocity is obtained by use of the HELP model (Schroeder et al. 1988). The seepage velocity is then used as input to the analytical solute transport code ODAST. An ODAST run is performed for each constituent that remains after initial toxicity and travel time screening, for each layer of the model. ODAST also includes the effects of source depletion and solute decay. For each constituent, ODAST output at the base of the vadose zone is used to calculate the aquifer mass loading history for input to the SWIFT saturated flow and solute transport model.

F.1.II.2 DESCRIPTION OF ODAST

The ODAST model implements an analytical solution to the partial differential equation

$$D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} - \lambda RC = R\frac{\partial C}{\partial t} \qquad \text{(F.1.II-1)}$$

where

C = constituent concentration (mass/volume) and with the constant coefficients
D = dispersion coefficient (length^2/time)
V = seepage velocity (length/time)
R = retardation factor (dimensionless)
λ = solute decay rate constant (time^{-1})

The solution must satisfy the initial and boundary conditions

$$C(x,0) = 0 \qquad \text{(F.1.II-2)}$$

$$-D\frac{\partial C}{\partial x} + VC\,|_{x=0} = \begin{cases} VC_o e^{-(\alpha+\lambda)t} & 0 \le t \le \tau_O \\ 0, & t > \tau_O \end{cases} \qquad \text{(F.1.II-3)}$$

$$\frac{\partial C}{\partial x}|_{x\to\infty} = 0 \qquad \text{(F.1.II-4)}$$

where the constants

C_o = initial source concentration (mass/vol)
α = source depletion rate constant (time^{-1})
τ_o = source depletion time (time)

The solution, which is too lengthy to list here, is obtained using a Laplace Transformation technique and involves products of exponential and complementary error functions (Javandel, et al. 1984).

Because the coefficients in the governing equation are constant and the solution must satisfy a zero concentration gradient condition as x approaches infinity, ODAST is only strictly applicable to 1-D transport in homogeneous, isotropic, semi-infinite media. However, the present application of ODAST is intended to provide conservative estimates of aquifer mass loading histories. Therefore, overburden layers that cannot reasonably satisfy these simplified conceptual models (e.g., brown clay layer) are not included in ODAST simulation.

Simulations of transport through two connected layers are carried out in two separate steps. In the first step, it is assumed that the first (top) layer is semi-infinite. Concentration history (breakthrough curve) of a constituent of interest is determined at distance $x = L_{top}$ which is equal to the distance from the source to the base of the first layer. The assumption of semi-infiniteness is also applicable to the second (bottom) layer. In the second step, the concentration history curve at the base of the top layer is discretized into a number of contiguous rectangular concentration pulses. For each rectangular concentration pulse, the solution of Equation (F.1.II-1) is used to describe the transport of the pulse from $x = 0$ at the interface between the first and second layers to $x = L_{bot}$ at the base of the second layer. The concentration at the bottom of the second layer is the sum of the contribution from all the concentration pulses at the base of the top layer. The resultant concentration at the base of the bottom layer is then normalized with respect to the concentration at the source.

Model runs are executed for each screened constituent, in each layer, and at each waste area in 125 by 125 foot unit areas. The relevant output is the normalized concentration history at the base of the layer considered (i.e., groundwater table). For a particular waste area and constituent, bottom layer ODAST output accounts for the delay in contaminant migration introduced by the top layer through the use of a concentration history curve at the base of the top layers, described above. For RI/FS modeling, concentrations are calculated up to 1,000 years, typically in steps of 20 years. Constituents that migrate quickly, such as organics, require smaller time steps for accurate representation of loading curves.

F.1.II.3 DETERMINATION OF ODAST INPUT PARAMETERS

F.1.II.3.1 Seepage Velocity

Seepage velocity is defined as the actual rate of movement of fluid particles through porous media (Fetter 1986). For ODAST, the vertical seepage velocity is determined by:

$$V = q^{\left(1 - \frac{1}{2b+3}\right)} \left[\frac{K_S^{\left(\frac{1}{2b+3}\right)}}{n}\right] \qquad \text{(F.1.II.3-1)}$$

where

V	= seepage velocity (length/time)
q	= percolation rate (length/time)
$\frac{1}{2b+3}$	= empirical soil-dependent parameter
K_S	= saturated vertical hydraulic conductivity (length/time)
n	= porosity

F.1.II.3.2 Dispersion Coefficient

Dispersion is a phenomenon by which a solute in flowing groundwater is mixed with uncontaminated water and is caused by differences in velocity that water particles travel at the pore level. Dispersion coefficient controls the extent of mixing. The greater the coefficient, the greater the extent of mixing. In the ODAST simulation runs, the following empirical expression is used (Biggar and Nielsen 1976):

$$D = 6.458 \ X \ 10^{-4} + .14V^{1.11} \qquad \text{(F.1.II.3-2)}$$

where

V	= seepage velocity (feet/day)
D	= hydrodynamic dispersion coefficient (feet^2/day)

Note that the above expression is unit-specific

F.1.II.3.3 Retardation Factor

Retardation factor is a factor by which a solute front travels more slowly than the actual seepage velocity (Fetter 1986). Retardation is caused by adsorption of solute onto the surface of the granular materials through which groundwater flows. For ODAST, retardation factor is determined by:

$$R = 1 + \frac{\rho_b K_d}{\theta} \qquad \text{(F.1.II.3-3)}$$

where

ρ_b = bulk density of solid (mass/vol)
K_d = constituent partitioning coefficient (vol/mass)
θ = soil moisture content (vol/vol)

F.1.II.3.4 Solute Decay Rate Constant

Decay rate constant is a constant that linearly relates the rate of decay (the rate of change of mass) of a chemical to the mass of the chemical. The decay rate constant of a constituent may be estimated from

$$\lambda = \frac{\ln(2)}{\tau_{1/2}} \qquad \text{(F.1.II.3-4)}$$

where

$\tau_{1/2}$ = constituent half-life (time)
λ = decay rate constant (time)

F.1.II.3.5 Source Depletion Rate Constant and Time

The source depletion rate constant and time are computed from the time integration of mass flow and decay and the specification of an arbitrary mass depletion fraction which is very close to unity:

$$M_{depl} = \int_0^{\tau_0} m dt = AqC_0 \int_0^{\tau_0} e^{-(\alpha + \lambda)t} dt \qquad \text{(F.1.II.3-5)}$$

000939

and

$$F = \frac{M_{depl}}{M_{tot}} = 1 - e^{-(\alpha + \lambda)\tau_0} \qquad \text{(F.1.II.3-6)}$$

where

M_{depl}	= mass of constituent depleted at τ_0
F	= mass depletion fraction which is specified to be close to unity
M_{tot}	= total mass of constituent in waste
m	= instantaneous source mass flow (mass/time)
A	= area covered by waste (length^2)

These lead to the two expressions

$$\alpha = \frac{qAC_0}{M_{tot}} - \lambda \qquad \text{(F.1.II.3-7)}$$

and

$$\tau_0 = \frac{-\ln(1-F)}{\alpha + \lambda} \qquad \text{(F.1.II.3-8)}$$

for source depletion factor and time.

Owing to the method of inverting the Laplace Transform used to obtain the closed form solution in ODAST, an execution error occurs when the parameter $[V^2 - 4DR(\alpha+\lambda)]$ becomes negative. This may occur occasionally for runs with relatively low retarded velocities and dispersion predominantly due to molecular diffusion. This error is avoided by implementing the following calculation steps:

1) In the event that $V^2 - 4DR(\alpha+\lambda)$ is less than zero, then set $\alpha = 0$ and

$$\tau_0 = \frac{M_{tot}}{qAC_0} \qquad \text{(F.1.II.3-9)}$$

2) If τ_0 calculated in Step 1 is less than 70 years, then set τ_0 = 70 years (70-year rule).

[Note: The US EPA "70-Year Rule" (US EPA 1988) is used to provide an estimate of the source term when data are not available or the data indicate that the source term would be depleted in less than 70 years. To apply the rule, it is assumed that 1/70 of the total contaminant inventory leaches into the groundwater each year for 70 years.]

Based on the principle of mass conservation, determine the initial concentration of the waste area using the following expressions:

$$C_0 = \frac{M_{tot}}{qA\tau_0} \quad , \lambda = 0 \qquad \text{(F.1.II.3-10)}$$

$$C_0 = \frac{\lambda M_{tot}}{qA(1 - e^{-\lambda\tau_0})} \quad , \lambda \neq 0 \qquad \text{(F.1.II.3-11)}$$

[Note that τ_0 in the above two expressions is equal to 70 years.]

F.1.II.4 REFERENCES

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ATTACHMENT F.2.I
OPERABLE UNIT 5 POST-RI FIELD AND LABORATORY GEOCHEMICAL STUDY

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ATTACHMENT F.2.I
OPERABLE UNIT 5 POST-RI FIELD AND LABORATORY GEOCHEMICAL STUDY

F.2.I.1 OVERALL OBJECTIVE

For Operable Unit 5 to properly remediate uranium-contaminated soil, it is important that the total extent of contamination and the concepts of leaching and subsequent transport of uranium, the major contaminant on site, be understood to properly assess the environmental impact this contaminated soil could have on the underlying groundwater quality in the Great Miami Aquifer. A limited amount of soil samples have been taken to determine the vertical extent of contamination in source/waste material outside of the former production area. Geochemical information collected to understand the concepts of leaching and transport of uranium was presented in the Operable Unit 5 RI Report (DOE 1995) in Appendix F.3, Attachments I and II. Attachment I describes the historical airborne release of uranium and geochemical concepts of the subsurface uranium distribution at the FEMP. Attachment II presents the zonation and values of geochemical parameters used for fate and transport modeling for the Operable Unit 5 RI Report to support the baseline risk assessment. Geochemical information for other contaminants was generally taken from literature sources and verified by limited site-specific TCLP data.

Two geochemical parameters, K_l and K_e, describe the leachability of a contaminant from a source material and the percent of the contaminant which is extractable from the source material, respectively. K_l is a source leaching coefficient which is a measure of a contaminants mobility due to dissolution and desorption from the source. This parameter is used to define the initial aqueous loading of a contaminant based on the extractable portion (i.e., K_e) or total mass of the contaminant in the source material. K_e defines the portion of the contaminant which is relatively more extractable from the source material. In general, the longer a contaminant remains adsorbed to the surface of a solid the more likely it is to be incorporated into the solid by surface reactions where it is no longer available for desorption under environmental conditions. K_e is the parameter which can be used to define the extractable fraction of contaminant which can be mobilized due to desorption. K_e can also be used as a measure of the homogeneity of the contaminant (primarily soluble or insoluble) in the source material.

Various release histories and forms of uranium in contaminant sources resulted in different values of K_l and K_e in different source areas. In general there were three types of material identified at the FEMP, two of which could be considered as contaminant source material (waste material and contaminated media) and the third was soil with background concentrations of uranium.

It was shown in Attachment II of the Operable Unit 5 RI Report that uranium K_l values of 15 L/kg and 325 L/kg were appropriate for contaminated soil in areas inside and outside portions of the

production area, respectively. These values were used for fate and transport modeling and were determined using area-specific uranium concentrations measured in in situ leachate, waste material, contaminated soil, perched water, TCLP samples, and/or batch test results. In addition, the percent of extractable uranium (K_e) in the waste material was described in this Attachment. K_e was shown to range from 30 to 50 percent for waste material. Sources of information used to determine K_e included the ORNL soil characterization and washing study (Lee and Marsh 1992) and Operable Unit 2 batch tests (DOE 1993).

Understanding K_e is important for describing the data collected from lysimeters in the south east portion of the FEMP. The results showed that at one time (1950s and 1960s) a highly soluble form of uranium (low K_l) was transported to this area which in turn resulted in high uranium leachate concentrations in this area. With time the highly soluble uranium leached out, leaving behind less soluble uranium with a much higher K_l. As the soluble uranium leached out of the material, the K_e value decreased with time. The K_e parameter was not used for fate and transport modeling for the Operable Unit 5 RI Report; however, it was used to explain the source of contamination detected in the lysimeters.

At the time Attachments I and II from Appendix F.3 of the Operable Unit 5 Draft RI Report were written, a limited amount of data (soil samples, batch test results, and TCLP results for uranium only) was available to determine the extent of uranium contamination and to develop uranium K_l and K_e values for outside of the former production area. There were several soil samples and little, if any, K_l and K_e data available for other contaminants in this area (refer to Figure F.3.II-2 in Attachment F.3.II of Appendix F of the Operable Unit 5 RI Report). Therefore, an additional investigation was conducted to support assumptions used for the fate and transport modeling performed as part of the Operable Unit 5 FS and to verify the assumptions made in the Operable Unit 5 Draft RI Report. This investigation was conducted to provide additional information as to the extent of uranium and other Operable Unit 5 COCs contamination; to confirm the leachability of uranium in surface and subsurface soils outside the former production area which have been affected by air deposition; and to determine the leachability of other Operable Unit 5 COCs in surface and subsurface soil. This information will be helpful in defining contaminant source terms and the need for remedial actions. The details of the project are described in the Project-Specific Plan for Operable Unit 5 K_l Soil Sampling and Analysis (DOE 1994).

At the present time, only the following preliminary information is available from the study and only these results will be described below. The results which are available include: soil sampling results for uranium and technetium-99; K_l and K_e results for uranium; and TCLP results for technetium-99 . The following sections describe the details of the laboratory procedures and analyses which were

conducted, as well as, the details of sample collection, derivation of equations, calculation procedures, and preliminary results.

F.2.I.2 EXTENT OF SOIL CONTAMINATION

F.2.I.2.1 Objective

Additional soil samples were collected by Operable Unit 5 in order to verify the areal and vertical extent of contamination. The samples were collected from various depths (0- to 30-inch) in the glacial overburden to determine the total depth of contamination. These samples were taken at numerous locations to provide information on the areal distribution of contamination. These additional samples will help to verify the extent of contaminant source material in the area outside of the former production area, as well as, provide initial contaminant soil concentrations for the batch tests and TCLP analyses.

F.2.I.2.2 Sampling Locations and Procedure

To better verify assumptions made on the extent of source material and the mobility of selected Operable Unit 5 COCs in soil located outside the former production area, which were previously assigned conservative K_l values in fate and transport modeling and which did not account for the extractable portion (i.e., assuming a K_e value of 100 percent) of contaminant in a source, additional soil sampling, batch tests, and TCLP analyses were conducted. Soil samples from six vertical intervals were collected at 15 locations within the FEMP property boundary (see Figure F.2.I-1), but outside the former production area. The locations of these samples were based on prevailing wind directions, source locations, and soil types. Sampling locations were biased toward areas of known or suspected surface soil contamination. Discrete soil samples were collected for dry bulk density analyses from intervals at 0 to 6 and 24 to 30 inches from an area adjacent (within a 3-foot radius) to each sampling location. Soil samples from the sampling locations were collected at the following intervals: 0 to 2 or 6, 6 to 12, 12 to 18, 18 to 24, and 24 to 30 inches. The 2 to 6 inch intervals within the vertical soil sample interval were not analyzed but were segregated and returned to the top of the excavated area during abandonment of the sampling site. Further details on the sampling locations and depths are provided in the PSP for Operable Unit 5 K_l Soil Sampling and Analysis (DOE 1994).

Soil sampling analyses were conducted for the list of parameters contained in Table F.2.I-1. A total of 26 HSL metals and 17 radiological contaminants, including isotopic as well as total uranium, are being analyzed. The analytical results were expected to be used in risk assessment calculations; therefore, laboratory method detection limits (MDLs) and highest allowable minimum detectable concentrations were set at or as near as technically feasible to a level approximating a 1×10^{-6} ILCR for each contaminant for the reasonable maximum exposure (RME) farmer/child risk scenario. In order for the off-site laboratory to achieve these low detection limits, large sample volumes were

required for the radiological constituents. Approximately four to seven gallons of soil were collected at each sample interval to provide an adequate sample volume for the specified analytical program. Reference can be made to Table F.2.I-1 for specific analytical volume/mass requirements and to Table F.2.I-2 for the minimum amount of soil collected from each soil interval per location in order to achieve analytical requirements. Table F.2.I-3 shows the quality control (QC) samples which were collected as part of the PSP for Operable Unit 5 K_1 Soil Sampling and Analysis (DOE 1994).

After collection, the soil samples were prepared by the following procedure. Each soil sample was passed through a No. 10 (2.0 millimeter) stainless steel sieve into a stainless steel container and then homogenized using a sample splitter or a riffle sampler. The sample splitter/riffle sampler separated the sample into multiple fractions of approximately equal volume. These samples were recombined and passed through the riffle sampler a second time to ensure sample homogeneity. After sample preparation was completed, the sample material was placed into the containers specified in Table F.2.I-1. Further details on sample preparation including preservatives and holding times are also provided in Table F.2.I-1.

One of the locations, KL-SS-15, was moved three times from its originally intended location in an attempt to sample from an undisturbed area. The soil collected from the final location for KL-SS-15, identified on Figure F.2.I-1, is still suspected of being from a disturbed area. Therefore, analytical results may not be representative or comparable to other samples collected from undisturbed areas under for the PSP for Operable Unit 5 K_1 Soil Sampling and Analysis (DOE 1994).

F.2.I.2.3 Laboratory Analyses

The total uranium analysis, which was performed to determine the concentration of uranium in the contaminant source material, was performed by both the FEMP (on-site) and Environmental Physics Incorporated (EPI) (off-site) laboratories. Reference can be made to Table F.2.I-1 for additional analyses which were performed by these laboratories. The analyses conducted at the FEMP laboratory were performed at Analytical Support Level (ASL) B and the off-site laboratory analyses were at ASL D. The ASL level is a measure of the QC which is performed by a laboratory during analytical methods. Although the analyses at the FEMP laboratory were performed at ASL B, replicate analyses were performed in order to strengthen the data set integrity. The FEMP laboratory methods used for isotopic uranium were 256-S-2001 (thermal mass spectrometry) and C94-161 (inductively coupled plasma/mass spectroscopy) and for total uranium, 3002 (Bromopadap). The FEMP laboratory methods used for total uranium analysis of the leachate was 256-S-1004 (kinetic phosphorescence). All of these methods are consistent with the Site-wide Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Quality Assurance Project Plan.

The off-site lab used in-house method number, EPI A-005, which used liquid scintillation detection methodology to measure concentrations of technetium-99 in soil.

F.2.I.2.4 Preliminary Results

The preliminary total uranium concentrations detected in the soil samples by the on-site lab are summarized in Tables F.2.I-4 and F.2.I-5. These concentrations are total uranium concentrations measured by direct total uranium analysis (3002, Bromopadap). The preliminary technetium-99 concentrations which were measured by the off-site laboratory are presented in Table F.2.I-6. Only the total uranium measurements have been validated to the study's requirement level, Level D (DOE 1994).

Table F.2.I-4 shows the uranium concentrations (Co) for the samples collected from the 0- to 2-inch interval and Table F.2.I-5 presents the uranium concentrations for the 24- to 30-inch interval. Table F.2.I-6 summarizes the technetium-99 concentrations which were measured for soil samples taken from both the 0- to 2-inch and 24- to 30-inch intervals.

From the results it can be seen that the total uranium concentrations measured in the 0- to 2-inch interval ranged from 2.8 μg/g (KL-SS-02) to 81.8 μg/g (KL-SS-10) with a majority (14 out of 16 samples) of the measurements over 10 μg/g. The total uranium concentrations measured in the 24- to 30-inch interval varied from 1.6 μg/g (KL-SS-01) to 10.7 μg/g (KL-SS-04) with only one measurement over 10 μg/g (KL-SS-04). Most of the uranium measurements for the 24- to 30-inch interval samples are close to the background uranium concentration which is 3.7 μg/g.

The preliminary technetium-99 concentrations in the soil samples from the 0- to 2-inch and 24- to 30-inch intervals ranged from 0.0085 pCi/g to 0.9458 pCi/g. The concentrations for technetium-99 are not broken down into two groups since only two preliminary concentrations are available for the samples collected from the 24- to 30-inch interval and this is not enough data to provide a meaningful range. Even with the large sample volumes which were collected and the extremely long counting times, difficulty (i.e., matrix interference and high secondary activity) was encountered in measuring technetium-99 soil concentrations at the K_l study's contract detection limit for soils (0.015 pCi/g). This limit is much lower than the SCQ limit for technetium-99 (1.0 pCi/g) which was used for Operable Unit 5 RI samples. Therefore, due to the difficulties and the fact that the results are unvalidated, all technetium-99 concentrations are considered to be preliminary.

F.2.I.3 TWO-STEP BATCH TEST

F.2.I.3.1 Objective

To verify assumptions made on the mobility of uranium in soil located outside the former production area, which was previously assigned conservative K_l values in fate and transport modeling and which

did not account for the extractable portion (i.e., assuming a K_e value of 100 percent) of contaminant in a source, a series of two-step desorption batch tests were conducted. The soil samples, which were described above, were used in the batch tests along with a leaching solution to determine site-specific K_l and K_e values for uranium. The following sections provide the details of the batch tests for uranium, including information on the procedure, theory, results, and observations.

F.2.I.3.2 Two-Step Batch Test Laboratory Procedure

A series of two-step desorption tests were performed on the soil of interest to determine the manner in which uranium will leach into solution from source materials. The parameters, resulting from the batch test, which describe the leaching/extraction process are K_{l1}, the average leaching coefficient for the total uranium mass minus background; K_{l2}, the leaching coefficient for the soluble portion of uranium; and K_e, the percent of extractable uranium and a measure of the homogeneity of the source material. K_{l1} is synonymous to K_l, the leaching coefficient described earlier, and it is the parameter which has been used for modeling in the Operable Unit 5 RI. K_{l2}, which has not been defined before, is the leaching coefficient which would be used if only the extractable (K_e) soluble mass of uranium was considered for modeling. For the Operable Unit 5 FS, K_{l2} and K_e are not directly used in the modeling but they are used to define the type of source material which was collected and to describe the lysimeter results which were discussed in Section F.2.I.1.

A total of 32 batch tests were performed on soil samples, which consisted of 16 soil samples from the 0- to 2-inch interval and 16 soil samples from the 24- to 30-inch interval. One sample from the 0- to 2-inch interval and one sample from the 24- to 30-inch interval were duplicate samples.

Total and isotope-specific uranium analyses on the initial soil samples were performed by both the FEMP and EPI, which participates in the U.S. Environmental Protection Agency's (EPA) Contract Laboratory Program (CLP). Additional analyses which were performed are included in Table F.2.I-1.

The desorption batch test consisted of placing a 400 gram portion of homogenized soil sample into a reactor with 3.5 L of pH adjusted water (water was pH adjusted with sulfuric acid to reflect acid rain conditions). The resulting initial liquid to soil ratio was 8.75. The soil and liquid mixture was tumbled at approximately 29 revolutions per minute until total uranium concentration in the pH adjusted water reached equilibrium.

The time period for the desorption test samples to reach equilibrium in each step was approximately two weeks. During each test, a sample of the leachate was analyzed periodically to verify when the sample reached equilibrium. This was performed by drawing off 20 mL of leachate and filtering the sample through a 0.45 micron size membrane filter to remove any solids. The samples were to be

collected at approximately 72, 144, 168, 240, 288, 360, and 384 hours, but some adjustments were made due to holidays or weekends. All of the intermediate leachate samples were analyzed for total uranium at the FEMP Laboratory to allow quick turnaround times which were required during the test. The final leachate samples from each test were split between the off-site laboratory and FEMP Laboratory and analyzed for isotopic uranium and total uranium, respectively.

After completion of the first step of the desorption test, the second step was run for each sample using fresh pH adjusted water and the soil sample from the first reaction. Identical testing procedures were followed for the second step of the test. At completion of the second batch test, a soil sample was collected from the tumbler and split for analysis of total and isotopic uranium by both the FEMP Laboratory and an off-site laboratory. The final leachate samples from each step were also split between the off-site laboratory and FEMP Laboratory and analyzed for isotopic uranium and total uranium, respectively. As described above, the total uranium analysis was performed by both the FEMP (on-site) and EPI (off-site) laboratories. The FEMP laboratory methods used for isotopic uranium were 256-S-2001 (thermal mass spectrometry) and C94-161 (inductively coupled plasma/mass spectroscopy) and for total uranium, 3002 (Bromopadap). The FEMP laboratory methods used for total uranium analysis of the leachate was 256-S-1004 (kinetic phosphorescence). All of these methods are consistent with the Site-wide Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Quality Assurance Project Plan.

Other parameters such as pH and specific conductivity can effect the desorption process and K_l value ([American Society for Testing and Materials] D-4319). Therefore, during each desorption test, periodic measurements were made for pH and specific conductivity. The measurements were made at the same time that leachate samples were collected for uranium analyses during the test. The pH and specific conductivity were measured by placing the instrument probe directly into the reactor. The instrument was calibrated each day for pH and specific conductivity. The specific conductivity was performed by zeroing the meter and the pH was calibrated by using a 4.0 and 7.0 pH buffer. Also, when using the probe, the reactors were organized to be sampled in increasing aqueous uranium concentration; the probe was also rinsed with deionized water between samples to avoid cross-contamination of the samples.

F.2.I.3.3 Derivation of Equations and Sample Calculations

Once the preliminary results of the completed batch tests were available, the leachability/extraction parameters of interest could be determined with the appropriate equations. These equations were derived mathematically considering the desorption/leaching processes. The following sections provide the details of the derivation of equations used for estimating uranium K_l values (i.e., K_{l1} and K_{l2}) and K_e values from the batch test results (See Section F.2.I.3.2 for a discussion on K_{l1}, K_{l2} and K_e) and a set of sample calculations for estimating these parameters.

F.2.I.3.3.1 Derivation of Equations

Parameters Measured During Laboratory Experiments

The parameters which were measured during the experiment and a definition of each parameter are summarized below.

C_0 = Initial concentration of contaminant in solid phase including background (μg/g)
C_{S0} = Initial concentration of contaminant in solid phase without background (μg/g)
C_{W1} = Concentration of contaminant in leachate at first equilibrium (μg/L)
C_{W2} = Concentration of contaminant in leachate at second equilibrium (μg/L)
W = Mass of test media for each test (g)
V = Volume of water used during each test (L)

(Note: Background uranium soil concentration = 3.7 μg/g; W = 400 g; V = 3.5 L)

Definitions of Variables

The variables which were estimated from the laboratory results defined above, are defined below.

m_{S0} = Initial mass of contaminant in solid phase without background (μg)
m_{W1} = Mass of contaminant in leachate at first equilibrium without background(μg)
C_{S1} = Concentration of total non-background contaminant in solid phase at first equilibrium (μg/g)
C'_{S1} = Extractable concentration of contaminant in solid phase at first equilibrium (μg/g)
C_{S2} = Concentration of total non-background contaminant in solid phase at second equilibrium (μg/g)
C'_{S2} = Extractable concentration of contaminant in solid phase at second equilibrium (μg/g)
K_{l1} = Leaching coefficient of total non-background contaminant mass in solid phase (L/kg)
K_e = Total extractable percent of contaminant in initial sample (percent)
(Note: K_e describes the total percent of soluble contaminants in the original test material. For practical application to Operable Unit 5 materials, contamination levels in Operable Unit 5 materials as determined through RI data can be reduced by a factor of K_e ($C = K_e \times C_{S0}/100$ percent). Since the non-soluble contaminants will not leach into infiltration waters and the contaminant pathway to receptors is disconnected, the non-soluble fraction of contaminants can be disregarded during the estimation of source terms for groundwater modeling.)
K_{l2} = Leaching coefficient of the extractable portion of contaminant (L/kg)
(Note: K_{l2} describes equilibrium balance between concentration of soluble contaminant in the solid phase and contaminant concentration in the leachate. Since equilibrium conditions are maintained in the natural state, the concentration of soluble contaminant in the solid phase and contaminant concentration in the liquid phase are always proportional. Therefore, K_{l2} provides the basis for estimating the rate of contaminant leaching as clean water infiltrates through the contaminated test material.)

Figure F.2.I-2 graphically shows these variables and the two-step desorption test concept.

Assumptions

The assumptions used for deriving the fundamental equations are presented below.

- The total volume of liquid samples collected for analyses during the two-step desorption test, but were not reintroduced into the desorption test vessel, did not significantly affect the soil:water mass ratio or the resulting equilibrium conditions.
- The total mass of suspended solids which were filtered out during analyses, but were not reintroduced into the desorption test vessel, are insignificant and will not impact the batch test results.
- A constant linear isotherm is maintained for the soluble contaminant between two equilibrium conditions.

Equations

The following information outlines the derivation of equations used to develop uranium K_{l1}, K_{l2}, and K_e values for Operable Unit 5. Figure F.2.I-2 presents the desorption mechanisms for the two-step desorption test pictorially.

From the original sample:

$$m_{S0} = C_{S0} \times W \tag{1}$$

From first equilibrium measurements:

$$m_{W1} = C_{W1} \times V \tag{2}$$

$$C_{S1} = \frac{m_{S0} - m_{W1}}{W} \tag{3}$$

$$K_{l1} = \frac{C_{S1}}{C_{W1}} \tag{4}$$

$$K_e = \frac{(C'_{S1} \times W) + (C_{W1} \times V)}{m_{S0}}(100\%) \tag{5}$$

From the second equilibrium measurements and by mass balance between the two equilibria:

$$(W \times C'_{S1}) - (W \times C'_{S2}) = C_{W2} \times V \qquad (6)$$

(Note: This equation shows that the difference between the two solid-phase soluble contaminant masses is the mass remaining in the second equilibrium leachate solution)

Assuming a constant linear isotherm for the soluble mass:

$$K_{l2} = \frac{C'_{S1}}{C_{W1}} = \frac{C'_{S2}}{C_{W2}} \qquad (7)$$

To derive the final equations the first step is to solve Equation 7 for C'_{S2}:

$$C'_{S2} = (C'_{S1})\left(\frac{C_{W2}}{C_{W1}}\right) \qquad (8)$$

The next step is to insert these results into Equation 6 to get:

$$(W)(C'_{S1})(1 - \frac{C_{W2}}{C_{W1}}) = (C_{W2})(V) \qquad (9)$$

and finally, solve for C'_{S1}:

$$C'_{S1} = \frac{(C_{W2})(V)}{(W)(1 - \frac{C_{W2}}{C_{W1}})} \qquad (10)$$

The final equations, determined by inserting C'_{S1} into Equations 5 and 7, are:

$$K_e = \frac{(C_{W1})^2(V)(100\%)}{(C_{S0})(W)(C_{W1} - C_{W2})} \qquad (11)$$

and

$$K_{l2} = \frac{(C_{W2})(V)}{(C_{W1} - C_{W2})(W)} \qquad (12)$$

For the special case when C_{W1} is less than or equal to C_{W2}, which typically results when the soil samples had background contaminant concentrations, K_e is undefined and the following equation can be used to determine K_l.

$$K_l = \frac{(C_{S0} \times W) - (C_{W1} \times V)}{(W \times C_{W1})} \tag{13}$$

F.2.I.3.3.2 Sample Calculations

Calculations were performed using the results of both the first and second desorption tests in order to determine K_{l1}, K_{l2} and K_e values. The calculations for these parameters were based on the desorption tests' analytical results from the FEMP Laboratory. Only the preliminary uranium results are presented in this document (Tables F.2.I-4 and F.2.I-5). A complete summary of the FEMP analytical results will be provided latter in a self-contained document (See Section F.2.I.5).

Two sample calculations are provided below. The first set of calculations is for KL-SS-01 from the 0- to 2-inch interval which has contaminant source material which is classified as contaminated media. The second set of calculations is for KL-SS-01 from the 24- to 30-inch interval which has contaminant levels in the source material which are classified as background. The calculations are organized in a manner which is similar to the derivation of equations (See Section F.2.I.3.3.1).

Calculations of Uranium K_l and K_e for KL-SS-01 (0- to 2-Inch Interval)

A sample calculation for estimating uranium K_l for the 0- to 2-inch interval is presented below.

$$m_{S0} = C_{S0} \times W = 6.9\ \mu g/g \times 400\ g = 2760\ \mu g$$

$$m_{W1} = C_{W1} \times V = 15\ \mu g/L \times 3.5\ L = 52.5\ \mu g$$

$$C_{S1} = \frac{m_{S0} - m_{W1}}{W} = \frac{2760\ \mu g - 52.5\ \mu g}{400\ g} = 6.77\ \mu g/g$$

$$K_{l1} = \frac{C_{S1}}{C_{W1}} = \frac{6.77\ \mu g/g}{15\ \mu g/L} \times 1000 g/kg = 451\ L/kg$$

$$K_e = \frac{(C_{W1})^2(V)(100\%)}{(C_{S0})(W)(C_{W1} - C_{W2})} = \frac{(15\ \mu g/L)^2(3.5\ L)(100\%)}{(6.9\ \mu g/g)(400\ g)(15\ \mu g/L - 0.9\ \mu g/L)} = 2.02\%$$

$$K_{l2} = \frac{(C_{W2})(V)}{(C_{W1} - C_{W2})(W)} = \frac{(0.9\ \mu g/L)(3.5\ L)}{(15\ \mu g/L - 0.9\ \mu g/L)(400\ g)} = 0.56\ L/kg$$

Calculations of Uranium K_l and K_e for KL-SS-01 (24- to 30-Inch Interval)

For the special case when C_{W1} is less than or equal to C_{W2}, which typically results when the soil samples had background contaminant concentrations, K_e is undefined and the following equation was used to determine the uranium K_l for KL-SS-01.

$$K_l = \frac{(C_{S0} \times W) - (C_{W1} \times V)}{(W \times C_{W1})} = \frac{(1.6\ \mu g/g \times 400\ g) - (0.9\ \mu g/L \times 3.5\ L)}{(400\ g \times 0.9\ \mu g/L)} \times 1000\frac{g}{kg} = 1769\ L/kg$$

F.2.I.3.4 Preliminary Results

The preliminary results of the series of two-step desorption tests for uranium contaminated soil taken from the 0- to 2-inch and the 24- to 30-inch intervals are presented in Tables F.2.I-4 and F.2.I-5, respectively. Included in the tables are the initial uranium concentrations (C_O) in the soil samples; the initial uranium concentrations (C_{SO}) in the soil samples minus the background concentration of uranium; the leachate concentrations (C_{W1} and C_{W2}); the initial non-background mass of uranium (m_{s0}) in the soil sample and the mass of uranium (m_{W1}) in the leachate after the first step of the desorption test; the concentration (C_{S1}) and extractable concentration (C'_{S1}) of uranium in solid phase at the first equilibrium; the leaching coefficient and extractable percent parameters (K_l and K_e) which were determined; and a classification system (i.e., CM = Contaminated Media, WM = Waste Material, and BG = Background Conditions) for categorizing the sample material which was tested.

From Table F.2.I-4 it can be seen that for the 0- to 2-inch interval that the K_{l1} for uranium ranged from 74 to 1688 L/kg, K_{l2} ranged from 0.55 to 55 L/kg, and K_e ranged from 0.75 percent to 46 percent. From Table F.2.I-5 it can be seen that for the 24- to 30-inch interval that the K_{l1} for uranium ranged from 627 to 2825 L/kg, K_{l2} ranged from 17.5 to 38,000 L/kg, and K_e ranged from 0.93 percent to undefined. Sample calculations for determining these parameters are presented in Section F.2.I.3.3.2.

F.2.I.3.5 Observations

In general the results of the two-step desorption batch test confirm the ideas used for fate and transport modeling in the Operable Unit 5 RI Report. The results of the batch test for uranium contaminated soil are also useful for describing the areal and vertical distribution of K_l and K_e in the area outside of the former production area, as well as, for determining the type of material which was collected at each sample location. For example, based on the K_{l1}, K_{l2}, and K_e values which were developed and an understanding of geochemistry, one can determine that there are three types of soil

which were collected including contaminated media, waste material, and material with background concentrations of contamination. The leaching/extraction characteristics of each type of material are described below.

0- to 2-Inch Interval

In general, the 0- to 2-inch interval samples exhibited high K_{l1} values, low K_{l2} values, and low K_e values. This implies that the overall uranium mass in the soil does not readily leach (K_{l1}) and the extractable percentage of overall uranium mass is low (K_e). However, a portion (i.e., 1 to 7 percent) of the uranium mass is relatively more leachable (K_{l2}) (Refer to Figure F.2.I-2). This type of material is classified as Contaminated Media (CM).

Two of the samples taken from the 0- to 2-inch interval were exceptions and exhibited low K_{l1} and K_{l2} values, and high K_e values. This implies that the overall uranium mass and the extractable uranium mass in the soil will readily leach and the extractable percentage of overall uranium mass is high (K_e). This type of material is classified as Waste Material (WM).

As described above, it can be seen from Table F.2.I-4 that a majority of the samples collected in the 0- to 2-inch interval were contaminated media (labeled as CM). Two samples, KL-SS-02 and KL-SS-15 taken from the 0- to 2-inch interval, showed characteristics of waste material (labeled as WM). These two samples were the only samples which had K_{l1} values (125 and 74 L/kg, respectively) which were less than 325 L/kg. As mentioned previously, KL-SS-15 was suspected of being a disturbed area, therefore the results may be biased. The location of KL-SS-02 is to the west of the waste pit area, and some recent construction activities have been performed in this area. It is possible that the surface soil at this location was disturbed. The K_{l1} range for the remaining locations for the 0- to 2-inch soil interval was from 365 to 1688 L/kg.

24- to 30-Inch Interval

A majority of the results for the batch test procedure on the samples from 24- to 30-inch interval exhibited high K_l and undefined K_e values. This implies that the overall uranium mass in soil does not readily leach (K_{l1}) and there is a very homogeneous form of non-leachable uranium (Refer to Figure F.2.I-2). This type of material is classified as Background Material (BG).

For two of the samples, KL-SS-02 and KL-SS-07 for the 24- to 30-inch interval, K_{l1} was high, K_{l2} was low and K_e was low. This again implies that the overall uranium mass in soil does not readily leach (K_{l1}) and the extractable percentage of overall uranium mass is low (K_e). However, a small portion of the uranium mass is relatively more leachable (K_{l2}). As described above, this material is classified as Contaminated Media (CM).

From Table F.2.I-5 it can be seen that a majority of the samples collected from the 24- to 30-interval had background concentrations of uranium (labeled in the table as BG). The initial soil uranium concentrations were very low for this interval as expected. In addition, leachate concentrations were also very low, most less than 1 μg/L. In most cases, final leachate concentrations from the second equilibrium were either greater than or equal to final leachate concentration from the first equilibrium. This is possible due to the difficulty in accurately measuring uranium concentrations at levels below 1 μg/L.

F.2.I.4 TCLP

F.2.I.4.1 Objective

In addition to the batch tests conducted to determine K_l and K_e values for uranium, TCLP analyses were also conducted on each of the soil samples collected which allowed for a determination of technetium-99 K_l values. Previously, literature technetium-99 K_d values for sand and clay were the only information available to estimate K_l. These additional tests provided sufficient information to estimate site-specific technetium-99 K_l values. A summary of the laboratory procedure and preliminary technetium-99 K_l values are described below.

F.2.I.4.2 Laboratory Procedure

Soil measurements and TCLP analyses were conducted for a total of 30 samples (i.e., 15 samples from 0- to 2-inch interval and 15 samples from 24- to 30-inch interval) for all COCs but only preliminary results of technetium-99 are available from the off-site laboratory. Measurements of technetium-99 concentrations in soil and TCLP leachate were made using liquid scintillation (EPI A-005). Difficulties were encountered when measuring technetium-99 and these difficulties are discussed in Section F.2.I.2.3. The contract detection limits for technetium-99 in soils and TCLP leachate were 0.015 pCi/g and 7 pCi/L, respectively. ASTM methods were followed for TCLP analyses. Because it is a standard procedure, additional details on the analytical method for TCLP analysis will not be provided in this attachment. All data is preliminary but will be validated to the study's requirement level, Level D (DOE 1994).

F.2.I.4.3 Preliminary Results

Table F.2.I-6 summarizes the preliminary soil sampling, TCLP, and K_l results for technetium-99. Included in the table are the sample number, soil sample collection depth, the initial soil concentration (C_0), the TCLP leachate concentration (C_l), and the resulting K_l values. If all of the soil samples, which have results listed, are considered, including those from the 0- to 2-inch and 24- to 30-inch intervals, the estimated technetium-99 K_l values range from 7.8 to 198 L/kg with a geometric mean of 37 L/kg. The technetium-99 K_l values which are presented in this table were estimated by dividing the TCLP leachate concentration (C_l) by the initial soil concentration.

Calculations of Technetium-99 K_l for KL-SS-01 (0- to 2-Inch Interval)

A sample calculation for estimating the technetium-99 K_l for the 0- to 2-inch interval is presented below.

$$K_l = \frac{C_S}{C_L} = \frac{0.0591\ pCi/g}{4.93\ pCi/L} \times 1000\ \frac{g}{kg} = 12\ L/kg$$

This same method for estimating K_l (technetium-99) was used for all samples including those collected from the 0- to 2-inch and the 24- to 30-inch intervals.

F.2.I.5 INFORMATION TO BE PRESENTED IN THE FINAL REPORT

A brief summary of the study's results for uranium and technetium-99 are presented in this FS attachment to document and backup the data used for the Operable Unit 5 RI and FS. A complete summary of all of the results cannot be presented since a majority of the results are not available yet. A final report will be prepared which will summarize all laboratory data and results. The data which will be included in the final report is summarized below.

Tables which will be included in the final report include: tables of initial contaminant concentrations; tables of concentration measurements with time from the two desorption tests; and tables showing the variation in specific-conductance and pH with time. Graphs which will be included in the final report include: graphs of sample-specific leachate concentrations over the duration of the two-step desorption tests; graphs showing specific-conductance and pH over the duration of the two-step desorption tests; and graphs showing the vertical distribution (i.e., change with depth) of contaminants at each sample location. Figures which will be included in the final report include: figures showing the areal distribution of contaminants; and figures showing the areal distribution of K_l and K_e values.

F.2.I.6 SUMMARY AND CONCLUSION

In summary, the sampling results show that outside of the former production area, the residual contamination (uranium oxides with a low solubility and high K_l), is contained in the top of the glacial overburden (0- to 2-inches). This supports Operable Unit 5's decision of using a high uranium K_l (325 L/kg) in the area outside of the former production area. The results also confirm that the soluble uranyl carbonate species (e.g. uranium fluorides with low K_l), which were once present in the waste material deposited by air deposition (1950s and 1960s), has leached out and passed through the glacial overburden. The reason the uranium remained in the aqueous phase and passed through the glacial overburden was due to the high solubility of the uranium species and due to the low K_d of the glacial overburden. These results are evident from the high concentrations of uranium measured in the 0- to 2-inch interval and the low concentrations (background) measured in the 24- to 30-inch interval. Therefore, only the residual contamination which is contained in the top few inches of the soil column must be considered as a source of contamination for remediation purposes. Based on this

information, it can also be said that the 1.5 foot contaminated soil thickness used for modeling the area outside of the former production area in the Operable Unit 5 RI and FS is very conservative.

Other results from the study (soil sample analyses and TCLP results for technetium-99) were used to determine technetium-99 K_l values for the source material. The technetium-99 K_l values which were determined ranged from 7.8 L/kg to 198 L/kg with a geometric mean of 37 L/kg. This mean K_l for technetium-99 in source material is approximately two orders of magnitude higher than the literature clay K_d (0.118 L/kg, Thiabault et al. 1990) which was originally being used as K_l for technetium-99. This site-specific K_l value was incorporated into the modeling performed for the Operable Unit 5 FS. The literature clay and sand K_d values (0.118 and 0.07 L/kg, respectively, (Thiabault et al. 1990)) are still used in the modeling for the media through which the migration occurs. All of the other geochemical parameters defined in the Operable Unit 5 RI Report remain the same for the Operable Unit 5 FS fate and transport modeling.

F.2.I.7 REFERENCES

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U.S. Department of Energy, 1994, "Project-Specific Plan for Operable Unit 5 K_l Soil Sampling and Analysis," Revision 0, Fernald Environmental Management Program, DOE, Fernald Field Office, Cincinnati, OH.

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TABLE F.2.I-1

SOIL SAMPLE ANALYTICAL PARAMETER REQUIREMENTS - K_t SOIL SAMPLING AND ANALYSIS PROGRAM

ANALYTE	LAB	ASL	NO. OF SAMPLES	MASS	HOLDING TIME	PRESERVATIVE	CONTAINER
Soil Samples:							
Total HSL Metals[a] (0 - 2 and 24 - 30)	R/C	D	32[d]	250 grams	180 days (Hg 28 days)	Cool, 4° C	16 oz. Glass
TCLP HSL Metals[a] (0 - 2 and 24 - 30)	R/C	D	30	250 grams	180 days (Hg 28 days)	Cool, 4° C	16 oz. Glass
Radiological Suite[b] (0 - 2 and 24 - 30)	TOS	D	30	3000 grams	180 days	None	1 1-gal. Glass
TCLP Radiological Suite[b] (0 - 2 and 24 - 30)	TOS	D	30	7000 grams	180 days	None	2 1-gal. Glass
Total Organic Carbon (0 - 2 and 24 - 30)	R/C	B	30	100 grams	28 days	Cool, 4° C	4 oz. Amber Glass
Dry Bulk Density (0 - 6 and 24 - 30)	UC	N/A	30	900 grams	N/A	None	Butyrate Tube or Soil Block
Gross Alpha/Beta[c] (0 - 2 and 24 - 30)	FEMP	A	32[d]	100 grams	180 days	None	4 oz. Glass
K_t (0 - 2 and 24 - 30)	FEMP	N/A	32[d]	400 grams	N/A	None	16 oz. Glass
Total and Isotopic Uranium (0 - 2 and 24 -30)	FEMP	B	32[d]	800 grams	180 days	None	1 L. Glass
Total and Isotopic Uranium (0 - 6, 6 - 12, 12 - 18, and 18 - 24)	FEMP	B	60	800 grams	180 days	None	1 L. Glass
Total Uranium (KL-SS-11, 0 - 2) (KL-SS-09, 24 - 30)	TOS	D	2[d]	100 grams	180 days	None	4 oz. Glass

[a] HSL metals include: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Cn, Hg, Fe, Pb, Mg, Mn, Mo, Ni, K, Na, Se, Si, Ag, Tl, V, Zn.
[b] Radiological Suite includes: Cs-137, Np-237, Pu-238, Pu-239/240, Pu-241, Ra-226, Ra-228, Sr-90, Tc-99, Th-227, Th-228, Th-232, Th-230, U-234, U-235/236, U-238, U-Total.
[c] Screen for shipping purposes only
[d] Includes two field duplicates [KL-SS-09 (24 - 30 inches) and KL-SS-11 (0 to 2 inches)].
( ) Sample interval in inches
N/A: Not Applicable
G/P: Glass or Plastic
R/C: RCRA/CERCLA Laboratory
TOS: Radiological Task Order Subcontract
FEMP: FERMCO Laboratory
UC: University of Cincinnati Geotechnical Laboratory (On-Site)

TABLE F.2.I-2

FIELD SOIL COLLECTION AND CONTAINERIZATION PER SAMPLE LOCATION

SOIL INTERVAL (inches)	CONTAINERS
0 - 2	7 1-gallon Glass
0 - 6	4 1-gallon Glass
6 - 12	4 1-gallon Glass
12 - 18	4 1-gallon Glass
18 - 24	4 1-gallon Glass
24 - 30	7 1-gallon Glass

Note: Additional core or soil block will be collected at each location for the 0- to 6-inch and the 24- to 30-inch intervals for dry bulk density.

TABLE F.2.I-3

FIELD QUALITY CONTROL SAMPLE PARAMETER REQUIREMENTS - K_1 SOIL SAMPLING AND ANALYSIS PROGRAM

ANALYTE	LAB	ASL	NO. OF SAMPLES	MASS	HOLDING TIME	PRESERVATIVE	CONTAINER
Rinsate:							
Total HSL Metals[a]	R/C	D	6	N/A	180 days (Hg 28 days)	Cool, 4° C HNO_3 < 2	1 L G/P
Total Uranium	TOS	D	6	N/A	180 days	Cool, 4° C HNO_3 < 2	1 L Glass
Gross Alpha/Beta	FEMP	A	6	N/A	180 days	None	120 ml G/P
Field Blank:							
Total HSL Metals[a]	R/C	D	15	N/A	180 days (Hg 28 days)	Cool, 4° C HNO_3 < 2	1 L G/P
Total Uranium	TOS	D	15	N/A	180 days	Cool, 4° C HNO_3 < 2	1 L Glass
Gross Alpha/Beta	FEMP	A	15	N/A	180 days	None	120 ml G/P

[a] HSL metals include: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Cn, Hg, Fe, Pb, Mg, Mn, Mo, Ni, K, Na, Se, Si, Ag, Tl, V, Zn.
N/A: Not Applicable
G/P: Glass or Plastic
R/C: RCRA/CERCLA Laboratory
TOS: Radiological Task Order Subcontract
FEMP: FERMCO Laboratory

TABLE F.2.I-4

SUMMARY OF PRELIMINARY K_l AND K_e VALUES FOR OPERABLE UNIT 5 - SAMPLES COLLECTED FROM 0- TO 2- INCH INTERVAL

Sample Number	C_o (μg/g)	C_{so} (μg/g)	C_{w1} (μg/L)	C_{w2} (μg/L)	m_{s0} (μg)	m_{w1} (μg)	C_{s1} (μg/g)	$C_{s1'}$ (μg/g)	K_{l1} (L/kg)	K_{l2} (L/kg)	K_e (%)	Material Category
KL-SS-01	10.6000	6.9000	15.0000	0.9000	2760.0000	52.5000	6.7688	0.0084	451.2500	0.5585	2.0236	CM
KL-SS-02	2.8000	2.8000	21.0000	18.0000	1120.0000	73.5000	2.6163	1.1025	124.5833	52.5000	45.9375	WM
KL-SS-03	19.4000	15.7000	42.0000	8.4000	6280.0000	147.0000	15.3325	0.0919	365.0595	2.1875	2.9260	CM
KL-SS-04	49.0000	45.3000	36.0000	2.4000	18120.0000	126.0000	44.9850	0.0225	1249.5833	0.6250	0.7450	CM
KL-SS-05	28.5000	24.8000	29.0000	25.0000	9920.0000	101.5000	24.5463	1.5859	846.4224	54.6875	7.4181	CM
KL-SS-06	13.0000	9.3000	22.0000	15.0000	3720.0000	77.0000	9.1075	0.4125	413.9773	18.7500	6.5054	CM
KL-SS-07	4.6000	0.9000	1.9000	0.9000	360.0000	6.6500	0.8834	0.0150	464.9342	7.8750	3.5097	CM
KL-SS-08	14.6000	10.9000	7.1000	1.6000	4360.0000	24.8500	10.8379	0.0181	1526.4613	2.5455	0.7358	CM
KL-SS-09	11.1000	7.4000	12.0000	1.7000	2960.0000	42.0000	7.2950	0.0173	607.9167	1.4442	1.6531	CM
KL-SS-10	81.8000	78.1000	48.0000	23.0000	31240.0000	168.0000	77.6800	0.3864	1618.3333	8.0500	1.0325	CM
KL-SS-11	69.6000	65.9000	59.0000	26.0000	26360.0000	206.5000	65.3838	0.4067	1108.1992	6.8939	1.4006	CM
KL-SS-12	20.5000	16.8000	9.9000	3.9000	6720.0000	34.6500	16.7134	0.0563	1688.2197	5.6875	0.8508	CM
KL-SS-13	39.1000	35.4000	45.0000	4.8000	14160.0000	157.5000	35.0063	0.0470	777.9167	1.0448	1.2451	CM
KL-SS-14	34.7000	31.0000	41.0000	13.0000	12400.0000	143.5000	30.6413	0.1666	747.3476	4.0625	1.6946	CM
KL-SS-15	10.9000	7.2000	87.0000	51.0000	2880.0000	304.5000	6.4388	1.0784	74.0086	12.3958	25.5512	WM
KL-SS-11D[a]	69.6000	65.9000	13.0000	28.0000	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
If C_{so} was a negative number after subtracting background from C_o, C_o was used to calculate K_{l1}
[a] C_{w1} measurement seems to be in error, no further calculations were performed
CM = Contaminated Media
WM = Waste Material
NA = Not Applicable

TABLE F.2.I-5

SUMMARY OF PRELIMINARY K_l AND K_e VALUES FOR OPERABLE UNIT 5 - SAMPLES COLLECTED FROM 24- TO 30- INCH INTERVAL

Sample Number	C_o (μg/g)	C_{so} (μg/g)	C_{w1} (μg/L)	C_{w2} (μg/L)	m_{s0} (μg)	m_{w1} (μg)	C_{s1} ug/g	$C_{s1'}$ (μg/g)	K_{l1} (L/kg)	K_{l2} (L/kg)	K_e (%)	Material Category
KL-SS-01	1.6000	1.6000	0.9000	1.0000	640.0000	3.1500	1.5921	NA	NA	1769.0278	UD	BG
KL-SS-02	2.1000	2.1000	3.3000	2.3000	840.0000	11.5500	2.0711	0.0664	627.6136	20.1250	4.5375	CM
KL-SS-03	6.3000	2.6000	0.1000	0.1000	1040.0000	0.3500	2.5991	NA	NA	25991.2500	UD	BG
KL-SS-04	10.7000	7.0000	0.2000	0.4000	2800.0000	0.7000	6.9983	NA	NA	34991.2500	UD	BG
KL-SS-05	4.5000	0.8000	0.3000	1.3000	320.0000	1.0500	0.7974	NA	NA	2657.9167	UD	BG
KL-SS-06	5.5000	1.8000	0.2000	0.4000	720.0000	0.7000	1.7983	NA	NA	8991.2500	UD	BG
KL-SS-07	5.4000	1.7000	0.6000	0.4000	680.0000	2.1000	1.6948	0.0105	2824.5833	17.5000	0.9265	CM
KL-SS-08	3.6000	3.6000	0.1000	0.6000	1440.0000	0.3500	3.5991	NA	NA	35991.2500	UD	BG
KL-SS-09	5.1000	1.4000	0.1000	0.3000	560.0000	0.3500	1.3991	NA	NA	13991.2500	UD	BG
KL-SS-10	2.5000	2.5000	0.1000	0.2000	1000.0000	0.3500	2.4991	NA	NA	24991.2500	UD	BG
KL-SS-11	2.7000	2.7000	0.1000	0.1000	1080.0000	0.3500	2.6991	NA	NA	26991.2500	UD	BG
KL-SS-12	4.2000	0.5000	0.1000	0.2000	200.0000	0.3500	0.4991	NA	NA	4991.2500	UD	BG
KL-SS-13	2.4000	2.4000	0.2000	0.5000	960.0000	0.7000	2.3983	NA	NA	11991.2500	UD	BG
KL-SS-14	4.1000	0.4000	0.1000	0.2000	160.0000	0.3500	0.3991	NA	NA	3991.2500	UD	BG
KL-SS-15	7.5000	3.8000	0.1000	0.1000	1520.0000	0.3500	3.7991	NA	NA	37991.2500	UD	BG
KL-SS-09D	5.1000	1.4000	0.1000	0.2000	560.0000	0.3500	1.3991	NA	NA	13991.2500	UD	BG

Notes:
If C_o is a negative number after subtracting background from C_o, C_o was used to calculate K_{l1}
NA = Not Applicable
BG = Background
CM = Contaminated Media
UD = Undefined

000965

6771

TABLE F.2.I-6

SUMMARY OF PRELIMINARY TECHNETIUM-99 K_l VALUES

Sample Number	Soil Sample Collection Depth (inches)	C_s (pCi/g)	TCLP C_l (pCi/L)	K_l[a] (L/kg)
KL-SS-01	0-2	0.0591	4.9257	11.998
	24-30	NA	0.9977	NA
KL-SS-02	0-2	0.0251	3.2265	7.779
	24-30	NA	1.8487	NA
KL-SS-03	0-2	0.1522	4.0153	37.905
	24-30	0.0085	1.0816	7.859
KL-SS-04	0-2	0.1672	3.8384	43.560
	24-30	NA	1.8681	NA
KL-SS-05	0-2	0.6459	3.2575	198.281
	24-30	NA	0.2180	NA
KL-SS-06	0-2	0.0756	2.5389	29.777
	24-30	NA	1.4212	NA
KL-SS-07	0-2	0.0395	2.7205	14.519
	24-30	0.0623	1.3936	44.704
KL-SS-08	0-2	0.0341	2.6862	12.695
	24-30	NA	2.9463	NA
KL-SS-09	0-2	0.0565	2.3691	23.849
	24-30	NA	1.2910	NA
KL-SS-10	0-2	0.9174	4.9954	183.649
	24-30	NA	1.5717	NA
KL-SS-11	0-2	0.9458	5.1061	185.229
	24-30	NA	1.4538	NA
KL-SS-12	0-2	0.0855	3.3121	25.814
	24-30	NA	-0.0199[b]	NA
KL-SS-13	0-2	0.2147	2.6068	82.362
	24-30	NA	2.3671	NA
KL-SS-14	0-2	0.1603	1.8925	84.703
	24-30	NA	2.3620	NA
KL-SS-15	0-2	0.3598	8.2226	43.757
	24-30	NA	2.1575	NA

[a] Geometric Mean of K_l = 36.58 L/kg
[b] Negative due to corrections, number is under review
NA = Data not available yet, will be presented in final K_l report

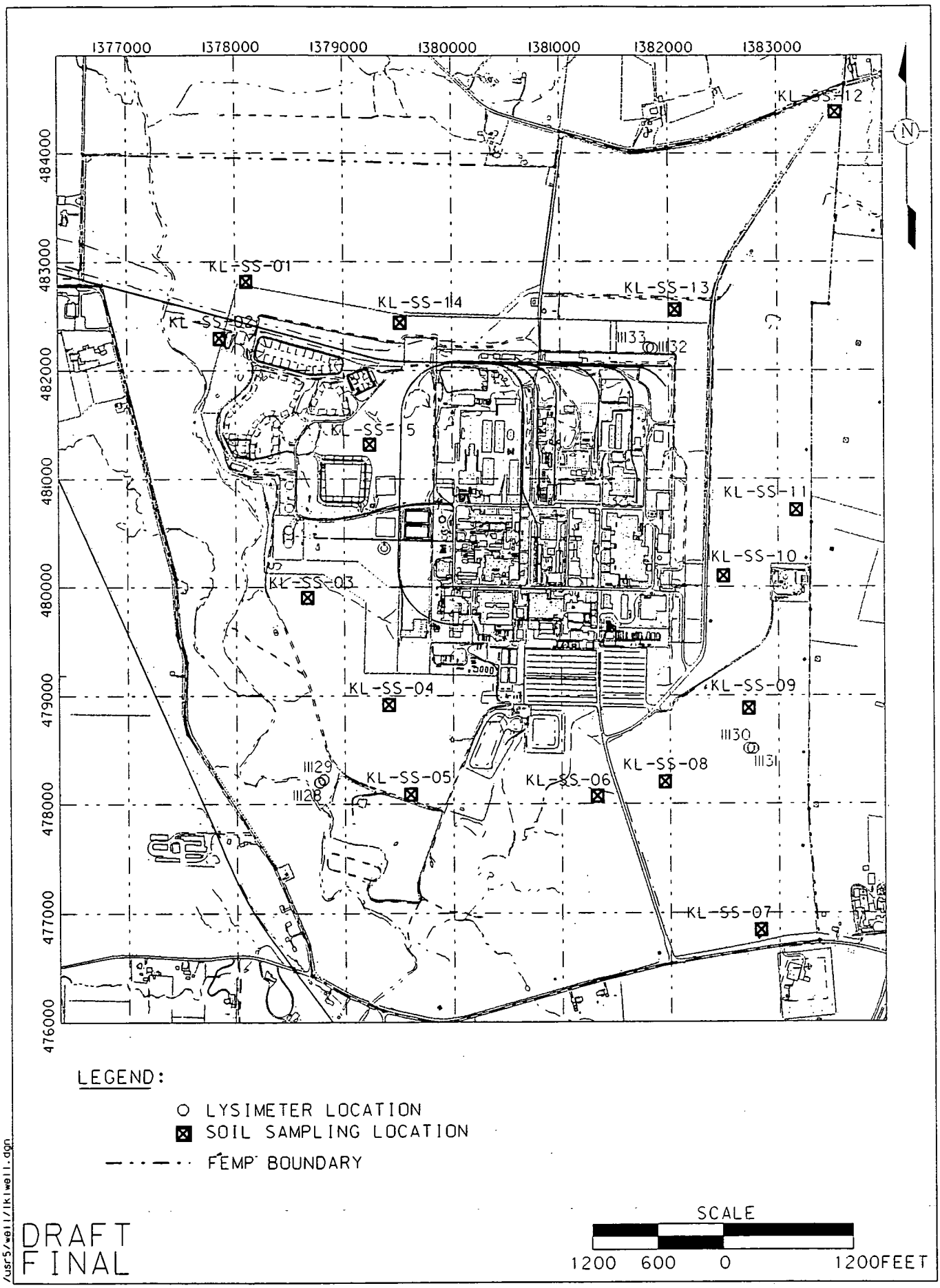
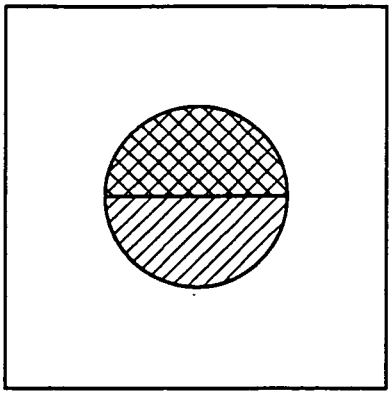


FIGURE F.2.1-1. K_1 SOIL SAMPLING AND LYSIMETER LOCATIONS

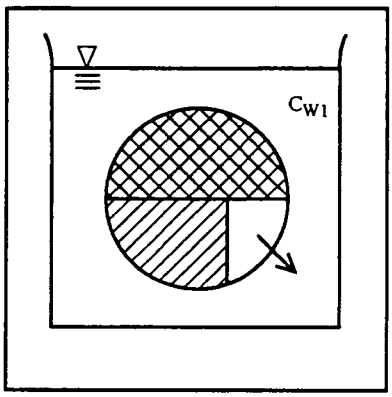


INITIAL TEST MEDIA

⊘ + ⊗ C_{SO} = INITIAL CONCENTRATION OF SOLID PHASE CONTAMINANT IN TEST MATERIAL WITHOUT BACKGROUND CONCENTRATION (µg/g)

⊗ NON-EXTRACTABLE MASS

⊘ EXTRACTABLE MASS



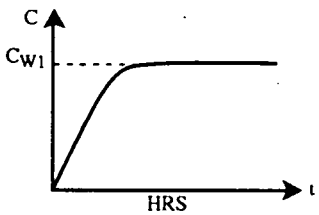
STEP 1. FIRST EQUILIBRIUM

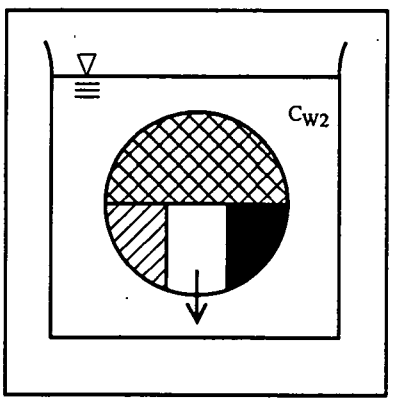
C_{W1} = CONCENTRATION OF CONTAMINANT IN LEACHATE AT FIRST EQUILIBRIUM (µg/L)

⊘ + ⊗ C_{S1} = CONCENTRATION OF TOTAL SOLID PHASE CONTAMINANT IN TEST MATERIAL AT FIRST EQUILIBRIUM (µg/g)

⊘ C'_{S1} = EXTRACTABLE CONCENTRATION OF SOLID PHASE CONTAMINANT IN TEST MATERIAL AT FIRST EQUILIBRIUM (µg/g)

○ REPRESENTS SOLUBLE CONTAMINANT MASS DISSOLVED INTO THE LEACHATE IN THE STEP 1





STEP 2. SECOND EQUILIBRIUM

C_{W2} = CONCENTRATION OF CONTAMINANT IN LEACHATE AT SECOND EQUILIBRIUM (µg/L)

⊘ + ⊗ C_{S2} = CONCENTRATION OF TOTAL SOLID PHASE CONTAMINANT IN TEST MATERIAL AT SECOND EQUILIBRIUM (µg/g)

⊘ C'_{S2} = EXTRACTABLE CONCENTRATION OF SOLID PHASE CONTAMINANT IN TEST MATERIAL AT SECOND EQUILIBRIUM (µg/g)

○ REPRESENTS SOLUBLE CONTAMINANT MASS DISSOLVED INTO THE LEACHATE IN THE STEP 2

● REPRESENTS ORIGINAL SOLUBLE CONTAMINANT MASS REMOVED FROM THE SYSTEM IN PREVIOUS EQUILIBRIUM

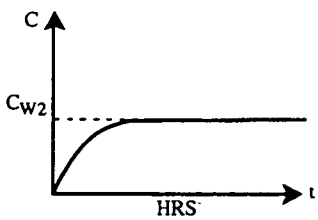


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FIGURE F.2.I-2. DESORPTION MECHANISMS FOR THE TWO-STEP DESORPTION TEST

ATTACHMENT F.5.I
WACs FOR RCRA REGULATED CONSTITUENTS

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F.5.I ADDITIONAL WASTE ACCEPTANCE CRITERIA FOR RCRA WASTE

F.5.I.1 INTRODUCTION

F.5.I.1.1 Objective

Waste acceptance criteria (WAC) are required for remedial alternatives which include certain on-site disposal facilities or remedial components. The WAC development process considers the benefits of engineering controls and potential waste treatments that can significantly change hydrogeological and geochemical conditions. Because potential disposal facilities will be located outside of the Zone V area (see Figure F.2-11) and will include earthen cover or cap, only the vertical migration of contaminants through the overburden into the Great Miami Aquifer is considered as the potential pathway of cross-media impact in the WAC development process.

Initially, the maximum acceptable leachate concentrations for contents of the disposal facilities are determined by fate and transport modeling. The leaching potential, solubility, and mobility of different contaminants and the effects of waste treatment are then considered to convert these leachate concentrations into solid phase WACs. The technical approach to fate and transport modeling conducted to develop WACs is summarized in Section F.5 of Appendix F. However, only the WACs for the groundwater pathway Constituents of Concern (COCs) that are identified in the Operable Unit 5 Draft RI and in Table F.2-2 were presented in Section F.5. This attachment presents the WACs for additional Resource Conservation and Recovery Act (RCRA) regulated constituents. These constituents can potentially be found in environmental media contaminated by the Hazardous Waste Management Units (HWMUs) and other former process operations at the site.

F.5.I.1.2 Important Factors for the Additional WAC Development

Types of Disposal Facilities

WACs for RCRA constituents in all three on-site disposal facilities (i.e., Consolidation Area with Earthen Cover, Consolidation Area with Cap, and Disposal Cell) evaluated in Section F.5 are presented in this attachment. The same conceptual cross-sections, infiltration rates, preliminary foot print, and locations for each of these three facilities specified in Section F.5 are used for developing the WACs for these additional contaminants.

General Modeling Approach

The modeling approach for the additional WAC development is similar to the approach described in Section F.5 and can be summarized as follows:

- The entire disposal area is considered as one future contaminant source with a 1000 feet by 1000 feet footprint.

- The pertinent ECTran model input is taken directly from the input data used for Cross-media Preliminary Remedial Goal (CPRG) modeling runs conducted under Sections F.3 and F.5.

- Gray clay and unsaturated Great Miami Aquifer sand and gravel thickness under the disposal area are 22 feet and 20 feet, respectively.

- The infiltration rate (i.e., 0.89 inches per year) through the two facilities which include a multi-layer cap are determined by Hydrologic Evaluation of Landfill Performance (HELP) simulations. The only difference between the consolidation with a cap and the disposal cell is the engineered clay liner. The infiltration rates for the two facilities are identical because of the assumption that the basal liner drains in the disposal cell have failed. For the consolidation area with earthen cover, infiltration is assumed to be equal to the current infiltration rate (i.e., 5.92 inches per year) at the selected foot print area for the on-site disposal facility.

- A 1000-year modeling period is chosen for WAC development (i.e., the predicted maximum impact within 1000 years should not exceed the groundwater Preliminary Remediation Goal [PRG]).

- For the On-site Disposal Cell and the Consolidation with Cap options, the contaminant source used in the ECTran model for WAC development is assumed to remain constant for the entire modeling period for most constituents (except for constituents which have K_l and K_d values that are less than 1 L/kg) because of the low infiltration rate and potential high concentrations. Constituents with these low K_l and K_d values can migrate from the disposal facility in a shorter period, relative to the other constituents. It is, therefore, not realistic to assume that the total mass of these chemicals is sufficient to sustain constant loading for 1000 years at the initial leachate concentration level. Therefore, depleting sources are utilized in the WAC development procress for the following constituents: acetone, benzene, methylene chloride, methyl ethyl ketone, methyl isobutyl ketone, and vinyl chloride.

- For the Consolidation with Earthen Cover option, the contaminant source used in the ECTran model for WAC development is simulated as a 30-foot thick depleting contaminant source for all the constituents because of the relatively higher infiltration rate.

- The potential exposure point for developing the WAC is the Great Miami Aquifer under the disposal facility.

- Potential transformation of constituents to other constituents are considered for determining conservative WACs for groups of chlorinated volatile constituents.

- An iterative procedure is used to back calculate an acceptable leachate concentration from the waste (i.e., initial WAC) based on meeting the Great Miami Aquifer groundwater PRG. The Great Miami Aquifer groundwater PRG is developed for the

reasonable maximum exposure (RME) Resident Farmer/Child exposure scenario. The acceptable leachate concentrations are then converted using K_d to develop corresponding solid phase WACs.

Modeling Tools

A contaminant fate and transport model for the groundwater pathway is used to develop WACs. Model simulations are conducted to back-calculate WACs at future disposal facilities, based on the exposure criteria set at receptor locations. For the WAC development, groundwater and contaminant migration within the overburden and saturated Great Miami Aquifer are simulated by ECTran (DOE 1993). Because source areas can be simulated individually in the development of WAC, ECTran can be used to develop WAC for each disposal facility.

The ECTran model is appropriate for WAC development since it is more conservative than the SWIFTLOAD/ODAST model and can be used efficiently to develop numerous COC-specific WACs and because the source areas, which require WACs, can be simulated individually for the initial design purposes. Modifications have been incorporated into the original ECTran version to consider multiple sublayers within the gray clay layer and engineered clay liner during WAC development. The modifications to ECTran are described in Attachment F.1.I.

Summary of Assumptions

Assumptions are necessary to simplify or conceptualize the natural environmental and migration processes so they can be simulated by models. Also, conservative modeling assumptions are made for developing WACs to ensure that they are acceptable. The modeling assumptions are summarized below.

- The brown, weathered clay is considered part of the till layer for infiltration calculations made using the HELP model. Since it is more permeable than the unweathered gray clay, including the brown clay in the infiltration calculations results in higher infiltration rates than using only the gray clay.

- The brown, weathered clay is not considered part of the till layer during contaminant fate and transport simulations using the ECTran model. The brown clay is weathered and fractured and has limited ability to impede contaminant migration. By not considering this layer, higher contaminant concentrations can reach the Great Miami Aquifer faster.

- A minimum mixing depth of the Great Miami Aquifer is assumed to be 10 feet for the Disposal Cell and the Consolidation Area with Cap.

- The mixing depth of the Great Miami Aquifer is estimated using the equation (i.e., Equation 8) presented in the ECTran development document (DOE 1993) for the Consolidation Area with Earthen Cover.

- The perched groundwater zone under the potential on-site disposal areas will be remediated as needed prior to construction of the proposed disposal facilities.

F.5.I.2 CHEMICAL CHARACTERISTICS AND GEOCHEMICAL PARAMETERS

F.5.I.2.1 Summary of General Model Parameters

Site- and soil-specific hydrogeologic parameters and site- and constituent-specific geochemical parameters used for WAC development are summarized in Tables F.5.I-1 and F.5.I-2, respectively. Included in Table F.5.I-1 are the hydraulic conductivities, porosities, bulk densities, and fraction of organic carbon (FOC) used for modeling. Table F.5.I-2 summarizes the constituent-specific K_l, K_d, and half-life. As shown in Table F.5.I-2, most of the constituents evaluated have relatively short half lives. Because of these short half lives, chemical decay is the most sensitive factor in the fate and transport model used to develop the WACs for these constituents. The references of these decay half lives can be found in "Handbook of Environmental Degradation Rates" (Howard et al. 1991).

F.5.I.2.2 Transformation of Constituents

Certain constituents can transform to other constituents which may have much higher mobility and higher toxicity. Without considering the potential transformation of constituents, the WACs may not be protective of the environment and future human receptors. For the RCRA constituents evaluated in this attachment, most of the chlorinated volatile hydrocarbons have short decay half lives but can transform to other constituents through the natural de-chlorination process. General discussions of transformation patterns of chlorinated volatile hydrocarbons can be found in "Migration and Degradation Patterns of Volatile Organic Compounds" (Cline 1984). The following three chains of transformation between various chlorinated volatile hydrocarbons are determined significant and need to be evaluated in the WAC development process:

- 1,1,1-Trichloroethane (1,1,1-TCA), 1,1-Dichloroethane (1,1-DCA), and **Chloroethane**.
- Tetrochloroethene (PCE), Trichloroethene (TCE), 1,1-Dichloroethene (1,1-DCE), 1,2-Dichloroethene (1,2-DCE), and **Vinyl Chloride**.
- **Carbon Tetrachloride**, Chloroform, Methylene Chloride, and Chloromethane.

Figure F.5.I-1 presents the transformation pathways of these three chains. Because chemical transformations between these constituents inside the disposal facility or in the natural environment can not be simulated by the groundwater models, a simplified but conservative approach is used to incorporate the potential impacts of these transformations into the WAC development process. To develop conservative WACs, the constituent in each chain that has the lowest reference dose (RFD) or highest cancer slope factor (CSF) is used to determine the exposure criteria (i.e., groundwater PRG). This constituent is defined as the representative constituent of the chain. Based on this requirement,

chloroethane, vinyl chloride, and carbon tetrachloride are the representative constituents in these three chains, respectively. For a chain in which the representative constituent is the head of the chain (i.e., carbon tetrachloride), summation of each individual constituent's decay half life is used to calculate the representative decay rates for the chain. For a chain in which the representative constituent is the tail of the chain (i.e., chloroethane and vinyl chloride), the longest decay half life among the constituents included in the chain is used to calculate the representative decay rate of the chain. 1,1,1-TCA has the longest half life for the first chain. The representative constituent (i.e., vinyl chloride) also has the longest half life among the constituents included in the second transformation chain.

The liquid-phase WAC for each chain is developed by fate and transport modeling using the representative constituent's geochemical parameters, representative exposure criteria, and representative decay rate of the chain. Because transformations primarily occur in liquid phase, the liquid-phase WAC determined by the model represents the acceptable total liquid-phase concentration of all the constituents in the chain and will be used to determine the acceptance of waste materials into disposal facilities. If necessary, the solid phase WAC for each constituent can be approximated by multiplying the constituent-specific K_l value to this common liquid-phase WAC of the chain. However, these solid-phase WACs should not be used individually. Solid-phase WACs are generally not required, as explained below.

When determining acceptance of waste materials for a disposal facility, the total leachate concentration of all the constituents, which are within a transformation chain, will be determined and compared with the liquid-phase WAC of the chain. For example, if a waste material has leachate concentrations (i.e., solid-phase source concentrations divided by constituent-specific K_l) of 1,1,1-TCA, 1,1-DCA, and chloroethane of 10 mg/L, 5 mg/L, and 1 mg/L, respectively, a total leachate concentration of 16 mg/L will be compared to the liquid-phase WAC developed for the 1,1,1-TCA chain.

F.5.I.3 EXPOSURE CRITERIA

Great Miami Aquifer exposure criteria for the RME Resident Farmer/Child exposure scenario applied in WAC development include $1x10^{-6}$ and $1x10^{-5}$ Incremental Lifetime Cancer Risks (ILCRs). For toxicants, WACs using exposure criteria at a Hazard Quotient (HQ) of 0.2 are developed. For contaminants that have maximum concentration limits (MCLs), WACs corresponding to MCLs are also determined. Exposure criteria considered during the WAC development are summarized in Table F.5.I-3. Based on these exposure criteria, WAC are developed using the fate and transport models and modeling processes described in this attachment for additional RCRA listed constituents.

F.5.I.4 WAC

Protective level-specific WACs are developed for additional RCRA listed constituents for the Consolidation Area with Earthen Cover. These WACs are presented in Tables F.5.I-4 and F.5.I-5. Table F.5.I-4 presents the liquid-phase WACs which are obtained directly from the modeling results. Table F.5.I-5 summarizes the solid-phase criteria after converting liquid-phase WACs using estimated constituent-specific K_l values. Tables F.5.I-6 and F.5.I-7 present the similar information for the Consolidation Area with Cap. WACs for the Disposal Cell are presented in Tables F.5.I-8 and F.5.I-9.

Literature solubility limits (Montgomery 1990) in water for the evaluated constituents are also included in these tables. When the numerical values of the modeled liquid-phase WACs are higher than solubility limits, the solubility limits are presented instead of the original WACs. Some of the solid-phase criteria also reach the levels of pure product concentrations as indicated in these tables.

F.5.I.5 APPLICATION OF WAC

The comparison between contaminant concentrations in excavated soil and facility-specific WACs are conducted on a unit-volume basis instead of total average basis for the entire facility. Every batch of soil evaluated during the process needs to have contaminant concentrations lower than the WAC to be accepted into a disposal facility. For the preliminary volume estimation purpose, the size of each unit-volume or batch is defined as the three-dimensional model-block size used in the solid block modeling process. In general, its maximum size is equal to 125 feet by 125 feet by 1 foot (i.e., 579 yd^3). With this approach, the actual average contaminant concentrations within each facility will be much lower than the WACs. Total leachate concentration of constituents which are within a transformation group will be determined and compared with the liquid-phase WAC assigned to the chain.

F.5.I.6 BEST MANAGEMENT PRACTICES FOR THE RCRA ORGANIC COCS

Several of the RCRA constituents shown in Tables F.5.I-4 through F.5.I-9, including a number of the RCRA organic solvents, do not have a calculated WAC value (i.e., indicated as solubility or pure product in the tables) because the modeling simulations show that these constituents do not have the capability to exceed designated Great Miami Aquifer action levels within the 1000 year simulation period, regardless of the starting concentrations for these constituents in the disposal facility.

It is recognized that for the organic solvents shown on the tables, the mass balance approach applied in the modeling for determining the WACs does not consider the potential deleterious effects that full-strength solvents can have on the earthen material comprising the disposal facility liners or the underlying native clays. Full strength solvents have been proven to cause shrinking of clays with a resulting potential for increases in clay liner permeability, as documents in Daniel (1987) and Mitchell

et al. (1987). As a best management practice for these compounds, the FEMP acknowledges that it cannot place any RCRA COCs into the disposal facility at concentrations that are incompatible with the clay liners (for those disposal alternatives relying on clay liners) or the underlying native clays beneath the liners. As a means to track these concentrations, the FEMP will rely on field screening methods (e.g., OVAs or field GCs) during the excavation control surveys to identify those soils that are contaminated with RCRA organics above threshold values. The RCRA organic compounds that are present at concentrations that are detectable with field screening equipment are expected to be segregated for treatment as necessary or sent off site for disposal, depending on the alternative under consideration.

The details of the excavation control surveys and field screening methods for the RCRA organic compounds will be identified during remedial design and the preparation of the implementation plans for the Operable Unit 5 response actions.

F.5.I.7 REFERENCES

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TABLE F.5.I-1

HYDROLOGIC PARAMETERS FOR WAC DEVELOPMENT

		Disposal Facilities		
Parameters	Layer Type	On-Site Disposal Cell	Consolidation Area with Cap	Consolidation Area with Earthen Cover
Porosity	Contaminated Soil	0.4	0.4	0.4
	Gray Clay	0.2	0.2	0.2
	Unsaturated GMA	0.3	0.3	0.3
	GMA	0.3	0.3	0.3
Density (g/cm^3)	Contaminated Soil	1.78	1.78	1.78
	Gray Clay	1.78	1.78	1.78
	Unsaturated GMA	1.6	1.6	1.6
	GMA	1.6	1.6	1.6
Saturation	Contaminated Soil	0.6	0.6	0.6
	Gray Clay	0.95	0.95	0.95
	Unsaturated GMA	0.13	0.13	0.13
	GMA	1.0	1.0	1.0
Horizontal Seepage Velocity (ft/yr)	GMA	304	304	304
Vertical Hydraulic Conductivity (ft/day)	Unsaturated GMA	45	45	45

GMA - Great Miami Aquifer

TABLE F.5.I-2

GEOCHEMICAL AND CHEMICAL PARAMETERS USED FOR WAC DEVELOPMENT

COC	K_1 (L/kg)	Gray Clay K_d (L/kg)	UGMA K_d (L/kg)	GMA K_d (L/kg)	Half Life (years)
Organics					
Chloroethane	2.85×10^{-2}	2.85×10^{-2}	5.38×10^{-3}	5.38×10^{-3}	1.53×10^{-1}
1,1,1-Trichloroethane	1.64×10^{0}	1.64×10^{0}	3.09×10^{-1}	3.09×10^{-1}	3.01×10^{0}
1,1-Dichloroethane	3.42×10^{-1}	3.42×10^{-1}	6.45×10^{-2}	6.45×10^{-2}	1.68×10^{0}
Carbon Tetrachloride	2.98×10^{0}	2.98×10^{0}	5.62×10^{-1}	5.62×10^{-1}	1.00×10^{0}
Chloroform	5.17×10^{-1}	5.17×10^{-1}	9.76×10^{-2}	9.76×10^{-2}	5.11×10^{-1}
Methylene Chloride	9.87×10^{-2}	9.87×10^{-2}	1.86×10^{-2}	1.86×10^{-2}	7.66×10^{-2}
Chloromethane	4.51×10^{-2}	4.51×10^{-2}	8.50×10^{-3}	8.50×10^{-3}	3.06×10^{-1}
Vinyl Chloride	2.21×10^{-2}	2.21×10^{-2}	4.16×10^{-3}	4.16×10^{-3}	7.91×10^{0}
Tetrachloroethene	1.88×10^{0}	1.88×10^{0}	3.55×10^{-1}	3.55×10^{-1}	4.52×10^{0}
Trichloroethene	1.88×10^{0}	1.88×10^{0}	3.55×10^{-1}	3.55×10^{-1}	4.52×10^{0}
1,1-Dichloroethene	1.67×10^{-1}	1.67×10^{-1}	3.16×10^{-2}	3.16×10^{-2}	4.93×10^{-1}
1,2-Dichloroethene	1.67×10^{-1}	1.67×10^{-1}	3.16×10^{-2}	3.16×10^{-2}	2.00×10^{0}
Acetone	3.16×10^{-3}	3.16×10^{-3}	5.96×10^{-4}	5.96×10^{-4}	7.66×10^{-2}
Benzene	7.48×10^{-1}	7.48×10^{-1}	1.41×10^{-1}	1.41×10^{-1}	2.00×10^{0}
Endrin	2.21×10^{3}	2.21×10^{3}	4.16×10^{2}	4.16×10^{2}	No Decay
Ethylbenzene	7.76×10^{0}	7.76×10^{0}	1.46×10^{0}	1.46×10^{0}	6.25×10^{-1}
Heptachlor	1.44×10^{2}	1.44×10^{2}	2.72×10^{1}	2.72×10^{1}	1.48×10^{-2}
Heptachlor Epoxide	2.49×10^{0}	2.49×10^{0}	4.71×10^{-1}	4.71×10^{-1}	3.03×10^{0}
Hexachlorobutadiene	3.34×10^{2}	3.34×10^{2}	6.31×10^{1}	6.31×10^{1}	1.00×10^{0}
Methoxychlor	2.66×10^{2}	2.66×10^{2}	5.01×10^{1}	5.01×10^{1}	1.00×10^{0}
Methyl Ethyl Ketone	1.08×10^{-2}	1.08×10^{-2}	2.04×10^{-3}	2.04×10^{-3}	7.67×10^{-2}
Methyl Isobutyl Ketone	5.43×10^{-2}	5.43×10^{-2}	1.02×10^{-2}	1.02×10^{-2}	7.67×10^{-2}
Methylene chloride	9.87×10^{-2}	9.87×10^{-2}	1.86×10^{-2}	1.86×10^{-2}	7.66×10^{-2}
Toluene	2.72×10^{0}	2.72×10^{0}	5.12×10^{-1}	5.12×10^{-1}	5.76×10^{-1}
Toxaphene	1.33×10^{1}	1.33×10^{1}	2.51×10^{0}	2.51×10^{0}	No Decay
Xylenes [a]	6.10×10^{0}	6.10×10^{0}	1.15×10^{0}	1.15×10^{0}	1.00×10^{0}
Inorganics					
Barium	1.14×10^{3}	1.14×10^{3}	2.00×10^{1}	2.00×10^{1}	No Decay
Lead	3.00×10^{3}	3.00×10^{3}	3.80×10^{1}	3.80×10^{1}	No Decay
Silver	1.80×10^{2}	1.80×10^{2}	9.00×10^{1}	9.00×10^{1}	No Decay

NA - Not Applicable
[a] Total Xylenes K_ds

TABLE F.5.I-3

EXPOSURE CRITERIA (MEDIA-SPECIFIC PRGS) USED FOR WAC DEVELOPMENT

COC	Unit	Risk-Based GMA PRG ILCR=10^{-6}	Risk-Based GMA PRG ILCR=10^{-5}	Risk-Based GMA PRG ILCR=10^{-4}	HQ = 0.2	MCL
Organics						
Chloroethane	µg/L	NA	NA	NA	1.46×10^{2}	NA
1,1,1-Trichloroethane	µg/L	NA	NA	NA	6.50×10^{2}	2.00×10^{2}
1,1-Dichloroethane	µg/L	NA	NA	NA	7.30×10^{2}	NA
Carbon tetrachloride	µg/L	8.75×10^{-2}	8.14×10^{-1}	8.14×10^{-1}	8.14×10^{-1}	5.00×10^{0}
Chloroform	µg/L	1.17×10^{-1}	1.17×10^{0}	1.17×10^{1}	NA	1.00×10^{2}
Methylene Chloride	µg/L	2.43×10^{0}	2.43×10^{1}	2.43×10^{2}	NA	NA
Chloromethane	µg/L	9.03×10^{-1}	9.03×10^{0}	9.03×10^{1}	NA	NA
Vinyl Chloride	µg/L	1.03×10^{-2}	1.03×10^{-1}	1.03×10^{0}	NA	2.00×10^{0}
Tetrachloroethene	µg/L	3.24×10^{-1}	3.24×10^{0}	3.24×10^{1}	NA	5.00×10^{0}
Trichloroethene	µg/L	9.12×10^{-1}	9.12×10^{0}	9.12×10^{1}	NA	5.00×10^{0}
1,1-Dichloroethene	µg/L	2.44×10^{-2}	2.44×10^{-1}	2.44×10^{0}	NA	7.00×10^{0}
1,2-Dichloroethene	µg/L	NA	NA	NA	5.19×10^{1}	7.00×10^{1}
Acetone	µg/L	NA	NA	NA	6.00×10^{2}	NA
Benzene	µg/L	8.45×10^{-1}	8.45×10^{0}	8.45×10^{1}	NA	5.00×10^{0}
Endrin	µg/L	NA	NA	NA	NA	2.00×10^{0}
Ethylbenzene	µg/L	NA	NA	NA	2.23×10^{2}	7.00×10^{2}
Heptachlor	µg/L	2.03×10^{-3}	2.03×10^{-2}	2.03×10^{-1}	NA	4.00×10^{-1}
Heptachlor Epoxide	µg/L	2.84×10^{-3}	2.84×10^{-2}	6.72×10^{-2}	6.72×10^{-2}	2.00×10^{-1}
Hexachlorobutadiene	µg/L	NA	NA	NA	NA	1.00×10^{0} [b]
Methoxychlor	µg/L	NA	NA	NA	8.45×10^{0}	4.00×10^{1}
Methyl Ethyl Ketone	µg/L	NA	NA	NA	3.60×10^{3}	NA
Methyl Isobutyl Ketone	µg/L	NA	NA	NA	3.00×10^{2}	NA
Toluene	µg/L	NA	NA	NA	1.79×10^{2}	1.00×10^{3}
Toxaphene	µg/L	8.10×10^{-3}	8.10×10^{-2}	8.10×10^{-1}	NA	3.00×10^{0}
Xylenes	µg/L	NA	NA	NA	7.06×10^{3}	1.00×10^{4}
Inorganics						
Barium	µg/L	NA	NA	NA	2.38×10^{2}	2.00×10^{3}
Lead	µg/L	NA	NA	NA	1.50×10^{1} [a]	NA
Silver	µg/L	NA	NA	NA	1.29×10^{0}	NA

[a] Action Level
[b] MCLG
NA - Not Applicable

TABLE F.5.I-4

LIQUID-PHASE WAC FOR CONSOLIDATION AREA WITH EARTHEN COVER

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL	Solubility in Water
Organics							
Chloroethane	μg/L	NA	NA	NA	7.05×10^4	NA	6.00×10^6
1,1,1-Trichloroethane	μg/L						4.40×10^6
1,1-Dichloroethane	μg/L						7.00×10^6
Carbon tetrachloride	μg/L	>solubility	>solubility	>solubility	>solubility	>solubility	1.16×10^6
Chloroform	μg/L						1.06×10^7
Methylene Chloride	μg/L						2.36×10^7
Chloromethane	μg/L						6.36×10^6
Vinyl Chloride	μg/L	4.32×10^0	4.32×10^1	4.32×10^2	NA	8.39×10^2	2.70×10^6
Tetrachloroethene	μg/L						1.50×10^5
Trichloroethene	μg/L						1.10×10^6
1,1-Dichloroethene	μg/L						6.40×10^6
1,2-Dichloroethene	μg/L						6.30×10^6
Acetone	μg/L	NA	NA	NA	*	NA	[c]
Benzene	μg/L	>solubility	>solubility	>solubility	NA	>solubility	1.86×10^6
Endrin	μg/L	NA	NA	NA	NA	>solubility	2.60×10^2
Ethylbenzene	μg/L	NA	NA	NA	>solubility	>solubility	2.08×10^5
Heptachlor	μg/L	>solubility	>solubility	>solubility	NA	>solubility	1.80×10^2
Heptachlor Epoxide	μg/L	>solubility	>solubility	>solubility	>solubility	>solubility	3.50×10^2
Hexachlorobutadiene	μg/L	NA	NA	NA	NA	>solubility[b]	2.00×10^5
Methoxychlor	μg/L	NA	NA	NA	>solubility	>solubility	6.20×10^2
Methyl Ethyl Ketone	μg/L	NA	NA	NA	>solubility	NA	2.75×10^8
Methyl Isobutyl Ketone	μg/L	NA	NA	NA	>solubility	NA	1.91×10^7
Toluene	μg/L	NA	NA	NA	>solubility	>solubility	5.15×10^5
Toxaphene	μg/L	1.72×10^{-1}	1.72×10^0	1.72×10^1	NA	6.37×10^1	3.00×10^3
Xylenes	μg/L	NA	NA	NA	>solubility	>solubility	2.13×10^5
Inorganics							
Barium	μg/L	NA	NA	NA	*	*	Hydrolyzes
Lead	μg/L	NA	NA	NA	>solubility[a]	NA	3.33×10^5 [d]
Silver	μg/L	NA	NA	NA	>solubility	NA	5.56×10^6 [d]

[a] Action Level
[b] MCLG
[c] Miscible in all proportions
[d] Calculated from 10^6 mg/kg (i.e., pure product) divided by K_l
NA - Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5.I-5

SOLID-PHASE WAC FOR CONSOLIDATION AREA WITH EARTHEN COVER

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL
Organics						
Chloroethane	mg/kg	NA	NA	NA	2.01×10^{0}	NA
1,1,1-Trichloroethane	mg/kg	NA	NA	NA	1.16×10^{2}	3.57×10^{1}
1,1-Dichloroethane	mg/kg	NA	NA	NA	2.40×10^{1}	NA
Carbon tetrachloride	mg/kg	*	*	*	*	*
Chloroform	mg/kg	*	*	*	*	*
Methylene Chloride	mg/kg	5.99×10^{5}	*	*	*	*
Chloromethane	mg/kg	2.74×10^{5}	*	*	*	*
Vinyl Chloride	mg/kg	9.55×10^{-5}	9.55×10^{-4}	9.55×10^{-3}	NA	1.85×10^{-2}
Tetrachloroethene	mg/kg	8.12×10^{-3}	8.12×10^{-2}	8.12×10^{-1}	NA	1.58×10^{0}
Trichloroethene	mg/kg	8.12×10^{-3}	8.12×10^{-2}	8.12×10^{-1}	NA	1.58×10^{0}
1,1-Dichloroethene	mg/kg	7.21×10^{-4}	7.21×10^{-3}	7.21×10^{-2}	NA	1.40×10^{-1}
1,2-Dichloroethene	mg/kg	7.21×10^{-4}	7.21×10^{-3}	7.21×10^{-2}	NA	1.40×10^{-1}
Acetone	mg/kg	NA	NA	NA	*	NA
Benzene	mg/kg	5.25×10^{3}	5.25×10^{4}	5.25×10^{5}	NA	3.11×10^{4}
Endrin	mg/kg	NA	NA	NA	NA	*
Ethylbenzene	mg/kg	NA	NA	NA	*	*
Heptachlor	mg/kg	*	*	*	NA	*
Heptachlor Epoxide	mg/kg	4.33×10^{3}	4.33×10^{4}	1.02×10^{5}	1.02×10^{5}	3.04×10^{5}
Hexachlorobutadiene	mg/kg	NA	NA	NA	NA	*[b]
Methoxychlor	mg/kg	NA	NA	NA	*	*
Methyl Ethyl Ketone	mg/kg	NA	NA	NA	*	NA
Methyl Isobutyl Ketone	mg/kg	NA	NA	NA	*	NA
Toluene	mg/kg	NA	NA	NA	*	*
Toxaphene	mg/kg	2.29×10^{-3}	2.29×10^{-2}	2.29×10^{-1}	NA	8.48×10^{-1}
Xylenes	mg/kg	NA	NA	NA	*	*
Inorganics						
Barium	mg/kg	NA	NA	NA	*	*
Lead	mg/kg	NA	NA	NA	*[a]	NA
Silver	mg/kg	NA	NA	NA	*	NA

[a] Action Level
[b] MCLG
NA - Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5.I-6
LIQUID-PHASE WAC FOR CONSOLIDATION AREA WITH CAP

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL	Solubility in Water
Organics							
Chloroethane	μg/L	NA	NA	NA	>solubility	NA	6.00×10^6
1,1,1-Trichloroethane	μg/L						4.40×10^6
1,1-Dichloroethane	μg/L						7.00×10^6
Carbon tetrachloride	μg/L	>solubility	>solubility	>solubility	>solubility	>solubility	1.16×10^6
Chloroform	μg/L						1.06×10^7
Methylene Chloride	μg/L						2.36×10^7
Chloromethane	μg/L						6.36×10^6
Vinyl Chloride	μg/L	1.90×10^2	1.90×10^3	1.90×10^4	NA	3.69×10^4	2.70×10^6
Tetrachloroethene	μg/L						1.50×10^5
Trichloroethene	μg/L						1.10×10^6
1,1-Dichloroethene	μg/L						6.40×10^6
1,2-Dichloroethene	μg/L						6.30×10^6
Acetone	μg/L	NA	NA	NA	*	NA	[c]
Benzene	μg/L	>solubility	>solubility	>solubility	NA	>solubility	1.86×10^6
Endrin	μg/L	NA	NA	NA	NA	>solubility	2.60×10^2
Ethylbenzene	μg/L	NA	NA	NA	>solubility	>solubility	2.08×10^5
Heptachlor	μg/L	>solubility	>solubility	>solubility	NA	>solubility	1.80×10^2
Heptachlor Epoxide	μg/L	>solubility	>solubility	>solubility	>solubility	>solubility	3.50×10^2
Hexachlorobutadiene	μg/L	NA	NA	NA	NA	>solubility[b]	2.00×10^5
Methoxychlor	μg/L	NA	NA	NA	>solubility	>solubility	6.20×10^2
Methyl Ethyl Ketone	μg/L	NA	NA	NA	>solubility	NA	2.75×10^8
Methyl Isobutyl Ketone	μg/L	NA	NA	NA	>solubility	NA	1.91×10^7
Toluene	μg/L	NA	NA	NA	>solubility	>solubility	5.15×10^5
Toxaphene	μg/L	2.97×10^3	>solubility	>solubility	NA	>solubility	3.00×10^3
Xylenes	μg/L	NA	NA	NA	>solubility	>solubility	2.13×10^5
Inorganics							
Barium	μg/L	NA	NA	NA	*	*	Hydrolyzes
Lead	μg/L	NA	NA	NA	>solubility[a]	NA	3.33×10^5 [d]
Silver	μg/L	NA	NA	NA	>solubility	NA	5.56×10^6 [d]

[a] Action Level
[b] MCLG
[c] Miscible in all proportions
[d] Calculated from 10^6 mg/kg (i.e., pure product) divided by K_l
NA - Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5.I-7

SOLID-PHASE WAC FOR CONSOLIDATION AREA WITH CAP

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL
Organics						
Chloroethane	mg/kg	NA	NA	NA	1.21×10^{5}	NA
1,1,1-Trichloroethane	mg/kg	NA	NA	NA	*	*
1,1-Dichloroethane	mg/kg	NA	NA	NA	*	NA
Carbon tetrachloride	mg/kg	*	*	*	*	*
Chloroform	mg/kg	*	*	*	*	*
Methylene Chloride	mg/kg	*	*	*	*	*
Cloromethane	mg/kg	*	*	*	*	*
Vinyl Chloride	mg/kg	4.21×10^{-3}	4.21×10^{-2}	4.21×10^{-1}	NA	8.18×10^{-1}
Tetrachloroethene	mg/kg	3.57×10^{-1}	3.57×10^{0}	3.57×10^{1}	NA	6.94×10^{1}
Trichloroethene	mg/kg	3.57×10^{-1}	3.57×10^{0}	3.57×10^{1}	NA	6.94×10^{1}
1,1-Dichloroethene	mg/kg	3.17×10^{-2}	3.17×10^{-1}	3.17×10^{0}	NA	6.16×10^{0}
1,2-Dichloroethene	mg/kg	3.17×10^{-2}	3.17×10^{-1}	3.17×10^{0}	NA	6.16×10^{0}
Acetone	mg/kg	NA	NA	NA	*	NA
Benzene	mg/kg	*	*	*	NA	*
Endrin	mg/kg	NA	NA	NA	NA	*
Ethylbenzene	mg/kg	NA	NA	NA	*	*
Heptachlor	mg/kg	*	*	*	NA	*
Heptachlor Epoxide	mg/kg	*	*	*	*	*
Hexachlorobutadiene	mg/kg	NA	NA	NA	NA	*[b]
Methoxychlor	mg/kg	NA	NA	NA	*	*
Methyl Ethyl Ketone	mg/kg	NA	NA	NA	*	NA
Methyl Isobutyl Ketone	mg/kg	NA	NA	NA	*	NA
Toluene	mg/kg	NA	NA	NA	*	*
Toxaphene	mg/kg	3.95×10^{1}	3.95×10^{2}	3.95×10^{3}	NA	1.46×10^{4}
Xylenes	mg/kg	NA	NA	NA	*	*
Inorganics						
Barium	mg/kg	NA	NA	NA	*	*
Lead	mg/kg	NA	NA	NA	*[a]	NA
Silver	mg/kg	NA	NA	NA	*	NA

[a] Action Level
[b] MCLG
NA - Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5.I-8

LIQUID-PHASE WAC FOR DISPOSAL CELL

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL	Solubility in Water
Organics							
Chloroethane	µg/L	NA	NA	NA	>solubility	NA	6.00×10^6
1,1,1-Trichloroethane	µg/L						4.40×10^6
1,1-Dichloroethane	µg/L						7.00×10^6
Carbon tetrachloride	µg/L	>solubility	>solubility	>solubility	>solubility	>solubility	1.16×10^6
Chloroform	µg/L						1.06×10^7
Methylene Chloride	µg/L						2.36×10^7
Chloromethane	µg/L						6.36×10^6
Vinyl Chloride	µg/L	3.52×10^2	3.52×10^3	3.52×10^4	NA	6.83×10^4	2.70×10^6
Tetrachloroethene	µg/L						1.50×10^5
Trichloroethene	µg/L						1.10×10^6
1,1-Dichloroethene	µg/L						6.40×10^6
1,2-Dichloroethene	µg/L						6.30×10^6
Acetone	µg/L	NA	NA	NA	*	NA	[c]
Benzene	µg/L	>solubility	>solubility	>solubility	NA	>solubility	1.86×10^6
Endrin	µg/L	NA	NA	NA	NA	>solubility	2.60×10^2
Ethylbenzene	µg/L	NA	NA	NA	>solubility	>solubility	2.08×10^5
Heptachlor	µg/L	>solubility	>solubility	>solubility	NA	>solubility	1.80×10^2
Heptachlor Epoxide	µg/L	>solubility	>solubility	>solubility	>solubility	>solubility	3.50×10^2
Hexachlorobutadiene	µg/L	NA	NA	NA	NA	>solubility[b]	2.00×10^5
Methoxychlor	µg/L	NA	NA	NA	>solubility	>solubility	6.20×10^2
Methyl Ethyl Ketone	µg/L	NA	NA	NA	>solubility	NA	2.75×10^8
Methyl Isobutyl Ketone	µg/L	NA	NA	NA	>solubility	NA	1.91×10^7
Toluene	µg/L	NA	NA	NA	>solubility	>solubility	5.15×10^5
Toxaphene	µg/L	>solubility	>solubility	>solubility	NA	>solubility	3.00×10^3
Xylenes	µg/L	NA	NA	NA	>solubility	>solubility	2.13×10^5
Inorganics							
Barium	µg/L	NA	NA	NA	*	*	Hydrolyzes
Lead	µg/L	NA	NA	NA	>solubility[a]	NA	3.33×10^5 [d]
Silver	µg/L	NA	NA	NA	>solubility	NA	5.56×10^6 [d]

[a] Action Level
[b] MCLG
[c] Miscible in all proportions
[d] Calculated from 10^{-6} mg/kg (i.e., pure product) divided by K_l
NA - Not Applicable
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

TABLE F.5.I-9

SOLID-PHASE WAC FOR DISPOSAL CELL

COC	Unit	ILCR=10^{-6}	ILCR=10^{-5}	ILCR=10^{-4}	HQ = 0.2	MCL
Organics						
Chloroethane	mg/kg	NA	NA	NA	3.92×10^{5}	NA
1,1,1-Trichloroethane	mg/kg	NA	NA	NA	*	*
1,1-Dichloroethane	mg/kg	NA	NA	NA	*	NA
Carbon tetrachloride	mg/kg	*	*	*	*	*
Chloroform	mg/kg	*	*	*	*	*
Methylene Chloride	mg/kg	*	*	*	*	*
Chloromethane	mg/kg	*	*	*	*	*
Vinyl Chloride	mg/kg	7.79×10^{-3}	7.79×10^{-2}	7.79×10^{-1}	NA	1.51×10^{0}
Tetrachloroethene	mg/kg	6.62×10^{-1}	6.62×10^{0}	6.62×10^{1}	NA	1.28×10^{2}
Trichloroethene	mg/kg	6.62×10^{-1}	6.62×10^{0}	6.62×10^{1}	NA	1.28×10^{2}
1,1-Dichloroethene	mg/kg	5.88×10^{-2}	5.88×10^{-1}	5.88×10^{0}	NA	1.14×10^{1}
1,2-Dichloroethene	mg/kg	5.88×10^{-2}	5.88×10^{-1}	5.88×10^{0}	NA	1.14×10^{1}
Acetone	mg/kg	NA	NA	NA	*	NA
Benzene	mg/kg	*	*	*	NA	*
Endrin	mg/kg	NA	NA	NA	NA	*
Ethylbenzene	mg/kg	NA	NA	NA	*	*
Heptachlor	mg/kg	*	*	*	NA	*
Heptachlor Epoxide	mg/kg	*	*	*	*	*
Hexachlorobutadiene	mg/kg	NA	NA	NA	NA	*[b]
Methoxychlor	mg/kg	NA	NA	NA	*	*
Methyl Ethyl Ketone	mg/kg	NA	NA	NA	*	NA
Methyl Isobutyl Ketone	mg/kg	NA	NA	NA	*	NA
Toluene	mg/kg	NA	NA	NA	*	*
Toxaphene	mg/kg	2.87×10^{2}	2.87×10^{3}	2.87×10^{4}	NA	1.06×10^{5}
Xylenes	mg/kg	NA	NA	NA	*	*
Inorganics						
Barium	mg/kg	NA	NA	NA	*	*
Lead	mg/kg	NA	NA	NA	*[a]	NA
Silver	mg/kg	NA	NA	NA	*	NA

[a] Action Level
[b] MCLG
NA - Not Applicable; Denotes compounds that do not have corresponding risk-based action levels in groundwater
* Compounds denoted with an asterisk will not exceed designated GMA action level within 1000 year performance period, regardless of starting concentration in the disposal facility. See Section F.5.I.5.6 for a discussion of best management practices for these compounds.

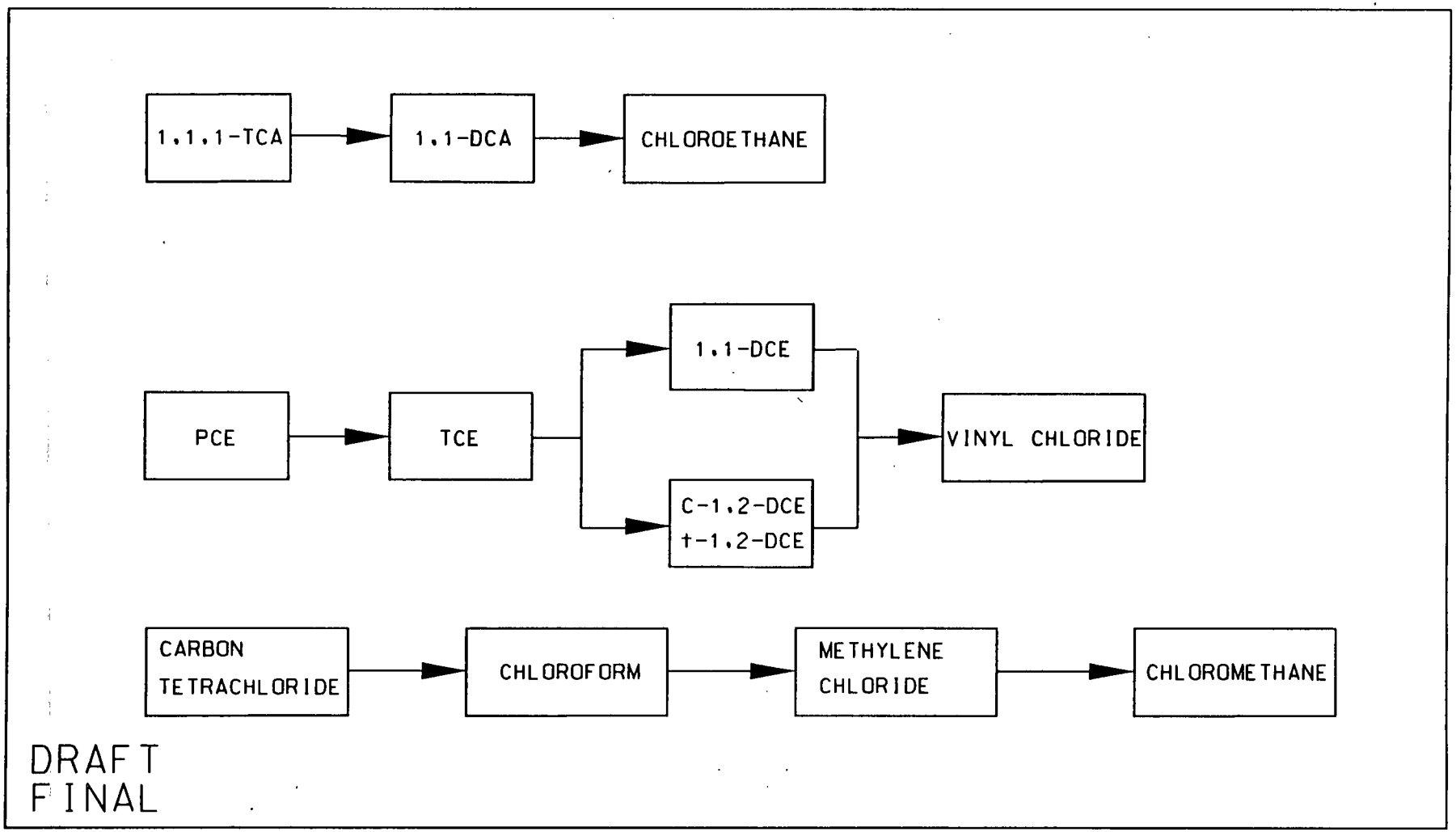

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FIGURE F.5.I-1. TRANSFORMATION PATHWAYS FOR VARIOUS CHLORINATED VOLATILE HYDROCARBONS IN SUBSURFACE ENVIRONMENTS

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ATTACHMENT F.5.II
SUMMARY OF MODELING RESULTS FOR LONG-TERM PERFORMANCE EVALUATION OF THE DISPOSAL CELL

LIST OF TABLES

NUMBER	TITLE
F.5.II-1	Summary of Monte Carlo Simulations for Long-Term Performance Evaluation of the Disposal Cell

TABLE F.5.II-1

SUMMARY OF MONTE CARLO SIMULATIONS FOR LONG-TERM PERFORMANCE EVALUATION OF THE DISPOSAL CELL

Disposal Cell Size: 1500 ft x 1500 ft
Liner Thickness = 3 ft, Liner Kd = 24 L/KG
Gray Clay Thickness = 30 ft, Gray Clay Kd = 3.1 L/KG
Sand Layer Thickness = 20 ft, Sand clay Kd = 1.78 L/KG
Constant Source Leachate Concentration = 6670 ug/L
Infiltration Rate Assumption:
0.04 in/yr from 0 to Time1, 0.89 in/yr form Time1 to Time2, and 3.0 in/yr from Time2 to 1000 yr.
Where Time1 and Time2 are the time point when a certain capping material fails.

Assumptions in Monte Carlo Simulation				Monte Carlo Simulation Results:			
Time1		Time2					
Mean (yr)	Standard Dev. (yr)	Mean (yr)	Standard Dev. (yr)	Mean GMA Concentration at 1000 yr (ug/L)	Percentile of the GMA Concentration at 1000 yr Less than 20 (ug/L)	100% chance of the GMA Concentration at 500 yr Less Than the Following Value (ug/L)	100% chance of the GMA Concentration at 200 yr Less Than the Followimg Value (ug/L)
200	50	600	200	20.04	64%	2.40	0.00
200	50	700	200	11.77	81%	1.52	0.00
200	50	800	200	7.30	88%	0.91	0.00

000992

ECTran Monte Carlo Simulation Model Outputs
for
Case 1-Upper Clay Sub-barriers

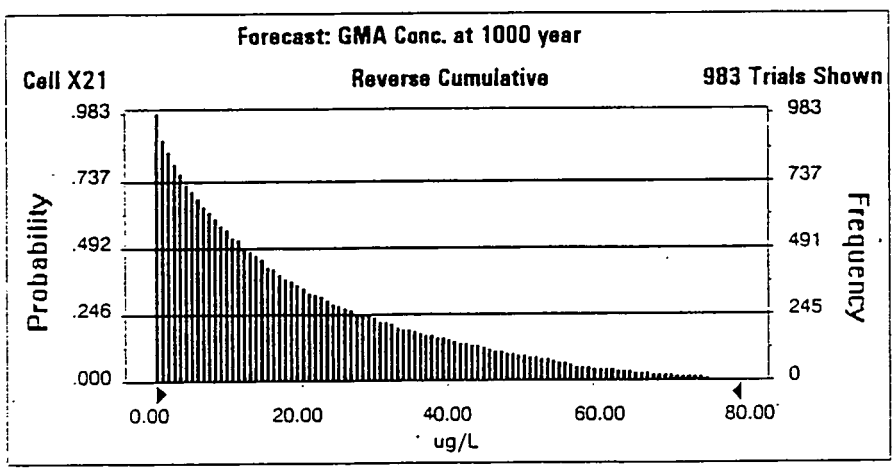
Mean
Hypothetical Performance
Lifetime = 600 years

Crystal Ball Report
Simulation started on 10/19/94 at 17:12:31
Simulation stopped on 10/19/94 at 19:36:16

Forecast: GMA Conc. at 1000 year **Cell: X21**

Summary:
Display Range is from 0.00 to 80.00 ug/L
Entire Range is from 0.03 to 112.98 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.67

Statistics:	Value
Trials	1000
Mean	20.04
Median (approx.)	12.70
Mode (approx.)	0.60
Standard Deviation	21.22
Variance	450.24
Skewness	1.43
Kurtosis	4.61
Coeff. of Variability	1.06
Range Minimum	0.03
Range Maximum	112.98
Range Width	112.95
Mean Std. Error	0.67



REPORT1.XLS

Forecast: GMA Conc. at 1000 year (cont'd) Cell: X21

Percentiles:

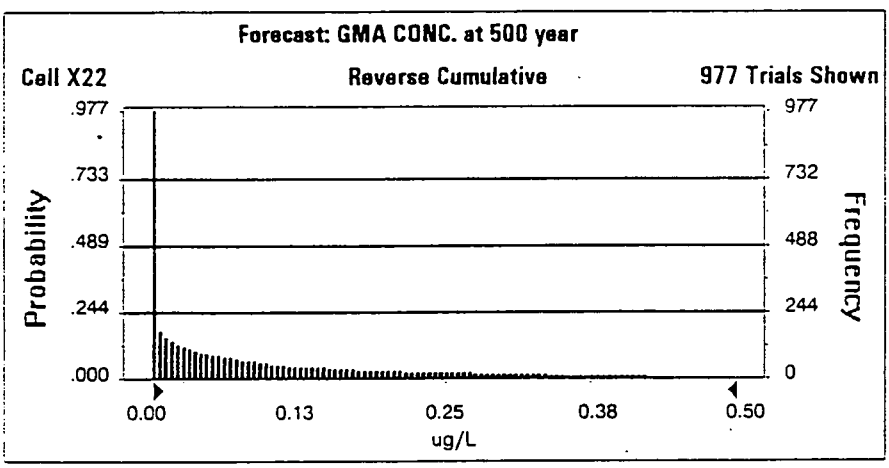
Percentile	ug/L (approx.)
0%	0.03
10%	0.85
20%	2.76
30%	5.23
40%	8.62
50%	12.70
60%	17.26
70%	24.28
80%	35.27
90%	52.87
100%	112.98

End of Forecast .

Forecast: GMA CONC. at 500 year **Cell: X22**

Summary:
Display Range is from 0.00 to 0.50 ug/L
Entire Range is from 0.00 to 2.40 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.01

Statistics:	Value
Trials	1000
Mean	0.04
Median (approx.)	0.00
Mode (approx.)	0.01
Standard Deviation	0.16
Variance	0.03
Skewness	7.66
Kurtosis	80.57
Coeff. of Variability	4.20
Range Minimum	0.00
Range Maximum	2.40
Range Width	2.40
Mean Std. Error	0.01



REPORT1.XLS

Forecast: GMA CONC. at 500 year (cont'd) **Cell: X22**

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.01
70%	0.01
80%	0.01
90%	0.07
100%	2.40

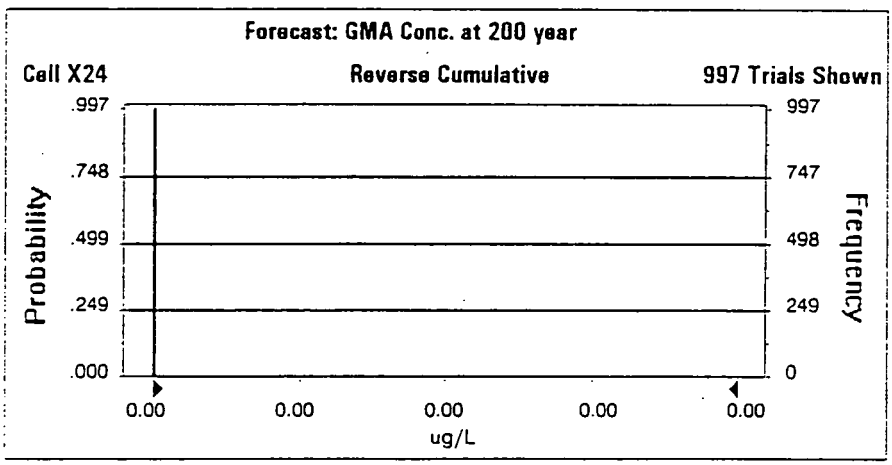
End of Forecast

REPORT1.XLS

Forecast: GMA Conc. at 200 year **Cell: X24**

Summary:
Display Range is from 0.00 to 0.00 ug/L
Entire Range is from 0.00 to 0.00 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.00

Statistics:	Value
Trials	1000
Mean	0.00
Median (approx.)	0.00
Mode (approx.)	0.00
Standard Deviation	0.00
Variance	0.00
Skewness	27.14
Kurtosis	788.75
Coeff. of Variability	21.26
Range Minimum	0.00
Range Maximum	0.00
Range Width	0.00
Mean Std. Error	0.00



REPORT1..XLS

Forecast: GMA Conc. at 200 year (cont'd) **Cell: X24**

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	0.00
90%	0.00
100%	0.00

End of Forecast

REPORT1.XLS

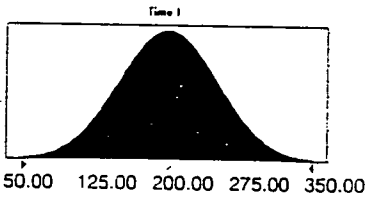
Assumptions

Assumption: Time 1 Cell: D6

Normal distribution with parameters:

Mean	200.00
Standard Dev.	50.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 199.57

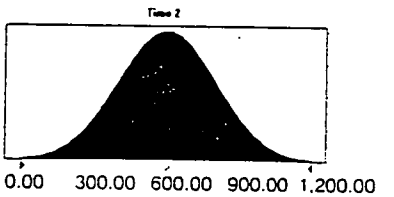


Assumption: Time 2 Cell: D7

Normal distribution with parameters:

Mean	600.00
Standard Dev.	200.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 599.72



End of Assumptions

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrun) MODEL

MCL(pCi/l): 2.24E+03

SITE:	Time 1	200	Infil 1(ft/yr)	0.003333333
	Time 2	600	Infil 2(ft/yr)	0.074166667
			Infil 3(ft/yr)	0.25
INVESTIGATOR:		WYU		
DATE:		10/20/94		

CONTAMINANT: U238		SPECIFIC ACTIVITY:	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	2.00E+01
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	6.67E+03
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG):	0.0000	B (FT):	75	Vzo (FT/YR):	0.847
WIDTH (FT):	1500	Kd (L/KG):	24.00	3	Kd (L/KG):	1.780			CU2 (PPB):	0
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION:	0.13	GW V.(FT/YR):	304.00	Kd (L/KG):	1.78
POROSITY 2:	0.3	THICKNESS (FT):	3.00	1	THICKNESS (FT):	22.00			RETARDATION:	11.0867
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY):	4.25E-13	EFF. POROSITY	0.30	q (FT/YR) :	0
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00			DECAY (1/YR):	1.6E-10
Ts(YEARS):	1000	D.F.(1/YR):	0				Az(FT):	0.03	CU3 (PPB):	0
AGE (YEARS):	0						Ax (FT):	100.00	P&T(YEARS):	0
							Ay (FT):	33.33	DISTANCE TO F.L.(FT)	1760

TIME INTERVAL (YRS) 20

LAYER 1 LEACHATE CONC. (UG/L))

ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	LINER	SUBLAYER 1			SUBLAYER 2		
0	0.003333333	6.67E+03	0.00E+00	0.00E+00			0.00E+00		
20	0.003333333	6.67E+03	3.45E+00	1.07E-02			3.34E-05		
40	0.003333333	6.67E+03	6.91E+00	3.22E-02			1.34E-04		
60	0.003333333	6.67E+03	1.04E+01	6.43E-02			3.33E-04		
80	0.003333333	6.67E+03	1.38E+01	1.07E-01			6.65E-04		
100	0.003333333	6.67E+03	1.73E+01	1.60E-01			1.16E-03		
120	0.003333333	6.67E+03	2.07E+01	2.24E-01			1.86E-03		
140	0.003333333	6.67E+03	2.41E+01	2.99E-01			2.78E-03		
160	0.003333333	6.67E+03	2.76E+01	3.84E-01			3.96E-03		
180	0.003333333	6.67E+03	3.10E+01	4.79E-01			5.44E-03		
200	0.074166667	6.67E+03	1.07E+02	7.62E+00			5.16E-01		
220	0.074166667	6.67E+03	1.82E+02	1.93E+01			1.78E+00		
240	0.074166667	6.67E+03	2.57E+02	3.52E+01			4.02E+00		
260	0.074166667	6.67E+03	3.30E+02	5.50E+01			7.43E+00		
280	0.074166667	6.67E+03	4.03E+02	7.83E+01			1.22E+01		
300	0.074166667	6.67E+03	4.75E+02	1.05E+02			1.84E+01		
320	0.074166667	6.67E+03	5.46E+02	1.34E+02			2.61E+01		
340	0.074166667	6.67E+03	6.16E+02	1.67E+02			3.56E+01		
360	0.074166667	6.67E+03	6.85E+02	2.01E+02			4.67E+01		
380	0.074166667	6.67E+03	7.54E+02	2.38E+02			5.95E+01		
400	0.074166667	6.67E+03	8.21E+02	2.77E+02			7.41E+01		
420	0.074166667	6.67E+03	8.88E+02	3.18E+02			9.04E+01		
440	0.074166667	6.67E+03	9.55E+02	3.61E+02			1.09E+02		
460	0.074166667	6.67E+03	1.02E+03	4.05E+02			1.28E+02		
480	0.074166667	6.67E+03	1.08E+03	4.51E+02			1.50E+02		
500	0.074166667	6.67E+03	1.15E+03	4.97E+02			1.73E+02		
520	0.074166667	6.67E+03	1.21E+03	5.45E+02			1.98E+02		
540	0.074166667	6.67E+03	1.27E+03	5.94E+02			2.25E+02		
560	0.074166667	6.67E+03	1.34E+03	6.44E+02			2.53E+02		
580	0.074166667	6.67E+03	1.40E+03	6.94E+02			2.82E+02		
600	0.25	6.67E+03	1.60E+03	8.83E+02			4.07E+02		
620	0.25	6.67E+03	1.79E+03	1.07E+03			5.46E+02		
640	0.25	6.67E+03	1.98E+03	1.26E+03			6.95E+02		
660	0.25	6.67E+03	2.16E+03	1.45E+03			8.52E+02		
680	0.25	6.67E+03	2.33E+03	1.63E+03			1.01E+03		
700	0.25	6.67E+03	2.49E+03	1.81E+03			1.18E+03		
720	0.25	6.67E+03	2.65E+03	1.99E+03			1.35E+03		
740	0.25	6.67E+03	2.81E+03	2.16E+03			1.52E+03		
760	0.25	6.67E+03	2.95E+03	2.32E+03			1.68E+03		
780	0.25	6.67E+03	3.09E+03	2.48E+03			1.85E+03		
800	0.25	6.67E+03	3.23E+03	2.64E+03			2.02E+03		
820	0.25	6.67E+03	3.36E+03	2.79E+03			2.18E+03		
840	0.25	6.67E+03	3.49E+03	2.94E+03			2.33E+03		
860	0.25	6.67E+03	3.61E+03	3.08E+03			2.49E+03		
880	0.25	6.67E+03	3.73E+03	3.21E+03			2.64E+03		
900	0.25	6.67E+03	3.84E+03	3.34E+03			2.79E+03		
920	0.25	6.67E+03	3.95E+03	3.47E+03			2.93E+03		
940	0.25	6.67E+03	4.05E+03	3.59E+03			3.07E+03		
960	0.25	6.67E+03	4.15E+03	3.71E+03			3.20E+03		
980	0.25	6.67E+03	4.24E+03	3.82E+03			3.33E+03		
1000	0.25	6.67E+03	4.34E+03	3.93E+03			3.45E+03		
MAXIMUM:	0.25	6.67E+03	4.34E+03				3.45E+03		

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	6.67E+03	1.00E+02	2.21E+03	3.36E+01
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrans) MODEL

SITE:

INVESTIGATOR: WYU
DATE: 10/20/94

CONTAMINANT: U238		SPECIFIC ACTIVITY(Ci/g):	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	1.83E+00
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	0.00E+00
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
							B (FT):	75	Vzo (FT/YR):	0.847
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG):	0.0000			CU2 (PPB):	0
WIDTH (FT):	1500	Kd (L/KG):	3.10	22.5	Kd (L/KG):	1.780	GW V.(FT/YR):	303.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION:	0.13			RETARDATION:	11.0867
POROSITY 2:	0.3	THICKNESS (FT):	3.75	6	THICKNESS (FT):	20.00	EFF. POROSITY	0.30	q (FT/YR) :	0
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY):	4.25E-13			DECAY (1/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00	Azi(FT):	0.35	CU3 (PPB):	0
Tsi(YEARS):	1000	D.F.(1/YR):	0				Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0						Ay (FT):	33.33	DISTANCE TO F.L.(FT)	2010

TIME INTERVAL (YRS)		20	LAYER 1 LEACHATE CONC. (UG/L))							SOURCE AREA CONC.	FEN LINE CONC.
ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	SUBLAYER 3	SUBLAYER 4	SUBLAYER 5	SUBLAYER 6	SUBLAYER 7	SUBLAYER 8	LAYER 2	(UG/L)	(UG/L)
0	0.003333333	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	0.003333333	3.34E-05	1.04E-07	3.24E-10	1.01E-12	3.13E-15	9.75E-18	3.03E-20	3.50E-23	3.27E-26	0.00E+00
40	0.003333333	1.34E-04	5.19E-07	1.94E-09	7.03E-12	2.50E-14	8.75E-17	3.03E-19	3.84E-22	4.10E-25	1.51E-31
60	0.003333333	3.33E-04	1.55E-06	6.77E-09	2.81E-11	1.12E-13	4.37E-16	1.66E-18	2.30E-21	2.74E-24	7.86E-28
80	0.003333333	6.65E-04	3.62E-06	1.80E-08	8.40E-11	3.73E-13	1.60E-15	6.62E-18	9.94E-21	1.30E-23	1.72E-26
100	0.003333333	1.16E-03	7.22E-06	4.04E-08	2.10E-10	1.02E-12	4.78E-15	2.15E-17	3.47E-20	4.95E-23	1.69E-25
120	0.003333333	1.86E-03	1.30E-05	8.07E-08	4.60E-10	2.43E-12	1.24E-14	6.00E-17	1.04E-19	1.59E-22	1.07E-24
140	0.003333333	2.78E-03	2.16E-05	1.48E-07	9.18E-10	5.30E-12	2.88E-14	1.50E-16	2.76E-19	4.32E-22	5.12E-24
160	0.003333333	3.96E-03	3.39E-05	2.52E-07	1.70E-09	1.06E-11	6.17E-14	3.41E-16	6.69E-19	1.16E-21	1.99E-23
180	0.003333333	5.44E-03	5.07E-05	4.09E-07	2.97E-09	1.98E-11	1.23E-13	7.23E-16	1.50E-18	2.74E-21	6.62E-23
200	0.074166667	5.16E-01	3.46E-02	2.32E-03	1.55E-04	1.04E-05	6.96E-07	4.67E-08	1.18E-09	2.44E-11	1.95E-22
220	0.074166667	1.78E+00	1.51E-01	1.23E-02	9.68E-04	7.45E-05	5.64E-06	4.22E-07	1.18E-08	2.81E-10	1.12E-16
240	0.074166667	4.02E+00	4.10E-01	3.89E-02	3.51E-03	3.05E-04	2.57E-05	2.11E-06	6.32E-08	1.73E-09	5.85E-13
260	0.074166667	7.43E+00	8.80E-01	9.53E-02	9.66E-03	9.31E-04	8.63E-05	7.76E-06	2.60E-07	7.64E-09	1.22E-11
280	0.074166667	1.22E+01	1.64E+00	1.99E-01	2.23E-02	2.36E-03	2.39E-04	2.32E-05	8.43E-07	2.69E-08	1.13E-10
300	0.074166667	1.84E+01	2.76E+00	3.70E-01	4.56E-02	5.26E-03	5.75E-04	6.02E-05	2.35E-06	8.08E-08	6.71E-10
320	0.074166667	2.61E+01	4.32E+00	6.35E-01	8.51E-02	1.06E-02	1.25E-03	1.40E-04	5.83E-06	2.14E-07	3.00E-09
340	0.074166667	3.56E+01	6.42E+00	1.02E+00	1.48E-01	1.98E-02	2.49E-03	2.97E-04	1.32E-05	5.15E-07	1.09E-08
360	0.074166667	4.67E+01	9.11E+00	1.56E+00	2.43E-01	3.47E-02	4.65E-03	5.89E-04	2.78E-05	1.14E-06	3.41E-08
380	0.074166667	5.95E+01	1.25E+01	2.30E+00	3.80E-01	5.79E-02	8.22E-03	1.10E-03	5.50E-05	2.37E-06	9.40E-08
400	0.074166667	7.41E+01	1.66E+01	3.25E+00	5.73E-01	9.24E-02	1.39E-02	1.95E-03	1.03E-04	4.63E-06	2.35E-07
420	0.074166667	9.04E+01	2.16E+01	4.48E+00	8.35E-01	1.42E-01	2.24E-02	3.33E-03	1.85E-04	8.64E-06	5.40E-07
440	0.074166667	1.09E+02	2.74E+01	6.02E+00	1.18E+00	2.12E-01	3.51E-02	5.46E-03	3.19E-04	1.54E-05	1.16E-06
460	0.074166667	1.28E+02	3.42E+01	7.90E+00	1.63E+00	3.07E-01	5.33E-02	8.66E-03	5.30E-04	2.66E-05	2.35E-06
480	0.074166667	1.50E+02	4.19E+01	1.02E+01	2.20E+00	4.34E-01	7.88E-02	1.34E-02	8.56E-04	4.43E-05	4.51E-06
500	0.074166667	1.73E+02	5.07E+01	1.29E+01	2.92E+00	6.01E-01	1.14E-01	2.01E-02	1.34E-03	7.15E-05	8.29E-06
520	0.074166667	1.98E+02	6.06E+01	1.61E+01	3.80E+00	8.15E-01	1.61E-01	2.95E-02	2.06E-03	1.13E-04	1.46E-05
540	0.074166667	2.25E+02	7.16E+01	1.98E+01	4.87E+00	1.09E+00	2.23E-01	4.25E-02	3.08E-03	1.73E-04	2.50E-05
560	0.074166667	2.53E+02	8.37E+01	2.41E+01	6.16E+00	1.43E+00	3.03E-01	5.99E-02	4.53E-03	2.60E-04	4.13E-05
580	0.074166667	2.82E+02	9.70E+01	2.90E+01	7.69E+00	1.85E+00	4.07E-01	8.31E-02	6.52E-03	3.83E-04	6.64E-05
600	0.25	4.07E+02	1.62E+02	5.66E+01	1.79E+01	5.19E+00	1.40E+00	3.58E-01	3.57E-02	9.25E-04	1.04E-04
620	0.25	5.46E+02	2.42E+02	9.52E+01	3.40E+01	1.12E+01	3.45E+00	1.00E+00	1.16E-01	2.99E-03	1.59E-04
640	0.25	6.95E+02	3.36E+02	1.45E+02	5.72E+01	2.08E+01	7.06E+00	2.26E+00	2.94E-01	8.37E-03	2.48E-04
660	0.25	8.52E+02	4.44E+02	2.08E+02	8.86E+01	3.49E+01	1.29E+01	4.47E+00	6.41E-01	2.00E-02	4.87E-04
680	0.25	1.01E+03	5.63E+02	2.82E+02	1.29E+02	5.45E+01	2.15E+01	8.03E+00	1.25E+00	4.25E-02	1.30E-03
700	0.25	1.18E+03	6.91E+02	3.67E+02	1.78E+02	8.03E+01	3.38E+01	1.34E+01	2.26E+00	8.21E-02	3.61E-03
720	0.25	1.35E+03	8.28E+02	4.63E+02	2.38E+02	1.13E+02	5.03E+01	2.11E+01	3.83E+00	1.48E-01	9.07E-03
740	0.25	1.52E+03	9.72E+02	5.69E+02	3.07E+02	1.54E+02	7.18E+01	3.17E+01	6.14E+00	2.50E-01	2.04E-02
760	0.25	1.68E+03	1.12E+03	6.84E+02	3.85E+02	2.02E+02	9.89E+01	4.57E+01	9.42E+00	3.92E-01	4.15E-02
780	0.25	1.85E+03	1.27E+03	8.07E+02	4.73E+02	2.58E+02	1.32E+02	6.37E+01	1.39E+01	6.21E-01	7.82E-02
800	0.25	2.02E+03	1.43E+03	9.36E+02	5.70E+02	3.23E+02	1.72E+02	8.63E+01	1.99E+01	9.25E-01	1.38E-01
820	0.25	2.18E+03	1.58E+03	1.07E+03	6.74E+02	3.96E+02	2.19E+02	1.14E+02	2.77E+01	1.31E+00	2.31E-01
840	0.25	2.33E+03	1.74E+03	1.21E+03	7.86E+02	4.78E+02	2.73E+02	1.47E+02	3.76E+01	1.87E+00	3.69E-01
860	0.25	2.49E+03	1.90E+03	1.35E+03	9.04E+02	5.67E+02	3.34E+02	1.86E+02	4.99E+01	2.56E+00	5.67E-01
880	0.25	2.64E+03	2.05E+03	1.50E+03	1.03E+03	6.63E+02	4.02E+02	2.31E+02	6.50E+01	3.43E+00	8.42E-01
900	0.25	2.79E+03	2.20E+03	1.65E+03	1.16E+03	7.66E+02	4.78E+02	2.83E+02	8.30E+01	4.50E+00	1.21E+00
920	0.25	2.93E+03	2.36E+03	1.79E+03	1.29E+03	8.75E+02	5.61E+02	3.41E+02	1.04E+02	5.80E+00	1.70E+00
940	0.25	3.07E+03	2.50E+03	1.94E+03	1.43E+03	9.90E+02	6.50E+02	4.05E+02	1.29E+02	7.36E+00	2.32E+00
960	0.25	3.20E+03	2.65E+03	2.09E+03	1.56E+03	1.11E+03	7.46E+02	4.76E+02	1.58E+02	9.20E+00	3.11E+00
980	0.25	3.33E+03	2.79E+03	2.23E+03	1.70E+03	1.23E+03	8.47E+02	5.54E+02	1.91E+02	1.13E+01	4.09E+00
1000	0.25	3.45E+03	2.93E+03	2.38E+03	1.84E+03	1.36E+03	9.54E+02	6.37E+02	2.28E+02	1.38E+01	5.27E+00
MAXIMUM:	0.25	3.45E+03	2.93E+03	2.38E+03	1.84E+03	1.36E+03	9.54E+02	6.37E+02	2.28E+02	1.38E+01	5.27E+00

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

ECTran Monte Carlo Simulation Model Outputs
for
Case 2 - Upper Clay Sub-barriers

Mean Hypothetical Performance
Lifetime = 700 years

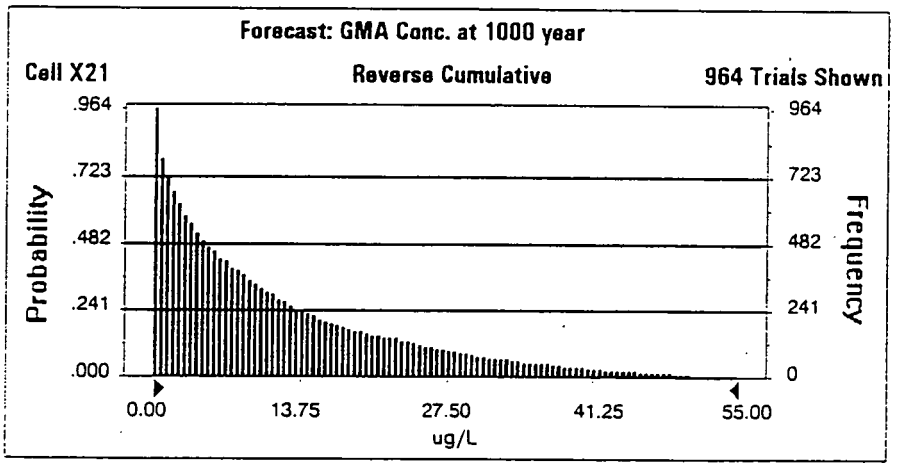
Report2

Crystal Ball Report
Simulation started on 10/19/94 at 13:14:49
Simulation stopped on 10/19/94 at 17:00:33

Forecast: GMA Conc. at 1000 year **Cell: X21**

Summary:
Display Range is from 0.00 to 55.00 ug/L
Entire Range is from 0.03 to 101.28 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.52

Statistics:	Value
Trials	1000
Mean	11.77
Median (approx.)	5.14
Mode (approx.)	0.53
Standard Deviation	16.29
Variance	265.34
Skewness	2.23
Kurtosis	8.45
Coeff. of Variability	1.38
Range Minimum	0.03
Range Maximum	101.28
Range Width	101.26
Mean Std. Error	0.52



Report2

Forecast: GMA Conc. at 1000 year (cont'd)

Cell: X21

Percentiles:

Percentile	ug/L (approx.)
0%	0.03
10%	0.25
20%	0.68
30%	1.73
40%	3.09
50%	5.14
60%	8.28
70%	12.47
80%	18.89
90%	32.43
100%	101.28

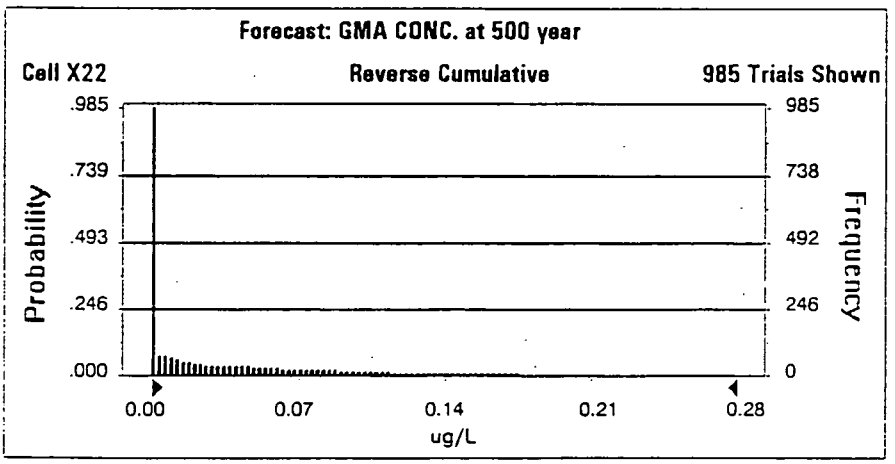
End of Forecast

Report2

Forecast: GMA CONC. at 500 year **Cell: X22**

Summary:
Display Range is from 0.00 to 0.28 ug/L
Entire Range is from 0.00 to 1.52 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.00

Statistics:	Value
Trials	1000
Mean	0.01
Median (approx.)	0.00
Mode (approx.)	0.01
Standard Deviation	0.09
Variance	0.01
Skewness	10.30
Kurtosis	133.40
Coeff. of Variability	6.22
Range Minimum	0.00
Range Maximum	1.52
Range Width	1.52
Mean Std. Error	0.00



Report2

Forecast: GMA CONC. at 500 year (cont'd) **Cell: X22**

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	0.00
90%	0.01
100%	1.52

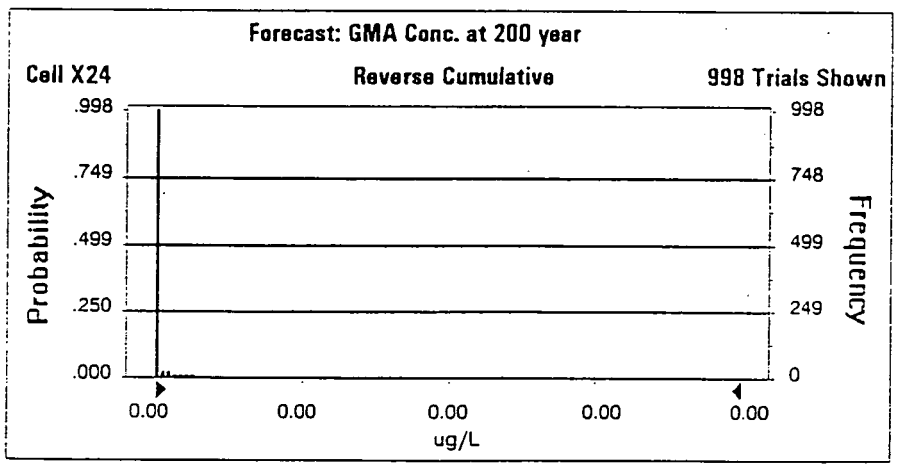
End of Forecast

Report2

Forecast: GMA Conc. at 200 year **Cell: X24**

Summary:
Display Range is from 0.00 to 0.00 ug/L
Entire Range is from 0.00 to 0.00 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.00

Statistics:	Value
Trials	1000
Mean	0.00
Median (approx.)	0.00
Mode (approx.)	0.00
Standard Deviation	0.00
Variance	0.00
Skewness	24.43
Kurtosis	625.84
Coeff. of Variability	20.54
Range Minimum	0.00
Range Maximum	0.00
Range Width	0.00
Mean Std. Error	0.00



Report2

Forecast: GMA Conc. at 200 year (cont'd)

Cell: X24

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	0.00
90%	0.00
100%	0.00

End of Forecast

Report2

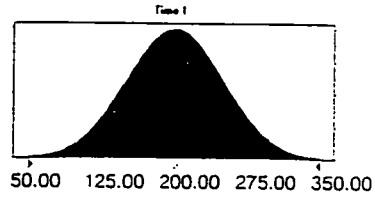
Assumptions

Assumption: Time 1 **Cell: D6**

Normal distribution with parameters:

Mean	200.00
Standard Dev.	50.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 201.77

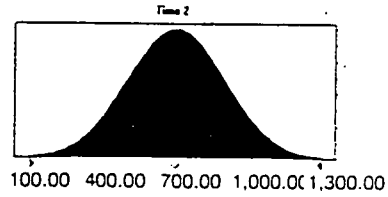


Assumption: Time 2 **Cell: D7**

Normal distribution with parameters:

Mean	700.00
Standard Dev.	200.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 700.75



End of Assumptions

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrns) MODEL

MCL(pCi/l): 2.24E+03

SITE:	Time 1	200	Infil 1(ft/yr)	0.003333333
	Time 2	700	Infil 2(ft/yr)	0.074166667
			Infil 3(ft/yr)	0.25
INVESTIGATOR:		WYU		
DATE:		10/20/94		

CONTAMINANT: U238		SPECIFIC ACTIVITY:	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	2.00E+01
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	6.67E+03
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG):	0.0000	B (FT):	75	Vzo (FT/YR):	0.847
WIDTH (FT):	1500	Kd (L/KG):	24.00	3	Kd (L/KG):	1.780			CU2 (PPB):	0
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION:	0.13	GW V.(FT/YR):	304.00	Kd (L/KG):	1.78
POROSITY 2:	0.3	THICKNESS (FT):	3.00	1	THICKNESS (FT):	22.00			RETARDATION:	11.0867
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY):	4.25E-13	EFF. POROSITY	0.30	q (FT/YR):	0
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00			DECAY (1/YR):	1.6E-10
Ts(YEARS):	1000	D.F.(1/YR):	0				Az(FT):	0.03	CU3 (PPB):	0
AGE (YEARS):	0						Ax (FT):	100.00	P&T(YEARS):	0
							Ay (FT):	33.33	DISTANCE TO F.L.(FT)	1760

TIME INTERVAL (YRS) 20

LAYER 1 LEACHATE CONC. (UG/L))

ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	LINER	SUBLAYER 1			SUBLAYER 2		
0	0.003333333	6.67E+03	0.00E+00	0.00E+00			0.00E+00		
20	0.003333333	6.67E+03	3.45E+00	1.07E-02			3.34E-05		
40	0.003333333	6.67E+03	6.91E+00	3.22E-02			1.34E-04		
60	0.003333333	6.67E+03	1.04E+01	6.43E-02			3.33E-04		
80	0.003333333	6.67E+03	1.38E+01	1.07E-01			6.65E-04		
100	0.003333333	6.67E+03	1.73E+01	1.60E-01			1.16E-03		
120	0.003333333	6.67E+03	2.07E+01	2.24E-01			1.86E-03		
140	0.003333333	6.67E+03	2.41E+01	2.99E-01			2.78E-03		
160	0.003333333	6.67E+03	2.76E+01	3.84E-01			3.96E-03		
180	0.003333333	6.67E+03	3.10E+01	4.79E-01			5.44E-03		
200	0.074166667	6.67E+03	1.07E+02	7.62E+00			5.16E-01		
220	0.074166667	6.67E+03	1.82E+02	1.93E+01			1.78E+00		
240	0.074166667	6.67E+03	2.57E+02	3.52E+01			4.02E+00		
260	0.074166667	6.67E+03	3.30E+02	5.50E+01			7.43E+00		
280	0.074166667	6.67E+03	4.03E+02	7.83E+01			1.22E+01		
300	0.074166667	6.67E+03	4.75E+02	1.05E+02			1.84E+01		
320	0.074166667	6.67E+03	5.46E+02	1.34E+02			2.61E+01		
340	0.074166667	6.67E+03	6.16E+02	1.67E+02			3.56E+01		
360	0.074166667	6.67E+03	6.85E+02	2.01E+02			4.67E+01		
380	0.074166667	6.67E+03	7.54E+02	2.38E+02			5.95E+01		
400	0.074166667	6.67E+03	8.21E+02	2.77E+02			7.41E+01		
420	0.074166667	6.67E+03	8.88E+02	3.18E+02			9.04E+01		
440	0.074166667	6.67E+03	9.55E+02	3.61E+02			1.09E+02		
460	0.074166667	6.67E+03	1.02E+03	4.05E+02			1.28E+02		
480	0.074166667	6.67E+03	1.08E+03	4.51E+02			1.50E+02		
500	0.074166667	6.67E+03	1.15E+03	4.97E+02			1.73E+02		
520	0.074166667	6.67E+03	1.21E+03	5.45E+02			1.98E+02		
540	0.074166667	6.67E+03	1.27E+03	5.94E+02			2.25E+02		
560	0.074166667	6.67E+03	1.34E+03	6.44E+02			2.53E+02		
580	0.074166667	6.67E+03	1.40E+03	6.94E+02			2.82E+02		
600	0.074166667	6.67E+03	1.46E+03	7.45E+02			3.13E+02		
620	0.074166667	6.67E+03	1.52E+03	7.97E+02			3.46E+02		
640	0.074166667	6.67E+03	1.58E+03	8.49E+02			3.80E+02		
660	0.074166667	6.67E+03	1.63E+03	9.02E+02			4.15E+02		
680	0.074166667	6.67E+03	1.69E+03	9.55E+02			4.51E+02		
700	0.25	6.67E+03	1.88E+03	1.15E+03			5.96E+02		
720	0.25	6.67E+03	2.06E+03	1.34E+03			7.51E+02		
740	0.25	6.67E+03	2.24E+03	1.53E+03			9.13E+02		
760	0.25	6.67E+03	2.41E+03	1.71E+03			1.08E+03		
780	0.25	6.67E+03	2.57E+03	1.89E+03			1.25E+03		
800	0.25	6.67E+03	2.73E+03	2.06E+03			1.42E+03		
820	0.25	6.67E+03	2.88E+03	2.23E+03			1.59E+03		
840	0.25	6.67E+03	3.02E+03	2.40E+03			1.76E+03		
860	0.25	6.67E+03	3.16E+03	2.56E+03			1.92E+03		
880	0.25	6.67E+03	3.29E+03	2.71E+03			2.09E+03		
900	0.25	6.67E+03	3.42E+03	2.86E+03			2.25E+03		
920	0.25	6.67E+03	3.55E+03	3.00E+03			2.41E+03		
940	0.25	6.67E+03	3.67E+03	3.14E+03			2.56E+03		
960	0.25	6.67E+03	3.78E+03	3.27E+03			2.71E+03		
980	0.25	6.67E+03	3.89E+03	3.40E+03			2.85E+03		
1000	0.25	6.67E+03	4.00E+03	3.53E+03			2.99E+03		
MAXIMUM:	0.25	6.67E+03	4.00E+03				2.99E+03		

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	6.67E+03	1.00E+02	2.24E+03	3.36E+01
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrans) MODEL

SITE:

INVESTIGATOR: WYU
DATE: 10/20/94

CONTAMINANT: U238		SPECIFIC ACTIVITY(Ci/g):	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	1.83E+00
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	0.00E+00
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE AREA:		LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
							B (FT):	75	Vzo (FT/YR):	0.847
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG):	0.0000			CU2 (PPB):	0
WIDTH (FT):	1500	Kd (L/KG):	3.10	22.5	Kd (L/KG):	1.780	GW V.(FT/YR):	303.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION:	0.13			RETARDATION:	11.0867
POROSITY 2:	0.3	THICKNESS (FT):	3.75	6	THICKNESS (FT):	20.00	EFF. POROSITY	0.30	q (FT/YR):	0
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY):	4.25E-13			DECAY (1/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00	Az(FT):	0.35	CU3 (PPB):	0
Ts(YEARS):	1000	D.F.(1/YR):	0				Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0						Ay (FT):	33.33	DISTANCE TO F.L.(FT)	2010

TIME INTERVAL (YRS)		20	LAYER 1 LEACHATE CONC. (UG/L)							SOURCE AREA CONC.	FEN LINE CONC.
ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	SUBLAYER 3	SUBLAYER 4	SUBLAYER 5	SUBLAYER 6	SUBLAYER 7	SUBLAYER 8	LAYER 2	(UG/L)	(UG/L)
0	0.003333333	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	0.003333333	3.34E-05	1.04E-07	3.24E-10	1.01E-12	3.13E-15	9.75E-18	3.03E-20	3.50E-23	3.27E-26	0.00E+00
40	0.003333333	1.34E-04	5.19E-07	1.94E-09	7.03E-12	2.50E-14	8.75E-17	3.03E-19	3.84E-22	4.10E-25	1.51E-31
60	0.003333333	3.33E-04	1.55E-06	6.77E-09	2.81E-11	1.12E-13	4.37E-16	1.66E-18	2.30E-21	2.74E-24	7.86E-28
80	0.003333333	6.65E-04	3.62E-06	1.80E-08	8.40E-11	3.73E-13	1.60E-15	6.62E-18	9.94E-21	1.30E-23	1.72E-26
100	0.003333333	1.16E-03	7.22E-06	4.04E-08	2.10E-10	1.02E-12	4.78E-15	2.15E-17	3.47E-20	4.95E-23	1.69E-25
120	0.003333333	1.86E-03	1.30E-05	8.07E-08	4.60E-10	2.45E-12	1.24E-14	6.00E-17	1.04E-19	1.59E-22	1.07E-24
140	0.003333333	2.78E-03	2.16E-05	1.48E-07	9.18E-10	5.30E-12	2.88E-14	1.50E-16	2.76E-19	4.52E-22	5.12E-24
160	0.003333333	3.96E-03	3.39E-05	2.52E-07	1.70E-09	1.06E-11	6.17E-14	3.41E-16	6.69E-19	1.16E-21	1.99E-23
180	0.003333333	5.44E-03	5.07E-05	4.09E-07	2.97E-09	1.98E-11	1.23E-13	7.23E-16	1.50E-18	2.74E-21	6.62E-23
200	0.074166667	5.16E-01	3.46E-02	2.32E-03	1.55E-04	1.04E-05	6.96E-07	4.67E-08	1.18E-09	2.44E-11	1.95E-22
220	0.074166667	1.78E+00	1.51E-01	1.23E-02	9.68E-04	7.45E-05	5.64E-06	4.22E-07	1.18E-08	2.81E-10	1.12E-16
240	0.074166667	4.02E+00	4.10E-01	3.89E-02	3.51E-03	3.05E-04	2.57E-05	2.11E-06	6.52E-08	1.73E-09	5.85E-13
260	0.074166667	7.43E+00	8.80E-01	9.53E-02	9.66E-03	9.31E-04	8.63E-05	7.76E-06	2.60E-07	7.64E-09	1.22E-11
280	0.074166667	1.22E+01	1.64E+00	1.99E-01	2.23E-02	2.36E-03	2.39E-04	2.32E-05	8.43E-07	2.69E-08	1.13E-10
300	0.074166667	1.84E+01	2.76E+00	3.70E-01	4.56E-02	5.26E-03	5.75E-04	6.02E-05	2.35E-06	8.08E-08	6.71E-10
320	0.074166667	2.61E+01	4.32E+00	6.35E-01	8.51E-02	1.06E-02	1.25E-03	1.40E-04	5.83E-06	2.14E-07	3.00E-09
340	0.074166667	3.56E+01	6.42E+00	1.02E+00	1.48E-01	1.98E-02	2.49E-03	2.97E-04	1.32E-05	5.15E-07	1.09E-08
360	0.074166667	4.67E+01	9.11E+00	1.36E+00	2.43E-01	3.47E-02	4.65E-03	5.89E-04	2.78E-05	1.14E-06	3.41E-08
380	0.074166667	5.95E+01	1.25E+01	2.30E+00	3.80E-01	5.79E-02	8.22E-03	1.10E-03	5.50E-05	2.37E-06	9.40E-08
400	0.074166667	7.41E+01	1.66E+01	3.25E+00	5.73E-01	9.24E-02	1.39E-02	1.95E-03	1.03E-04	4.63E-06	2.35E-07
420	0.074166667	9.04E+01	2.16E+01	4.48E+00	8.35E-01	1.42E-01	2.24E-02	3.33E-03	1.85E-04	8.64E-06	5.40E-07
440	0.074166667	1.09E+02	2.74E+01	6.02E+00	1.18E+00	2.12E-01	3.51E-02	5.46E-03	3.19E-04	1.54E-05	1.16E-06
460	0.074166667	1.28E+02	3.42E+01	7.90E+00	1.63E+00	3.07E-01	5.33E-02	8.66E-03	5.30E-04	2.66E-05	2.35E-06
480	0.074166667	1.50E+02	4.19E+01	1.02E+01	2.20E+00	4.34E-01	7.88E-02	1.34E-02	8.56E-04	4.43E-05	4.51E-06
500	0.074166667	1.73E+02	5.07E+01	1.29E+01	2.92E+00	6.01E-01	1.14E-01	2.01E-02	1.34E-03	7.15E-05	8.29E-06
520	0.074166667	1.98E+02	6.06E+01	1.61E+01	3.80E+00	8.15E-01	1.61E-01	2.95E-02	2.06E-03	1.13E-04	1.46E-05
540	0.074166667	2.25E+02	7.16E+01	1.98E+01	4.87E+00	1.09E+00	2.23E-01	4.25E-02	3.08E-03	1.73E-04	2.50E-05
560	0.074166667	2.53E+02	8.37E+01	2.41E+01	6.16E+00	1.43E+00	3.03E-01	5.99E-02	4.53E-03	2.60E-04	4.13E-05
580	0.074166667	2.82E+02	9.70E+01	2.90E+01	7.69E+00	1.85E+00	4.07E-01	8.32E-02	6.32E-03	3.83E-04	6.64E-05
600	0.074166667	3.13E+02	1.12E+02	3.45E+01	9.49E+00	2.36E+00	5.38E-01	1.14E-01	9.24E-03	5.54E-04	1.04E-04
620	0.074166667	3.46E+02	1.27E+02	4.07E+01	1.16E+01	2.98E+00	7.01E-01	1.53E-01	1.29E-02	7.88E-04	1.59E-04
640	0.074166667	3.80E+02	1.44E+02	4.76E+01	1.40E+01	3.71E+00	9.03E-01	2.03E-01	1.77E-02	1.10E-03	2.39E-04
660	0.074166667	4.15E+02	1.62E+02	5.53E+01	1.68E+01	4.59E+00	1.15E+00	2.67E-01	2.40E-02	1.52E-03	3.51E-04
680	0.074166667	4.51E+02	1.82E+02	6.38E+01	1.99E+01	5.61E+00	1.45E+00	3.46E-01	3.22E-02	2.08E-03	5.07E-04
700	0.25	5.96E+02	2.68E+02	1.06E+02	3.79E+01	1.23E+01	3.72E+00	1.05E+00	1.17E-01	3.71E-03	7.20E-04
720	0.25	7.51E+02	3.69E+02	1.61E+02	6.36E+01	2.30E+01	7.74E+00	2.44E+00	3.10E-01	9.10E-03	1.01E-03
740	0.25	9.13E+02	4.82E+02	2.28E+02	9.78E+01	3.86E+01	1.42E+01	4.89E+00	6.90E-01	2.15E-02	1.41E-03
760	0.25	1.08E+03	6.06E+02	3.07E+02	1.41E+02	6.00E+01	2.37E+01	8.82E+00	1.36E+00	4.59E-02	2.23E-03
780	0.25	1.25E+03	7.40E+02	3.97E+02	1.95E+02	8.81E+01	3.71E+01	1.47E+01	2.47E+00	8.94E-02	4.46E-03
800	0.25	1.42E+03	8.82E+02	4.98E+02	2.58E+02	1.23E+02	5.51E+01	2.31E+01	4.19E+00	1.61E-01	1.01E-02
820	0.25	1.59E+03	1.03E+03	6.09E+02	3.31E+02	1.67E+02	7.84E+01	3.47E+01	6.72E+00	2.73E-01	2.21E-02
840	0.25	1.76E+03	1.18E+03	7.28E+02	4.14E+02	2.18E+02	1.08E+02	4.99E+01	1.03E+01	4.40E-01	4.50E-02
860	0.25	1.92E+03	1.34E+03	8.55E+02	5.06E+02	2.78E+02	1.43E+02	6.93E+01	1.52E+01	6.79E-01	8.52E-02
880	0.25	2.09E+03	1.49E+03	9.87E+02	6.06E+02	3.46E+02	1.85E+02	9.35E+01	2.17E+01	1.01E+00	1.51E-01
900	0.25	2.25E+03	1.65E+03	1.13E+03	7.14E+02	4.23E+02	2.35E+02	1.23E+02	3.01E+01	1.45E+00	2.53E-01
920	0.25	2.41E+03	1.81E+03	1.27E+03	8.30E+02	5.08E+02	2.92E+02	1.58E+02	4.07E+01	2.03E+00	4.04E-01
940	0.25	2.56E+03	1.96E+03	1.41E+03	9.51E+02	6.00E+02	3.56E+02	1.99E+02	5.39E+01	2.78E+00	6.20E-01
960	0.25	2.71E+03	2.12E+03	1.56E+03	1.08E+03	7.00E+02	4.28E+02	2.47E+02	6.99E+01	3.71E+00	9.18E-01
980	0.25	2.85E+03	2.27E+03	1.71E+03	1.21E+03	8.06E+02	5.07E+02	3.01E+02	8.91E+01	4.85E+00	1.32E+00
1000	0.25	2.99E+03	2.42E+03	1.86E+03	1.34E+03	9.18E+02	5.92E+02	3.62E+02	1.12E+02	6.24E+00	1.84E+00
MAXIMUM:	0.25	2.99E+03	2.42E+03	1.86E+03	1.34E+03	9.18E+02	5.92E+02	3.62E+02	1.12E+02	6.24E+00	1.84E+00

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

ECTran Monte Carlo Simulation Model Outputs
for
Case 3 - Upper Clay Sub-barriers

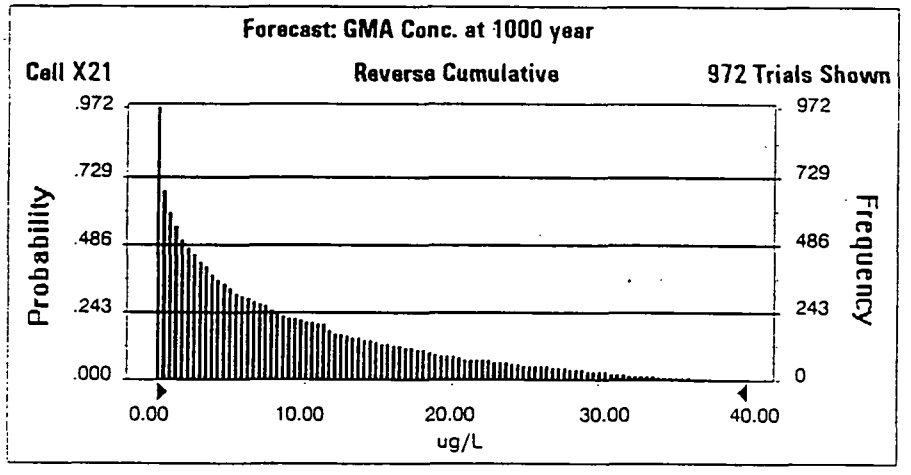
Mean Hypothetical Performance
Lifetime = 800 years

Crystal Ball Report
Simulation started on 10/19/94 at 14:22:21
Simulation stopped on 10/19/94 at 17:56:41

Forecast: GMA Conc. at 1000 year **Cell: X21**

Summary:
Display Range is from 0.00 to 40.00 ug/L
Entire Range is from 0.02 to 89.19 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.38

Statistics:	Value
Trials	1000
Mean	7.30
Median (approx.)	1.97
Mode (approx.)	0.46
Standard Deviation	11.92
Variance	142.04
Skewness	2.78
Kurtosis	12.89
Coeff. of Variability	1.63
Range Minimum	0.02
Range Maximum	89.19
Range Width	89.17
Mean Std. Error	0.38



REPORT3.XLS

Forecast: GMA Conc. at 1000 year (cont'd) **Cell: X21**

Percentiles:

Percentile	ug/L (approx.)
0%	0.02
10%	0.13
20%	0.24
30%	0.43
40%	1.03
50%	1.97
60%	3.77
70%	6.83
80%	12.13
90%	22.01
100%	89.19

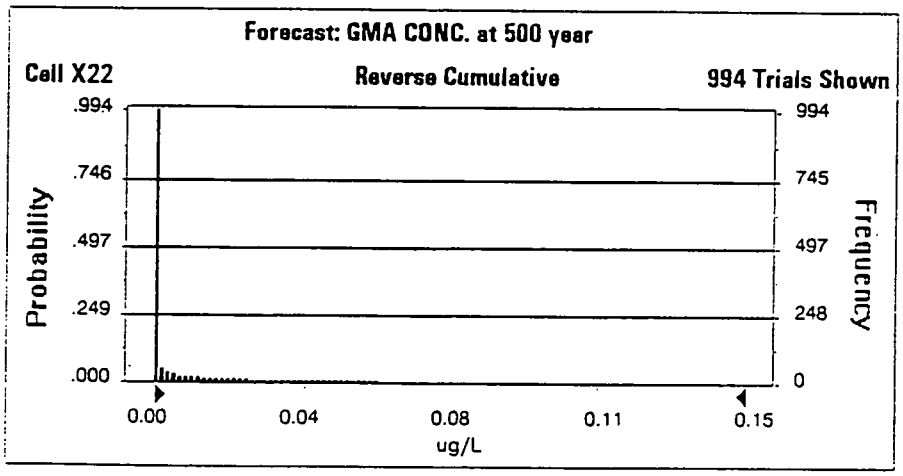
End of Forecast

REPORT3.XLS

Forecast: GMA CONC. at 500 year **Cell: X22**

Summary:
Display Range is from 0.00 to 0.15 ug/L
Entire Range is from 0.00 to 0.91 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.00

Statistics:	Value
Trials	1000
Mean	0.00
Median (approx.)	0.00
Mode (approx.)	0.00
Standard Deviation	0.05
Variance	0.00
Skewness	14.72
Kurtosis	244.08
Coeff. of Variability	9.87
Range Minimum	0.00
Range Maximum	0.91
Range Width	0.91
Mean Std. Error	0.00



REPORT3.XLS

Forecast: GMA CONC. at 500 year (cont'd) **Cell: X22**

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	0.00
90%	0.00
100%	0.91

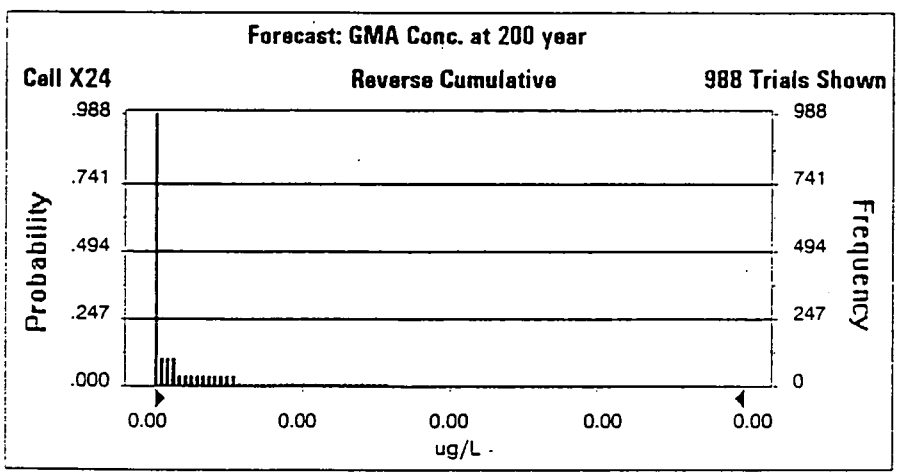
End of Forecast

REPORT3.XLS

Forecast: GMA Conc. at 200 year **Cell: X24**

Summary:
Display Range is from 0.00 to 0.00 ug/L
Entire Range is from 0.00 to 0.00 ug/L
After 1,000 Trials, the Std. Error of the Mean is 0.00

Statistics:	Value
Trials	1000
Mean	0.00
Median (approx.)	0.00
Mode (approx.)	0.00
Standard Deviation	0.00
Variance	0.00
Skewness	17.29
Kurtosis	350.12
Coeff. of Variability	9.27
Range Minimum	0.00
Range Maximum	0.00
Range Width	0.00
Mean Std. Error	0.00



REPORT3.XLS

Forecast: GMA Conc. at 200 year (cont'd) **Cell: X24**

Percentiles:

Percentile	ug/L (approx.)
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	0.00
90%	0.00
100%	0.00

End of Forecast

REPORT3.XLS

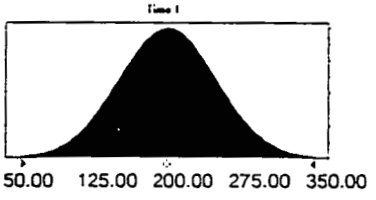
Assumptions

Assumption: Time 1 **Cell: D6**

Normal distribution with parameters:

Mean	200.00
Standard Dev.	50.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 202.87

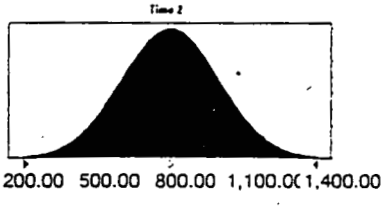


Assumption: Time 2 **Cell: D7**

Normal distribution with parameters:

Mean	800.00
Standard Dev.	200.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 789.00



End of Assumptions

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BROWN & ROOT ENVIRONMENTAL

SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrans) MODEL

MCL(pCi/l): 2.24E+03

		Infil 1(ft/yr)	0.003333333	
SITE:	Time 1	200	Infil 2(ft/yr)	0.074166667
	Time 2	800	Infil 3(ft/yr)	0.25
INVESTIGATOR:		WYU		
DATE:		10/20/94		

CONTAMINANT: U238		SPECIFIC ACTIVITY:	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	2.00E+01
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	6.67E+03
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)		GREAT MIAMI AQUIFER (SAT. S. & G.)			
							B (FT):	75	Vzo (FT/YR):	0.847
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG):	0.0000			CU2 (PPB):	0
WIDTH (FT):	1500	Kd (L/KG):	24.00	3	Kd (L/KG):	1.780	GW V.(FT/YR):	304.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION:	0.13			RETARDATION:	11.0867
POROSITY 2:	0.3	THICKNESS (FT):	3.00	1	THICKNESS (FT):	22.00	EFF. POROSITY	0.30	q(FT/YR) :	0
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY):	4.25E-13			DECAY (1/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB):	0.00E+00	Az(FT):	0.03	CU3 (PPB):	0
Ts(YEARS):	1000	D.F.(1/YR):	0				Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0						Av (FT):	11.33	DISTANCE TO E.L.(FT)	1760

TIME INTERVAL (YRS) 20

LAYER 1 LEACHATE CONC. (UG/L))

ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	LINER	SUBLAYER 1			SUBLAYER 2		
0	0.003333333	6.67E+03	0.00E+00	0.00E+00			0.00E+00		
20	0.003333333	6.67E+03	3.45E+00	1.07E-02			3.34E-05		
40	0.003333333	6.67E+03	6.91E+00	3.22E-02			1.34E-04		
60	0.003333333	6.67E+03	1.04E+01	6.43E-02			3.33E-04		
80	0.003333333	6.67E+03	1.38E+01	1.07E-01			6.65E-04		
100	0.003333333	6.67E+03	1.73E+01	1.60E-01			1.16E-03		
120	0.003333333	6.67E+03	2.07E+01	2.24E-01			1.86E-03		
140	0.003333333	6.67E+03	2.41E+01	2.99E-01			2.78E-03		
160	0.003333333	6.67E+03	2.76E+01	3.84E-01			3.96E-03		
180	0.003333333	6.67E+03	3.10E+01	4.79E-01			5.44E-03		
200	0.074166667	6.67E+03	1.07E+02	7.62E+00			5.16E-01		
220	0.074166667	6.67E+03	1.82E+02	1.93E+01			1.78E+00		
240	0.074166667	6.67E+03	2.57E+02	3.52E+01			4.02E+00		
260	0.074166667	6.67E+03	3.30E+02	5.50E+01			7.43E+00		
280	0.074166667	6.67E+03	4.03E+02	7.83E+01			1.22E+01		
300	0.074166667	6.67E+03	4.75E+02	1.05E+02			1.84E+01		
320	0.074166667	6.67E+03	5.46E+02	1.34E+02			2.61E+01		
340	0.074166667	6.67E+03	6.16E+02	1.67E+02			3.56E+01		
360	0.074166667	6.67E+03	6.85E+02	2.01E+02			4.67E+01		
380	0.074166667	6.67E+03	7.54E+02	2.38E+02			5.95E+01		
400	0.074166667	6.67E+03	8.21E+02	2.77E+02			7.41E+01		
420	0.074166667	6.67E+03	8.88E+02	3.18E+02			9.04E+01		
440	0.074166667	6.67E+03	9.55E+02	3.61E+02			1.09E+02		
460	0.074166667	6.67E+03	1.02E+03	4.05E+02			1.28E+02		
480	0.074166667	6.67E+03	1.08E+03	4.51E+02			1.50E+02		
500	0.074166667	6.67E+03	1.15E+03	4.97E+02			1.73E+02		
520	0.074166667	6.67E+03	1.21E+03	5.45E+02			1.98E+02		
540	0.074166667	6.67E+03	1.27E+03	5.94E+02			2.25E+02		
560	0.074166667	6.67E+03	1.34E+03	6.44E+02			2.53E+02		
580	0.074166667	6.67E+03	1.40E+03	6.94E+02			2.82E+02		
600	0.074166667	6.67E+03	1.46E+03	7.45E+02			3.13E+02		
620	0.074166667	6.67E+03	1.52E+03	7.97E+02			3.46E+02		
640	0.074166667	6.67E+03	1.58E+03	8.49E+02			3.80E+02		
660	0.074166667	6.67E+03	1.63E+03	9.02E+02			4.15E+02		
680	0.074166667	6.67E+03	1.69E+03	9.55E+02			4.51E+02		
700	0.074166667	6.67E+03	1.75E+03	1.01E+03			4.88E+02		
720	0.074166667	6.67E+03	1.81E+03	1.06E+03			5.27E+02		
740	0.074166667	6.67E+03	1.86E+03	1.12E+03			5.66E+02		
760	0.074166667	6.67E+03	1.92E+03	1.17E+03			6.06E+02		
780	0.074166667	6.67E+03	1.97E+03	1.22E+03			6.48E+02		
800	0.25	6.67E+03	2.15E+03	1.42E+03			8.08E+02		
820	0.25	6.67E+03	2.32E+03	1.60E+03			9.74E+02		
840	0.25	6.67E+03	2.49E+03	1.79E+03			1.14E+03		
860	0.25	6.67E+03	2.65E+03	1.97E+03			1.32E+03		
880	0.25	6.67E+03	2.80E+03	2.14E+03			1.49E+03		
900	0.25	6.67E+03	2.95E+03	2.31E+03			1.66E+03		
920	0.25	6.67E+03	3.09E+03	2.47E+03			1.83E+03		
940	0.25	6.67E+03	3.23E+03	2.63E+03			2.00E+03		
960	0.25	6.67E+03	3.36E+03	2.78E+03			2.16E+03		
980	0.25	6.67E+03	3.48E+03	2.93E+03			2.32E+03		
1000	0.25	6.67E+03	3.60E+03	3.07E+03			2.48E+03		
MAXIMUM:	0.25	6.67E+03	3.60E+03				2.48E+03		

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	6.67E+03	1.00E+02	2.24E+03	3.36E+01
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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BROWN & ROOT ENVIRONMENTAL
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTrans) MODEL

SITE:

INVESTIGATOR: WYU
DATE: 10/20/94

CONTAMINANT: U238		SPECIFIC ACTIVITY(Ci/g):	3.36E-07
KOC (L/KG):	0.00	WATER CRITERIA (UG/L):	1.83E+00
HALF LIFE (YRS)		PRECIPITATION CONC. (UG/L)	0.00E+00
LAYER 1:	4.47E+09	SOURCE LEACHATE Kd (L/KG):	1.50E+01
LAYER 2:	4.47E+09	INITIAL LAYER 1 SOIL CONC. (MG/KG):	0.00E+00
GMA:	4.47E+09	INITIAL LAYER 2 SOIL CONC. (MG/KG):	0.00E+00

UNSAT. SOURCE	AREA:	LAYER 1 (GLACIAL OVERBURDEN)			LAYER 2 (SAND & GRAVEL)	GREAT MIAMI AQUIFER (SAT. S. & G.)			
						B (FT):	75	Vzo (FT/YR):	0.847
LENGTH (FT):	1500	FOC (KG/KG):	0	THICKNESS(FT)	FOC (KG/KG): 0.0000			CU2 (PPB):	0
WIDTH (FT):	1500	Kd (L/KG):	3.10	22.5	Kd (L/KG): 1.780	GW V.(FT/YR):	303.00	Kd (L/KG):	1.78
POROSITY 1:	0.2	SATURATION:	0.95	SUBLAYERS	SATURATION: 0.13			RETARDATION:	11.0867
POROSITY 2:	0.3	THICKNESS (FT):	3.75	6	THICKNESS (FT): 20.00	EFF. POROSITY	0.30	q (FT/YR):	0
DENSITY 1 (G/CM3):	1.78	DECAY (1/DAY):	4.25E-13		DECAY (1/DAY): 4.25E-13			DECAY (1/YR):	1.6E-10
DENSITY 2 (G/CM3):	1.60	CAo (UG/L):	0.00E+00		CBo (PPB): 0.00E+00	Az(FT):	0.35	CU3 (PPB):	0
Td(YEARS):	1000	D.F.(1/YR):	0			Ax (FT):	100.00	P&T(YEARS):	0
AGE (YEARS):	0					Ay (FT):	33.33	DISTANCE TO F.L.(FT)	2010

TIME INTERVAL (YRS)		20	LAYER 1 LEACHATE CONC. (UG/L))							SOURCE AREA CONC.	FEN LINE CONC.
ELAPSED TIME - YRS	INF.RATE (FT/YR)	CU1(PPB)	SUBLAYER 3	SUBLAYER 4	SUBLAYER 5	SUBLAYER 6	SUBLAYER 7	SUBLAYER 8	LAYER 2	(UG/L)	(UG/L)
0	0.003333333	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	0.003333333	3.34E-05	1.04E-07	3.24E-10	1.01E-12	3.13E-15	9.75E-18	3.03E-20	3.50E-23	3.27E-26	0.00E+00
40	0.003333333	1.34E-04	5.19E-07	1.94E-09	7.03E-12	2.50E-14	8.75E-17	3.03E-19	3.84E-22	4.10E-25	1.51E-31
60	0.003333333	3.33E-04	1.55E-06	6.77E-09	2.81E-11	1.12E-13	4.37E-16	1.66E-18	2.30E-21	2.74E-24	7.86E-28
80	0.003333333	6.65E-04	3.62E-06	1.80E-08	8.40E-11	3.73E-13	1.60E-15	6.62E-18	9.94E-21	1.30E-23	1.72E-26
100	0.003333333	1.16E-03	7.22E-06	4.04E-08	2.10E-10	1.02E-12	4.78E-15	2.15E-17	3.47E-20	4.95E-23	1.69E-25
120	0.003333333	1.86E-03	1.30E-05	8.07E-08	4.60E-10	2.45E-12	1.24E-14	6.00E-17	1.04E-19	1.59E-22	1.07E-24
140	0.003333333	2.78E-03	2.16E-05	1.48E-07	9.18E-10	5.30E-12	2.88E-14	1.50E-16	2.76E-19	4.52E-22	5.12E-24
160	0.003333333	3.96E-03	3.39E-05	2.52E-07	1.70E-09	1.06E-11	6.17E-14	3.41E-16	6.69E-19	1.16E-21	1.99E-23
180	0.003333333	5.44E-03	5.07E-05	4.09E-07	2.97E-09	1.98E-11	1.23E-13	7.23E-16	1.50E-18	2.74E-21	6.62E-23
200	0.074166667	5.16E-01	3.46E-02	2.32E-03	1.55E-04	1.04E-05	6.96E-07	4.67E-08	1.18E-09	2.44E-11	1.95E-22
220	0.074166667	1.78E+00	1.51E-01	1.23E-02	9.68E-04	7.45E-05	5.64E-06	4.22E-07	1.18E-08	2.81E-10	1.12E-16
240	0.074166667	4.02E+00	4.10E-01	3.89E-02	3.51E-03	3.05E-04	2.57E-05	2.11E-06	6.52E-08	1.73E-09	5.85E-13
260	0.074166667	7.43E+00	8.80E-01	9.53E-02	9.66E-03	9.31E-04	8.63E-05	7.76E-06	2.60E-07	7.64E-09	1.22E-11
280	0.074166667	1.22E+01	1.64E+00	1.99E-01	2.23E-02	2.36E-03	2.39E-04	2.32E-05	8.43E-07	2.69E-08	1.13E-10
300	0.074166667	1.84E+01	2.76E+00	3.70E-01	4.56E-02	5.26E-03	5.75E-04	6.02E-05	2.35E-06	8.08E-08	6.71E-10
320	0.074166667	2.61E+01	4.32E+00	6.35E-01	8.51E-02	1.06E-02	1.25E-03	1.40E-04	5.83E-06	2.14E-07	3.00E-09
340	0.074166667	3.56E+01	6.42E+00	1.02E+00	1.48E-01	1.98E-02	2.49E-03	2.97E-04	1.32E-05	5.15E-07	1.09E-08
360	0.074166667	4.67E+01	9.11E+00	1.56E+00	2.43E-01	3.47E-02	4.65E-03	5.89E-04	2.78E-05	1.14E-06	3.41E-08
380	0.074166667	5.95E+01	1.25E+01	2.30E+00	3.80E-01	5.79E-02	8.22E-03	1.10E-03	5.50E-05	2.37E-06	9.40E-08
400	0.074166667	7.41E+01	1.66E+01	3.25E+00	5.73E-01	9.24E-02	1.39E-02	1.95E-03	1.03E-04	4.63E-06	2.35E-07
420	0.074166667	9.04E+01	2.16E+01	4.48E+00	8.35E-01	1.42E-01	2.24E-02	3.33E-03	1.85E-04	8.64E-06	5.40E-07
440	0.074166667	1.09E+02	2.74E+01	6.02E+00	1.18E+00	2.12E-01	3.51E-02	5.46E-03	3.19E-04	1.24E-05	1.16E-06
460	0.074166667	1.28E+02	3.42E+01	7.90E+00	1.63E+00	3.07E-01	5.33E-02	8.66E-03	5.30E-04	2.66E-05	2.35E-06
480	0.074166667	1.50E+02	4.19E+01	1.02E+01	2.20E+00	4.34E-01	7.88E-02	1.34E-02	8.56E-04	4.43E-05	4.51E-06
500	0.074166667	1.73E+02	5.07E+01	1.29E+01	2.92E+00	6.01E-01	1.14E-01	2.01E-02	1.34E-03	7.15E-05	8.29E-06
520	0.074166667	1.98E+02	6.06E+01	1.61E+01	3.80E+00	8.15E-01	1.61E-01	2.95E-02	2.06E-03	1.13E-04	1.46E-05
540	0.074166667	2.25E+02	7.16E+01	1.98E+01	4.87E+00	1.09E+00	2.23E-01	4.25E-02	3.08E-03	1.73E-04	2.50E-05
560	0.074166667	2.53E+02	8.37E+01	2.41E+01	6.16E+00	1.43E+00	3.03E-01	5.99E-02	4.53E-03	2.60E-04	4.13E-05
580	0.074166667	2.82E+02	9.70E+01	2.90E+01	7.69E+00	1.85E+00	4.07E-01	8.32E-02	6.52E-03	3.83E-04	6.64E-05
600	0.074166667	3.13E+02	1.12E+02	3.45E+01	9.49E+00	2.36E+00	5.38E-01	1.14E-01	9.24E-03	5.54E-04	1.04E-04
620	0.074166667	3.46E+02	1.27E+02	4.07E+01	1.16E+01	2.98E+00	7.01E-01	1.53E-01	1.29E-02	7.88E-04	1.59E-04
640	0.074166667	3.80E+02	1.44E+02	4.76E+01	1.40E+01	3.71E+00	9.03E-01	2.03E-01	1.77E-02	1.10E-03	2.39E-04
660	0.074166667	4.15E+02	1.62E+02	5.53E+01	1.68E+01	4.59E+00	1.15E+00	2.67E-01	2.40E-02	1.52E-03	3.51E-04
680	0.074166667	4.51E+02	1.82E+02	6.38E+01	1.99E+01	5.61E+00	1.45E+00	3.46E-01	3.22E-02	2.08E-03	5.07E-04
700	0.074166667	4.88E+02	2.02E+02	7.30E+01	2.35E+01	6.81E+00	1.81E+00	4.44E-01	4.26E-02	2.80E-03	7.20E-04
720	0.074166667	5.27E+02	2.24E+02	8.31E+01	2.75E+01	8.19E+00	2.24E+00	5.64E-01	5.58E-02	3.72E-03	1.01E-03
740	0.074166667	5.66E+02	2.47E+02	9.41E+01	3.19E+01	9.78E+00	2.74E+00	7.10E-01	7.24E-02	4.89E-03	1.39E-03
760	0.074166667	6.06E+02	2.71E+02	1.06E+02	3.69E+01	1.16E+01	3.33E+00	8.85E-01	9.31E-02	6.37E-03	1.89E-03
780	0.074166667	6.48E+02	2.96E+02	1.19E+02	4.24E+01	1.37E+01	4.03E+00	1.10E+00	1.19E-01	8.22E-03	2.55E-03
800	0.25	8.08E+02	4.03E+02	1.78E+02	7.06E+01	2.55E+01	8.51E+00	2.64E+00	3.28E-01	1.24E-02	3.39E-03
820	0.25	9.74E+02	5.22E+02	2.50E+02	1.08E+02	4.27E+01	1.56E+01	5.35E+00	7.44E-01	2.48E-02	4.46E-03
840	0.25	1.14E+03	6.51E+02	3.33E+02	1.55E+02	6.61E+01	2.61E+01	9.68E+00	1.49E+00	5.08E-02	5.86E-03
860	0.25	1.32E+03	7.90E+02	4.28E+02	2.12E+02	9.65E+01	4.08E+01	1.62E+01	2.70E+00	9.80E-02	8.20E-03
880	0.25	1.49E+03	9.35E+02	5.34E+02	2.79E+02	1.35E+02	6.03E+01	2.54E+01	4.59E+00	1.77E-01	1.36E-02
900	0.25	1.66E+03	1.09E+03	6.49E+02	3.56E+02	1.81E+02	8.54E+01	3.79E+01	7.35E+00	2.99E-01	2.59E-02
920	0.25	1.83E+03	1.24E+03	7.72E+02	4.43E+02	2.35E+02	1.17E+02	5.43E+01	1.12E+01	4.81E-01	5.03E-02
940	0.25	2.00E+03	1.40E+03	9.03E+02	5.39E+02	2.99E+02	1.55E+02	7.52E+01	1.66E+01	7.41E-01	9.38E-02
960	0.25	2.16E+03	1.56E+03	1.04E+03	6.43E+02	3.70E+02	2.00E+02	1.01E+02	2.36E+01	1.10E+00	1.65E-01
980	0.25	2.32E+03	1.72E+03	1.18E+03	7.55E+02	4.51E+02	2.52E+02	1.33E+02	3.26E+01	1.58E+00	2.77E-01
1000	0.25	2.48E+03	1.87E+03	1.32E+03	8.74E+02	5.39E+02	3.12E+02	1.70E+02	4.40E+01	2.20E+00	4.41E-01
MAXIMUM:	0.25	2.48E+03	1.87E+03	1.32E+03	8.74E+02	5.39E+02	3.12E+02	1.70E+02	4.40E+01	2.20E+00	4.41E-01

UNITS	UG/L	MG/KG	pCi/L	pCi/g
PERCIPITATION CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 1 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LAYER 2 CONC.	0.00E+00	0.00E+00	0.00E+00	0.00E+00

ATTACHMENT F.6.I
PROCEDURE FOR PRELIMINARY ASSESSMENT OF PERCHED GROUNDWATER REMEDIAL REQUIREMENTS

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F.6.I.1.0 PROCEDURE FOR A PRELIMINARY ASSESSMENT OF REMEDIAL REQUIREMENTS

F.6.I.1.1 OBJECTIVE

The main objective of this procedure is to provide a preliminary assessment of remedial requirements for the perched groundwater zone. This assessment procedure is conducted to determine the most likely workable remedial measures for the perched groundwater zone so that pertinent detailed analyses may be performed.

F.6.I.1.2 THEORETICAL BASIS

The preliminary assessment is based on a comparison between two quantities: the maximum possible extraction rate within a given period of time (35 years), Q_1^M; and the necessary extraction rate within a prescribed period of time (i.e., 35 years) to reduce the initial contaminant concentration to a target concentration, Q_2.

Based on the principle of mass conservation, Q_1^M may be estimated from:

$$Q_1^M = Q_I + \frac{b\theta A_{tot}}{\Delta t} \qquad \text{(F.6.I.1-1)}$$

where

Q_1^M = maximum possible extraction rate (ft^3/day)
Q_I = net influx due to lateral recharge and infiltration (ft^3/day)
Δt = time interval of interest (day)
A_{tot} = total area of interest (ft^2)
θ = porosity (dimensionless)
b = aquifer thickness (ft)

Q_1^M as shown is Equation F.6.I.1-1 implies that the aquifer will have been completely dewatered after the prescribed 35-year remediation period.

The net influx may be determined from the local long-term steady state water budget, as follows:

$$Q_{Infil} + Q_{Inflow}^H - Q_{Disch}^V - Q_{Disch}^H = 0 \qquad \text{(F.6.I.1-2)}$$

Q_{Infil} = areal recharge rate due to infiltration (ft^3/day)
Q_{Inflow}^H = lateral inflow rate (ft^3/day)
Q_{Disch}^V = vertical discharge rate (ft^3/day)
Q_{Disch}^H = lateral discharge rate (ft^3/day)

Because the areal recharge rate (vertical infiltration rate) is approximately equal to the vertical discharge rate, it may be inferred that the lateral inflow rate is equal to the lateral discharge rate. Therefore,

$$Q_I \approx Q^H_{Inflow} \approx Q^H_{Disch} \qquad \text{(F.6.I.1-3)}$$

which, in turn, may be estimated from:

$$Q_I \approx Q^H_{Disch} = \sum_{i=1}^{n_{seg}} L_i I_i b_i K_i \qquad \text{(F.6.I.1-4)}$$

where

n_{seg} = number of lineal segments along discharge boundaries of the subject area
L_i = length of segment i along discharge boundaries (ft)
I_i = average hydraulic gradient along segment i (ft/ft)
K_i = average hydraulic conductivity along segment i (ft/day)
b_i = average perched-zone saturated thickness along segment i (ft)

During the remediation period, it is imperative that the perched water zone be maintained saturated in order to remove the maximum amount of contaminants within a given period of time without leaving a fraction of contaminants relatively immobile in the desaturated zone. Based on this reason, the lower bound for the amount of water available for extraction may be approximated by:

$$Q_1^L = Q_I \frac{L_{cont}}{\sum_{i=1}^{n_{seg}} L_i} \qquad \text{(F.6.I.1-5)}$$

where

Q_1^L = Lower bound of amount of water available for extraction (ft^3/day)
L_{cont} = length normal to the groundwater flow direction in the contaminated zone (ft)

The necessary extraction rate Q_2 may be estimated from a reactor type model which is based on the following assumptions:

- The concentration within the area of interest is uniform at all times due to complete mixing within the area
- Clean groundwater migrates into the area of interest at all times
- Initial contaminant concentration is uniform throughout the area of interest

The reactor model used in this calculation procedure is described by the principle of mass conservation (Bear 1972) below:

$$bA_{cont}[\theta+\rho_b K_d]\frac{\partial c}{\partial t} = -\lambda bA_{cont}[\theta+\rho_b K_d]c - Q_2 c \qquad \text{(F.6.I.1-6)}$$

Solving Equation F.6.I.1-6 for Q_2 leads to

$$Q_2 = A_{cont} b(\theta+\rho_b K_d)\left[\frac{1}{\Delta t}\ln\left(\frac{c_o}{c_{target}}\right)-\lambda\right] \qquad \text{(F.6.I.1-7)}$$

where

c_o	= initial concentration (mg/L)
c_{target}	= target remedial concentration (mg/L)
λ	= decay factor (1/day)
ρ_b	= bulk density of soil matrix (g/ml)
K_d	= partitioning coefficient (ml/g)
A_{cont}	= area of contaminated zone (plume) (ft^2)
Δt	= time interval of interest (day)

F.6.I.1.3 PROCEDURE

The procedure is summarized in Figure F.6.I.1-1. Details are presented below.

1) Estimate Q_1^M and Q_1^L from Equations (F.6.I.1-1), (F.6.I.1-3), (F.6.I.1-4), and (F.6.I.1-5).

2) Estimate Q_2 from Equation (F.6.I.1-7).

3) Compare Q_1^M and Q_2:
   a. If $Q_2 > Q_1^M$, then it is physically impossible to extract at this rate for a long period of time. Injection is necessary. Proceed to Step 4.
   b. If $Q_2 < Q_1^M$, then compare Q_2 and Q_1^L
      1. If $Q_2 > Q_1^L$, then a significant amount of contaminant mass may remain in the desaturated zone; injection is also necessary to avoid this. Proceed to Step 5.
      2. If $Q_2 < Q_1^L$, injection is not required. Proceed to Step 6.

4) The required injection rate, Q_{inj}, is bounded by

$$Q_2 - Q_1^M \leq Q_{inj} \leq Q_2 - Q_1^L$$

The upper bound is utilized in subsequent design calculations. The excess amount of water introduced by injection is removed from the system through extraction wells. If

$$Q_2 >>> Q_1^L, \textit{ then } Q_{inj} \approx Q_2.$$

From Step 3a, determine possible configurations of trenches and injection-pumping wells necessary to provide the required injection rate (see Attachment F.6.I.2.0, Procedure for the Analysis of Active Remedial Trenches; and Attachment F.6.I.3.0, Procedure for the Analysis of Pumping-Injection System, for details).

Proceed to Step 6.

5) The required injection rate, Q_{inj}, is bounded by

$$Q_2 - Q_1^M \leq Q_{inj} \leq Q_2 - Q_1^L$$

The upper bound is utilized in subsequent design calculations. The excess amount of water introduced by injection is removed from the system through extraction wells. If

$$Q_2 >>> Q_1^L, \textit{ then } Q_{inj} \approx Q_2.$$

From Step 3.b.1, evaluate the necessity for injection.

Determine whether the transmissive portion of the perched zone is desaturated. If the desaturated zone occurs in the sandy portion, injection is necessary. Determine possible configurations of trenches and pumping-injection wells. Proceed to Step 6.

6) Perform more detailed analyses on the chosen options to assess the feasibility of implementing these options. (See Attachment F.6.I.2.0, Procedure for the Analysis of Active Remedial Trenches; and Attachment F.6.I.3.0, Procedure for the Analysis of Pumping-Injection System, for details).

F.6.I.1.4 SAMPLE CALCULATION

Calculations were performed for Cases 1, 2, and 3 to determine all the relevant flow rates (recharge, infiltration, extraction/injection). A calculation sample, based on information relating to Case 1, is

000100

001030

provided below. The calculation is organized in a fashion similar to the calculation procedure presented in Section F.6.I.1.3.

1) **Estimation of Q_1^M and Q_1^L**

To estimate the maximum possible extraction rate, the net influx due to recharge and infiltration is calculated using Equation (F.6.I.1-4) and the following parameter values:

$$
\begin{aligned}
n_{seg} &= 3 \\
L_i &= 1000 \text{ ft, } 2000 \text{ ft, and } 1200 \text{ ft for } i = 1, 2, \text{ and } 3, \text{ respectively} \\
I_i &= 0.01, 0.0122, \text{ and } 0.0158 \text{ for } i = 1, 2, \text{ and } 3, \text{ respectively} \\
K_i &= 3.55 \text{ ft/day for all values of } i \\
b_i &= 15 \text{ ft for all values of } i \\
Q_1 &= 3.55 \times 15(1000 \times 0.01 + 2000 \times 0.0122 + 1200 \times 0.0158) \\
&= 2{,}841.42 \text{ ft}^3\text{/day} \\
&= 14.8 \text{ gpm} \quad (1 \text{ gpm} = 192 \text{ ft}^3\text{/day})
\end{aligned}
$$

The maximum possible extraction rate may then be estimated using Equation (F.6.I.1-1) and the following parameter values:

$$
\begin{aligned}
\Delta t &= 35 \; yr \times 365.25 \; days/yr \\
A_{tot} &= 4.47 \times 10^6 \text{ ft}^2 \\
\theta &= 0.3 \\
b &= 15 \text{ ft} \\
Q_1^M &= 2841.42 + \frac{15 \times 0.3 \times 4.47 \times 10^6}{35 \times 365.25} \\
&= 2{,}841.42 + 1{,}573.48 \\
&= 4{,}414.90 \text{ ft}^3\text{/day} \\
&= 23.0 \text{ gpm} \quad (1 \text{ gpm} = 192 \text{ ft}^3\text{/day})
\end{aligned}
$$

The lower bound for the amount of water available for extraction may then be estimated using Equation (F.6.I.1-5). Using the dimensions given in Tables F.6-17 to calculate L_{cont}, thus:

$$
\begin{aligned}
L_{cont} &= 600 + 200 + 400 + 800 + 300 + 800 \\
&= 3100 \text{ ft;}
\end{aligned}
$$

and using the L_i values given above to estimate the total length of the discharge boundary, thus:

$$\sum_{i=1}^{n_{seg}} L_i = 1000 + 2000 + 1200$$

$$= 4200 \text{ ft};$$

Equation (F.6.I.1-5) may be used to estimate Q_1^L as shown below:

$$Q_1^L = 2841.42 \times \frac{3100}{4200}$$

$$= 2097.24 \text{ ft}^3/\text{day}$$

$$= 10.92 \text{ gpm (1 gpm} = 192 \text{ ft}^3/\text{day}).$$

2) **Estimation of Q_2**

For subzone I1GPM-1 of Case 1, Q_2 may be calculated using Equation (F.6.I.1-7) and the following parameters:

c_o = 5.6914 mg/L
c_{target} = 0.00446 mg/L
λ = 4.25×10^{-13} 1/day
ρ_b = 1.855 g/ml
K_d = 1.78 ml/g
A_{cont} = 421,600 ft^2
Δt = 35 × 365 days,

thus:

$$Q_2 = 421{,}600 \times 15 \times (0.3 + 1.855 \times 1.78)\left[\frac{1}{35 \times 365.25} \ln \frac{5.6914}{0.00446} - 4.25 \times 10^{-13}\right] 2$$

$$= 12{,}751.56 \text{ ft}^3/\text{day}$$

$$= 66.42 \text{ gpm}.$$

Similarly, using c_o values in Table F.6-16 and the subzone dimensions in Table F.6-17, the Q_2 values for the remaining subzones are 2.12, 9.17, 16.26, 2.50, and 36.34 gpm, for subzones I1GPM-2, I1GPM-3, I1GPM-4, O1GPM-1, and O1GPM-2, respectively. Note that for the I1GPM subzones, c_{target} = 0.00446 mg/l, and for the O1GPM subzones, c_{target} = 0.0744 mg/L.

Summing up Q_2s in all the subzones, one obtains the total Q_2, which is equal to 132.81 gpm.

Using the same calculation procedure, one can determine the total Q_2 for K_d = 15 L/kg, which is 1037.30 gpm.

3) **Comparison between Q_1^M and Q_2**

Based on results from the above calculation, one can see that

$$Q_1^M <<< Q_2$$

and, therefore, injection is required. The injection rate is approximated by

$$Q_{inj} \approx Q_2.$$

4) **Trench and well configurations**

See Attachments F.6.I.2.0 and F.6.I.3.0.

5) **Evaluation of necessity for injection**

It has been established that injection is required.

6) **Detailed analyses for trenches and wells**

See Attachments F.6.I.2.0 and F.6.I.3.0.

F.6.I.2.0 PROCEDURE FOR THE ANALYSIS OF ACTIVE REMEDIAL TRENCHES

F.6.I.2.1 OBJECTIVE

The main objective of this procedure is to provide a necessary technical framework for the assessment of groundwater remediation in the perched zone through the use of active trenches.

F.6.I.2.2 THEORETICAL BASIS

In this analysis, an active trench is defined as the trench which is utilized for the purposes of recharge or extraction at the rate greater than the natural groundwater flowrate in the perched zone.

The analysis is based on the following assumptions:

- The area of interest may be idealized as an equivalent rectangle;
- Spacing between trenches is sufficiently small so that contaminant concentration is uniformly distributed between two adjacent trenches at all time; and
- Material properties and thickness are uniform between two neighboring trenches.

Assuming that the area of interest may be idealized as a rectangle of width, W (ft), and length, L (ft), and that trenches in the area are oriented widthwise with the spacing of ΔL (ft), the number of trenches in the area of interest is determined geometrically by:

$$n_{Tr} = 1 + \frac{L}{\Delta L} \qquad \text{(F.6.I.2-1)}$$

The trench spacing may be determined using the principle of mass conservation (Bear 1972), thus:

$$bA_{cont}[\theta + \rho_b K_d]\frac{\partial c}{\partial t} = -\lambda bA_{cont}[\theta + \rho_b K_d]c - Q_2 c \qquad \text{(F.6.I.2-2)}$$

Solving Equation (F.6.I.2-2), with an assumption that the initial concentration c_o is also uniform between two adjacent trenches, leads to

$$Q_T = A_{cont} b(\theta + \rho_b K_d)\left[\frac{1}{\Delta t}\ln\left(\frac{c_o}{c_{target}}\right) - \lambda\right] \qquad \text{(F.6.I.2-3)}$$

where

c_o	= initial concentration (mg/l)
c_{target}	= target remedial concentration (mg/l)
λ	= decay factor (1/day)
ρ_b	= bulk density of soil matrix (g/ml)
K_d	= partitioning coefficient (ml/g)
A_{cont}	= area between two trenches (ft^2)
	= W ΔL
b	= thickness of the perched zone (ft)

Δt = time interval of interest (day)
Q_T = flow rate between two adjacent trenches (ft^3/day)
θ = porosity (dimensionless)

The flow rate between two adjacent trenches may be estimated from

$$Q_T = KbW\frac{\Delta H}{\Delta L} \qquad \text{(F.6.I.2-4)}$$

where

ΔH = head difference between the two adjacent (injection and extraction) trenches (ft)
K = hydraulic conductivity (ft/day)

Using Equations (F.6.I.2-3) and (F.6.I.2-4) to solve for ΔL, one obtains:

$$\Delta L = \left[\frac{K\Delta H}{(\theta+\rho_b K_d)\left[\frac{1}{\Delta t}\ln\left(\frac{c_o}{c_{target}}\right)-\lambda\right]}\right]^{\frac{1}{2}} \qquad \text{(F.6.I.2-5)}$$

ΔH is subject to the constraint below:

$$\Delta H \le B_{CL} \qquad \text{(F.6.I.2-6)}$$

where

B_{CL} = thickness of the overburden brown clay layer (ft)

The constraint above ensures that the perched zone (or any transmissive zone of interest) is always saturated so that each adsorptive contaminant maintains its maximum mobility.

F.6.I.2.3 PROCEDURE

1) Define a contaminated area in which concentration is approximately uniform. Determine the width, W, and length, L of the area. Use the average concentration in this area as the initial concentration, c_o.

2) Determine target concentration c_{target} (from the SWIFTLOAD/ODAST simulations).

3) Determine ΔH, constraint applicable to the area [B_{CL} in Equation (F.6.I.2-6)], and use Equation (F.6.I.2-5) to determine spacing between trenches.

4) Use Equation (F.6.I.2-1) to determine the required number of trenches.

F.6.I.2.4 SAMPLE CALCULATION

Calculations were performed for Cases 1, 2, and 3 to determine the required lineal trench lengths. A calculation sample, based on information relating to Case 1, is provided below. The calculation is organized in a fashion similar to the calculation procedure presented in Section F.6.I.2.3.

1) **Determination of geometry and initial concentration**

Subzone initial concentrations and Case-1 geometry are presented in Tables F.6-16 and F.6-17, respectively. For Subzone I1GPM-1,

Width normal to the flow direction	=	600 ft
Length along the flow direction	=	703 ft
Initial concentration	=	5.6914 mg/l

2) **Determination of target concentration**

For Subzone I1GPM-1,

c_{Target} = 0.00446 mg/l.

See Subsection F.6.I.1.4 of Attachment F.6.I.1.0 for the c_{Target} values of other subzones.

3) **Determination of trench spacing**

Using Equation (F.6.I.2-5), the following parameter values:

c_o	=	5.6914 mg/L
c_{target}	=	0.00446 mg/L
λ	=	4.25×10^{-13} 1/day
ρ_b	=	1.855 g/ml
K_d	=	1.78 L/kg
b	=	15 ft
Δt	=	35×365 days
θ	=	0.3
K	=	1.64 ft/day,

and the following constraint,

$$\Delta H = 5 \text{ ft},$$

the trench spacing for Subzone I1GPM-1 is given by

$$\Delta L = \left[\frac{1.64\times5}{(0.3+1.855\times1.78)\left[\frac{1}{35\times365}\ln\left(\frac{5.6914}{0.00446}\right)-4.25\times10^{-13}\right]}\right]^{0.5}$$

$$= 63.77 \text{ ft}$$

4. **Determination of number of trenches and trench lengths**

From Equation (F.6.I.2-1), the number of trenches in Subzone I1GPM-1 is given by

$$n_{Tr} = 1 + \frac{703}{63.77} = 12.02$$

The total trench length for Subzone I1GPM-1 is therefore

$$W\times n_{Tr} = 600\times12.02 = 7212\ ft.$$

Using the same procedure for other subzones, one obtains the following subzone trench lengths:

Subzone	I1GPM-2:	486 ft
Subzone	I1GPM-3:	1860 ft
Subzone	I1GPM-4:	5448 ft
Subzone	O1GPM-1:	579 ft
Subzone	O1GPM-2:	7400 ft

Summing up the trench lengths from all subzones, the total trench length is 22,985 ft.

Similarly, for K_d = 15 L/kg, the total trench length was estimated to be 58,677 ft. For the hydraulic conductivity in the I1GPM area and its vicinity equal to 47.11 ft/day, the total trench lengths were estimated to be 7045 and 14,101 ft for K_d = 1.78 and 15 L/kg, respectively.

F.6.I.3.0 PROCEDURE FOR THE ANALYSIS OF THE PUMPING-INJECTION WELL SYSTEM

F.6.I.3.1 OBJECTIVE

The main objective of this procedure is to provide a necessary technical framework for the assessment of groundwater remediation in the perched zone through the use of a pumping injection well system.

F.6.I.3.2 THEORETICAL BASIS

In this analysis, a pumping-injection well system is defined in Figure F.6.I.3-1. In the figure, a pumping well is surrounded by four injection wells, and vice versa. The net injection and extraction rate of the injection-extraction system is zero so that no additional water is introduced into the perched water system. It should be noted here that, for the net injection and extraction rate to be zero, the perimeter extraction/ injection wells would have appropriately less strengths than those of the interior wells.

The analysis is based on the following assumptions:

- Spacing between neighboring wells is sufficiently small so that contaminant concentration is uniformly distributed between wells as well as throughout the area of interest;
- Material properties and thickness are uniform throughout the area of interest;
- The strengths of all interior pumping and injection wells are identical;
- The spacing between injection wells is uniform throughout the well field;
- The spacing between injection and extraction wells is uniform throughout the well field; and
- The flow domain is extended to infinity.

Through the use of complex functions for sources and sinks, the distribution of potential due to the sources and sinks in Figure F.6.I.3-1 is given by (Bear 1972)

$$\phi = KbH = \sum_{i=1}^{n_w} \frac{q_i}{2\pi} \ln(r_i) \qquad \text{(F.6.I.3-1)}$$

where

Φ = velocity potential function (ft^3)
K = hydraulic conductivity (ft/day)
b = saturated thickness of the perched zone (ft)
H = hydraulic head of the perched zone (ft)
q_i = strength of injection and pumping wells (positive denotes injection and negative denotes pumping) (ft^3/day)

r_i = radial distance from center of well i to the point of observation (ft)
n_w = total number of wells

Equation (F.6.I.3-1) is used to determine the maximum difference between upconing and drawdown between two adjacent pumping and injection wells, ΔH_{max}, thus:

$$\Delta H_{max} = H_{inj}(\delta r) - H_{pmp}(\delta r) \qquad \text{(F.6.I.3-2)}$$

where

δr = small distance from well center typically equal to the radius of gravel packing (ft)
H_{inj} = hydraulic head adjacent to gravel packing of an injection well (ft)
H_{pmp} = hydraulic head adjacent to gravel packing of a pumping well (ft)

ΔH_{max} is subject to the constraint below:

$$H_{max} \leq B_{CL} \qquad \text{(F.6.I.3-3)}$$

where

B_{CL} = thickness of overburden brown clay layer (ft)

The constraint above ensures that the perched zone (or any transmissive zone of interest) is always saturated so that each adsorptive contaminant maintains its maximum mobility.

Typically, the required injection rate is much greater than the local natural recharge rate. It can be further assumed, therefore, that the total pumping rate is roughly equal to the total injection rate. For a given ΔH_{max}, the appropriate number of pumping wells, n_{pmp}, which satisfies the prescribed ΔH_{max} may be obtained through an iterative process by varying n_{pmp} until the constraint is satisfied. For a given n_{pmp}, the total number of wells may be estimated from an assumption that the extraction wells are arranged in an $\sqrt{n_{pmp}} \times \sqrt{n_{pmp}}$ array and the injection wells in an $(\sqrt{n_{pmp}} + 1) \times (\sqrt{n_{pmp}} + 1)$ array, thus:

$$n_{tot} \approx 2n_{pmp} + 2\sqrt{n_{pmp}} + 1 \qquad \text{(F.6.I.3-4)}$$

When n_{pmp} is relatively large, ΔH_{max} remains relatively uniform in the interior of the well field. The determination of ΔH_{max} may be simplified by using an adequately large array of pumping-injection wells. For practical purposes, a 20 x 20 array is adequately large and used throughout the analysis for the calculation of ΔH_{max}.

F.6.I.3.3 PROCEDURE

1) Define a contaminated area in which concentration is approximately uniform. Determine the required injection rate using the procedure in Attachment F.6.I.1.0, Procedure for a Preliminary Assessment of Remedial Requirements. Use the average concentration in this area as the initial concentration, c_o.

2) Determine target concentration c_{target} (from the SWIFTLOAD/ODAST simulations).

3) Determine ΔH_{max} applicable to the area, using Equation (F.6.I.3-3).

4) Assume n_{pmp}.

5) Determine a single-well extraction rate (total extraction rate/assumed n_{pmp}).

6) Iterate until the ΔH_{max} constraint is satisfied, using Equations (F.6.I.3-1), (F.6.I.3-2), and (F.6.I.3-3). If Constraint (F.6.I.3-3) is not satisfied, return to Step 4.

7) Use Equation (F.6.I.3-4) to determine the required number of wells.

F.6.I.3.4 SAMPLE CALCULATION

Calculations were performed for Cases 1, 2, and 3 to determine the required number of injection and extraction wells. A calculation sample, based on information relating to Case 1, is provided below. The calculation is organized in a fashion similar to the calculation procedure presented in Section F.6.I.3.3.

1. **Determination of geometry and initial concentration**

Subzone initial concentrations and Case-1 geometry are presented in Tables F.6-16 and F.6-17, respectively. For Subzone I1GPM-1,

Total area = 421,600 ft^2
Initial concentration = 5.6914 mg/L

2. **Determination of target concentration**

For Subzone I1GPM-1,

c_{Target} = 0.00446 mg/L

See Section F.6.I.1.4 of Attachment F.6.I.1.0 for the c_{Target} values of other subzones.

3. **Determination of constraint**

Using Equation (F.6.I.3-3),

$H_{max} \leq 5\ ft$.

4. **Assume number of extraction wells**

Assume $n_{pmp} = 115$.

5. **Determination of single well extraction rate**

The total extraction rate required for Subzone I1GPM-1 is given in Section F.6.I.1.4, Attachment F.6.I.1.0.

For $K_d = 1.78$ L/kg, the required extraction rate, Q_2, is 12,751.56 ft^3/day.

Based on the total extraction rate above, the single-well extraction is

$$\frac{12751.56}{115} = 110.88\ ft^3/day.$$

6. **Determination of H_{max}**

Based on the extraction and the subzone total area, the well spacing may be determined from:

$$\text{Area per extraction well} = \frac{421600}{115} = 3666.08\ \ ft^2$$

$$\text{Therefore, well spacing} \approx \sqrt{3666.08} \approx 60\ \ ft.$$

The calculation of H_{max} was standardized by using a standard 20 × 20 array of injection wells in which is embedded a 19 × 19 array of extraction wells. The composite well array has 400 injection wells and 361 extraction wells, 761 wells in total. This configuration provides an approximate solution to Equation (F.6.I.3-1). H_{max} was calculated from the velocity potential values at two adjacent extraction and injection wells close to the center of the composite well array. These two wells are located in an injection-extraction well cell, located at five well spacings from two orthogonal edges of the composite well array. (It was found that the difference between the potentials at two adjacent injection and extraction wells became constant within two well spacings from any two orthogonal edges of the composite well array.)

Assuming the radius of gravel packing is 0.5 ft, and with

n_w = 761,

q_i = ± 110.88 ft^3/day (positive denotes injection and negative extraction)

along with Equation (F.6.I.3-1), one obtains:

$$H_{inj}(0.5) = \sum_{i=1}^{761} \frac{\pm 110.88}{2\pi} \ln(r_{i,i+0.5}) = 1.932 \ ft$$

$$H_{ext}(0.5) = \sum_{i=1}^{761} \frac{\pm 110.88}{2\pi} \ln(r_{i,e+.5}) = -3.057 \ ft$$

and

$$H_{max} = 1.932 - (-3.057) = 4.99 \ ft \leq 5 \ ft$$

where

$r_{i,i+0.5}$ = radial distance from well i to observation point located at 0.5 feet from an injection well axis.

$r_{i,e+0.5}$ = radial distance from well i to observation point located at 0.5 feet from the axis of an extraction well adjacent to the above injection well.

7. **Determination of total number of wells**

Using Equation (F.6.I.3-4), the required total number of wells is

$$n_{tot} \approx 2\times115+2\times\sqrt{115}+1 = 252 \ wells.$$

Using the same procedure for other subzones, one obtains the following numbers of wells:

Subzone	I1GPM-2:	13
Subzone	I1GPM-3:	45.5
Subzone	I1GPM-4:	85
Subzone	O1GPM-1:	15.5
Subzone	O1GPM-2:	168.

Note that the above numbers of wells are not rounded off. Rounding off occurs after the summation of all the numbers of wells in all subzones. Summing up the well numbers in all subzones, the total number of wells is 579.

Similarly, for K_d = 15 L/kg, the total number of wells was estimated to be 3176. For the hydraulic conductivity in the I1GPM area and its vicinity equal to 47.11 ft/day, the total numbers of wells were estimated to be 64 and 265, for K_d = 1.78 and 15 L/kg, respectively.

F.6.I.4.0 PROCEDURE FOR THE ANALYSIS OF CONTAINMENT TRENCHES

F.6.I.4.1 OBJECTIVE

The main objective of this procedure is to provide a necessary technical framework for the assessment of groundwater remediation in the perched zone through the use of containment trenches.

F.6.I.4.2 THEORETICAL BASIS

In this analysis, a containment trench is defined as the trench which is utilized for the purposes of extraction at the rate equal to the natural groundwater flowrate in the perched zone. The operational period of the trench is from the completion of the trench to the time at which the concentration of contaminant of interest attenuates to below the target concentration.

Consider a containment trench whose axis is located at a distance L along a natural flow line from the centroid of a contaminant plume. The analysis consists of determining the required operational period of the trench based on the history of the effluent concentration of the contaminant of interest at the trench. The trench operation is terminated when the contaminant concentration detected in the trench is permanently below a target concentration, c_{target}. In the analysis, it is conservatively assumed that lateral hydrodynamic dispersion is absent so that the analysis may be carried out one-dimensionally along the flow direction.

With the following initial conditions:

$$c = c_o; \qquad -\frac{W_P}{2} \le x \le \frac{W_P}{2} \qquad \text{(F.6.I.4-1)}$$

$$c = 0; \qquad \textit{elsewhere} \qquad \text{(F.6.I.4-2)}$$

and a one-dimensional transport equation (Bear 1972):

$$(\theta+\rho_b K_d)\frac{\partial c}{\partial t} + \theta v\frac{\partial c}{\partial x} = \frac{\partial}{\partial x}\theta D_L\frac{\partial c}{\partial x} - \lambda(\theta+\rho_b K_d)c\ , \qquad \text{(F.6.I.4-3)}$$

the concentration at the trench at time t is given by (Carslaw and Jaeger 1959):

$$c(L,t) = 0.5c_o\ \exp(-\lambda t)\left[erfc\left(\frac{L-\frac{v}{R_d}t-0.5W_p}{2\sqrt{\frac{D_L}{R_d}t}}\right) - erfc\left(\frac{L-\frac{v}{R_d}t+0.5W_p}{2\sqrt{\frac{D_L}{R_d}t}}\right)\right] \qquad \text{(F.6.I.4-4)}$$

where

c = contaminant concentration (mg/L)
c_o = initial concentration of the plume (mg/L)
W_P = plume width along the considered flowline (ft)

x = distance along the considered flowline from the centroid of contaminant plume (ft)
L = distance along the considered flowline from the centroid of contaminant plume to the axis of the trench (ft)

$$R_d = \left(1+\frac{\rho_b}{\theta}K_d\right)$$

= retardation factor (dimensionless)
λ = decay factor (1/day)
ρ_b = bulk density of soil matrix (g/ml)
K_d = partitioning coefficient (ml/g)
t = time (days)
v = groundwater velocity $= -\frac{K}{\theta}\frac{\partial H}{\partial x}$ (ft/day)
K = hydraulic conductivity (ft/day)
$\frac{\partial H}{\partial x}$ = hydraulic gradient (ft/ft)

The analytical framework outlined above is based on an assumption that only one plume of uniform concentration c_o exists. Several plumes may be included in the analysis through the use of superposition techniques.

F.6.I.4.3 PROCEDURE

1) Define a contaminated area in which concentration is approximately uniform. Determine the plume width, W_P. Use the average concentration in this area as the initial concentration, c_o.

2) Determine target concentration c_{target} (from the SWIFTLOAD/ODAST simulations).

3) Determine L applicable to the area and use Equation (F.6.I.4-4) to determine contaminant concentration at time t at the trench axis. The minimum operational period required is determined from the time at which contaminant concentration attenuates to the target concentration.

F.6.I.4.4 SAMPLE CALCULATION

Calculations were performed for Cases 1, 2, and 3 to determine the required operational periods for containment trenches. A calculation sample, based on information relating to Case 1, is provided below. The calculation is organized in a fashion similar to the calculation procedure presented in section F.6.I.4.3.

1) **Determination of plume width and initial concentration**

Subzone initial concentrations are presented in Table F.6-16.

For Subzone O1GPM-1,

Initial concentration = 0.831 mg/L
Plume width = 200 ft,

and for Subzone O1GPM-2

Initial concentration = 0.634 mg/L
Plume width = 600 ft.

Note that the above plume widths are similar but not identical to those in Table F.6-17. For any given plume, the plume width was chosen from a location considered to be close to the bulk of the plume and closest to the discharge boundary.

2) **Determination of c_{Target}**

For Case 1, c_{Target} is 0.0744 mg/L for all O1GPM subzones.

3) **Determination of operational period**

Using the following parameters:

λ = 4.25×10^{-13} 1/day
ρ_b = 1.855 g/ml
K_d = 1.78 L/kg
θ = 0.3
α_L = 40 ft
T = 0.29
D_d = 1.86×10^{-3} ft^2/day
K = 2.0 ft/day in Subzone O1GPM-1 (Table F.6-2)
= 3.55 ft/day in Subzone O1GPM-2 (Table F.6-2)
$\frac{\partial H}{\partial x}$ = 0.01 in Subzone O1GPM-1 (See Table F.6-2)

= 0.0122 in Subzone O1GPM-2 (See Table F.6-2 and Section F.6.I.1.4 in Attachment F.6.I.1.0)

$$R_d = 1 + \frac{1.855 \times 1.78}{0.3} = 12.006$$

the following may be estimated:

$$v = \frac{2 \times 0.010}{0.3} = 0.06666667 \ \ ft/day, \text{ in O1GPM-1}$$

$$= \frac{3.55 \times 0.0122}{0.3} = 0.144367 \ \ ft/day, \text{ in O1GPM-2}$$

$$D_L = 40 \times 0.0666667 + 0.00186 \times 0.29$$

$$= 2.667 \text{ ft}^2/\text{day, in O1GPM-1}$$

$$= 40 \times 0.144367 + 0.00186 \times 0.29$$

$$= 5.775 \text{ ft}^2/\text{day, in O1GPM-2.}$$

Using Equation (F.6.I.4-4) and the parameters above, U_{238} concentrations at times 230 and 232 years at the containment trench located at 120 ft downgradient from the plume centroid in Subzone O1GPM-1 may be estimated, as shown below:

c(120 ft, 230 yrs)

$$= 0.5 \times 0.831 \ [erfc(-1.634) - erfc(-0.902)]$$

$$= 0.0753 \text{ mg/L}$$

c(120 ft, 232 yrs)

$$= 0.5 \times 0.831 \ [erfc(-1.642) - erfc(-0.913)]$$

$$= 0.0733 \text{ mg/L.}$$

As shown above the concentration of U_{238} attenuates to below 0.0744 mg/L at approximately 232 years.

Similarly, using Equation (F.6.I.4-4) and the parameters above, U_{238} concentrations at times 236 and 238 years at the containment trench located at 400 ft downgradient from the plume centroid in Subzone O1GPM-2 may be estimated, as shown below:

c(400 ft, 236 yrs)

$$= 0.5 \times 0.634 \ [erfc(-2.3) - erfc(-0.826)]$$

$$= 0.0765 \text{ mg/L}$$

c(400 ft, 238 yrs)

$$= 0.5 \times 0.634\ [erfc(-2.311) - erfc(-0.844)]$$

$$= 0.0734 \text{ mg/L.}$$

As shown above the concentration of U_{238} attenuates to below 0.0744 mg/L at approximately 238 years.

Based on the same calculation procedure for K_d = 15 L/kg, the operational periods for Subzones O1GPM-1 and O1GPM-2 were estimated, using Equation (F.6.I.4-4), to be 1,804 and 1,854 years, respectively.

4) **Cases 2 and 3**

Below are the parameters that were used in the estimation of operational periods for Cases 2 and 3. Results are presented in Table F.6-23.

CASE	SUBZONE	c_o (mg/L)	c_{Target} (mg/L)	W_p (ft)	L (ft)
2	O1GPM-1	1.032	0.1488	150	120
	O1GPM-2	1.060	0.1488	500	450
3	O1GPM-1	1.032	0.1488	150	120
	O1GPM-2[a]	3.701	0.1488	1100	800

Note: [a]Modeled plume also includes contamination inside 1 gpm zone.

F.6.I.5.0 ANALYSIS OF CONTAMINANT TRANSPORT IN SOIL BLOCKS WITH RELATIVELY LOW HYDRAULIC CONDUCTIVITY

F.6.I.5.1 OBJECTIVE

The main objective of this procedure is to provide a necessary technical framework for the analysis of contaminant transport in soil blocks with relatively low hydraulic conductivity.

During the course of remediation through groundwater injection and extraction. It is possible that areas with relatively low hydraulic conductivity (fine-grained materials, silt) may be by-passed due to their high hydraulic resistance compared with the surrounding areas with relatively high hydraulic conductivity. Because of this phenomenon, a significant amount of contaminants may be left in the low-hydraulic-conductivity blocks. This analysis was conducted to determine the amount of contaminants that may remain in the low-hydraulic-conductivity blocks after the remediation period.

F.6.I.5.2 THEORETICAL BASIS

To simplify the analysis, the following assumptions were adopted:

- Within a low-hydraulic-conductivity block, mechanical dispersion is negligible compared with molecular diffusion;
- The time frame of interest (35 years) is adequately short compared with the time required to remove the mass completely from the block through molecular diffusion (1000s of years); and
- The half live of the chemical of interest is adequately large so that the decay component is negligible within the time frame of interest.

Following the first two assumptions, the area of interest may be analyzed by a one-dimensional approximation. In other words, because mass transport occurs mainly in the vicinity of the block surface, from the contaminant transport standpoint the block geometry may be extended to infinity depthwise and widthwise without significant loss of accuracy.

The equation describing contaminant transport within a block may be written as (Bear 1972):

$$(\theta + K_d \rho_b)\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left[\theta T D_m \frac{\partial C}{\partial x}\right] \qquad \text{(F.6.I.5-1)}$$

where

C	=	contaminant concentration (mg/L)
t	=	time (days)
x	=	distance from the centroid of the low-hydraulic-conductivity block of interest (ft)
D_m	=	molecular diffusion coefficient (ft^2/day)

θ = porosity (dimensionless)
T = tortuosity (dimensionless)
K_d = partitioning coefficient (ml/g)
ρ_b = bulk density of soil matrix (g/ml)

For the region $0 < x < L$ with initial concentration $C_o(x)$, no flow of mass at x = 0, and x = L kept at concentration $C_2(t)$, the solution was given by Carslaw and Jaeger (1959) as:

$$C(x,t)=\frac{2}{l}\sum_{n=0}^{\infty}\exp\left(\frac{-\kappa(2n+1)^2\pi^2 t}{4l^2}\right)\cos\left(\frac{(2n+1)\pi x}{2l}\right)[A_1A_2 + A_3] \qquad \text{(F.6.I.5-2)}$$

where

$$A_1 = \frac{(2n+1)\pi\kappa(-1)^n}{2l}$$

$$A_2 = \int_0^t \exp\left(\frac{\kappa(2n+1)^2\pi^2\beta}{4l^2}\right)C_2(\beta)d\beta$$

$$A_3 = \int_0^l C_o(x')\cos\left(\frac{(2n+1)\pi x'}{2l}\right)dx'$$

$$\kappa = \frac{D_m T\theta}{\theta+K_d\rho_b}$$

It should be noted that L is the half length of a block of length 2L of which both ends are subject to $C_2(t)$, i.e. at x = -L and x = L, C = $C_2(t)$. Because of symmetry, the no-mass flow condition may be imposed at x = 0.

$C_2(t)$, the concentration in the higher conductivity zone, in the following analysis is based on the expression derived for Q_2 in Attachment F.6.I-1, shown below:

$$C_2(t) = C_o\exp\left[-\frac{Q_2 t}{A_{cont}b(\theta+k_d\rho_b)}\right] \qquad \text{(F.6.I.5-3)}$$

where

A_{cont} = area of contaminated zone (plume) (ft^2)
b = formation thickness (ft)
Q_2 = total groundwater extraction rate (ft^3/day)

F.6.I.5.3 RESULTS

With $C_o(x)$ kept constant at C_o, and $C_2(t)$ equal to that in Equation (F.6.I.5-3), Equation (F.6.I.5-2) was used to estimate concentration profiles along blocks at different times. Two block half lengths were used in the analysis, 30 feet and 6 feet. Parameters used in the analysis are presented in Table F.6.I.5-1.

Dimensionless concentration profiles (C/C_O) shown in Figures F.6.I.5-1, to F.6.I.5-4 represent results from the following respective cases:

- L = 30 feet, K_d = 1.78 L/kg
- L = 30 feet, K_d = 15.0 L/kg
- L = 6 feet, K_d = 1.78 L/kg
- L = 6 feet, K_d = 15.0 L/kg

In these figures, concentration profiles at 35, 100, 500, 1000, and 2000 years are shown. In all cases, it can be seen that within the period of 35 years, significant mass removal occurs only within the first few feet from the surface of the block (interface between low-hydraulic-conductivity zone and high-hydraulic-conductivity zone).

F.6.I.6.0 REFERENCES

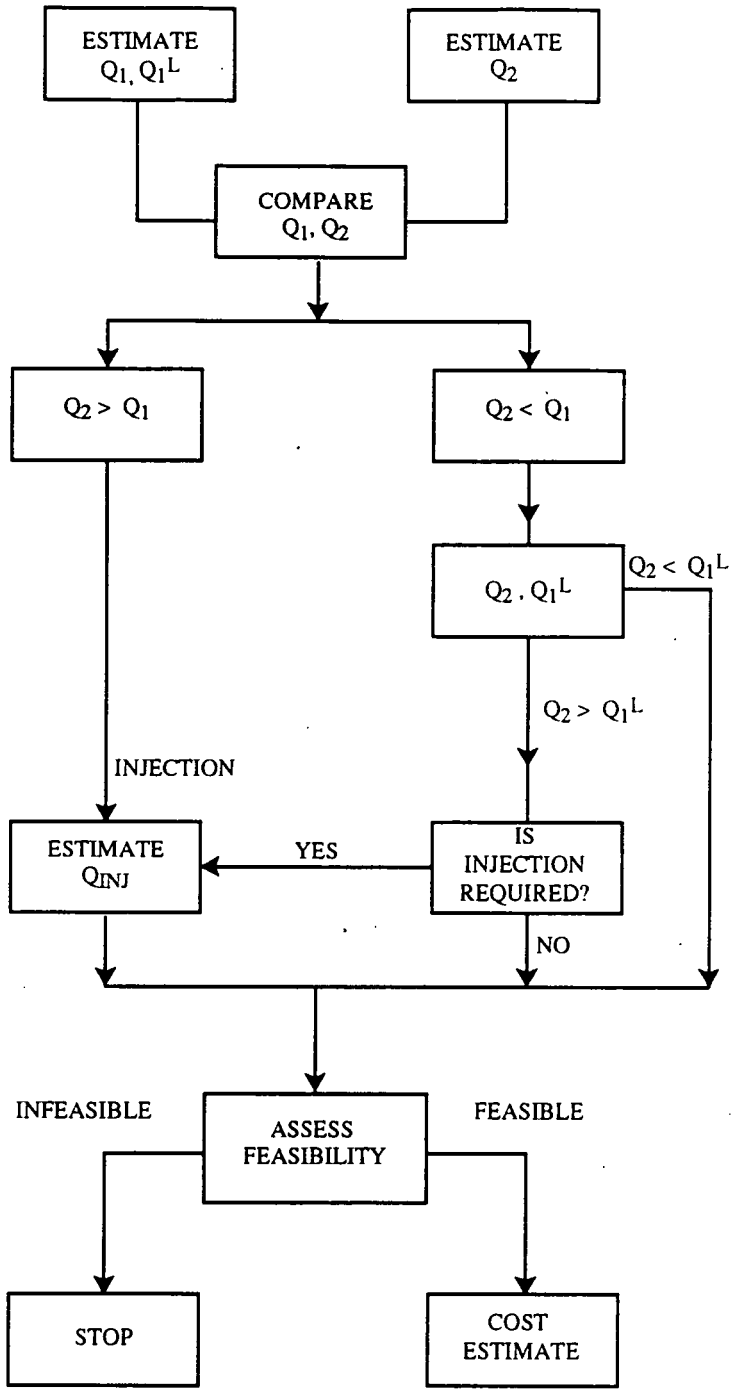
Bear, J. (1972), Dynamics of Fluids in Porous Media, American Elsevier, New York.

Carslaw, H.S. and Jaeger, J.C. (1959), Conduction of Heat in Solids, Oxford University Press, London.

TABLE F.6.I.5-1

PARAMETERS USED IN THE ANALYSIS OF CONTAMINANT TRANSPORT IN LOW-HYDRAULIC-CONDUCTIVITY BLOCKS

PARAMETER	VALUE
Molecular diffusion coefficient (ft^2/day)	1.86×10^{-3}
Tortuosity (dimensionless)	0.29
Bulk density (gm/cm^3)	1.855
Initial concentration (dimensionless)	1.0
Porosity	0.3
Partitioning coefficient (L/kg)	1.78 and 15
Area of contaminated plume (ft^2)	421,600
Formation thickness (ft)	15
Groundwater extraction rate (gpm)	68.6 (K_d = 1.78 L/kg) 535.5 (K_d = 15.0 L/kg)



NOTE:

Q_1 = MAXIMUM DISCHARGE RATE POSSIBLE IN INFILTRATION ZONE V IN 35 YEARS

Q_2 = EXTRACTION DISCHARGE RATE REQUIRED TO DEPLETE PLUME TO APPLICABLE MCL OR PERCHED WATER PRG FOR RESIDENT FARMER/CHILD IN 35 YEARS

Q_1^L = LOWER LIMIT OF MAXIMUM DISCHARGE RATE (Q_1)

Q_{INJ} = INJECTION RATE DUE TO INJECTION REQUIRED TO DEPLETE PLUME IN 35 YEARS

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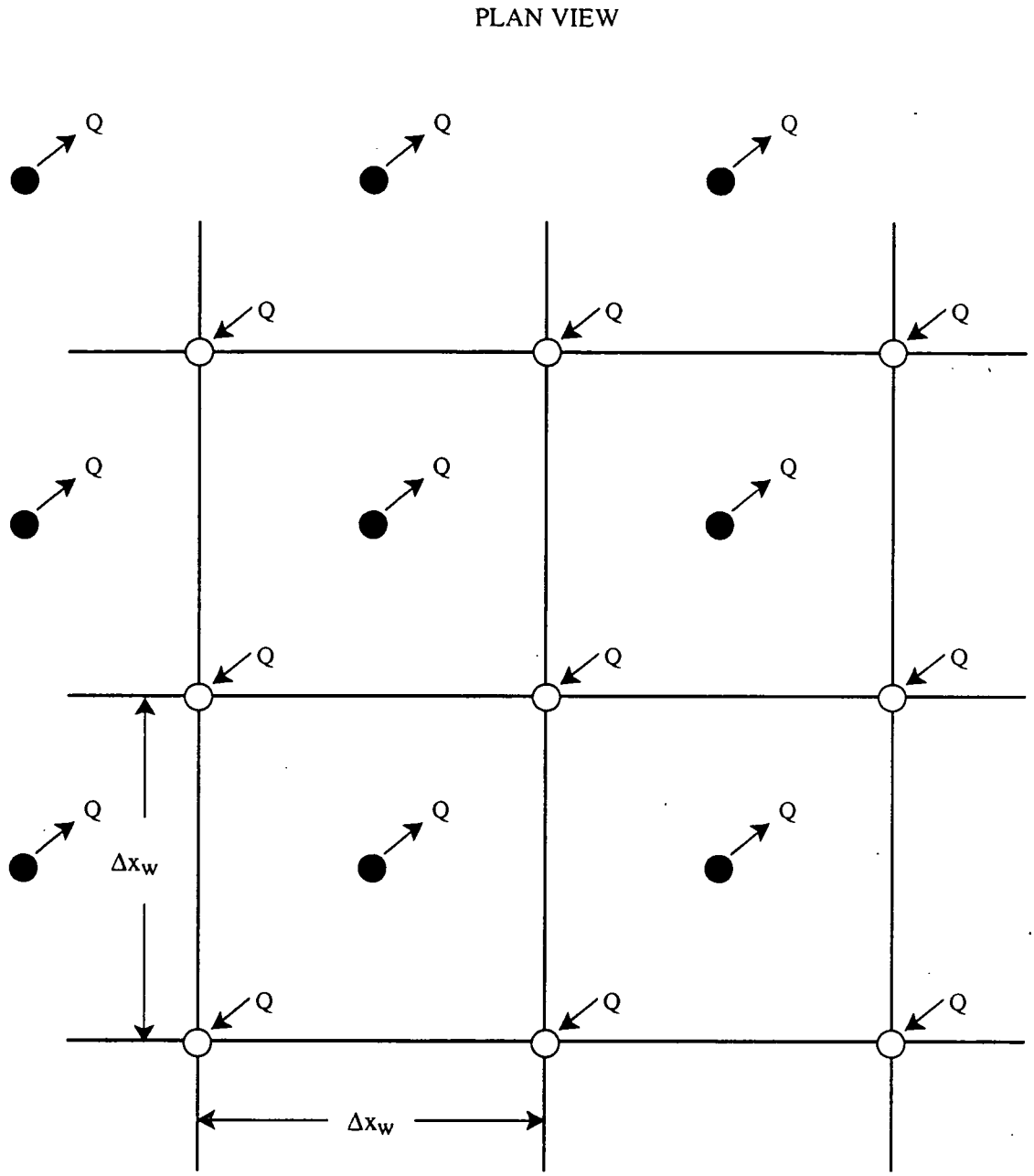
FIGURE F.6.I-1. APPROACH FOR EVALUATING FEASIBILITY OF TRENCHES/WELLS FOR PERCHED WATER REMEDIATION



LEGEND:
- ● PUMPING WELL
- ○ INJECTION WELL
- ↗Q PUMPING RATE
- ↙Q INJECTION RATE
- Δx_w WELL SPACING

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FIGURE F.6.I-2. IDEALIZED CONFIGURATION OF PUMPING AND INJECTION WELLS AND A PUMPING-INJECTION REMEDIAL SYSTEM

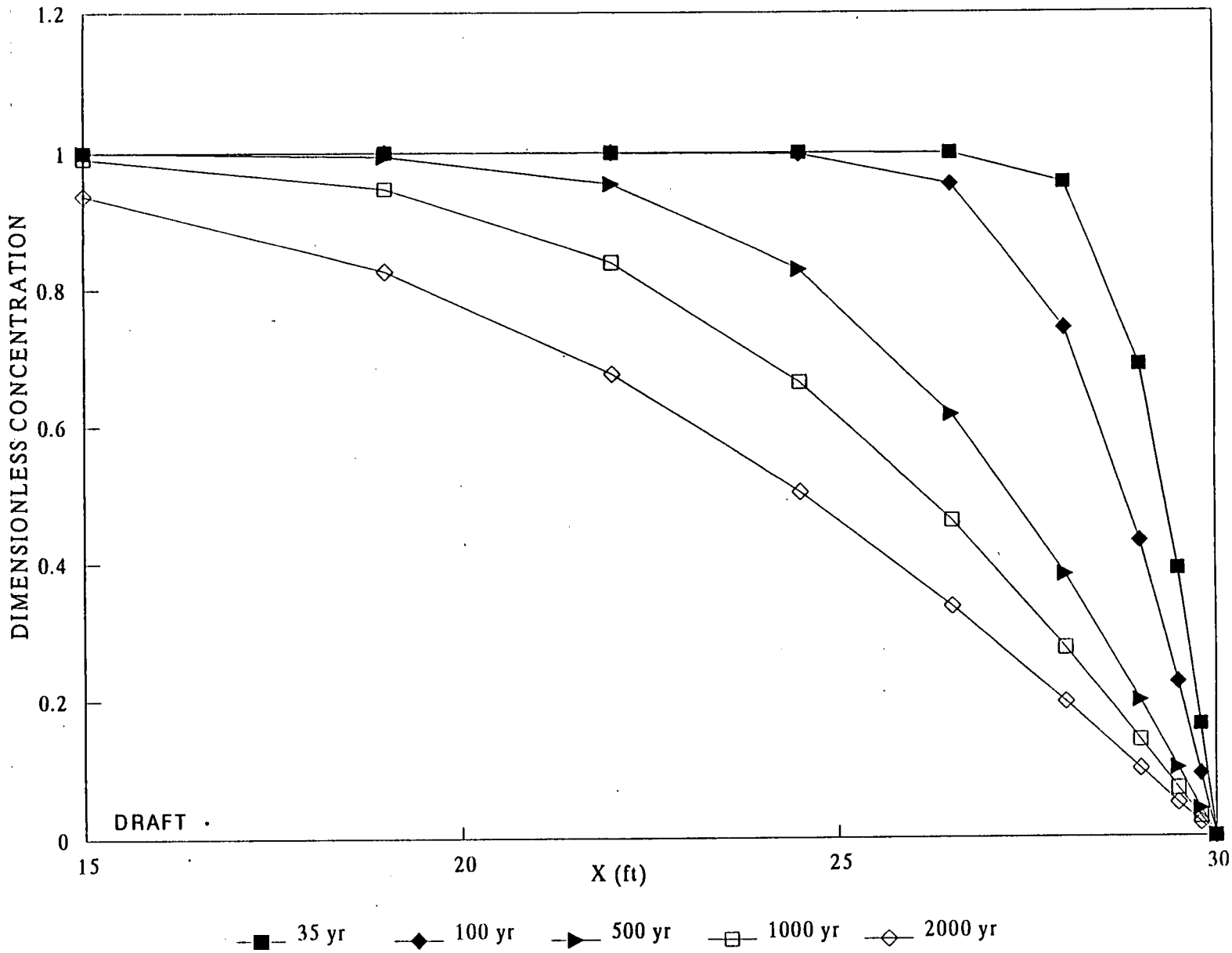

FIGURE F.6.I-3 1-D CONCENTRATION PROFILES FOR MOLECULAR DIFFUSION IN A 30-FOOT BLOCK, Kd = 1.78 ml/g

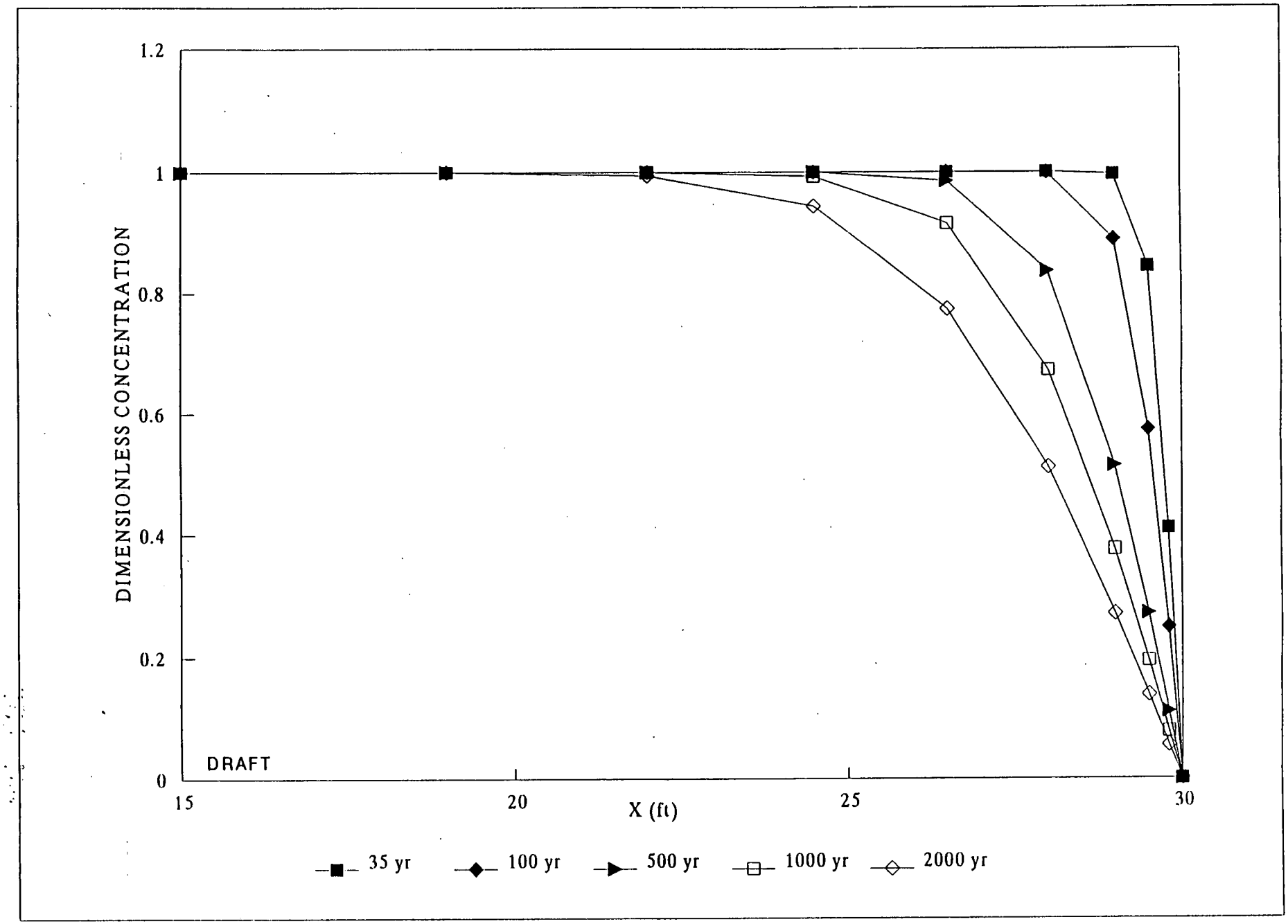

FIGURE F.6.I-4 1-D CONCENTRATION PROFILES FOR MOLECULAR DIFFUSION IN A 30-FOOT BLOCK, Kd = 15 ml/g

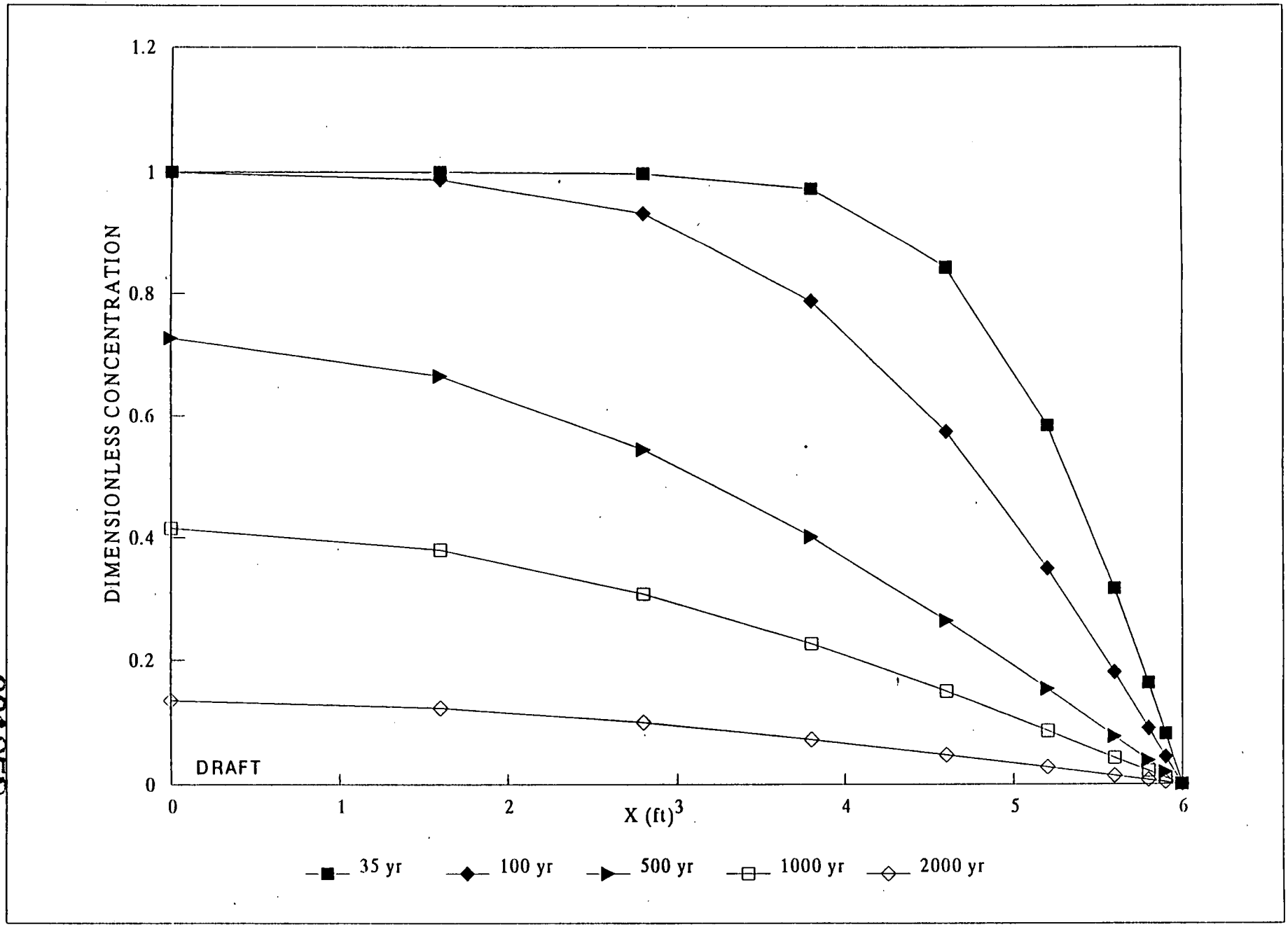

FIGURE F.6.I-5 1-D CONCENTRATION PROFILES FOR MOLECULAR DIFFUSION IN A 6-FOOT BLOCK, Kd = 1.78 ml/g

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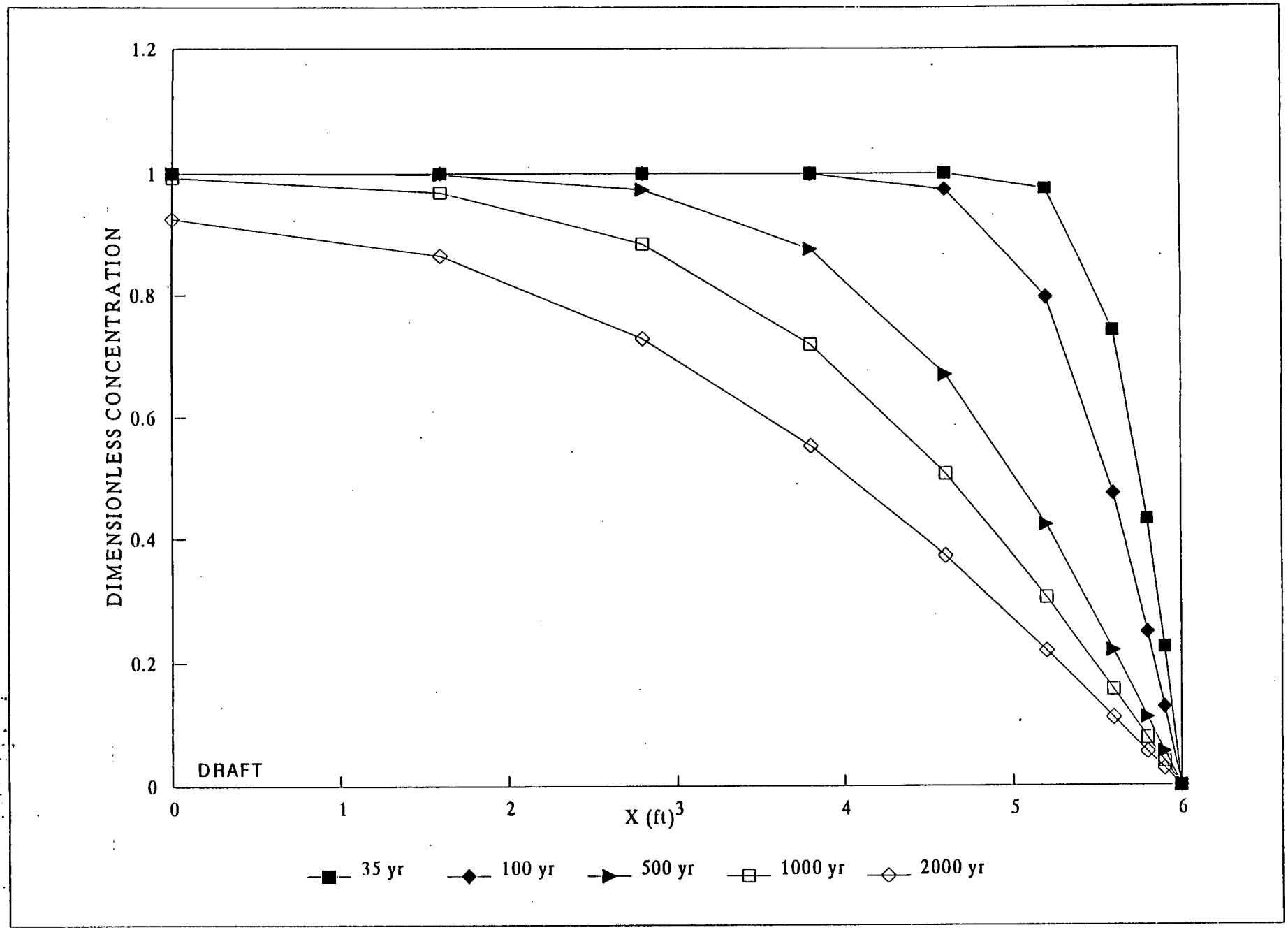

FIGURE F.6.I-6 1-D CONCENTRATION PROFILES FOR MOLECULAR DIFFUSION IN A 6-FOOT BLOCK, Kd = 15 ml/g

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ATTACHMENT F.8.I

SURFACE WATER LOADING OF URANIUM TO GROUNDWATER

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SURFACE WATER LOADING OF URANIUM TO GROUNDWATER

F.8.I.1.0 INTRODUCTION

The Surface Water Flow and Infiltration Model (SWF&IM [DOE 1993]) was used to determine the loading of uranium to the Great Miami Aquifer via the surface water pathway of contaminant transport. This model is described in detail in the above-referenced report and the Remedial Investigation (RI) Report for Operable Unit 5 (DOE 1994a). The source of contamination to the surface water considered in the surface water modeling is the surface soil covering the FEMP. In the surface water modeling, the land surface is divided into 35 source areas to account for varying concentration of contaminants and various transport properties of the contaminants. Figure F.8.I.1-1 presents the source areas used in the surface water model. For any constituent of concern, a specific partitioning coefficient and source concentration is required for each of the 35 source areas. The surface water uranium loading to the groundwater occurs when contaminated water flowing in streams at the FEMP infiltrates through the streambeds and enters the underlying aquifer. The loadings occur in four stream reaches (cross section C-C to D-D, D-D to E-E, E-E to F-F, in Paddys Run, and I-I to J-J in the Storm Sewer Outfall Ditch [SSOD]) as indicated on Figure F.8.I.1-1.

A conservative surface water mass loading scenario (i.e., using RI source terms for 20 years) was used in the Operable Unit 5 Feasibility Study (FS) to evaluate the feasibility of the groundwater recovery system. Additional surface water loading scenarios are simulated after the draft Operable Unit 5 FS report to support the optimization of groundwater extraction and treatment system design for the Great Miami Aquifer.

The surface water loading to the groundwater is simulated for 1000 years. The 1000-year modeling time frame is broken into three time periods to account for the changing loading conditions which will occur at the site from the present time to the post-remediation period. The three time periods (present time to 10 years, 10 to 20 years, and 20 to 1000 years) are simulated using six model simulations. The first time period simulates the current loading condition at the FEMP; the second time period simulates the loading midway through the remedial construction period; and the third time period simulates the loading from the site after remediation has been completed. The following sections describe the six additional loading scenarios and the model results.

The partitioning coefficients used to calculate the surface water loading to the groundwater were the same as used in the draft Operable Unit 5 FS. For a sensitivity analysis, several runs were completed using K_{l1} and K_{l2} values (as described in Attachment F.2.I of the Operable Unit 5 Draft FS, DOE 1994b) calculated from preliminary batch test results instead of the K_d values used in the FS. This was completed to determine what effect these different methods of calculating partitioning coefficients would have on the surface water loading to the groundwater.

F.8.I.1.2.0 MODELING SOURCE-LOADING SCENARIOS

Three source-loading scenarios were developed to simulate current conditions which are expected to last for 10 years (present time to 10 years). The three different current modeling conditions were developed for comparison purposes. One source-loading scenario was developed to simulate the condition during the second 10 years of the modeling time frame. Two source-loading scenarios were used to simulate the remaining modeling time frame (e.g., 20 to 1000 years). The following subsections describe each of the modeling scenarios.

The surface water model estimate of the total amount of uranium released to Paddys Run per inch of rainfall is calculated by summing the estimated yearly amount of uranium released to the surface water in both the adsorbed phase (sediment) and in the dissolved phases for each subbasin (excluding flow from the production area and the waste pit area, since these areas have surface water controls and do not contribute contaminated flow to Paddys Run and the SSOD in the first two time periods). This yields the total mass of uranium released to Paddys Run per year. The annual rainfall in the vicinity of the FEMP is approximately 41 inches per year. Dividing the total mass per year of uranium released to Paddys Run by the total inches of rainfall per year results in the estimate of pounds of uranium released to Paddys Run and the SSOD per inch of rainfall.

F.8.I.1.2.1 Model Simulations for the First 10 Years

For the current condition, it is assumed that the remediation of the other operable units, and Operable Unit 5 areas are not yet complete in the first 10 years. The assumption is made that these areas continue to contribute to the surface water loading for the full 10 years, although it is likely that some areas will have completed remediation within 10 years.

The surface water loading incorporated uranium partitioning coefficient values of 325 L/kg for areas not containing soluble forms of uranium and 15 L/kg for areas containing soluble forms of uranium in surface soil. These are the same partitioning coefficient values used in the Operable Unit 5 FS Report. The partitioning coefficient value of 325 L/kg is based on the geometric mean of the K_d values calculated for areas not having soluble forms of uranium in the production area as presented in Table F.3.II-2 in the Operable Unit 5 RI Report (DOE 1994a). The loading contribution from the other operable unit areas (Operable Units 1, 2, and 4) was accounted for in the surface water model runs by including the representative surface soil concentrations and K_d values presented in each respective operable unit's RI report in the simulations.

The baseline source concentration terms presented in the Operable Unit 5 RI Report (DOE 1994a) were used as the basis for the source terms for two of the three methods used to calculate the surface water loading for current conditions. Source-loading Scenario 1 simulates current conditions using the representative, baseline source concentration terms used in the Operable Unit 5 RI, the K_d values

described above, and the K_d and source terms for Operable Units 1, 2, and 4 from their respective RI reports. The representative, baseline source concentration terms used in the Operable Unit 5 RI are based on the Upper Confidence Level (UCL) on the mean of the surface soil sample data in each source area. The source concentration terms and K_d values used for the other operable units do not change between the three source-loading scenarios used to simulate the current conditions.

The input for Source-loading Scenario 2 is the same as Scenario 1 except that source concentration terms for areas outside the production area are limited to 100 mg/kg of total uranium. 100 mg/kg was the target of removal actions conducted to reduce exposed soil contamination in these areas. It was felt that limiting the source concentration terms to 100 mg/kg provided a more realistic estimate of the amount of uranium that could be released into the surface water from the surface soil after these removal actions. The RI database actually include some samples collected before these removal actions. The following source areas shown on Figure F.8.I.1-1 were limited to 100 mg/kg: 560b, 560c, 560d, 570b, 570d, 581d, 582b, and WPA.

The input for Source-loading Scenario 3 used the average of the soil sample uranium concentrations in each source area for the source concentration terms as initial estimates. These concentrations were taken from the surface water model performance evaluation simulations in attachment F.2.V of the Operable Unit 5 RI Report (DOE 1994a). It was felt that the average of the surface soil sample data provided more realistic source concentration terms. These source terms were then modified in order to calibrate the surface water model output to a estimate of uranium released to Paddys Run and the SSOD based on field measurements. The FEMP reports a general estimate of the current amount of uranium released to Paddy Run and the SSOD as 6.3 pounds of uranium per inch of rainfall. This estimate is based on a series of grab samples collected in various on-property drainage ditches that convey water into Paddys Run (DOE 1994a). During a calibration process, any source concentration area outside of the production area which had a average concentration greater than 200 mg/kg was adjusted until the surface water model also predicted 6.3 pounds of uranium released to the surface water per inch of rainfall. Source areas concentrations for areas 560c (fire training area), 570d (west of the production area), 581b (east of the production area), and 581d (the sewage treatment plant) were all reduced by one third to match the FEMP estimate.

F.8.I.1.2.2 Model Simulations for the Second 10 Years

For years 10 to 20, it is assumed that Operable Units 1, 2, and 4 have been remediated. It is also assumed that the Operable Unit 5 area outside of the former production area are also remediated. The storm water controls (retention basins) are assumed to be still functioning. One model scenario (Source-loading Scenario 4) was used to simulated this time period.

The modeling approach assumed that remediated source area are either covered or replaced by

uncontaminated soil containing background levels of uranium. Scenario 4 used background concentrations (3.27 mg/kg) and partitioning coefficients of 325 L/kg for the remediated areas. Using a K_d value of 325 L/kg for the background soil is conservative since the K_d values calculated from preliminary batch tests results indicate that the uranium partitioning coefficient for soil containing background uranium are consistently much higher than 325 L/kg (Table F.2.I-5; [DOE 1994b]). The same areas outside of the production area as indicated in the Operable Unit 5 CRARE surface water modeling (DOE 1994b) were assumed to be remediated and were assigned background surface soil concentrations.

F.8.I.1.2.3 Model Simulations for the Remaining Modeling Time Frame

After 20 years it is assumed that the remediation at the FEMP has been completed. It is assumed that the storm water controls around the production area have failed and surface water runoff which formerly was collected and treated now empties into Paddys Run and the SSOD. Two model scenarios (Source-loading Scenarios 5 and 6) were used to simulate this time frame.

Scenario 5 represents the surface water loading from the FEMP when all of the remediation is complete. The same source areas that are assumed remediated in the Operable Unit 5 CRARE modeling are also assumed to be remediated for Scenario 5.

Scenario 6 represents the surface water loading from the FEMP if remediation of Operable Unit 5 areas has not occurred. It is presented for comparison purposes only. Scenario 6 is the same as the future condition modeled in the Operable Unit 5 RI except that the partitioning coefficient for the source areas containing less soluble forms of uranium has been updated (325 L/kg is used instead of 222 L/kg). Operable Units 1, 2, 3, and 4 are assumed to be remediated and the surface water controls are assumed to have failed. Remediation of Operable Unit 3 but not Operable Unit 5 implies that the buildings in the production area have been removed exposing the highly contaminated soil underneath the buildings to rainwater and subsequent runoff. This results in much higher loading to the groundwater from the surface water.

Table F.8.I.1-1 presents a brief summary of the six source-loading scenarios. Table F.8.I.1-2 presents a summary of the source concentrations and partitioning coefficients used in the surface water modeling for each of the six scenarios.

F.8.I.1.3.0 MODEL RESULTS

Figure F.8.I.1-2 presents a comparison of the estimates of the total amount of uranium released to Paddys Run and the SSOD from surface runoff per inch of rainfall. Also included in Figure F.8.I.1-2 for comparison is the FEMP estimate of uranium released in the runoff to Paddys Run and the SSOD per inch of rainfall based on measurements.

As shown in Figure F.8.I.1-2, outputs from Scenarios 2 and 3 are very close. Therefore only the output of Scenario 3, which is slightly higher, is used for the surface water loading to the groundwater fate and transport model during the first ten years. This uranium loading best approximates the estimated amount of uranium released to Paddys Run and the SSOD based on measurements and would represent the most current and realistic loading. It is more reasonable to use Scenarios 3 instead of Scenario 1 (as in the draft Operable Unit 5 FS) for groundwater modeling to support the optimization of the groundwater extraction and treatment system design. Scenario 4 is used for the second 10 years and Scenario 5 is used for the surface water loading after 20 years. Table F.8.I.1-3 presents the surface water loading to the Great Miami Aquifer in kg/year in each stream reach in the groundwater model for each time period.

F.8.I.1.4.0 SENSITIVITY ANALYSIS

Two additional methods of assigning the partitioning coefficients were used to check the sensitivity of the surface water loadings to surface soil geochemical conditions. The first method of assigning the partitioning coefficients was based on using the values of 325 and 15 L/kg as described in the previous sections.

The second method used to calculated the surface water loadings to the groundwater incorporated the preliminary K_{l1} values calculated from the batch test results for the 0-2 inch depth soil samples presented in Table F.2.I-4 (DOE 1994b). The K_{l1} values represent the total leaching coefficient for the soil samples tested. The K_{l1} values are calculated based on both the extractable and nonextractable percentages of uranium contained in the soil. The soil sample locations and the corresponding batch test K_{l1} results were plotted on a plan showing the surface soil source areas. The K_{l1} values were then assigned to each source area. If a source area contained several calculated K_{l1} values or was surrounded by several K_{l1} values, an arithmetic mean was calculated and used as the partitioning coefficient for that source area.

The third method used to calculate the surface water loading to the groundwater incorporated the preliminary K_{l2} and K_e values calculated from the batch test results for the 0-2 inch depth soil samples presented in Table F.2.I-4 (DOE 1994b). The K_{l2} values represent the leaching coefficient of only the extractable portion of the uranium in the surface soil. The K_e values represent the percent of extractable uranium contained in each soil sample. The source concentration terms were modified using the K_e coefficient to only represent the extractable portion of uranium in the surface soil. The K_{l2} and K_e values were assigned to source areas in the same way as the K_{l1} values were assigned to source areas in method 2.

The use of K_e to adjust the source terms will yield valid results for the dissolved-phase concentrations and loadings, however, the sediment concentrations (not used in this sensitivity analysis) predicted

with the model will not reflect the actual concentrations. The uranium transported with the sediment is not actually extracted from the soil but is transported with the small soil particles. Conducting transport calculations based on only the extractable portion of uranium will result in lower than actual uranium sediment concentrations.

Tables F.8.I.1-4 and F.8.I.1-5 present the source terms and partitioning coefficients used for the sensitivity analyses. Table F.8.I.1-6 presents a comparison of the loading calculated using the three methods of assigning K_d values. The loadings for each of the six scenarios are presented. Overall the loadings calculated with the three methods are similar. The loadings in Paddys Run are consistently higher using K_{l1} and K_{l2} values than the runs using K_d = 325 L/kg for most of the site. This is because the K_{l1} and K_{l2} values along some portions of Paddys Run are less than the K_d value of 325 L/kg. The loadings to the SSOD are consistently lower than the loadings calculated using K_d = 325 L/kg because the K_{l1} and K_{l2} values on the eastern side of the site are higher than the K_d of 325 L/kg. Since the 325 L/kg value is used for most of the site, it must account for both the low and high values of K_d. Because the overall loadings are similar for all the methods of assigning partitioning coefficients, it indicates that using the 325 L/kg value for K_d for most of the site is reasonable.

TABLE F.8.I-1

SURFACE WATER MODELING LOADING SCENARIOS

Scenario	Description
Scenario 1	Scenario 1 simulates the current site conditions (the first 10 years) using the source concentration terms developed for the Operable Unit 5 RI, and includes loading contributions from other operable units. All of the current loading scenarios (1, 2, and 3) assume that the other operable units are unremediated and that the storm water controls are functioning.
Scenario 2	Scenario 2 simulates the current site conditions using source concentrations used in the Operable Unit 5 RI, however surface soil concentrations outside of the production area are limited to 100 mg/kg to reflect the goal of the removal actions. Scenario 2 is intended to give a more realistic estimate of the surface water loading.
Scenario 3	Scenario 3 simulates the current site conditions using the average source terms used in the model performance evaluation in the Operable Unit 5 RI. The source terms are then modified to reflect calibration of the surface water model to estimates of uranium released (based on measurements) to the surface water.
Scenario 4	Scenario 4 simulates the site conditions during the second ten years of remediation. It is assumed that Operable Units 1, 2, and 4 have been remediated and that all remediation outside of the production area has been completed. The storm water controls are assumed to be still functioning.
Scenario 5	Scenario 5 simulates the site conditions after remediation is complete (after 20 years). It is assumed that all of the remedial activities are complete. It is also assumed that the storm water controls are no longer functioning.
Scenario 6	Scenario 6 simulates the site conditions assuming that the site remediation is complete except for Operable Unit 5 areas. It is assumed that the storm water controls have failed.

TABLE F.8.I-2

SURFACE WATER MODEL INPUT
SOURCE TERMS AND PARTITIONING COEFFICIENTS (K_ds) FOR URANIUM
K_d FOR BACKGROUND CONTAMINATION AND AREAS OUTSIDE THE PRODUCTION AREA

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
Area	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)
560A	3.25×10^2	1.55×10^1	3.25×10^2	1.55×10^1	3.25×10^2	1.35×10^1	3.25×10^2	1.55×10^1	3.25×10^2	1.55×10^1	3.25×10^2	1.55×10^1
560B	3.25×10^2	3.04×10^2	3.25×10^2	1.00×10^2	3.25×10^2	1.52×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.04×10^2
560C	1.50×10^1	1.17×10^3	1.50×10^1	1.00×10^2	1.50×10^1	1.70×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	1.50×10^1	1.17×10^3
560D	3.25×10^2	3.62×10^2	3.25×10^2	1.00×10^2	3.25×10^2	1.74×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.62×10^2
SWL	7.50×10^1	2.30×10^2	7.50×10^1	2.30×10^2	7.50×10^1	2.30×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0
570A North	3.25×10^2	7.79×10^1	3.25×10^2	7.79×10^1	3.25×10^2	8.84×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	7.79×10^1
570A South	3.25×10^2	7.79×10^1	3.25×10^2	7.79×10^1	3.25×10^2	8.84×10^1	3.25×10^2	7.79×10^1	3.25×10^2	7.79×10^1	3.25×10^2	7.79×10^1
570B	3.25×10^2	4.28×10^2	3.25×10^2	1.00×10^2	3.25×10^2	1.10×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	4.28×10^2
570C	3.25×10^2	3.60×10^1	3.25×10^2	3.60×10^1	3.25×10^2	3.50×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.60×10^1
570D	3.25×10^2	2.77×10^3	3.25×10^2	1.00×10^2	3.25×10^2	3.89×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	2.77×10^3
570E	3.25×10^2	6.35×10^1	3.25×10^2	6.35×10^1	3.25×10^2	4.75×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	6.35×10^1
575A	3.25×10^2	2.40×10^1	3.25×10^2	2.40×10^1	3.25×10^2	1.43×10^1	3.25×10^2	2.40×10^1	3.25×10^2	2.40×10^1	3.25×10^2	2.40×10^1
575B	3.25×10^2	5.88×10^1	3.25×10^2	5.88×10^1	3.25×10^2	5.88×10^1	3.25×10^2	5.88×10^1	3.25×10^2	5.88×10^1	3.25×10^2	5.88×10^1
SF	1.77×10^2	2.74×10^1	1.77×10^2	2.74×10^1	1.77×10^2	2.74×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0
580A	3.25×10^2	1.87×10^1	3.25×10^2	1.87×10^1	3.25×10^2	1.35×10^1	3.25×10^2	1.87×10^1	3.25×10^2	1.87×10^1	3.25×10^2	1.87×10^1

TABLE F.8.I-2
(Continued)

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
Area	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)
581A	3.25×10^{2}	2.13×10^{1}	3.25×10^{2}	2.13×10^{1}	3.25×10^{2}	1.83×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	2.13×10^{1}
581B	3.25×10^{2}	5.63×10^{2}	3.25×10^{2}	1.00×10^{2}	3.25×10^{2}	1.43×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	5.63×10^{2}
581C	3.25×10^{2}	4.76×10^{1}	3.25×10^{2}	4.76×10^{1}	3.25×10^{2}	4.00×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	4.76×10^{1}
581D	1.50×10^{1}	7.57×10^{3}	1.50×10^{1}	1.00×10^{2}	1.50×10^{1}	8.34×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	7.57×10^{3}
582A	3.25×10^{2}	1.15×10^{1}	3.25×10^{2}	1.15×10^{1}	3.25×10^{2}	8.59×10^{0}	3.25×10^{2}	1.15×10^{1}	3.25×10^{2}	1.15×10^{1}	3.25×10^{2}	1.15×10^{1}
582B	3.75×10^{1}	4.44×10^{2}	3.75×10^{1}	1.00×10^{2}	3.75×10^{1}	9.39×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.75×10^{1}	4.44×10^{2}
AFP	3.75×10^{1}	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
PAA	1.50×10^{1}	1.23×10^{4}	1.50×10^{1}	1.23×10^{4}	1.50×10^{1}	1.23×10^{3}	1.50×10^{1}	1.23×10^{4}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	1.23×10^{4}
PAB	1.50×10^{1}	7.08×10^{2}	1.50×10^{1}	7.08×10^{2}	1.50×10^{1}	7.23×10^{2}	1.50×10^{1}	7.08×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	7.08×10^{2}
PAC	1.50×10^{1}	9.14×10^{2}	1.50×10^{1}	9.14×10^{2}	1.50×10^{1}	2.92×10^{2}	1.50×10^{1}	9.14×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	9.14×10^{2}
PAD	1.50×10^{1}	4.07×10^{2}	1.50×10^{1}	4.07×10^{2}	1.50×10^{1}	1.92×10^{2}	1.50×10^{1}	4.07×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	4.07×10^{2}
PAE	1.50×10^{1}	6.77×10^{3}	1.50×10^{1}	6.77×10^{3}	1.50×10^{1}	1.58×10^{3}	1.50×10^{1}	6.77×10^{3}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	6.77×10^{3}
PAF	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	1.68×10^{2}	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	2.22×10^{2}
PAG	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	3.95×10^{3}	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	4.31×10^{4}
PAH	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	5.18×10^{1}	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	9.94×10^{1}
PAI	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	2.41×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}
LSP	2.65×10^{3}	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
WPAA	3.25×10^{2}	3.74×10^{2}	3.25×10^{2}	1.00×10^{2}	3.25×10^{2}	1.61×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.74×10^{2}
WPA.OU1	1.20×10^{1}	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
WPA.OU4	1.20×10^{1}	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}

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TABLE F.8.I-3

SURFACE WATER LOADING TO THE GROUNDWATER FOR URANIUM (KG/YR) K_d FOR BACKGROUND CONTAMINATION

Scenario	Stream Reach			
	C-D	D-E	E-F	SSOD
First 10 Years (Scenario 2)	1.49	0.742	0.131	2.07
First 10 Years (Scenario 3)	2.21	0.909	0.274	6.03
Second 10 Years (Scenario 4)	0.318	0.246	0.0364	0.435
Remaining Modeling Time Frame (Scenario 5)	0.332	0.254	0.039	0.722

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TABLE F.8.I-4

SURFACE WATER MODEL INPUT
SOURCE TERMS AND PARTITIONING COEFFICIENTS (K_ds) FOR URANIUM
$K_d = K_i1$ FOR AREAS OUTSIDE THE PRODUCTION AREA

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
Area	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)
560A	6.59×10^2	1.55×10^1	6.59×10^2	1.55×10^1	6.59×10^2	1.35×10^1	6.59×10^2	1.55×10^1	6.59×10^2	1.55×10^1	6.59×10^2	1.55×10^1
560B	7.62×10^2	3.04×10^2	7.62×10^2	1.00×10^2	7.62×10^2	1.52×10^2	7.62×10^2	3.27×10^0	7.62×10^2	3.27×10^0	7.62×10^2	3.04×10^2
560C	1.50×10^1	1.17×10^3	1.50×10^1	1.00×10^2	1.50×10^1	1.70×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	1.50×10^1	1.17×10^3
560D	7.62×10^2	3.62×10^2	7.62×10^2	1.00×10^2	7.62×10^2	1.74×10^2	7.62×10^2	3.27×10^0	7.62×10^2	3.27×10^0	7.62×10^2	3.62×10^2
SWL	7.50×10^1	2.30×10^2	7.50×10^1	2.30×10^2	7.50×10^1	2.30×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0
570A North	7.40×10^1	7.79×10^1	7.40×10^1	7.79×10^1	7.40×10^1	8.84×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	7.40×10^1	7.79×10^1
570A South	8.07×10^2	7.79×10^1	8.07×10^2	7.79×10^1	8.07×10^2	8.84×10^1	8.07×10^2	7.79×10^1	8.07×10^2	7.79×10^1	8.07×10^2	7.79×10^1
570B	7.40×10^1	4.28×10^2	7.40×10^1	1.00×10^2	7.40×10^1	1.10×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	7.40×10^1	4.28×10^2
570C	7.40×10^1	3.60×10^1	7.40×10^1	3.60×10^1	7.40×10^1	3.50×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	7.40×10^1	3.60×10^1
570D	7.40×10^1	2.77×10^3	7.40×10^1	1.00×10^2	7.40×10^1	3.89×10^2	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^0	7.40×10^1	2.77×10^3
570E	8.07×10^2	6.35×10^1	8.07×10^2	6.35×10^1	8.07×10^2	4.75×10^1	8.07×10^2	3.27×10^0	8.07×10^2	3.27×10^0	8.07×10^2	6.35×10^1
575A	8.46×10^2	2.40×10^1	8.46×10^2	2.40×10^1	8.46×10^2	1.43×10^1	8.46×10^2	2.40×10^1	8.46×10^2	2.40×10^1	8.46×10^2	2.40×10^1
575B	8.47×10^2	5.88×10^1	8.47×10^2	5.88×10^1	8.47×10^2	5.88×10^1	8.47×10^2	5.88×10^1	8.47×10^2	5.88×10^1	8.47×10^2	5.88×10^1
SF	1.77×10^2	2.74×10^1	1.77×10^2	2.74×10^1	1.77×10^2	2.74×10^1	3.25×10^2	3.27×10^1	3.25×10^2	3.27×10^0	3.25×10^2	3.27×10^1
580A	8.36×10^2	1.87×10^1	8.36×10^2	1.87×10^1	8.36×10^2	1.35×10^1	8.36×10^2	1.87×10^1	8.36×10^2	1.87×10^1	8.36×10^2	1.87×10^1

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TABLE F.8.I-4
(Continued)

Area	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)	K_d (l/kg)	Conc (mg/kg)
581A	9.30×10^{2}	2.13×10^{1}	9.30×10^{2}	2.13×10^{1}	9.30×10^{2}	1.83×10^{1}	9.30×10^{2}	3.27×10^{0}	9.30×10^{2}	3.27×10^{0}	9.30×10^{2}	2.13×10^{1}
581B	1.36×10^{3}	5.63×10^{2}	1.36×10^{3}	1.00×10^{2}	1.36×10^{3}	1.43×10^{2}	1.36×10^{3}	3.27×10^{0}	1.36×10^{3}	3.27×10^{0}	1.36×10^{3}	5.63×10^{2}
581C	1.11×10^{3}	4.76×10^{1}	1.11×10^{3}	4.76×10^{1}	1.11×10^{3}	4.00×10^{1}	1.11×10^{3}	3.27×10^{0}	1.11×10^{3}	3.27×10^{0}	1.11×10^{3}	4.76×10^{1}
581D	1.50×10^{1}	7.57×10^{3}	1.50×10^{1}	1.00×10^{2}	1.50×10^{1}	8.34×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	7.57×10^{3}
582A	4.64×10^{2}	1.15×10^{1}	4.64×10^{2}	1.15×10^{1}	4.64×10^{2}	8.59×10^{0}	4.64×10^{2}	1.15×10^{1}	4.64×10^{2}	1.15×10^{1}	4.64×10^{2}	1.15×10^{1}
582B	3.75×10^{1}	4.44×10^{2}	3.75×10^{1}	1.00×10^{2}	3.75×10^{1}	9.39×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.75×10^{1}	4.44×10^{2}
AFP	3.75×10^{1}	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
PAA	1.50×10^{1}	1.23×10^{4}	1.50×10^{1}	1.23×10^{4}	1.50×10^{1}	1.23×10^{3}	1.50×10^{1}	1.23×10^{4}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	1.23×10^{4}
PAB	1.50×10^{1}	7.08×10^{2}	1.50×10^{1}	7.08×10^{2}	1.50×10^{1}	7.23×10^{2}	1.50×10^{1}	7.08×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	7.08×10^{2}
PAC	1.50×10^{1}	9.14×10^{2}	1.50×10^{1}	9.14×10^{2}	1.50×10^{1}	2.92×10^{2}	1.50×10^{1}	9.14×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	9.14×10^{2}
PAD	1.50×10^{1}	4.07×10^{2}	1.50×10^{1}	4.07×10^{2}	1.50×10^{1}	1.92×10^{2}	1.50×10^{1}	4.07×10^{2}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	4.07×10^{2}
PAE	1.50×10^{1}	6.77×10^{3}	1.50×10^{1}	6.77×10^{3}	1.50×10^{1}	1.58×10^{3}	1.50×10^{1}	6.77×10^{3}	3.25×10^{2}	3.27×10^{0}	1.50×10^{1}	6.77×10^{3}
PAF	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	1.68×10^{2}	3.25×10^{2}	2.22×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	2.22×10^{2}
PAG	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	3.95×10^{3}	3.25×10^{2}	4.31×10^{4}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	4.31×10^{4}
PAH	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	5.18×10^{1}	3.25×10^{2}	9.94×10^{1}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	9.94×10^{1}
PAI	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	2.41×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}
LSP	2.65×10^{3}	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
WPAA	1.25×10^{2}	3.74×10^{2}	1.25×10^{2}	1.00×10^{2}	1.25×10^{2}	1.61×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	1.25×10^{2}	3.74×10^{2}
WPA.OU1	1.20×10^{1}	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}
WPA.OU4	1.20×10^{1}	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}	3.25×10^{2}	3.27×10^{0}

TABLE F.8.I-5

SURFACE WATER MODEL INPUT
SOURCE TERMS AND PARTITIONING COEFFICIENTS (K_ds) FOR URANIUM
$K_d = K_l2$ AND C = KeCo FOR AREAS OUTSIDE THE PRODUCTION AREA

	Scenario 1				Scenario 2				Scenario 3			
Area	K_l2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)	K_l2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)	K_l2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)
560A	1.88×10^0	1.55×10^1	1.653	2.56×10^{-1}	1.88×10^0	1.55×10^1	1.7	2.56×10^{-1}	1.88×10^0	1.35×10^1	1.7	2.22×10^{-1}
560B	2.55×10^0	3.04×10^2	1.47	4.47×10^0	2.55×10^0	1.00×10^2	1.5	1.47×10^0	2.55×10^0	1.52×10^2	1.5	2.23×10^0
560C	1.50×10^1	1.17×10^3	100	1.17×10^3	1.50×10^1	1.00×10^2	100	1.00×10^2	1.50×10^1	1.70×10^2	100	1.70×10^2
560D	2.55×10^0	3.62×10^2	1.47	5.32×10^0	2.55×10^0	1.00×10^2	1.5	1.47×10^0	2.55×10^0	1.74×10^2	1.5	2.56×10^0
SWL	7.50×10^1	2.30×10^2	100	2.30×10^2	7.50×10^1	2.30×10^2	100	2.30×10^2	7.50×10^1	2.30×10^2	100	2.30×10^2
570A North	1.24×10^1	7.79×10^1	25.55	1.99×10^1	1.24×10^1	7.79×10^1	26	1.99×10^1	1.24×10^1	8.84×10^1	26	2.26×10^1
570A South	1.40×10^0	7.79×10^1	1.836	1.43×10^0	1.40×10^0	7.79×10^1	1.8	1.43×10^0	1.40×10^0	8.84×10^1	1.8	1.62×10^0
570C	1.24×10^1	3.60×10^1	25.55	9.20×10^0	1.24×10^1	3.60×10^1	26	9.20×10^0	1.24×10^1	3.50×10^1	26	8.94×10^0
570D	1.24×10^1	2.77×10^3	25.55	7.08×10^2	1.24×10^1	1.00×10^2	26	2.56×10^1	1.24×10^1	3.89×10^2	26	9.93×10^1
570E	1.40×10^0	6.35×10^1	1.836	1.17×10^0	1.40×10^0	6.35×10^1	1.8	1.17×10^0	1.40×10^0	4.75×10^1	1.8	8.72×10^{-1}
575A	5.47×10^1	2.40×10^1	7.418	1.78×10^0	5.47×10^1	2.40×10^1	7.4	1.78×10^0	5.47×10^1	1.43×10^1	7.4	1.06×10^0
575B	1.40×10^1	5.88×10^1	1.836	1.08×10^0	1.40×10^0	5.88×10^1	1.8	1.08×10^0	1.40×10^0	5.88×10^1	1.8	1.08×10^0
SF	1.77×10^2	2.74×10^1	100	2.74×10^1	1.77×10^2	2.74×10^1	100	2.74×10^1	1.77×10^2	2.74×10^1	100	2.74×10^1
580A	2.47×10^1	1.87×10^1	4.89	9.14×10^{-1}	2.47×10^1	1.87×10^1	4.9	9.14×10^{-1}	2.47×10^1	1.35×10^1	4.9	6.58×10^{-1}
581A	6.66×10^0	2.13×10^1	2.297	4.89×10^{-1}	6.66×10^0	2.13×10^1	2.3	4.89×10^{-1}	6.66×10^0	1.83×10^1	2.3	4.19×10^{-1}
581B	7.47×10^0	5.63×10^2	1.22	6.87×10^0	7.47×10^0	1.00×10^2	1.2	1.22×10^0	7.47×10^0	1.43×10^2	1.2	1.74×10^0
581C	6.89×10^0	4.76×10^1	1.4	6.67×10^{-1}	6.89×10^0	4.76×10^1	1.4	6.67×10^{-1}	6.89×10^0	4.00×10^1	1.4	5.60×10^{-1}

TABLE F.8.I-5
(Continued)

	Scenario 1				Scenario 2				Scenario 3			
Area	K_d2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)	K_d2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)	K_d2 (l/kg)	Conc (mg/kg)	K_e	Adjusted Conc (mg/kg)
581D	1.50×10^{1}	7.57×10^{3}	100	7.57×10^{3}	1.50×10^{1}	1.00×10^{2}	100	1.00×10^{2}	1.50×10^{1}	8.34×10^{2}	100	8.34×10^{2}
582A	7.88×10^{0}	1.15×10^{1}	3.51	4.03×10^{-1}	7.88×10^{0}	1.15×10^{1}	3.5	4.03×10^{-1}	7.88×10^{0}	8.59×10^{0}	3.5	3.01×10^{-1}
582B	3.75×10^{1}	4.44×10^{2}	100	4.44×10^{2}	3.75×10^{1}	1.00×10^{2}	100	1.00×10^{2}	3.75×10^{1}	9.39×10^{1}	100	9.39×10^{-1}
AFP	3.75×10^{1}	1.07×10^{1}	100	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	100	1.07×10^{1}	3.75×10^{1}	1.07×10^{1}	100	1.07×10^{1}
PAA	1.50×10^{1}	1.23×10^{4}	100	1.23×10^{4}	1.50×10^{1}	1.23×10^{4}	100	1.23×10^{4}	1.50×10^{1}	1.23×10^{3}	100	1.23×10^{3}
PAB	1.50×10^{1}	7.08×10^{2}	100	7.08×10^{2}	1.50×10^{1}	7.08×10^{2}	100	7.08×10^{2}	1.50×10^{1}	7.23×10^{2}	100	7.23×10^{2}
PAC	1.50×10^{1}	9.14×10^{2}	100	9.14×10^{2}	1.50×10^{1}	9.14×10^{2}	100	9.14×10^{2}	1.50×10^{1}	2.92×10^{2}	100	2.92×10^{2}
PAD	1.50×10^{1}	4.07×10^{2}	100	4.07×10^{2}	1.50×10^{1}	4.07×10^{2}	100	4.07×10^{2}	1.50×10^{1}	1.92×10^{2}	100	1.92×10^{2}
PAE	1.50×10^{1}	6.77×10^{3}	100	6.77×10^{3}	1.50×10^{1}	6.77×10^{3}	100	6.77×10^{3}	1.50×10^{1}	1.58×10^{3}	100	1.58×10^{3}
PAF	3.25×10^{2}	2.22×10^{2}	100	2.22×10^{2}	3.25×10^{2}	2.22×10^{2}	100	2.22×10^{2}	3.25×10^{2}	1.68×10^{2}	100	1.68×10^{2}
PAG	3.25×10^{2}	4.31×10^{4}	100	4.31×10^{4}	3.25×10^{2}	4.31×10^{4}	100	4.31×10^{4}	3.25×10^{2}	3.95×10^{3}	100	3.95×10^{3}
PAH	3.25×10^{2}	9.94×10^{1}	100	9.94×10^{1}	3.25×10^{2}	9.94×10^{1}	100	9.94×10^{1}	3.25×10^{2}	5.18×10^{1}	100	5.18×10^{1}
PAI	3.25×10^{2}	4.17×10^{1}	100	4.17×10^{1}	3.25×10^{2}	4.17×10^{1}	100	4.17×10^{1}	3.25×10^{2}	2.41×10^{1}	100	2.41×10^{1}
LSP	2.65×10^{3}	1.98×10^{2}	100	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	100	1.98×10^{2}	2.65×10^{3}	1.98×10^{2}	100	1.98×10^{2}
WPAA	5.25×10^{1}	3.74×10^{2}	45.93	1.72×10^{2}	5.25×10^{1}	1.00×10^{2}	46	4.59×10^{1}	5.25×10^{1}	1.61×10^{2}	46	7.38×10^{1}
WPA.OU1	1.20×10^{1}	7.28×10^{2}	100	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	100	7.28×10^{2}	1.20×10^{1}	7.28×10^{2}	100	7.38×10^{2}
WPA.OU4	1.20×10^{1}	3.57×10^{2}	100	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	100	3.57×10^{2}	1.20×10^{1}	3.57×10^{2}	100	3.57×10^{2}

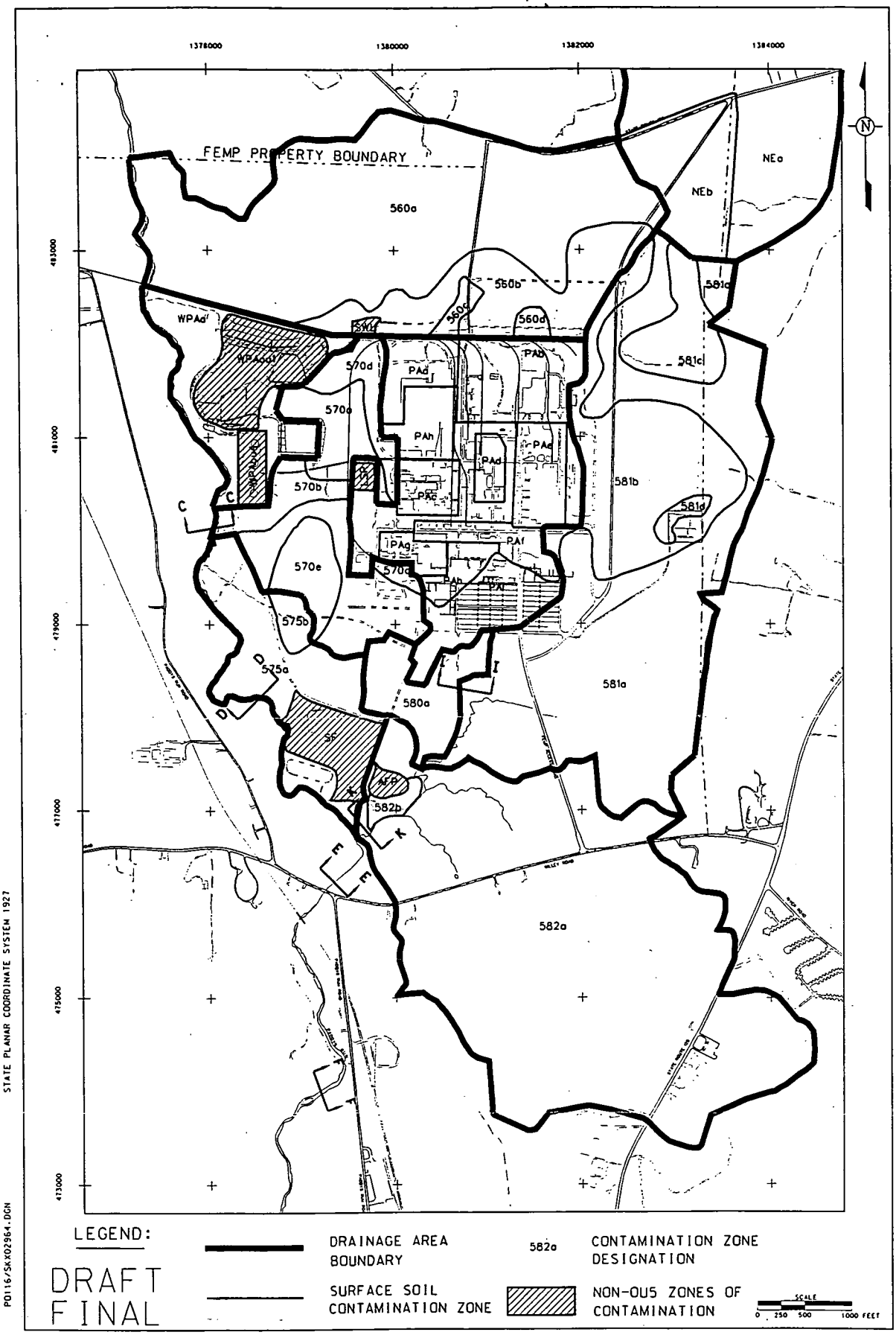


FIGURE F.8.1-1. SURFACE SOIL CONTAMINATION ZONES

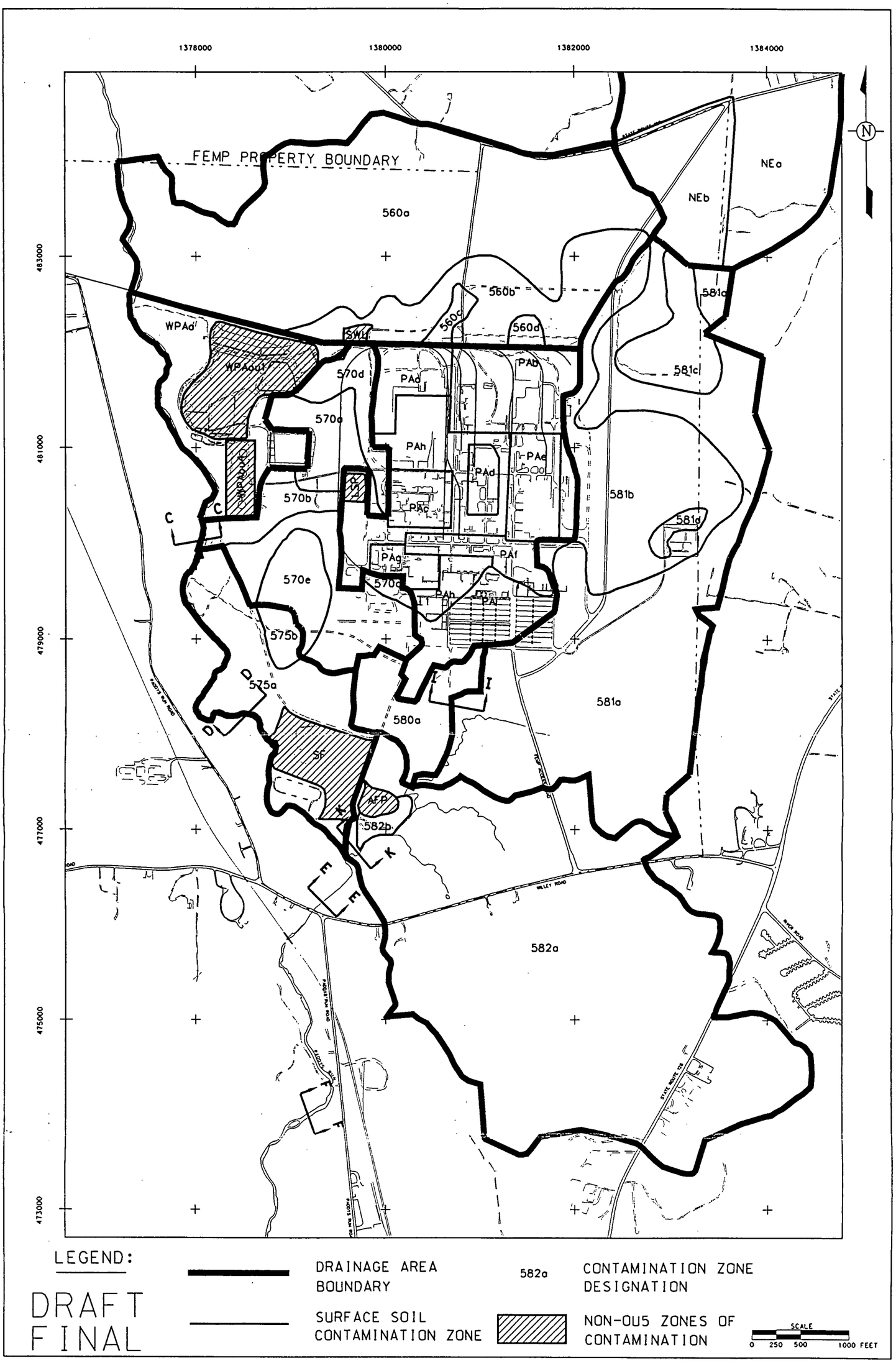
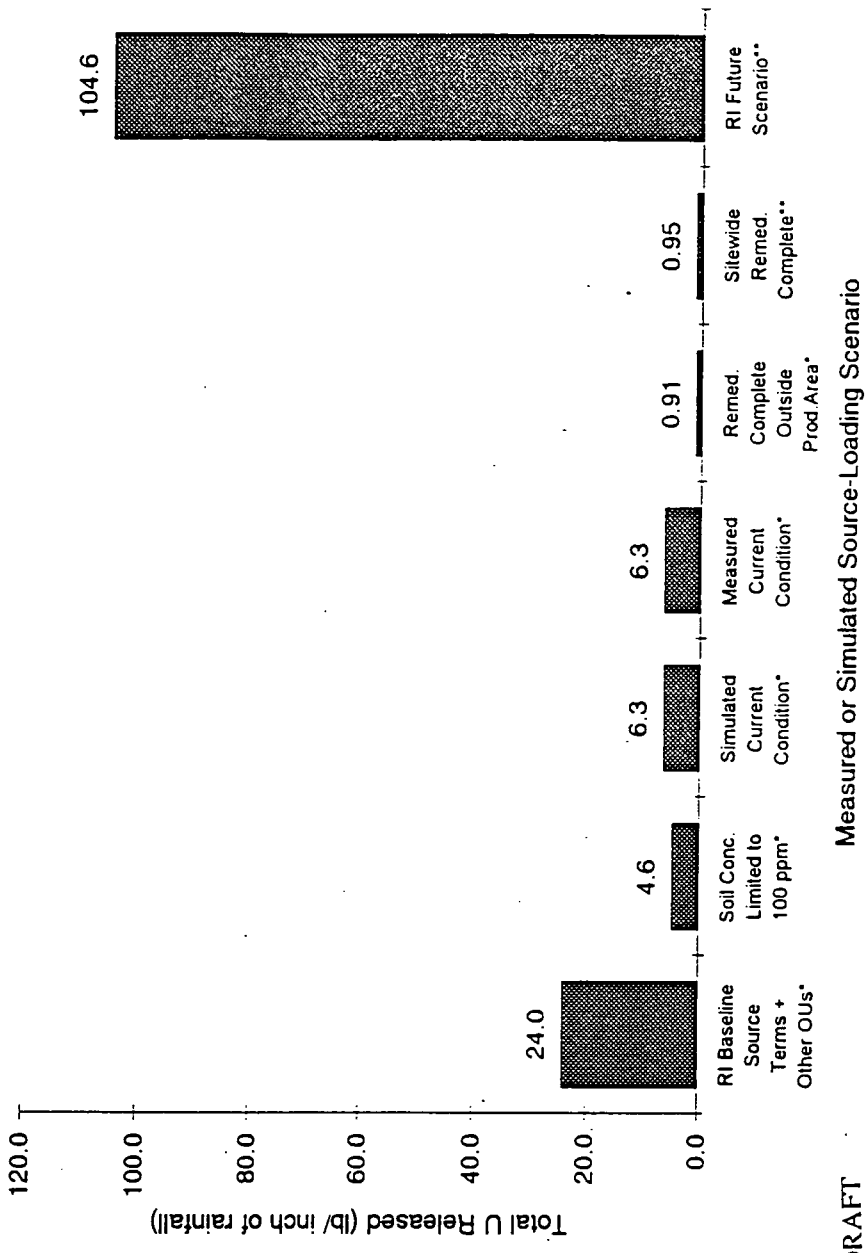


FIGURE F.8.1-1. SURFACE SOIL CONTAMINATION ZONES

LDGCHRT Chart 1



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* Scenario includes stormwater controls (retention basin)
** Scenario assumes stormwater controls are no longer operating

FIGURE F.8.I. -2 - TOTAL URANIUM RELEASED TO PADDYS RUN DRAINAGE BASIN IN SURFACE WATER (lb/in of rainfall)

ATTACHMENT F.8.II

GROUNDWATER MODELING RESULTS

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RD-7	Revised Dispersion Scenario, Treatment Rate vs. Time
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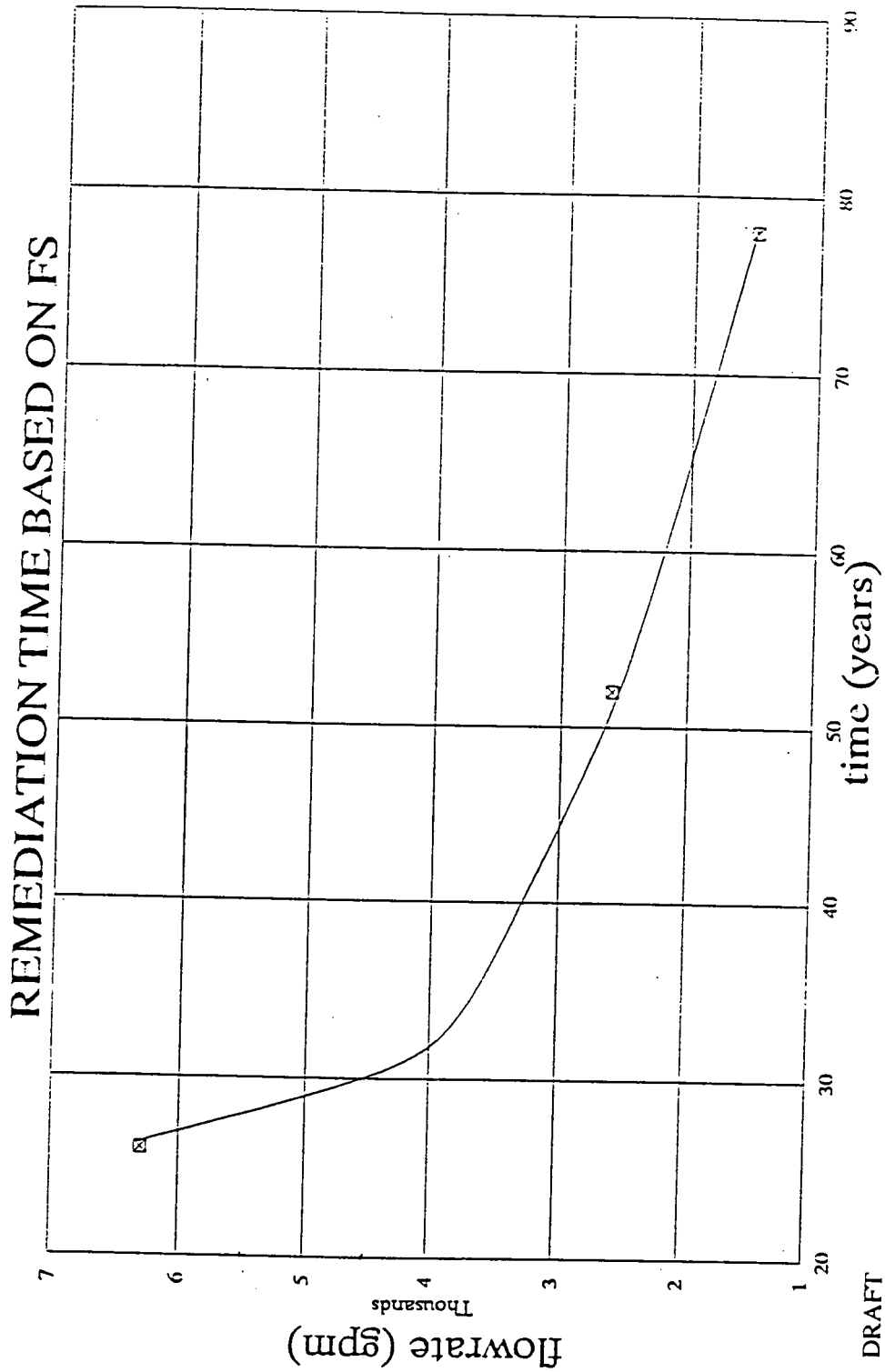

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FINAL

HYP-1 - ESTIMATED REMEDIATION TIME FOR HYPOTHETICAL CASES

PUMP RATE	5500	PUMP RATE	5000	PUMP RATE	4500	PUMP RATE	4000	PUMP RATE	3000	PUMP RATE	2000	PUMP RATE	4500	BASE RATE	6300
MO	4488	MO	4488	MO	4488	MO	4000	MO	3000	MO	2000	MO	1500	MO	4488
TIME	17	TIME	19	TIME	20	TIME	22	TIME	35	TIME	57	TIME	20	TIME	15
TARGET	28584	TARGET	28584	TARGET	28584	TARGET	28584	TARGET	28584	TARGET	28584	TARGET		TARGET	
MATCH	28584	MATCH	28584	MATCH	28584	MATCH	28584	MATCH	28584	MATCH	28584	MATCH		MATCH	
ALPHA	0.144850	ALPHA	0	ALPHA	0	ALPHA	0	ALPHA	0	ALPHA	0	ALPHA		ALPHA	

TIME	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR	TREAT GPM	RIVER GPM	CUM GPM*YR
1	898	598		898	598		898	598		898	598		898	598		898	598		898	598		898	598	
2	898	598		898	598		898	598		898	598		898	598		898	598		898	598		898	598	
3	898	598		898	598		898	598		898	598		898	598		898	598		898	598		898	598	
4	898	598		898	598		898	598		898	598		898	598		898	598		898	598		898	598	
5	898	598		898	598		898	598		898	598		898	598		898	598		898	598		898	598	
6	4488	1012	4185	4488	512	4178	4488	12	4175	4000	0	3751	3000	0	2854	2000	0	1934	1500	3000	1500	4488	1812	4488
7	3863	1617	7808	3868	1132	7779	3863	837	7769	3501	499	7034	2708	292	5431	1867	133	3739	1500	3000	3000	3780	2510	8278
8	3359	2141	10939	3334	1666	10882	3324	1176	10861	3065	935	9907	2445	555	7757	1743	257	5425	1500	3000	4500	3790	2510	12066
9	2906	2594	13649	2873	2127	13557	2861	1639	13523	2683	1317	12423	2207	793	9857	1628	372	6998	1500	3000	6000	2513	3787	14581
10	2514	2986	15994	2476	2524	15862	2462	2038	15814	2348	1652	14625	1993	1007	11753	1520	480	8468	1500	3000	7500	2513	3787	17094
11	2175	3325	18023	2134	2866	17849	2119	2381	17786	2055	1945	16552	1799	1201	13465	1419	581	9840	1500	3000	9000	1755	4545	18850
12	1882	3618	19776	1839	3161	19562	1824	2676	19483	1799	2201	18239	1624	1376	15010	1325	675	11120	1500	3000	10500	1755	4545	20605
13	1628	3872	21296	1585	3415	21038	1570	2930	20943	1575	2425	19716	1466	1534	16405	1237	763	12316	1500	3000	11926	1436	4864	22041
14	1409	4091	22610	1366	3634	22310	1351	3149	22200	1379	2621	21009	1324	1676	17665	1155	845	13433	1351	3149	13182	1436	4864	23477
15	1219	4281	23746	1178	3822	23406	1163	3337	23282	1207	2793	22140	1195	1805	18802	1078	922	14475	1163	3337	14264	1277	5023	24754
16	1054	4446	24730	1015	3985	24351	1001	3499	24213	1056	2944	23130	1079	1921	19828	1007	993	15449	1001	3499	15195	1277	5023	26030
17	912	4588	25580	875	4125	25165	861	3639	25014	925	3075	23997	974	2026	20755	940	1060	16357	861	3639	15996	957	5343	26988
18	789	4711	26316	754	4246	25867	741	3759	25703	809	3191	24756	879	2121	21591	878	1122	17206	741	3759	16686	957	5343	27945
19	683	4817	26953	650	4350	26472	638	3862	26297	708	3292	25420	794	2206	22347	819	1181	17998	638	3862	17280	319	5981	28264
20	591	4909	27504	560	4440	26993	549	3951	26808	620	3380	26002	717	2283	23029	765	1235	18738	549	3951	17790	319	5981	28584
21	511	4989	27980	483	4517	27442	473	4027	27247	543	3457	26511	647	2353	23644	714	1286	19428	473	4027	18230	0	6300	28584
22	442	5058	28393	418	4584	27830	407	4093	27626	475	3525	26956	584	2416	24200	667	1333	20073	407	4093	18608	0	6300	28584
23	382	5118	28584	359	4641	28183	350	4150	27951	416	3584	27346	527	2473	24702	623	1377	20675	350	4150	18934	0	6300	28584
24	0	5500	28584	309	4691	28451	301	4199	28232	364	3636	27688	476	2524	25155	581	1419	21237	301	4199	19214	0	6300	28584
25	0	5500	28584	266	4734	28584	259	4241	28473	319	3681	27986	430	2570	25584	543	1457	21762	259	4241	19455	0	6300	28584
26	0	5500	28584	0	5000	28584	223	4277	28584	279	3721	28248	388	2612	25933	507	1493	22251	223	4277	19567	0	6300	28584
27	0	5500	28584	0	5000	28584	0	4500	28584	244	3756	28477	350	2650	26266	473	1527	22709	0	4500	19567			
28	0	5500	28584	0	5000	28584	0	4500	28584	214	3786	28584	316	2684	26567	442	1558	23136	0	4500	19567			
29				0	5000	28584	0	4500	28584	0	4000	28584	286	2714	26838	412	1588	23535	0	4500	19567			
30							0	4500	28584	0	4000	28584	258	2742	27084	385	1615	23907	0	4500				
31										0	4000	28584	233	2767	27305	360	1640	24255						
32										0	4000	28584	210	2790	27505	336	1664	24579						
33													190	2810	27685	313	1687	24882						
34													171	2829	27848	293	1707	25165						
35													155	2845	27995	273	1727	25429						
36													140	2860	28128	255	1745	25676						
37													126	2874	28248	238	1762	25906						
38													114	2886	28356	222	1778	26121						
39													103	2897	28454	208	1792	26322						
40													93	2907	28542	194	1806	26509						
41													84	2916	28584	181	1819	26684						
42													0	3000	28584	169	1831	26847						
43													0	3000	28584	158	1842	27000						
44													0	3000	28584	147	1853	27142						
45																138	1862	27275						
46																128	1872	27399						
47																120	1880	27515						
48																112	1888	27623						
49																104	1896	27724						
50																98	1902	27819						
51																91	1909	27907						
52																85	1915	27989						
53																79	1921	28066						
54																74	1926	28137						
55																69	1931	28204						
56																65	1935	28267						
57																60	1940	28325						
58																56	1944	28380						
59																53	1947	28430						
60																49	1951	28478						
61																46	1954	28522						
62																43	1957	28564						
63																40	1960	28584						
64																0	2000	28584						
65																0	2000	28584						

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HYP-2 - ESTIMATED TREATMENT RATES FOR HYPOTHETICAL CASES

FERICRU5\APX\APP-F\SECT-8\ATTACH\F8-IIF.PGS

March 10, 1995 2:31pm

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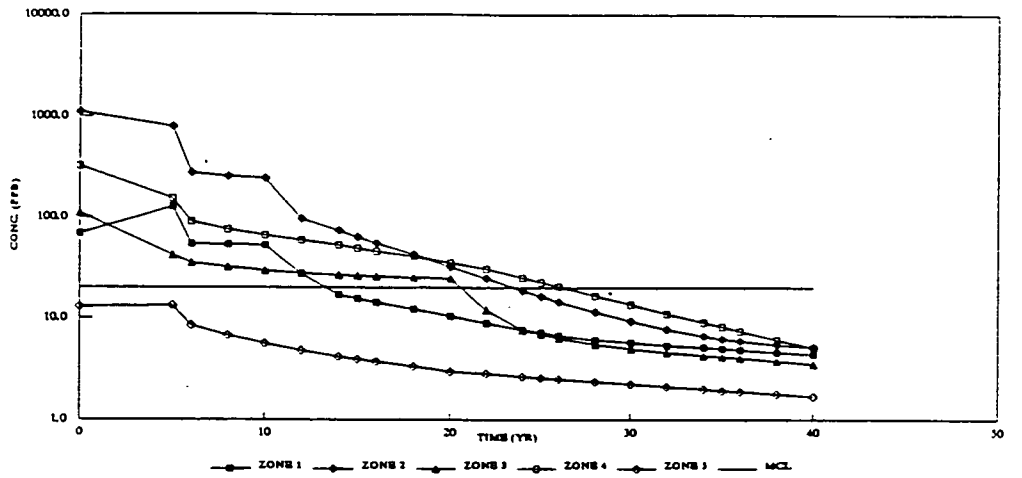
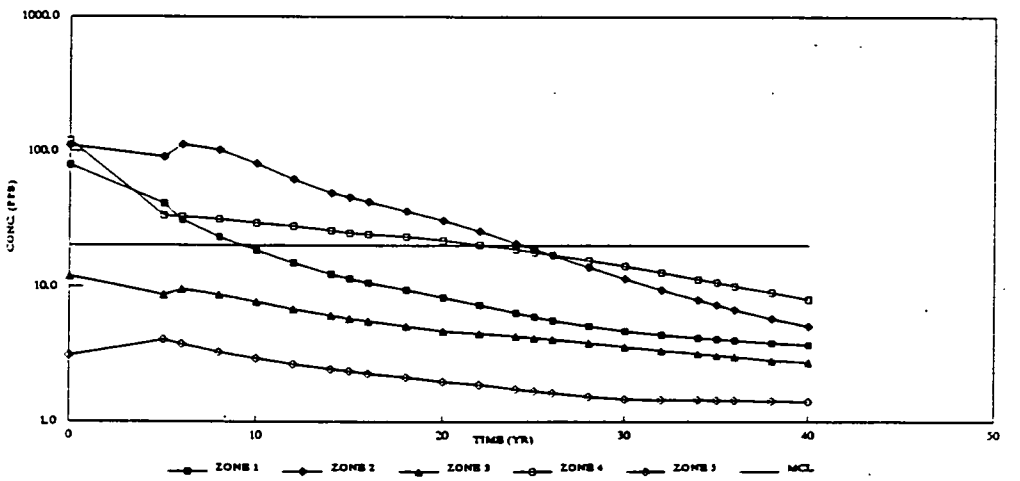
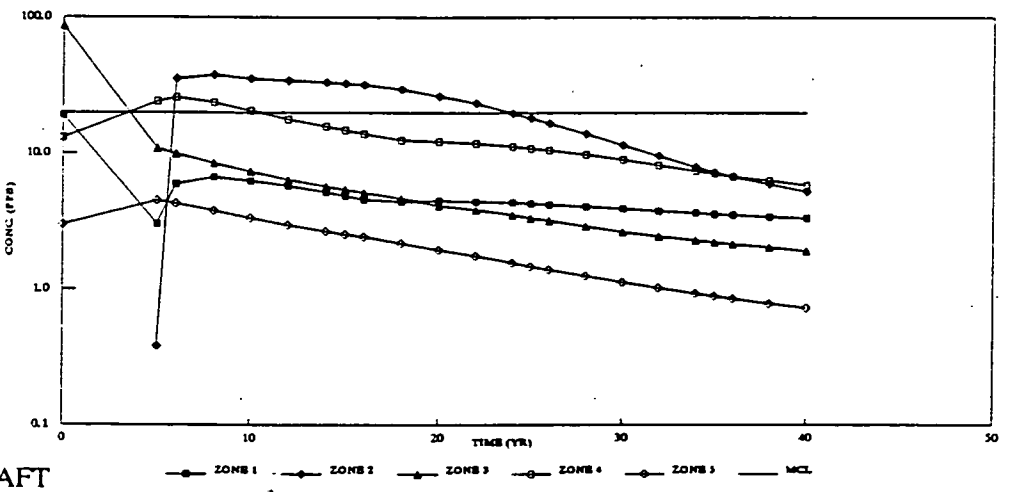


LAYER 1



LAYER 3



LAYER 6

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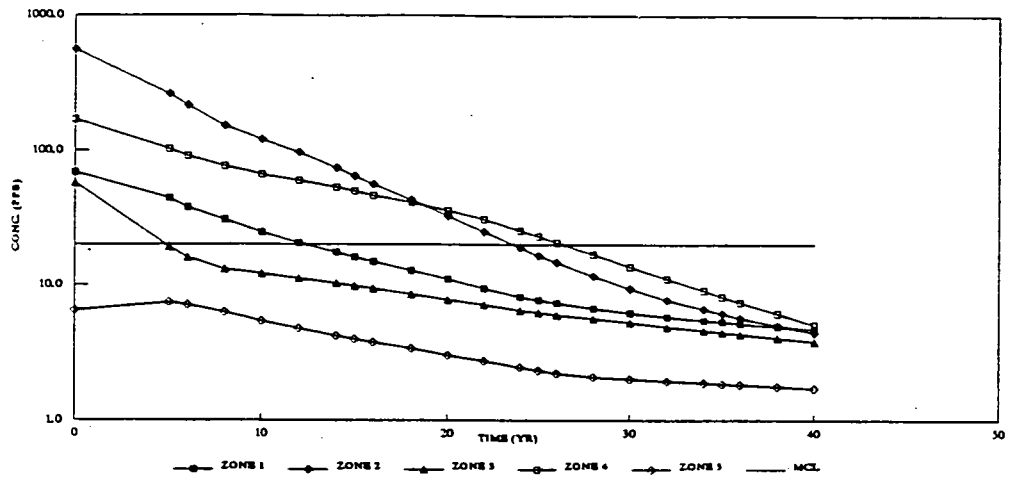
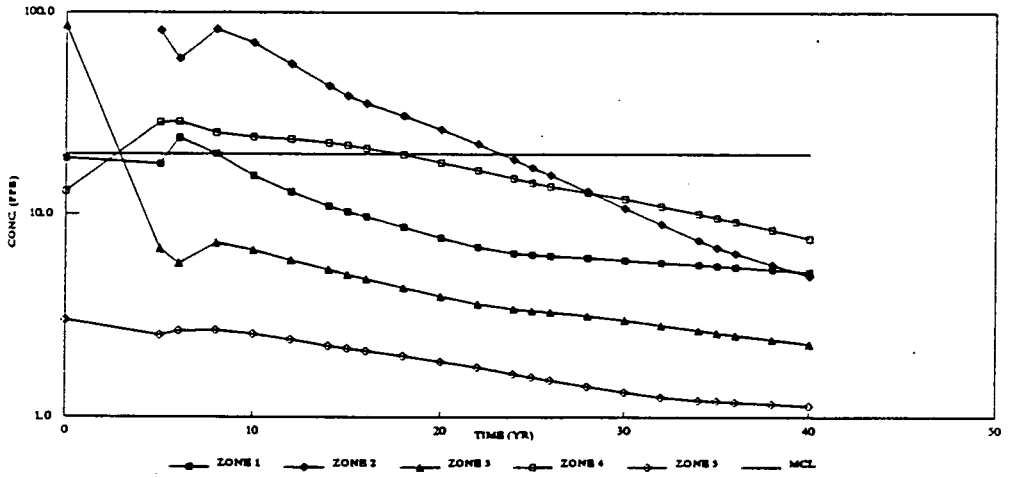
FINAL

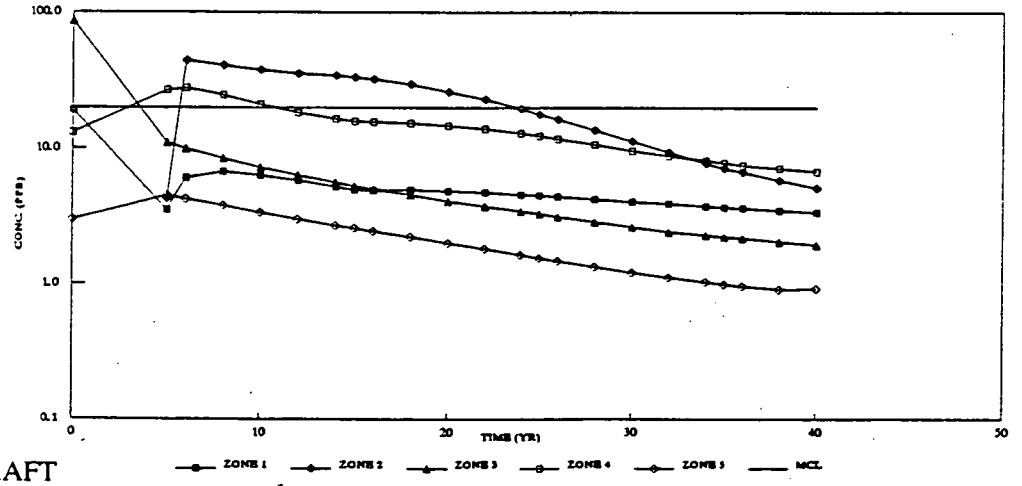
RB-1 - REVISED BASELINE, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



LAYER 2



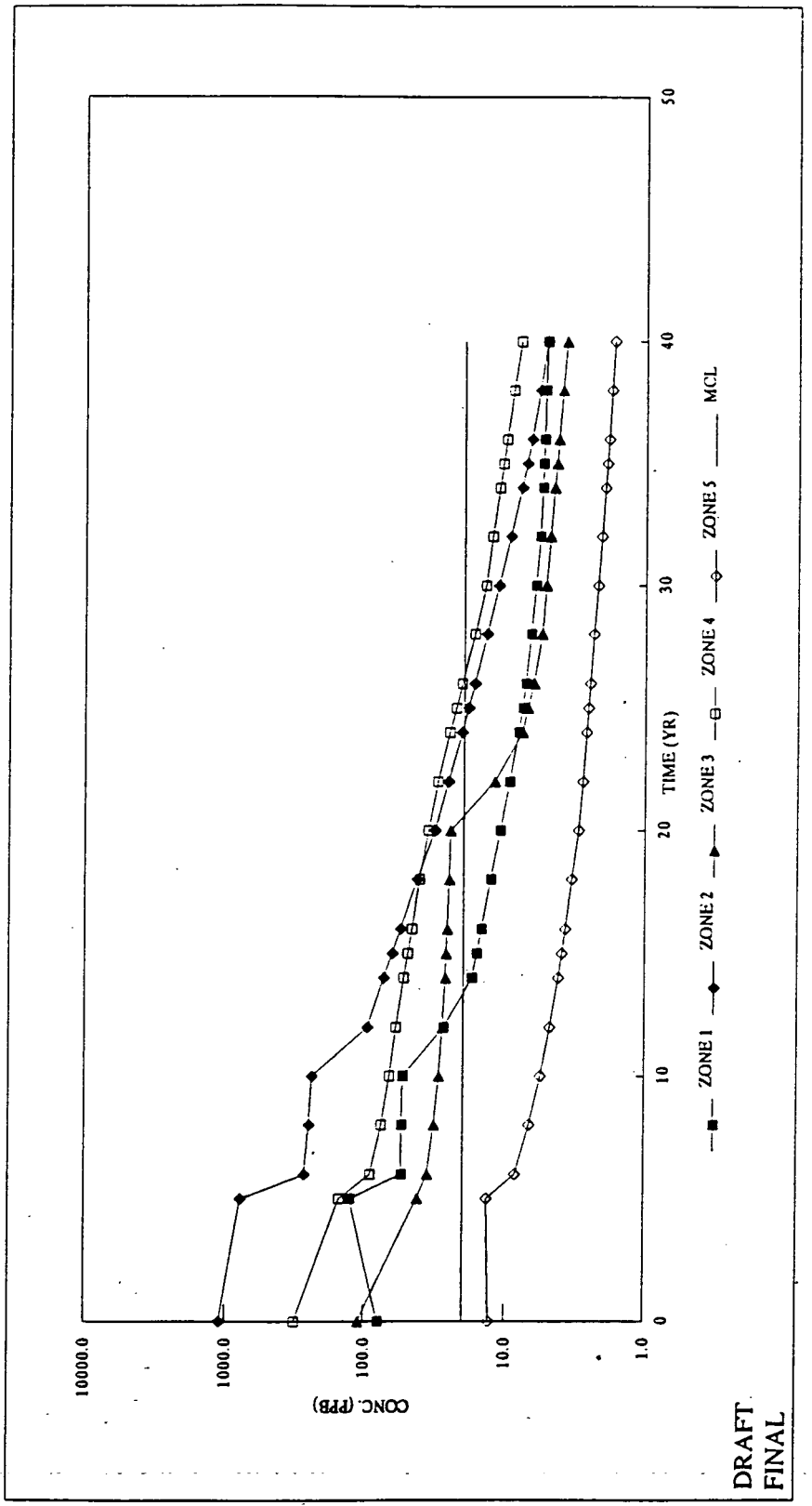
LAYER 4



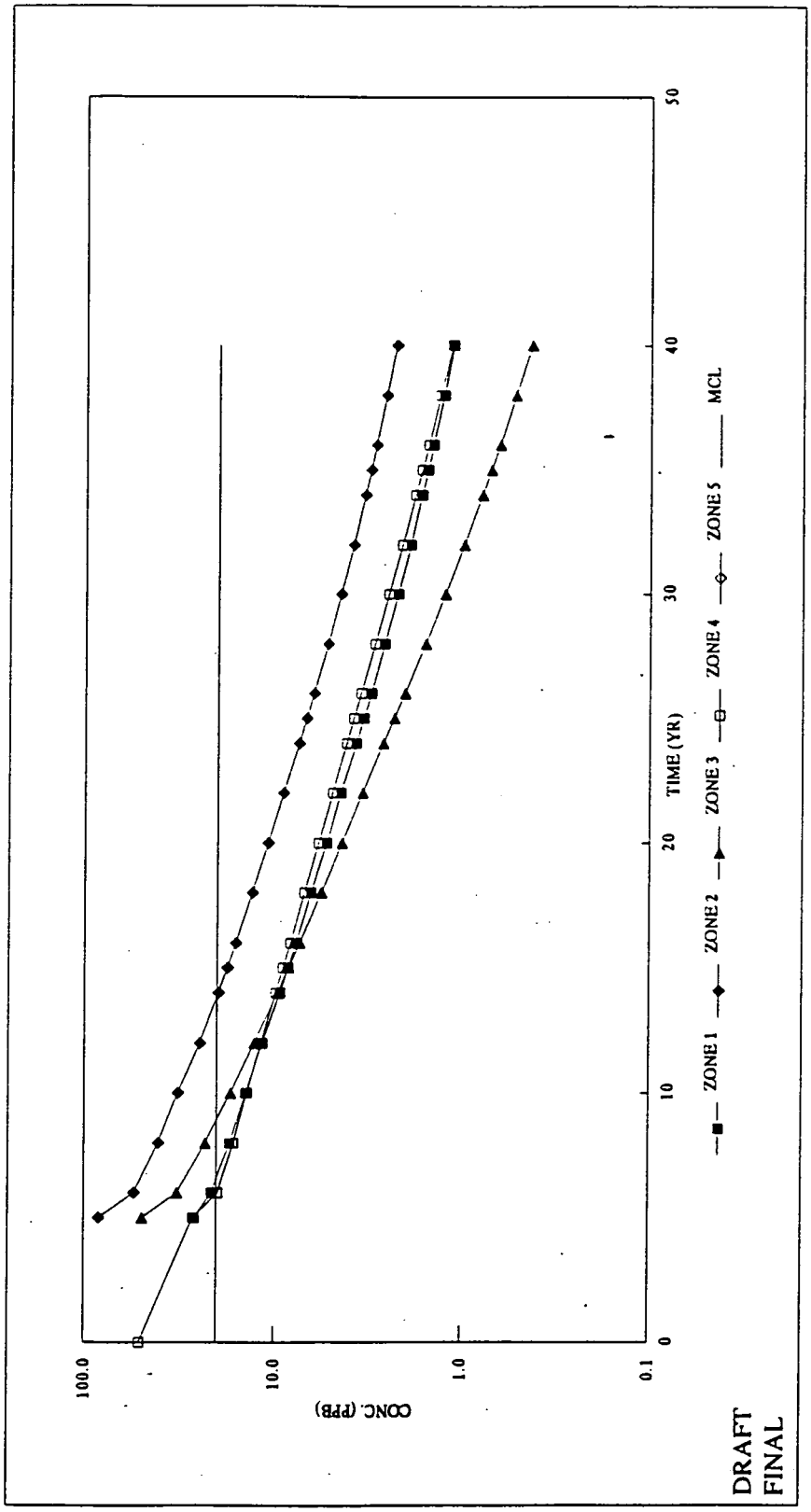
LAYER 5

DRAFT
FINAL

RB-2 - REVISED BASELINE, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)

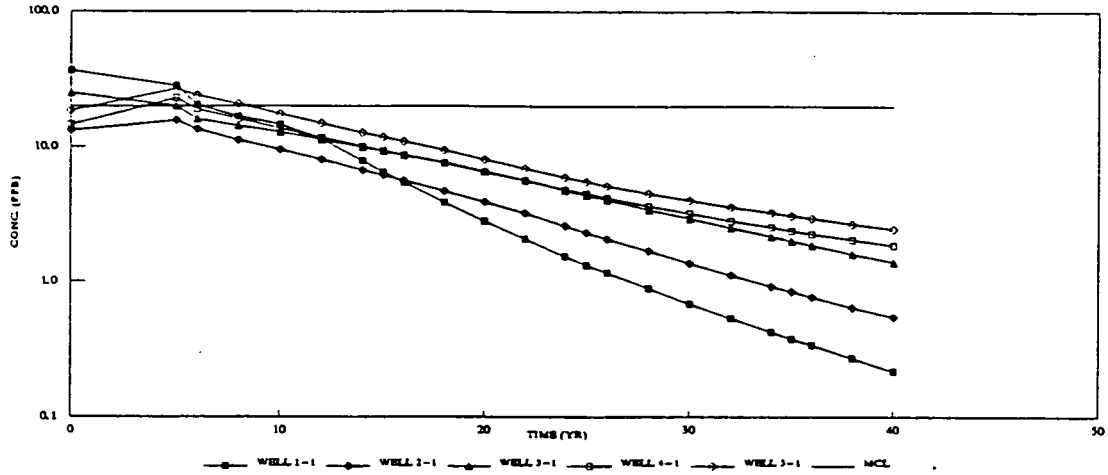


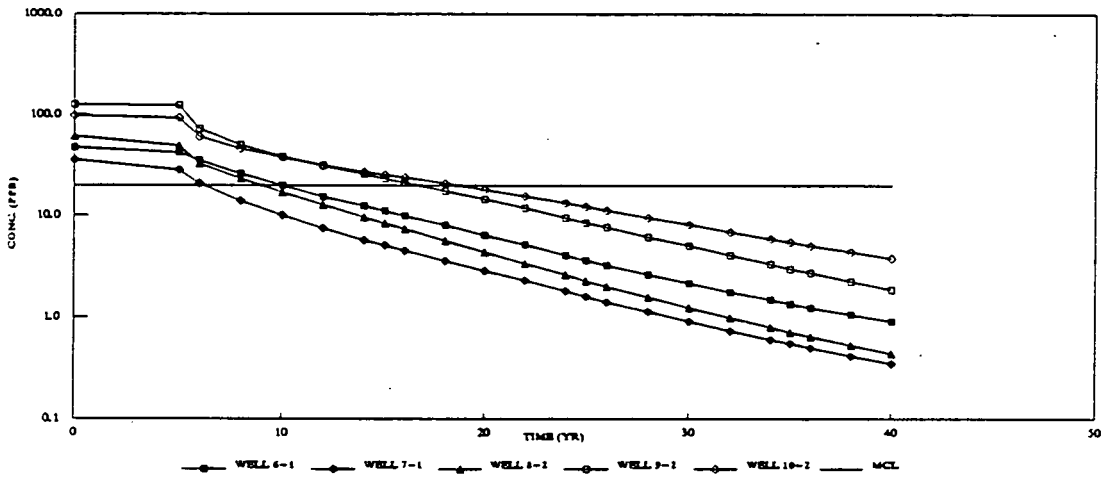
RB-3 - REVISED BASELINE, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE

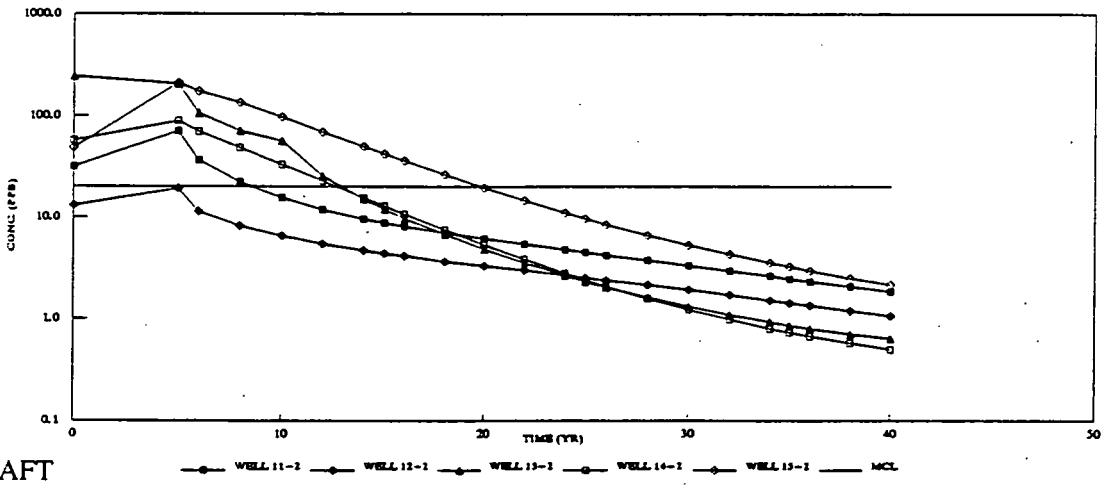


RB-4 - REVISED BASELINE, SYSTEM AVERAGE CONCENTRATIONS VS. TIME

FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 10, 1995 2:31pm







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RB-5 - REVISED BASELINE, WELL AVERAGE CONCENTRATIONS VS. TIME

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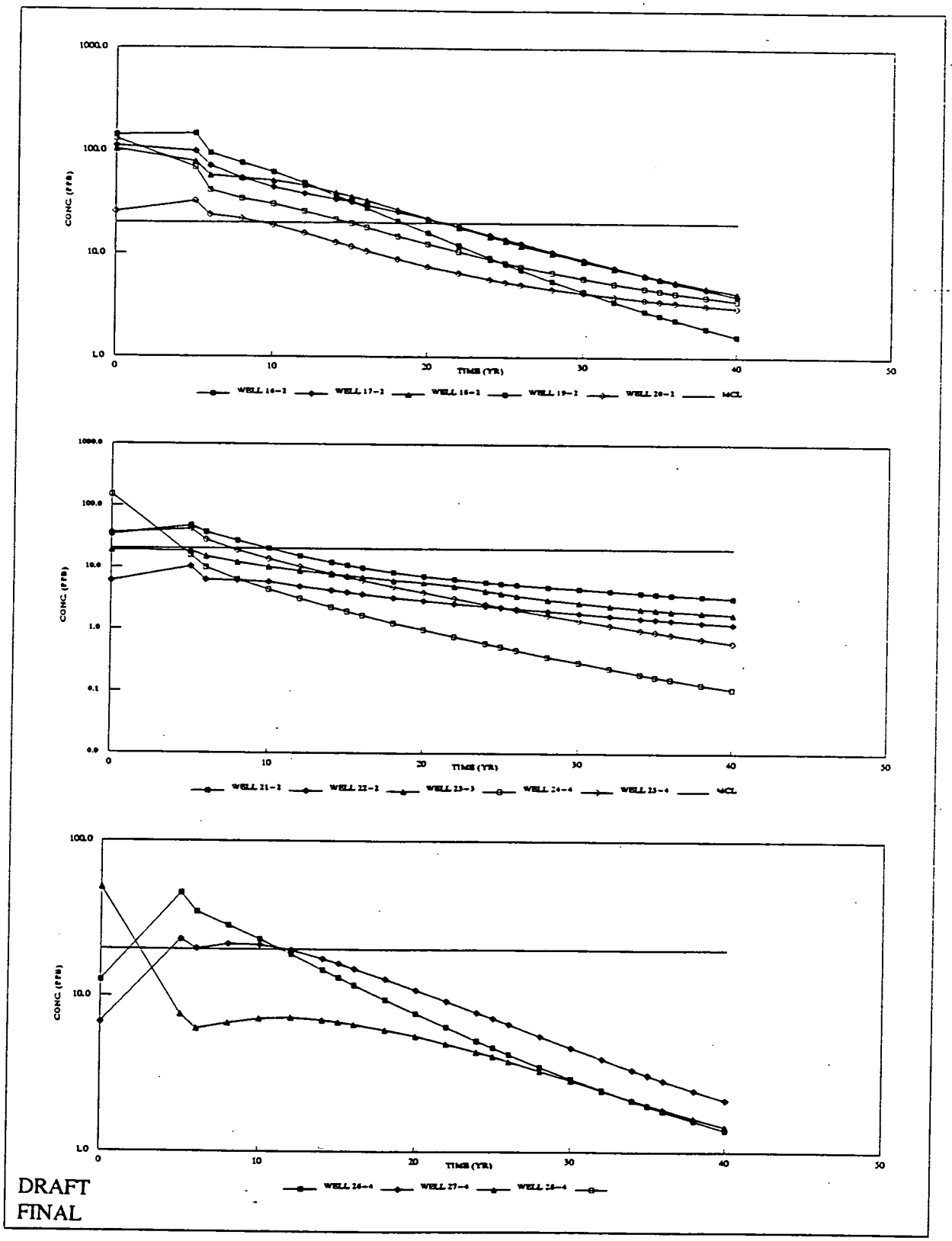
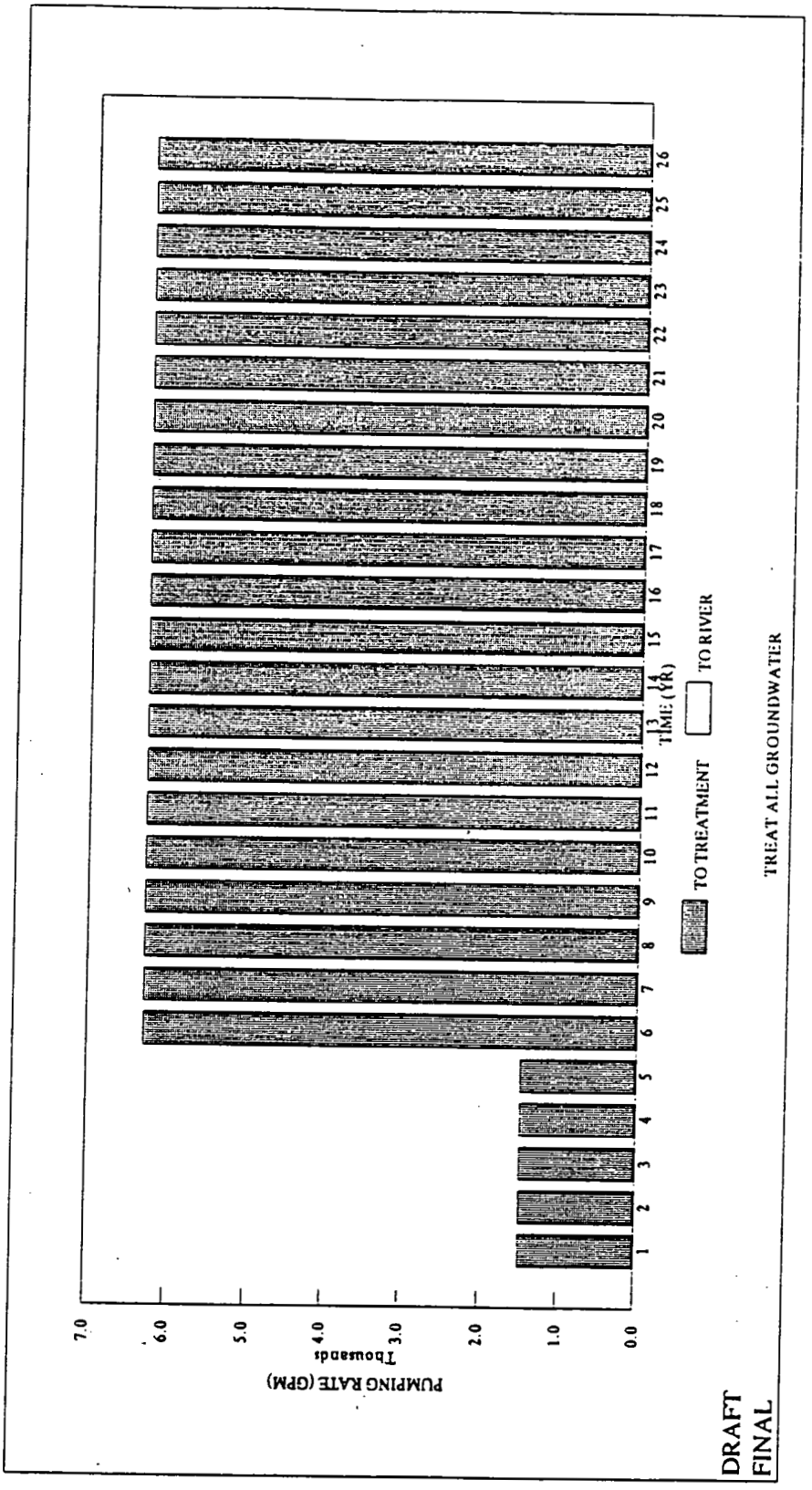
March 10, 1995 2:31pm



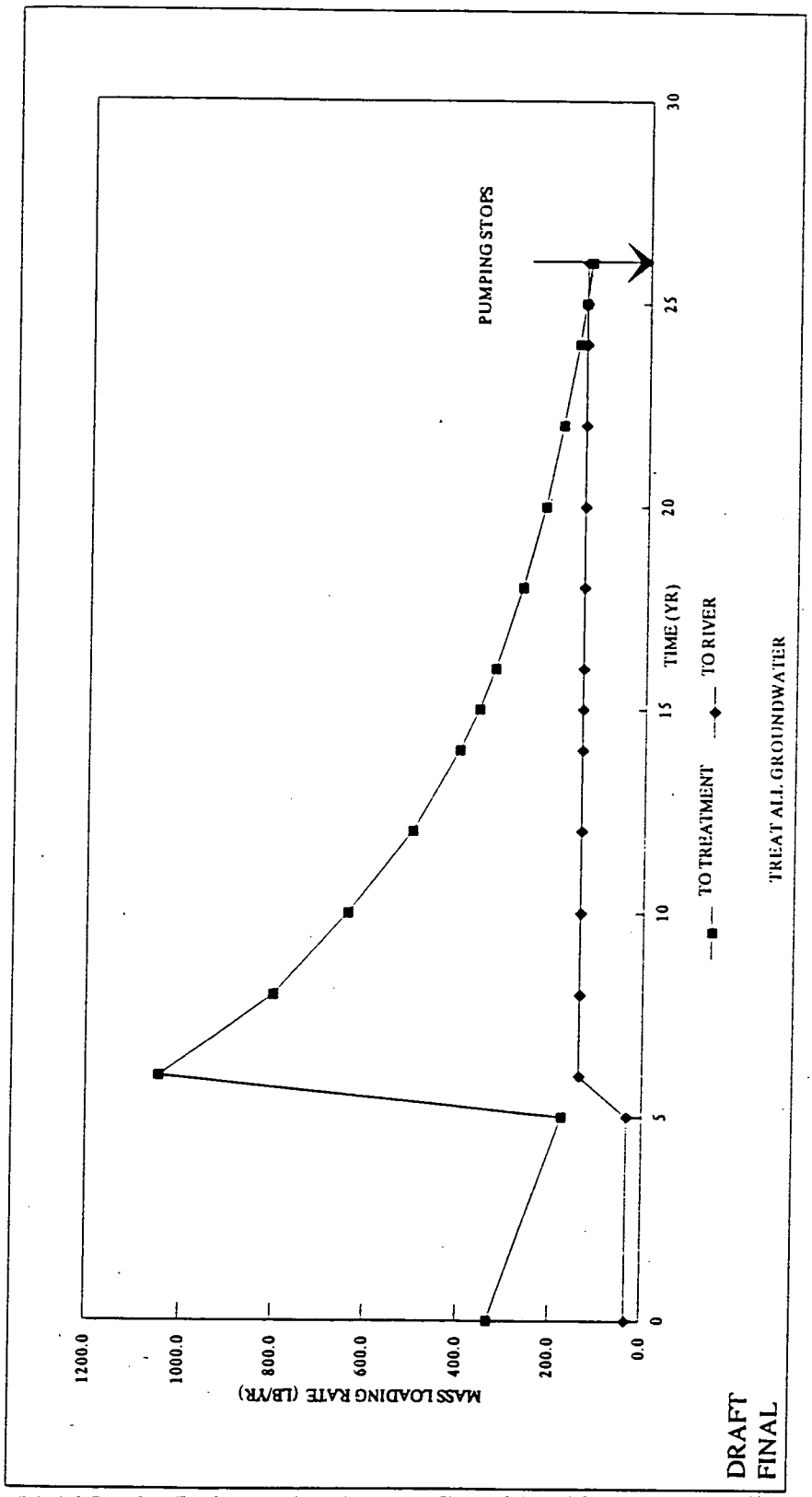
RB-6 - REVISED BASELINE, WELL AVERAGE CONCENTRATIONS VS. TIME



RB-7 - REVISED BASELINE, TREATMENT RATE VS. TIME (TREAT ALL GROUNDWATER)

FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS

March 10, 1995 2:31pm



RB-8 - REVISED BASELINE, MASS LOADING RATE VS. TIME (TREAT ALL GROUNDWATER)

FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 10, 1995 2:31pm

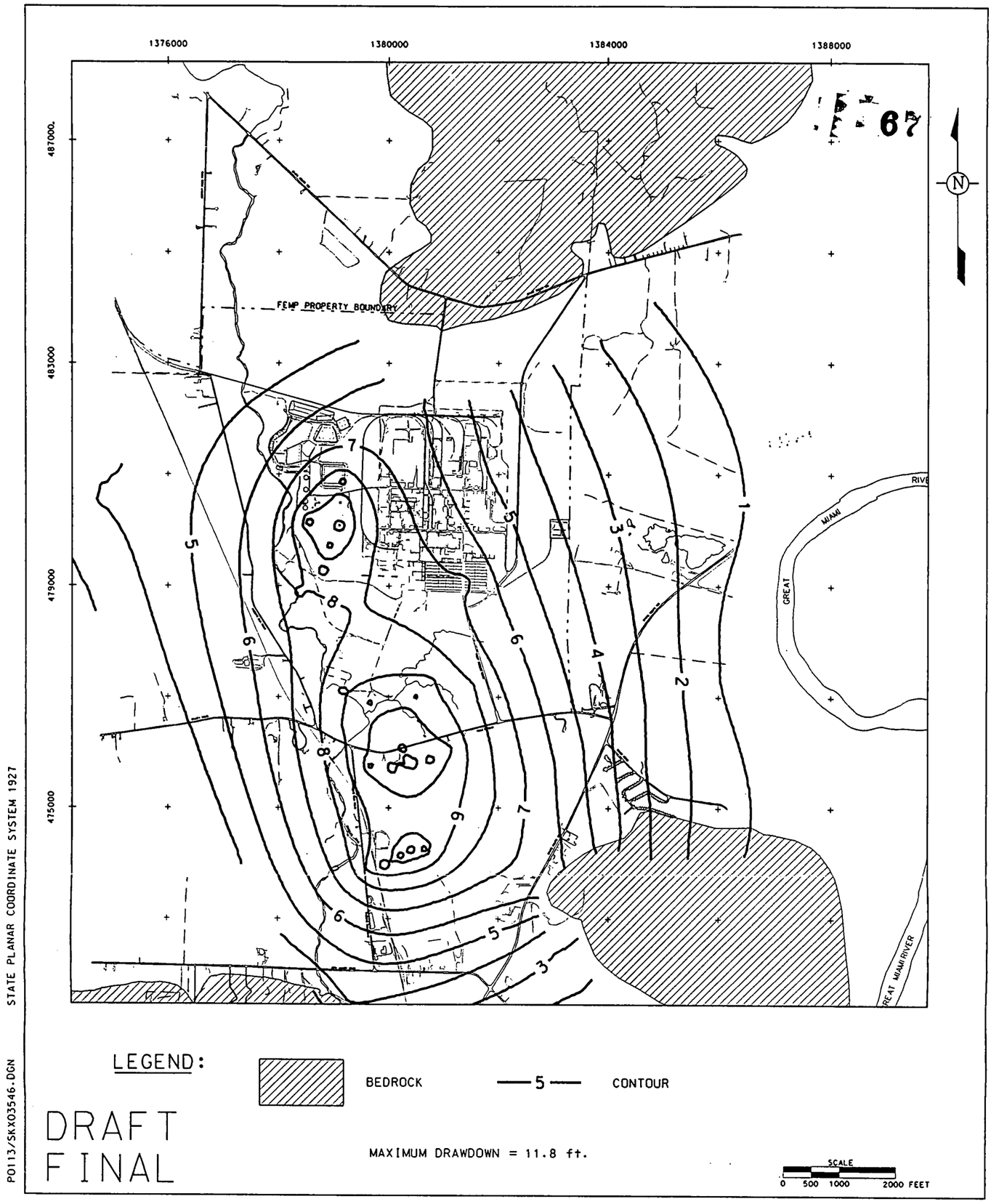


FIGURE RB-9. REVISED BASELINE, GROUNDWATER DRAWDOWN CONTOURS

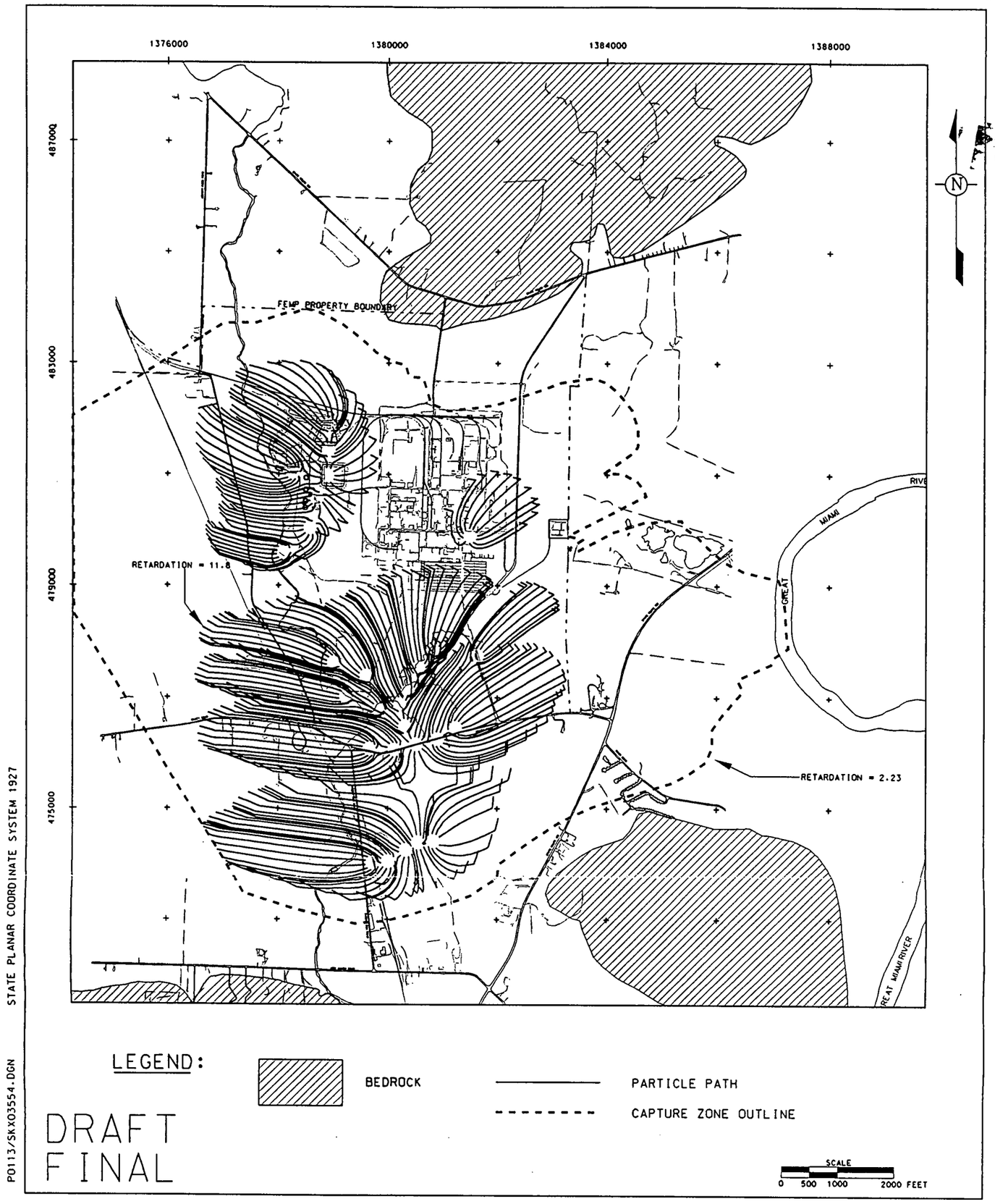
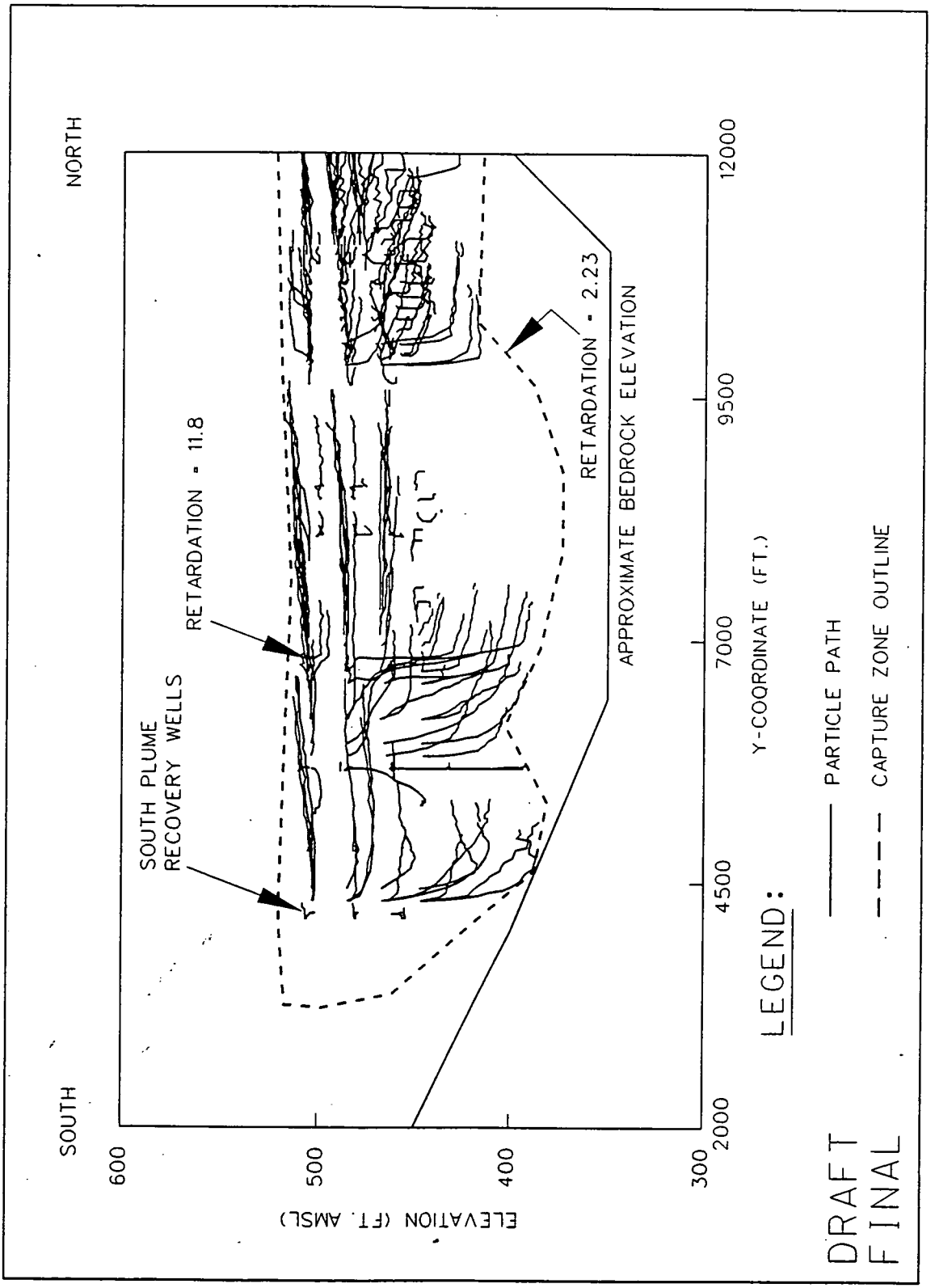


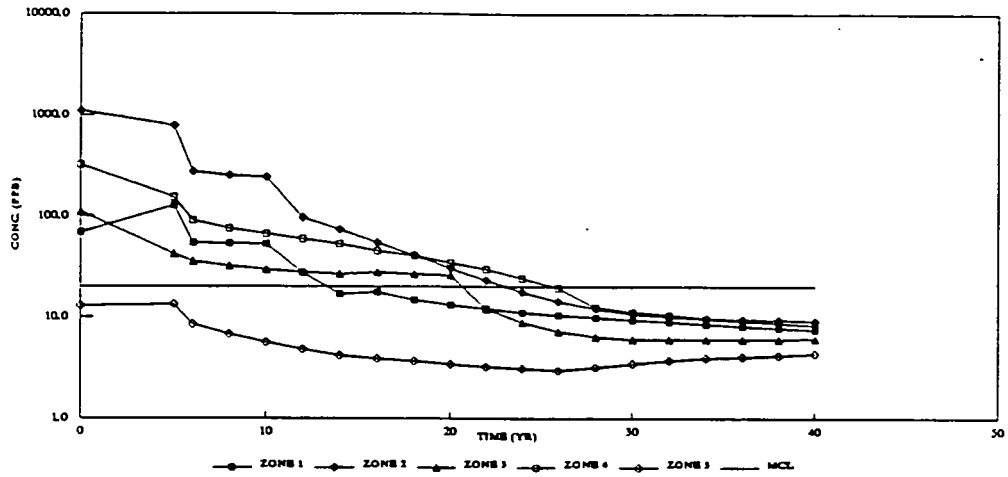
FIGURE RB-10. REVISED BASELINE, CAPTURE ZONE PLOT, YEARS 0-26



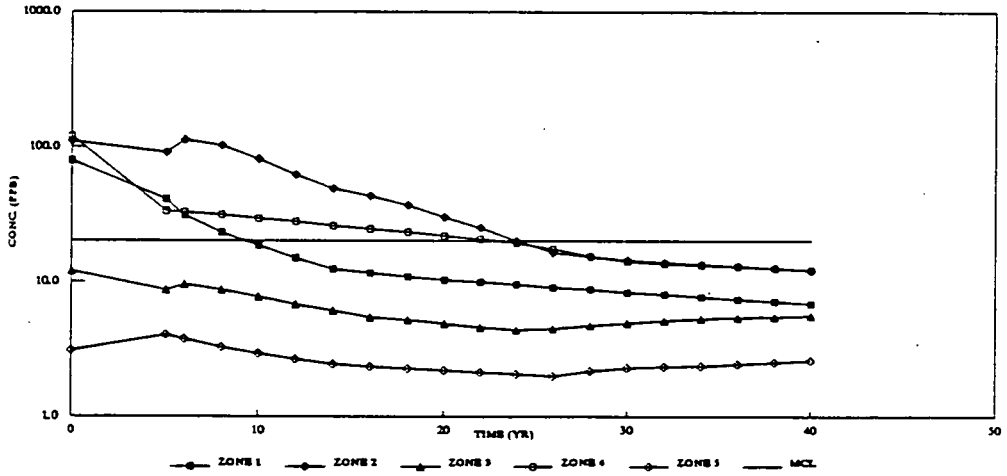
P0113/SKX03559.DGN

RB-11 - REVISED BASELINE, CAPTURE ZONE PLOT, YEARS 0 - 26, NORTH-SOUTH CROSS SECTION

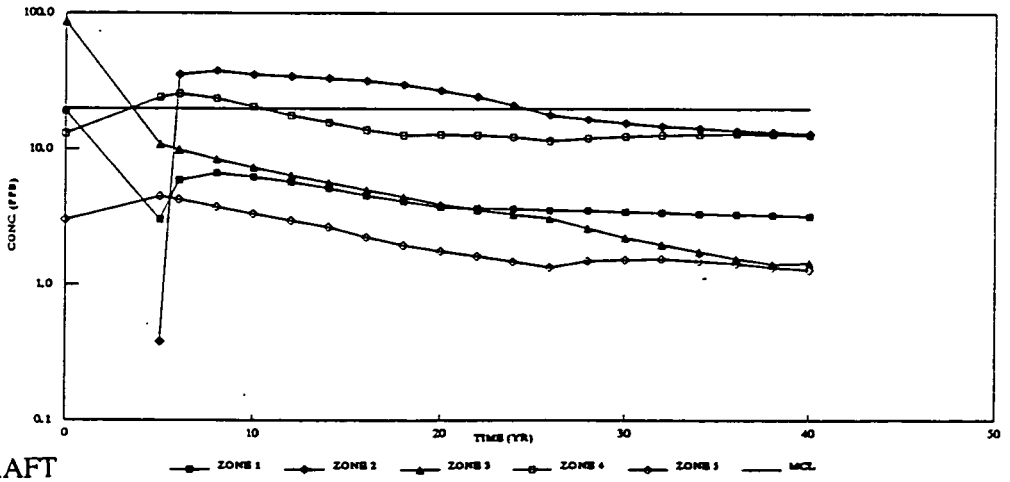
FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 14, 1995 10:00am



LAYER 1



LAYER 3



LAYER 6

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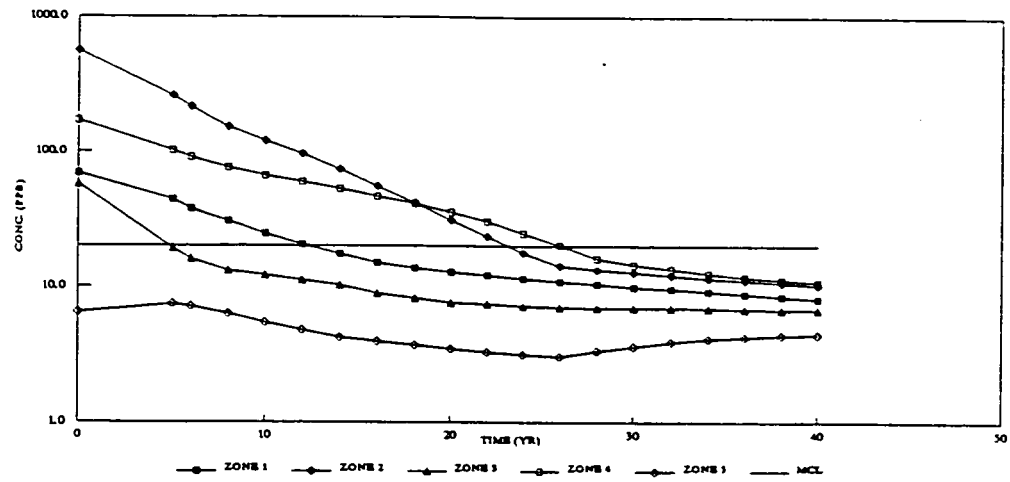
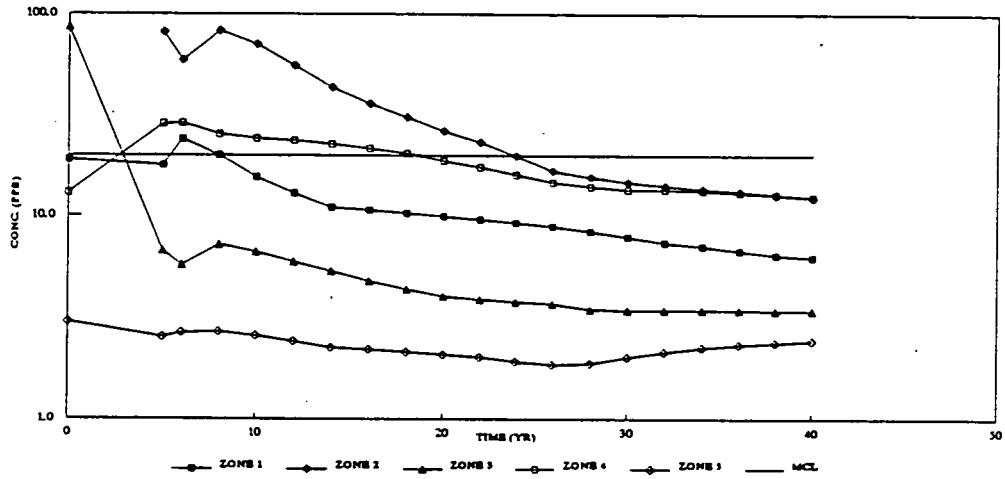
FINAL

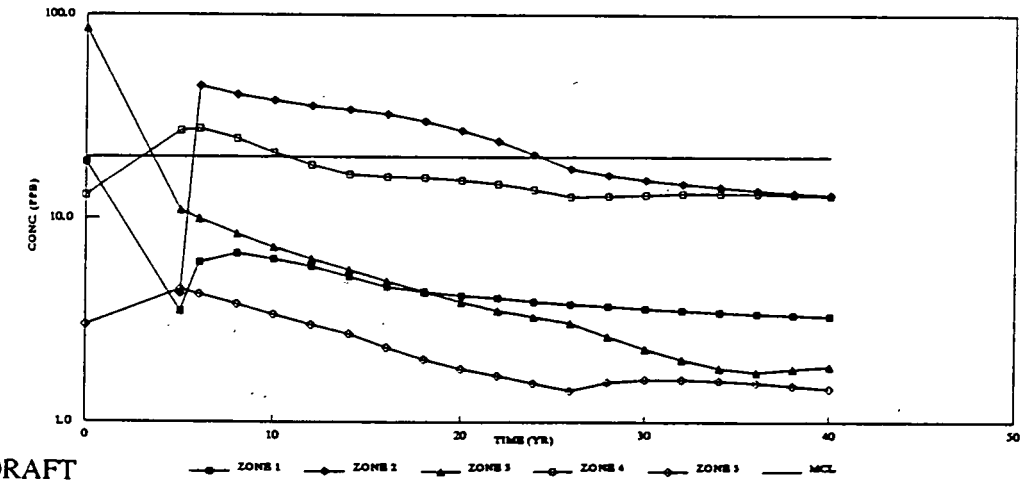
V1-1 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



LAYER 2



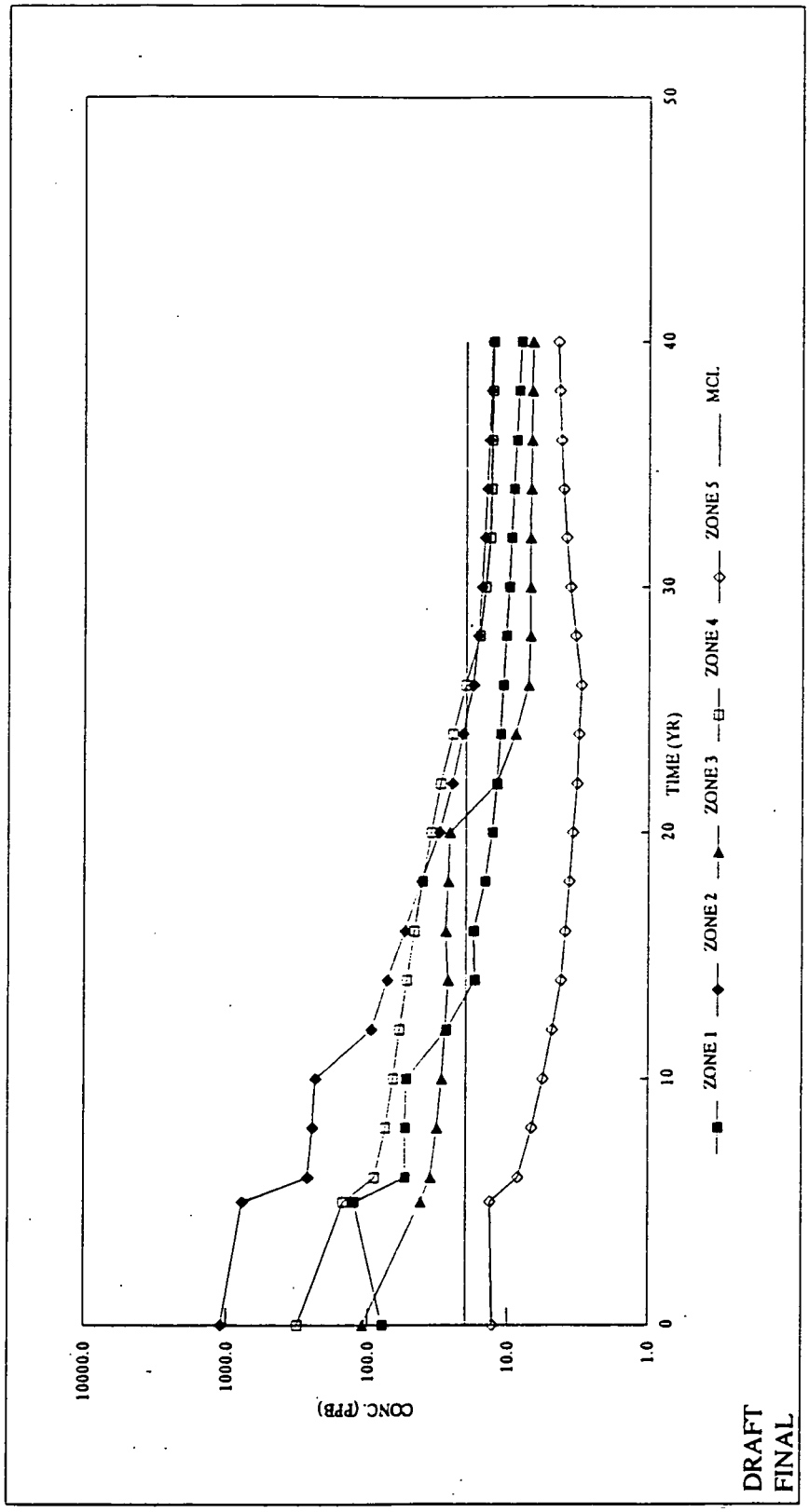
LAYER 4



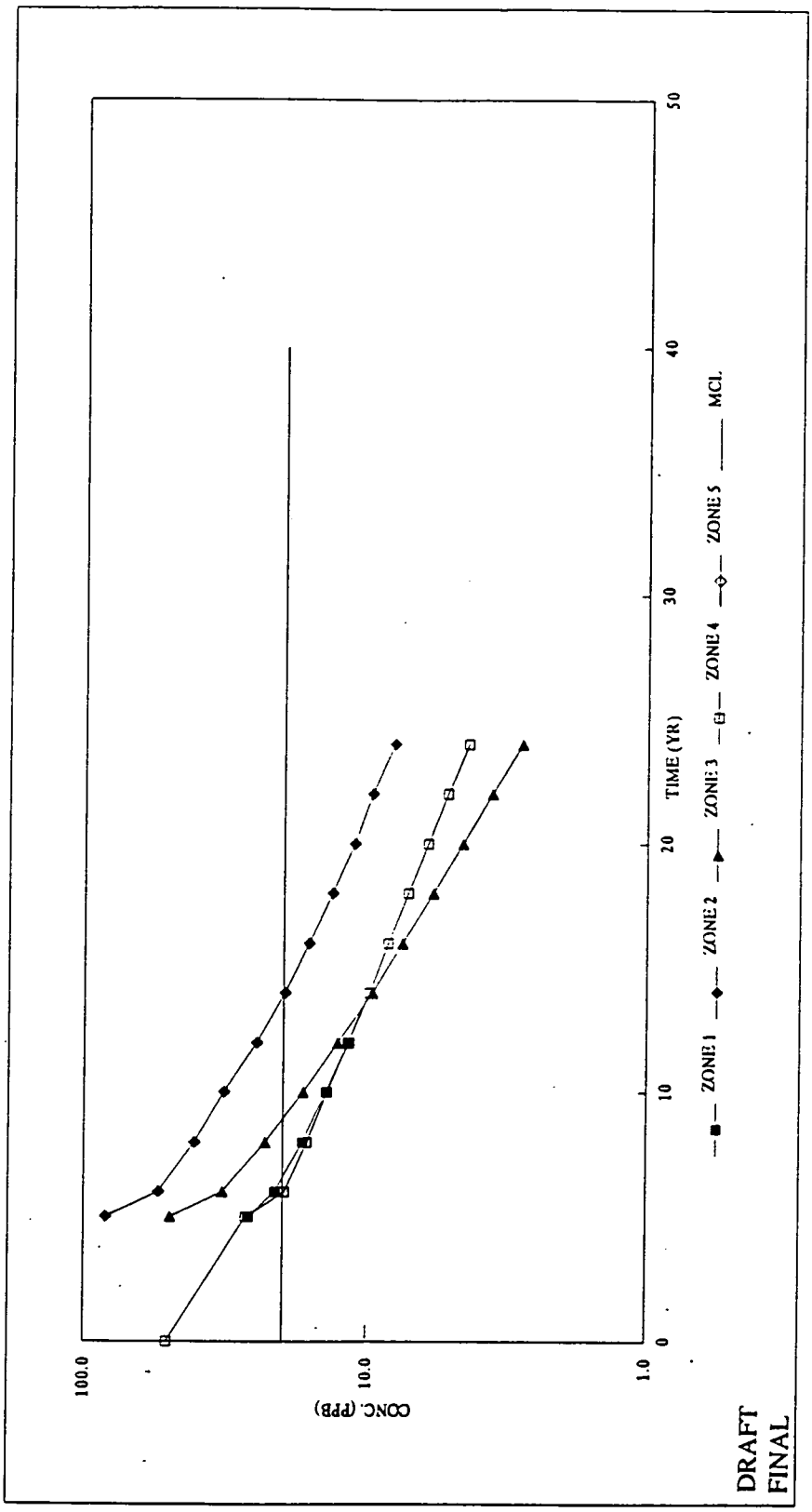
LAYER 5

DRAFT
FINAL

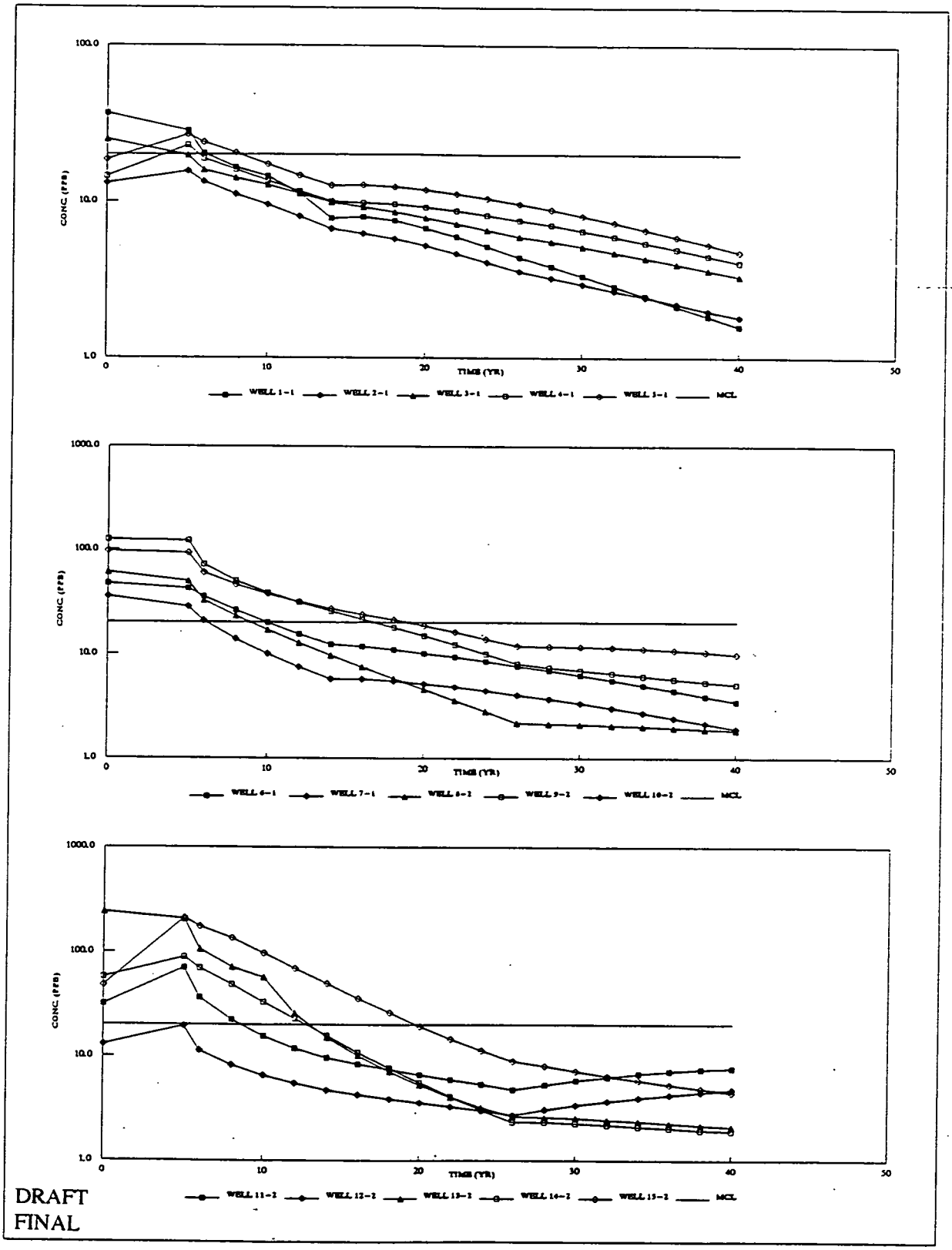
V1-2 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)



V1-3 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE

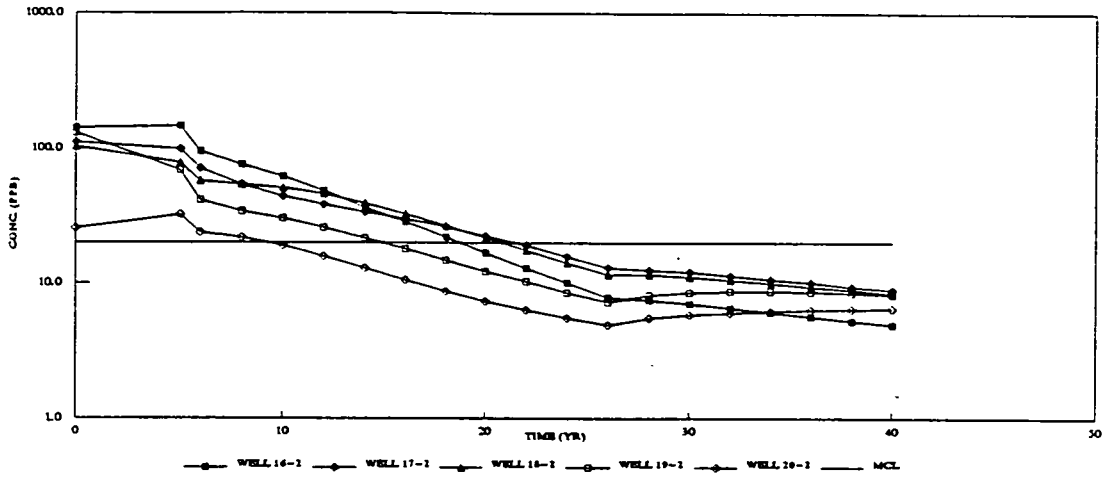


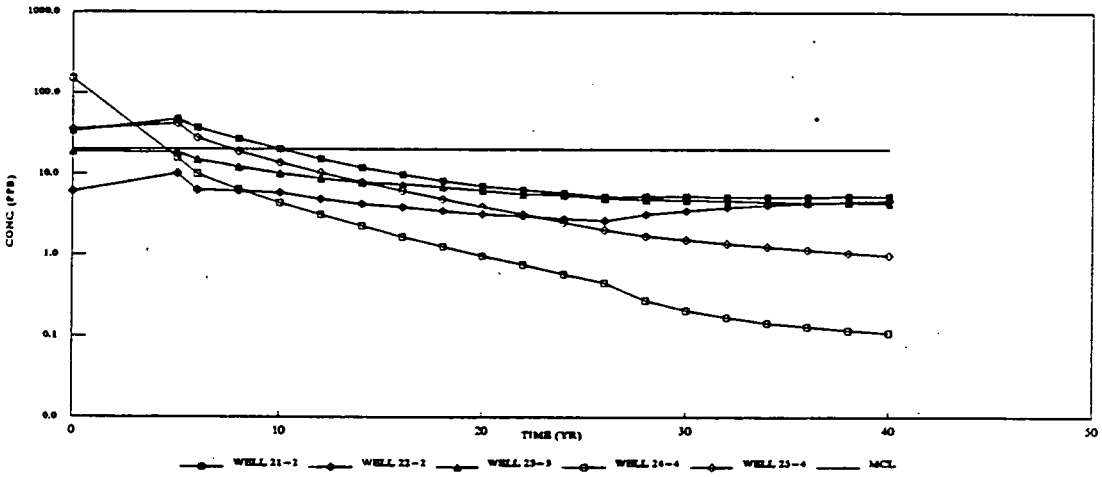
V1-4 - VARIABLE PUMPING RATE, SYSTEM AVERAGE CONCENTRATIONS VS. TIME

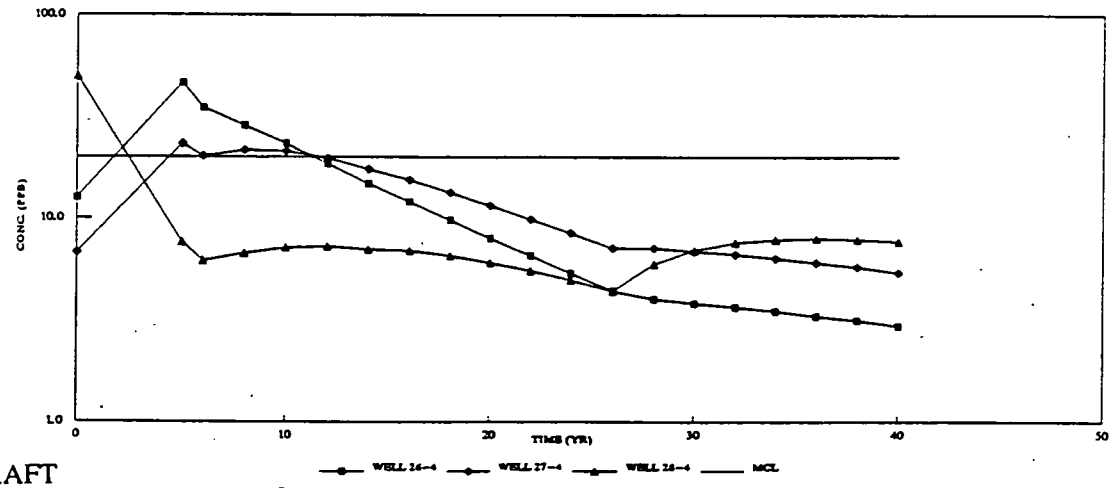


DRAFT
FINAL

V1-5 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)







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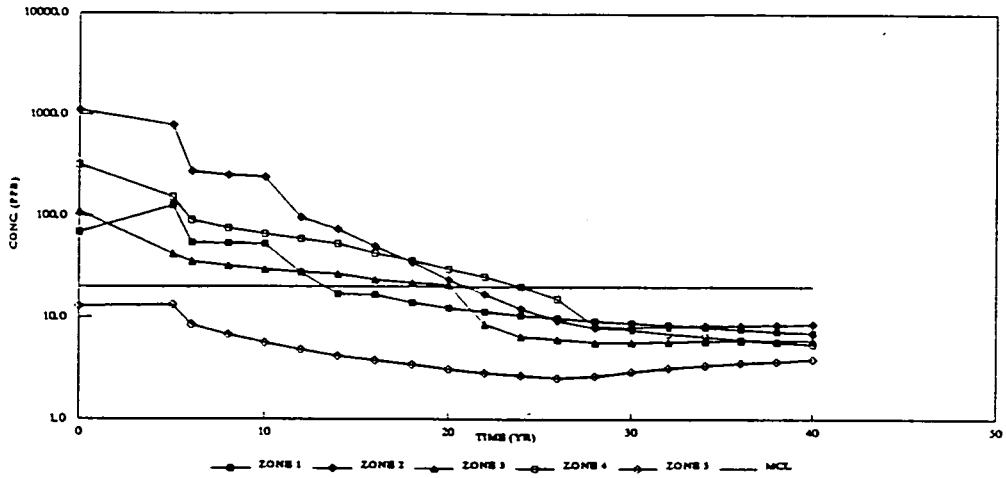
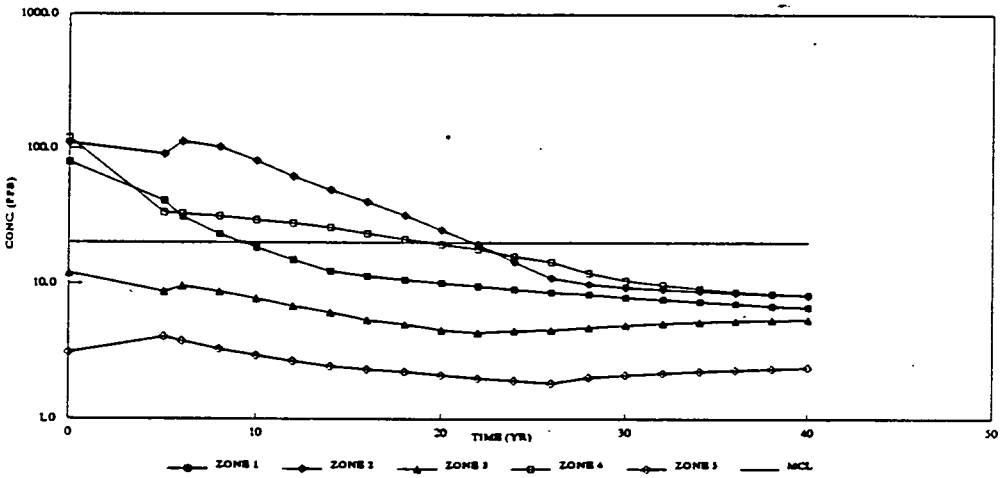
FINAL

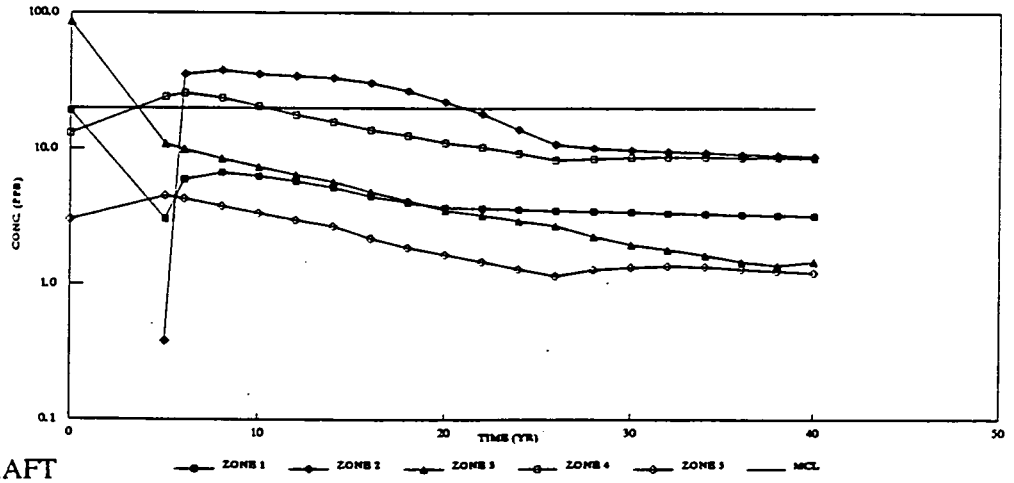
V1-6 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)



LAYER 1



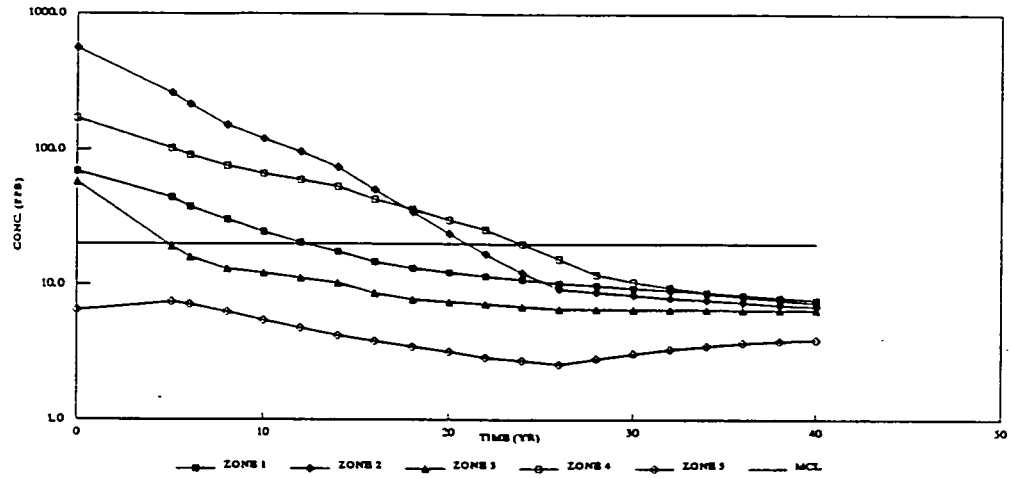
LAYER 3



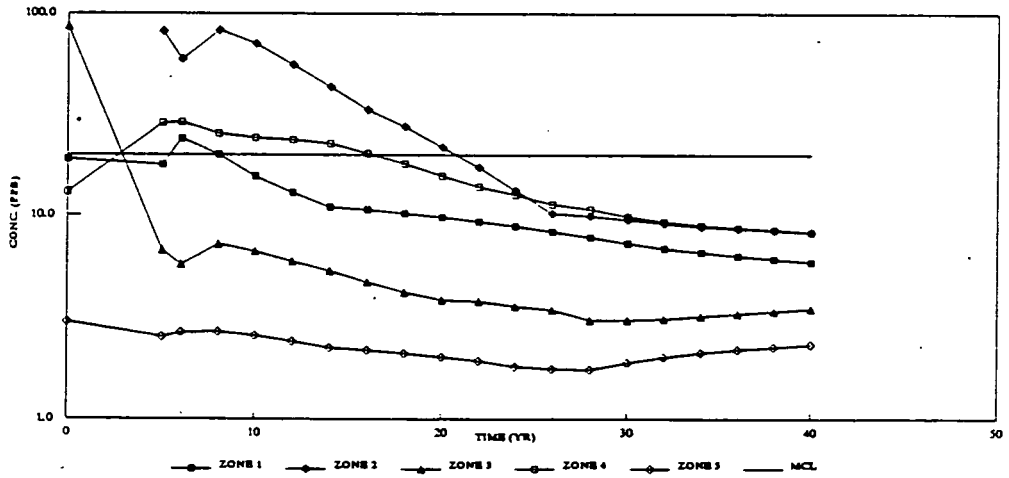
LAYER 6

DRAFT
FINAL

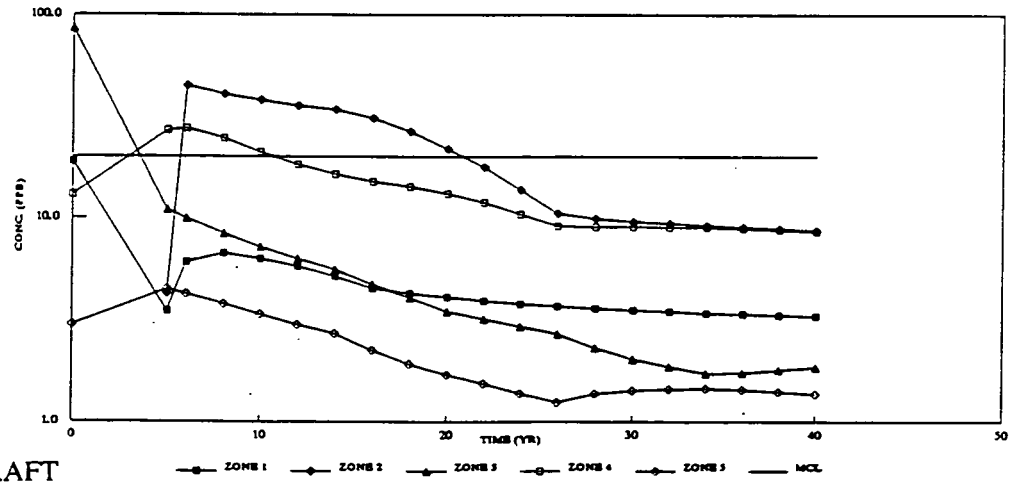
V2-1 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



LAYER 2



LAYER 4



LAYER 5

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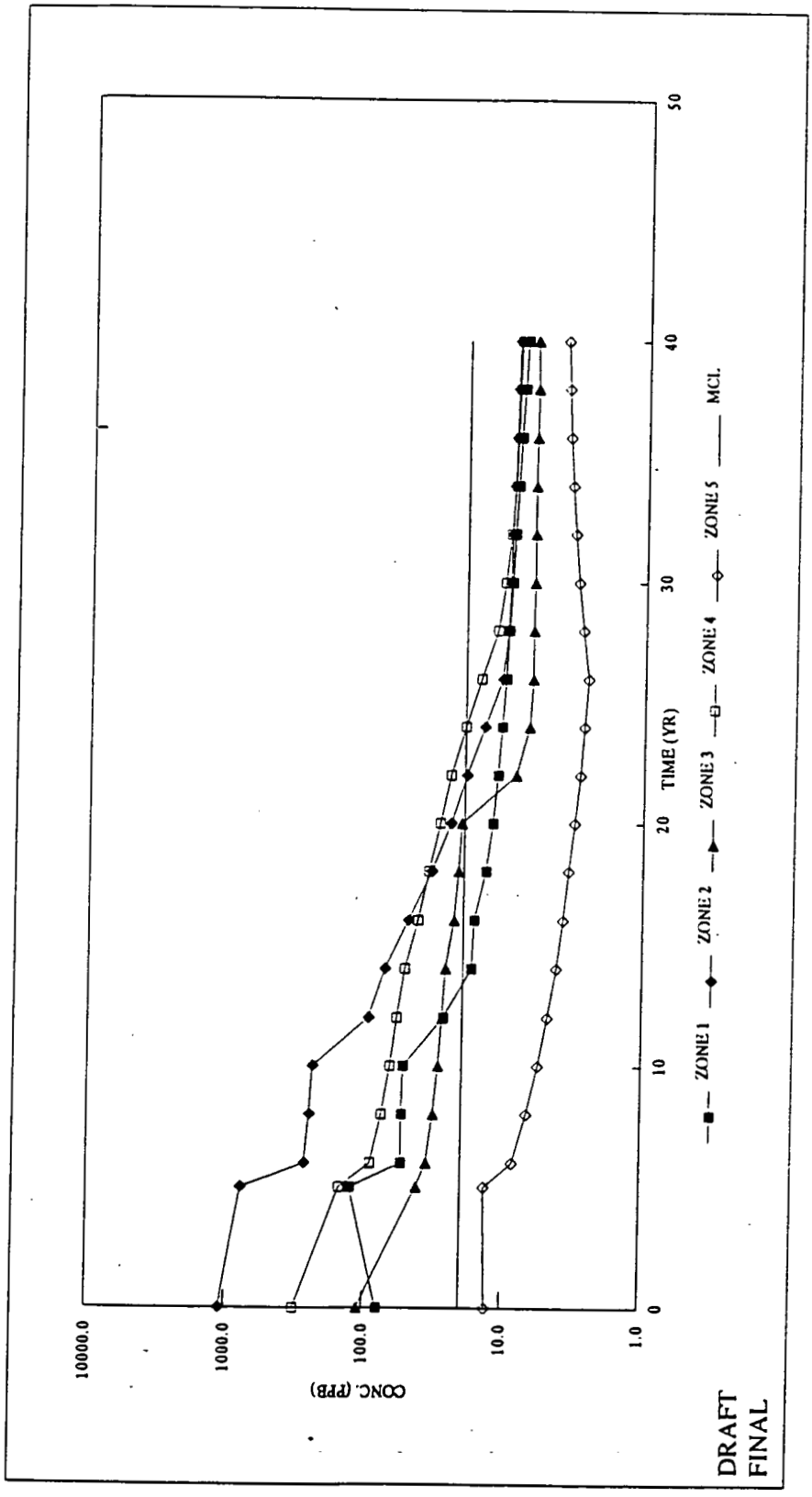
V2-2 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)



V2-3 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE

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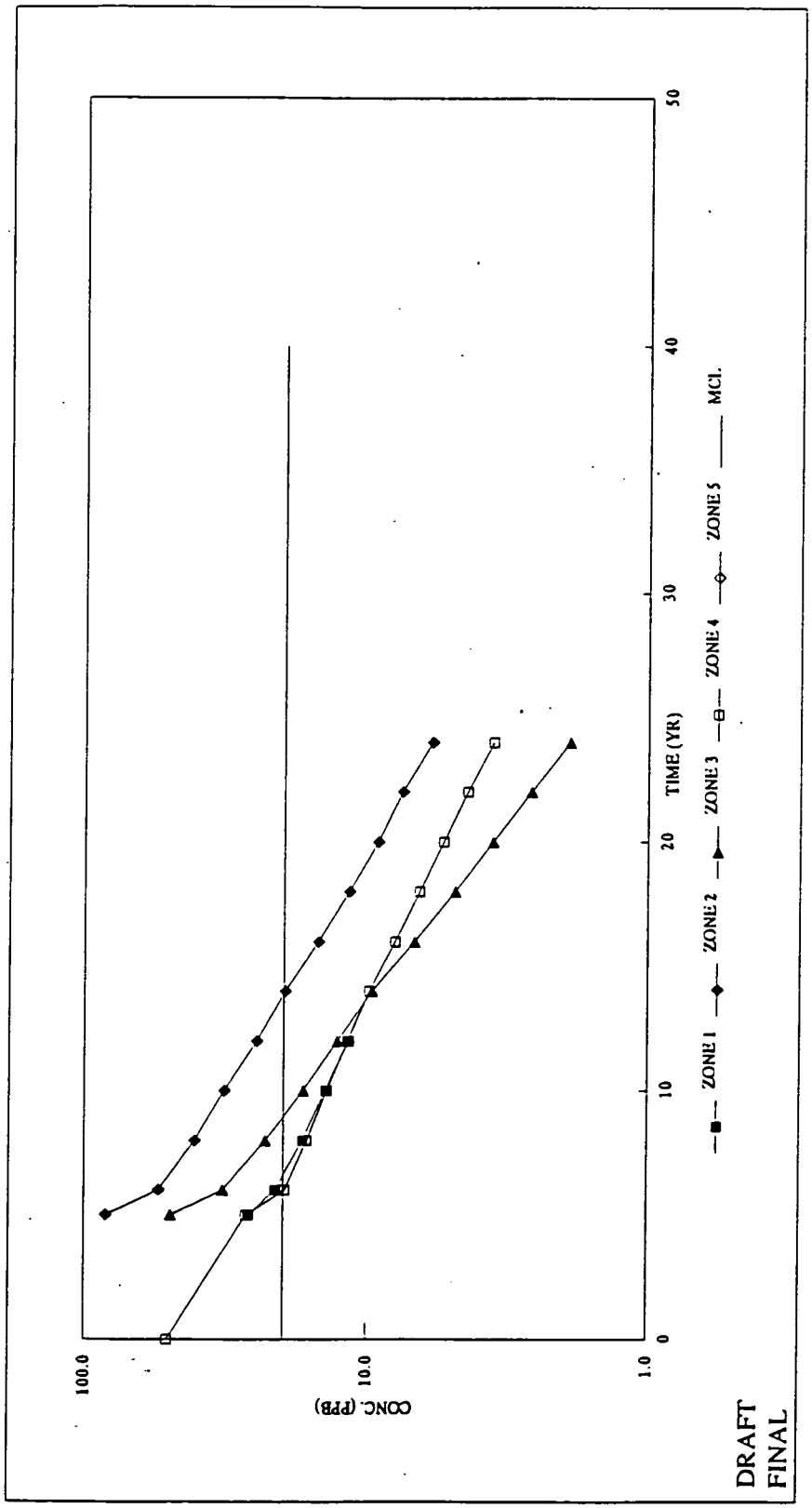
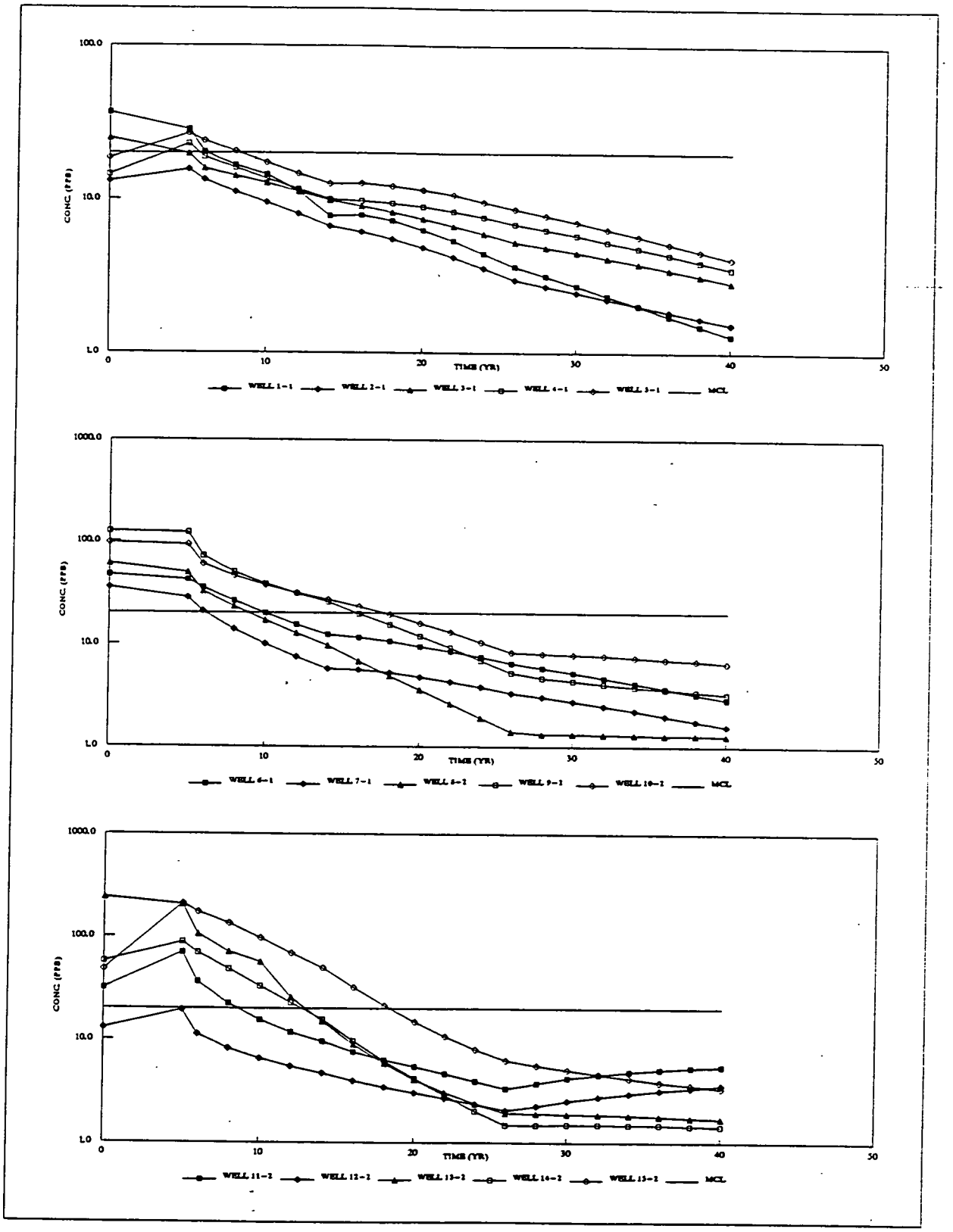
March 10, 1995 2:31pm



V2-4 - VARIABLE PUMPING RATE; SYSTEM AVERAGE CONCENTRATIONS VS. TIME



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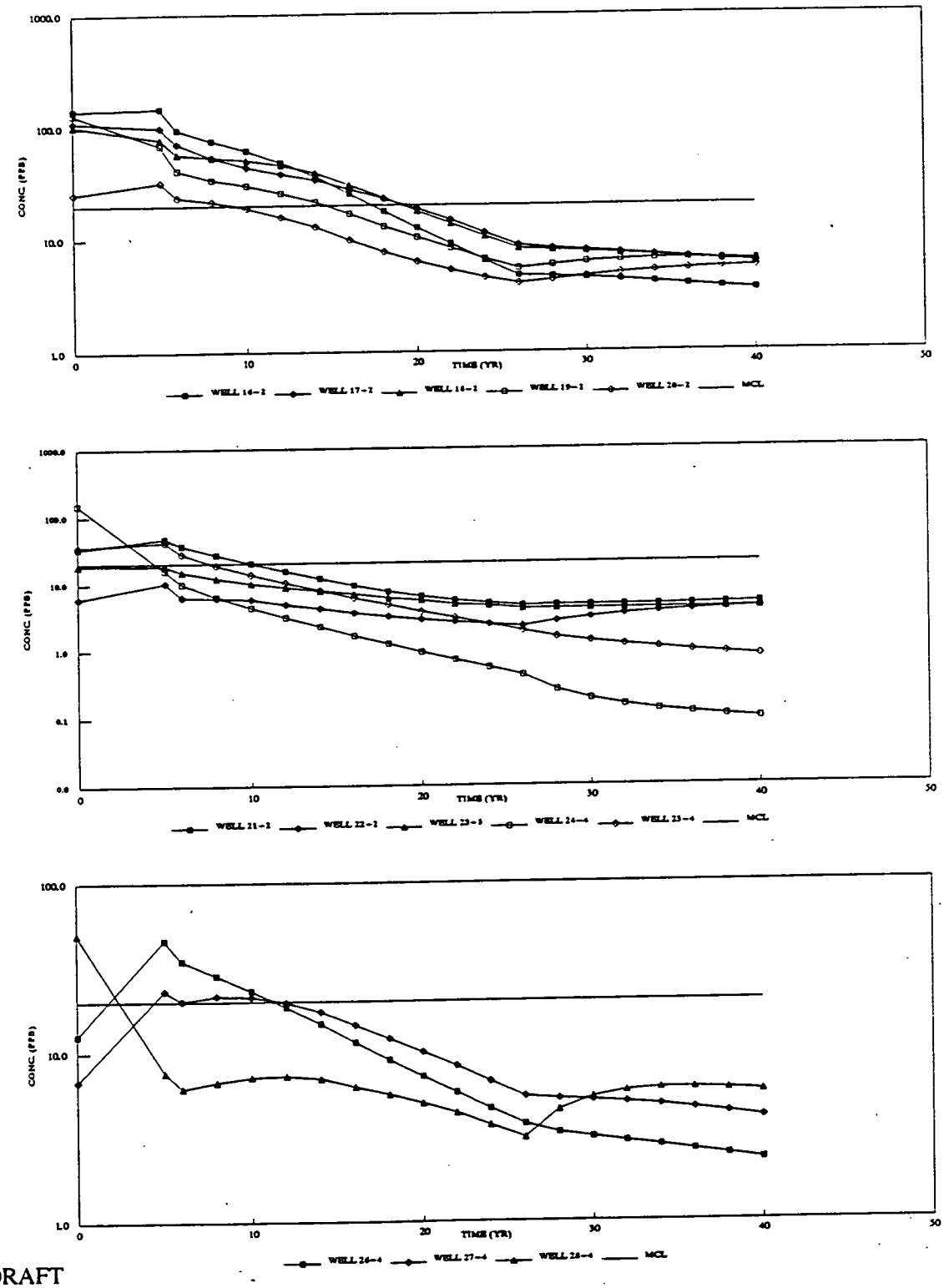
V2-5 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)



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V2-6 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)

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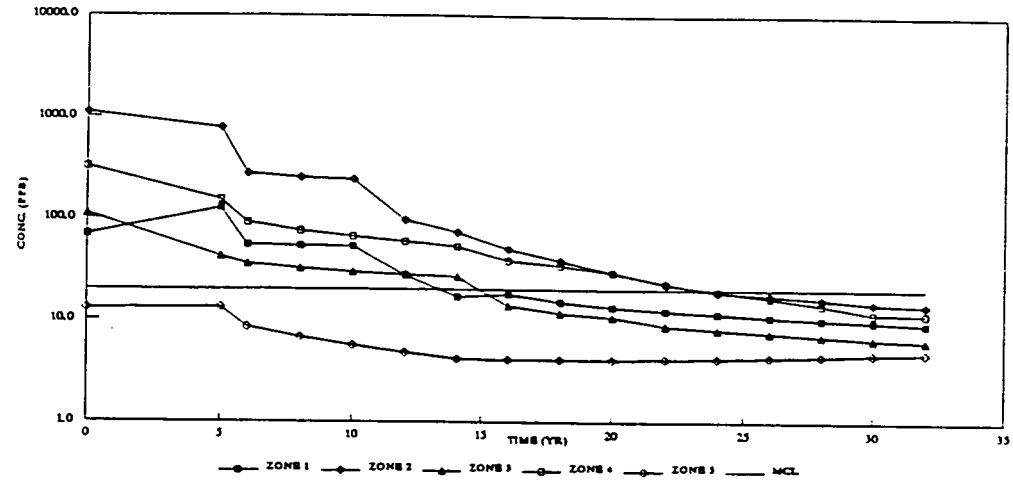
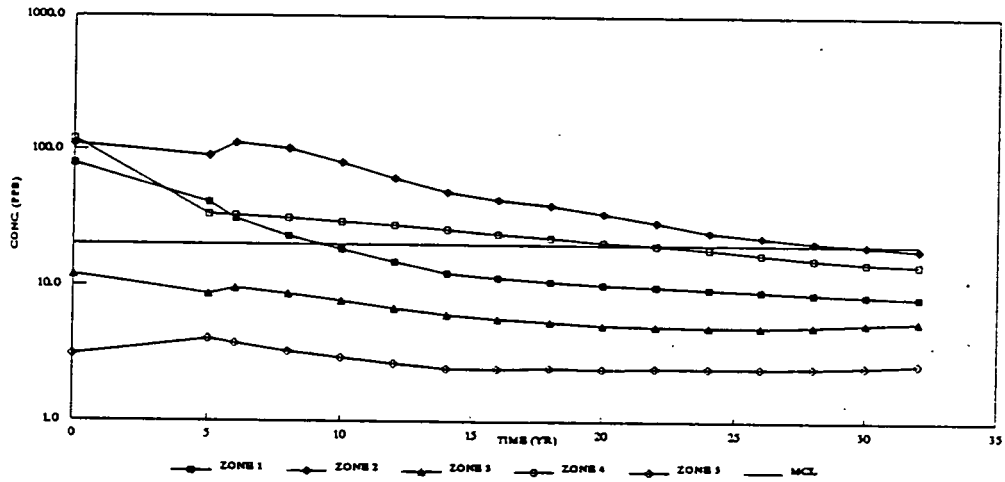
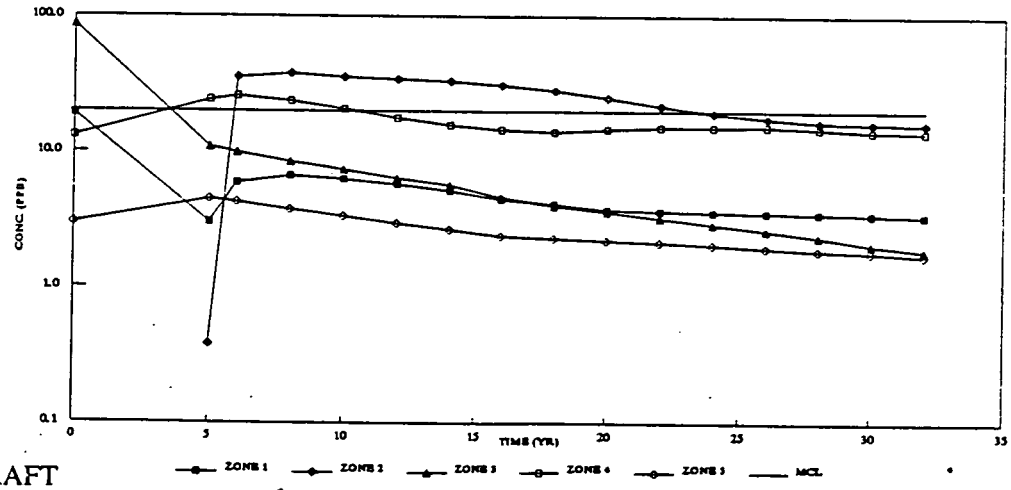


LAYER 1



LAYER 3



LAYER 6

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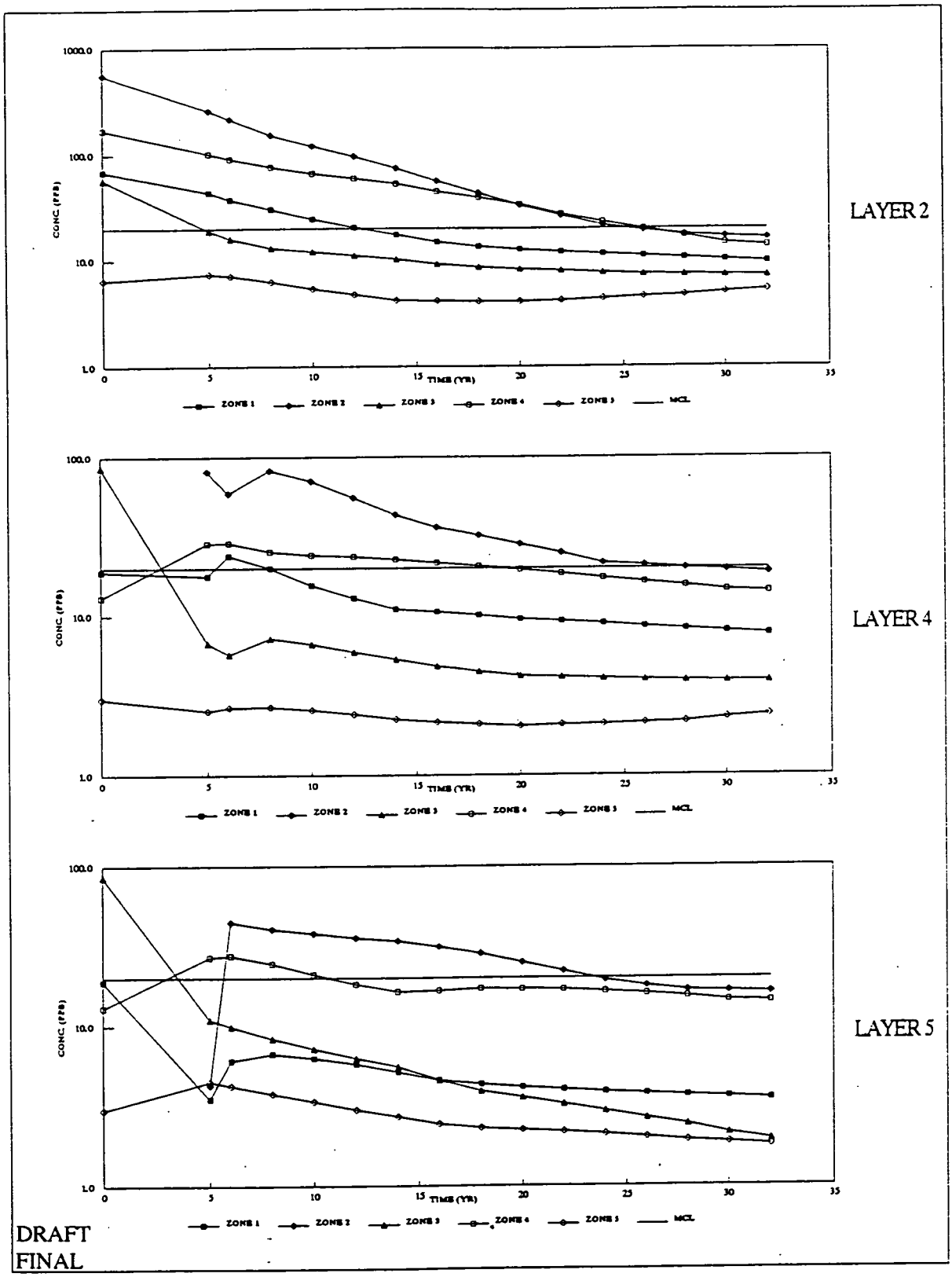
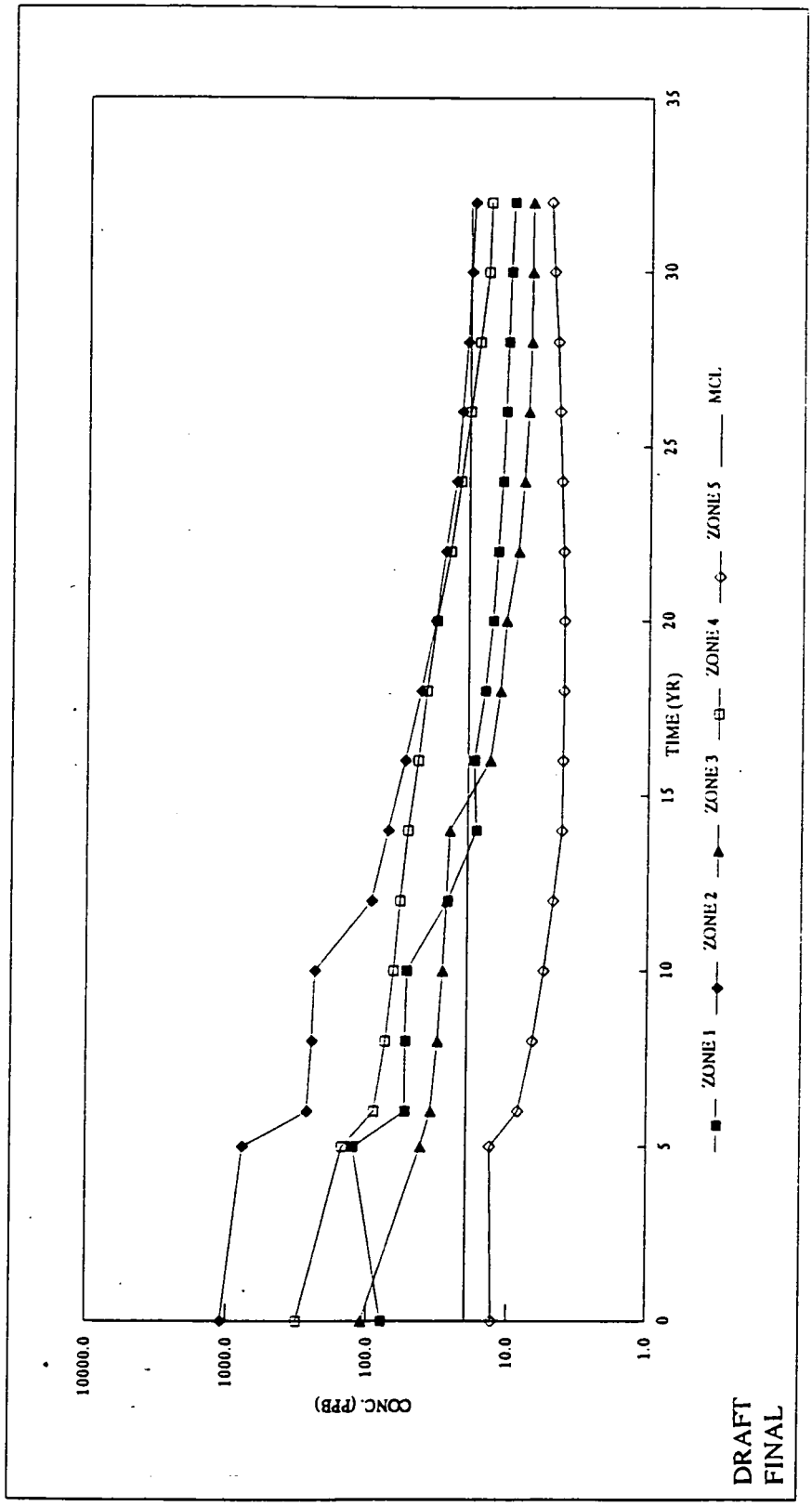
FINAL

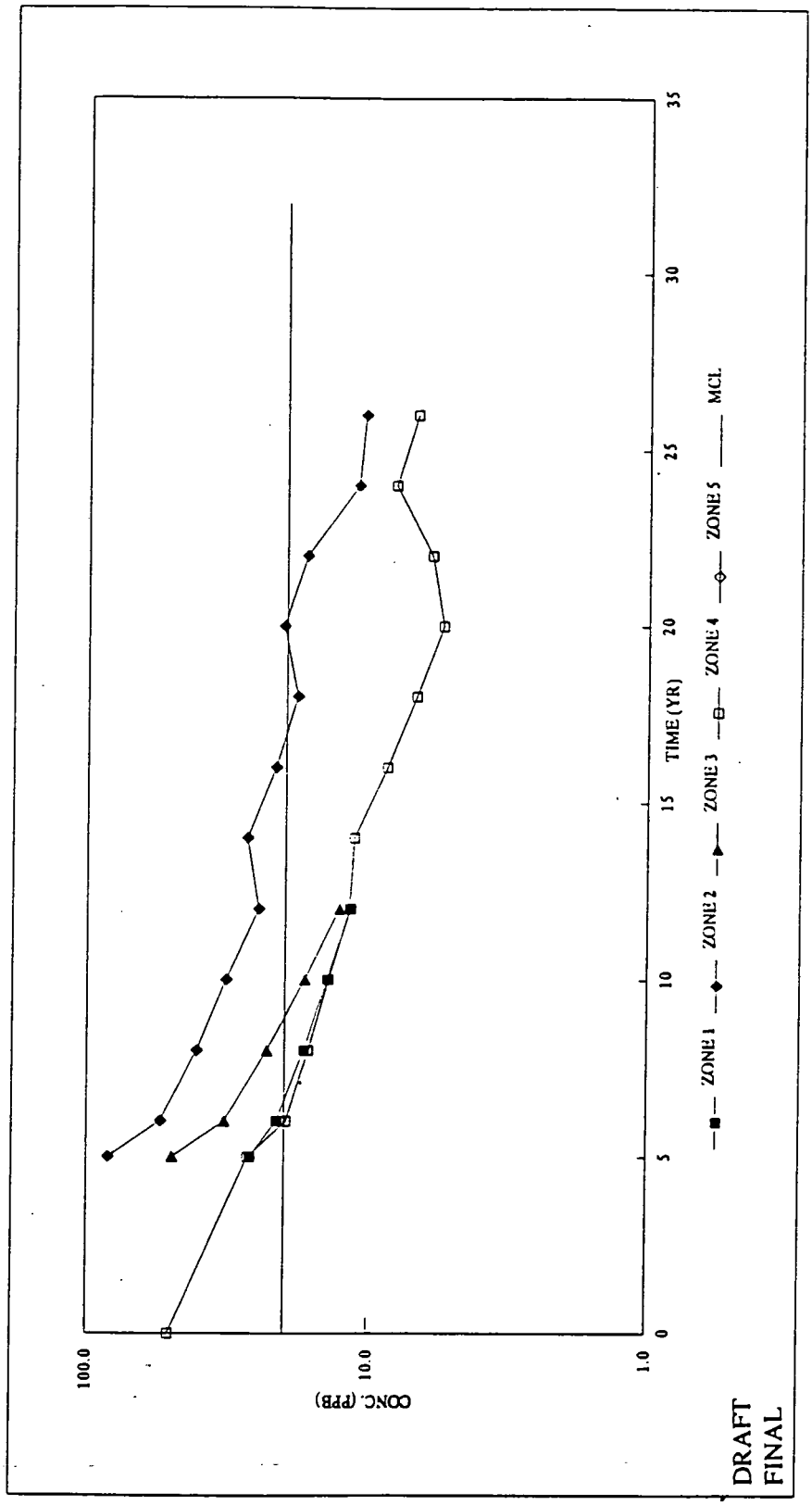
V3-1 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



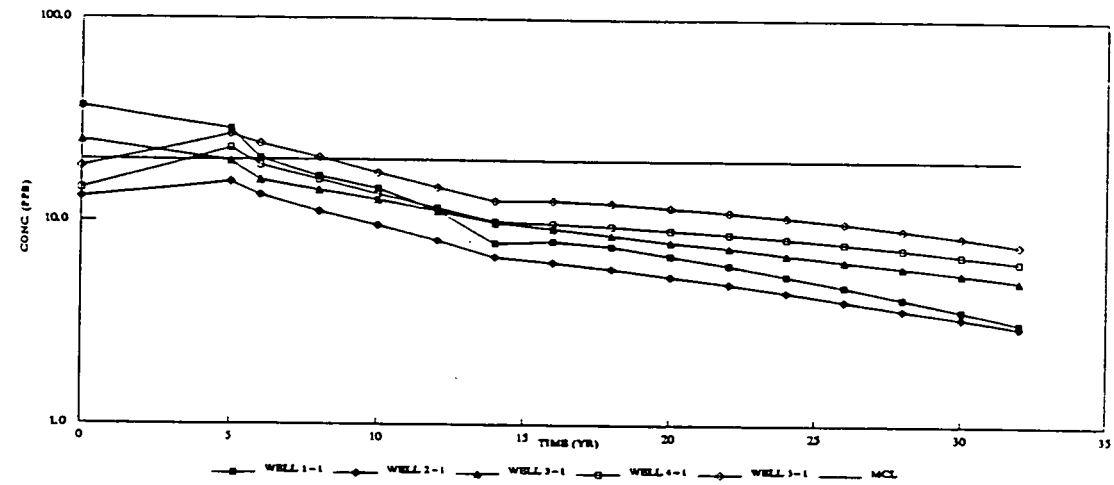
V3-2 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)

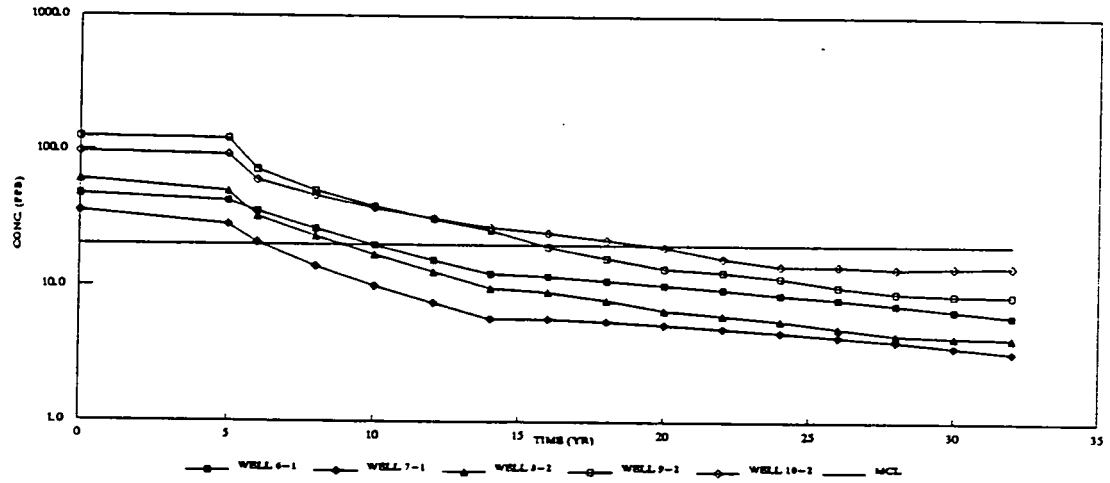


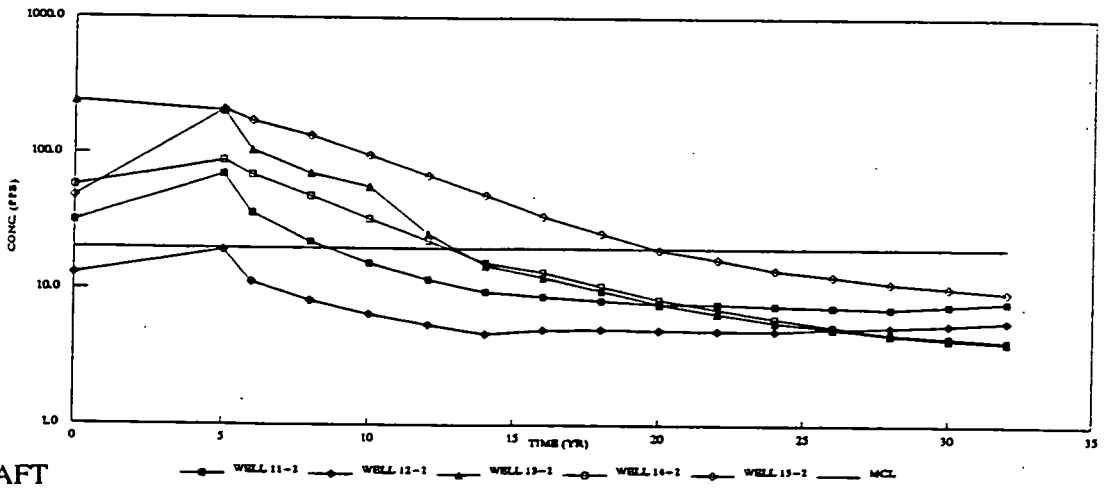
V3-3 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE



V3-4 - VARIABLE PUMPING RATE, SYSTEM AVERAGE CONCENTRATIONS VS. TIME







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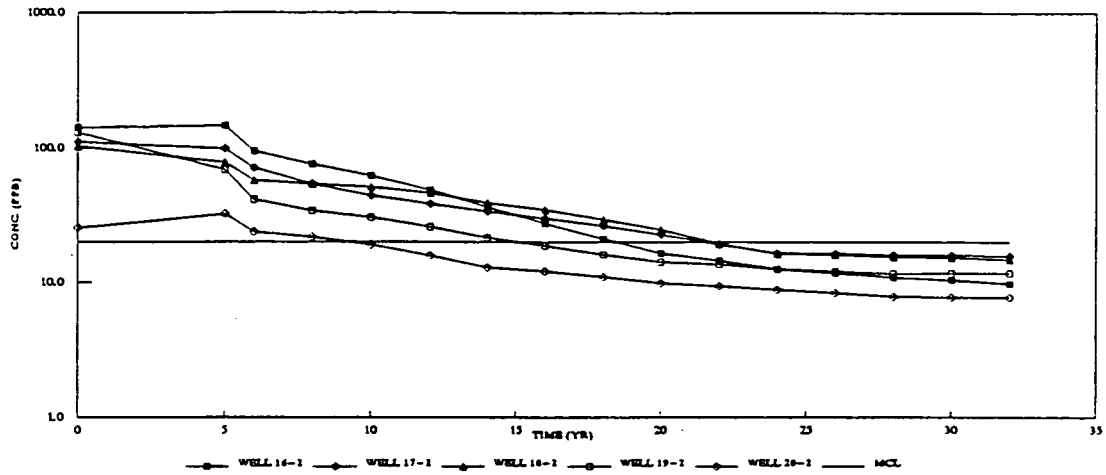
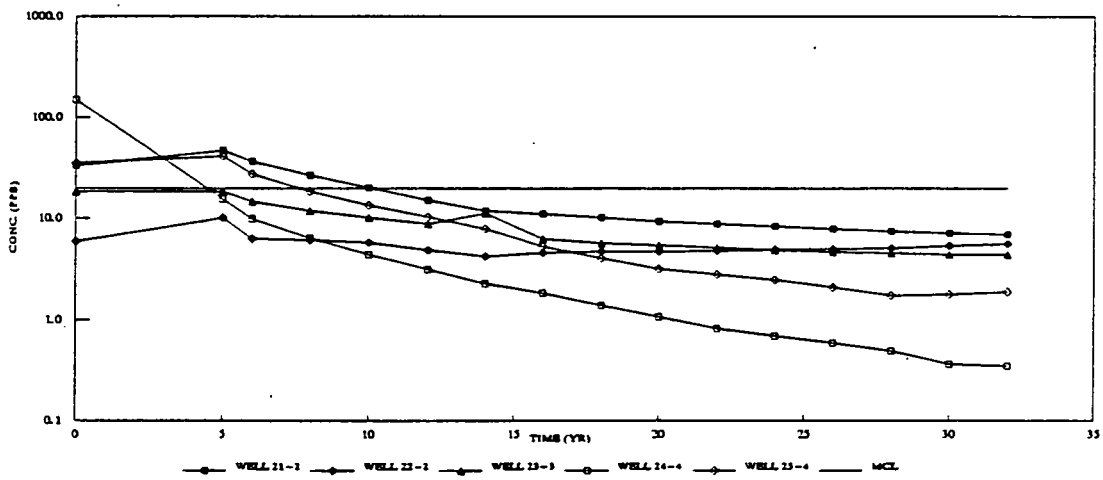
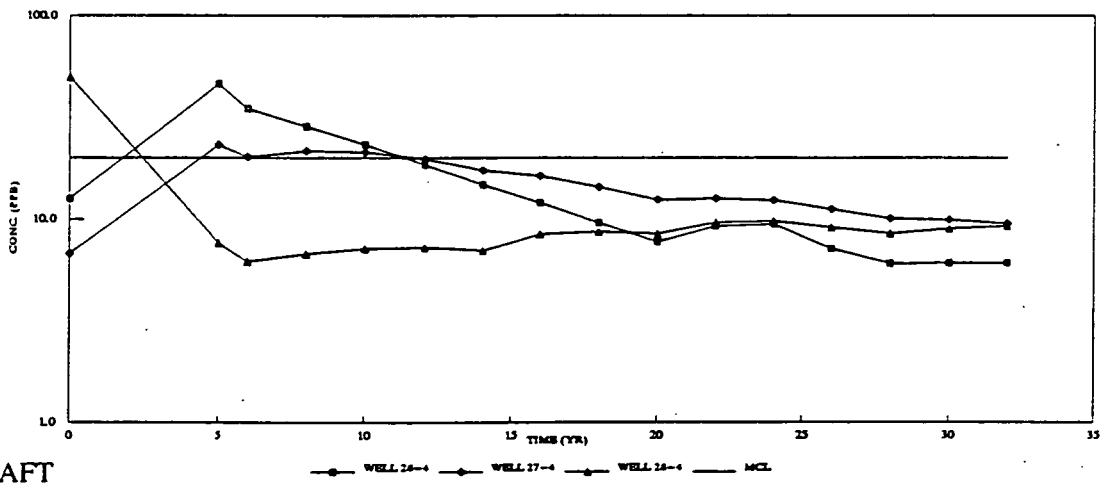
FINAL

V3-5 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)







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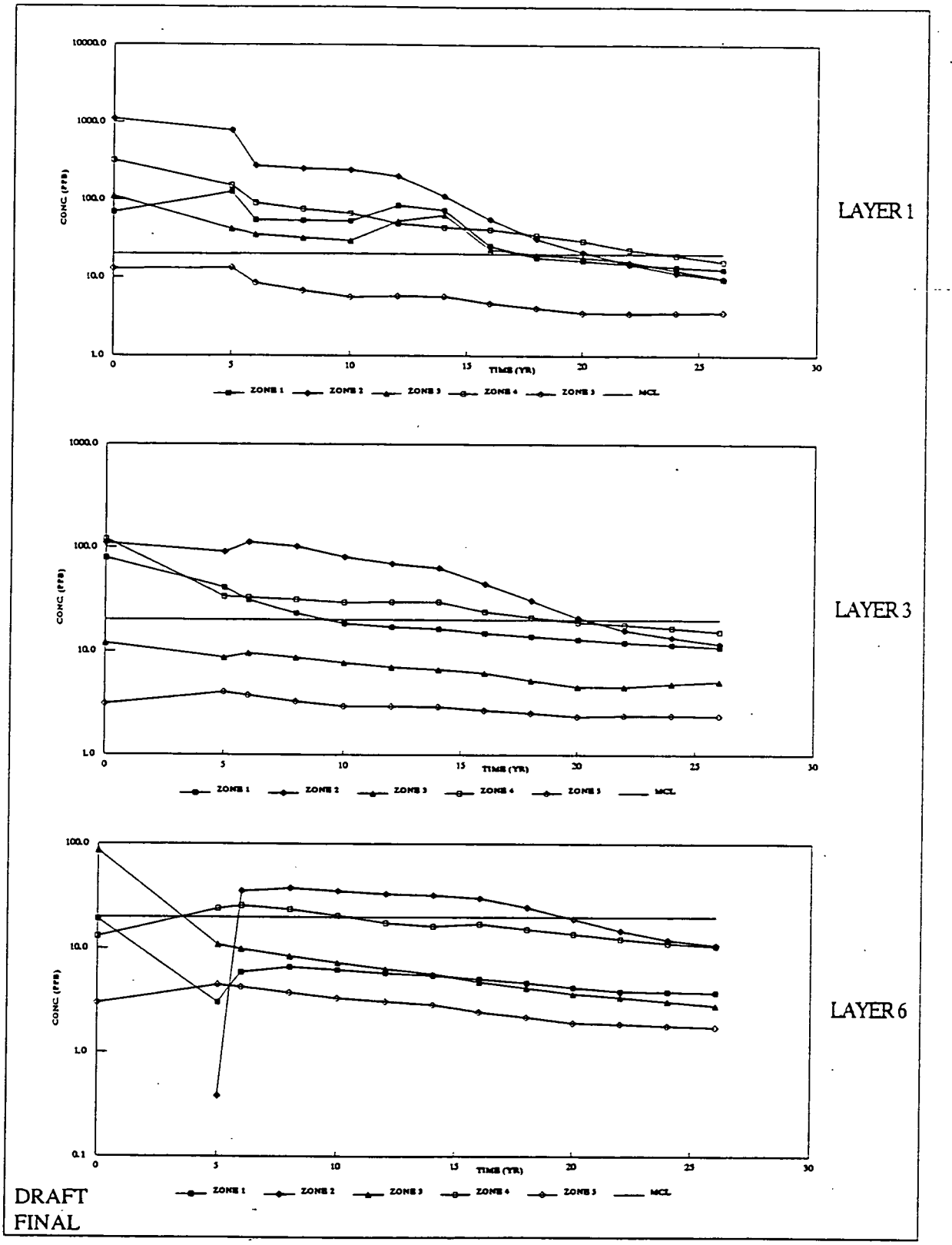
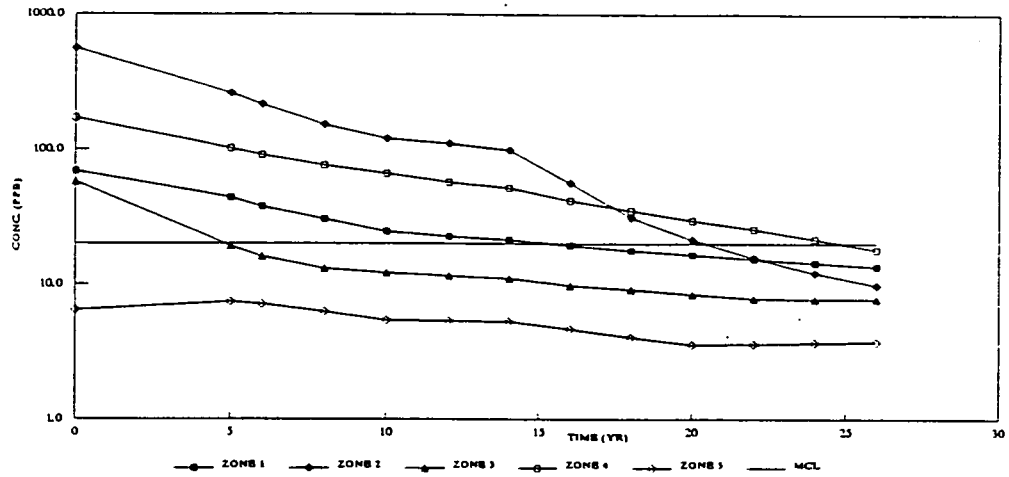
FINAL

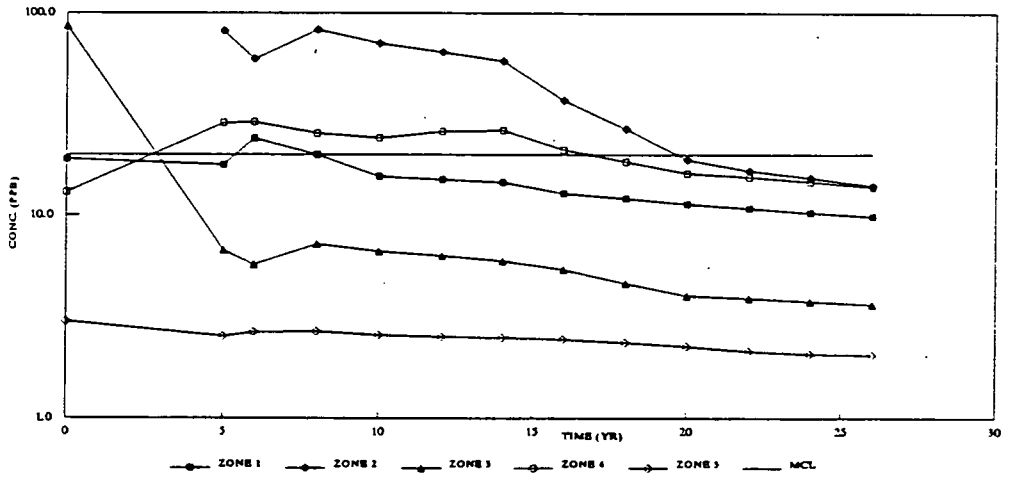
V3-6 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)



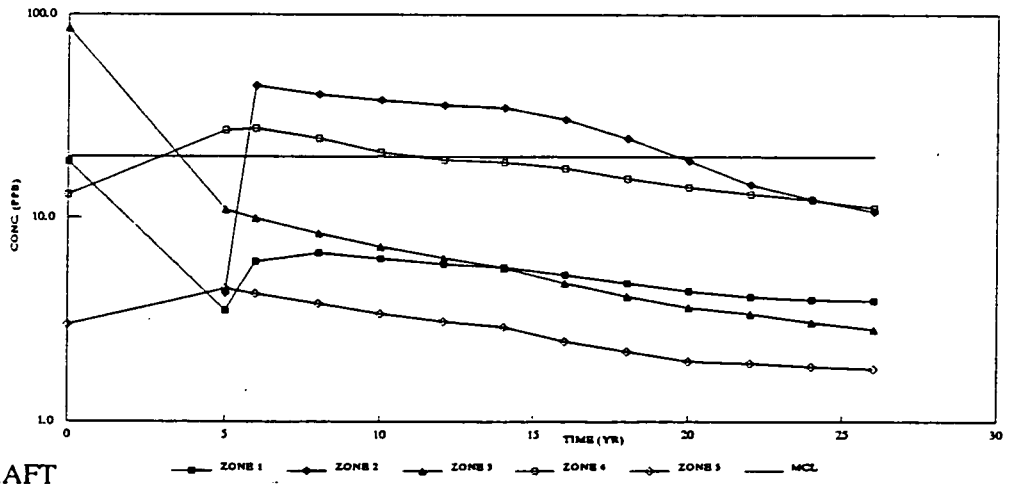
V4-1 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



LAYER 2



LAYER 4



LAYER 5

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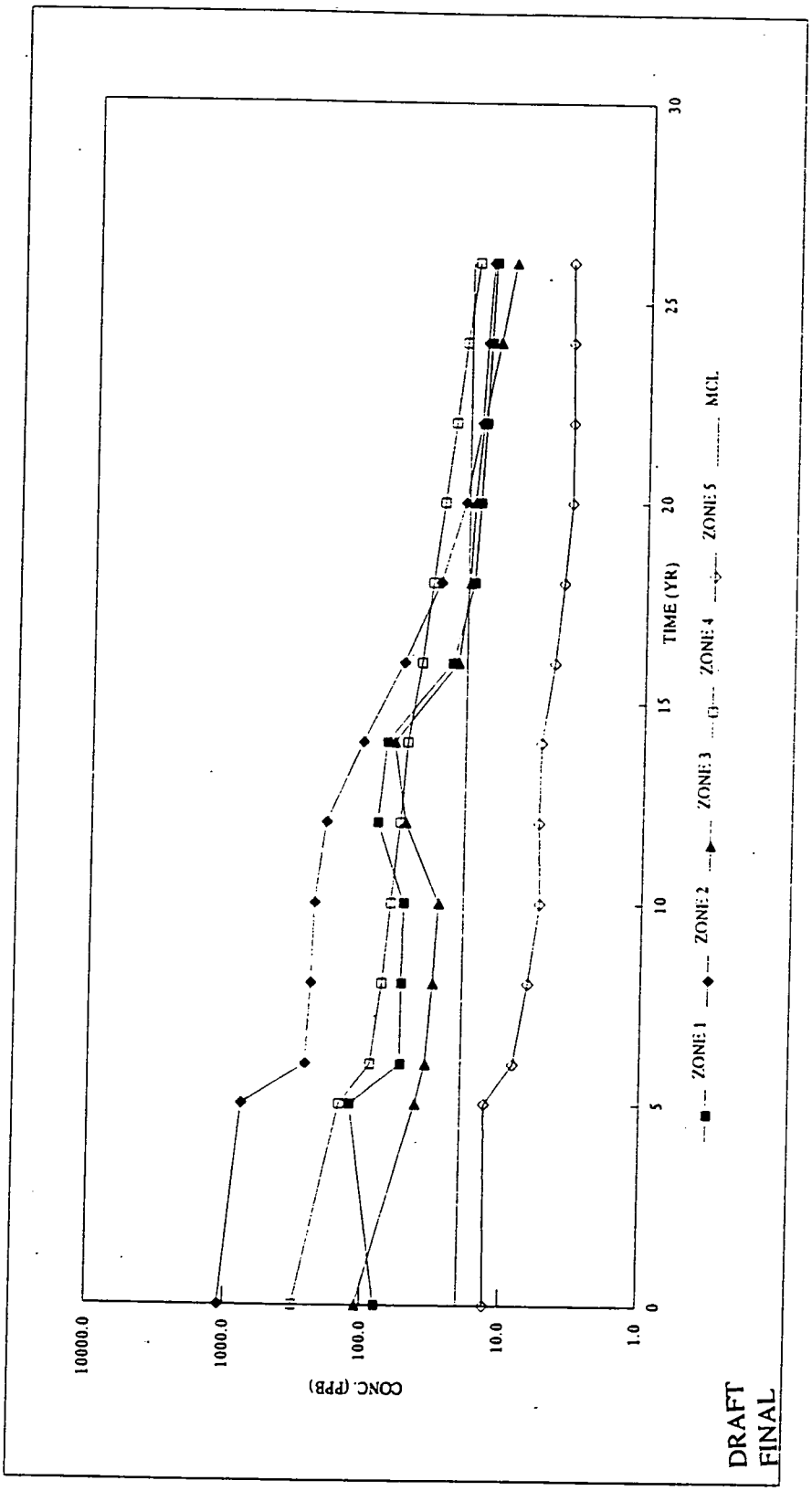
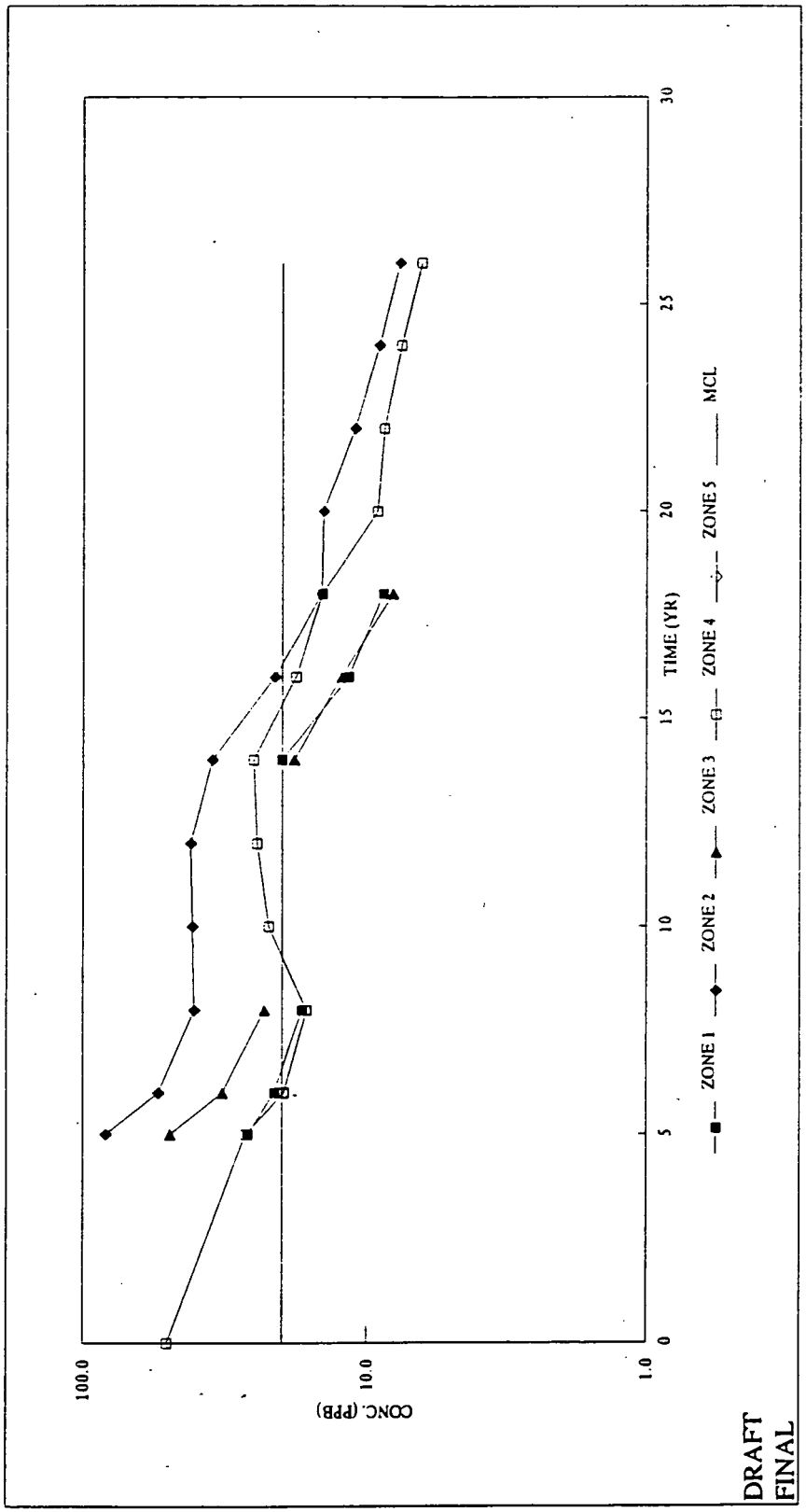
FINAL

V4-2 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)



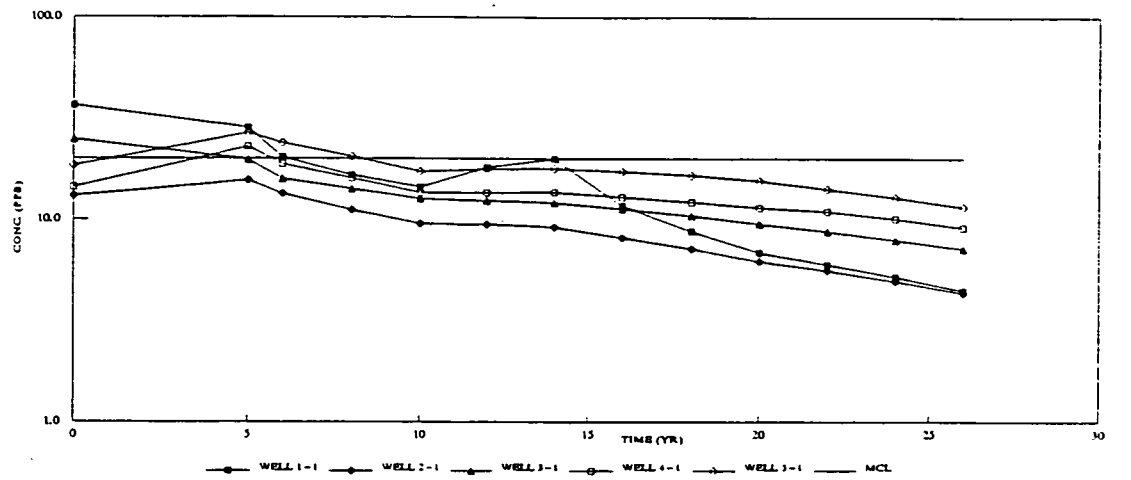
V4-3 - VARIABLE PUMPING RATE, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE

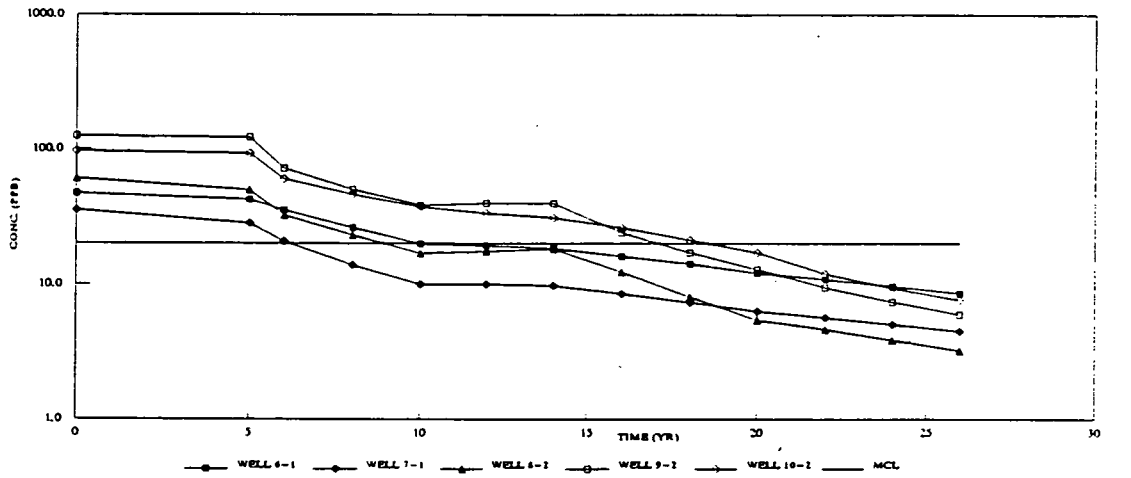
FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 10, 1995 2:31pm

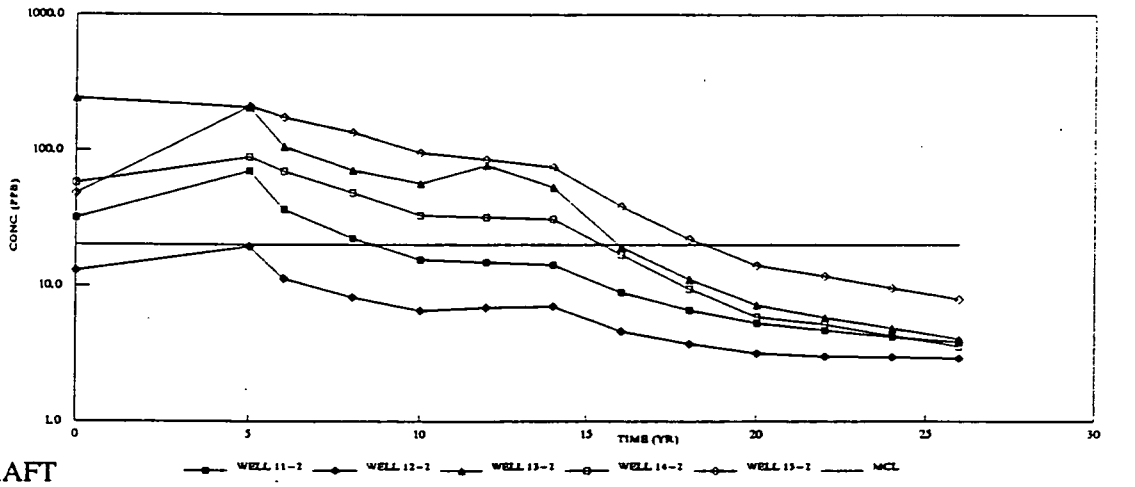


V4-4 - VARIABLE PUMPING RATE, SYSTEM AVERAGE CONCENTRATIONS VS. TIME

FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 10, 1995 2:31pm







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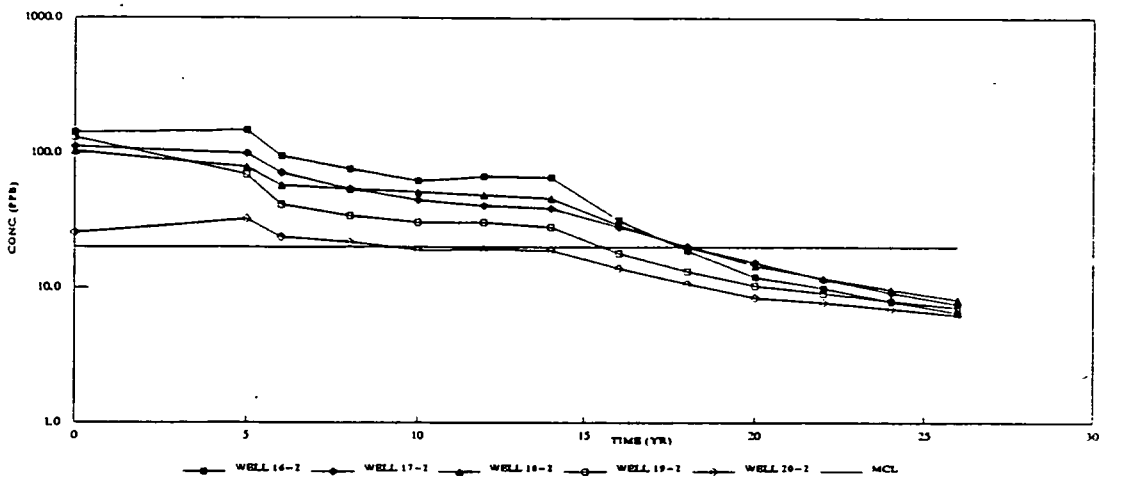
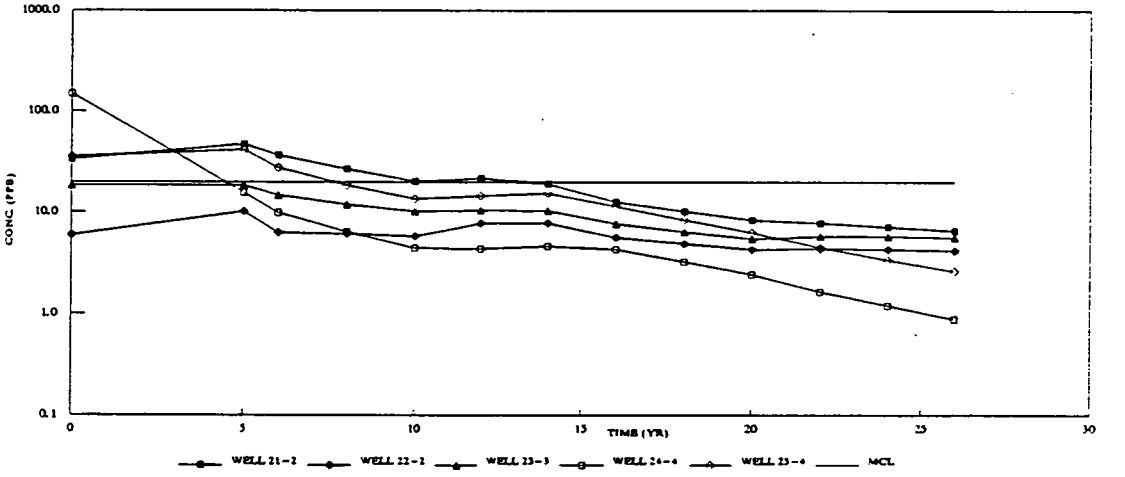
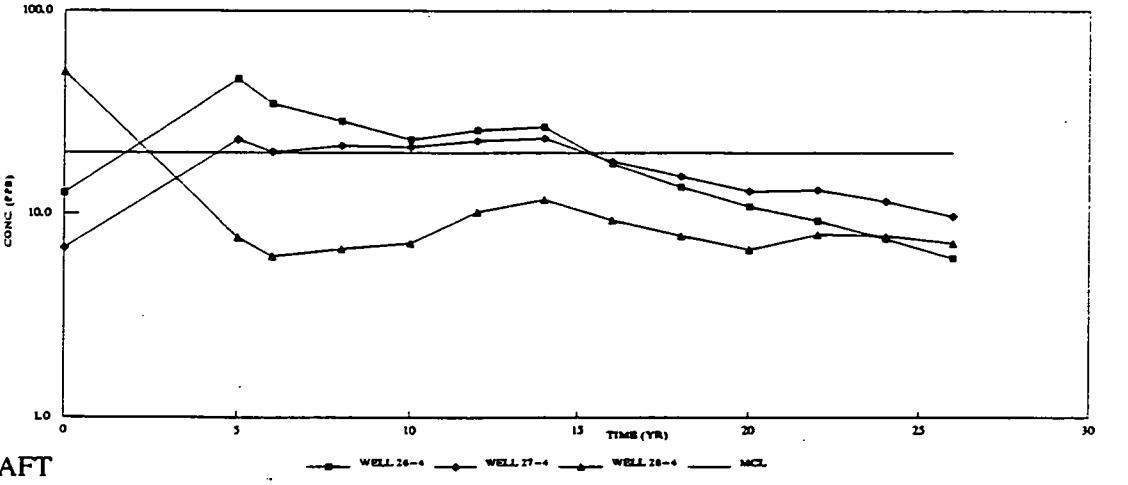
FINAL

V4-5 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)







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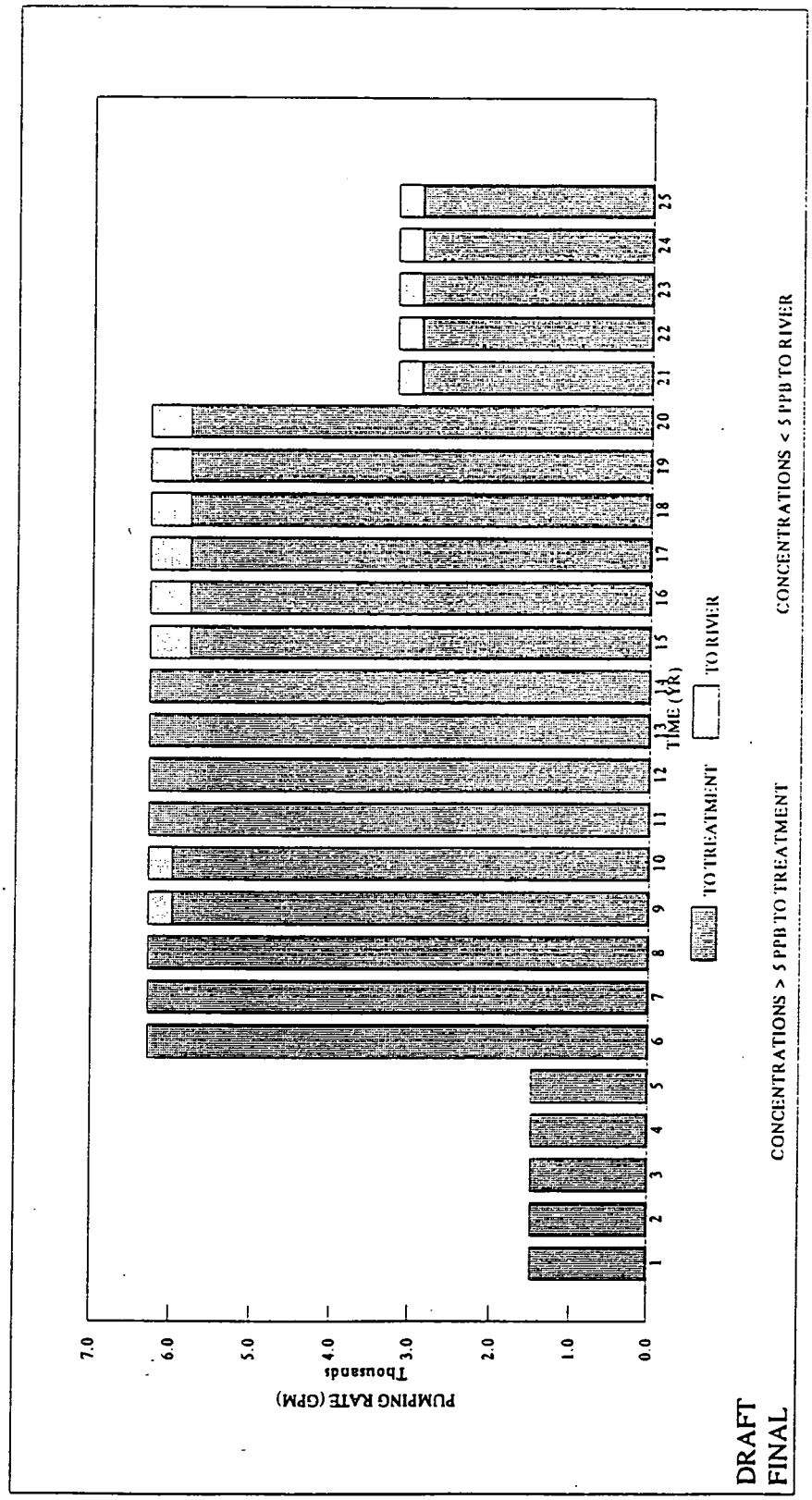
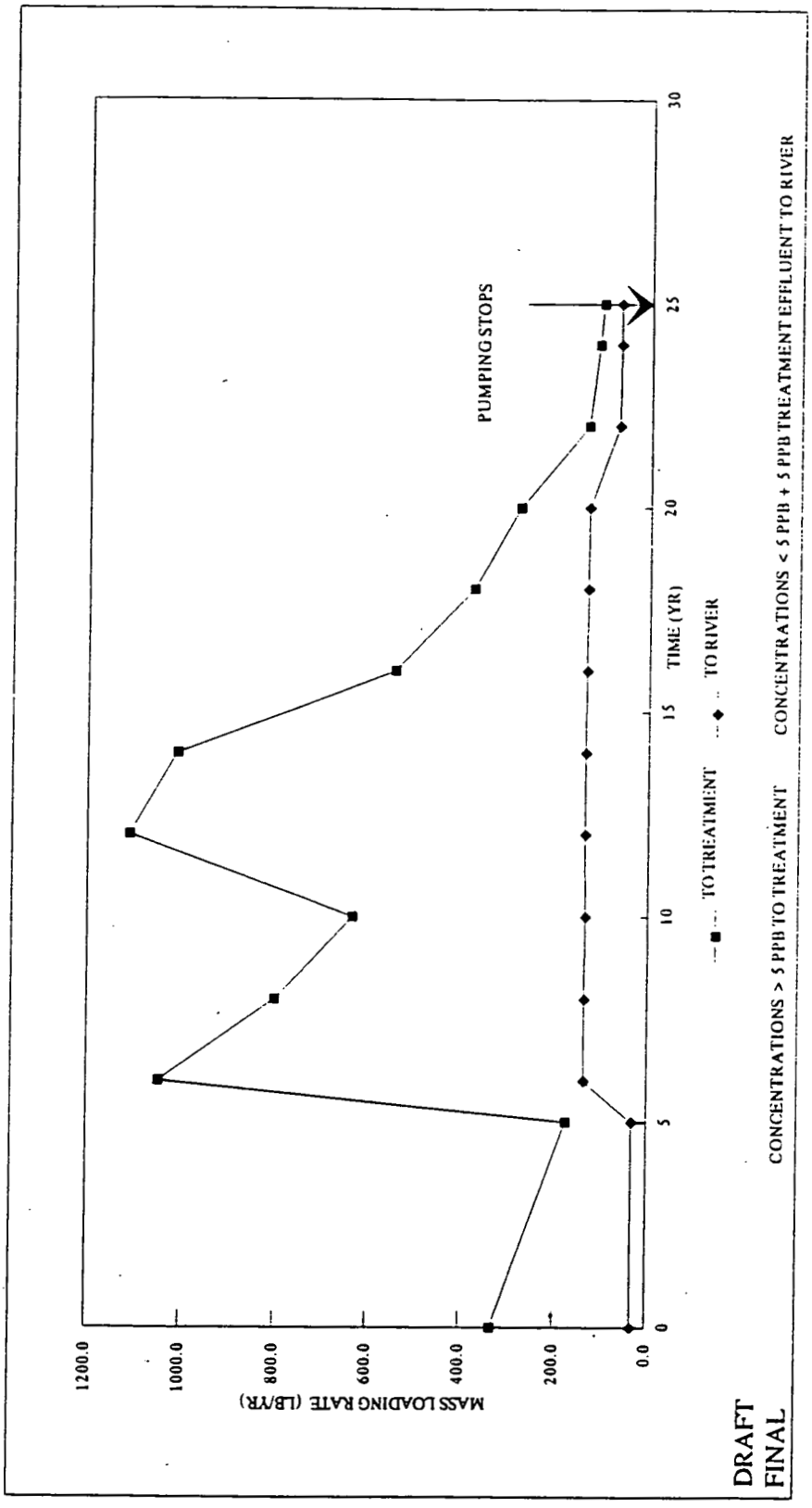
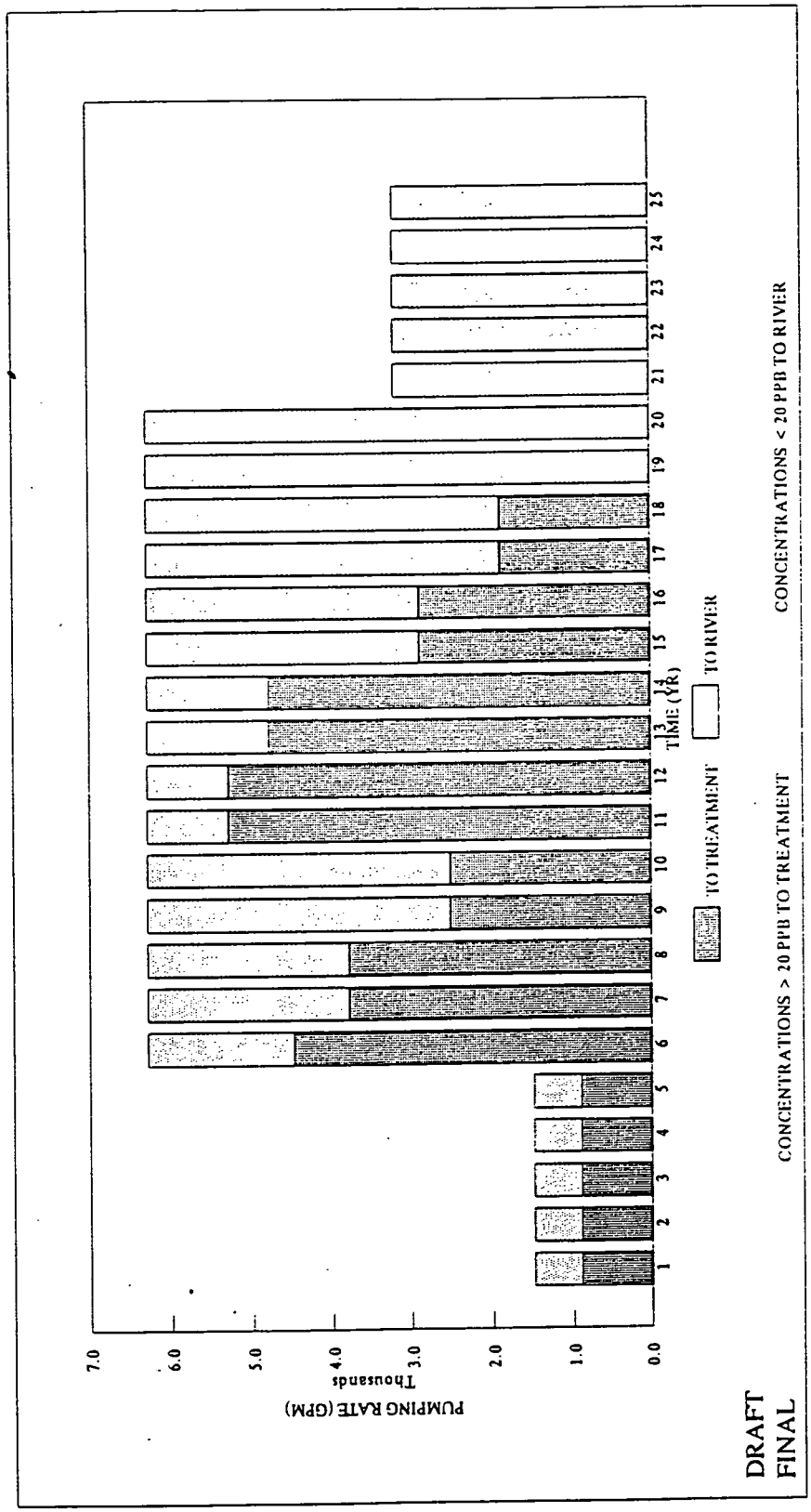
V4-6 - VARIABLE PUMPING RATE, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)



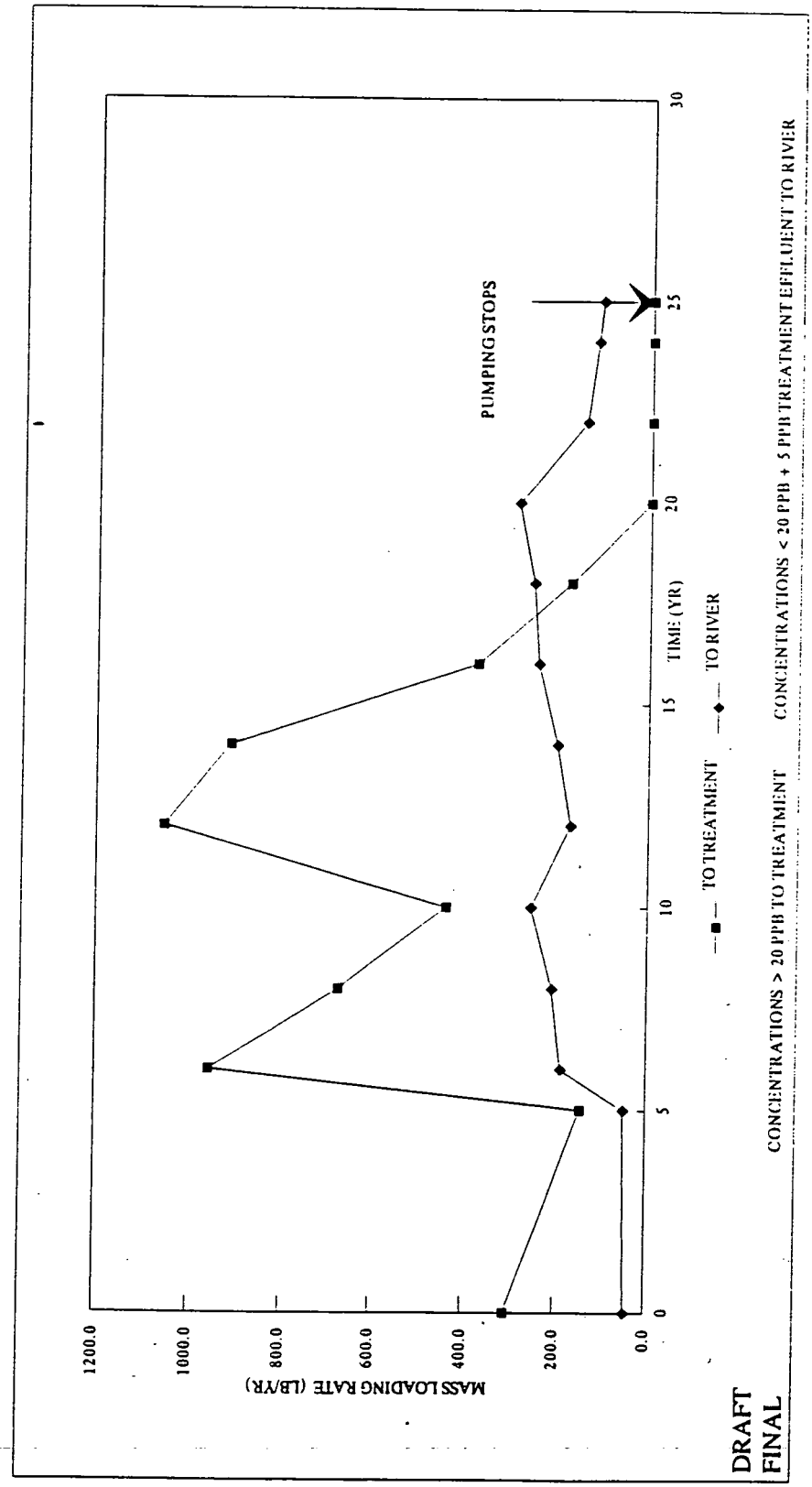
V4-7 - VARIABLE PUMPING RATE, TREATMENT RATE VS. TIME (TREAT > 5 PPB)



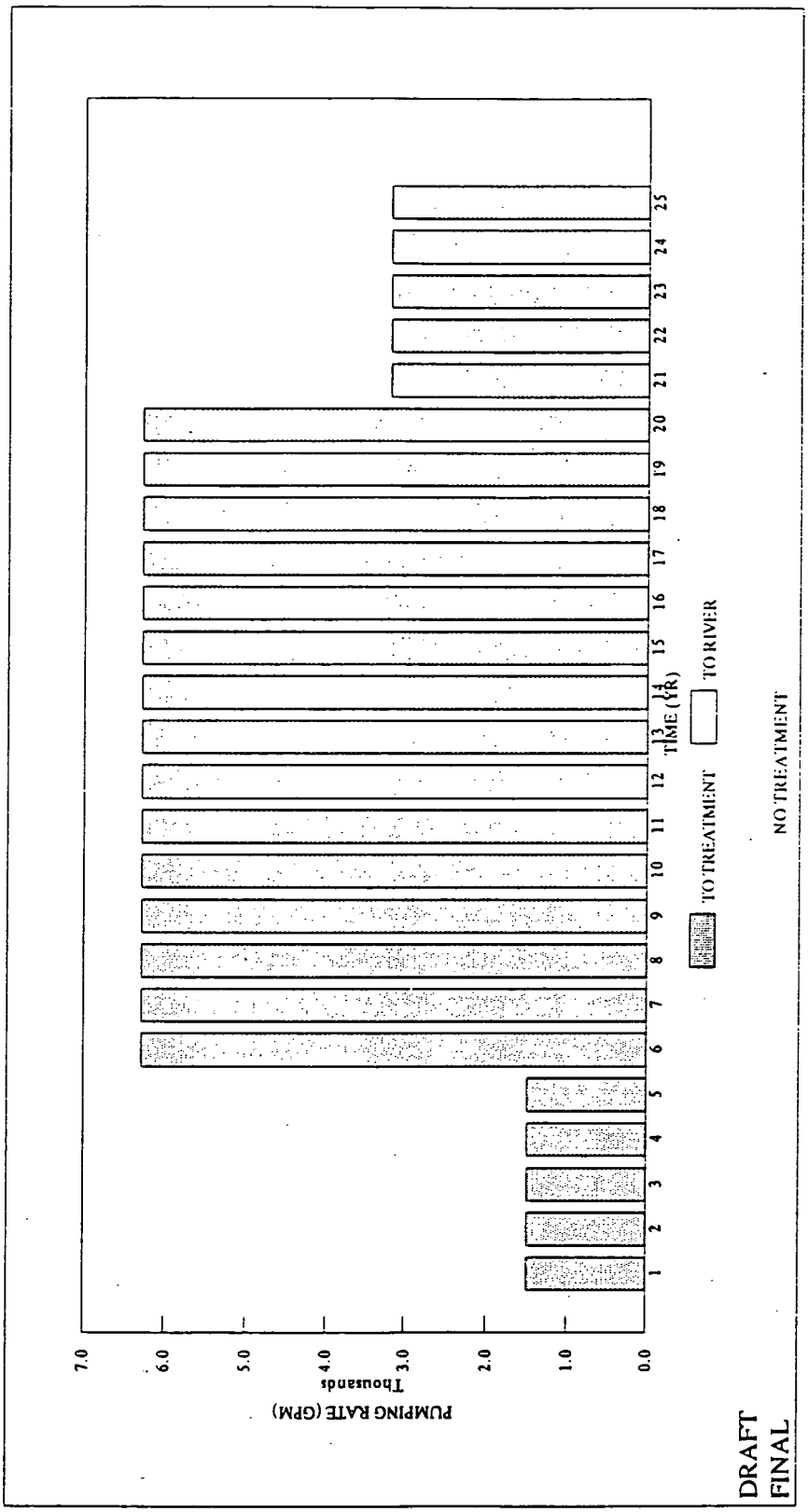
V4-8 - VARIABLE PUMPING RATE, MASS LOADING RATE VS. TIME (TREAT > 5 PPB)



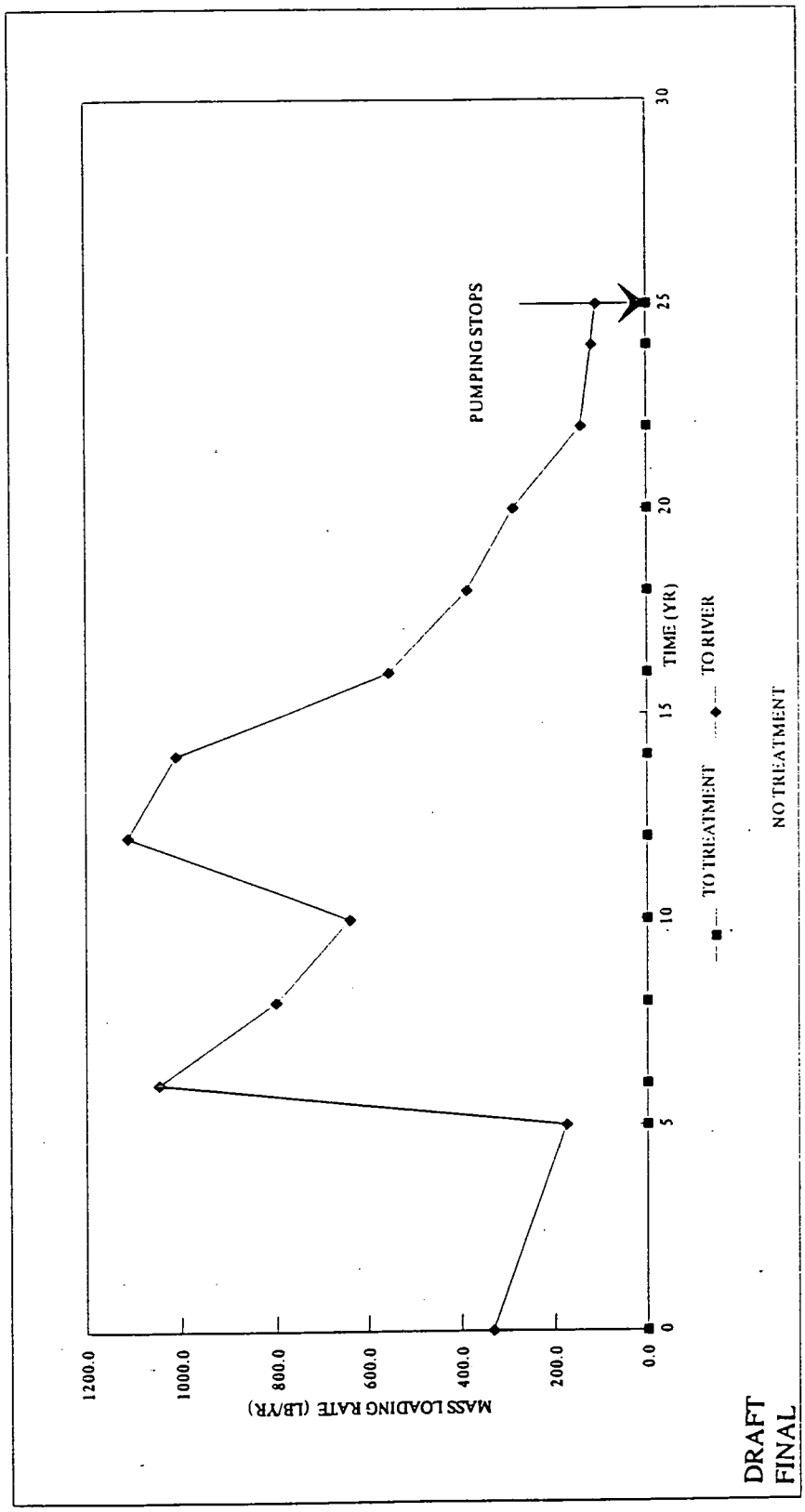
V4-9 - VARIABLE PUMPING RATE, TREATMENT RATE VS. TIME (TREAT > 20 PPB)



V4-10 - VARIABLE PUMPING RATE, MASS LOADING RATE VS. TIME (TREAT > 20 PPB)

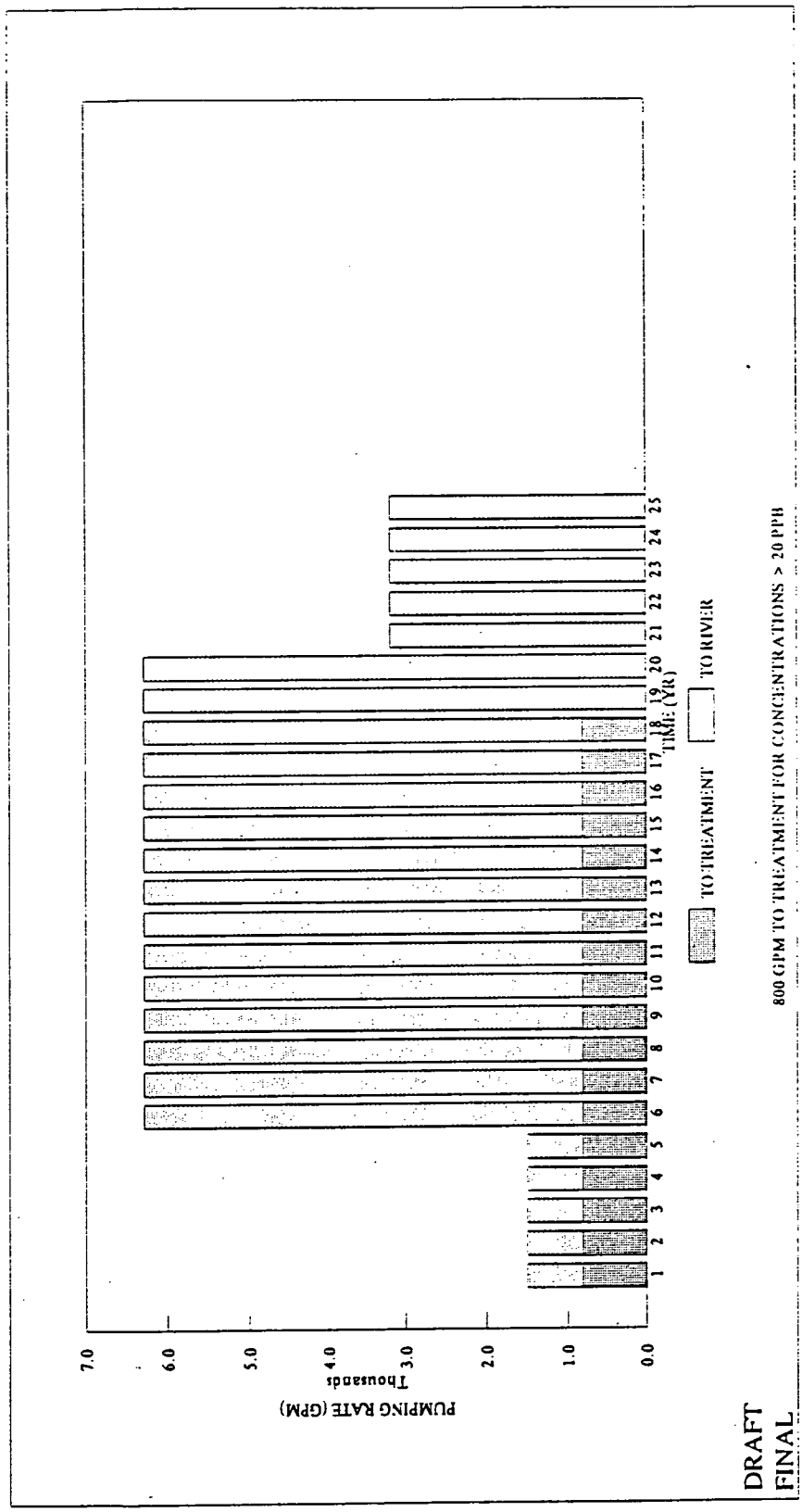


V4-11 - VARIABLE PUMPING RATE, TREATMENT RATE VS. TIME (NO TREATMENT)

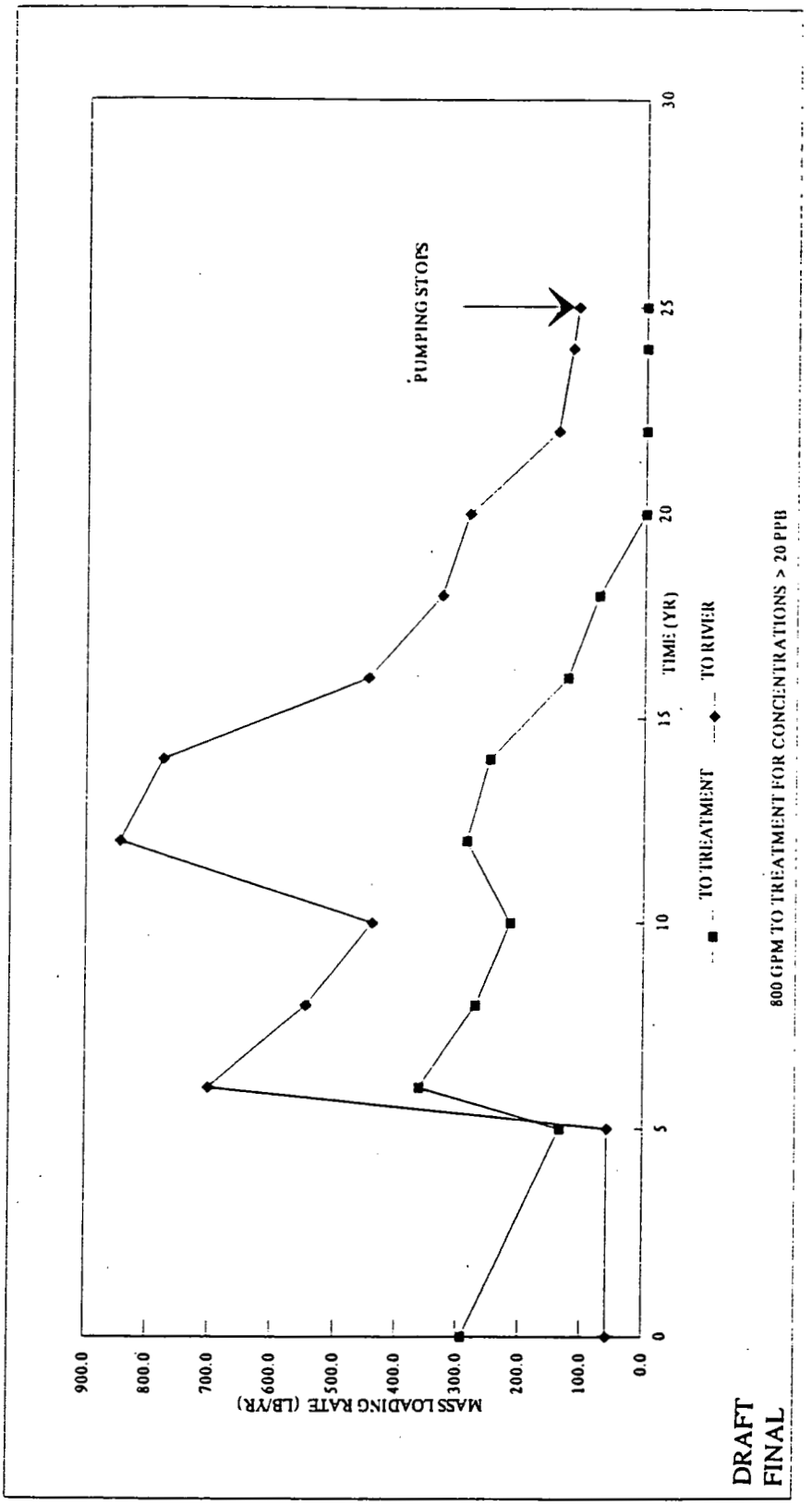


V4-12 - VARIABLE PUMPING RATE, MASS LOADING RATE VS. TIME (NO TREATMENT)

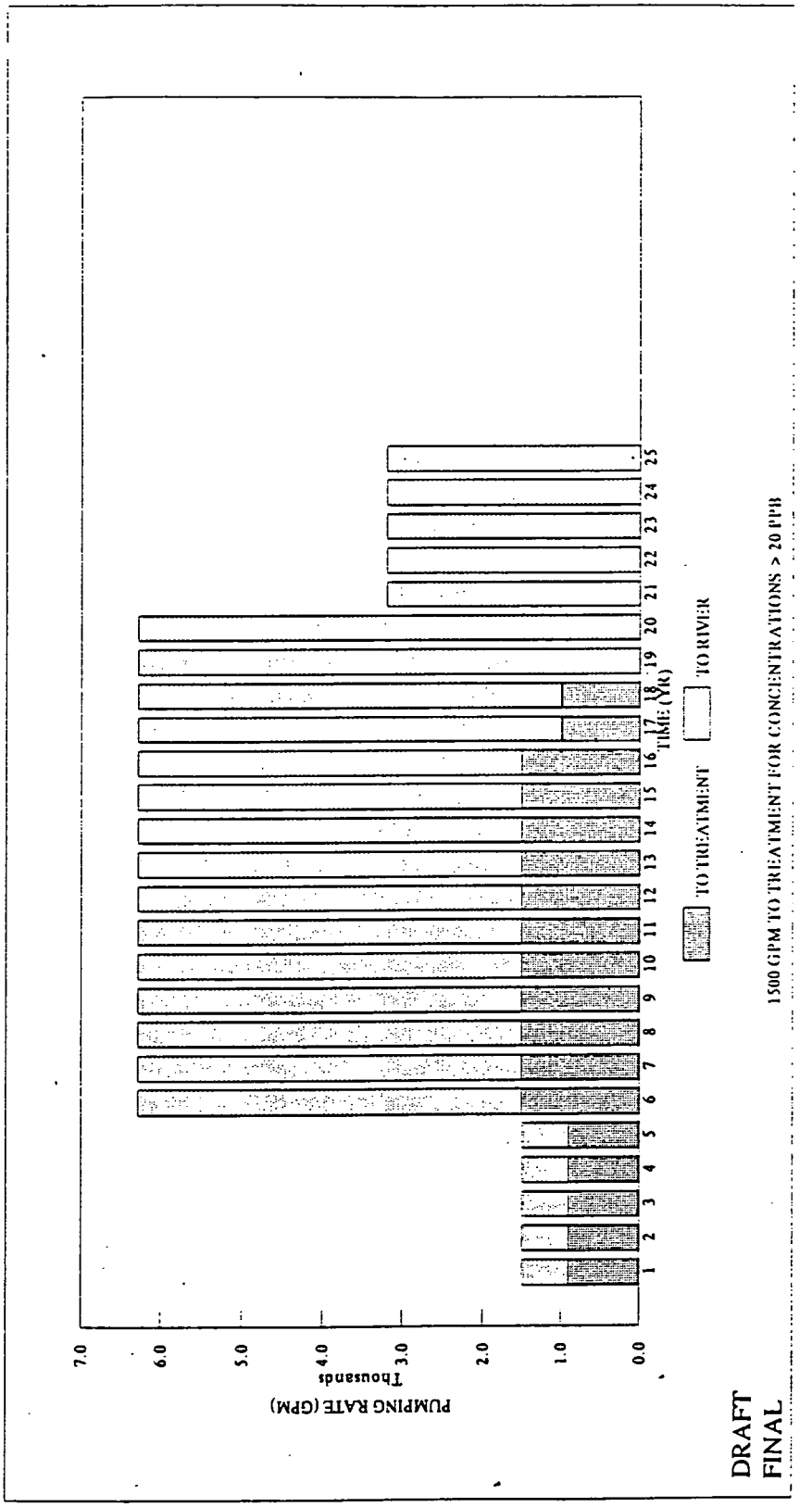
FER\CRU5\APXS\APP-F\SECT-8\ATTACH\F8-IIF.PGS March 10, 1995 2:31pm



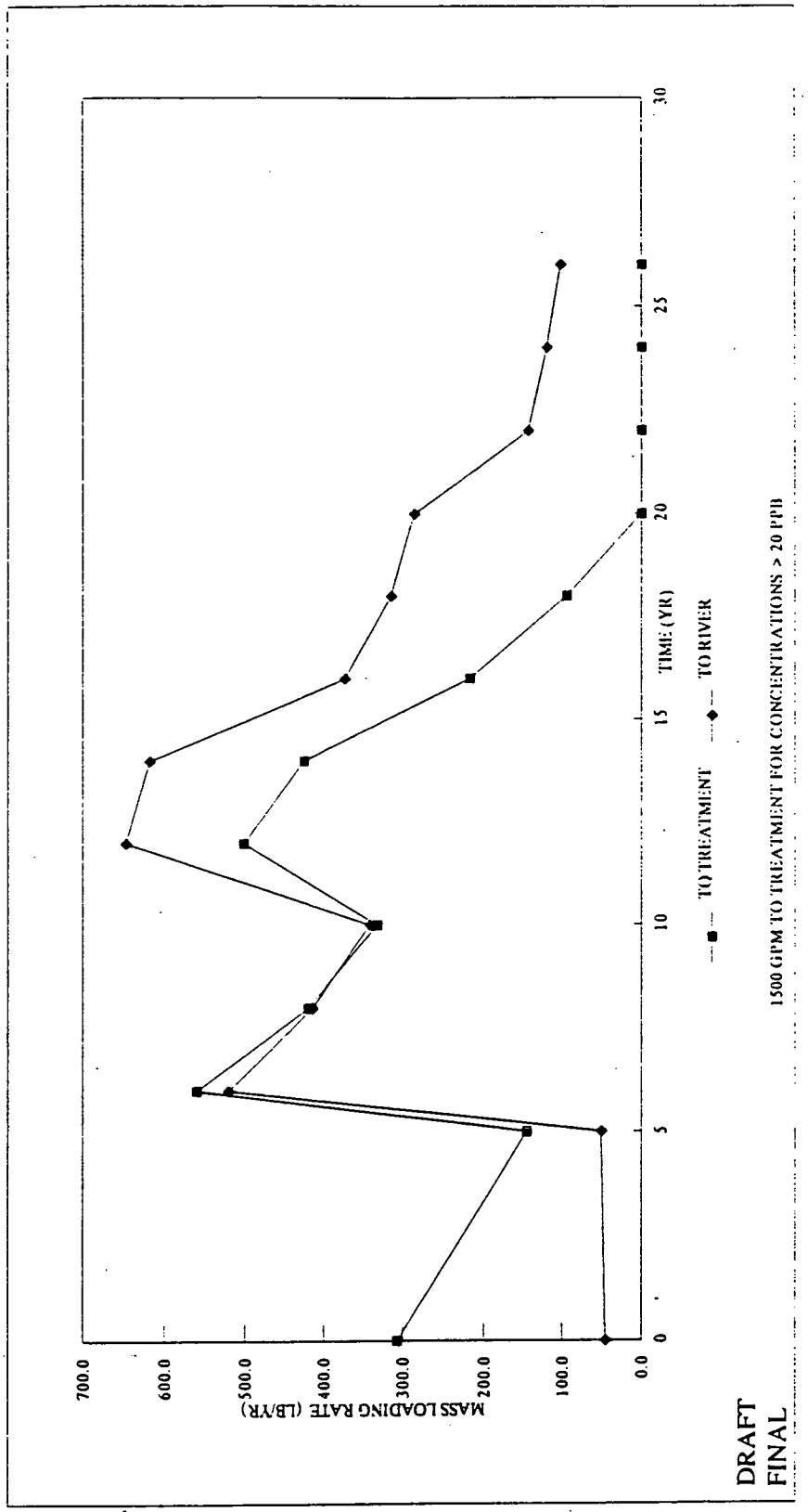
V4-13 - VARIABLE PUMPING RATE, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 800 GPM)



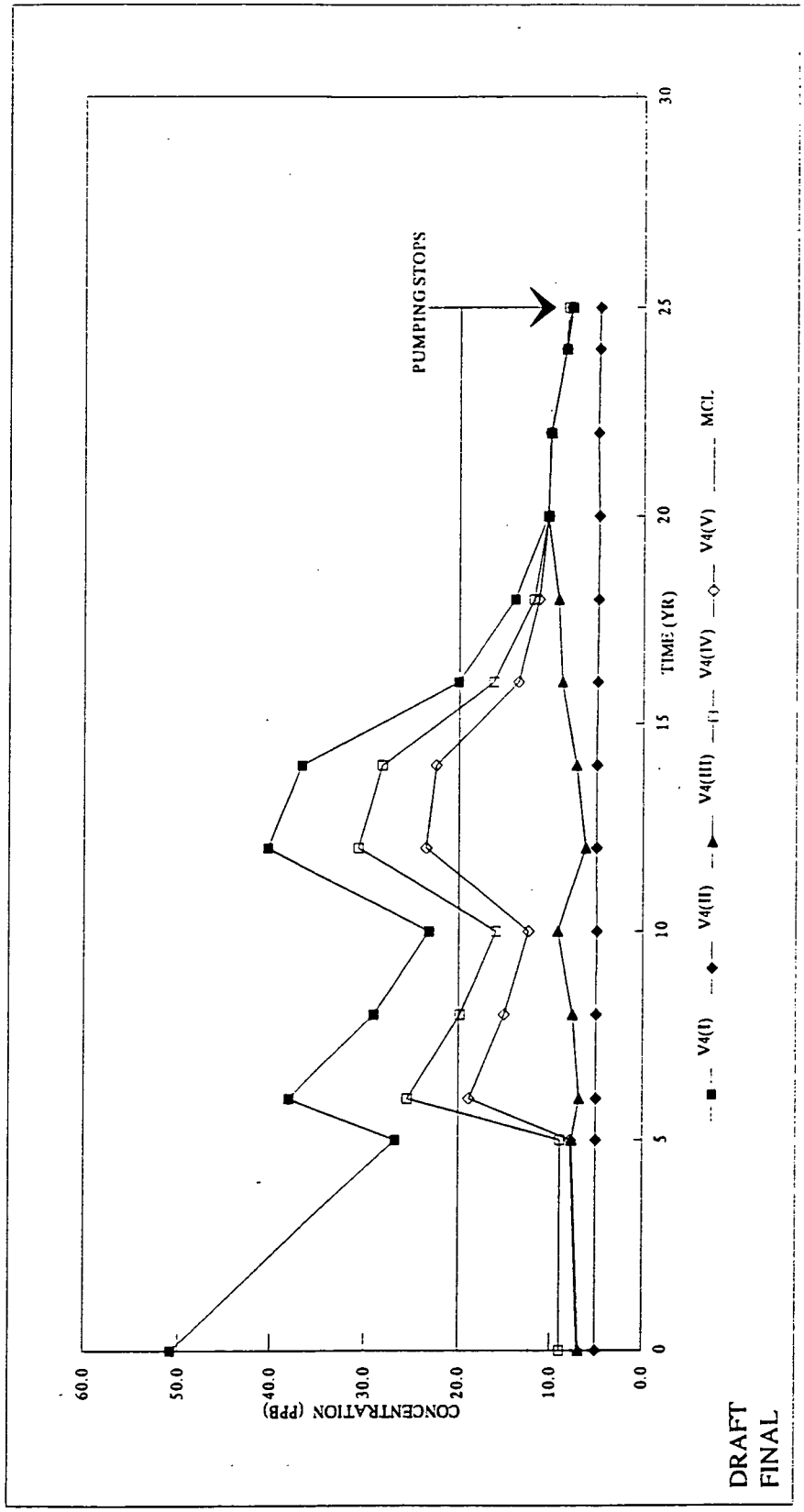
V4-14 - VARIABLE PUMPING RATE, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 800 GPM)



V4-15 - VARIABLE PUMPING RATE, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM)



V4-16 - VARIABLE PUMPING RATE, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM)



V4-17 - VARIABLE PUMPING, BLENDED OUTFALL CONCENTRATION VS. TIME

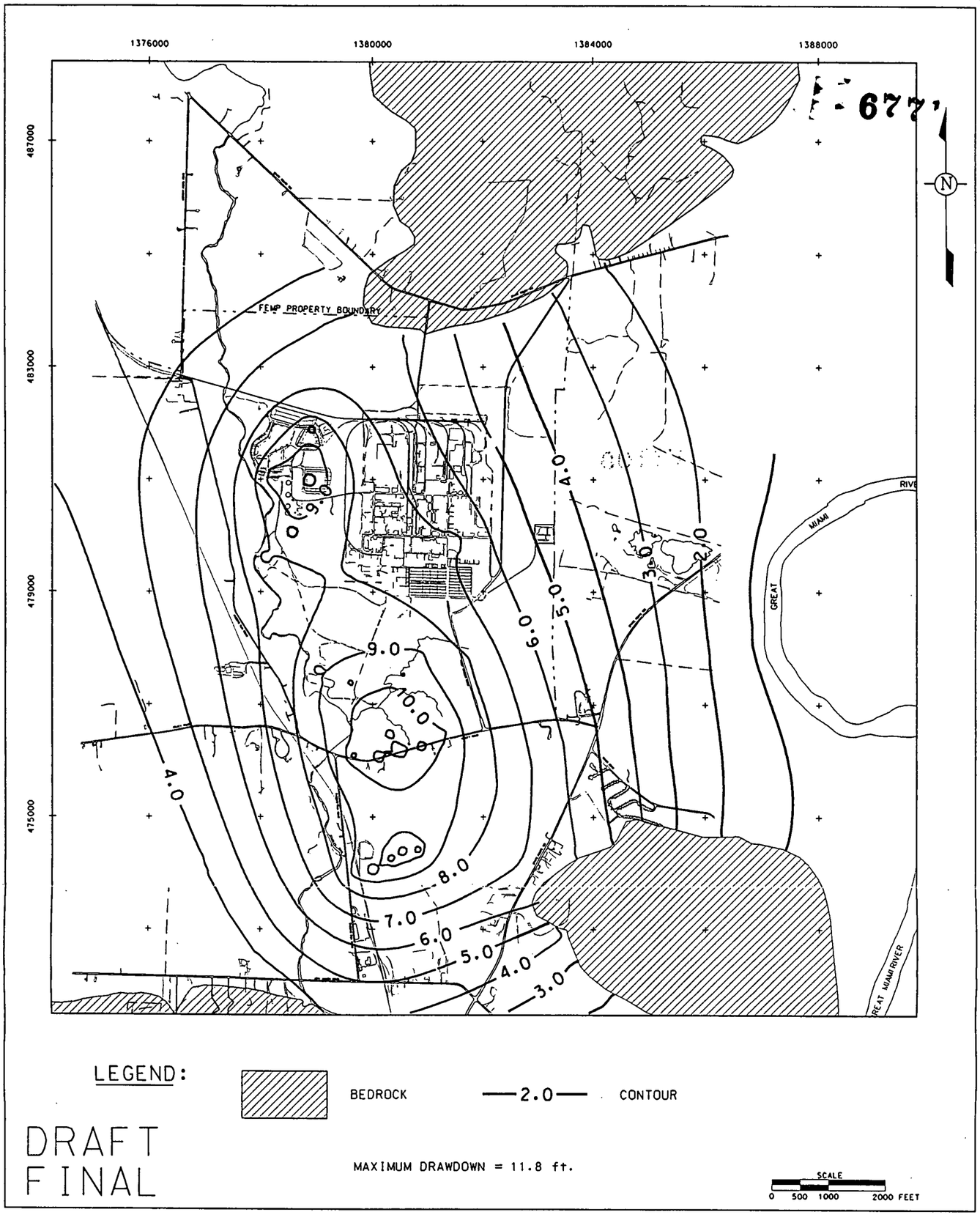


FIGURE V4-18. VARIABLE PUMPING, GROUNDWATER DRAWDOWN CONTOURS

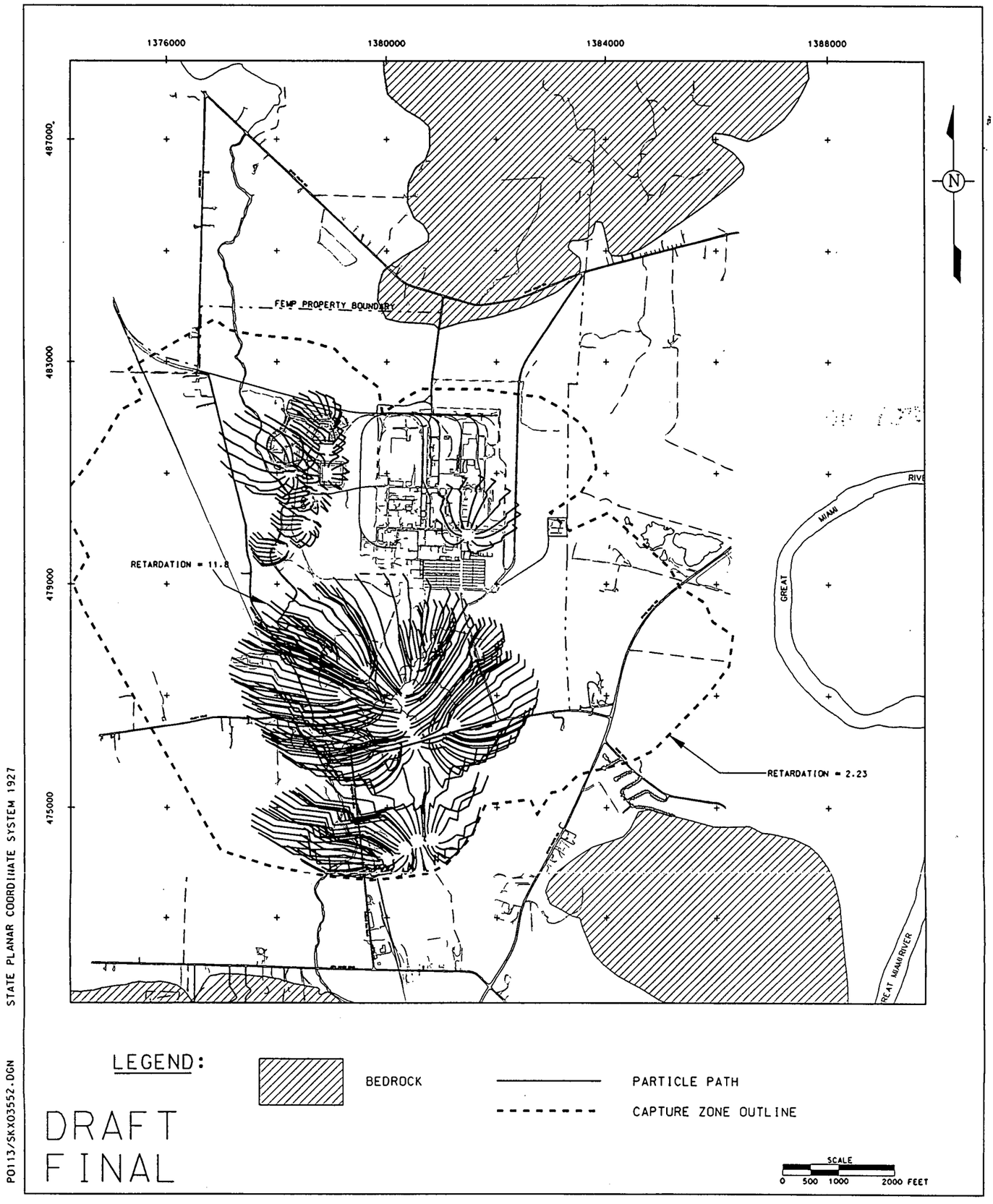
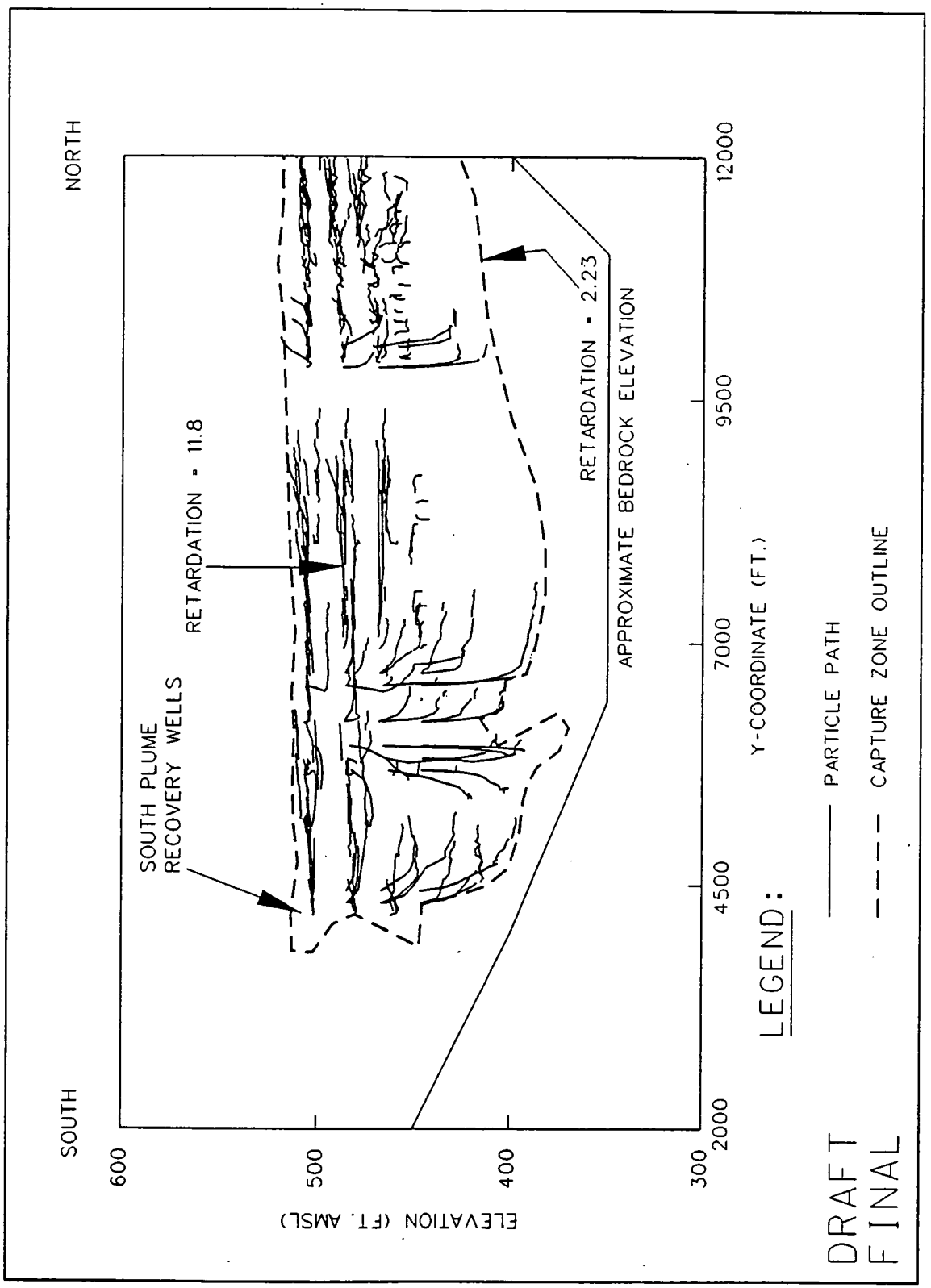


FIGURE V4-19. VARIABLE PUMPING, CAPTURE ZONE PLOT, YEARS 0-25, PLANAR VIEW



P0113/SKX03557.DGN

V4-20 - VARIABLE PUMPING, CAPTURE ZONE PLOT, YEARS 0 - 25, NORTH-SOUTH CROSS SECTION

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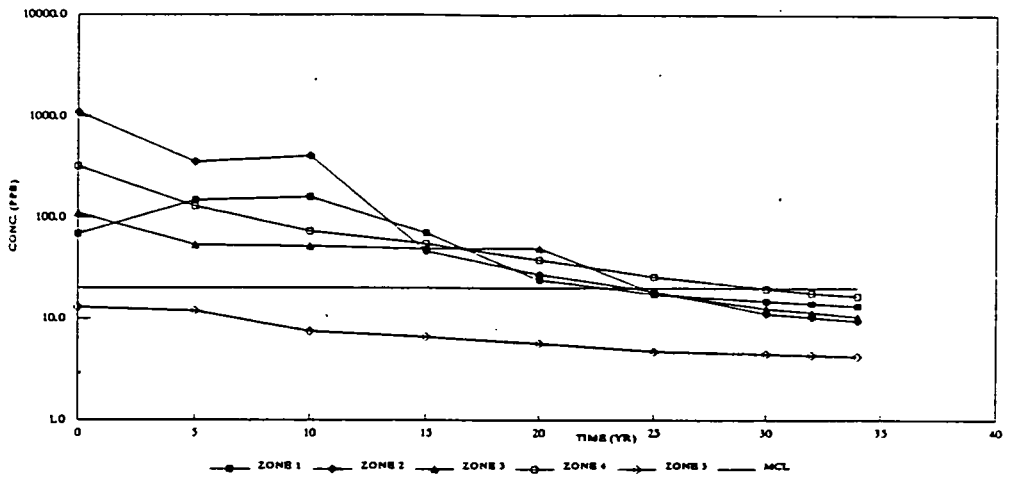
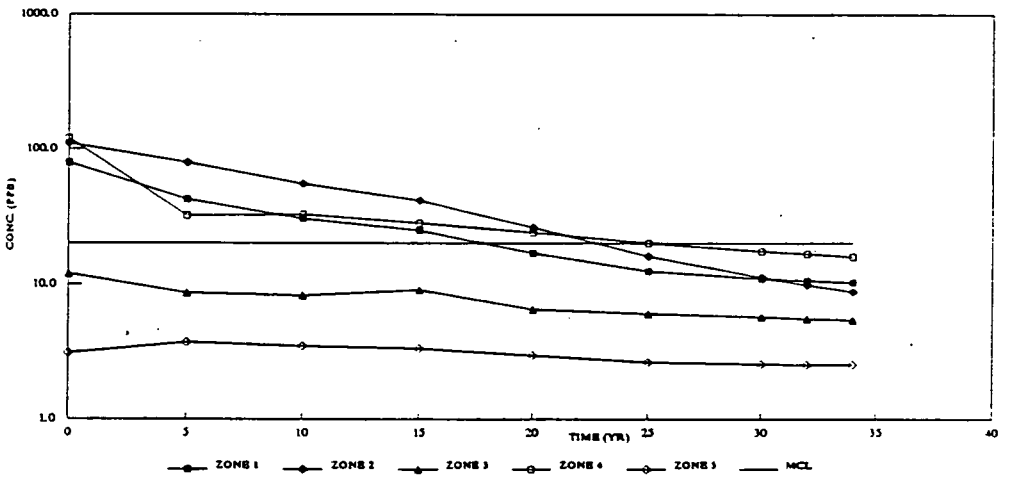
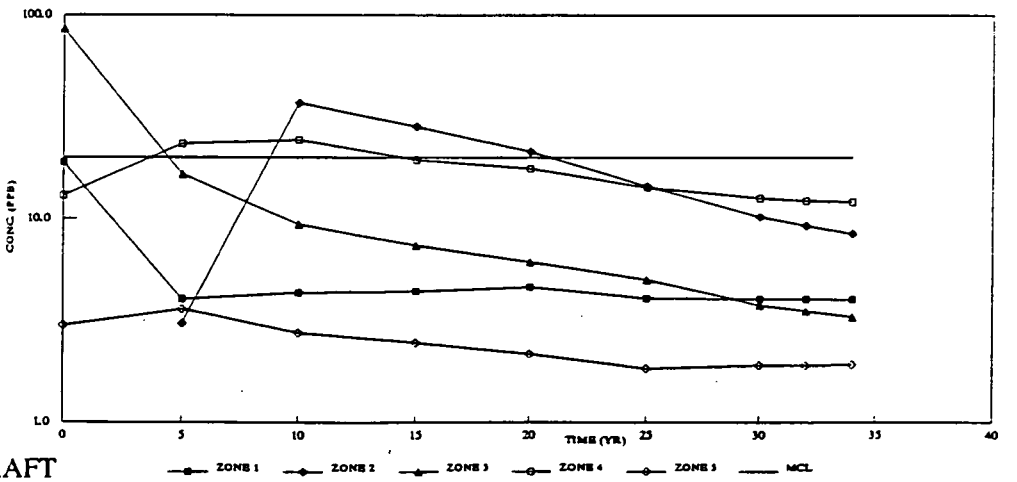
March 14, 1995 10:00am



LAYER 1



LAYER 3



LAYER 6

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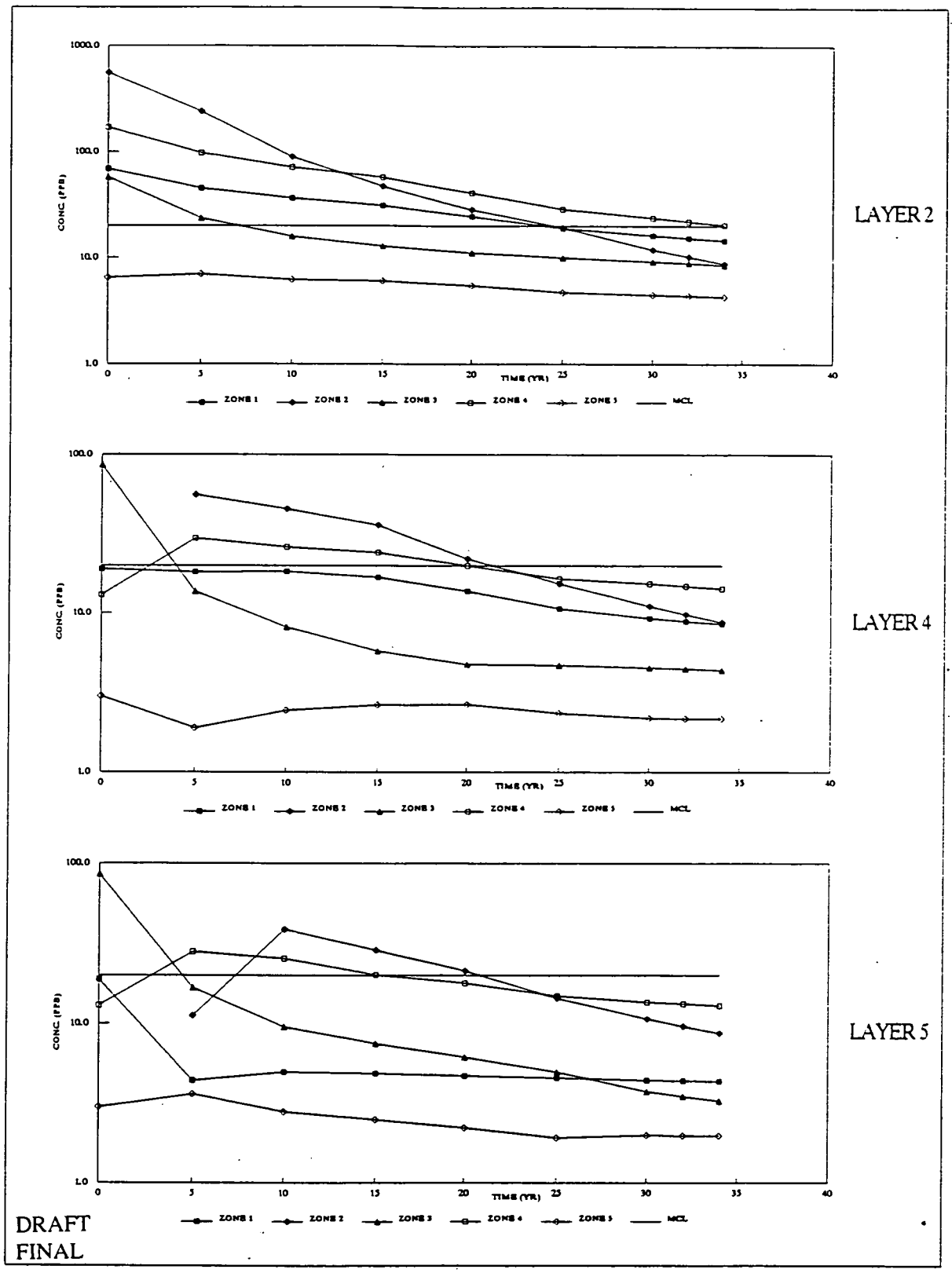
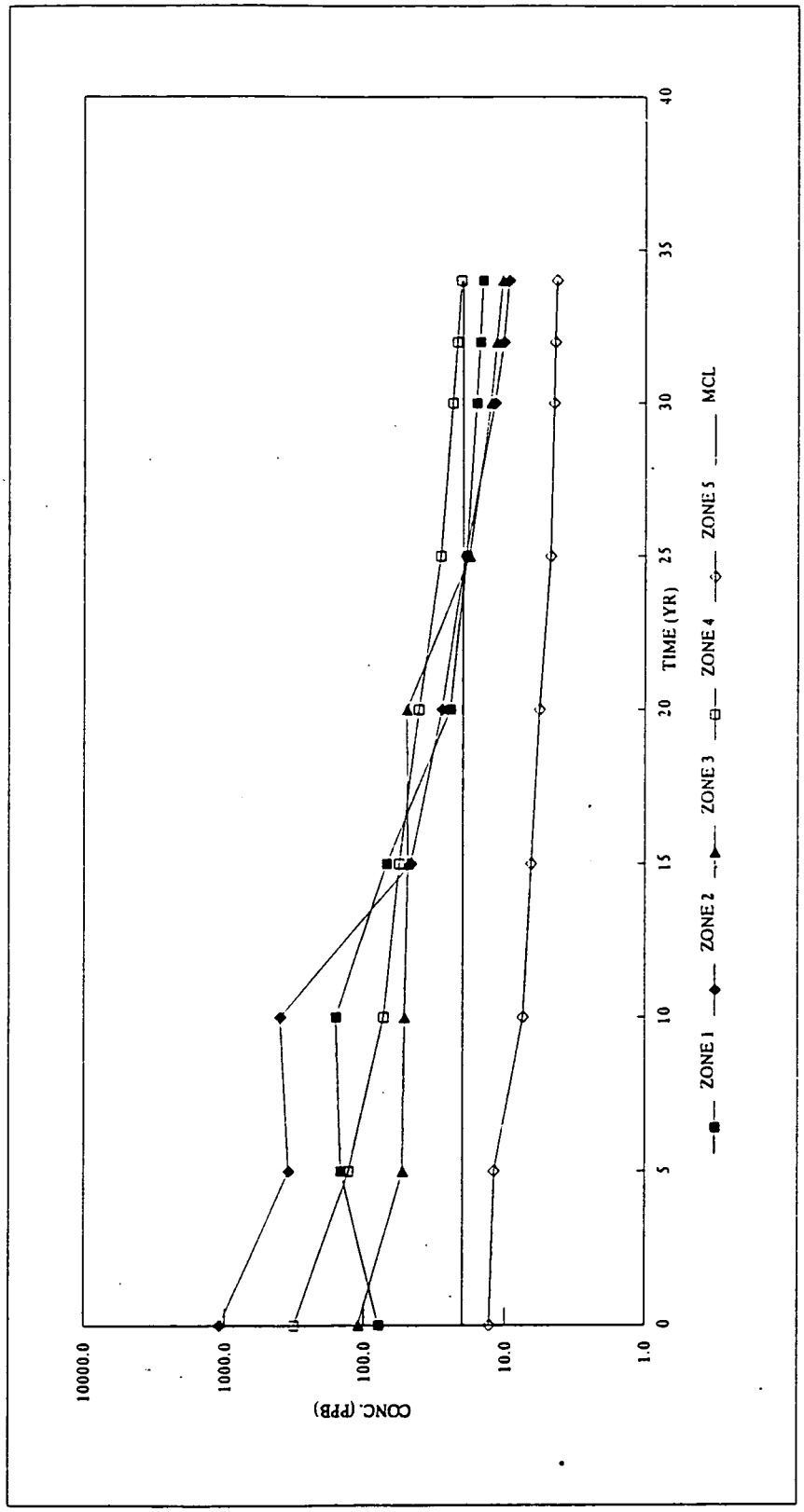
FINAL

S1-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



S1-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)



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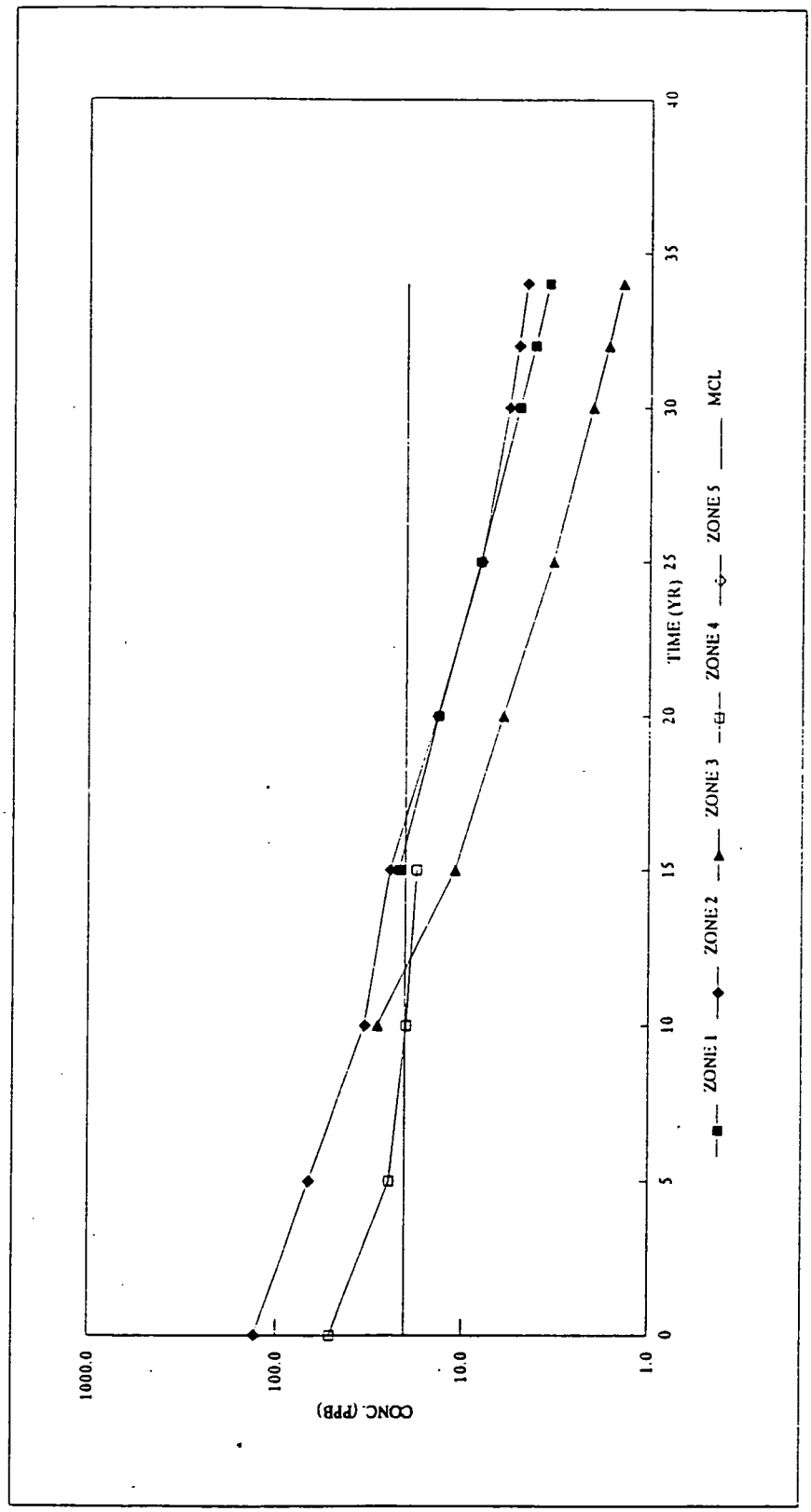
FINAL

S1-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE



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S1-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME

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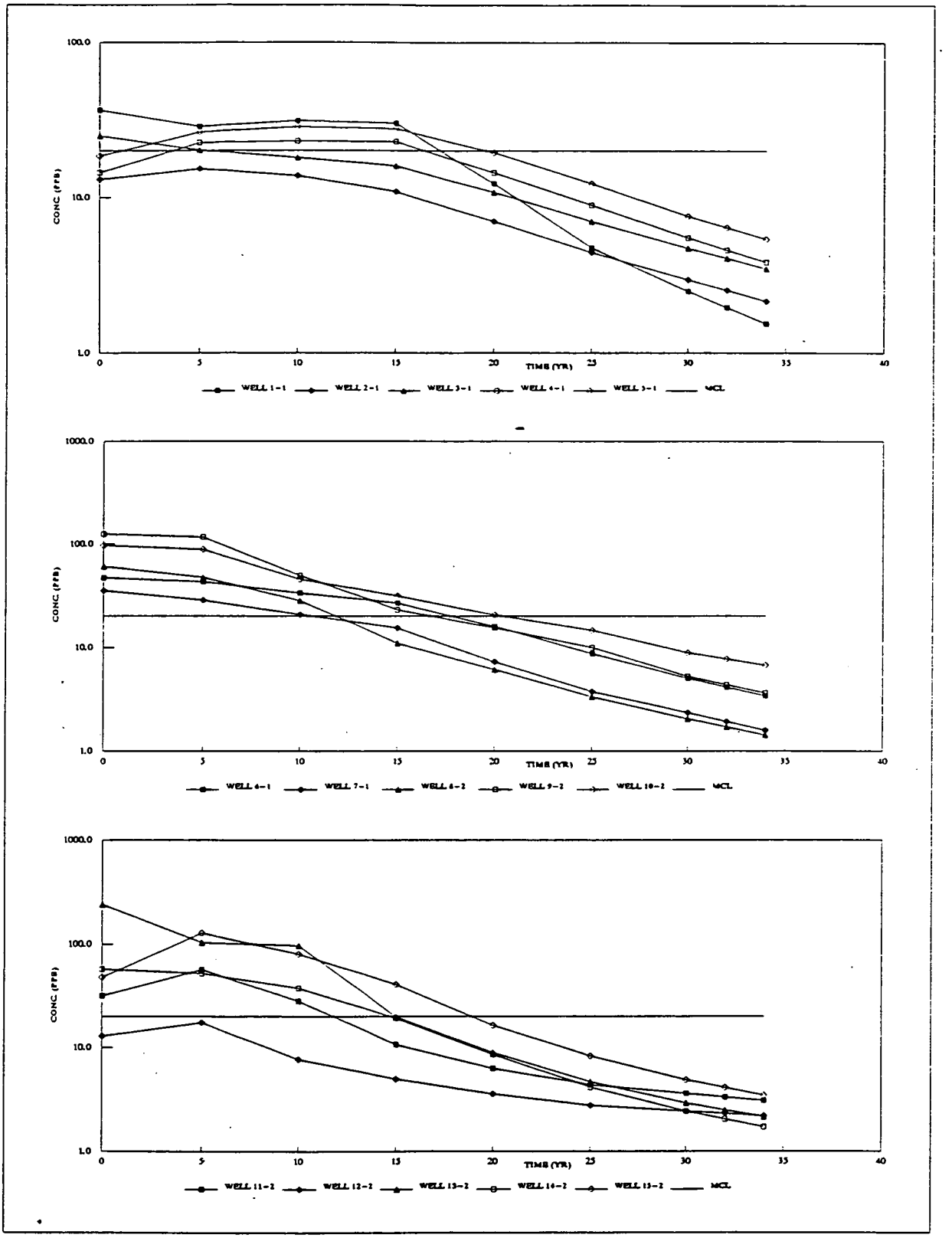

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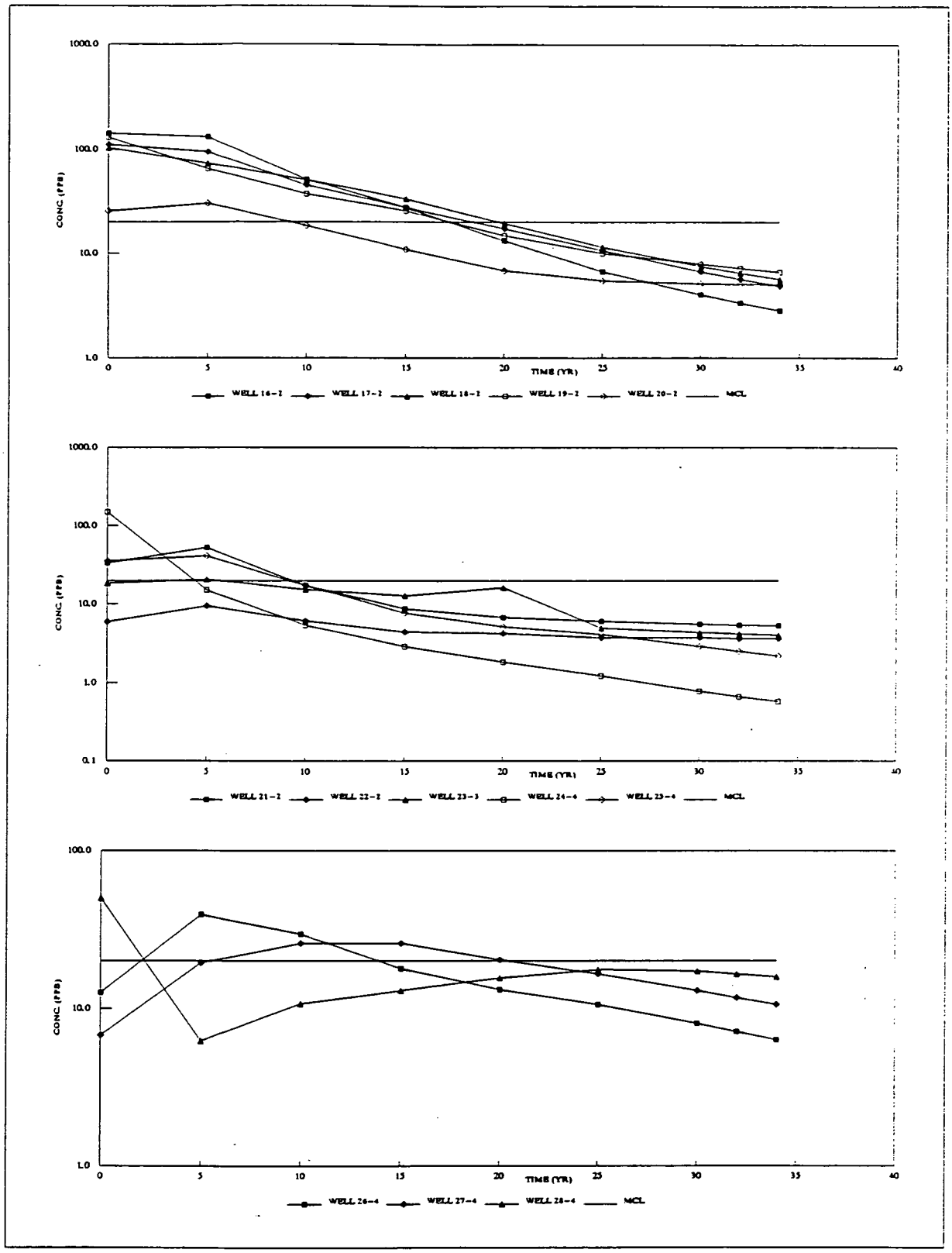
S1-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)



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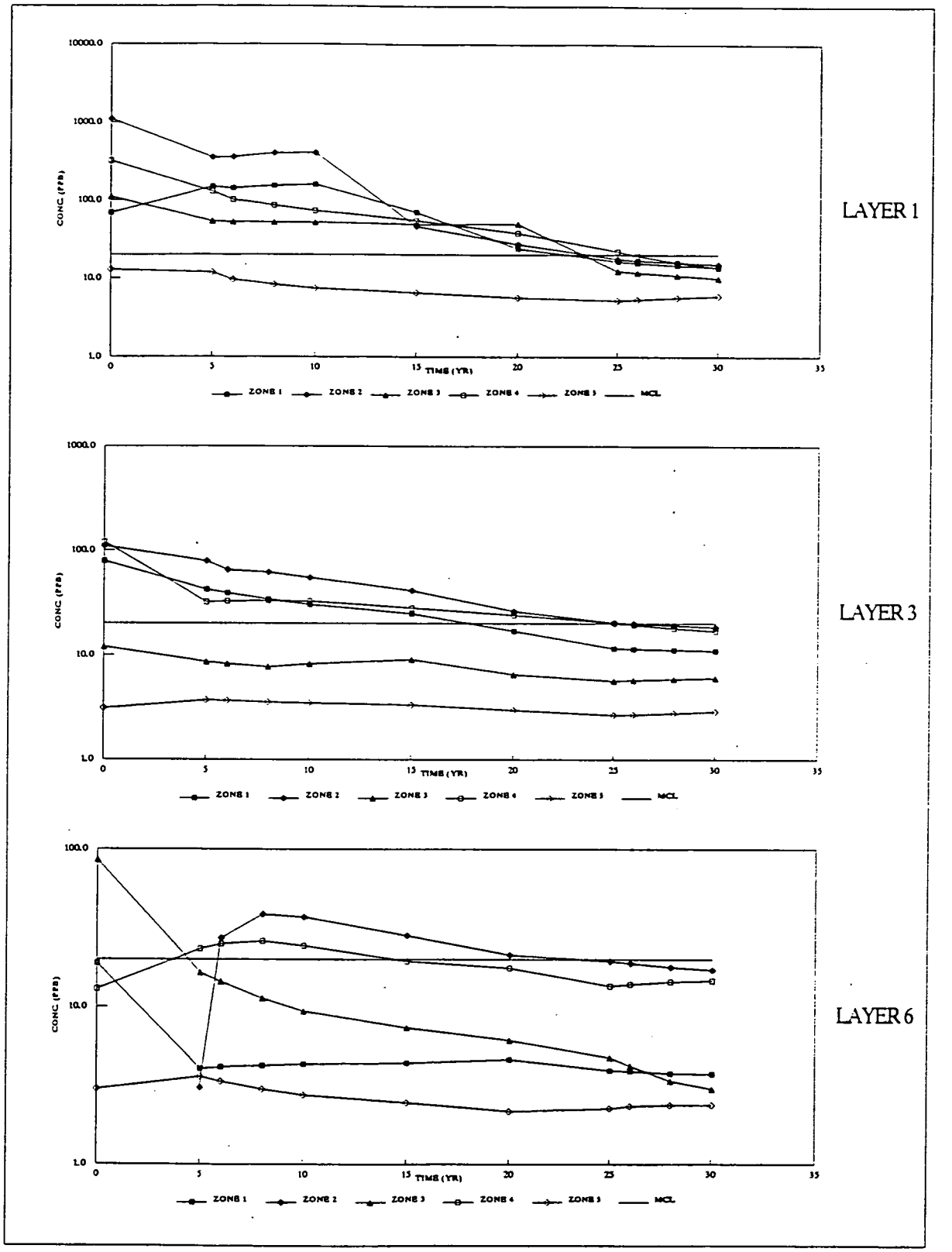
S1-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)



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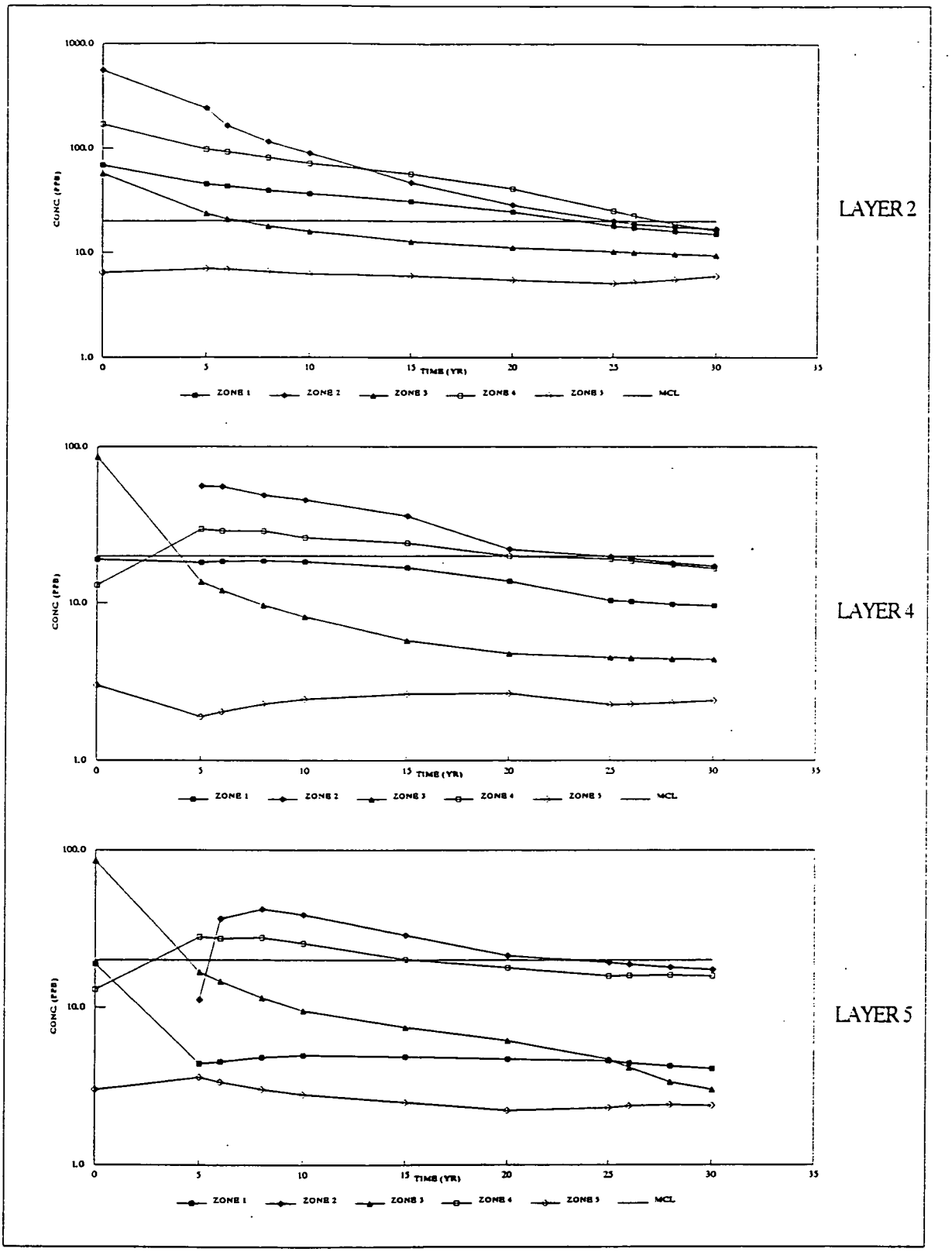
S2-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6)



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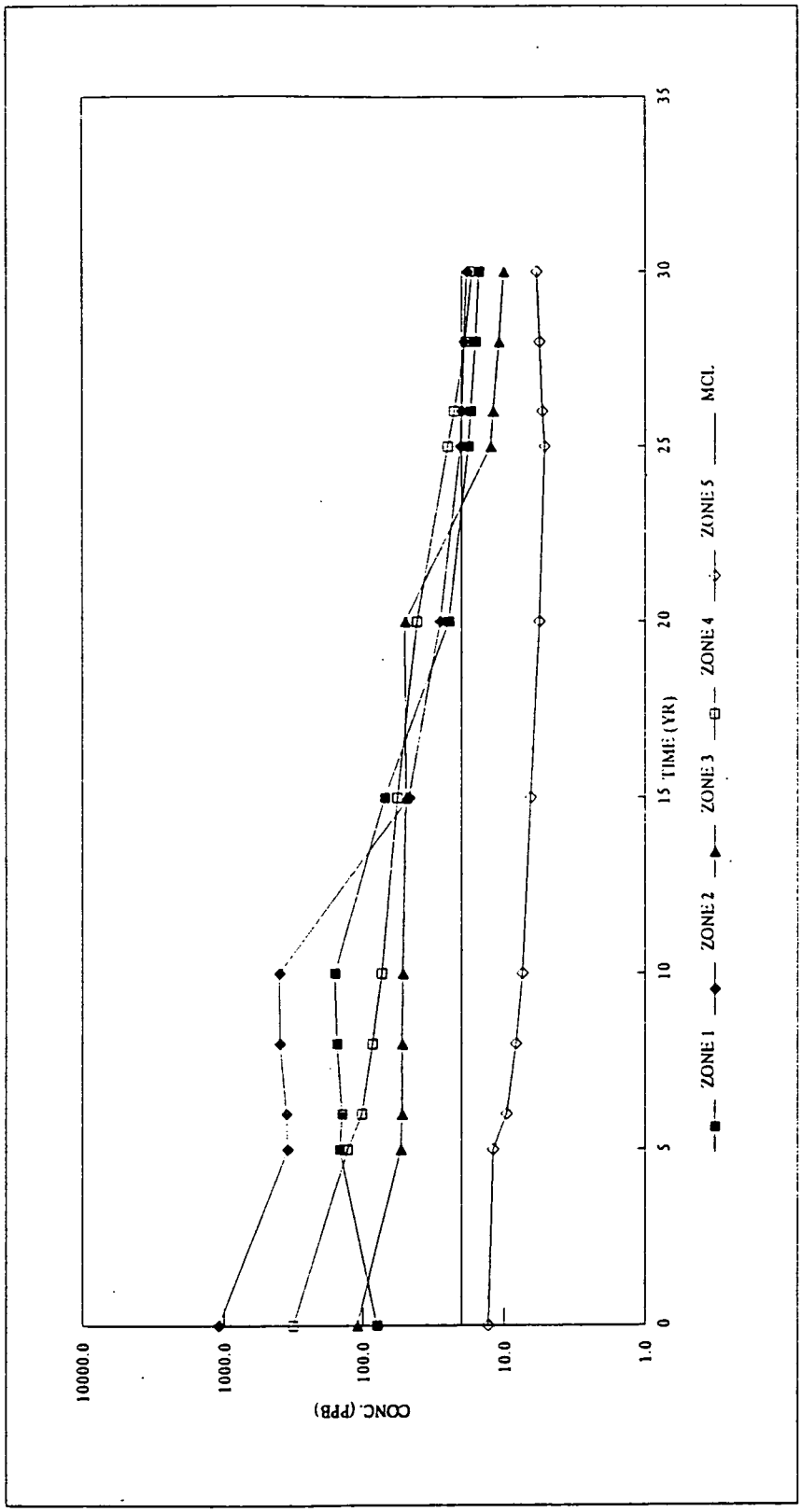
S2-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5)



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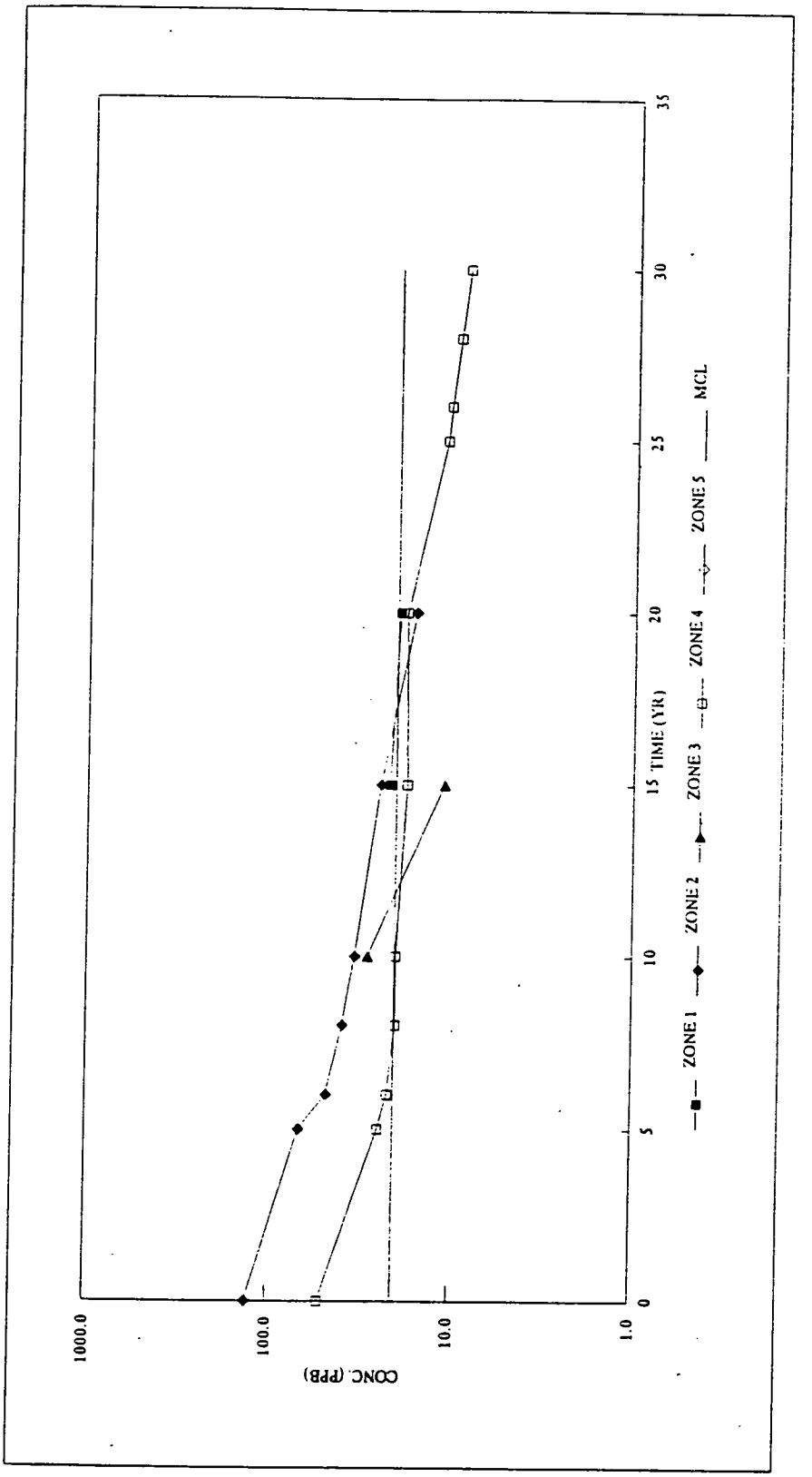
S2-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE



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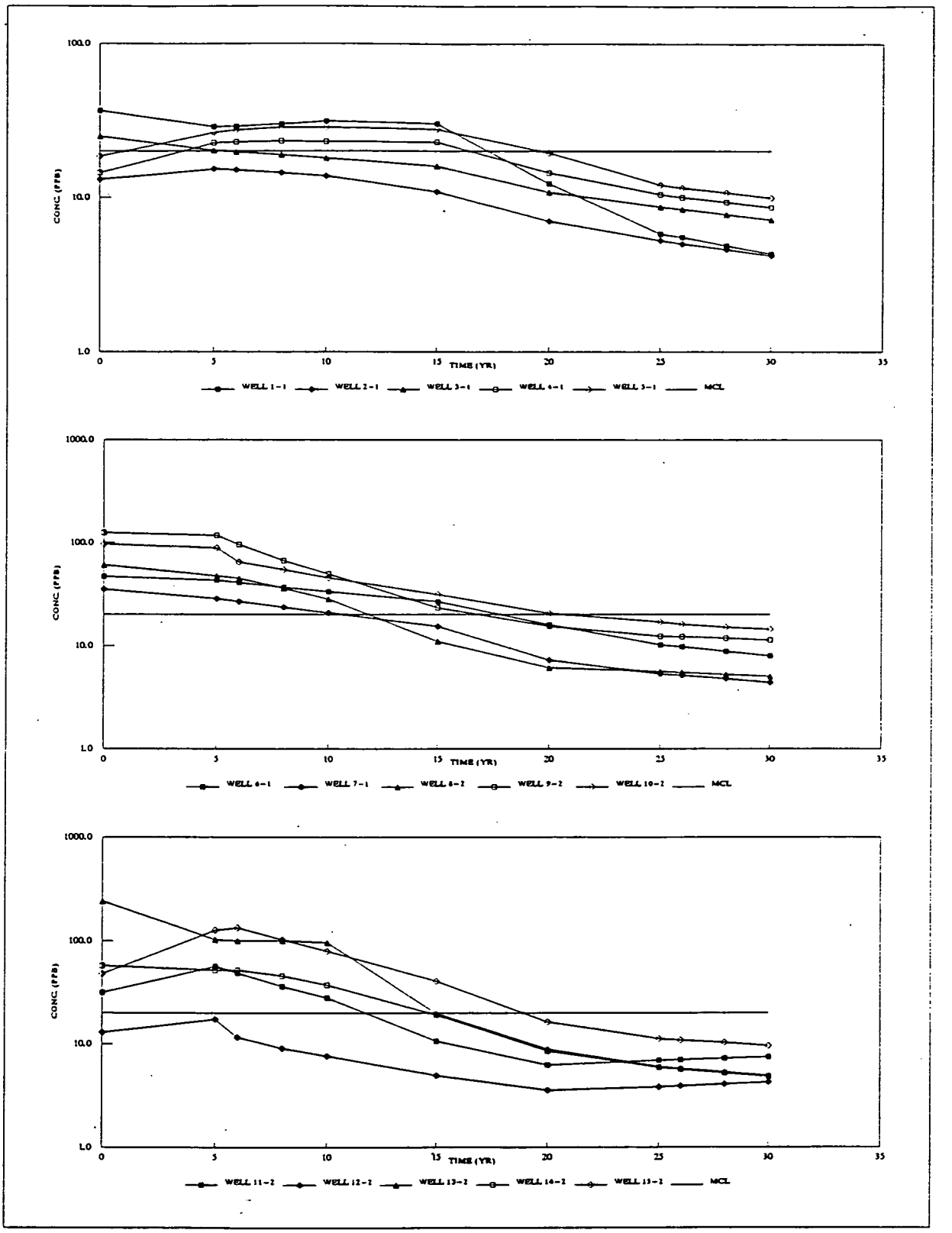
S2-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME



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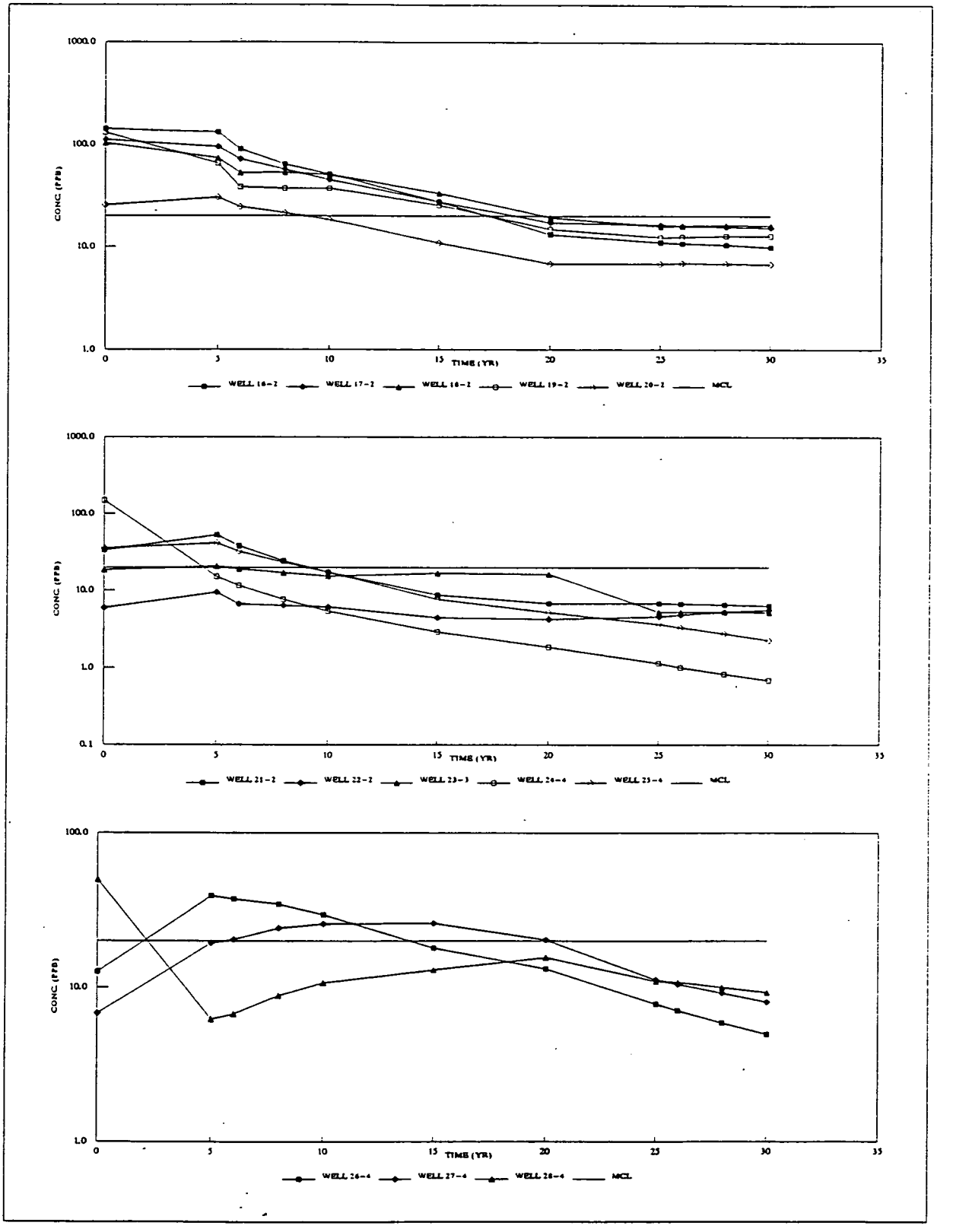
S2-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15)



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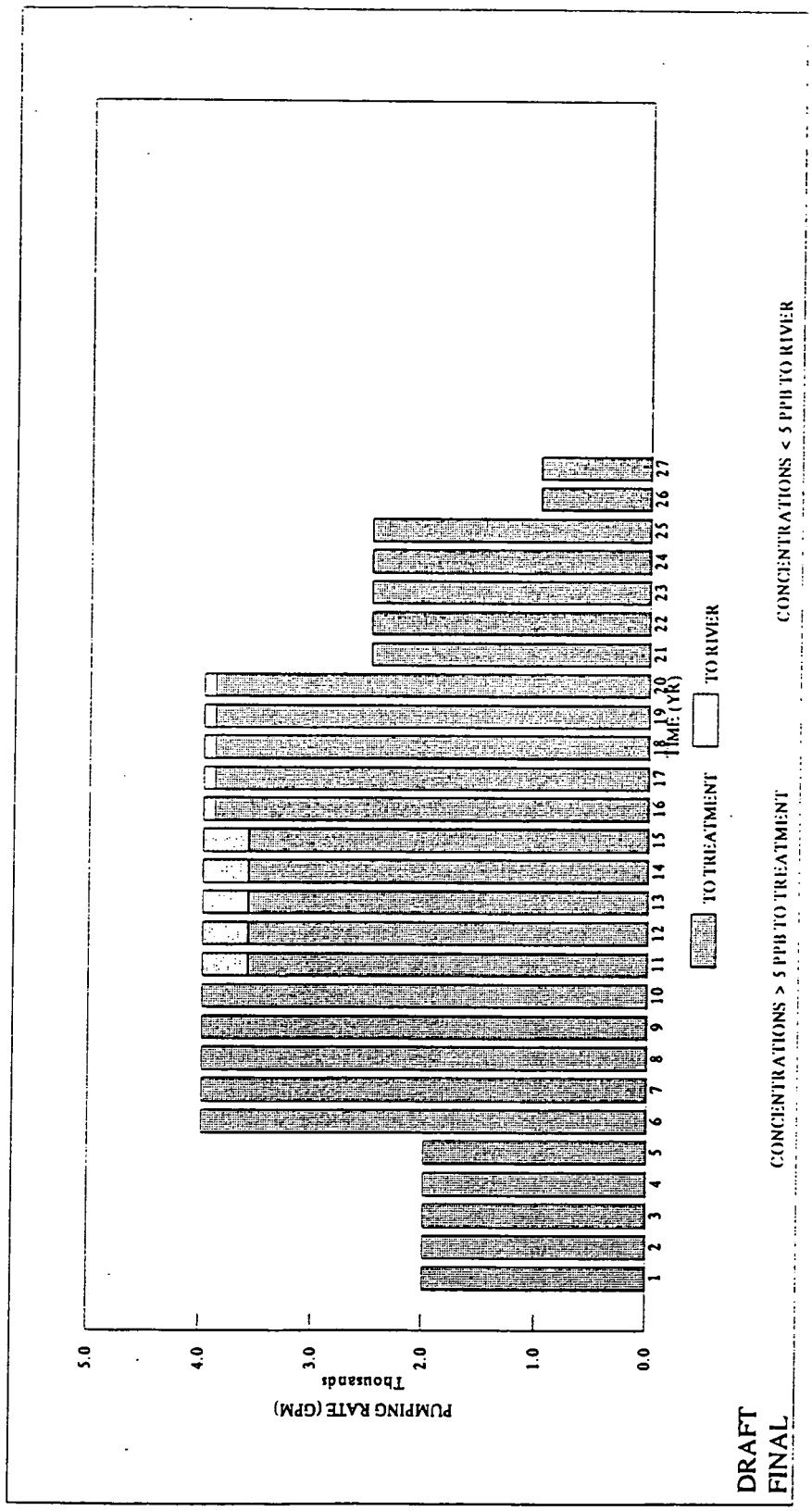
S2-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28)



S2-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 5 PPB)

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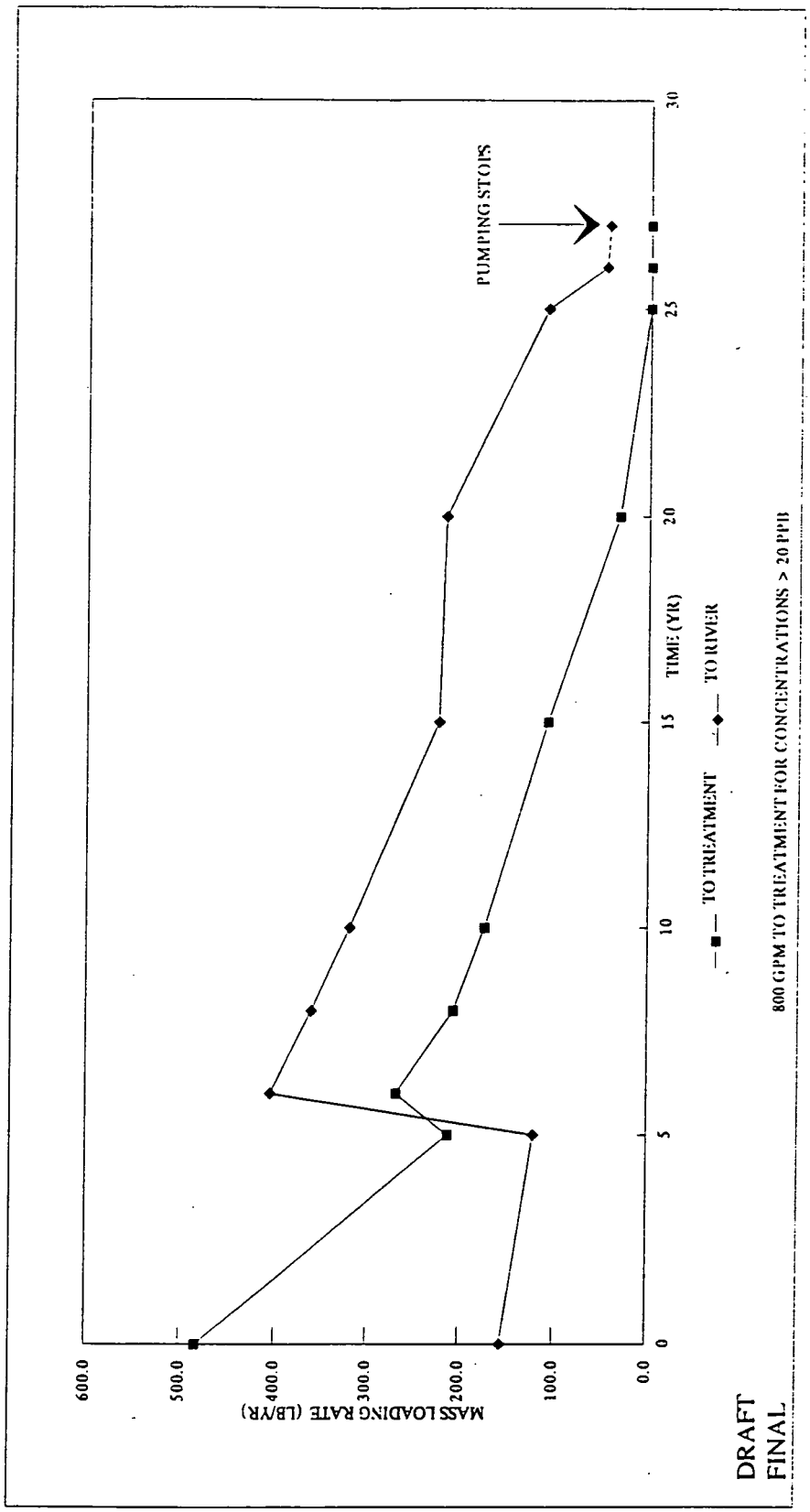

S2-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 5 PPB)

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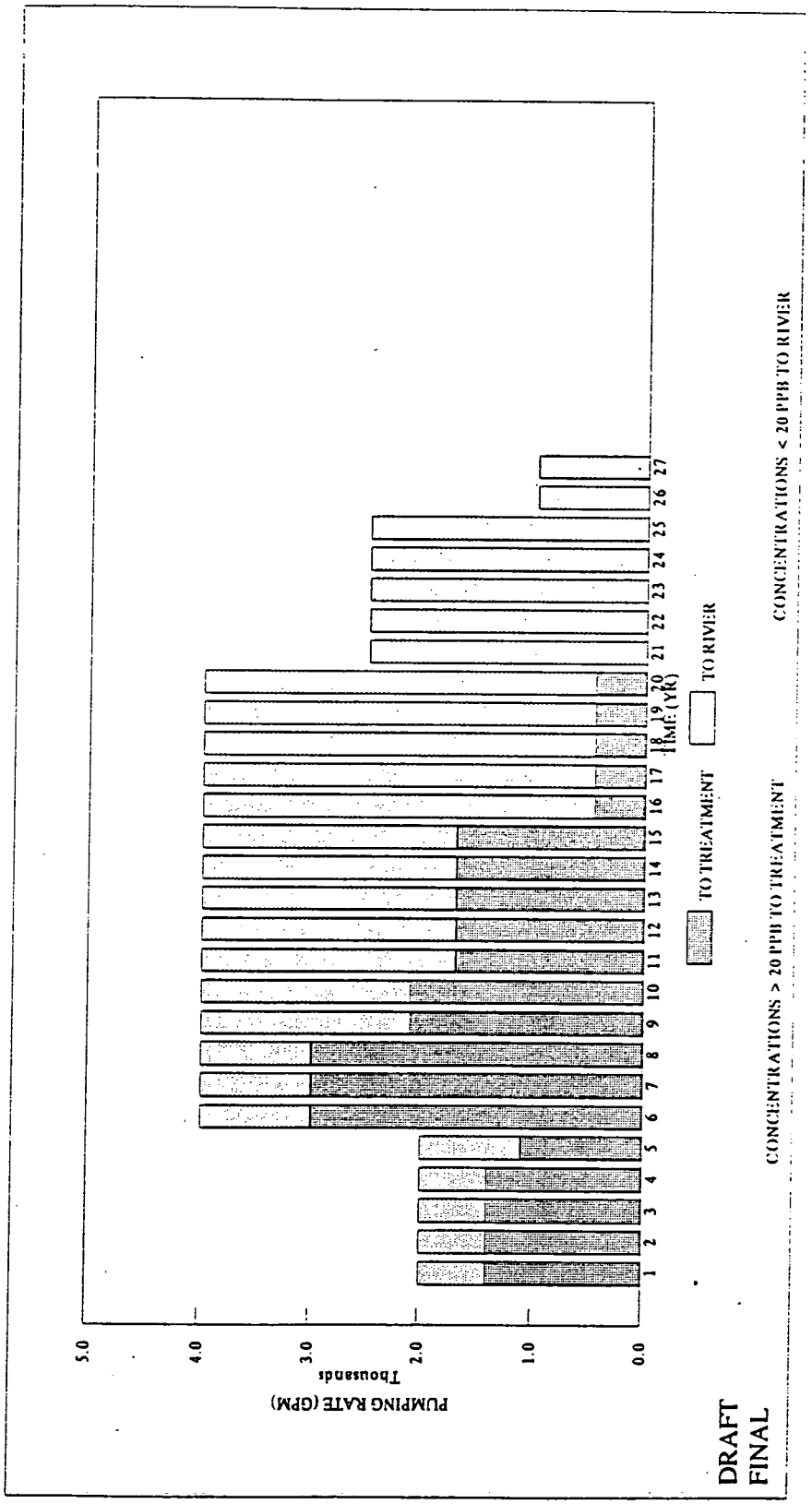
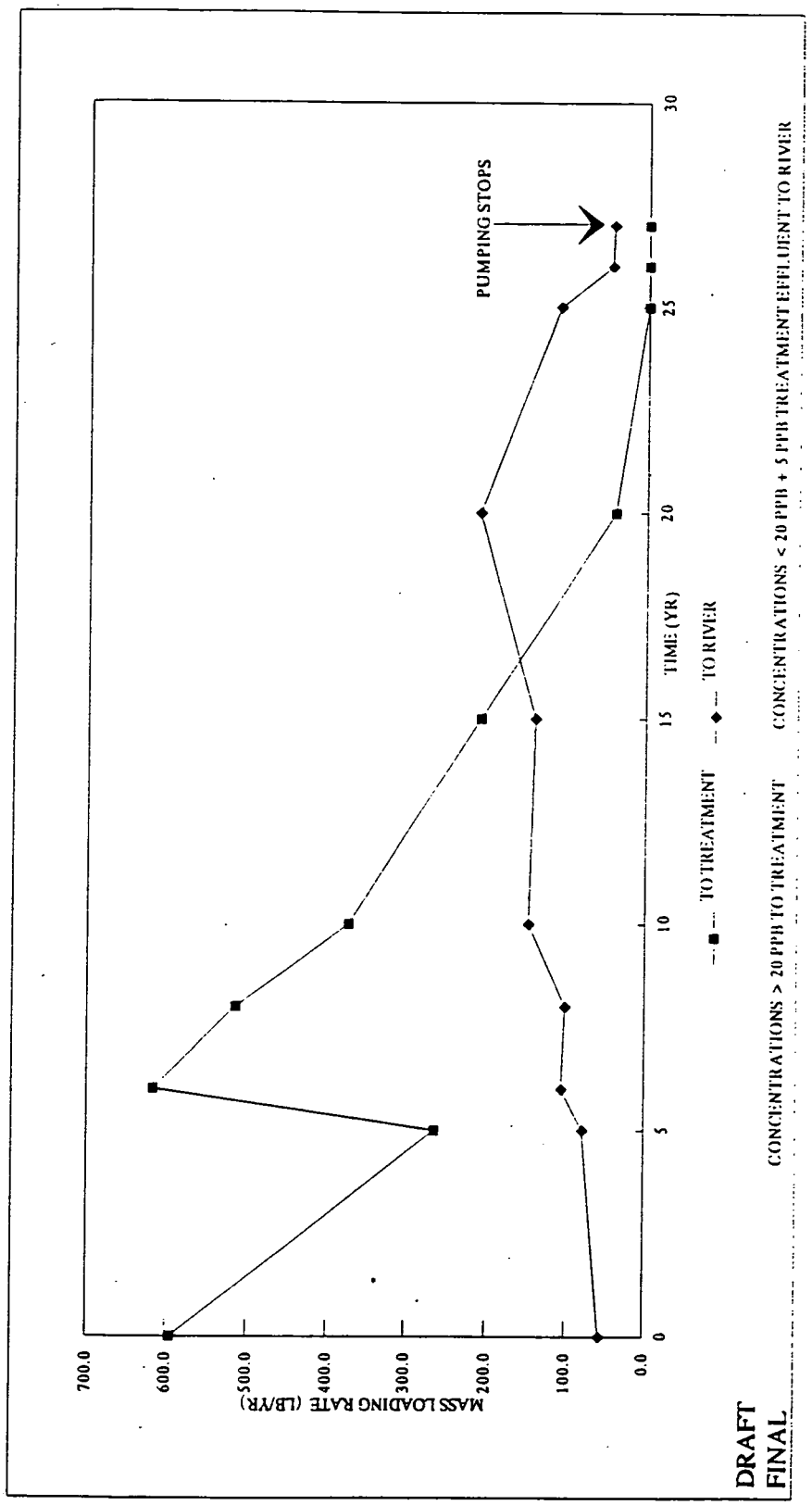
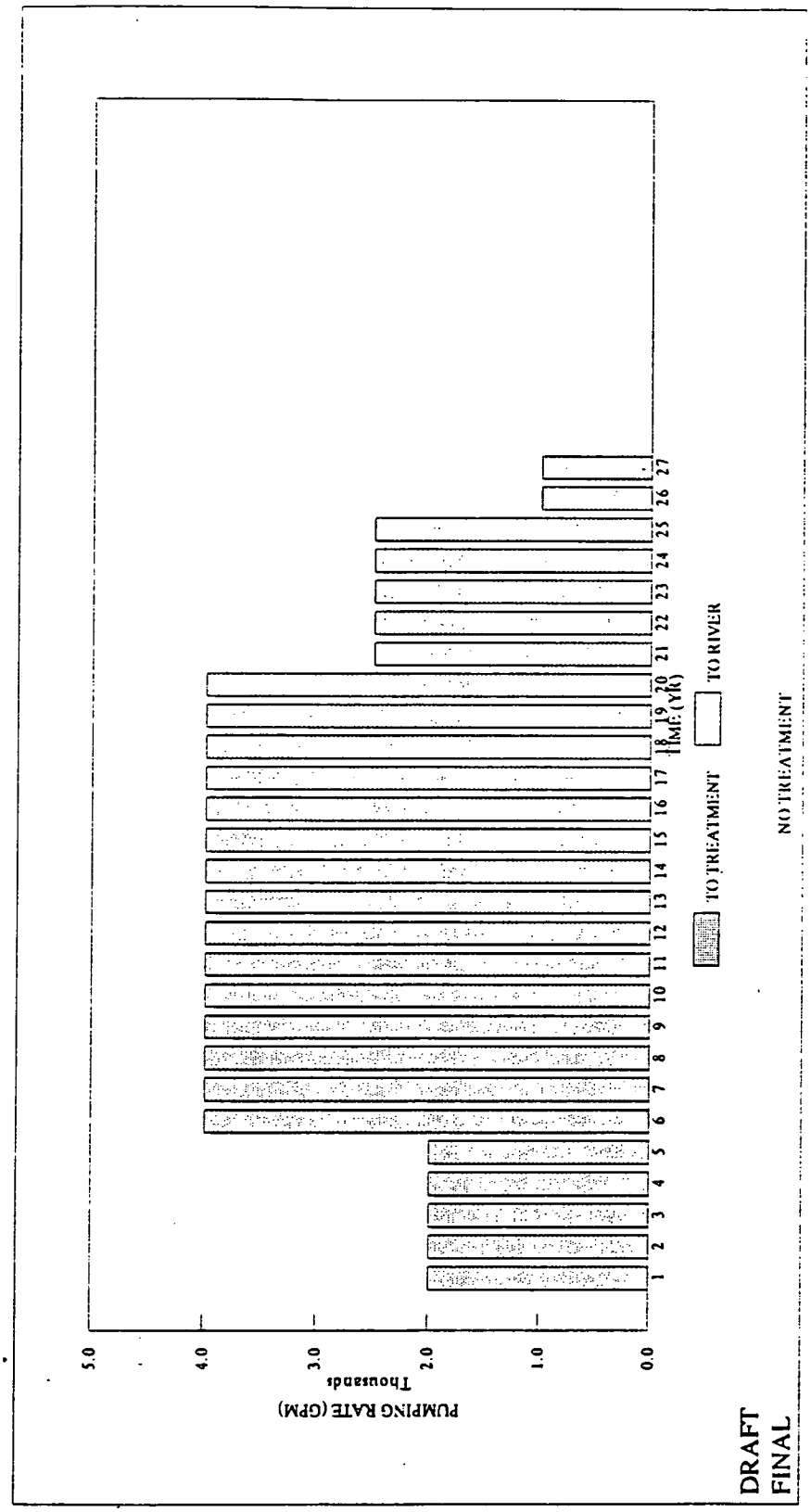


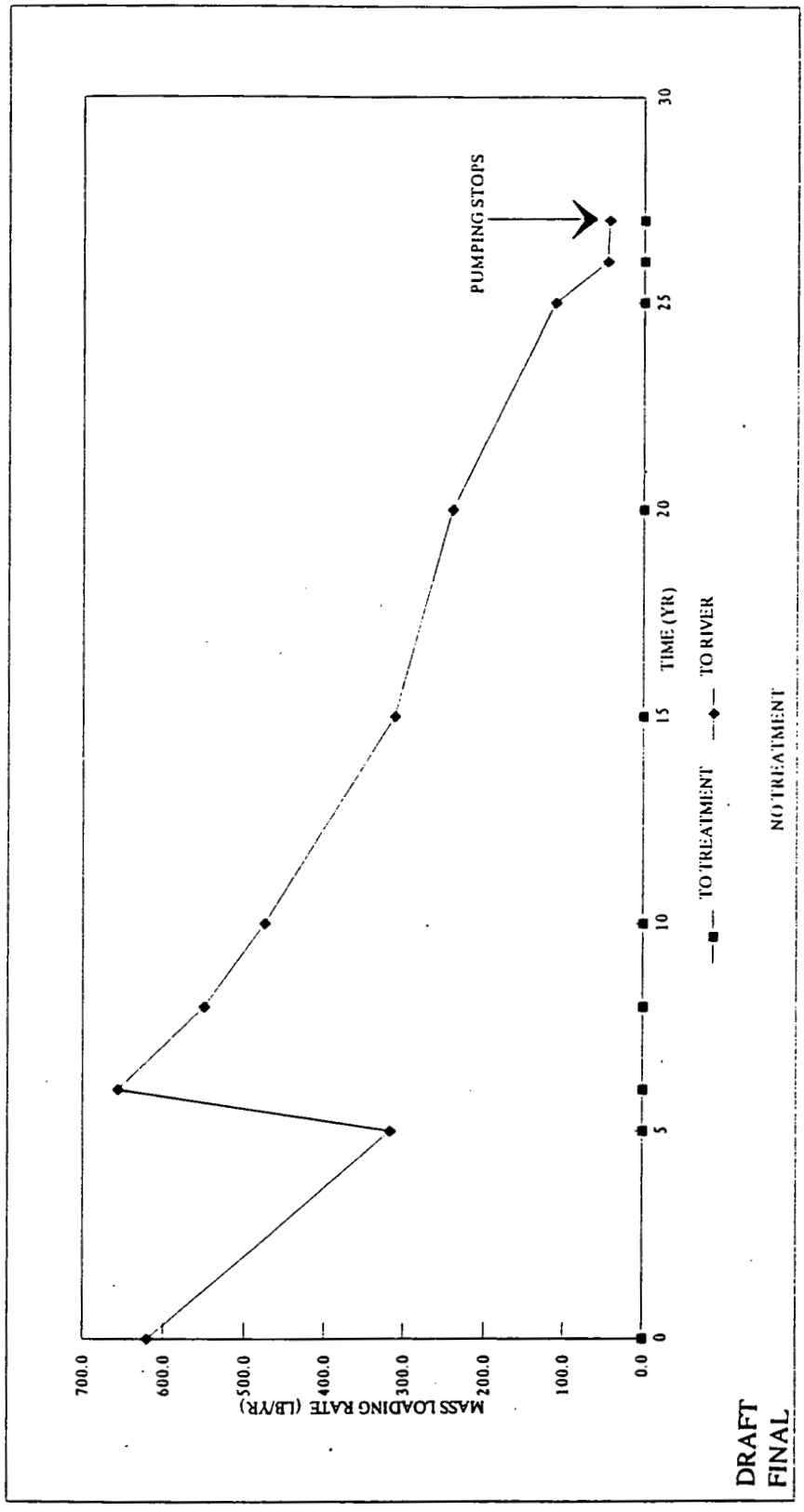
S2-9 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB)



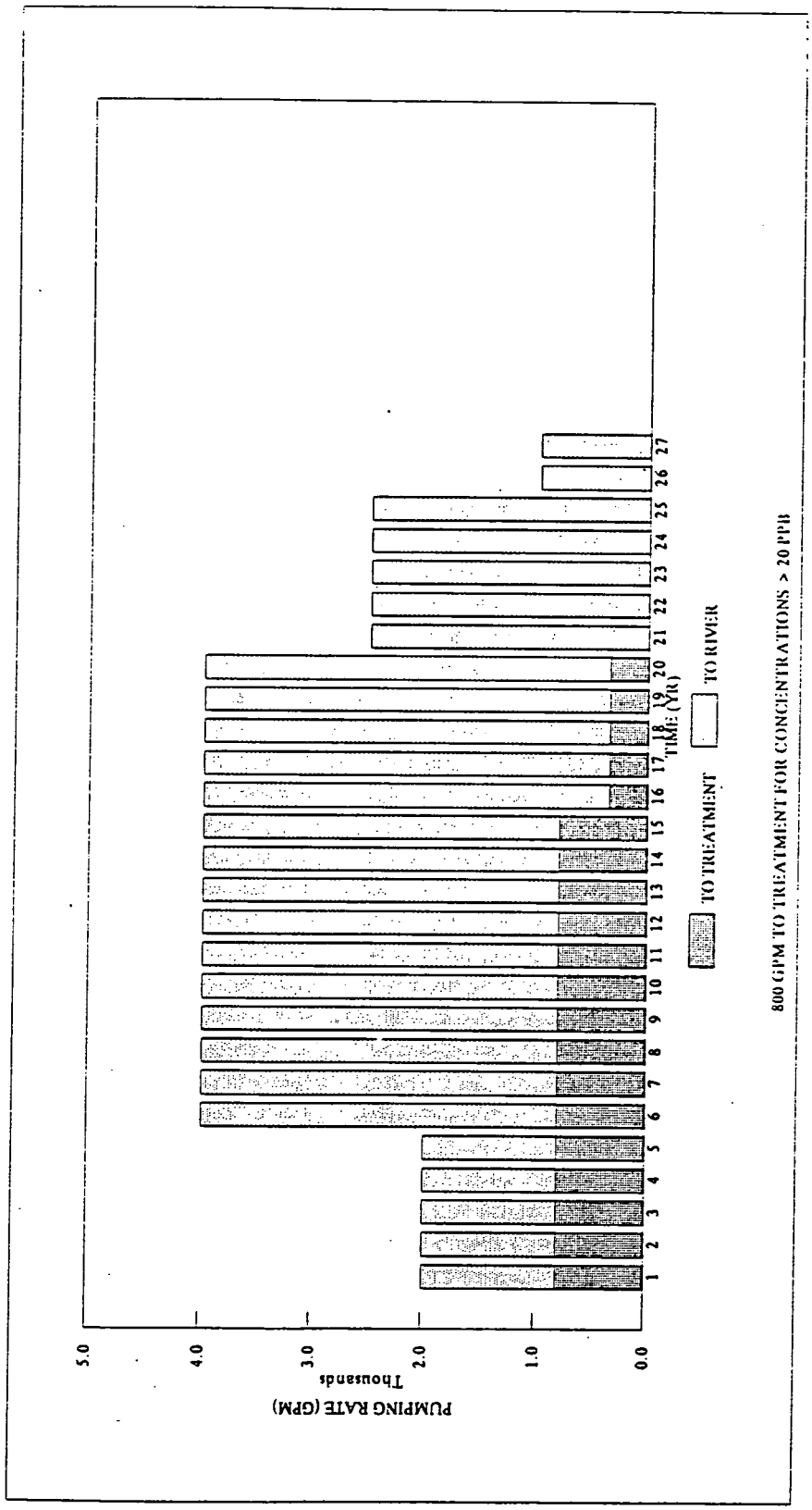
S2-10 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB)



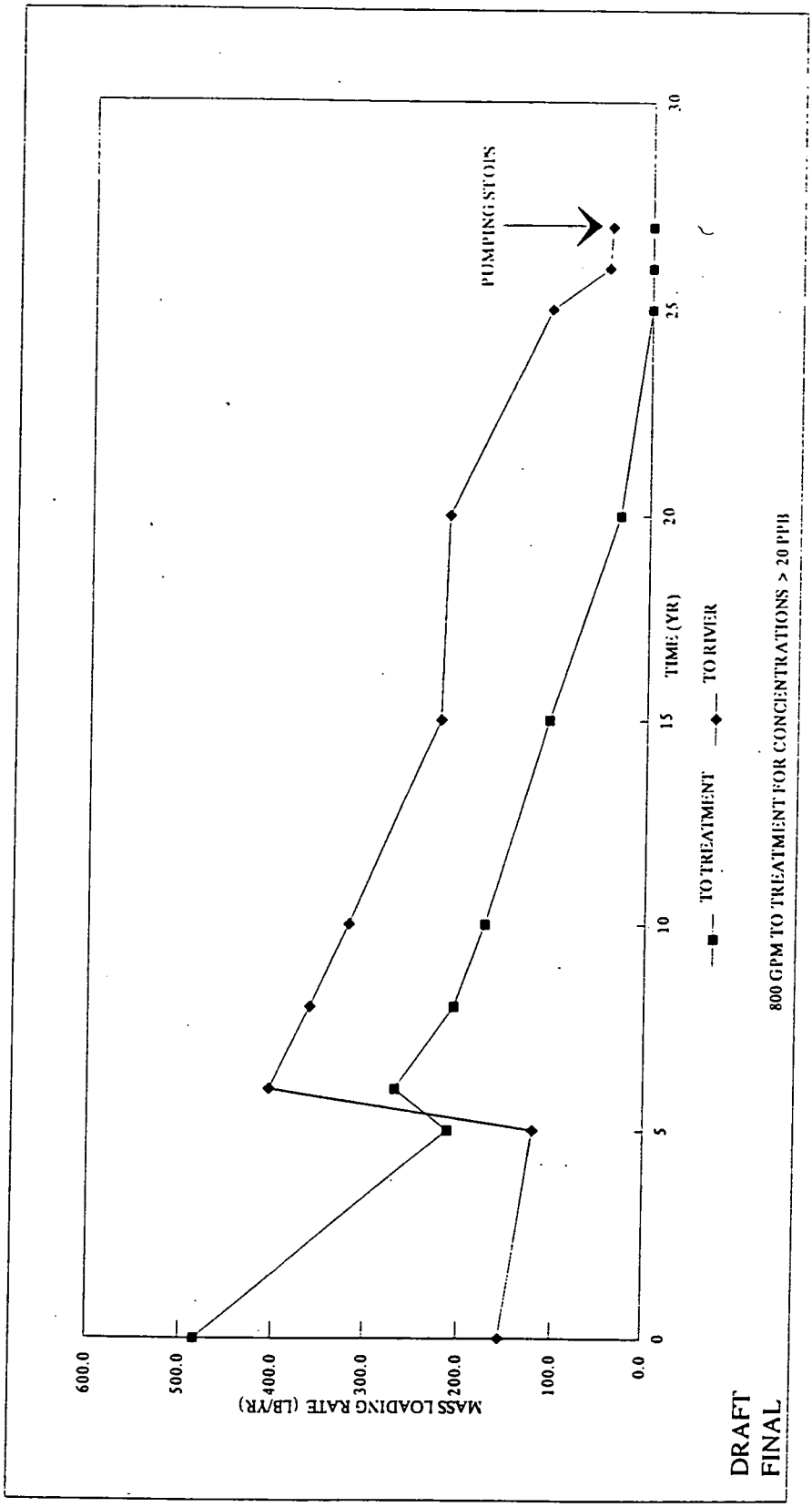
S2-11 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (NO TREATMENT)



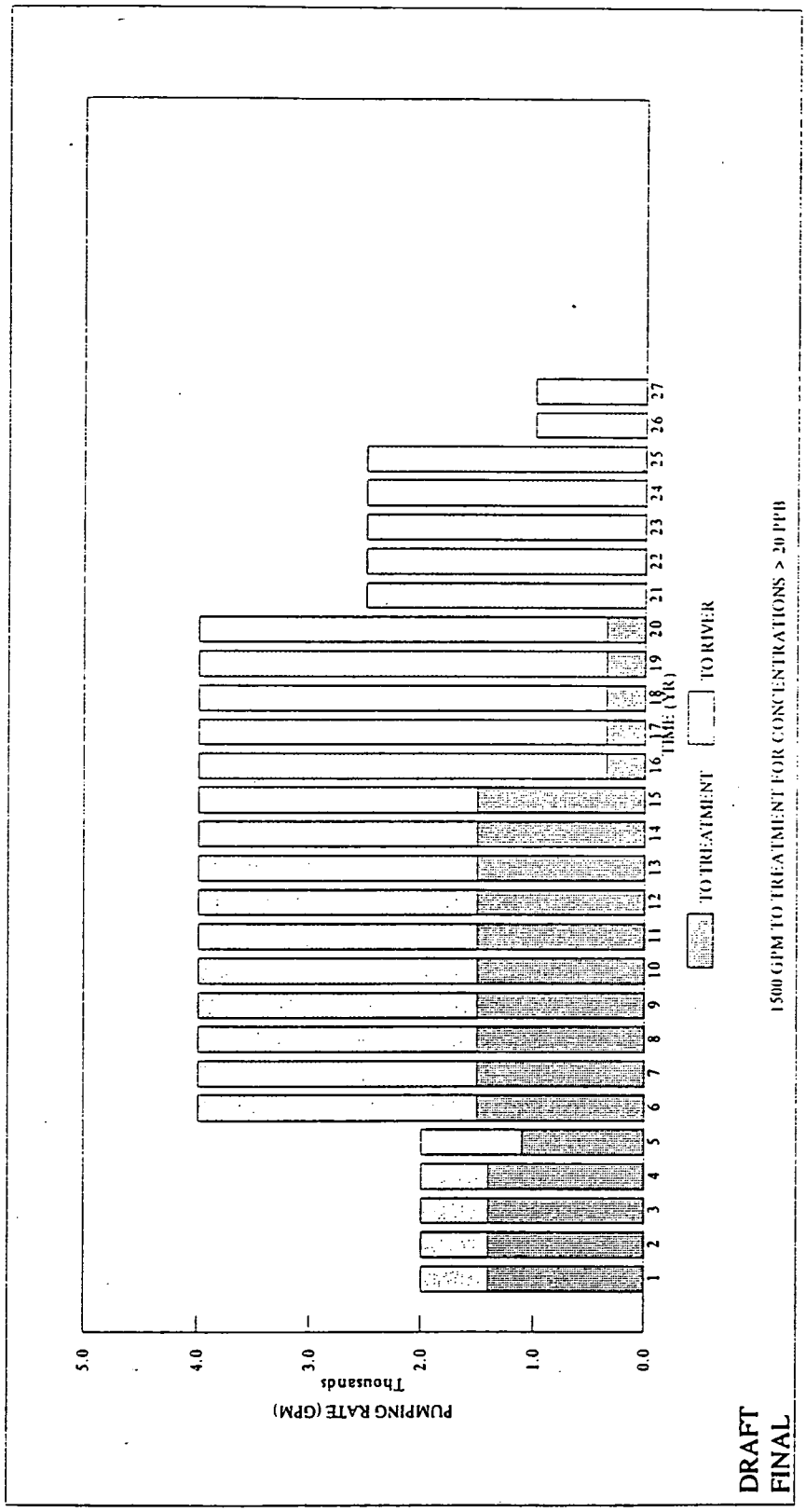
S2-12 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (NO TREATMENT)



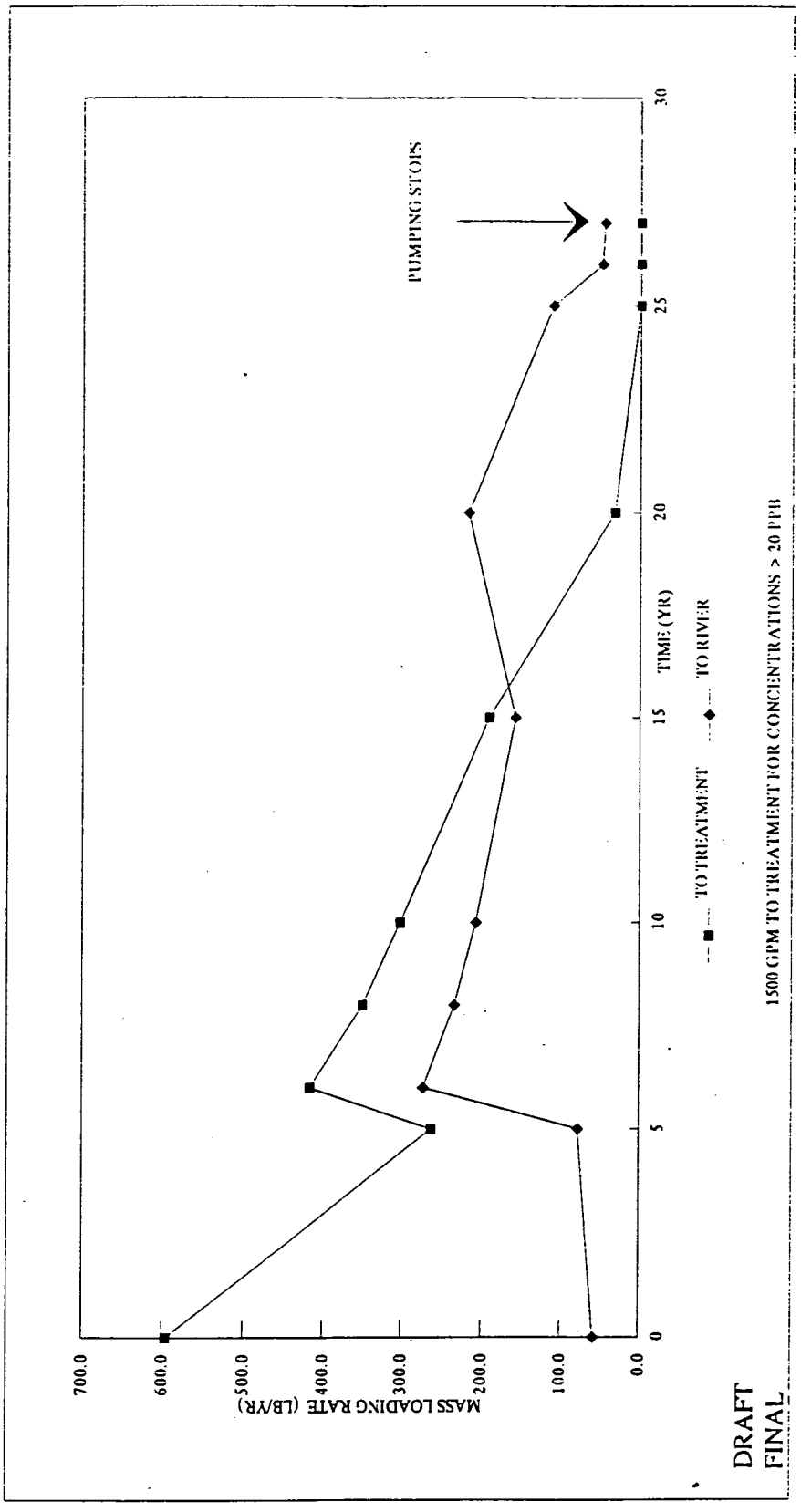
S2-13 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 800 GPM)



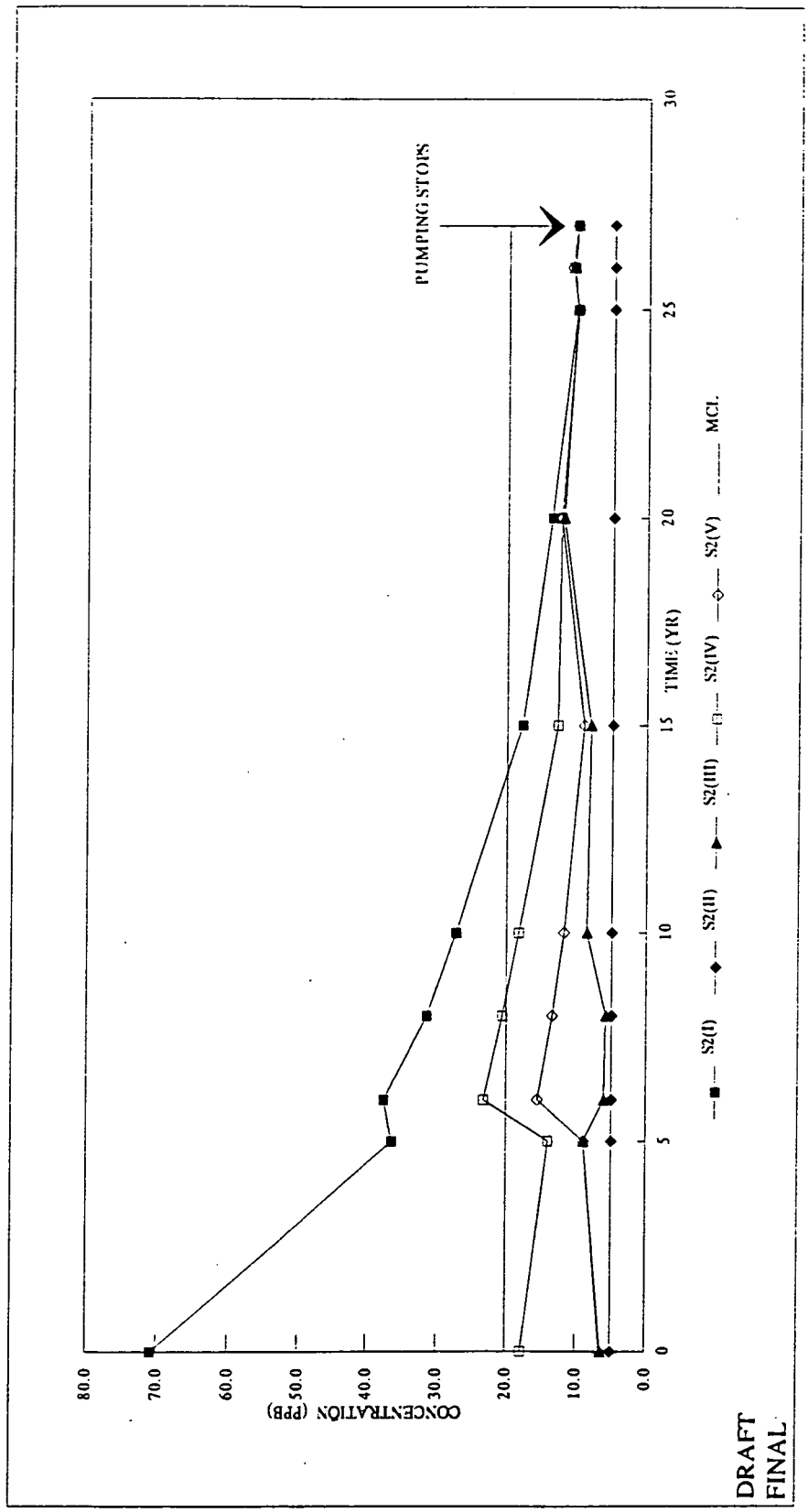
S2-14 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 800 GPM)



S2-15 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM)



S2-16 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM)



S2-17 - SEQUENTIAL PUMPING, BLENDED OUTFALL CONCENTRATION VS. TIME

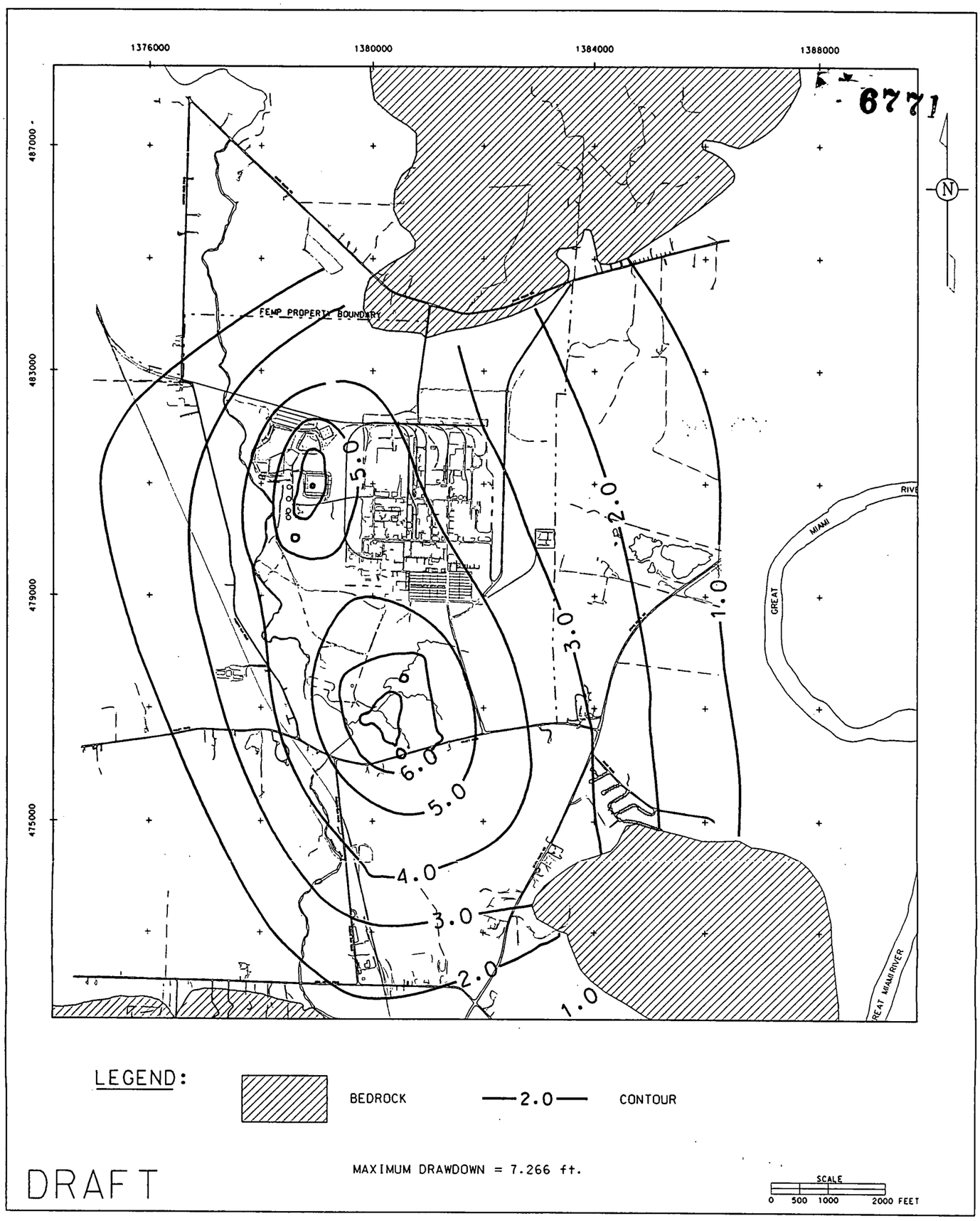


FIGURE S2-18. SEQUENTIAL PUMPING, GROUNDWATER DRAWDOWN CONTOURS

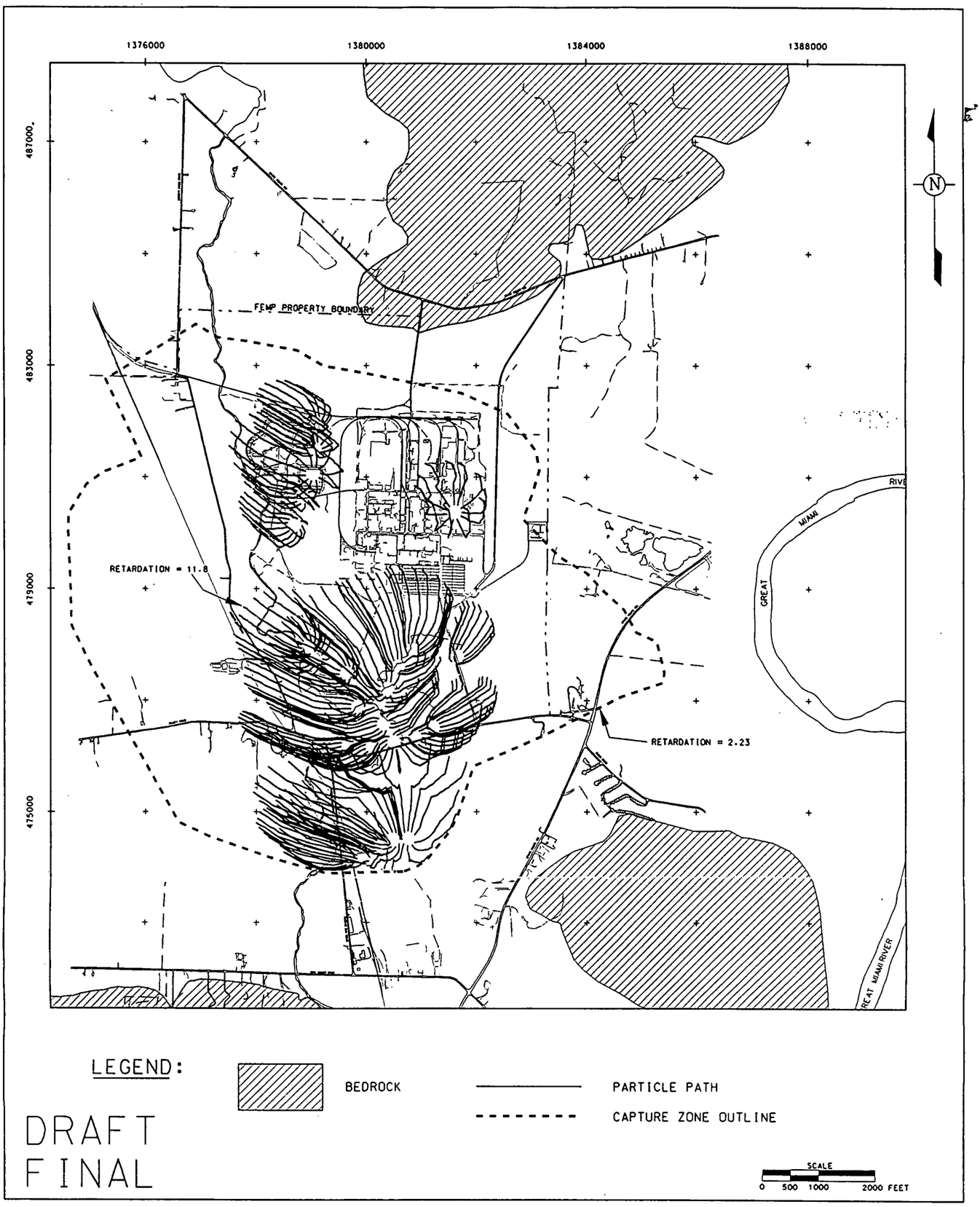


FIGURE S2-19. SEQUENTIAL PUMPING, CAPTURE ZONE PLOT, YEARS 0 TO 27 (PLANAR VIEW)

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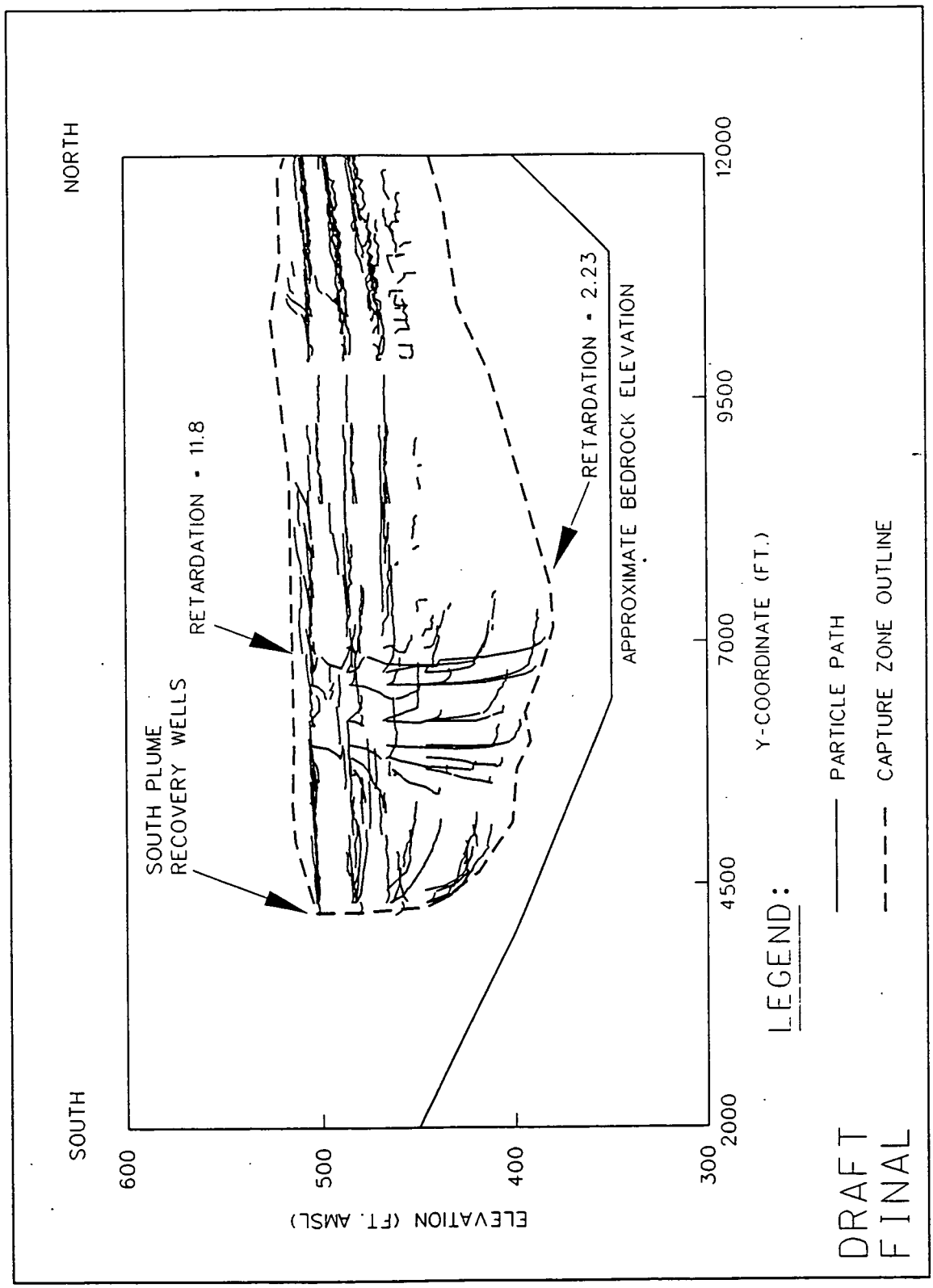
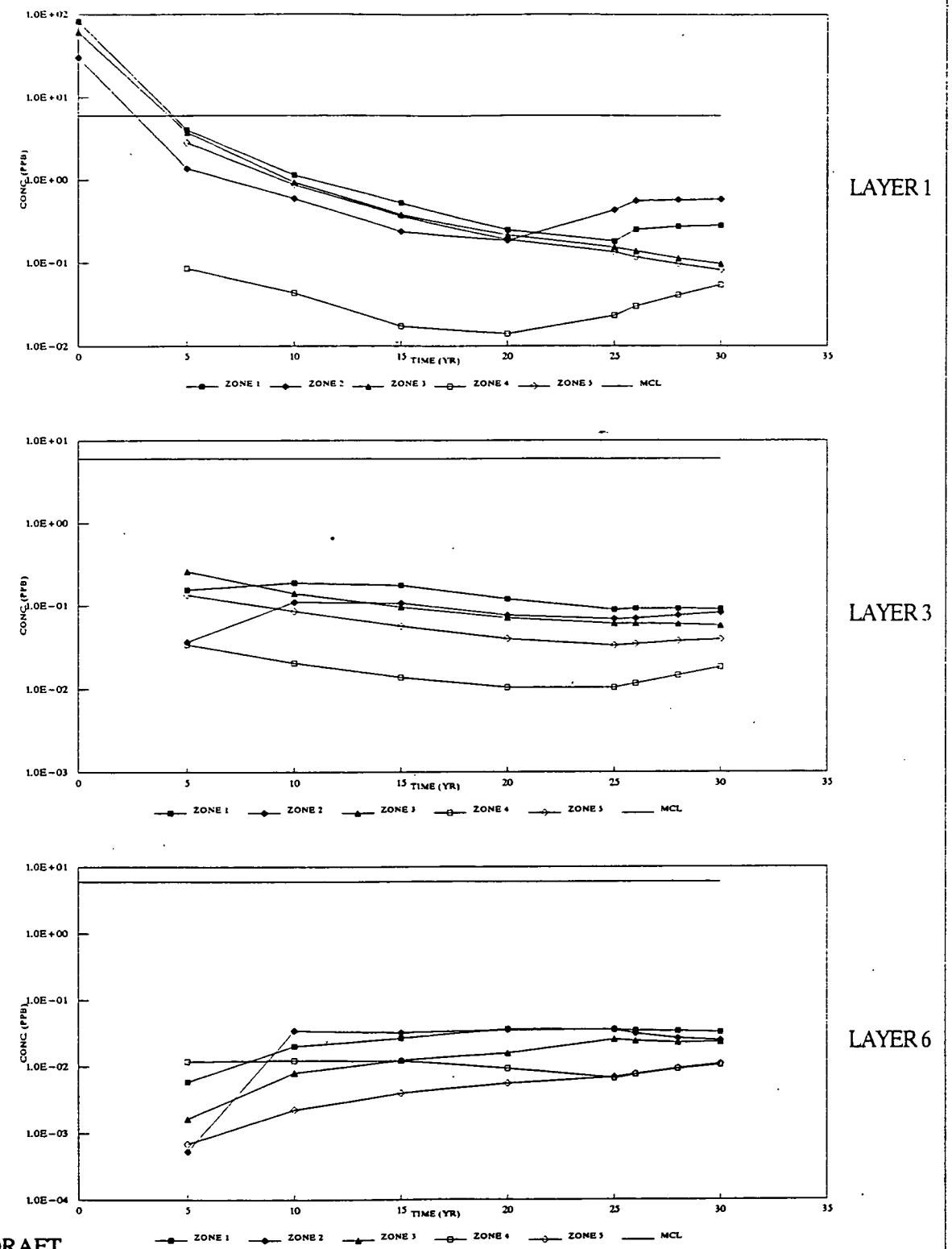


P0113/SKX03558.DGN

S2-20 - SEQUENTIAL PUMPING, CAPTURE ZONE PLOT, YEARS 0 - 27, NORTH-SOUTH CROSS SECTION



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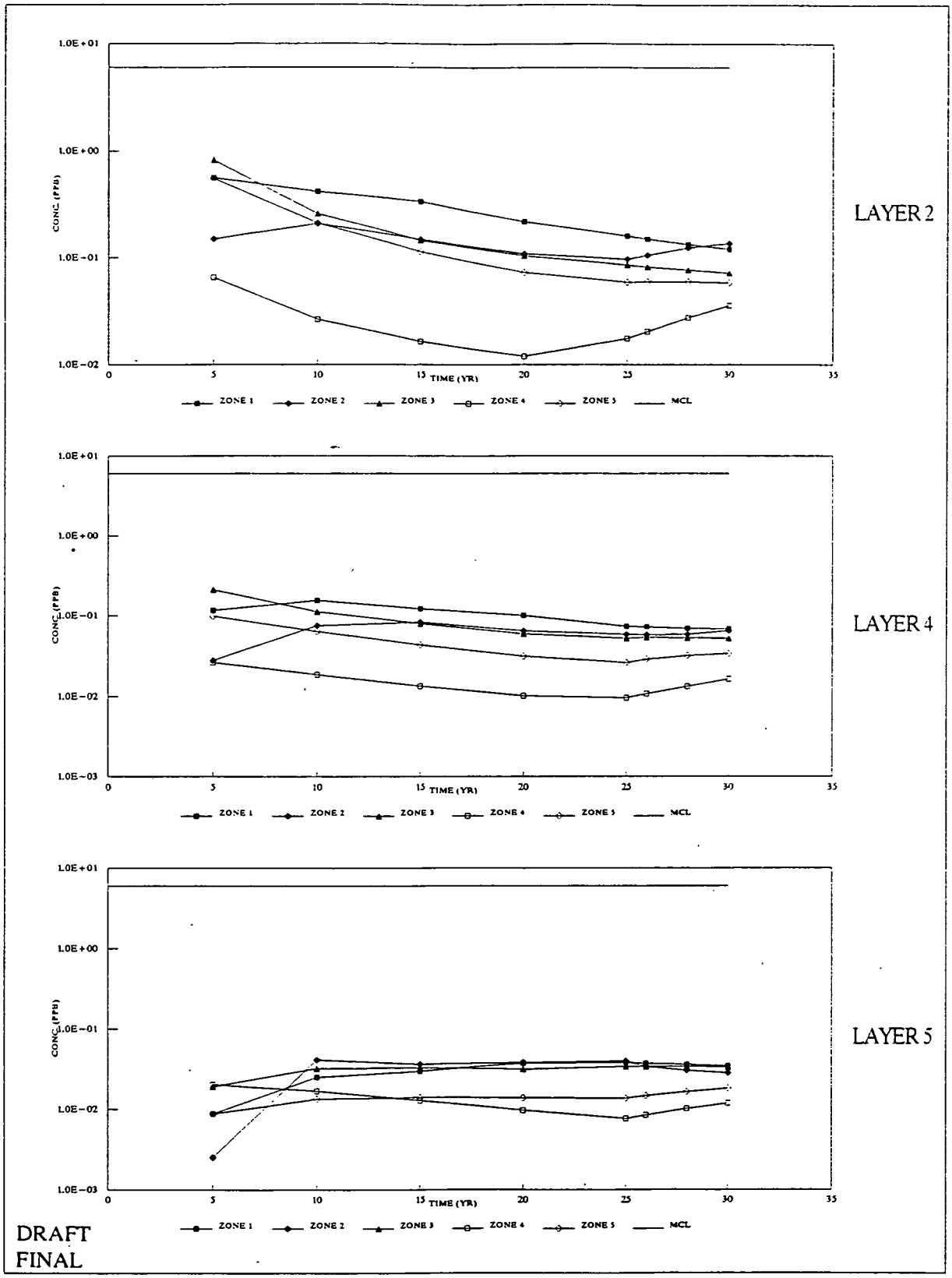
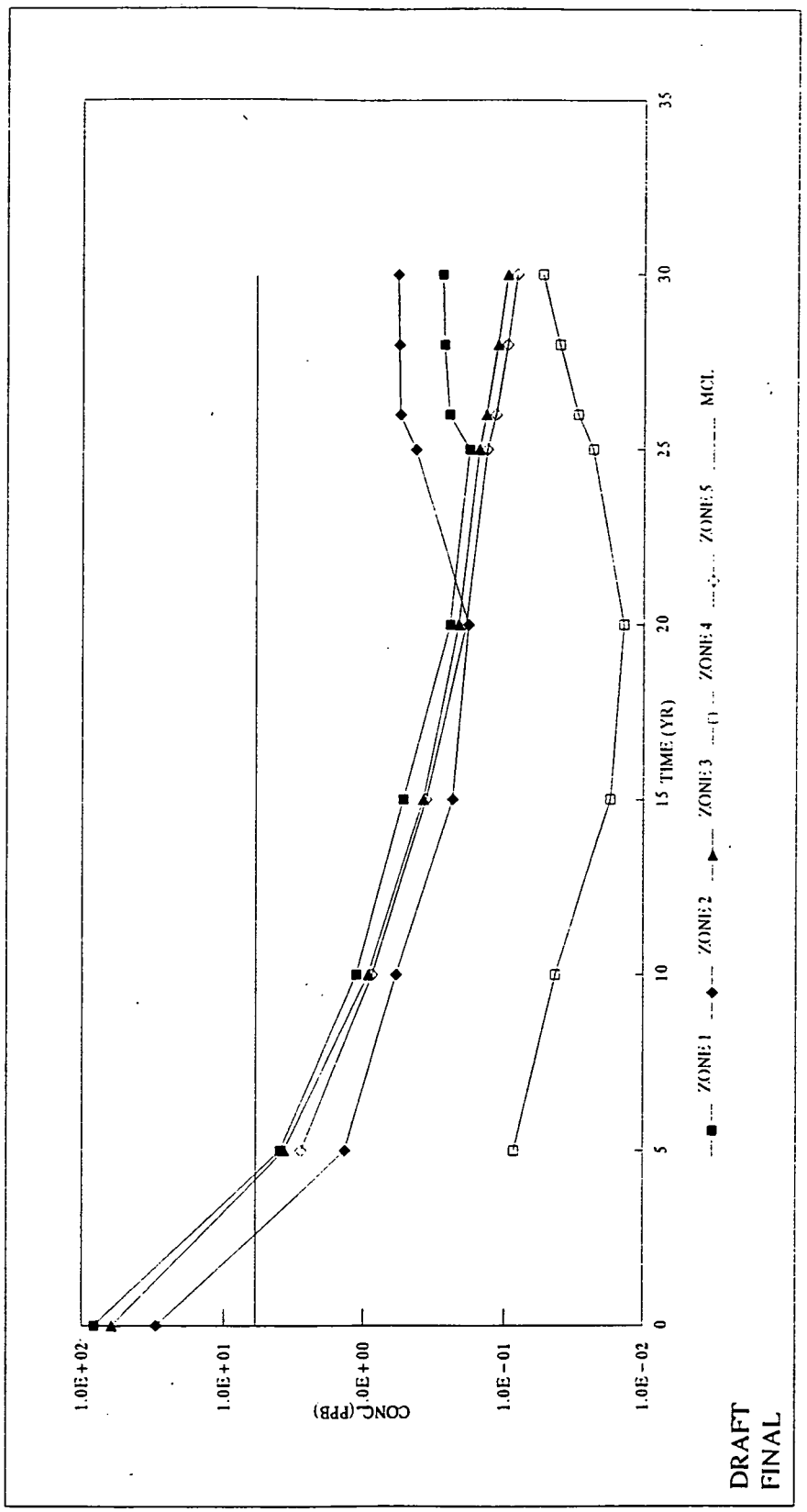
SB-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6), ANTIMONY



SB-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5), ANTIMONY



SB-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, ANTIMONY

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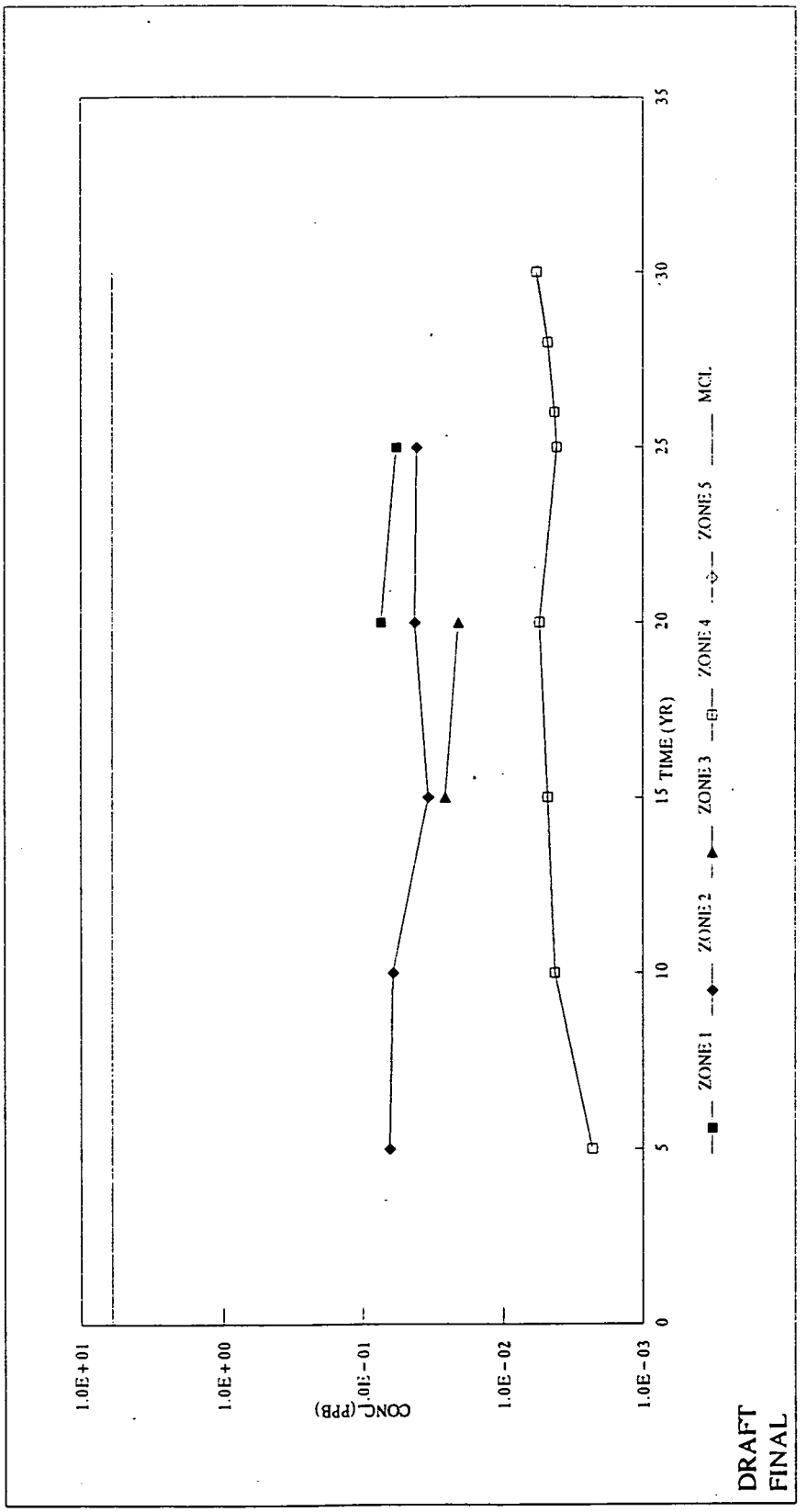
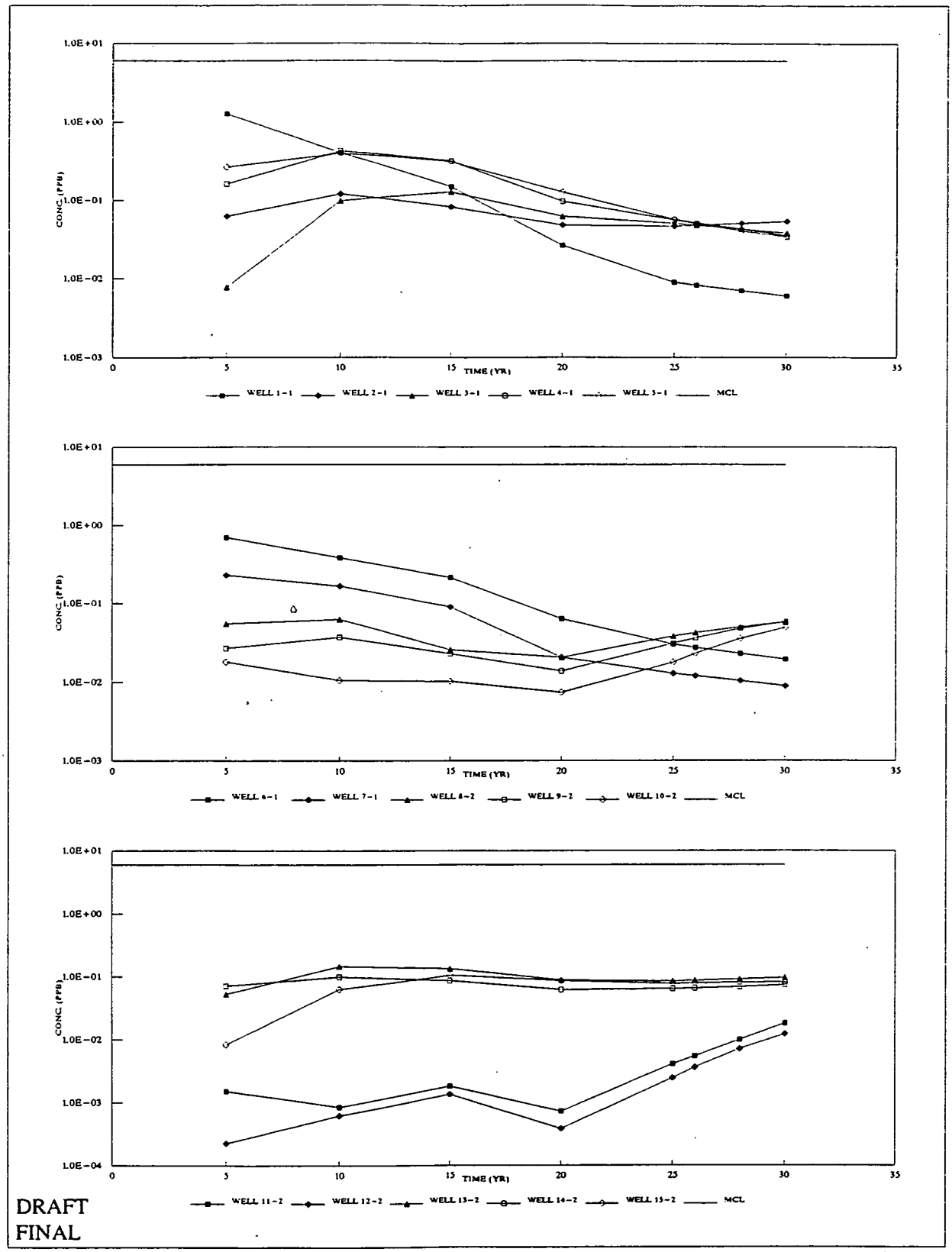


SB-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, ANTIMONY



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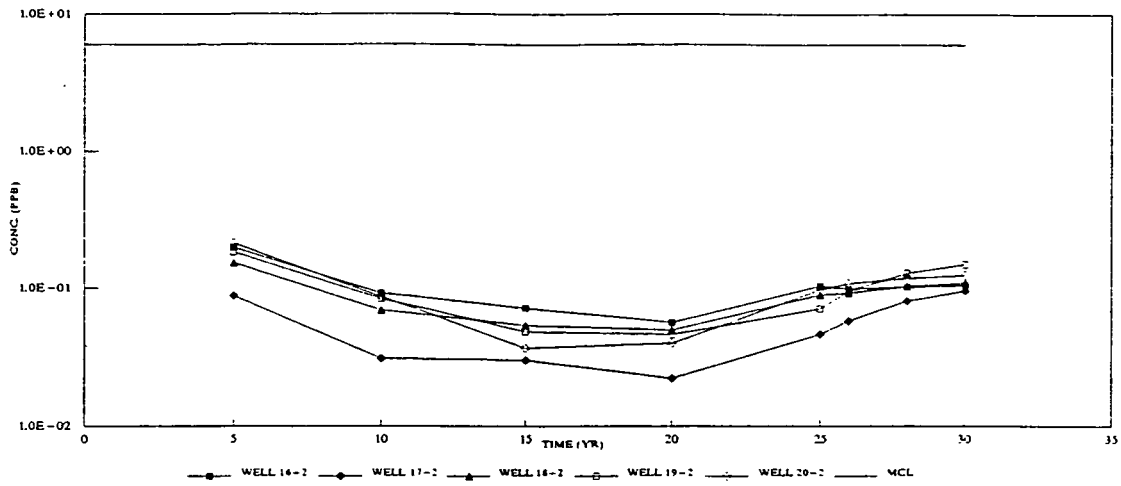
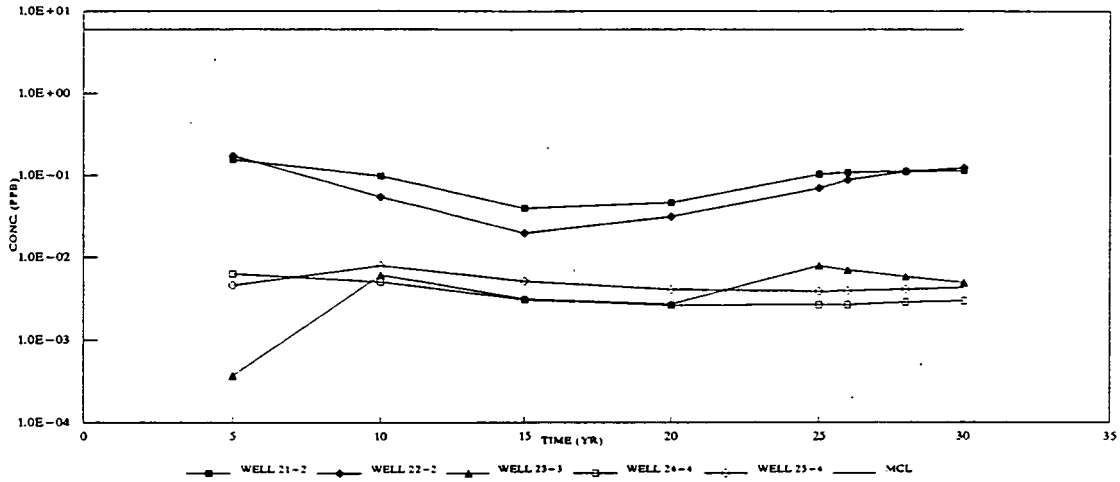
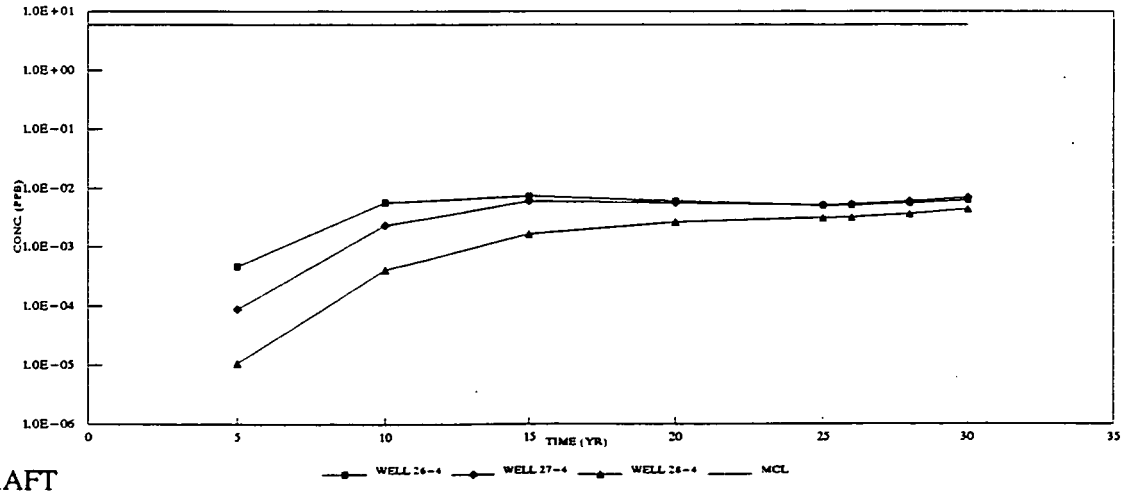
SB-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), ANTIMONY







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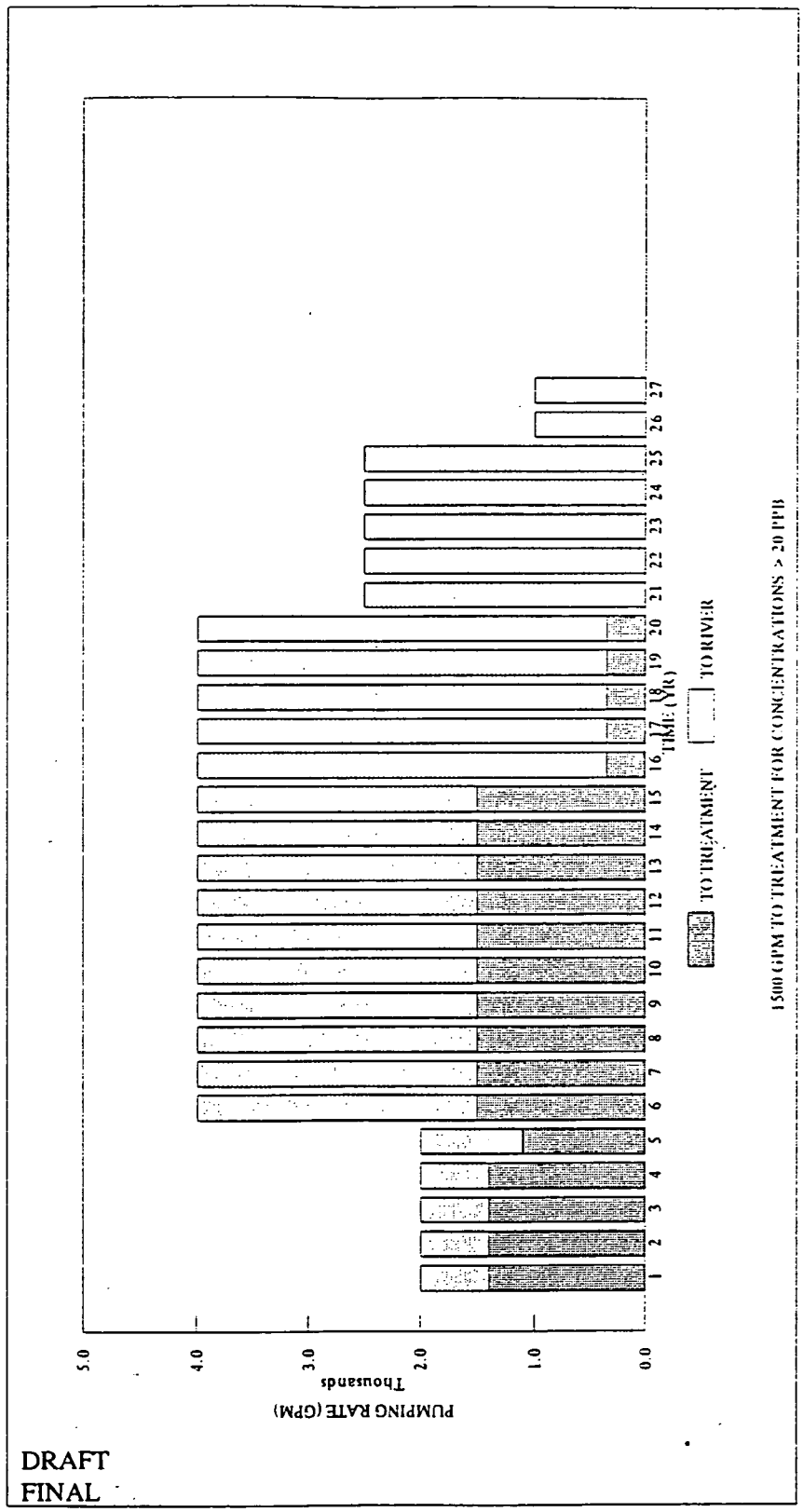
SB-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), ANTIMONY



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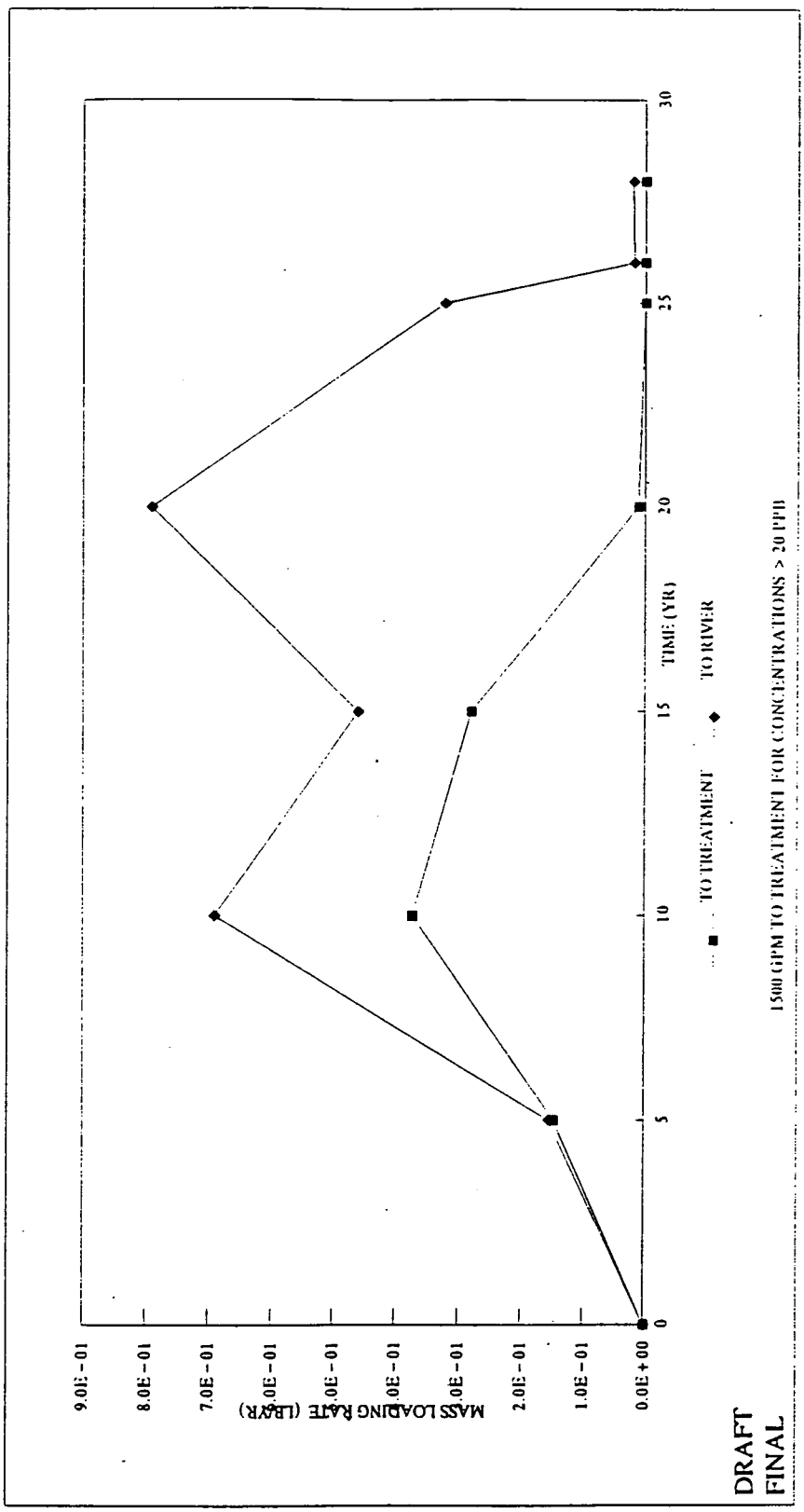
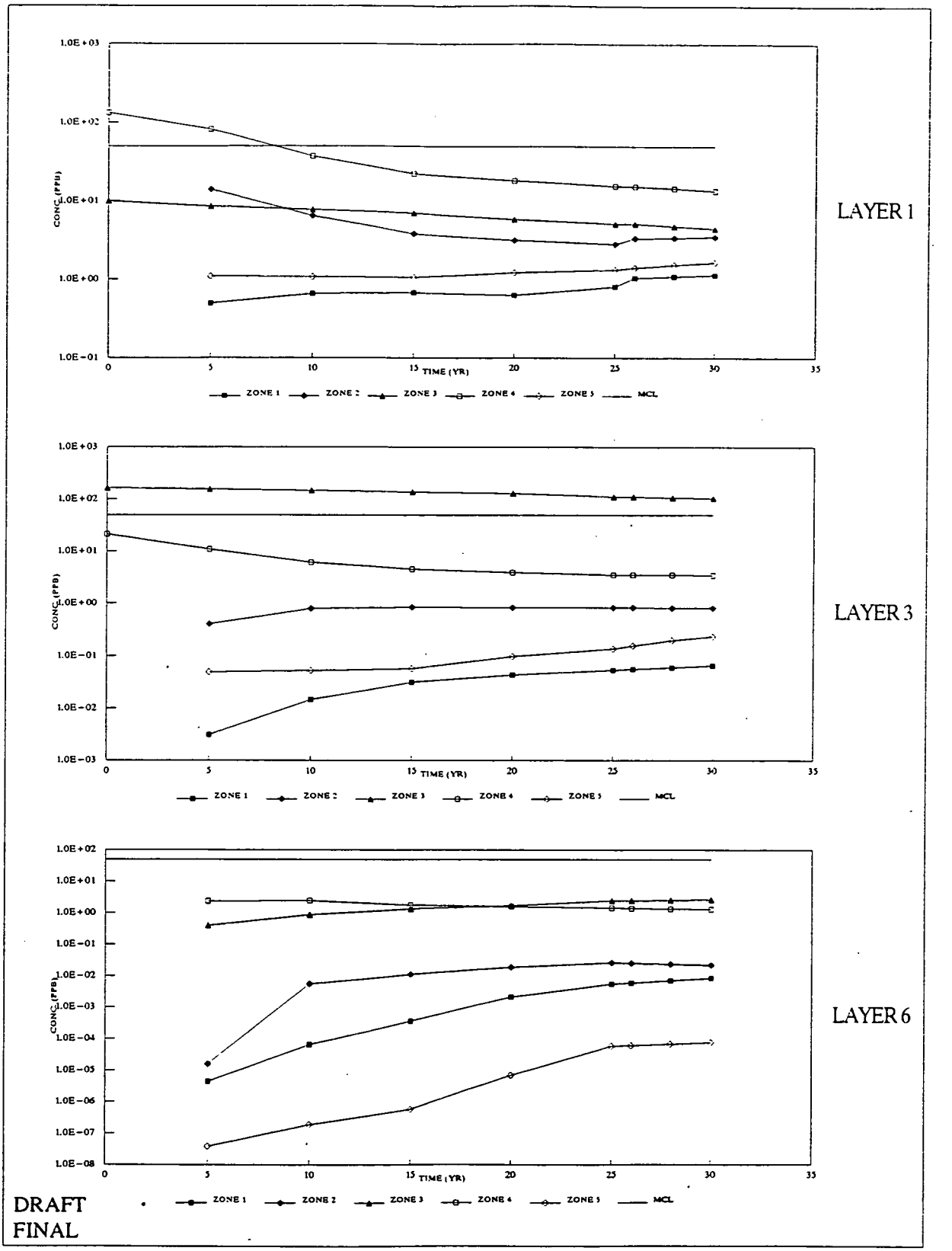
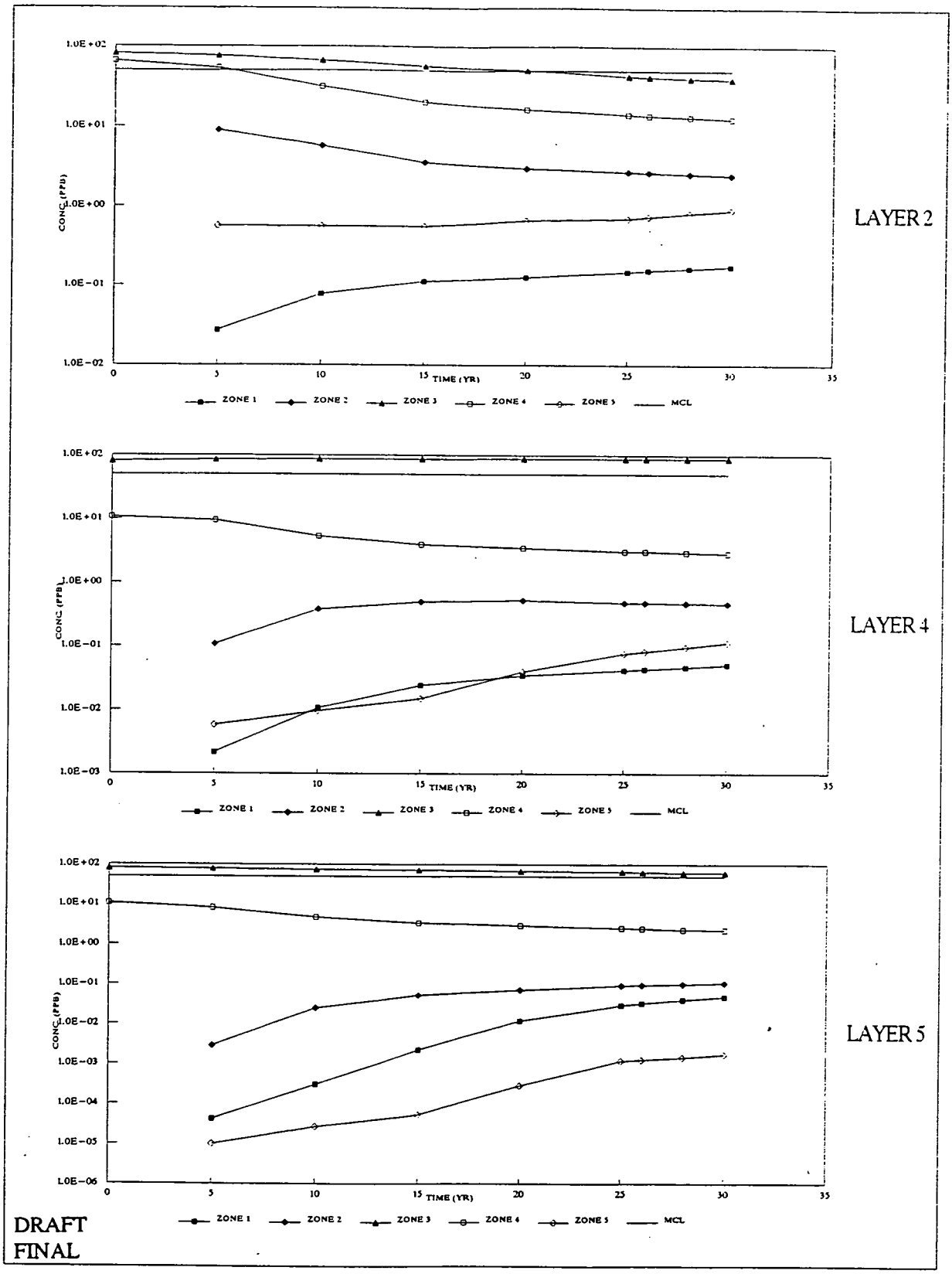
SB-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), ANTIMONY



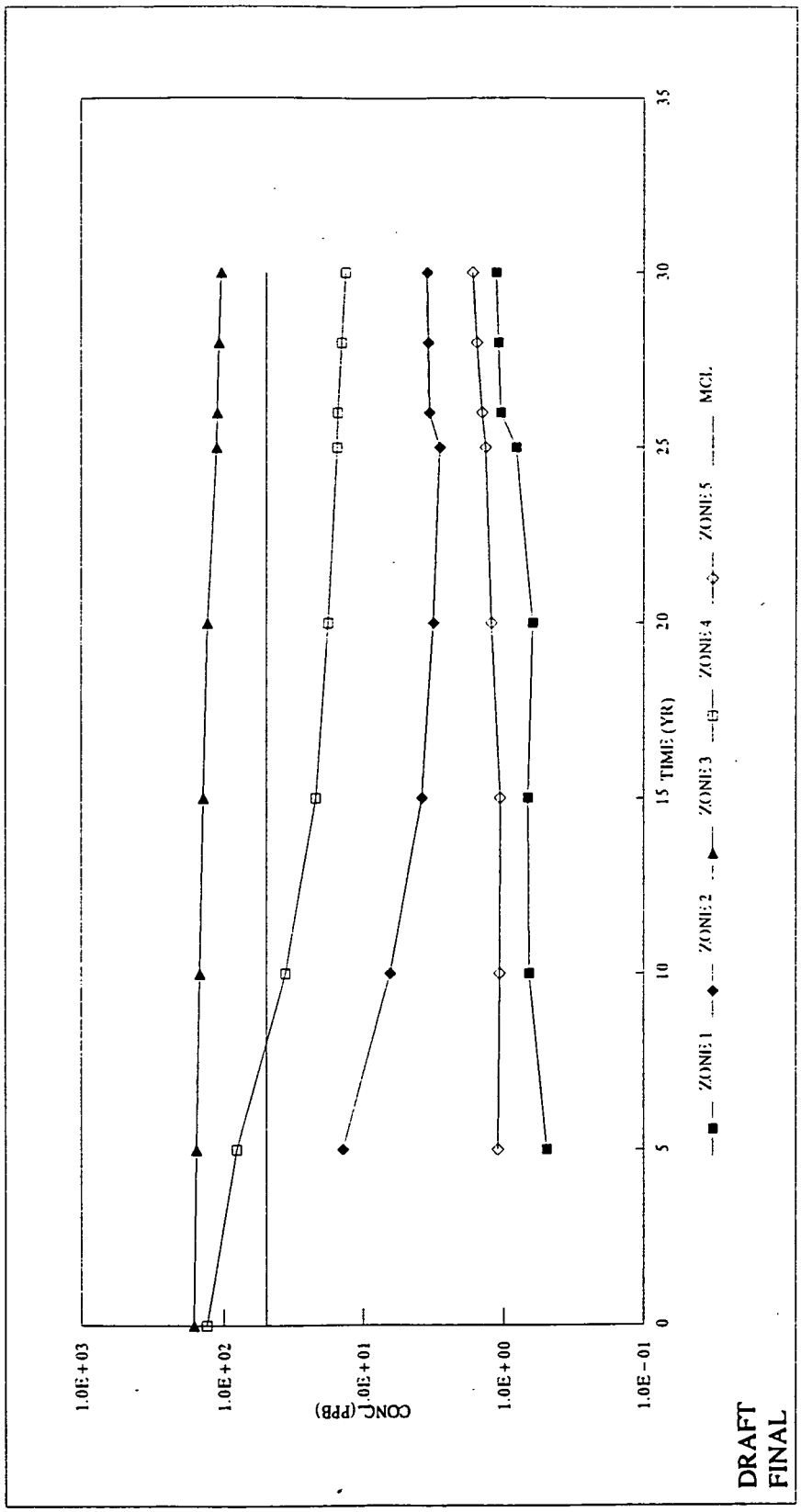
SB-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), ANTIMONY



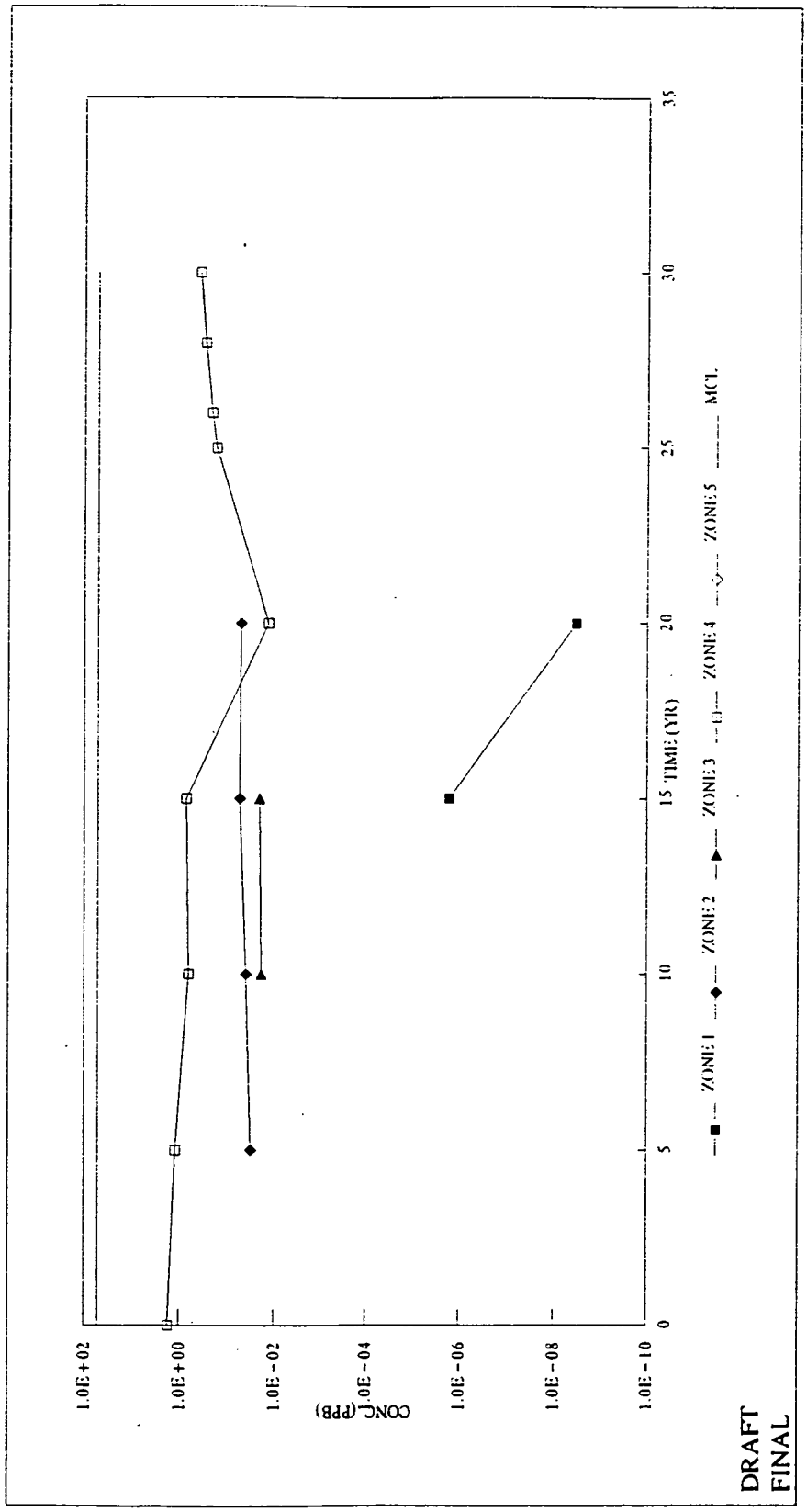
AS-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6), ARSENIC



AS-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5), ARSENIC



AS-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, ARSENIC



AS-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, ARSENIC

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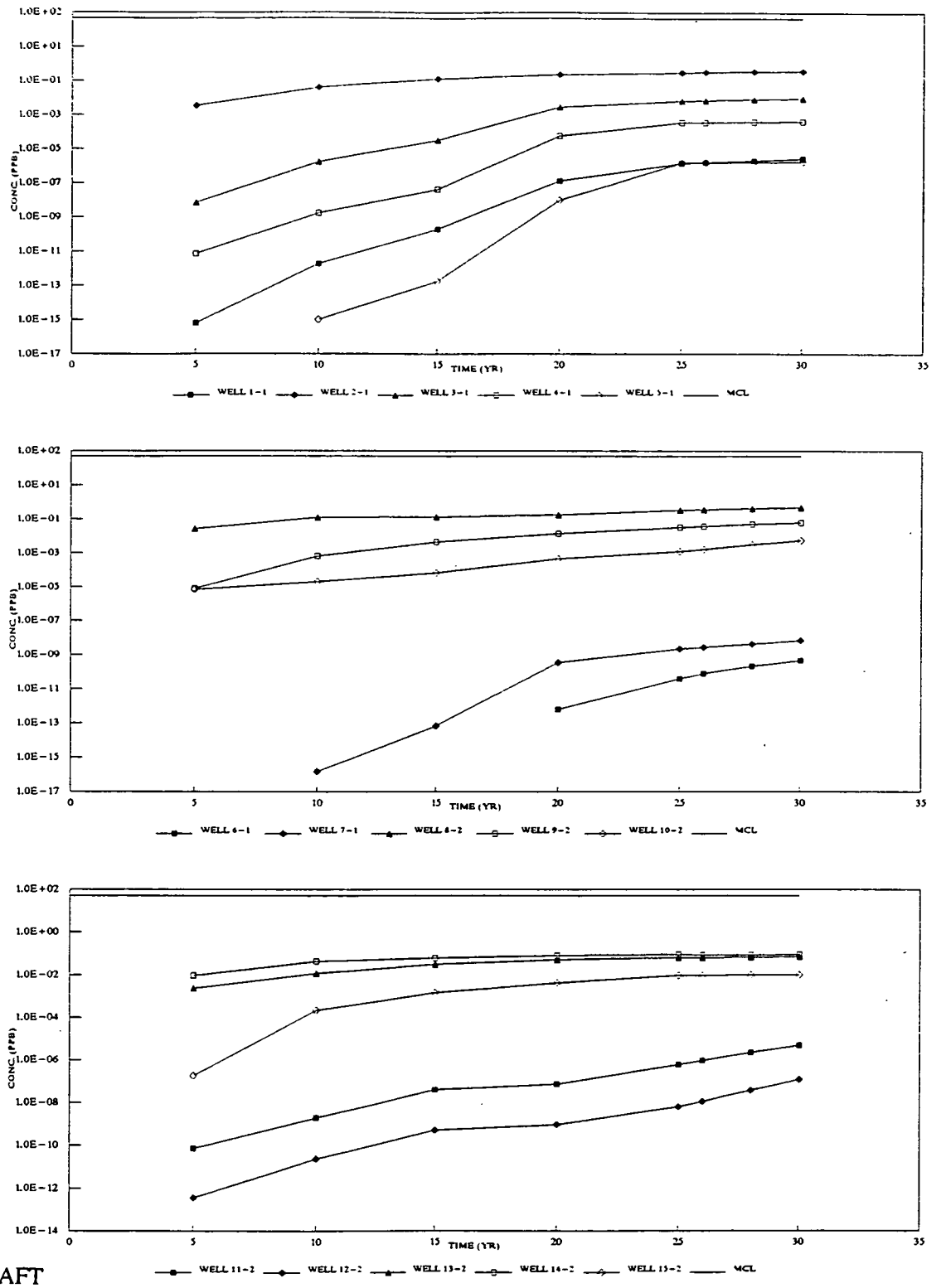

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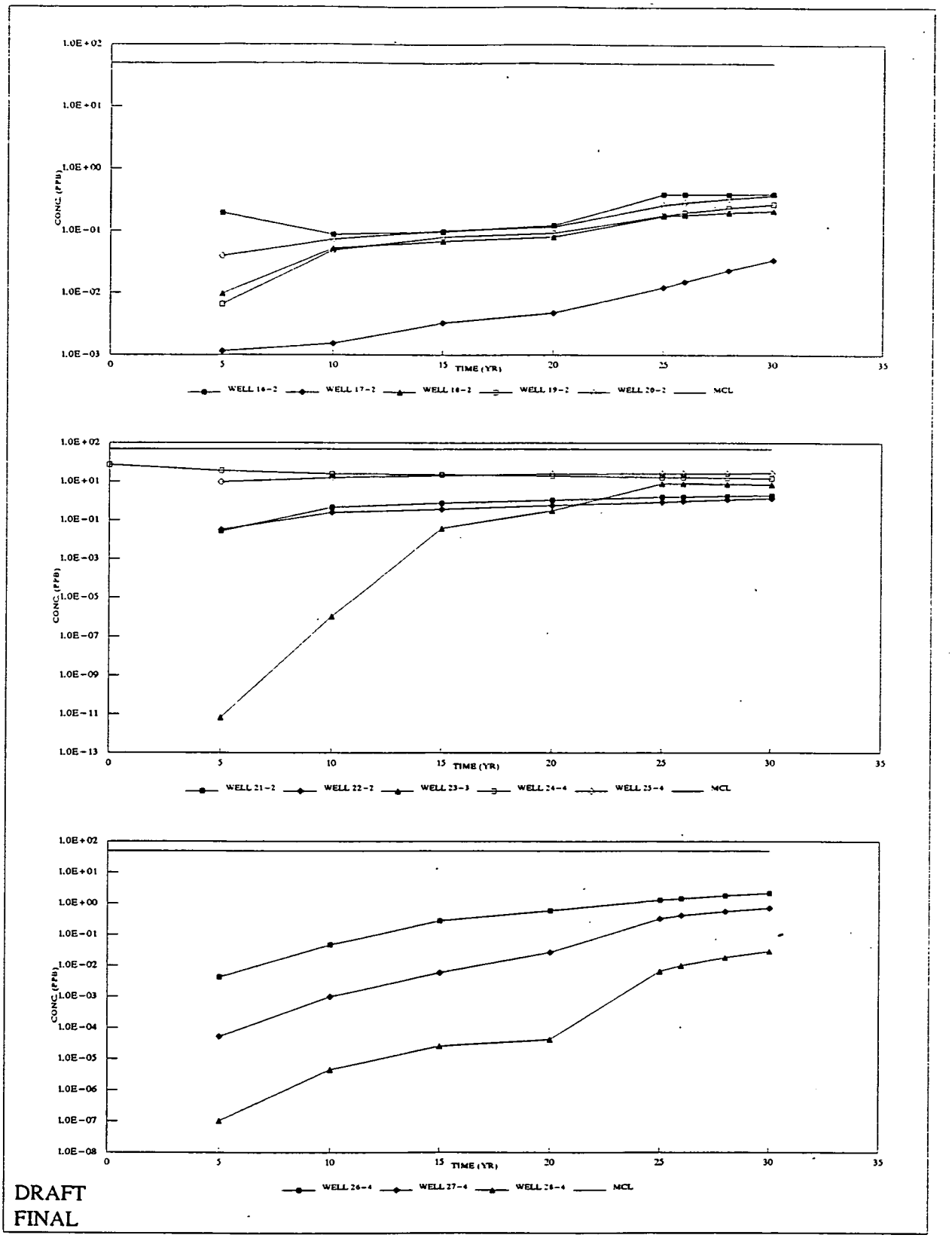
AS-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), ARSENIC



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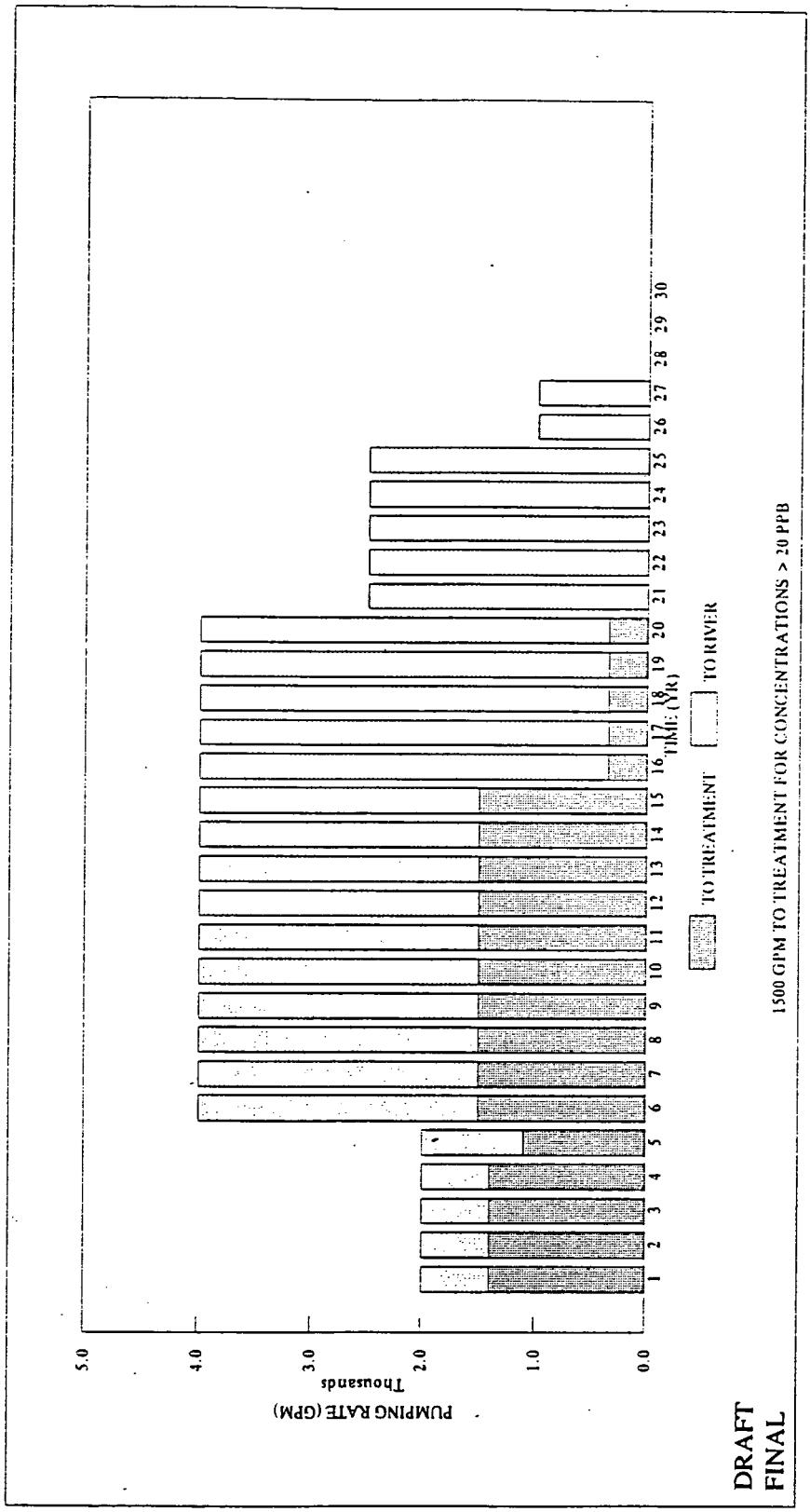
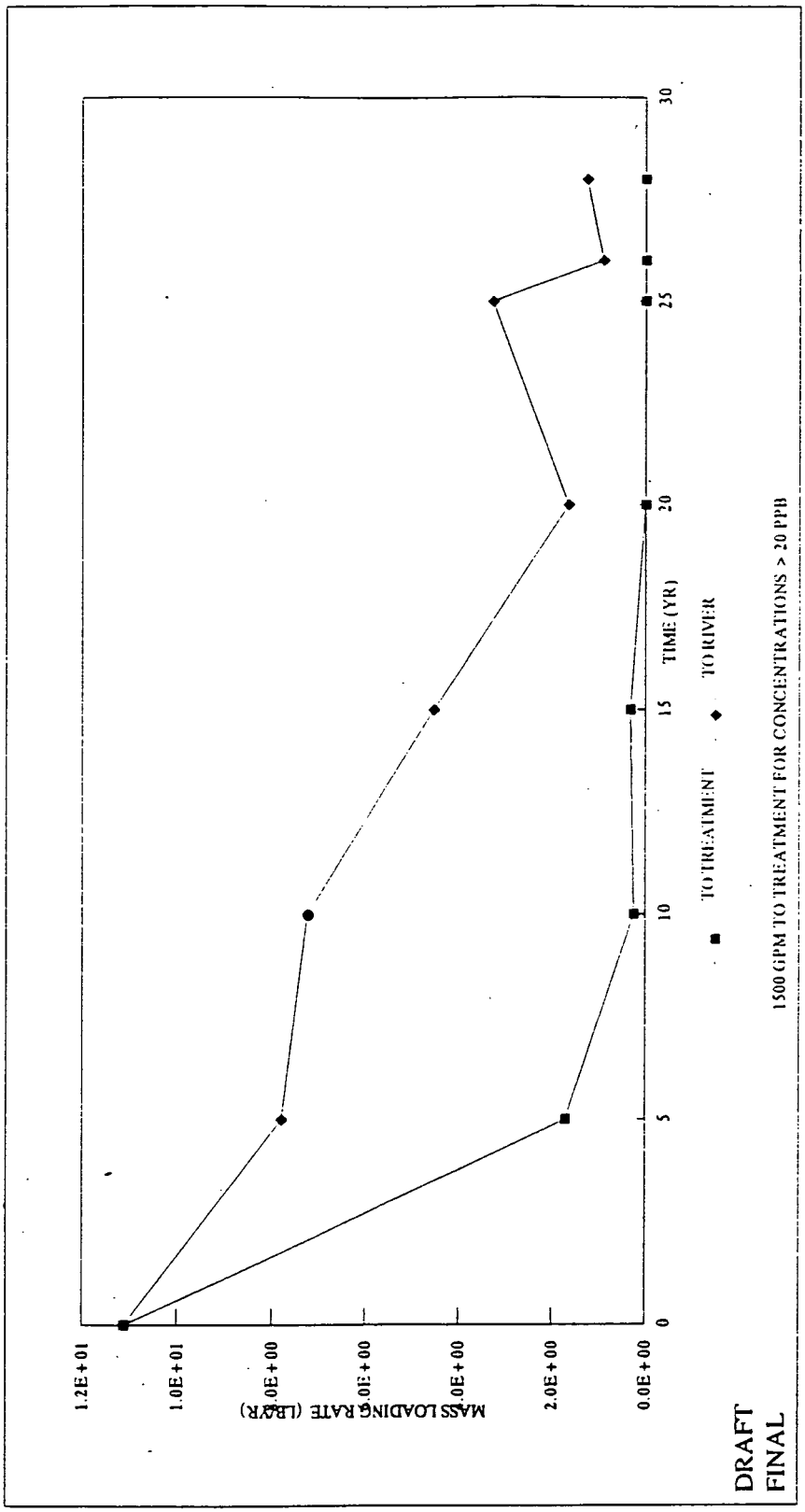
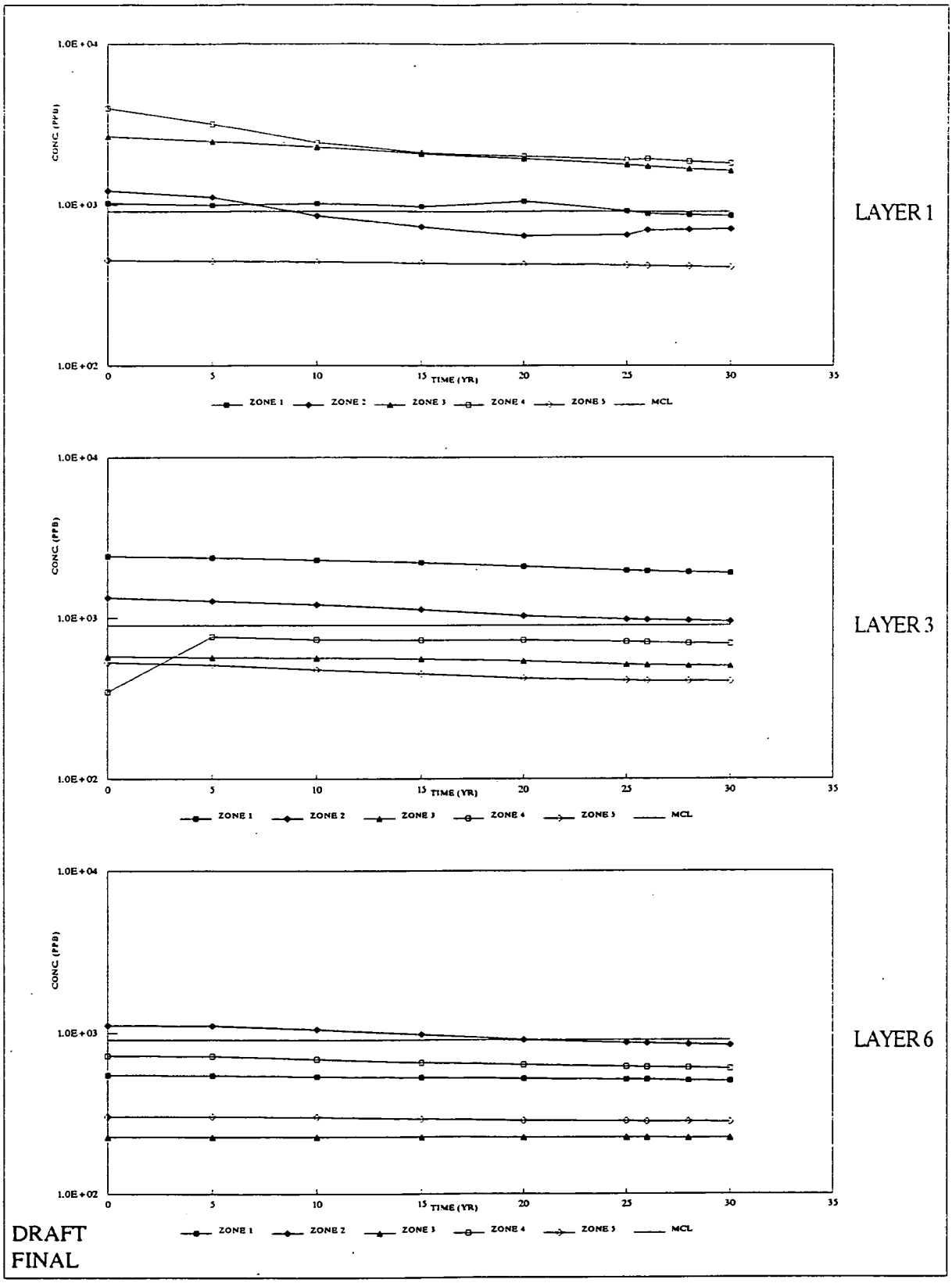
AS-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), ARSENIC



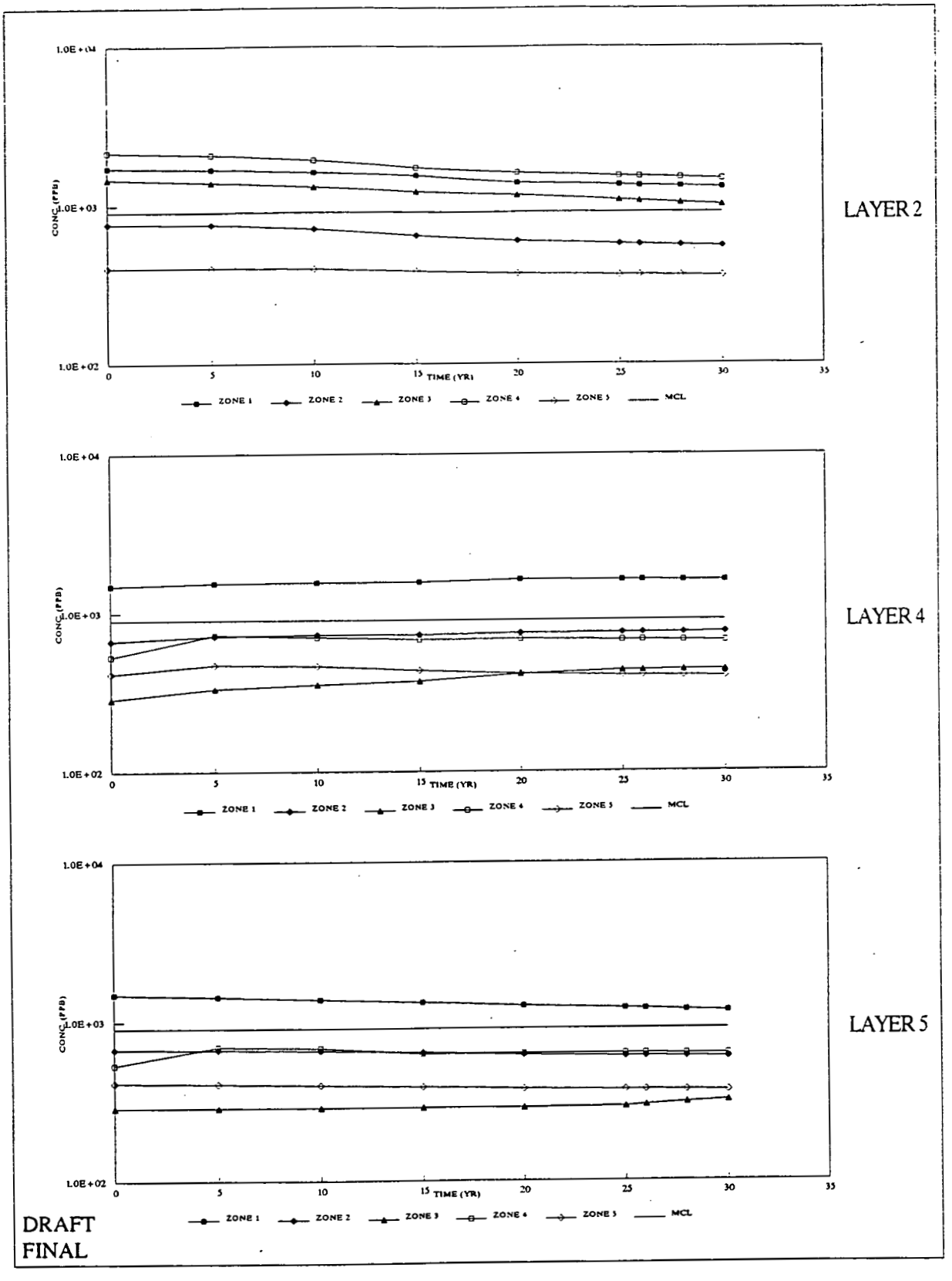
AS-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), ARSENIC



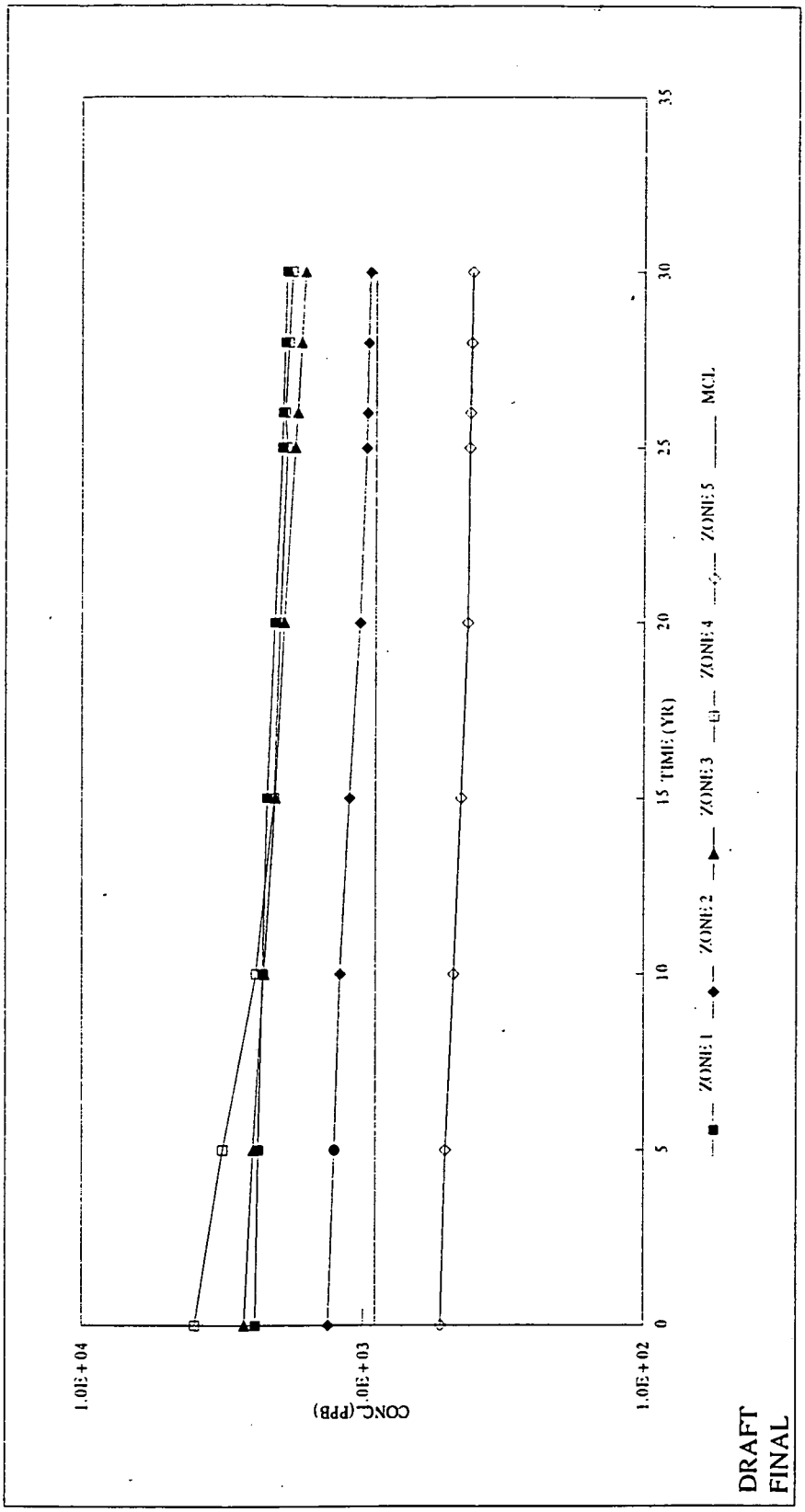
AS-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), ARSENIC



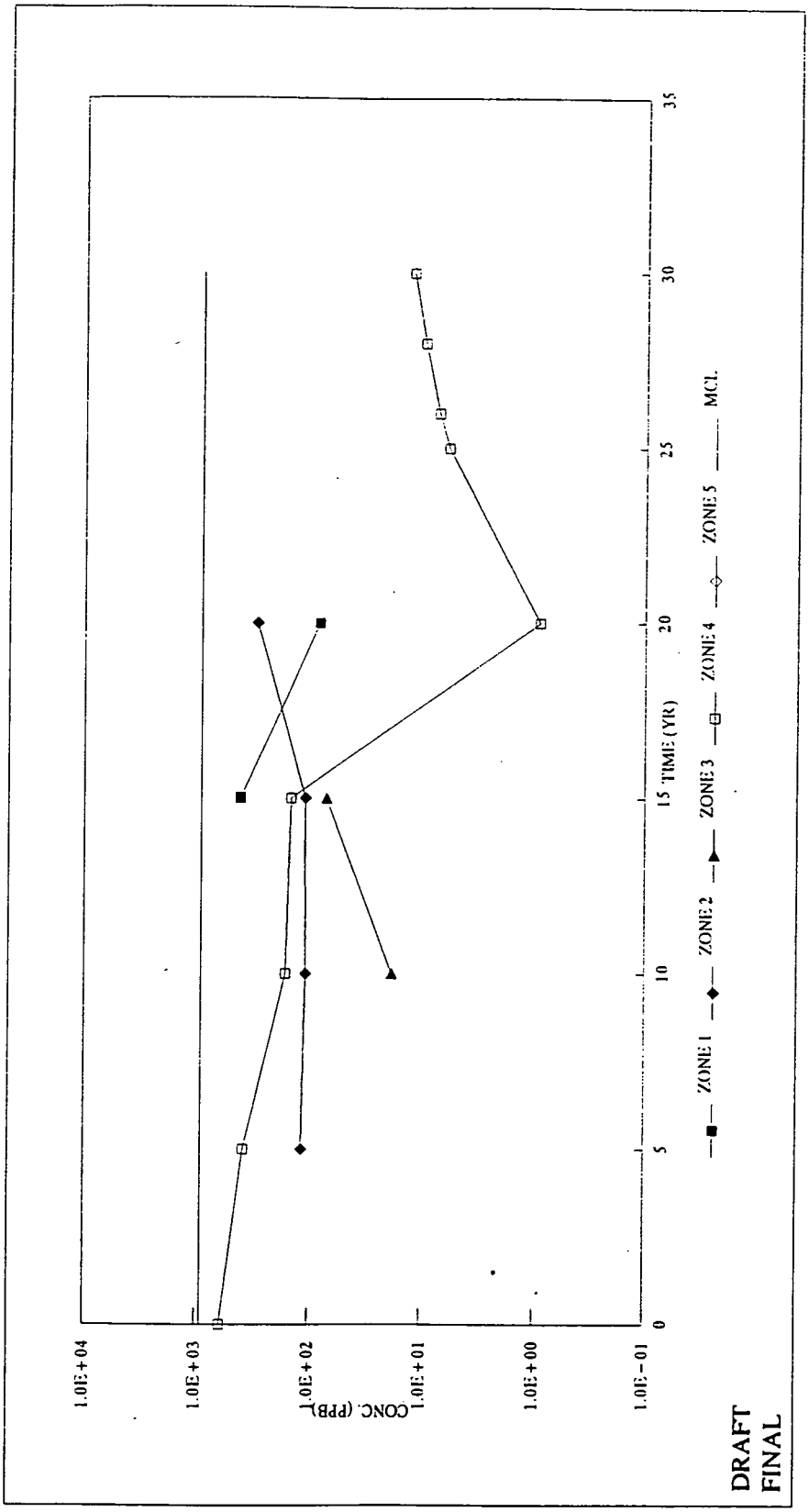
MN-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 1, 3, AND 6), MANGANESE



MN-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 2, 4, AND 5), MANGANESE



MN-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, MANGANESE



MN-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, MANGANESE

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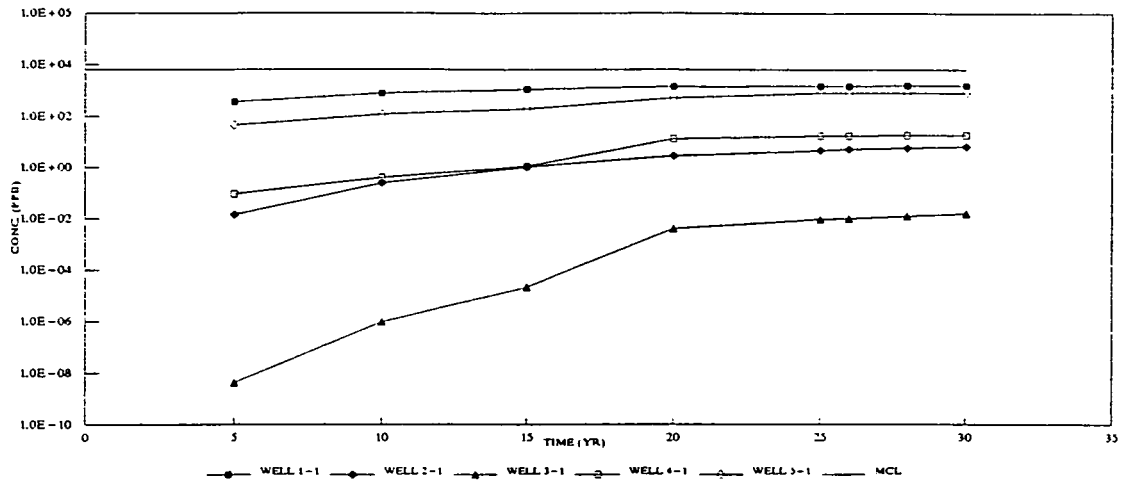

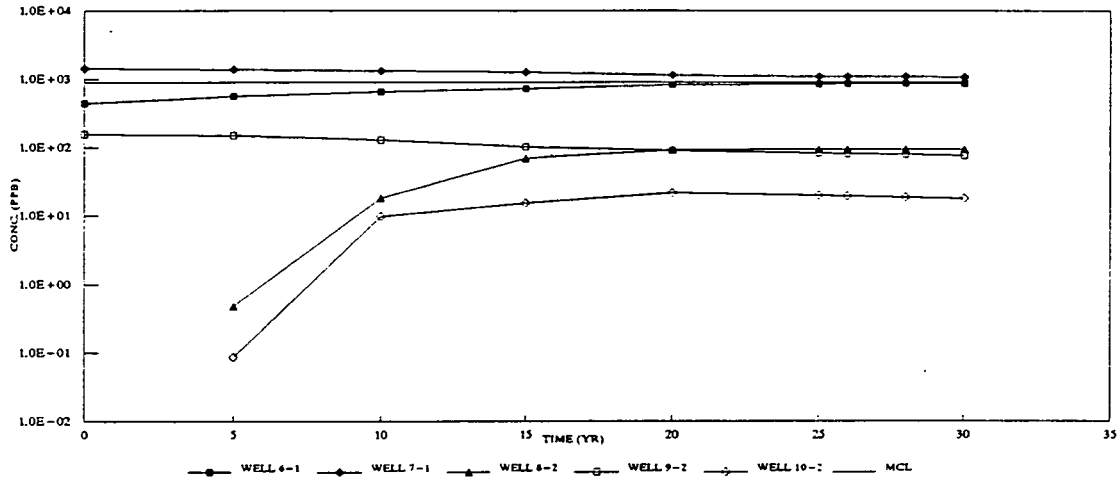

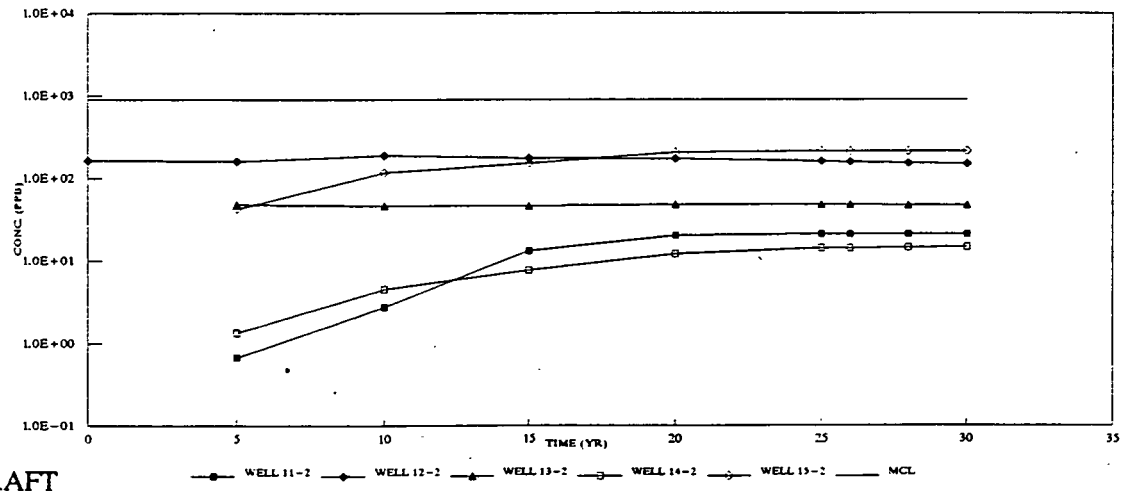

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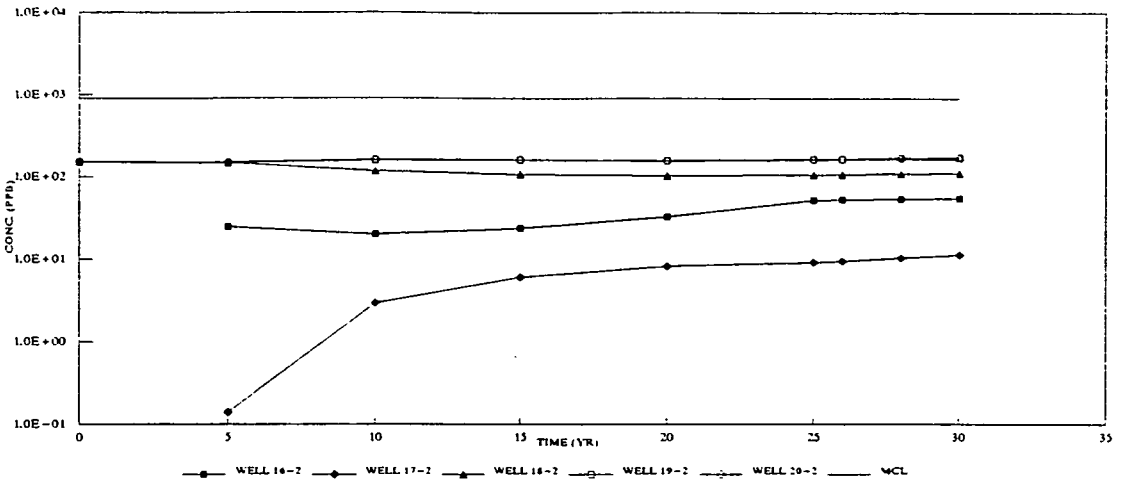
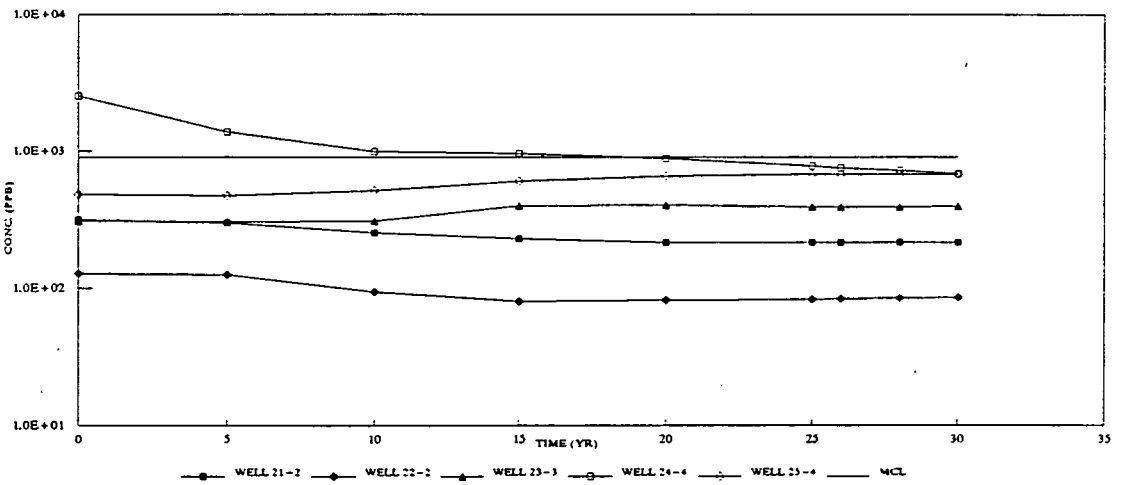
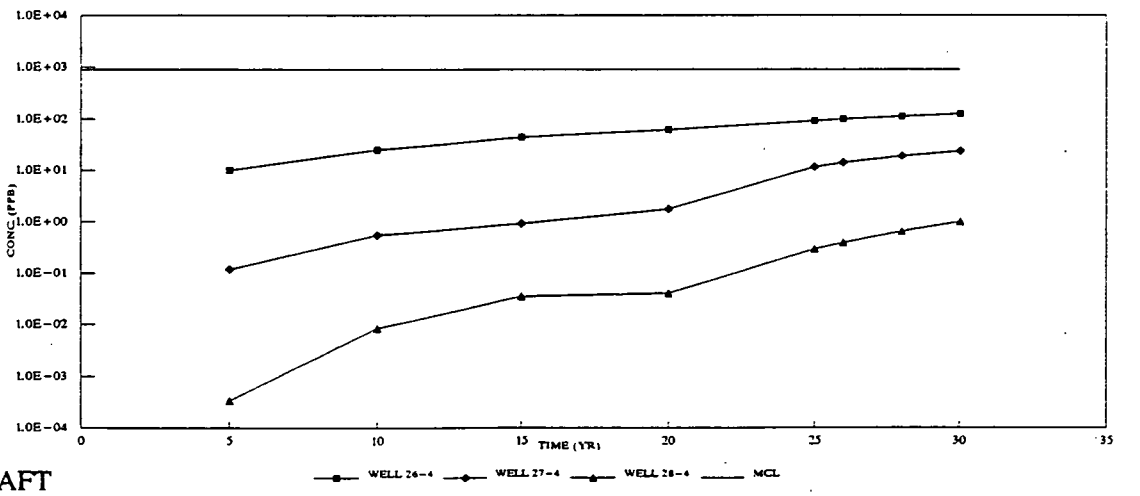
MN-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), MANGANESE







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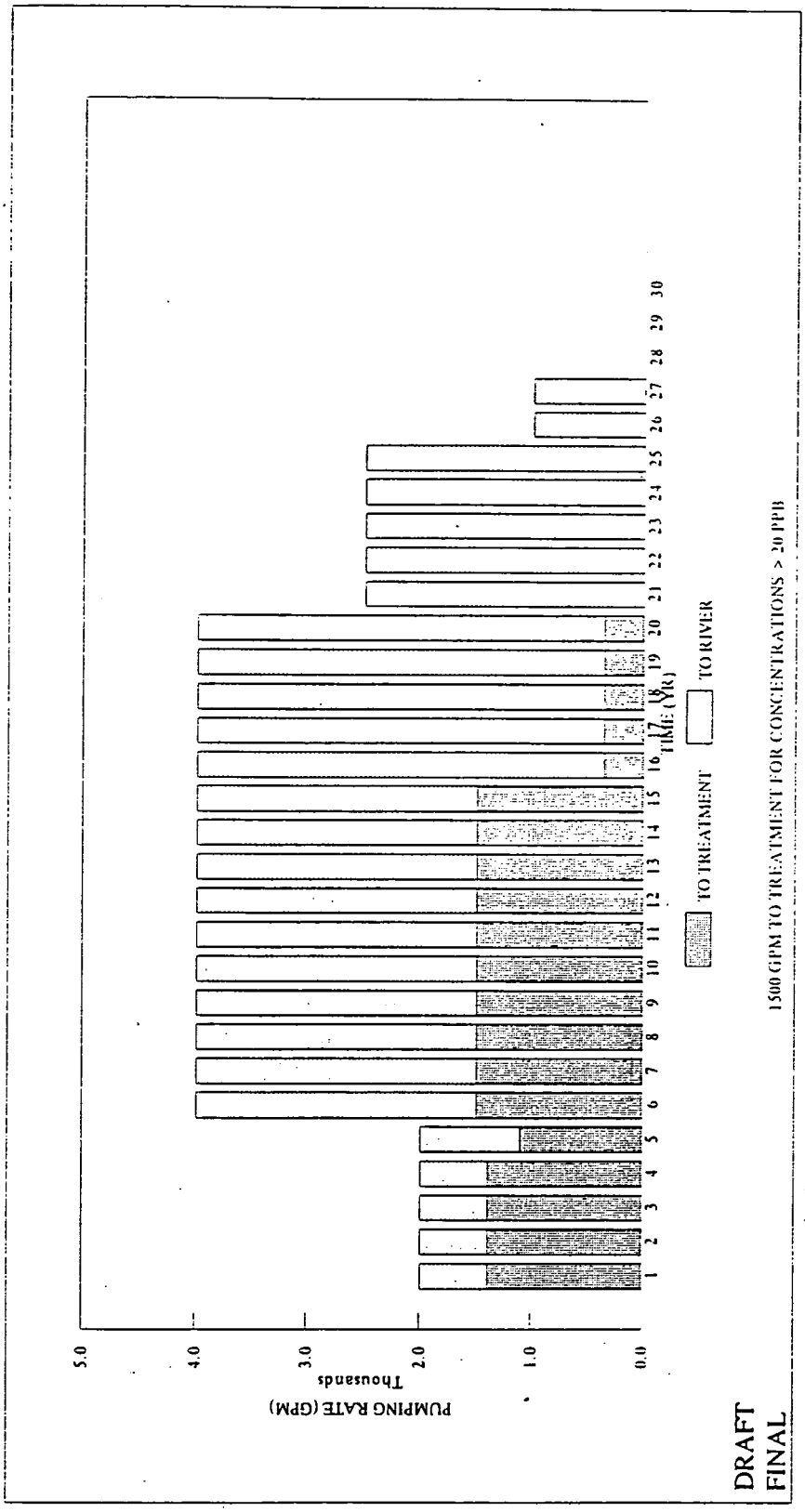
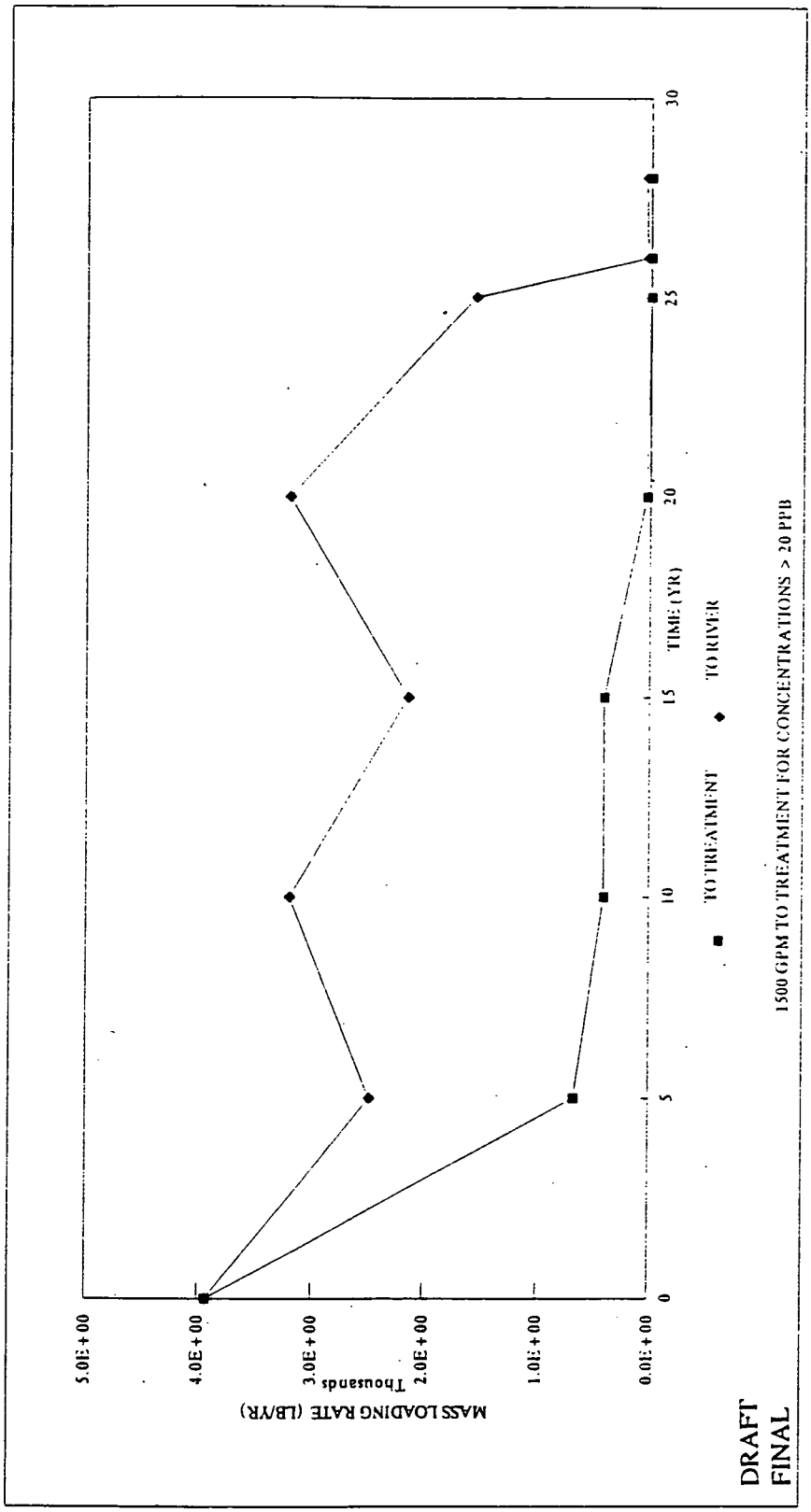
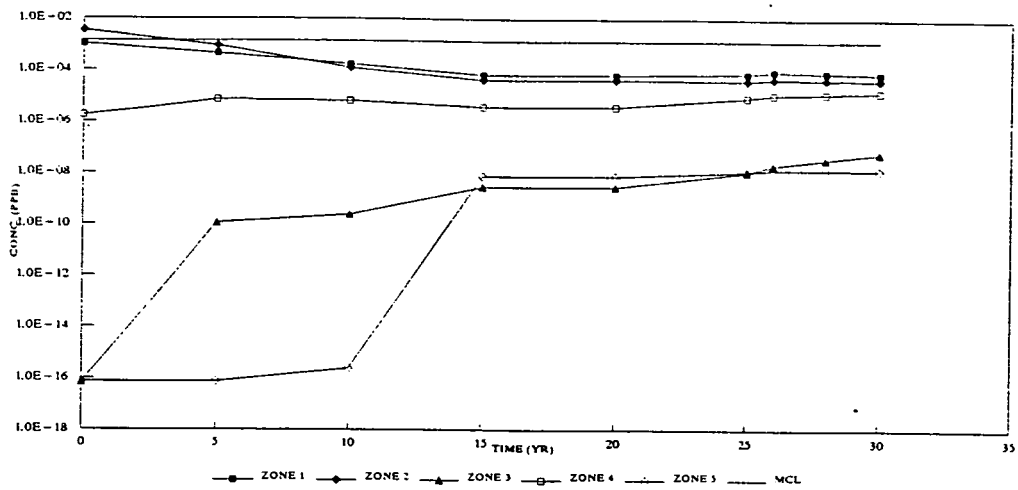
MN-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), MANGANESE



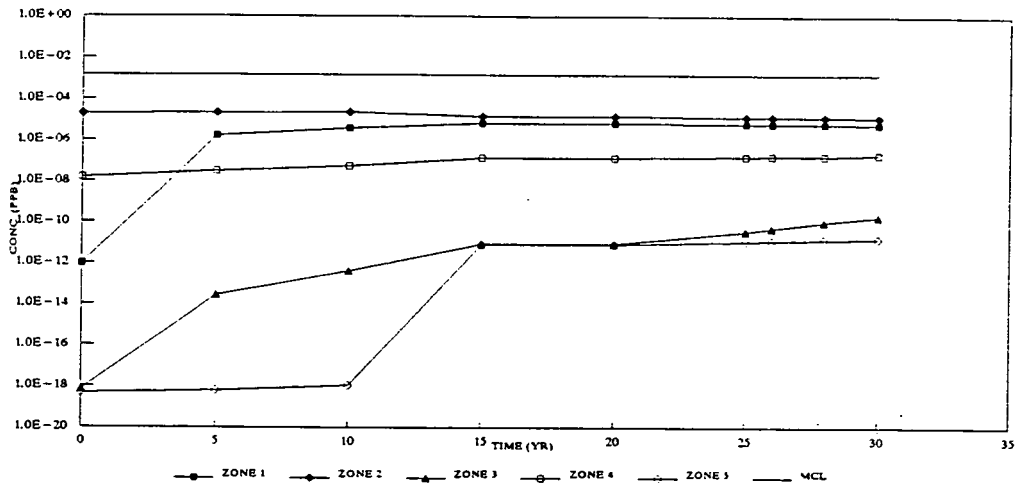
MN-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), MANGANESE



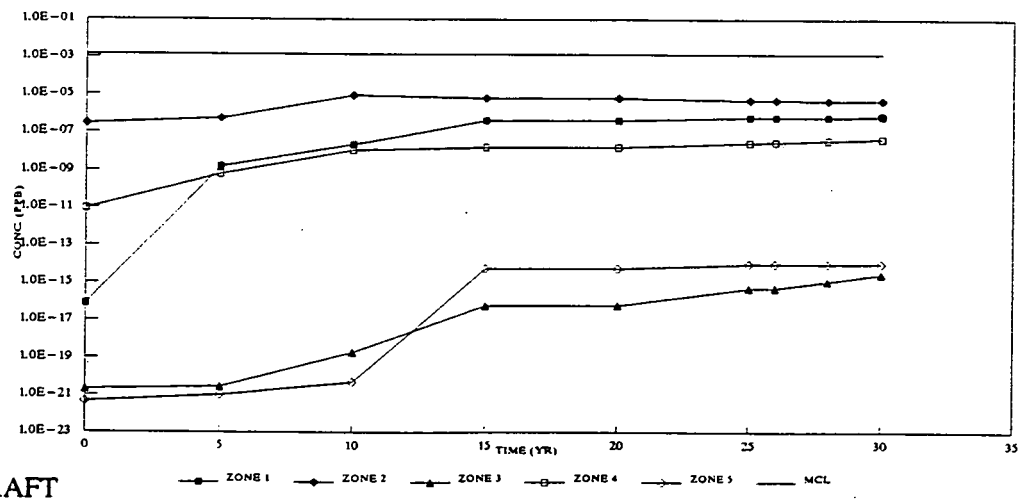
MN-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), MANGANESE



LAYER 1



LAYER 3



LAYER 6

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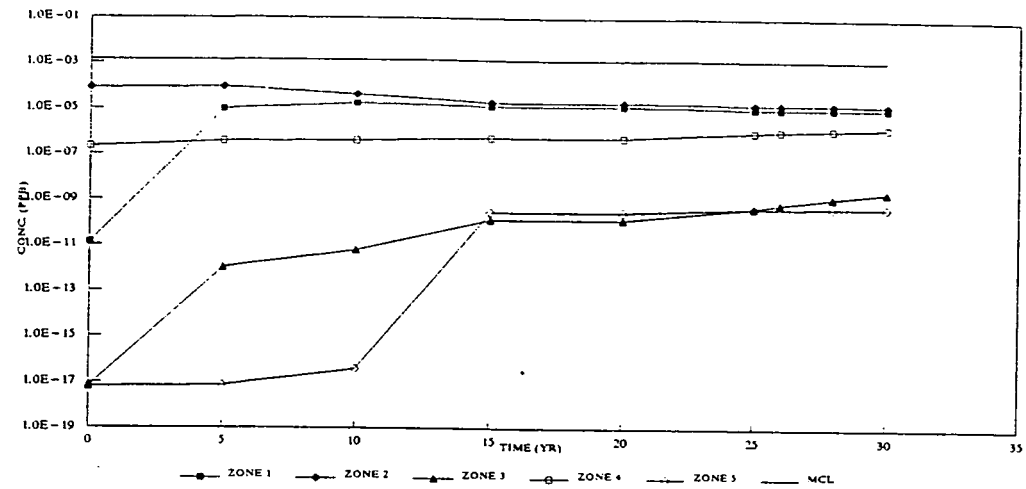
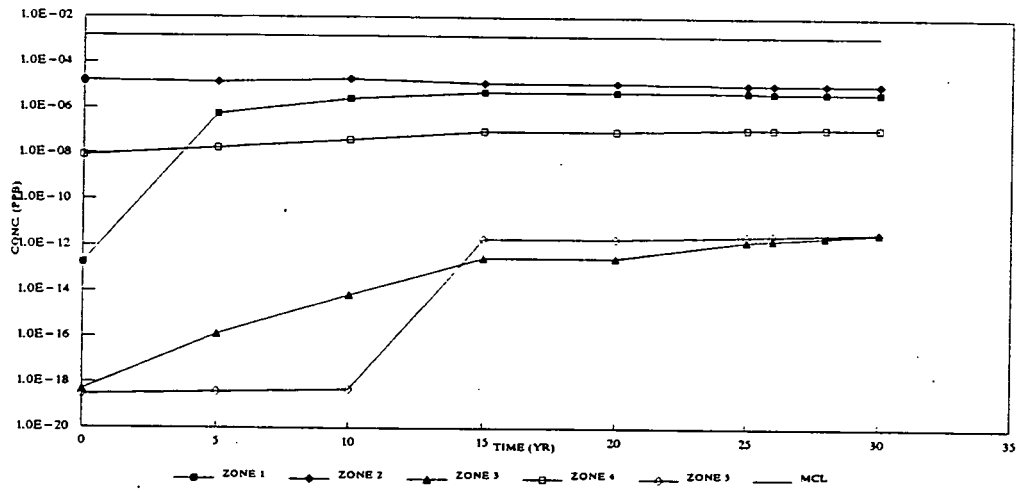
FINAL

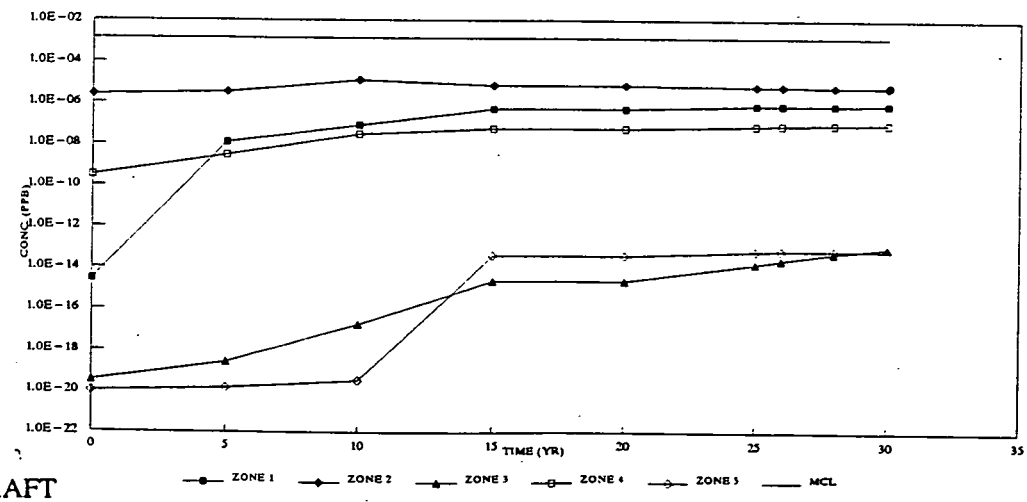
NP-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 1, 3, AND 6), NEPTUNIUM-237



LAYER 2



LAYER 4



LAYER 5

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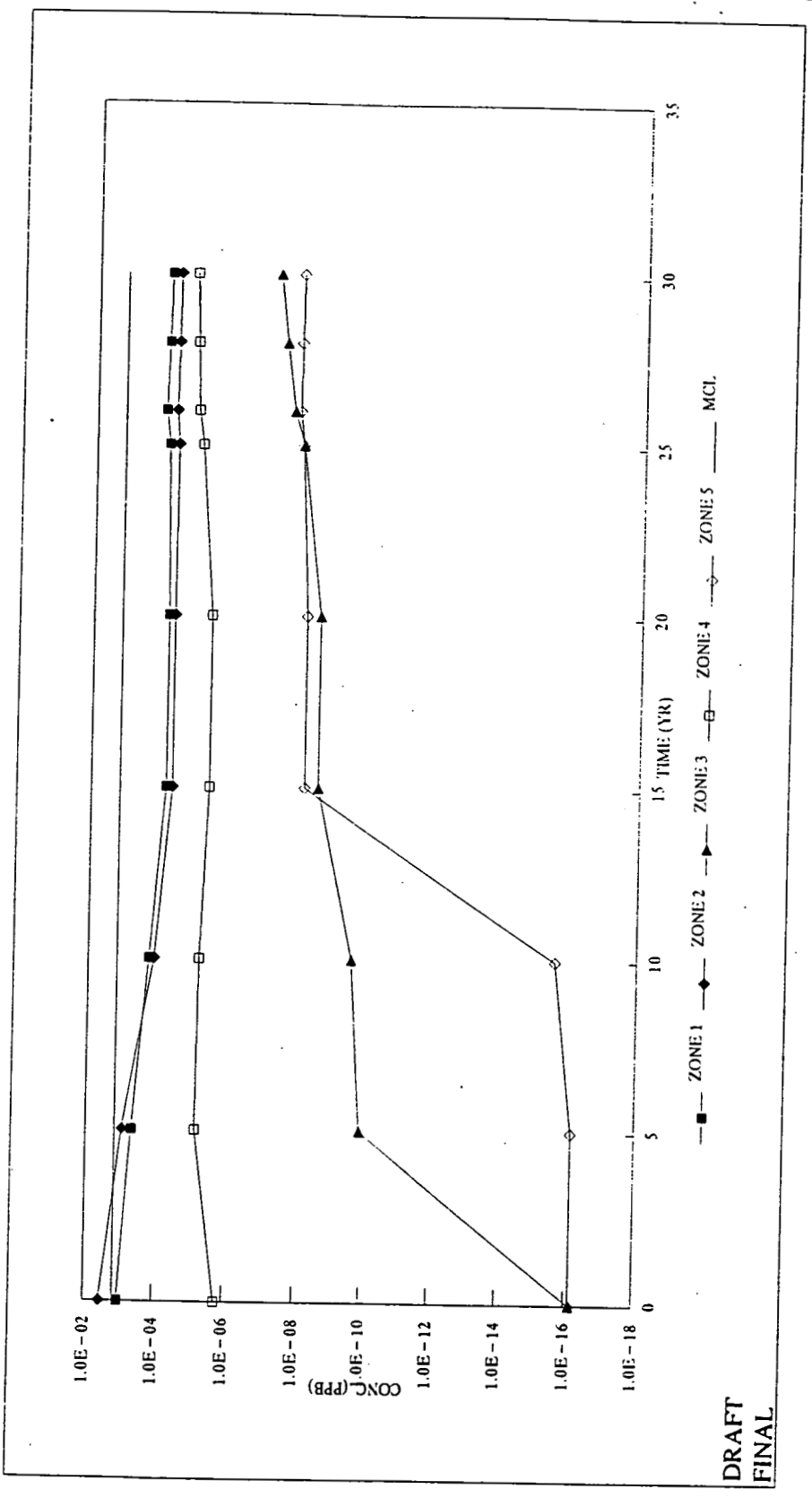
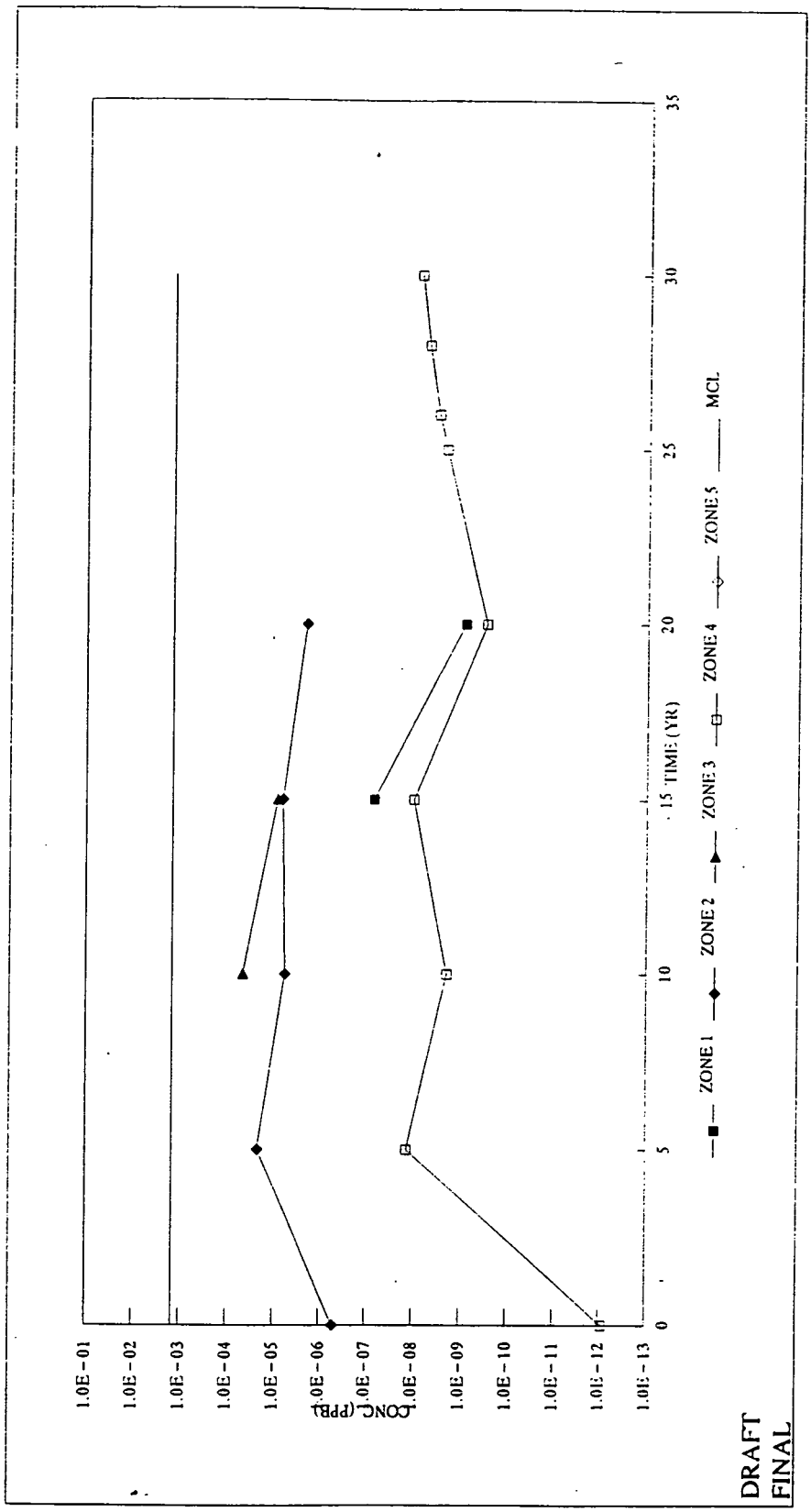
FINAL

NP-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5), NEPTUNIUM-237



NP-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, NEPTUNIUM-237



NP-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, NEPTUNIUM-237

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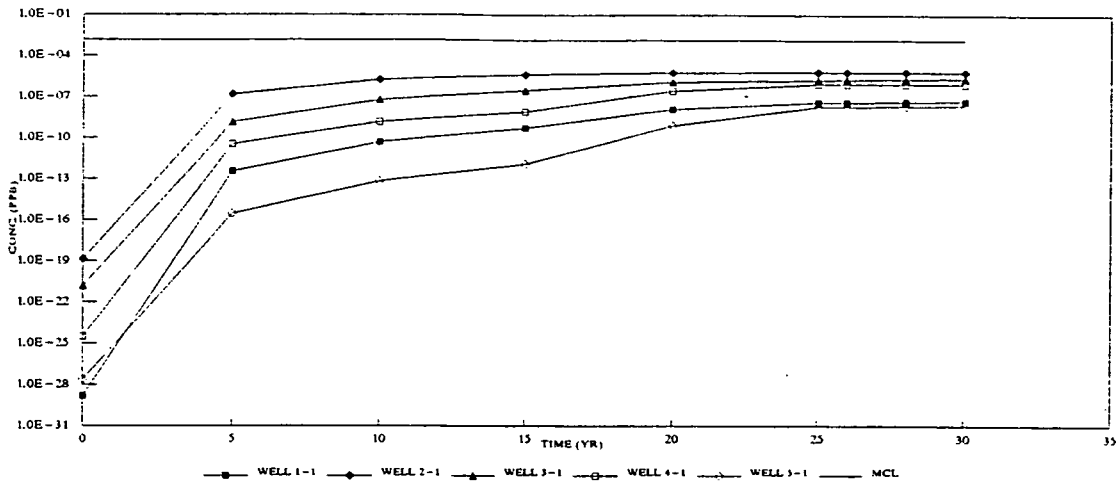

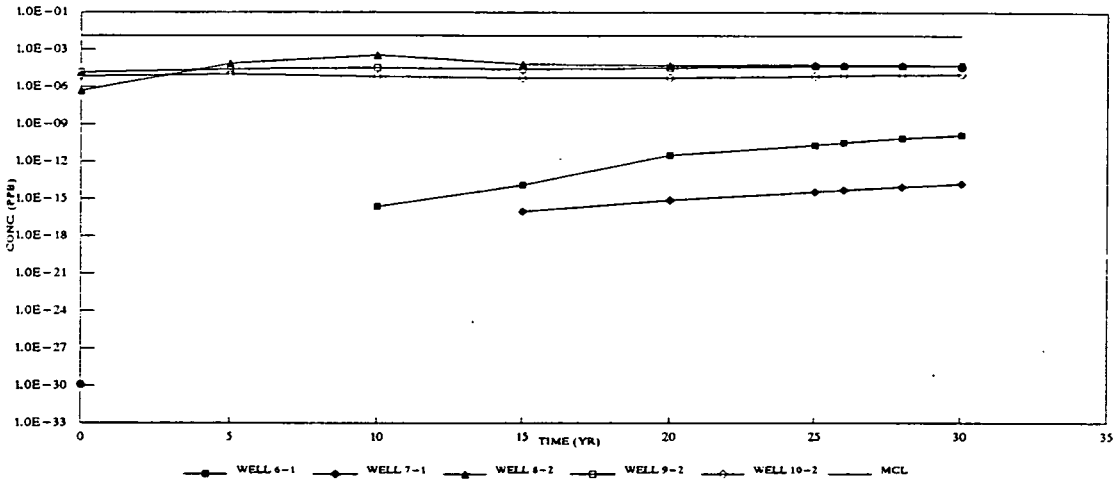

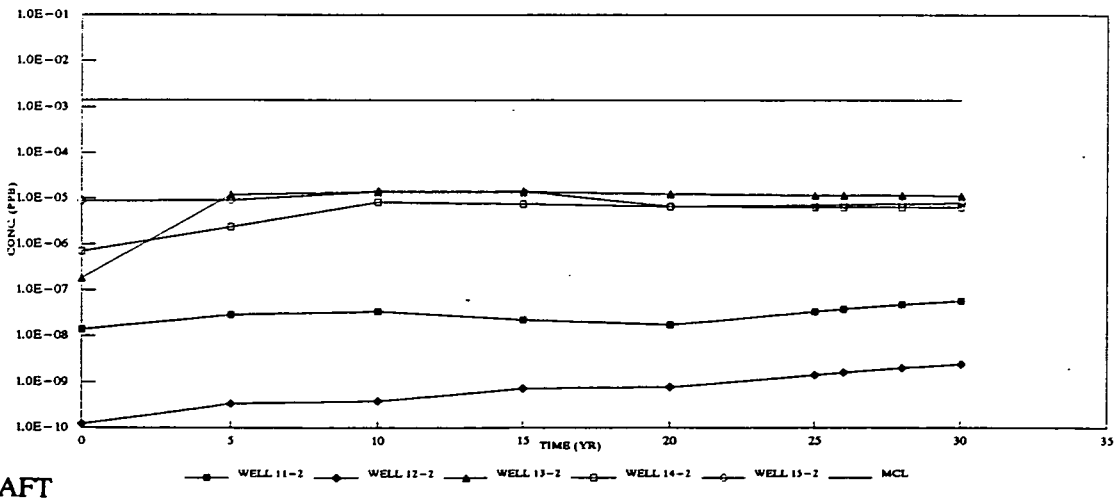

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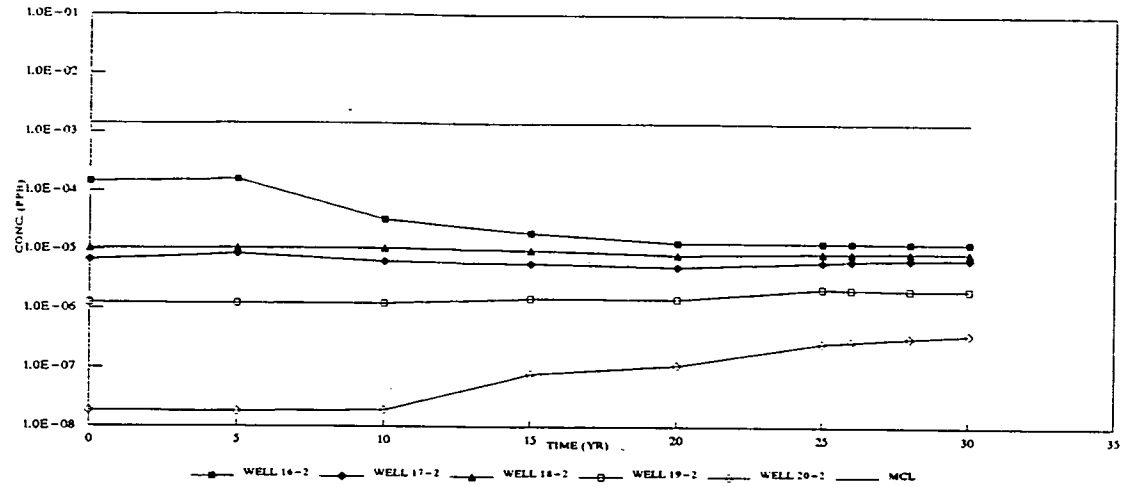
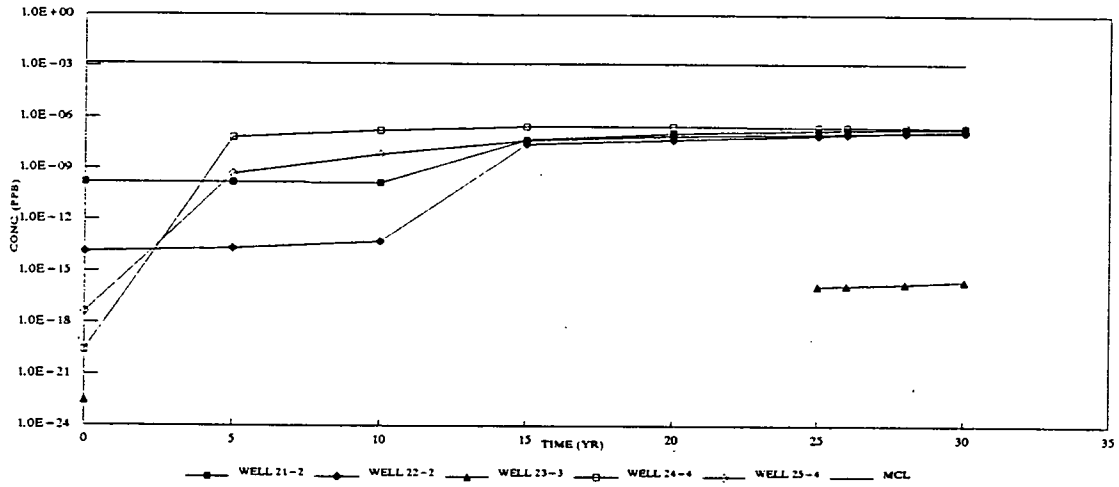
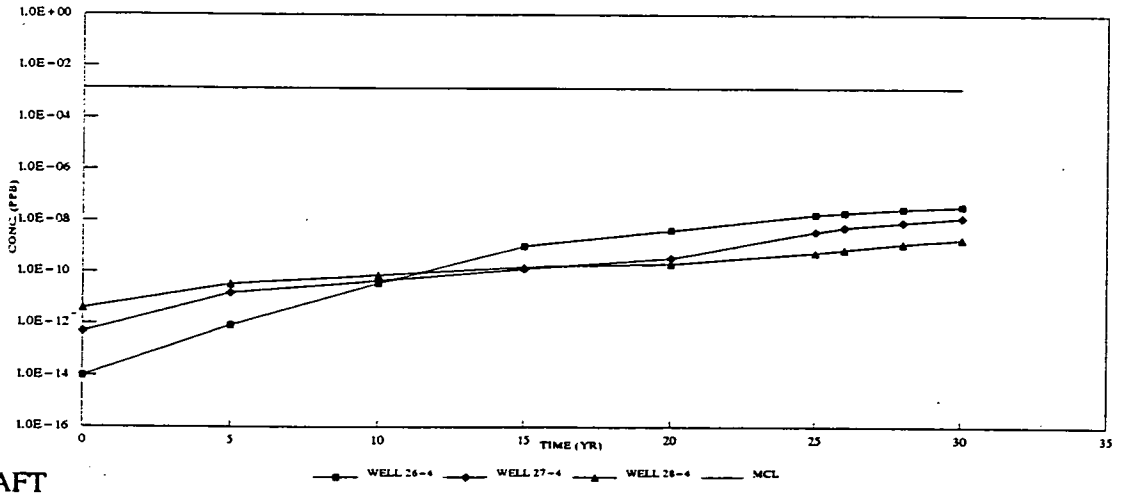
FINAL

NP-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), NEPTUNIUM-237







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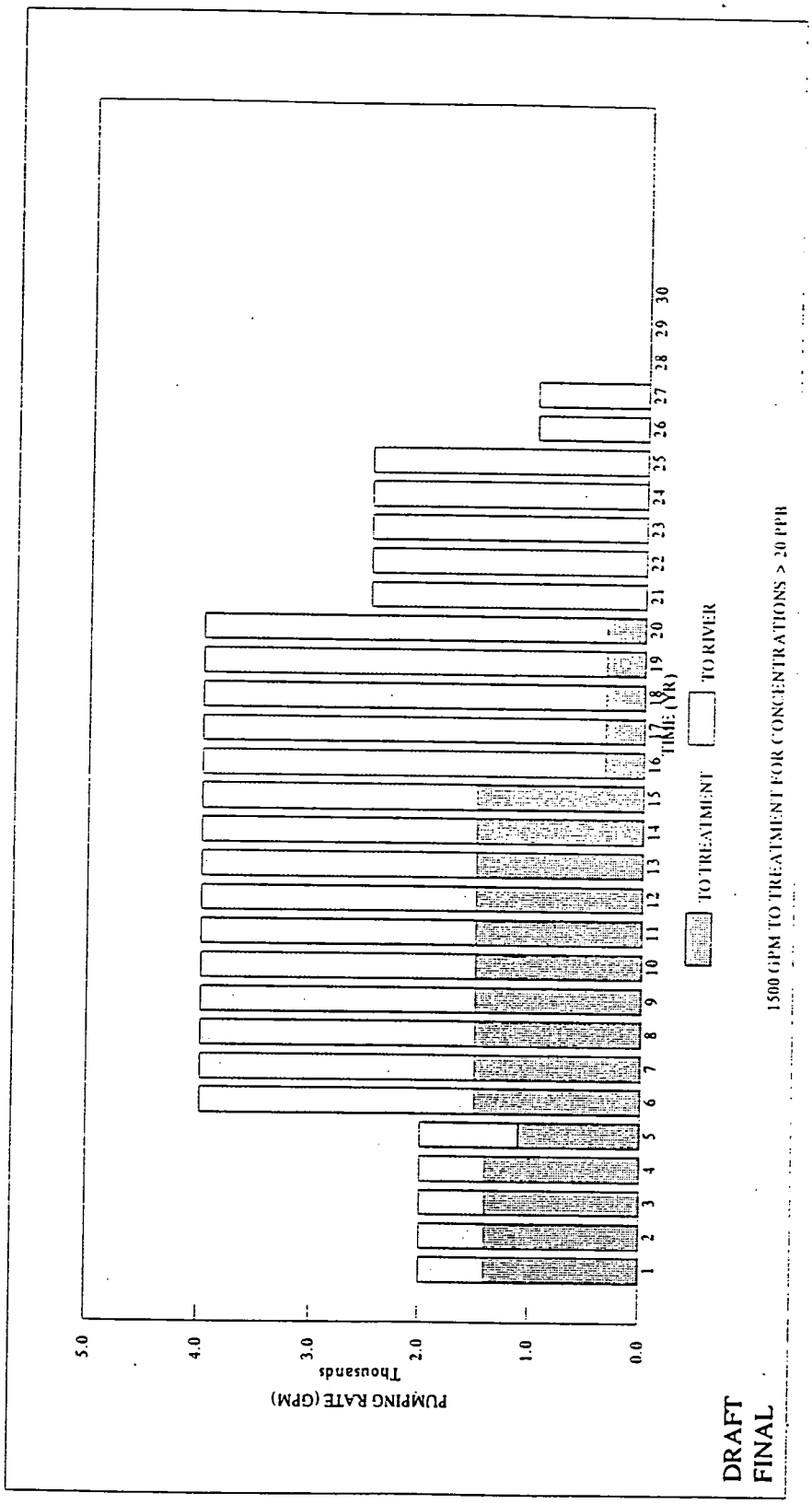
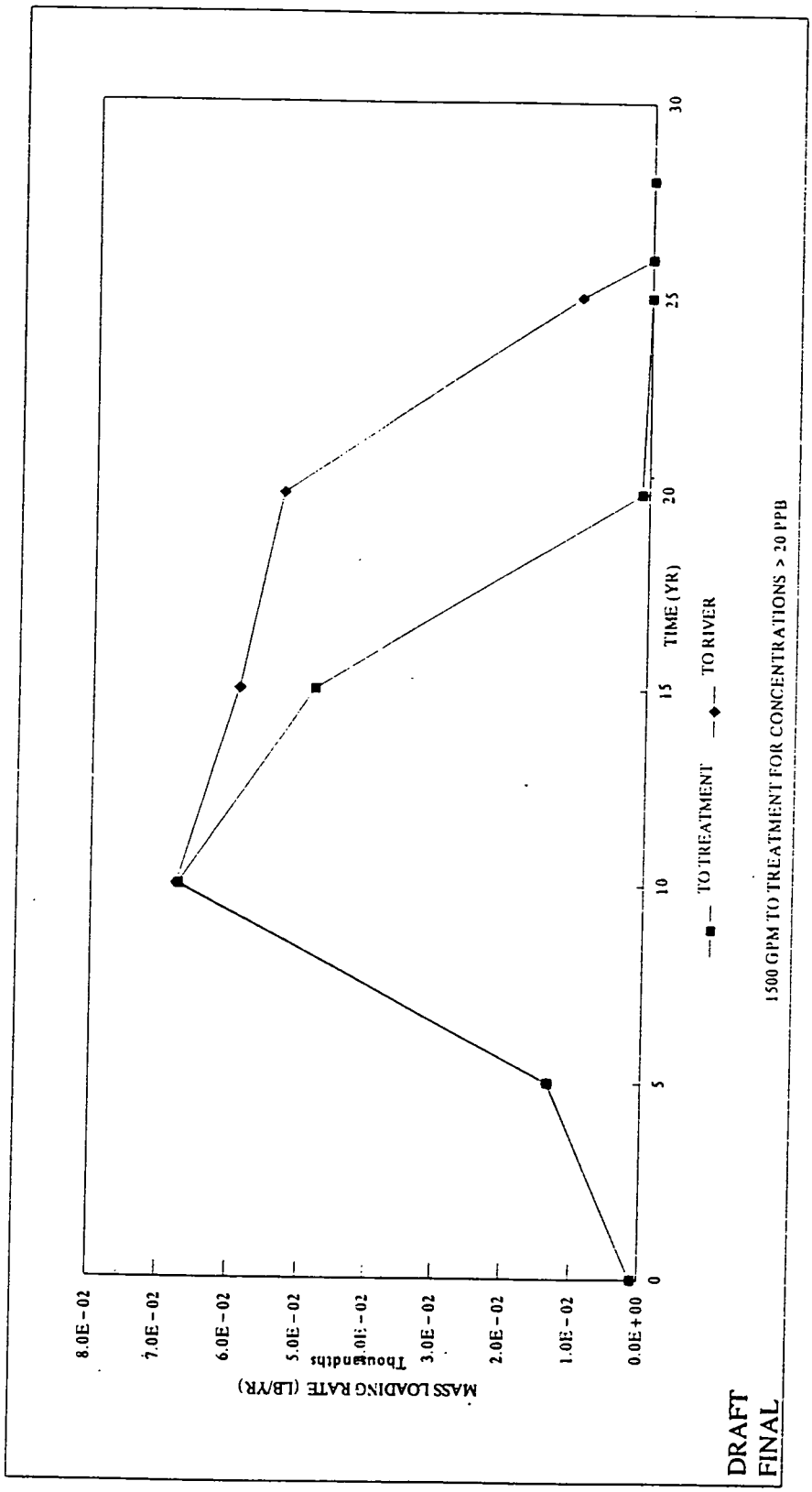
FINAL

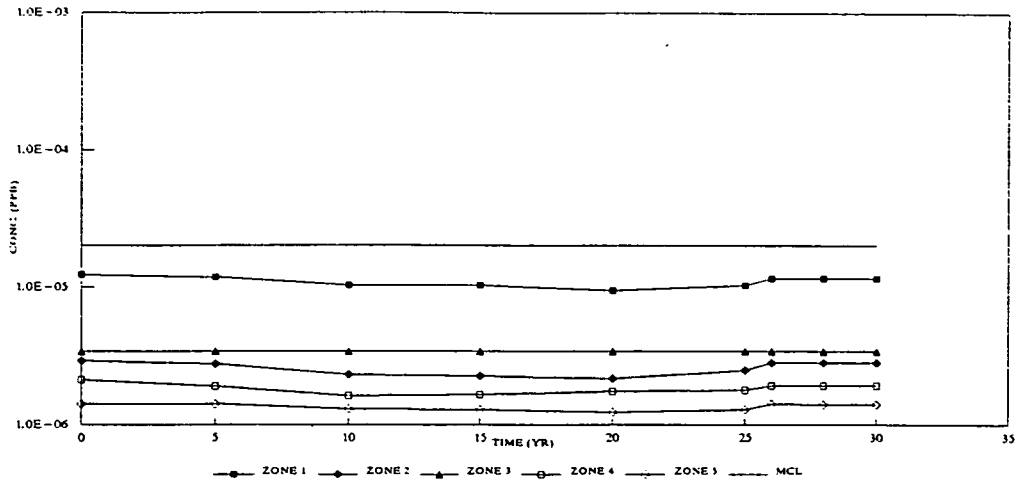
NP-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), NEPTUNIUM-237



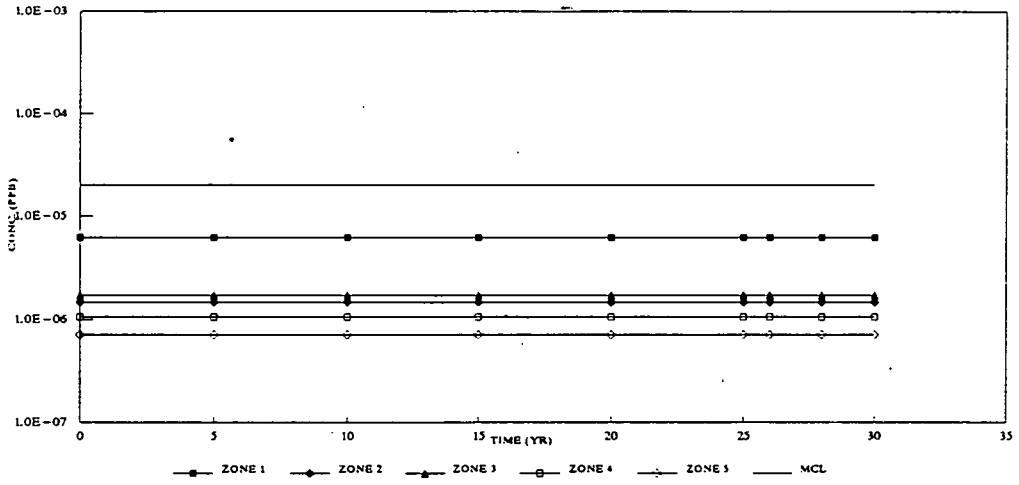
NP-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), NEPTUNIUM-237



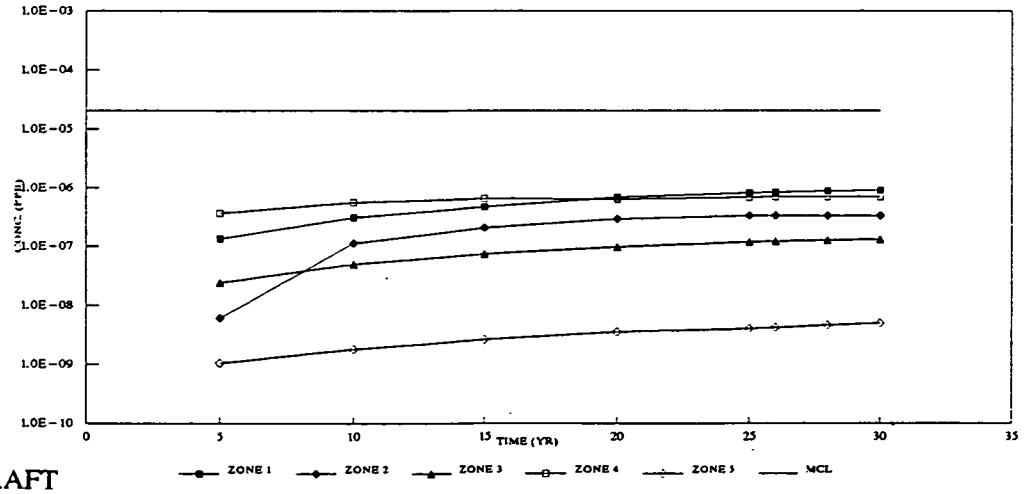
NP-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), NEPTUNIUM -237



LAYER 1



LAYER 3



LAYER 6

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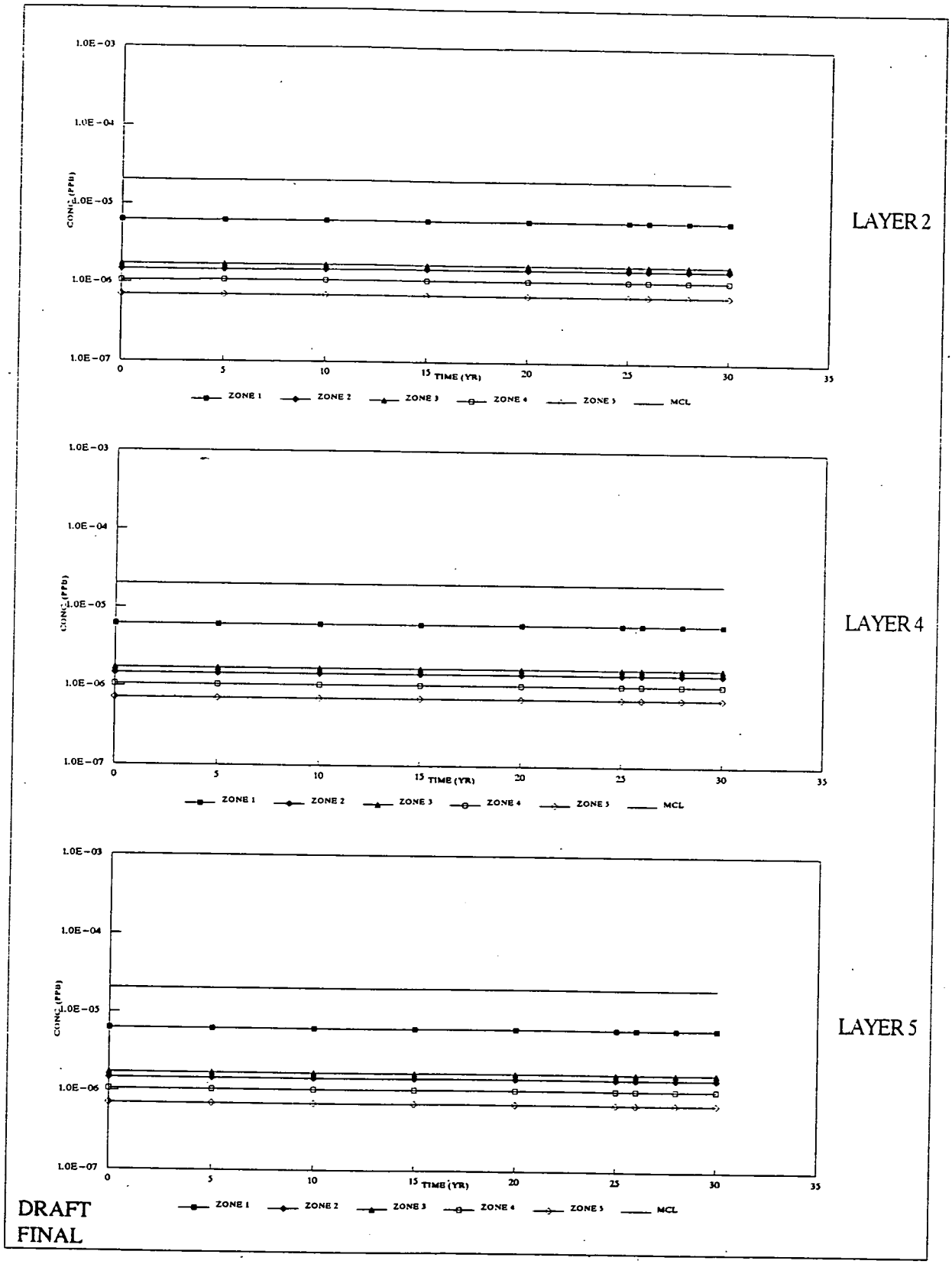
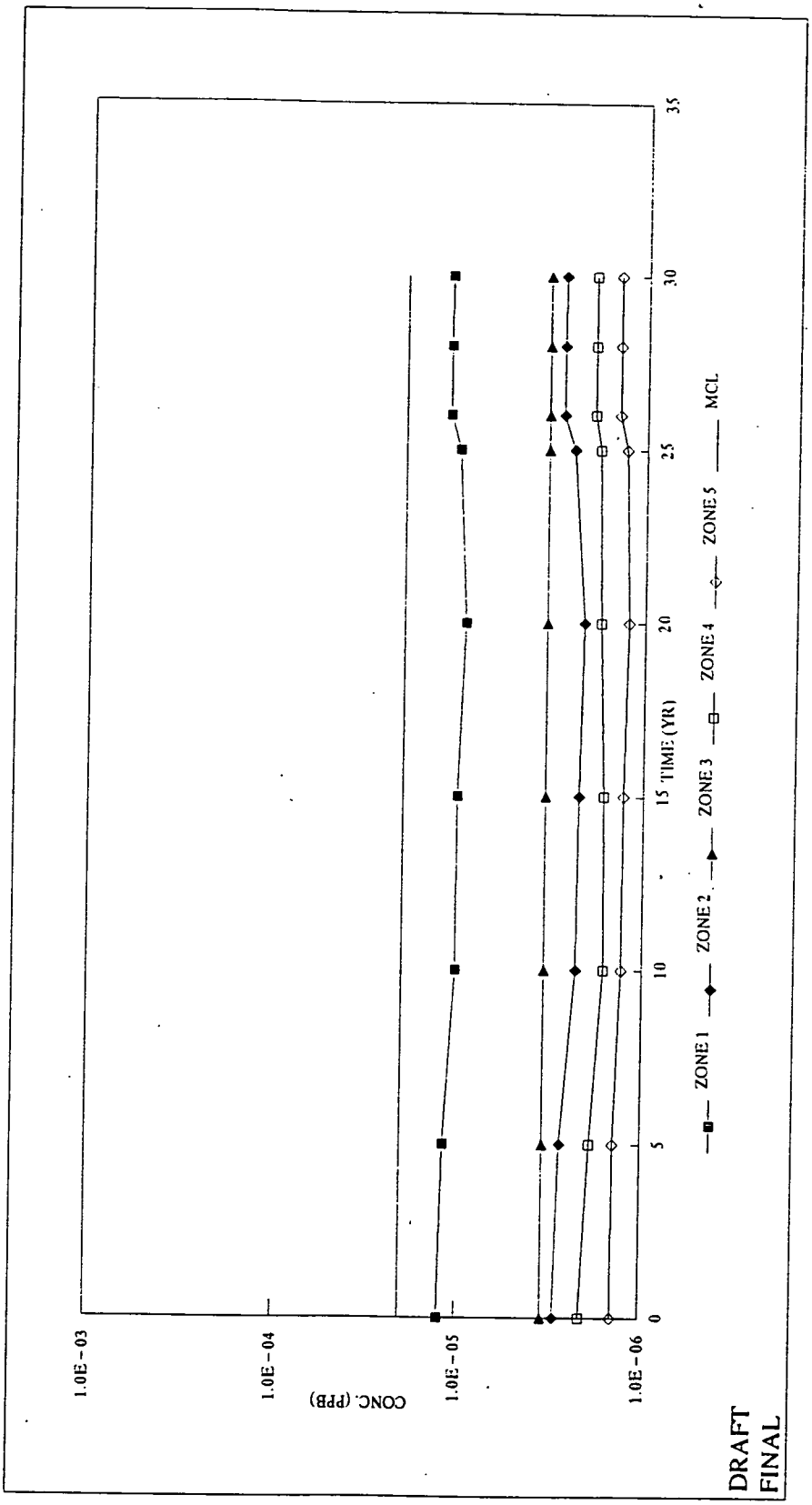
FINAL

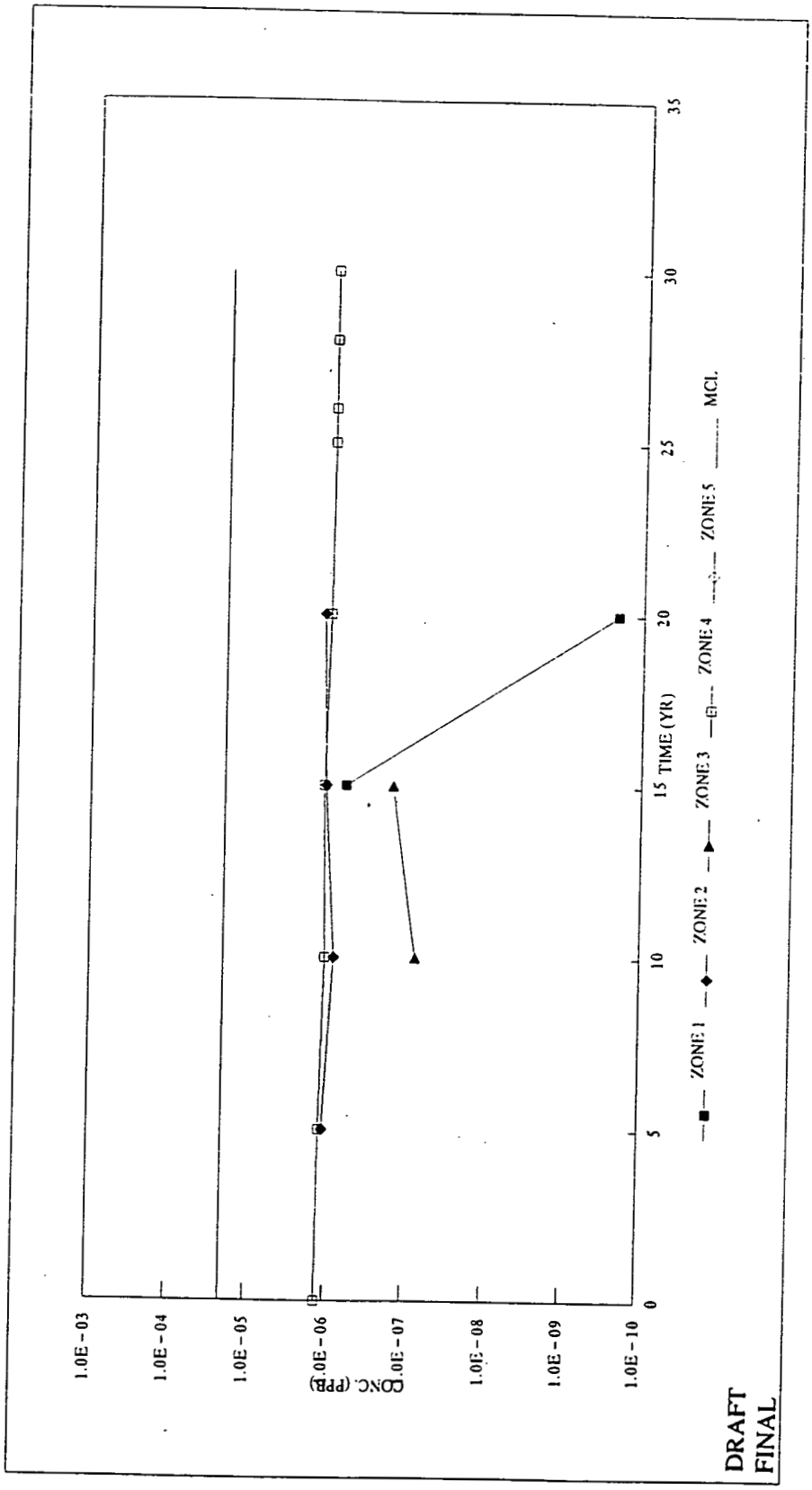
RA-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 1, 3, AND 6), RADIUM-226



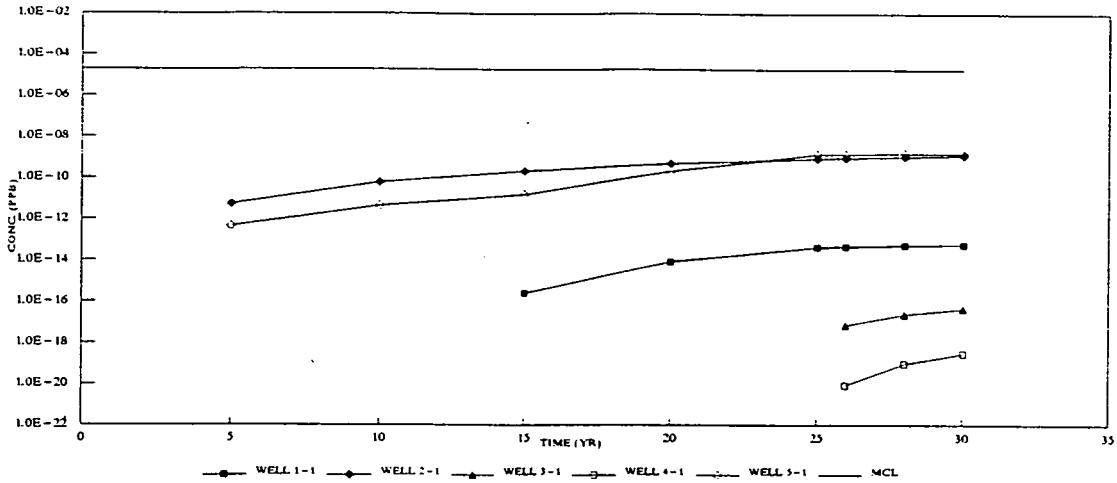
RA-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES (LAYERS 2, 4, AND 5), RADIUM-226

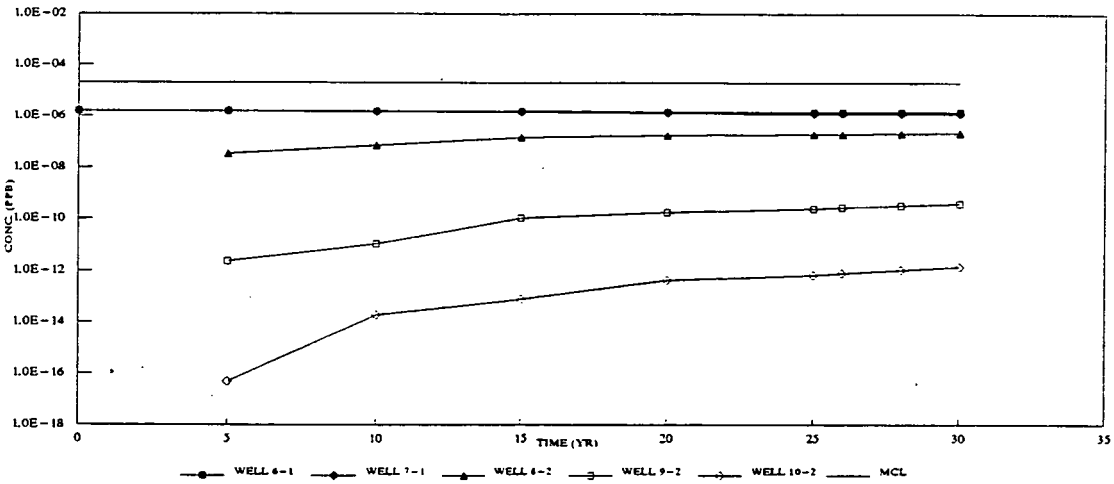


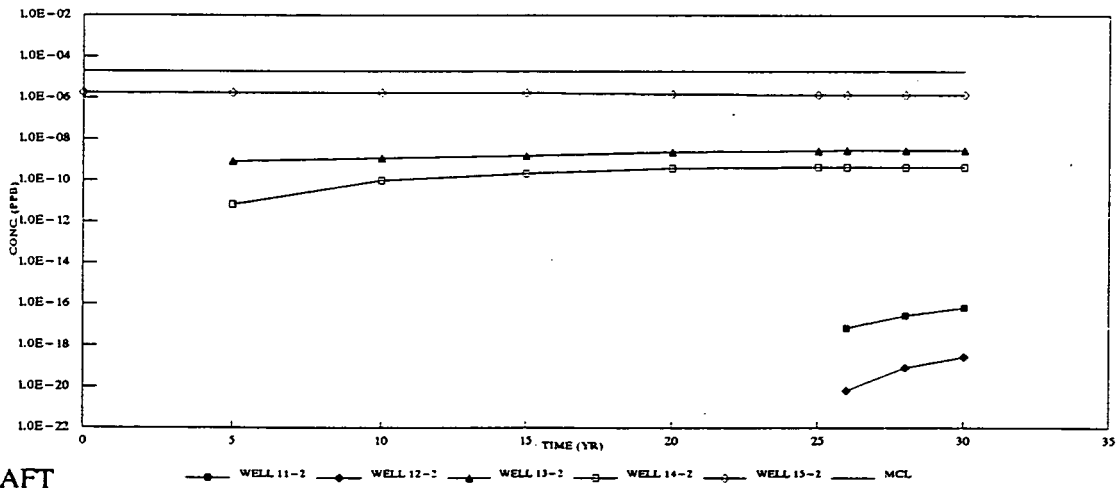
RA-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, RADIUM-226



RA-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, RADIUM-226







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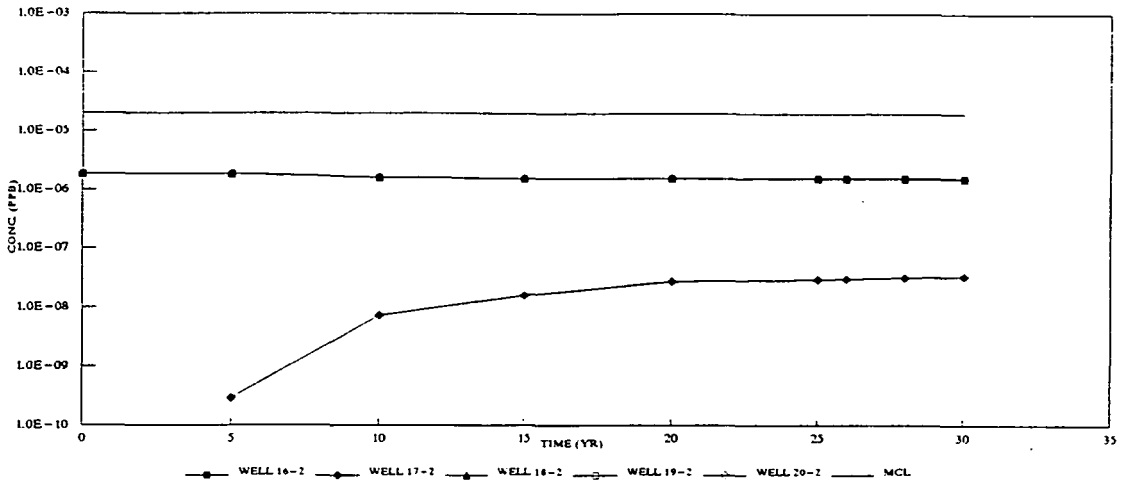
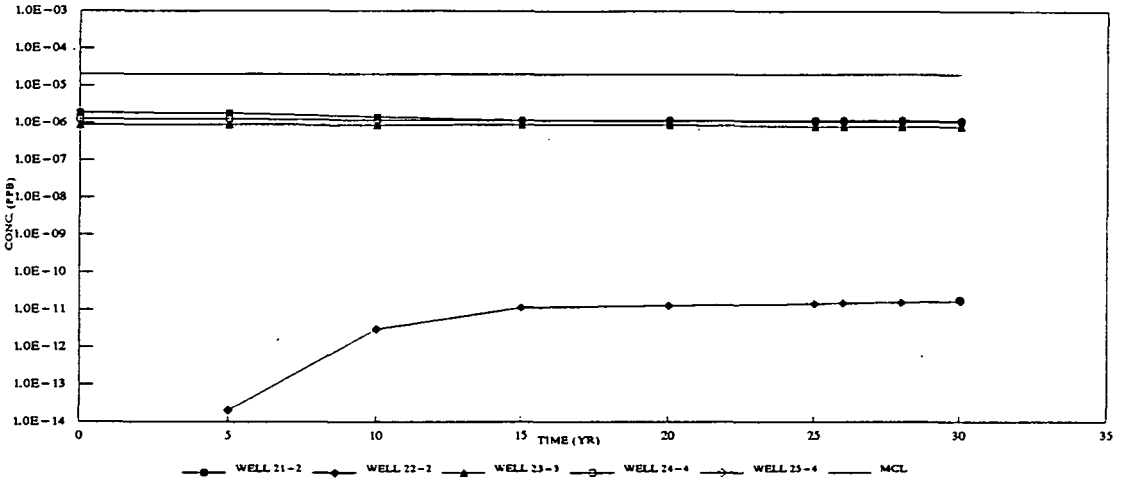
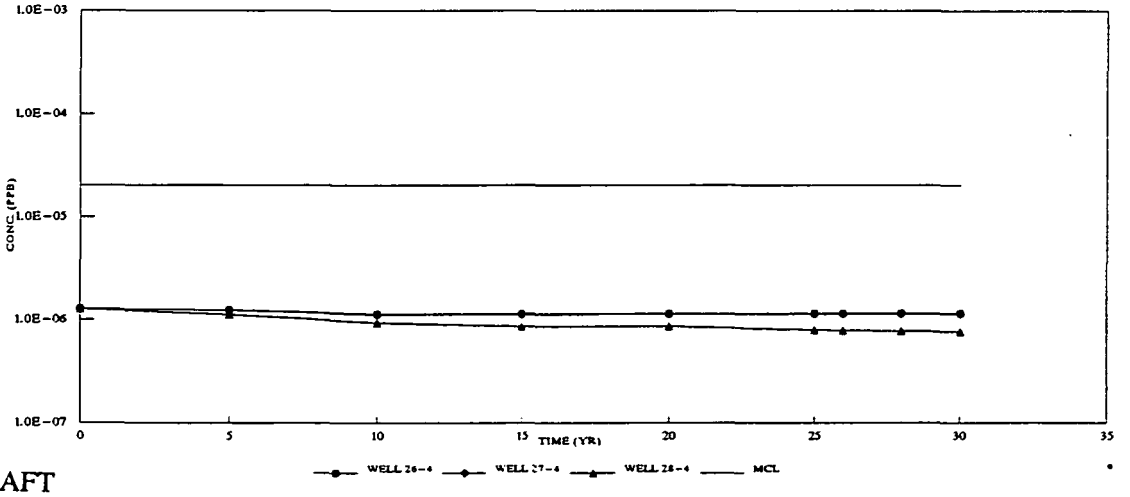
RA-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), RADIUM-226







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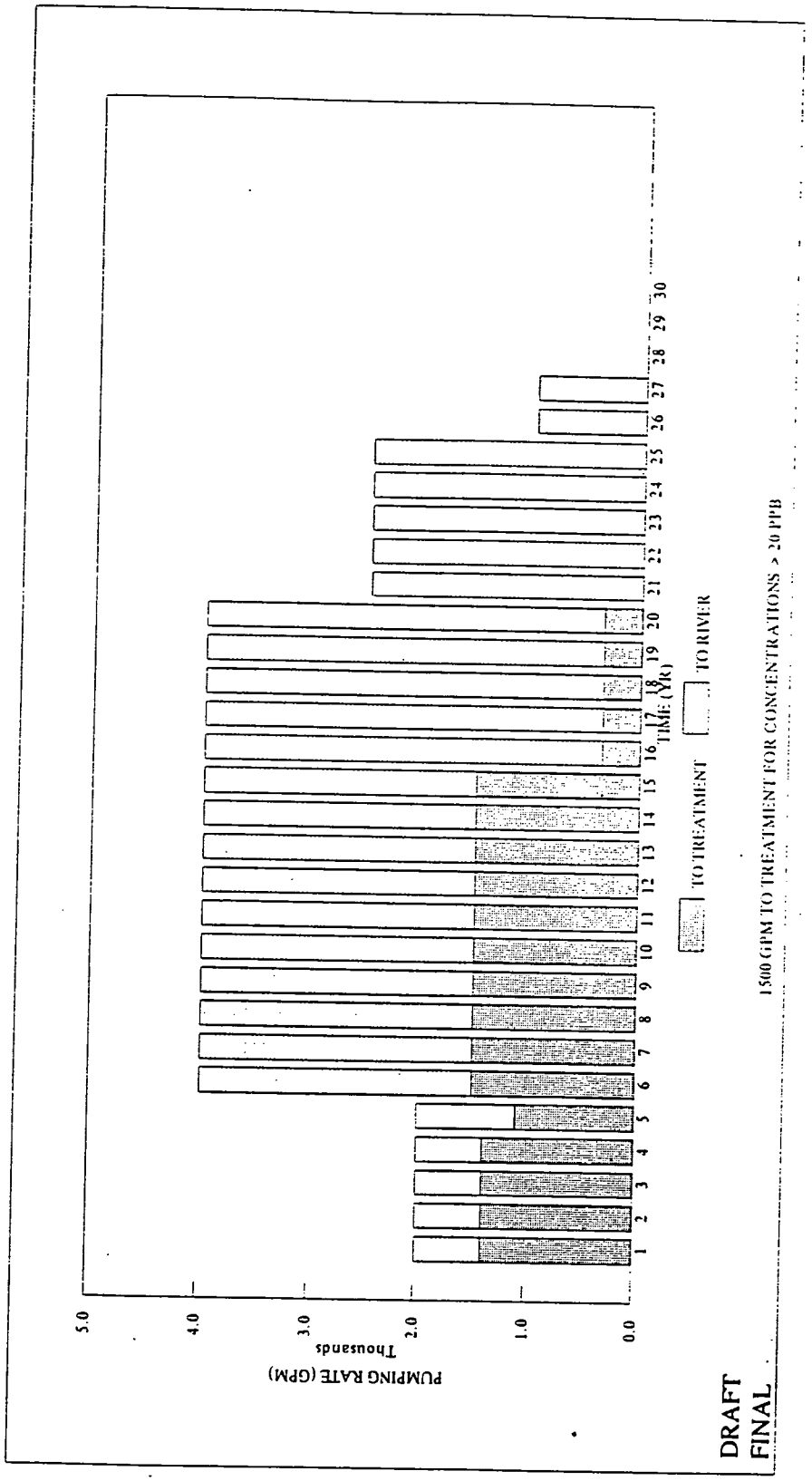
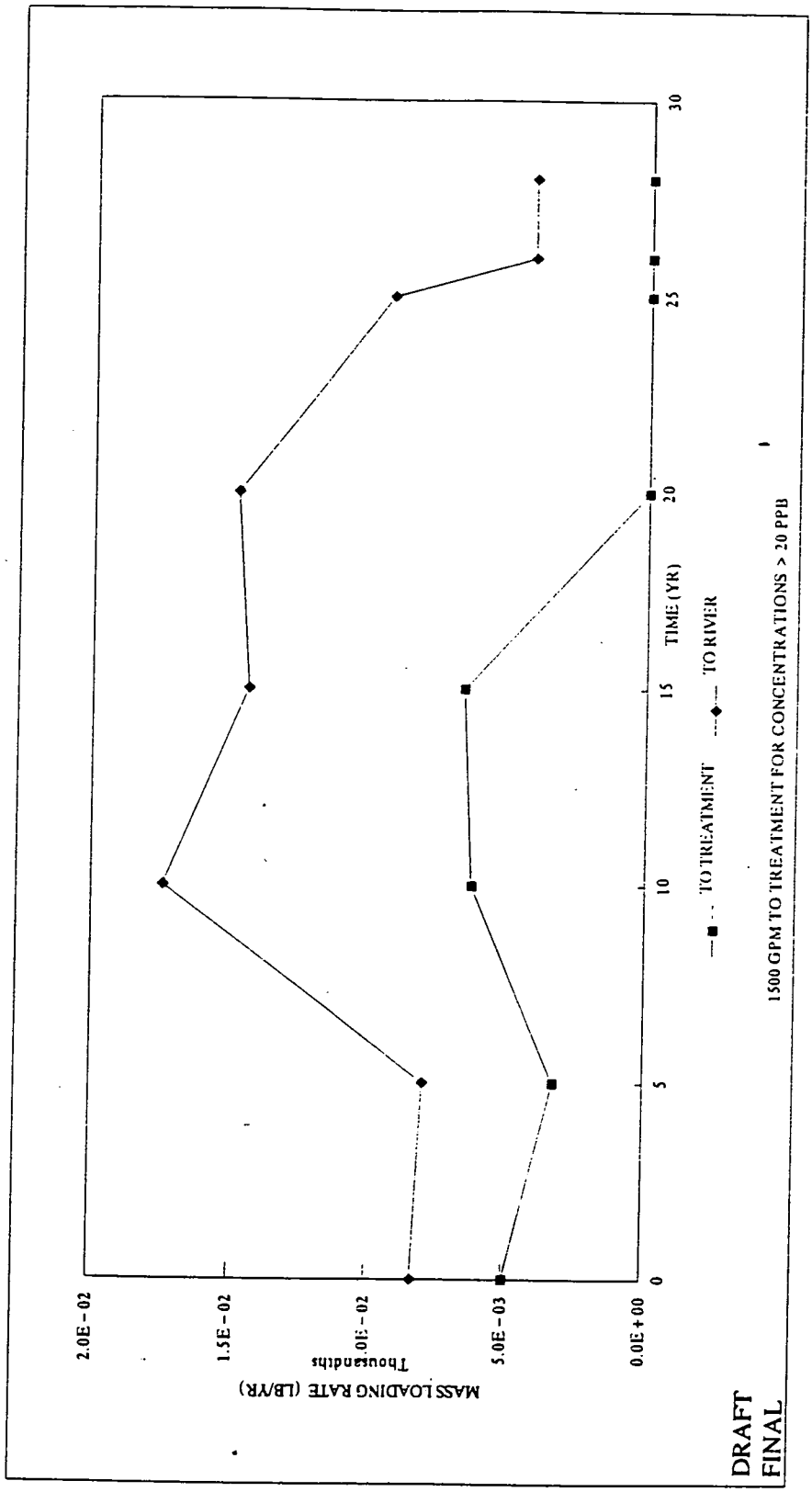
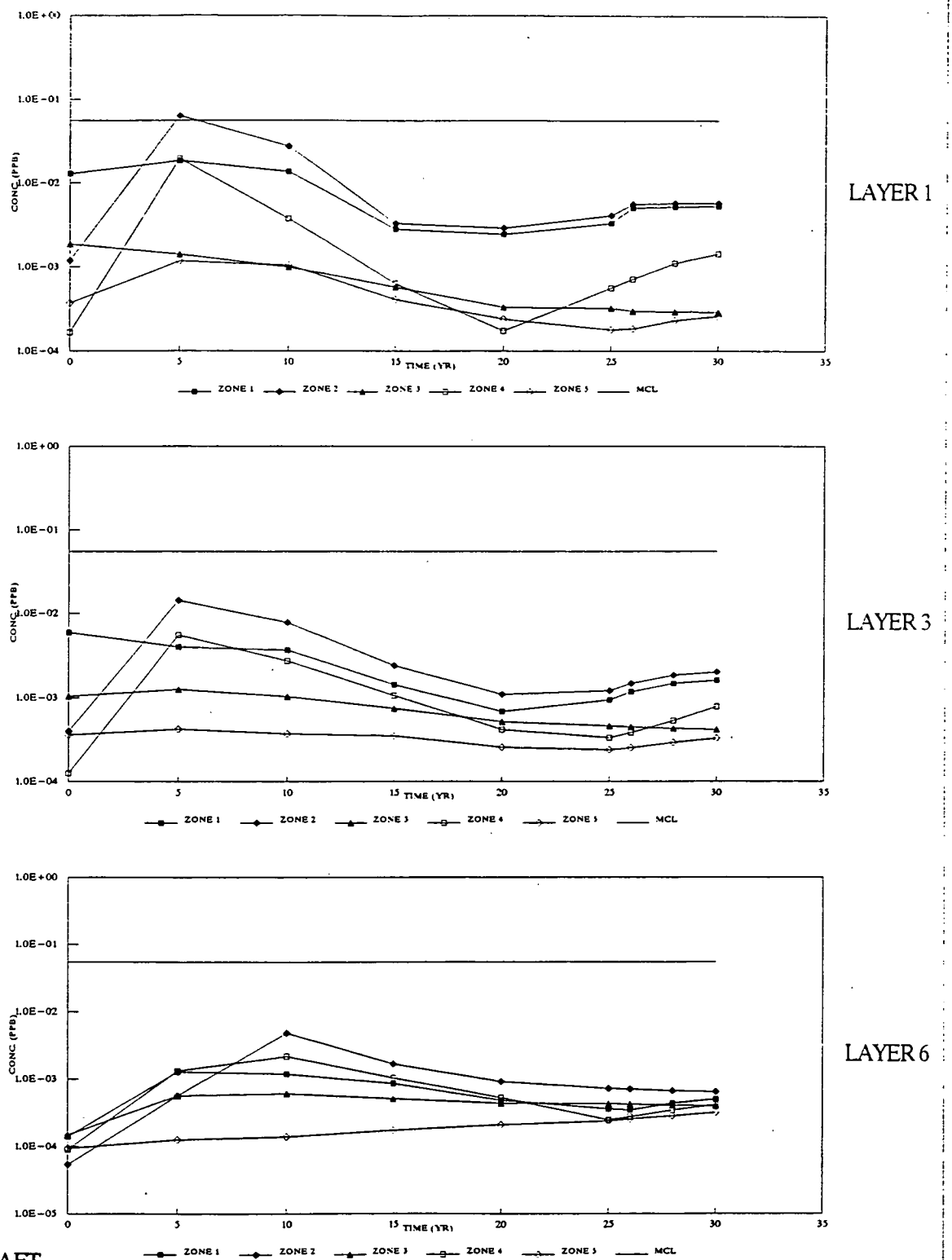
RA-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), RADIUM-226



RA-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), RADIUM-226



RA-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), RADIUM-226



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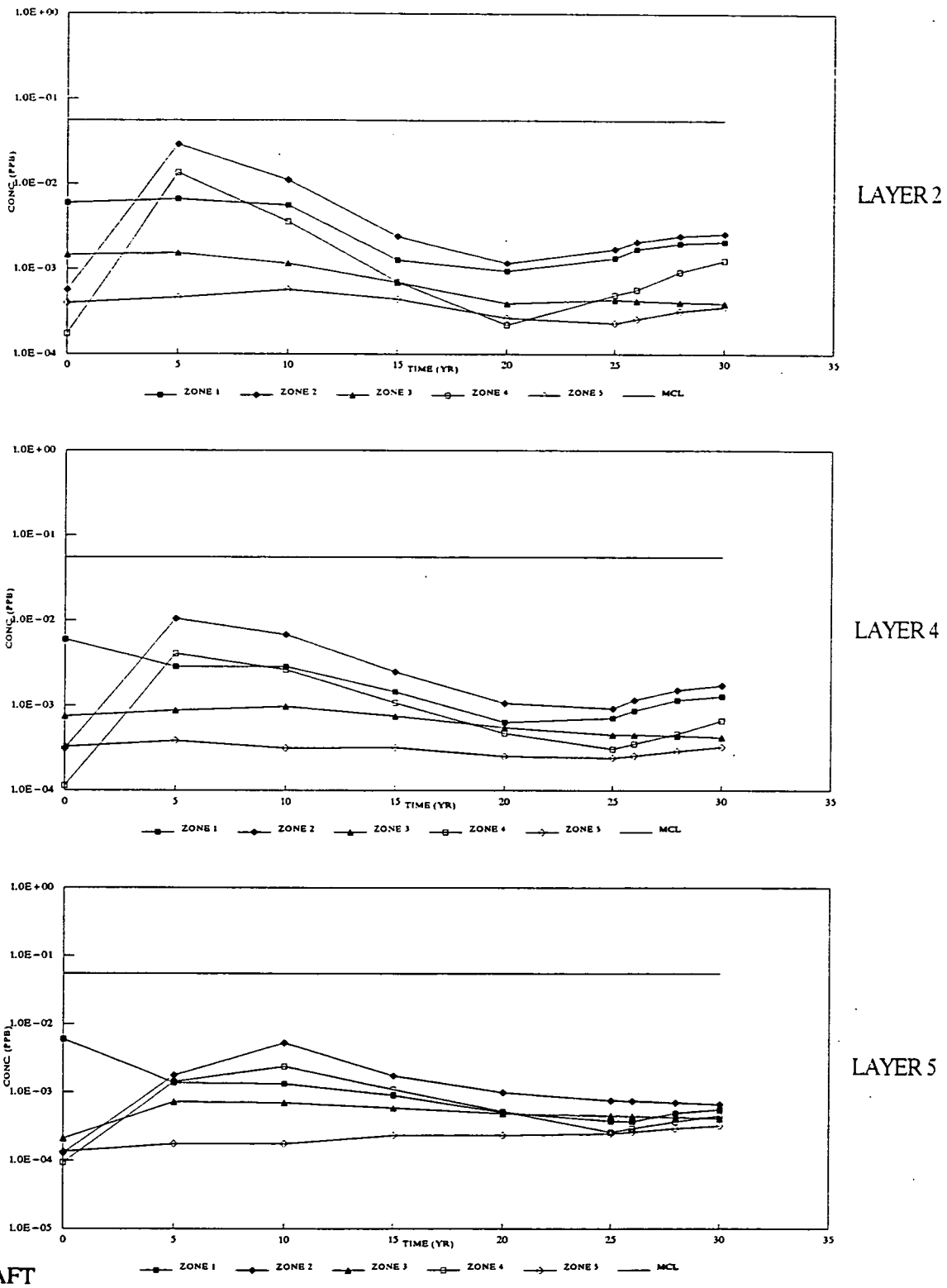
FINAL

TC-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 1, 3, AND 6), TECHNETIUM-99



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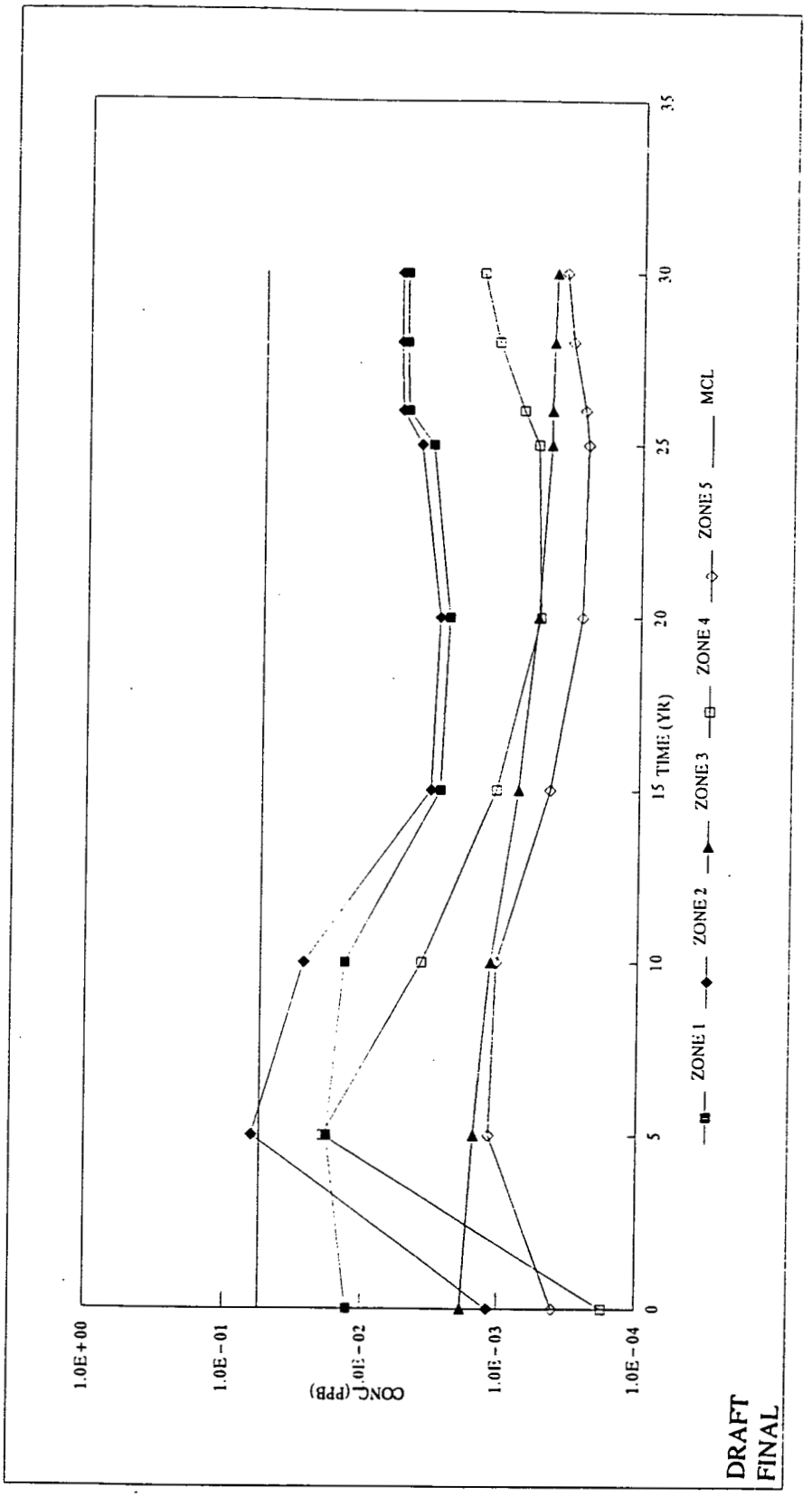
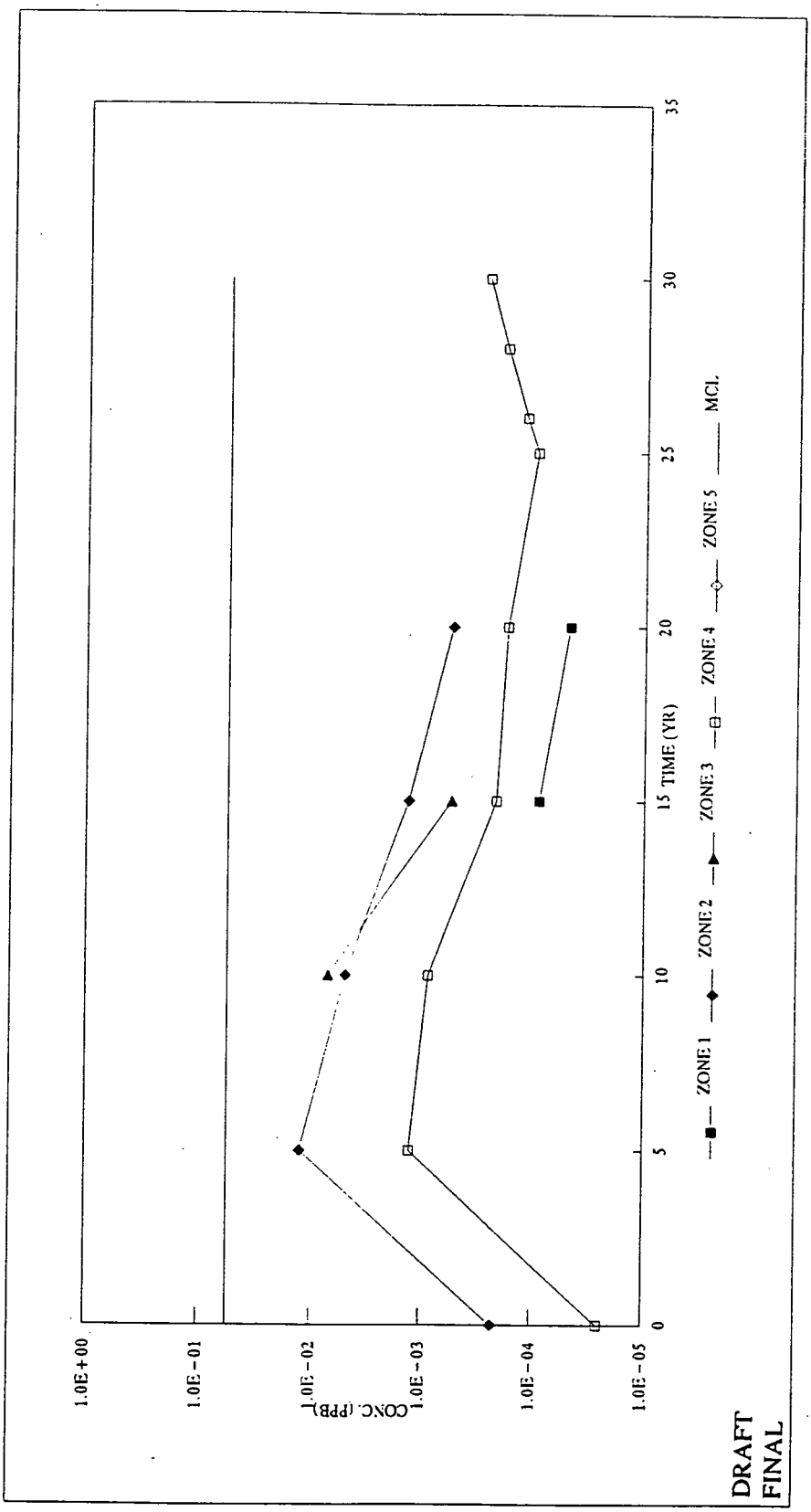
FINAL

TC-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 2, 4, AND 5), TECHNETIUM-99



TC-3 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION OF LAYER 1-6 BY ZONE, TECHNETIUM-99



TC-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, TECHNETIUM-99

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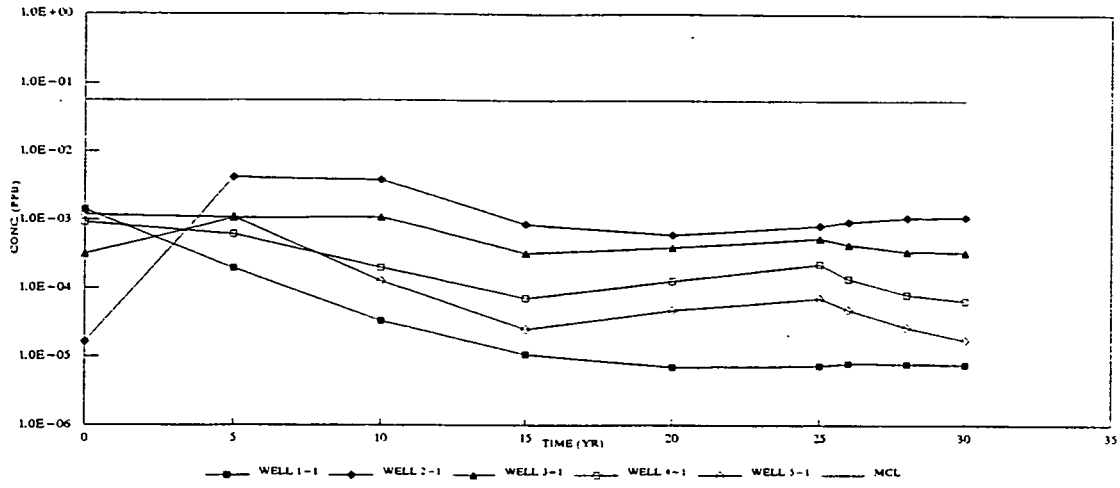

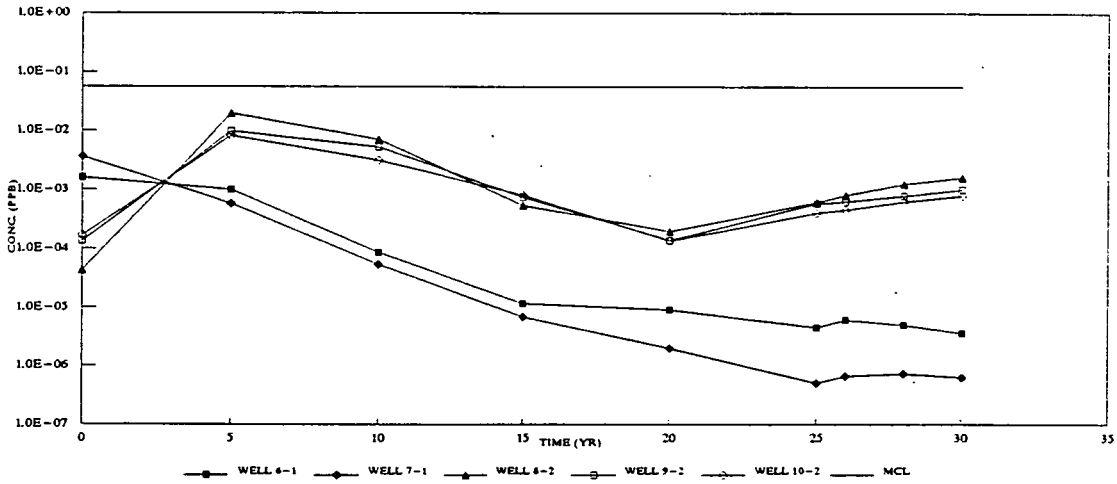

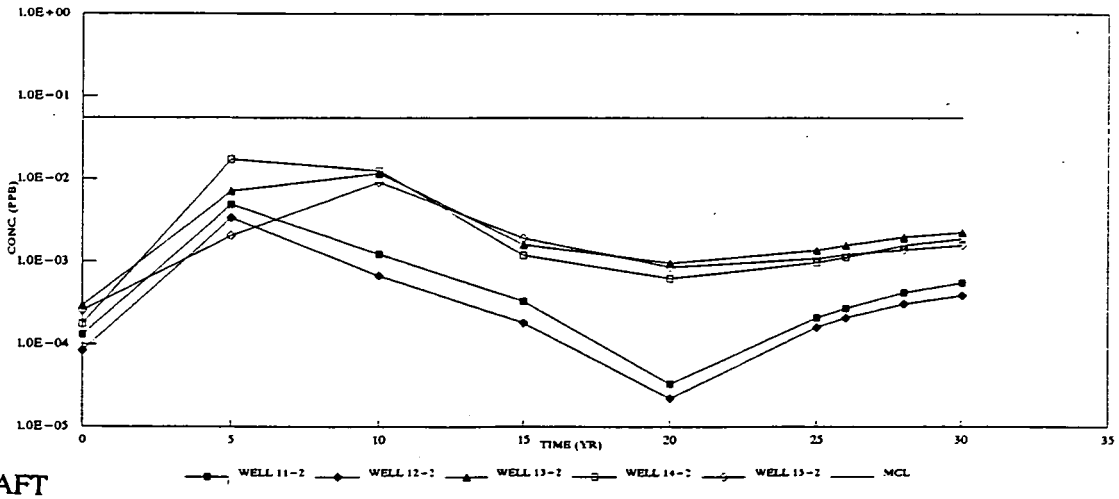

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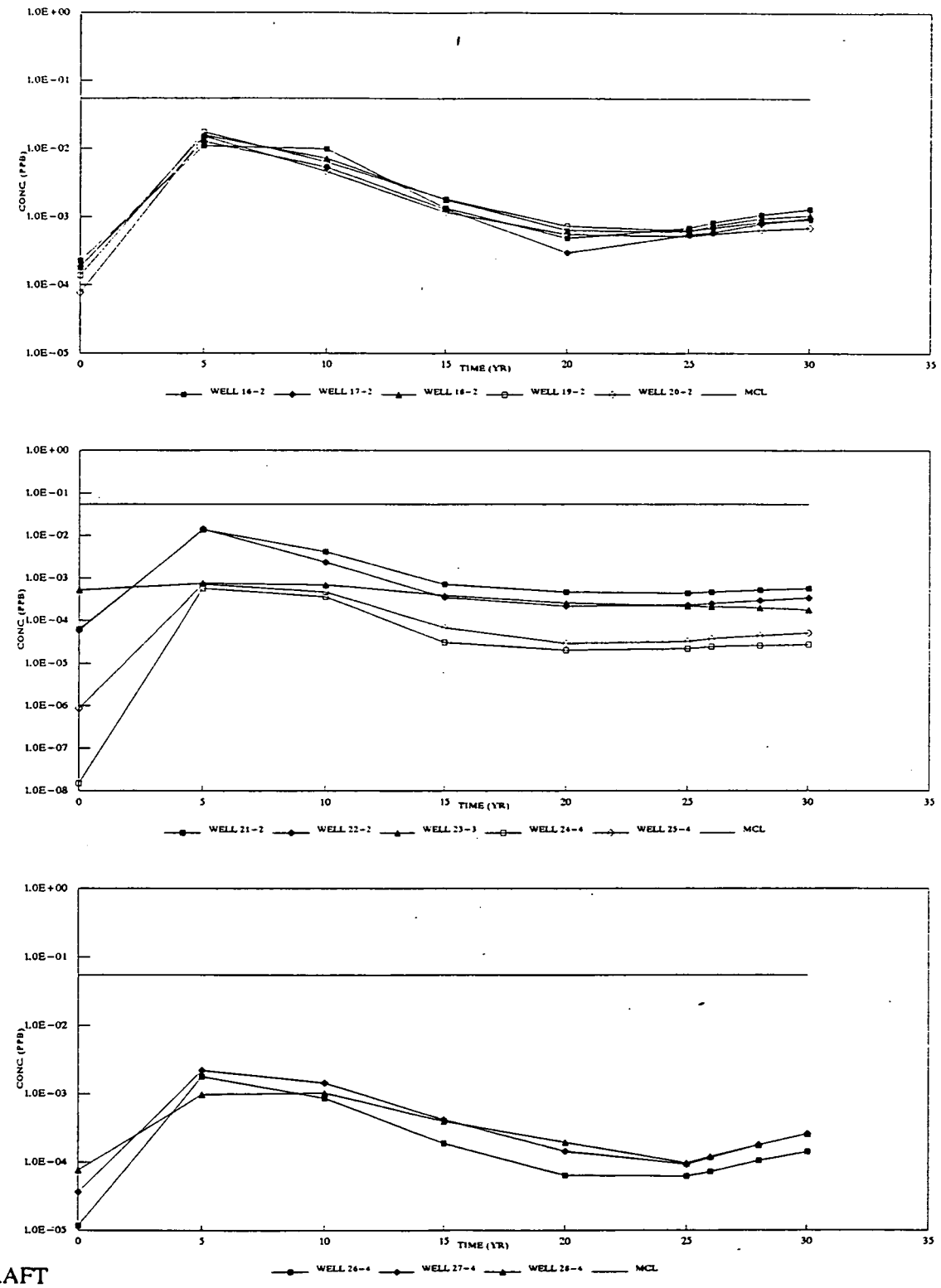
FINAL

TC-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), TECHNETIUM-99



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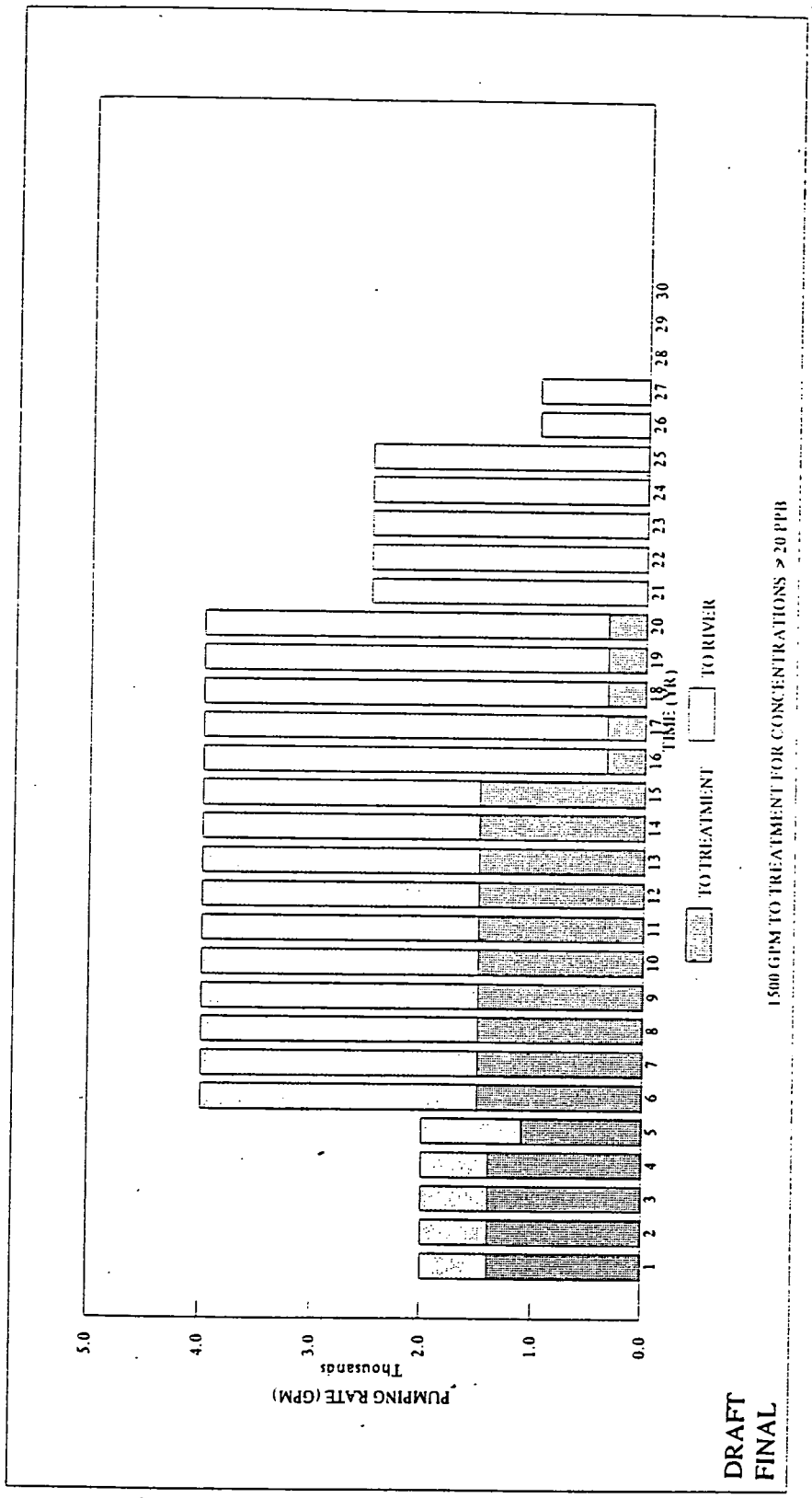
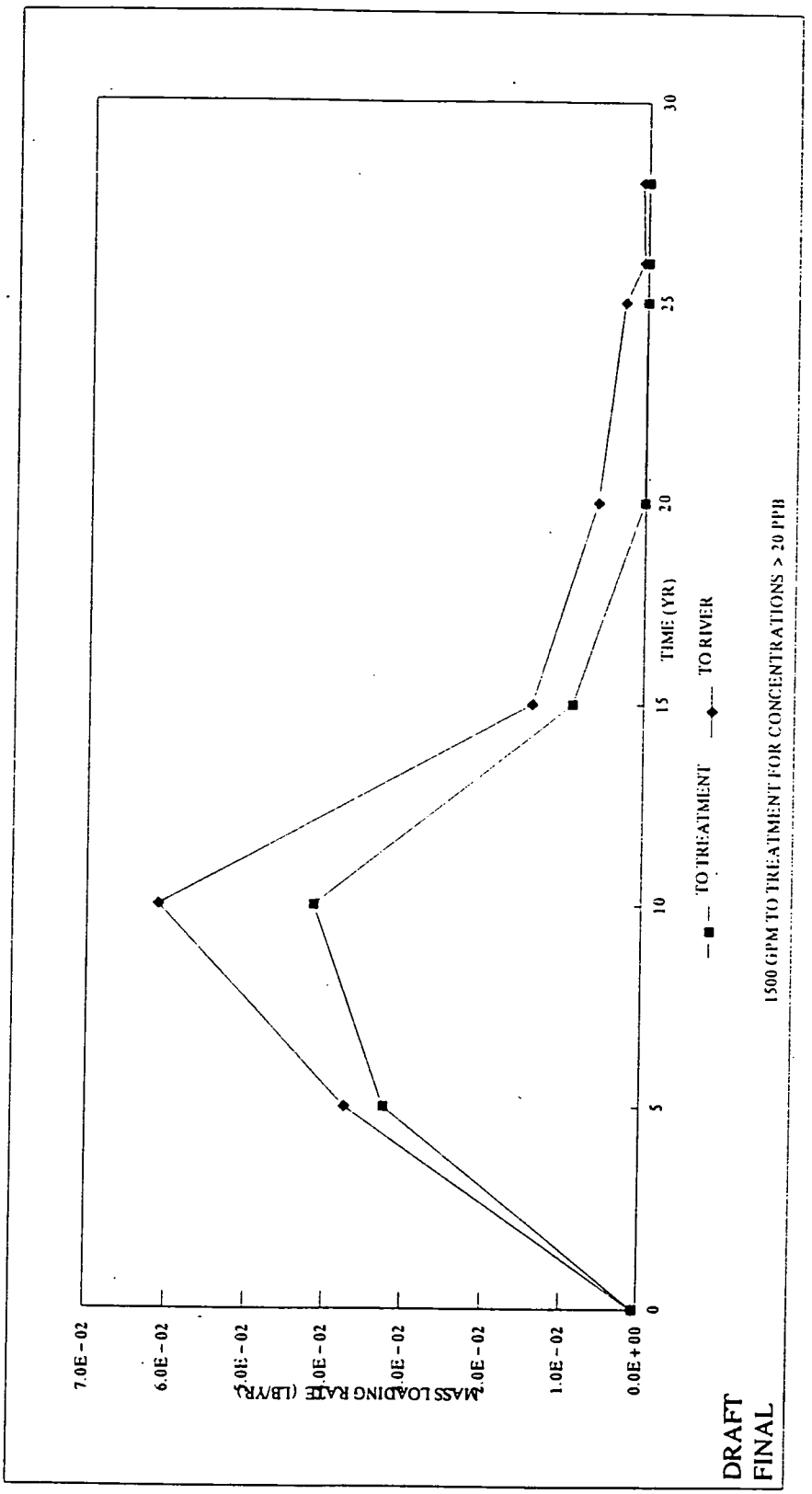
FINAL

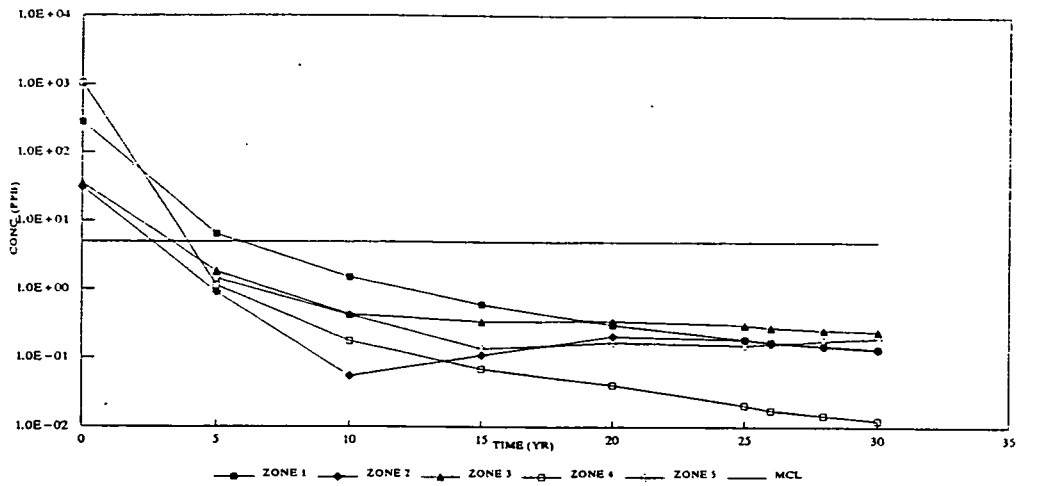
TC-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), TECHNETIUM-99



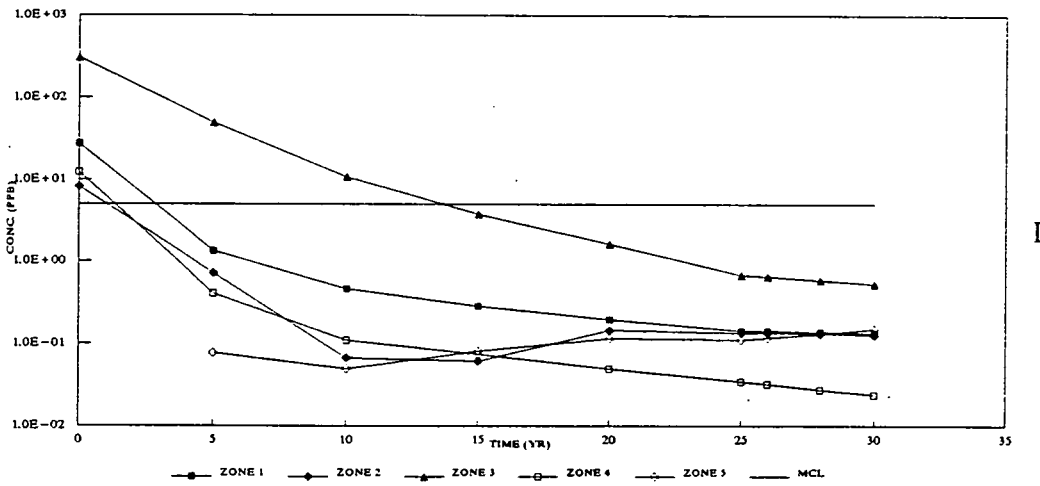
TC-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), TECHNETIUM-99



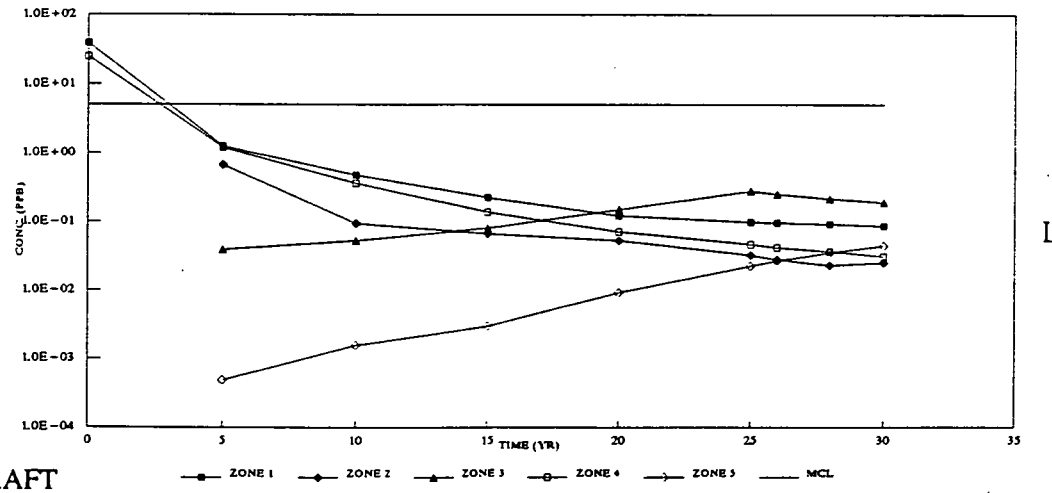
TC-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), TECHNETIUM-99



LAYER 1



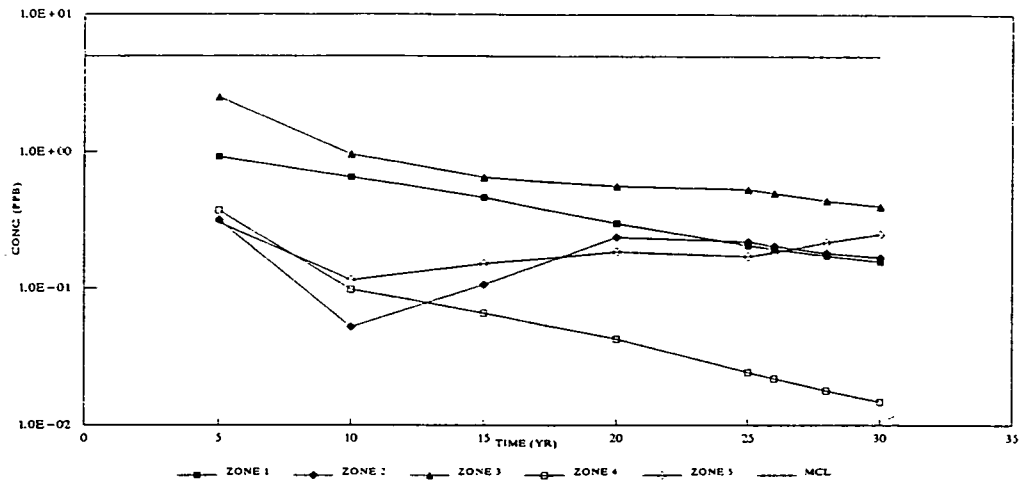
LAYER 3



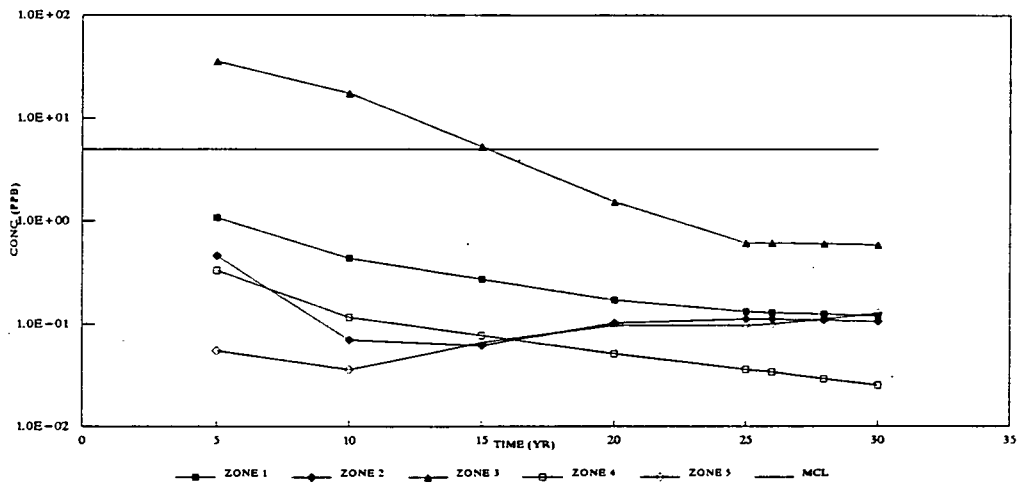
LAYER 6

DRAFT
FINAL

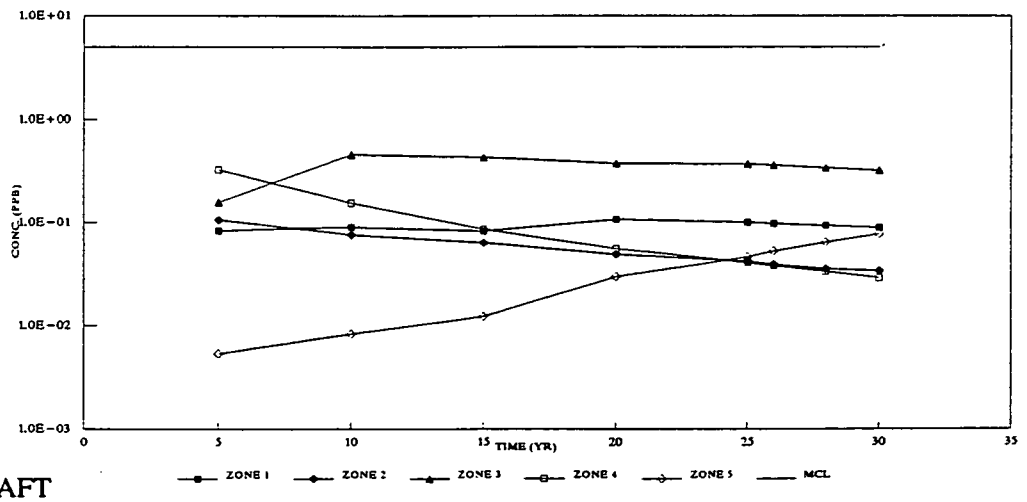
VOC-1 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 1, 3, AND 6), TOTAL VOCS



LAYER 2



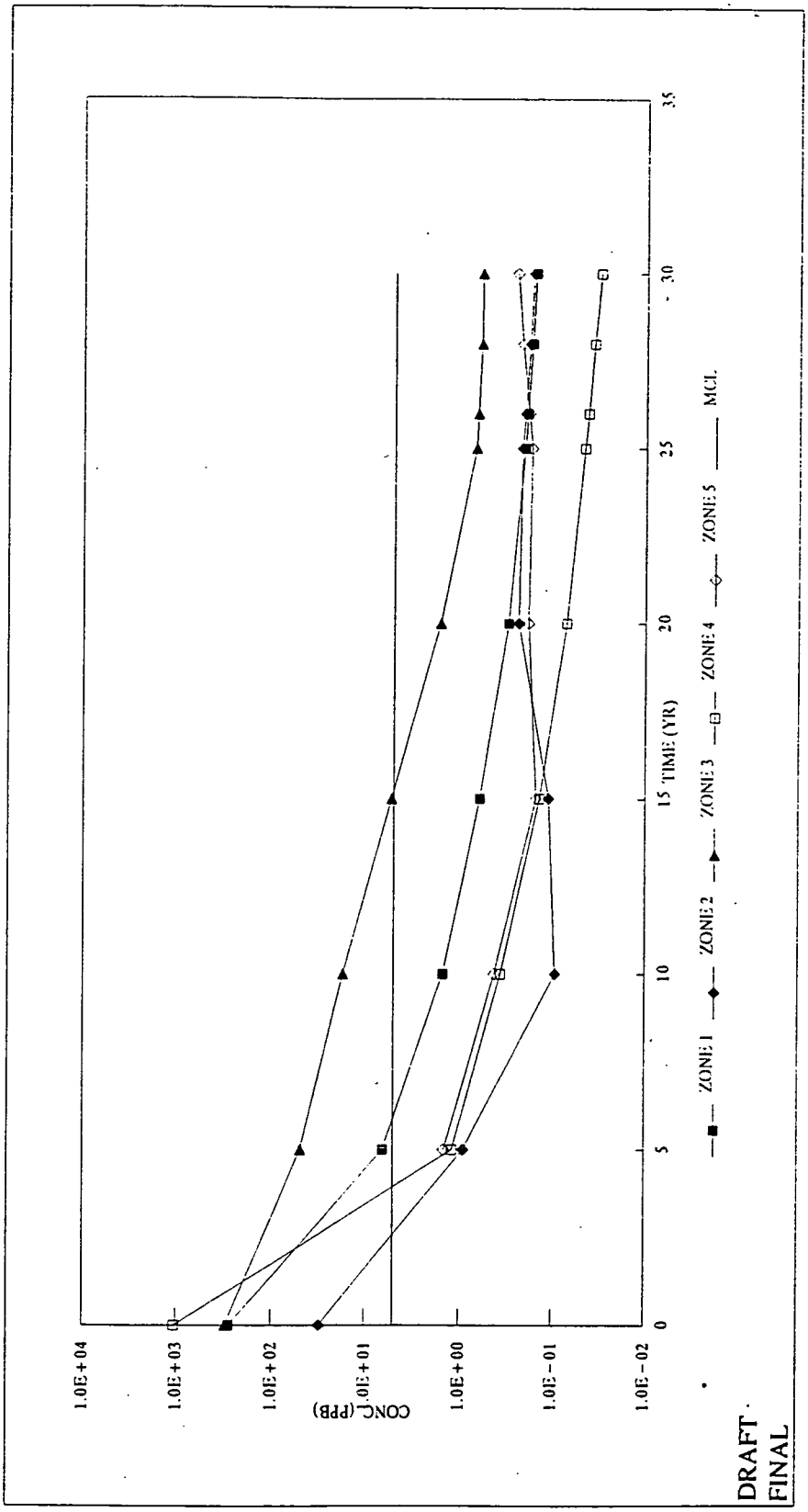
LAYER 4



LAYER 5

DRAFT
FINAL

VOC-2 - SEQUENTIAL PUMPING, MAXIMUM CONCENTRATION CURVES
(LAYERS 2, 4, AND 5), TOTAL VOCS



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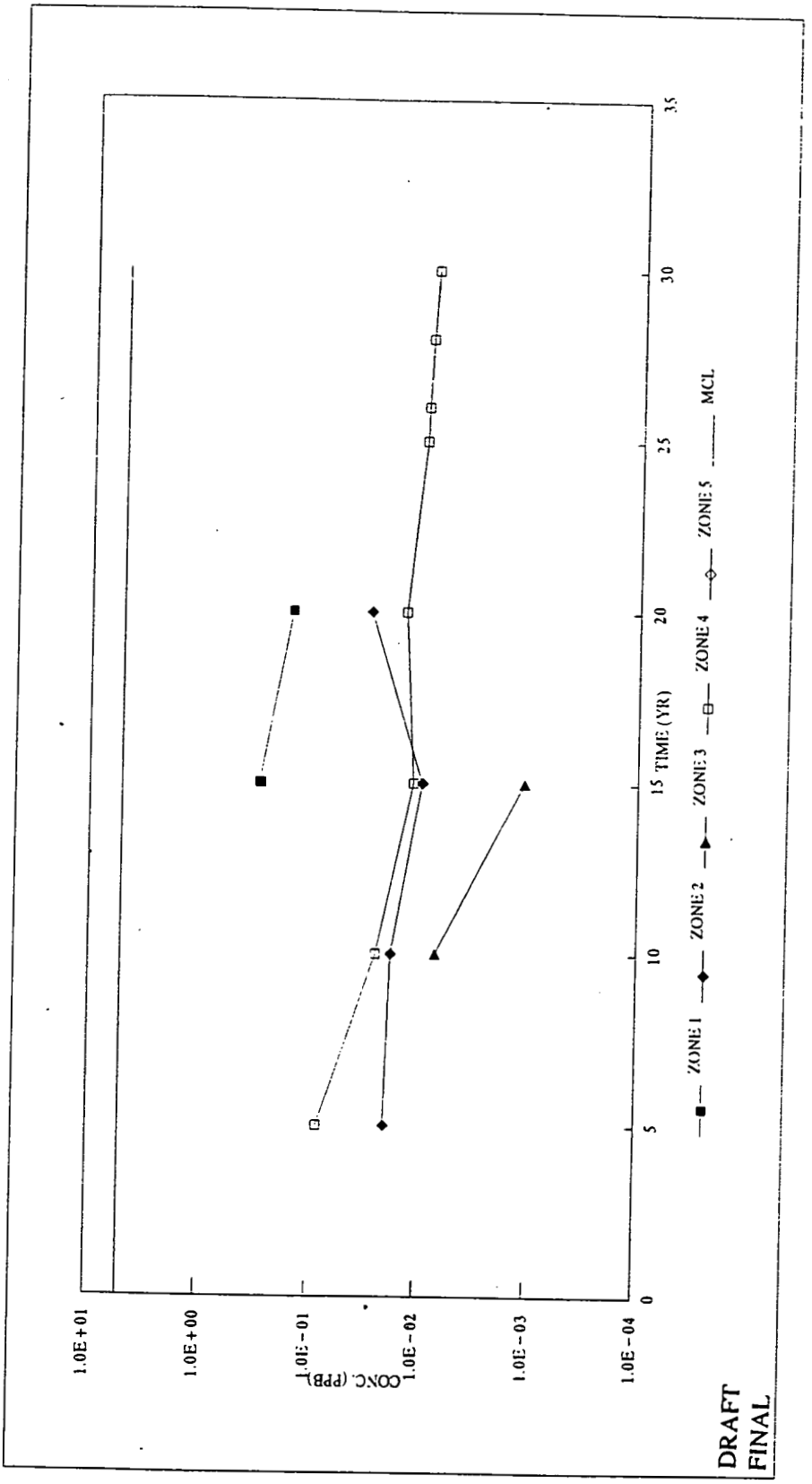

VOC-4 - SEQUENTIAL PUMPING, SYSTEM AVERAGE CONCENTRATIONS VS. TIME, TOTAL VOCS

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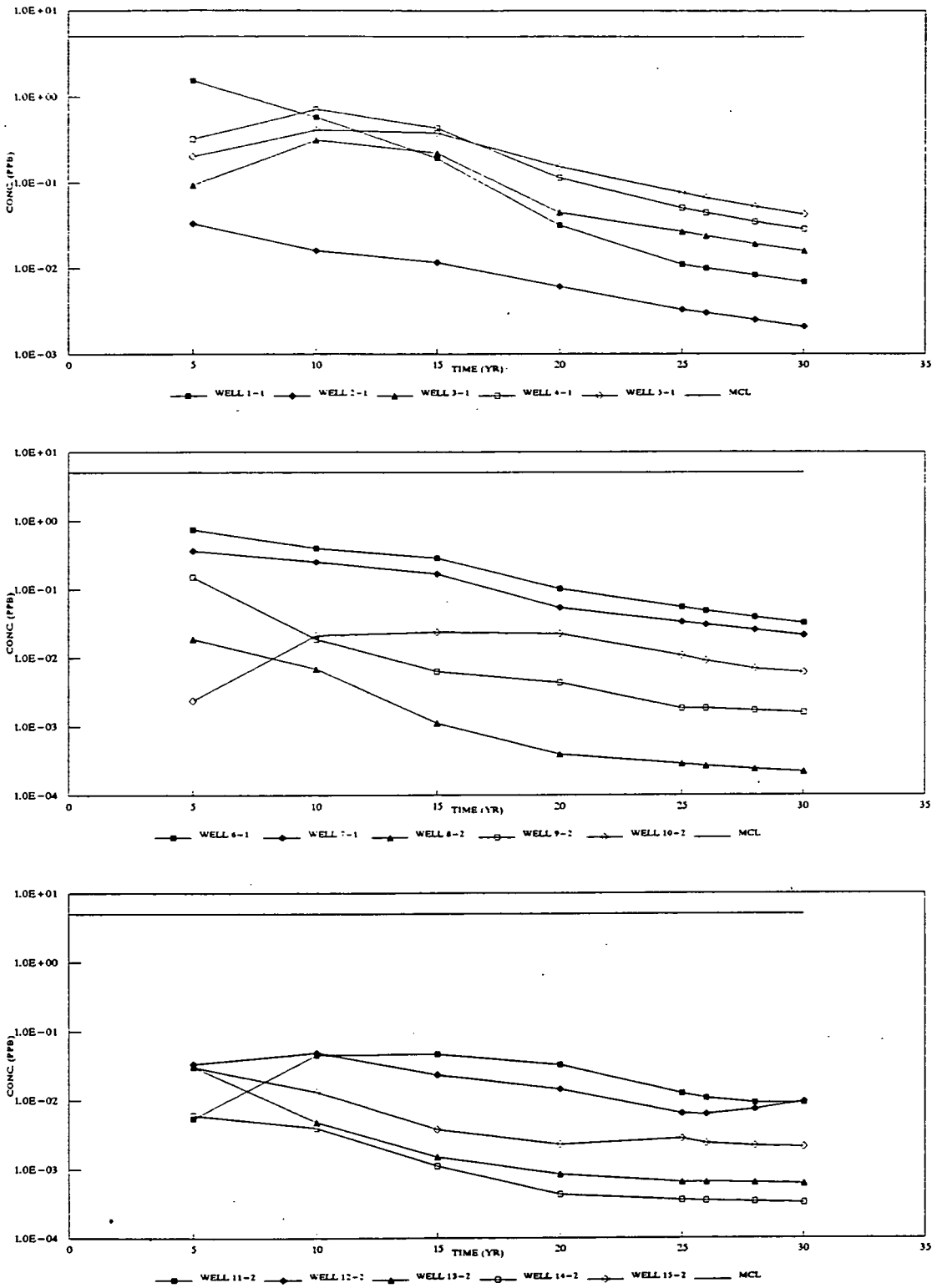

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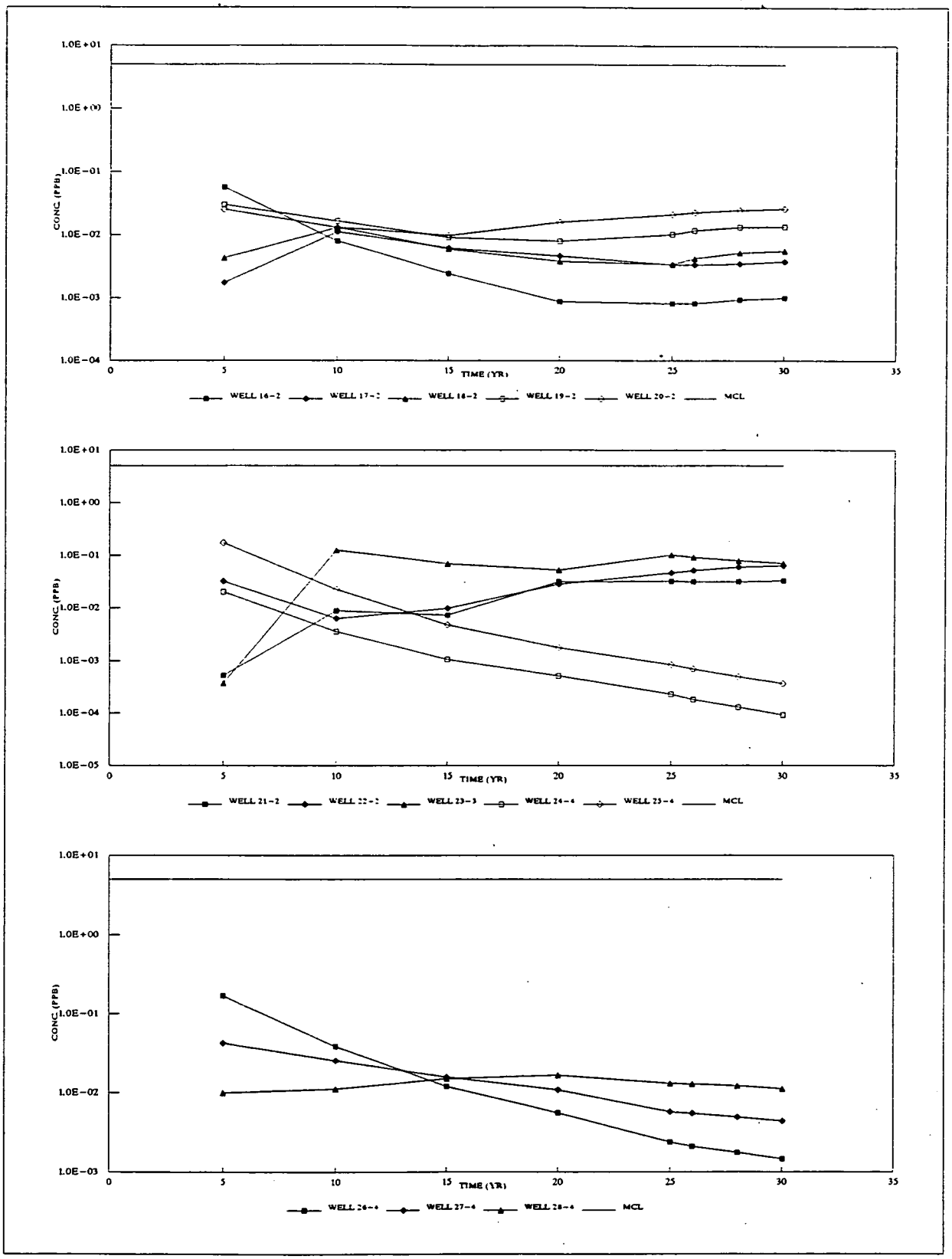
VOC-5 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 1-15), TOTAL VOCS



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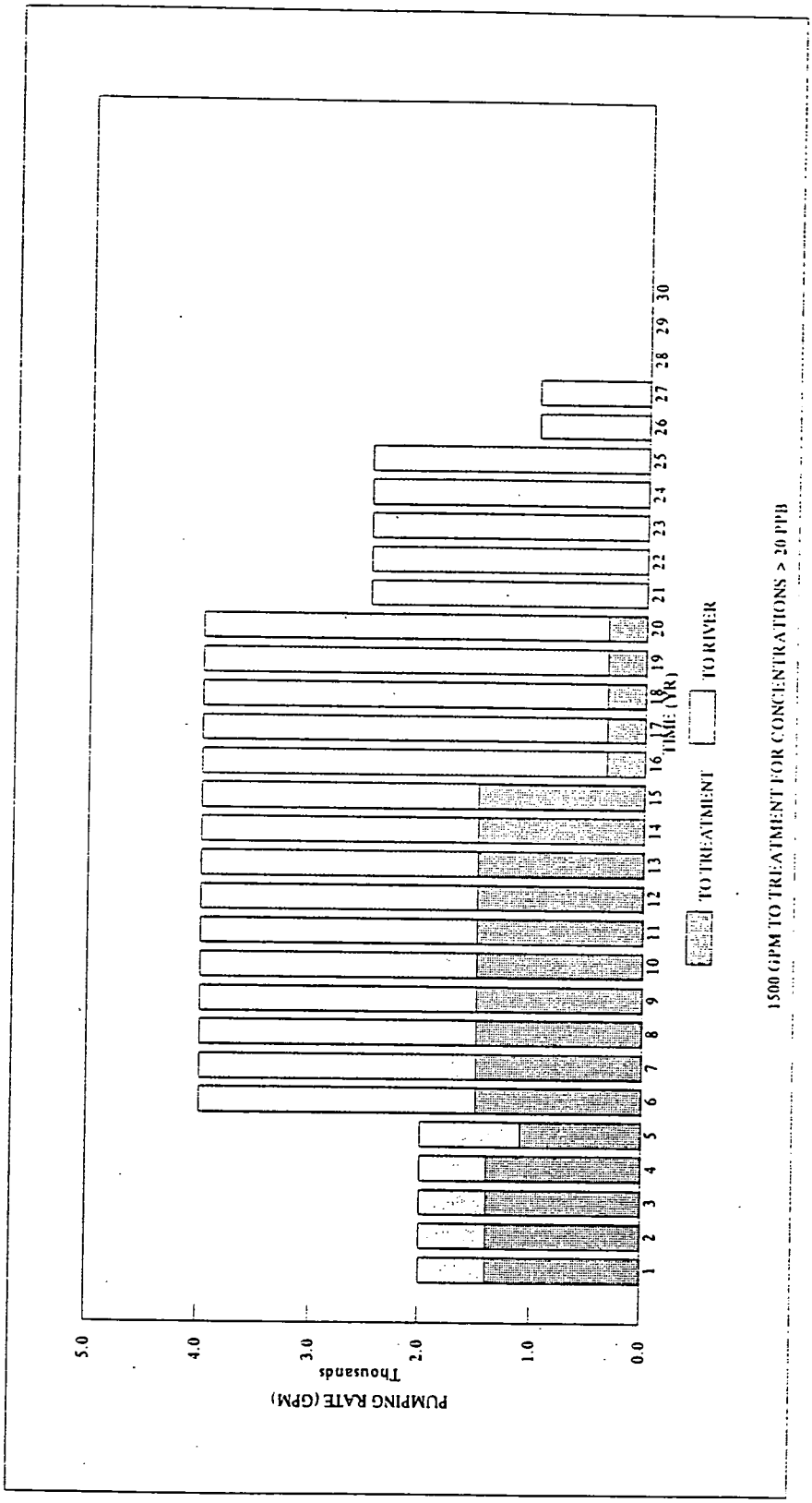
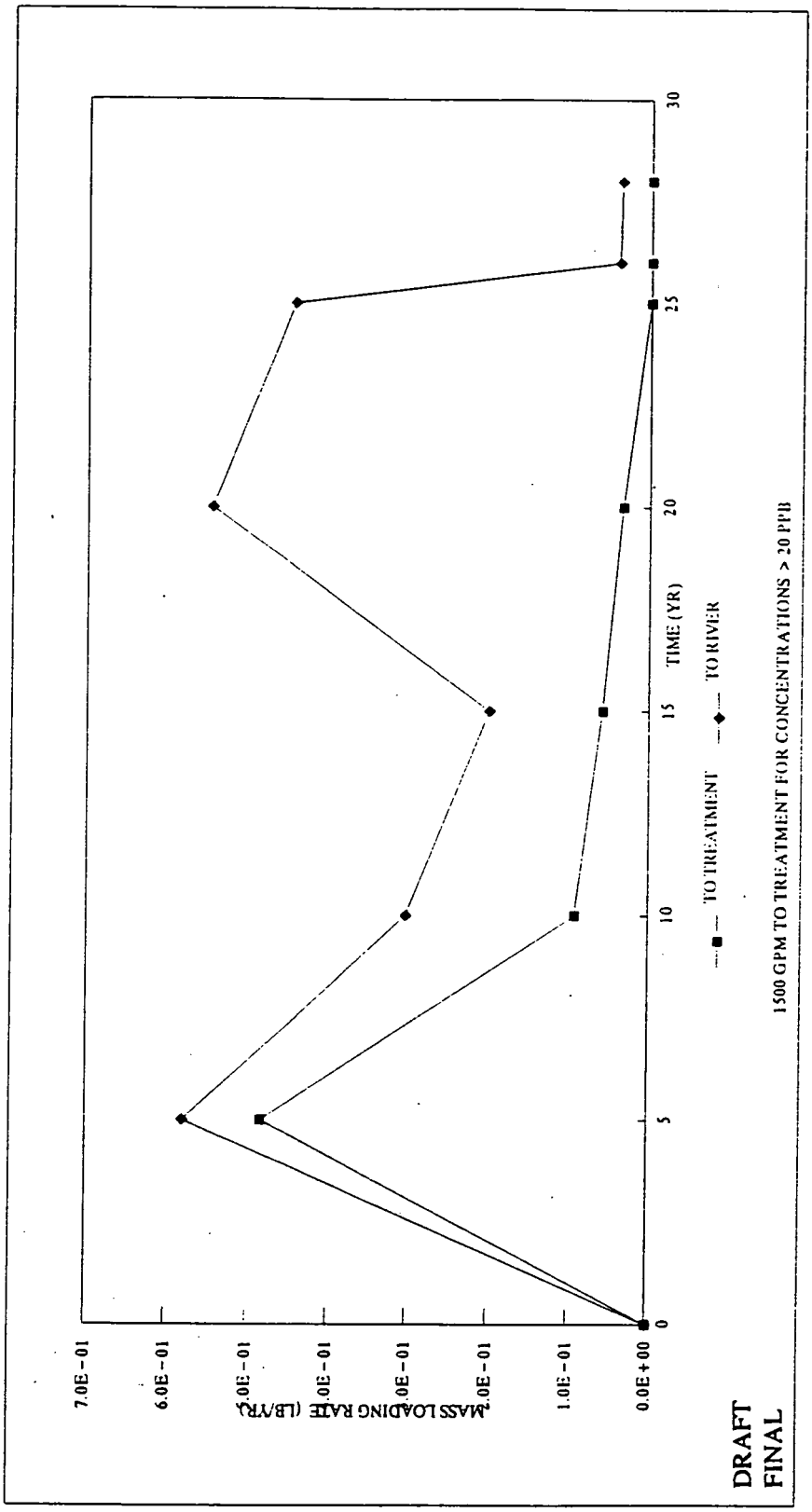
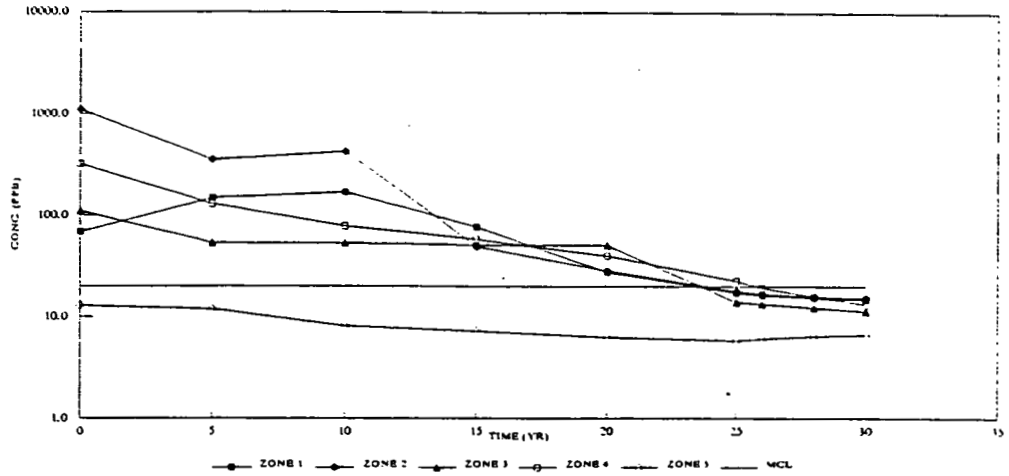
VOC-6 - SEQUENTIAL PUMPING, WELL AVERAGE CONCENTRATIONS VS. TIME (WELLS 16-28), TOTAL VOCS



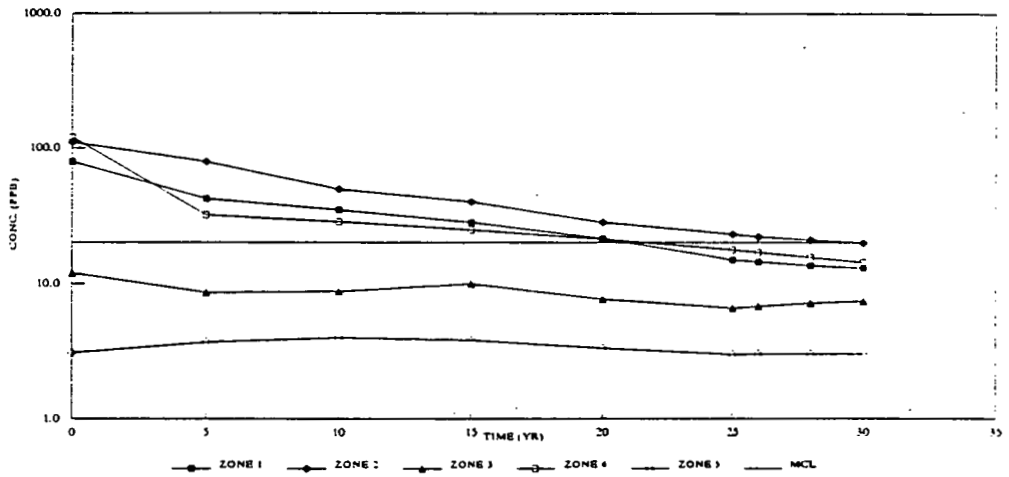
VOC-7 - SEQUENTIAL PUMPING, TREATMENT RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), TOTAL VOCS



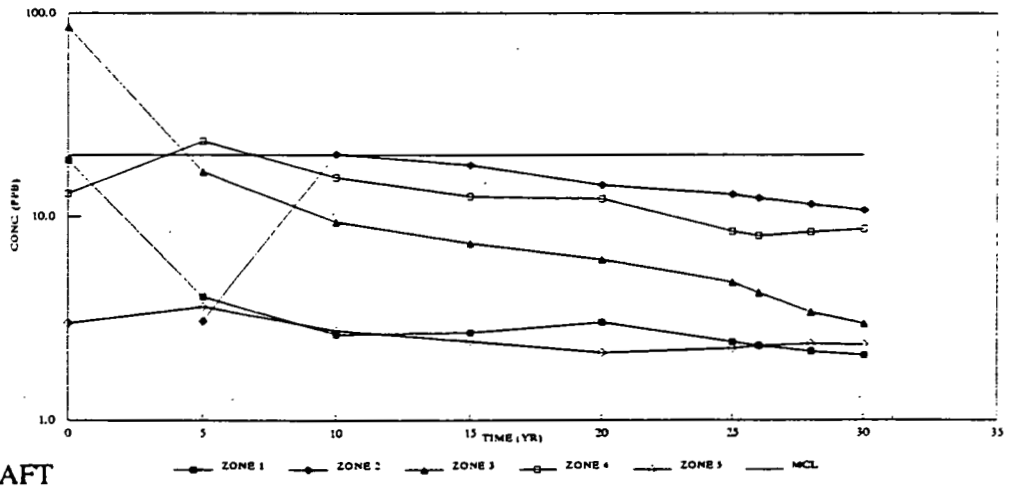
VOC-8 - SEQUENTIAL PUMPING, MASS LOADING RATE VS. TIME (TREAT > 20 PPB UP TO 1500 GPM), TOTAL VOCS



LAYER 1



LAYER 3



LAYER 6

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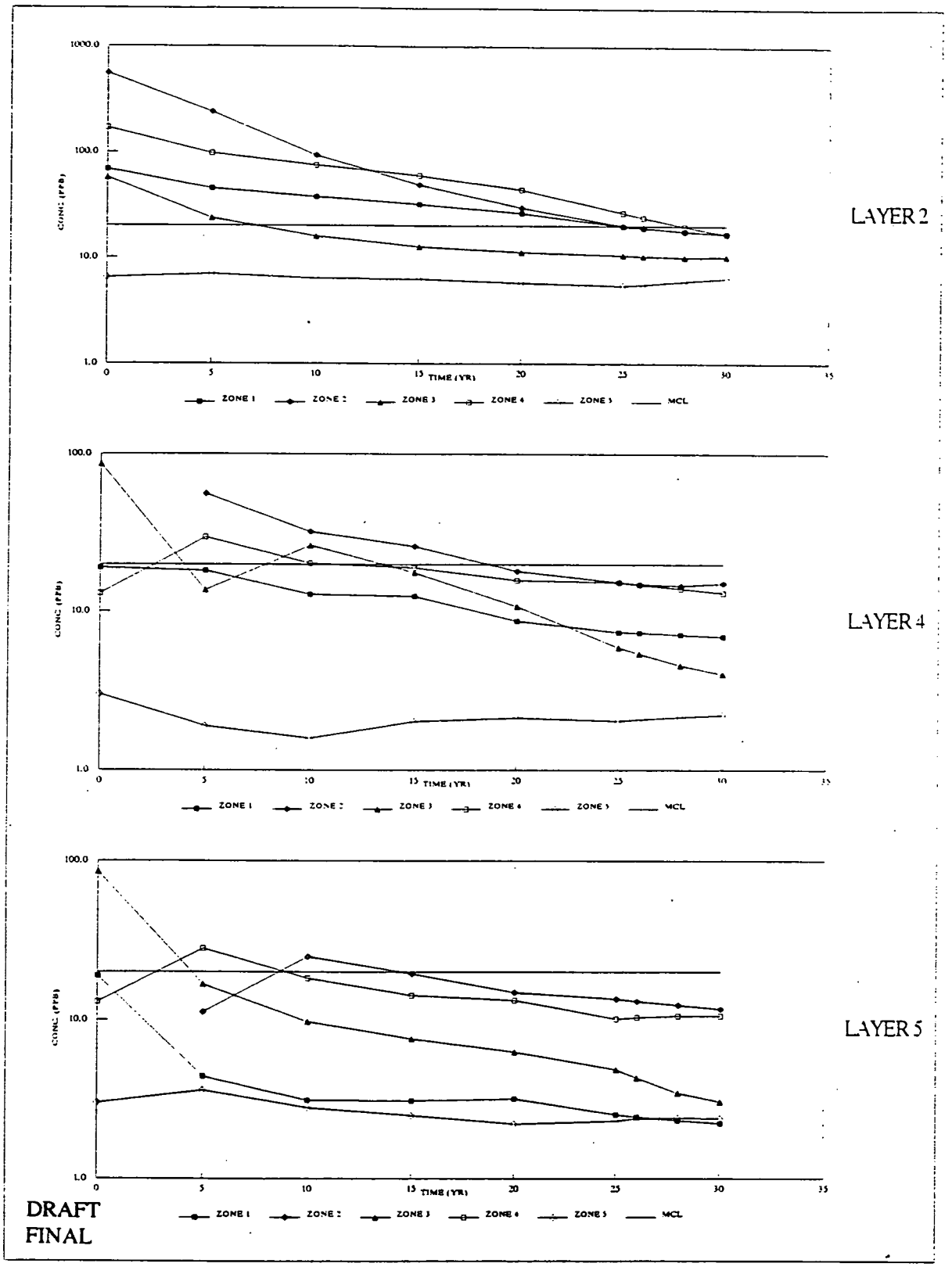
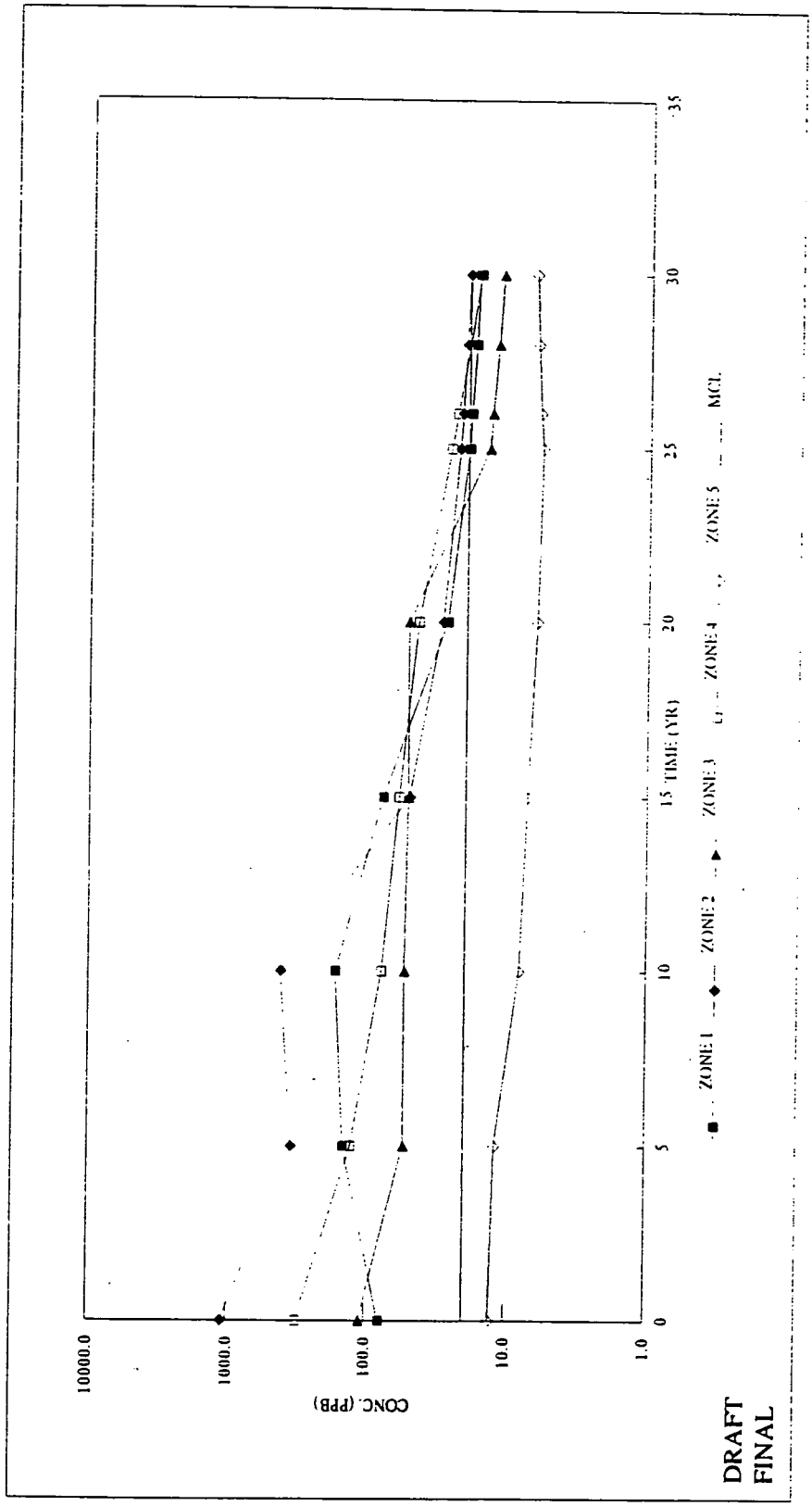
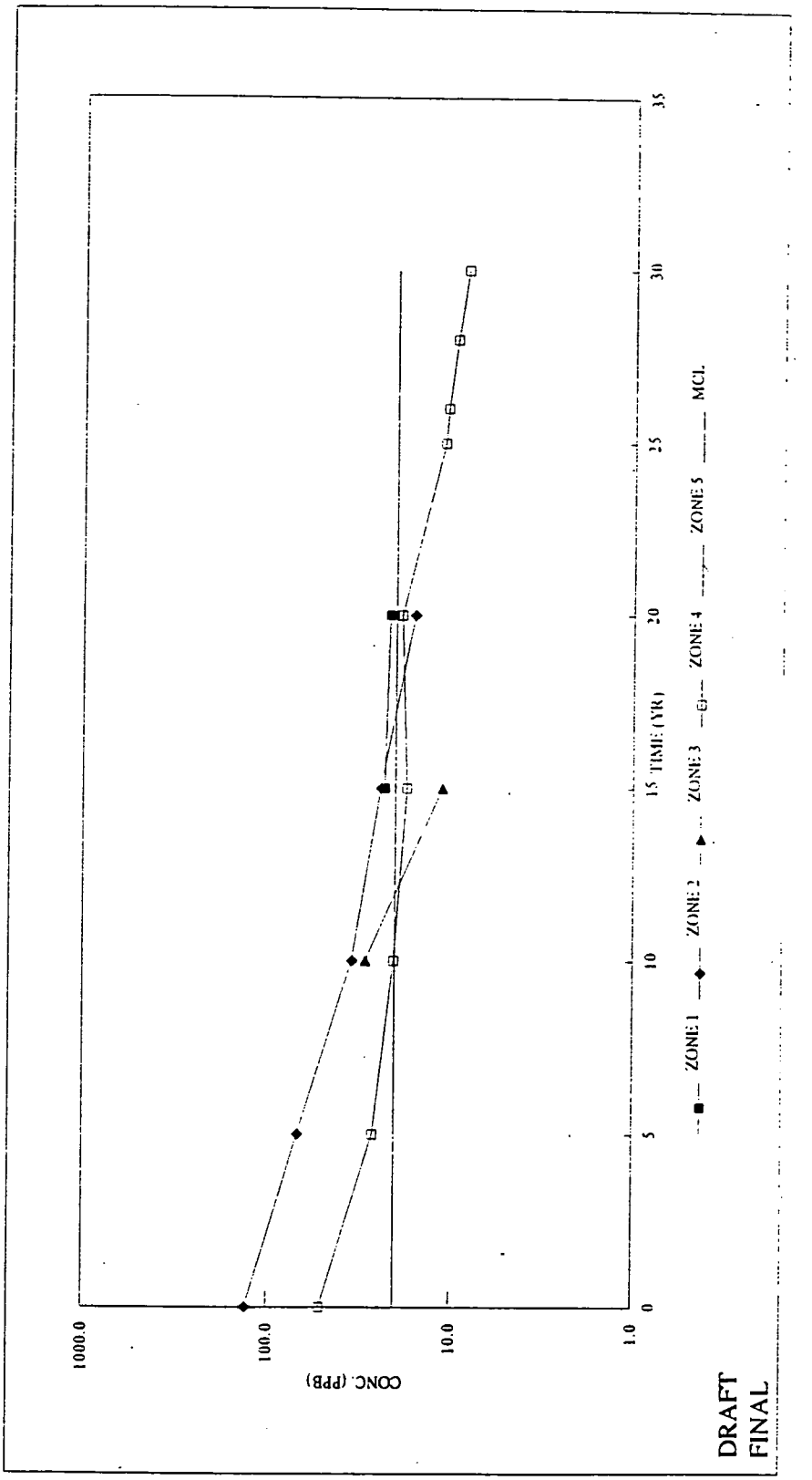
RD-1 - REVISED DISPERSION SCENARIO, MAXIMUM CONCENTRATION CURVES
(LAYERS 1, 3, AND 6)



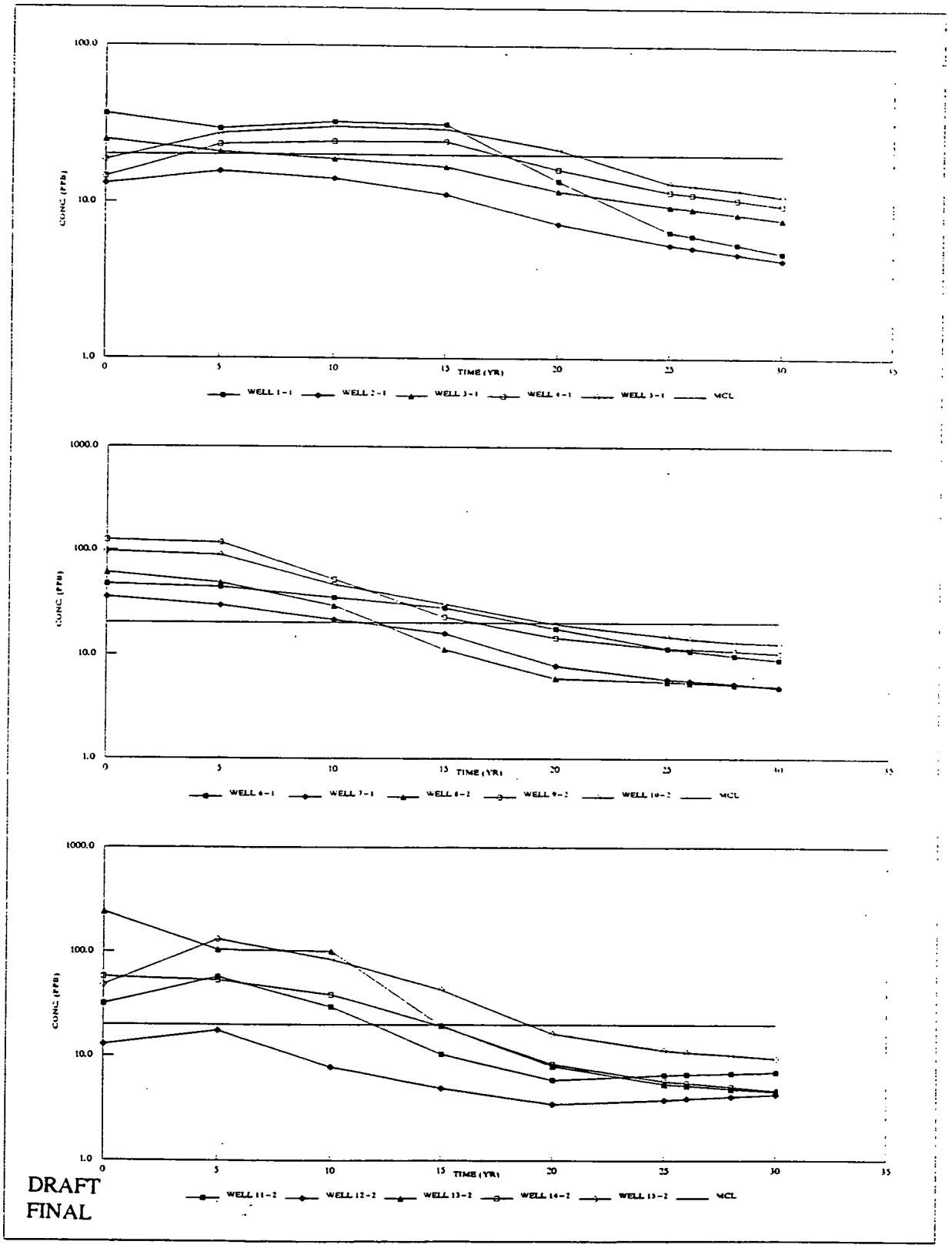
RD-2 - REVISED DISPERSION SCENARIO, MAXIMUM CONCENTRATION CURVES
(LAYERS 2, 4, AND 5)



RD-3 - REVISED DISPERSION SCENARIO, MAXIMUM CONCENTRATION CURVES OF LAYERS 1-6 BY ZONE



RD-4 - REVISED DISPERSION SCENARIO, SYSTEM AVERAGE CONCENTRATIONS VS. TIME



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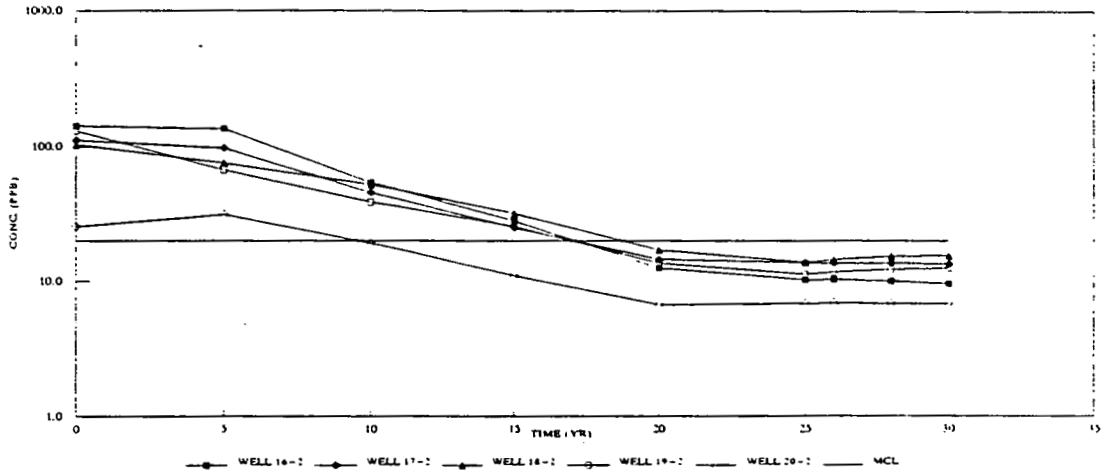
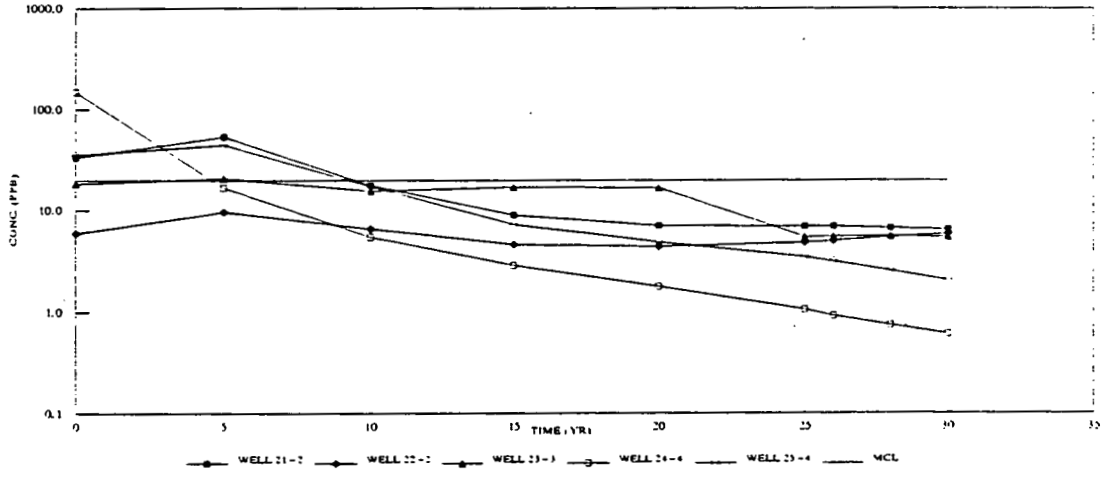
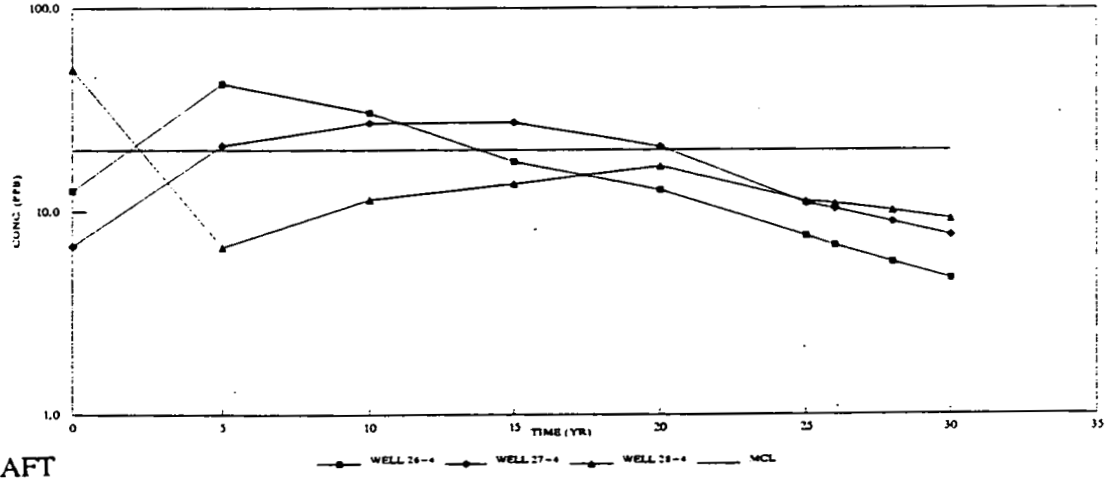
RD-5 - REVISED DISPERSION SCENARIO, WELL AVERAGE CONCENTRATIONS VS. TIME







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RD-6 - REVISED DISPERSION SCENARIO, WELL AVERAGE CONCENTRATIONS VS. TIME

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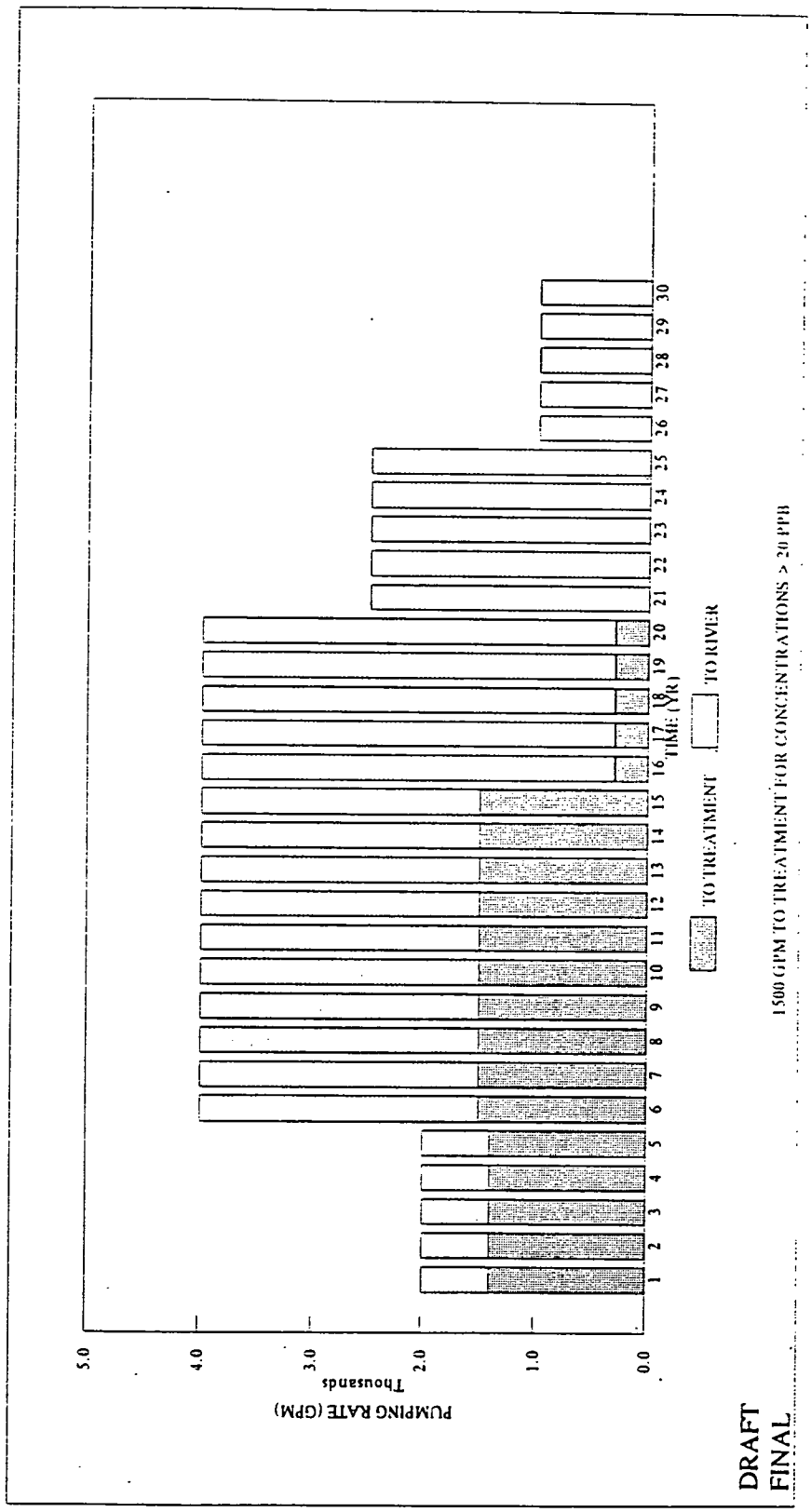

RD-7 - REVISED DISPERSION SCENARIO, TREATMENT RATE VS. TIME

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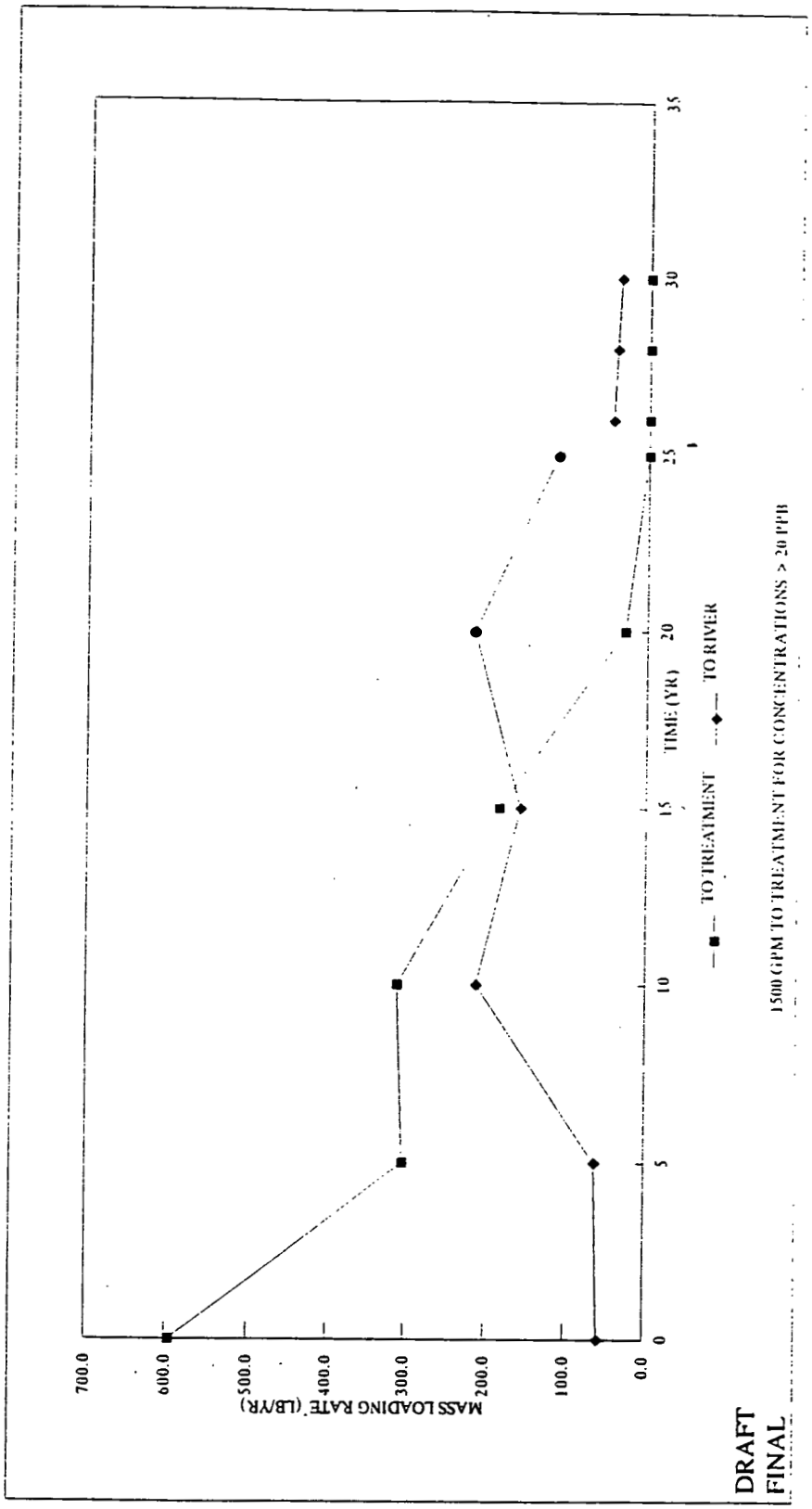

RD-8 - REVISED DISPERSION SCENARIO, MASS LOADING RATE VS. TIME

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ATTACHMENT F.8.III

SENSITIVITY ANALYSIS OF GEOCHEMICAL CONDITIONS

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SENSITIVITY ANALYSIS OF GEOCHEMICAL CONDITIONS

F.8.III.1.0 INTRODUCTION

Contaminant mass exists in both dissolved and adsorbed phases in the aquifer. Only dissolved contamination can be readily recovered by groundwater extraction. However, adsorbed contaminant mass can continuously and usually slowly desorb into dissolved phases. The aquifer restoration system therefore needs to recover contaminant mass in both forms until groundwater concentrations caused by prolonged desorption of contaminant from soil particles will no longer exceed the desired cleanup level. Due to the limited ability to predict the tendency of the soil particles composing the aquifer system to release the contaminants to groundwater for extraction, there is considerable uncertainty in the long-term efficiency of extraction system and the amount of time required to attain remediation levels for uranium and several other contaminants.

A sensitivity analysis is conducted to evaluate impacts of different uranium desorption characteristics (i.e., lower desorption rates than the baseline condition) during aquifer restoration. Potential impacts may include 1) reduced size of uranium plume after the first flush of dissolved contaminant from the initial plume, and 2) locally higher groundwater flushing rate required to achieve restoration. The first part of this sensitivity analysis is to evaluate the size and location of plume that may have prolonged desorption of uranium mass causing future groundwater concentrations to exceed the cleanup level. Using the results of recently completed laboratory desorption batch tests for uranium contaminated aquifer soil in the South Field area, the second part of the sensitivity analysis consists of analytical model simulations to determine the relation between groundwater flushing rate and the required time to reach the aquifer cleanup level in the potential problem area. Results of this sensitivity analysis are used to make recommendations for potential adjustments in the groundwater extraction operations.

An uniform uranium solid/liquid partition coefficient (K_d) value of 1.78 L/kg and the assumption of fully reversible adsorption/desorption process were used in all the previously described simulations of the groundwater extraction strategies. Although the calibrated K_d value of 1.78 L/kg (DOE 1993) is representative of the adsorption phase of uranium transport and can be used to estimate the amount of currently adsorbed uranium mass, K_d values during aquifer restoration (i.e., desorption phase) may be higher and non-uniform in groundwater plume underlying the original contaminant source areas because of different chemical forms of uranium and the long duration in which uranium mass has been in adsorbed phase. For example, recently completed laboratory desorption batch tests for uranium contaminated aquifer soil under the South Field area are summarized in Appendix D. The measured uranium adsorbed-phase concentrations of the archived aquifer soil sample are less than 10 mg/kg with an average of 3.78 mg/kg. The range of measured uranium desorption K_d values for contaminated soil is between 7.9 and 100.9 L/kg with an arithmetic average of 32.64 L/kg. The low

adsorbed-phase uranium concentrations verify that the adsorption K_d value used in previous modeling is reasonable. However, the higher desorption K_d values indicate lower desorption rates of the adsorbed contaminant mass and, therefore, a potentially longer cleanup time. Because aquifer restoration goal is to reduce groundwater concentration to cleanup level everywhere in the aquifer in a reasonable time frame, impacts of higher local uranium desorption K_d values as well as limitations in hydraulic efficiency on performance of the aquifer extraction system need to be evaluated.

F.8.III.2.0 PLUME SIZE DURING RESTORATION

The first part of this sensitivity analysis is to evaluate the size and location of plume that may have prolonged desorption of uranium mass causing future groundwater concentrations to exceed the cleanup level. Higher desorption K_d values indicate lower tendency for residual uranium mass adsorbed on the soil particles to desorb. Therefore higher the desorption K_d value, smaller the remaining groundwater plume will be after extracting the initial dissolved contaminant mass.

To identify the size and location of plume in which the remaining adsorbed-phase uranium can still desorb and cause future groundwater concentrations to exceed the cleanup level (i.e., the proposed MCL of 20 ppb), the following simple equation can be used to obtain an indicating groundwater concentration:

$$C_{min} = \frac{20 \times K_d}{1.78} \qquad (1)$$

where: C_{min} is the indicating groundwater concentration (ppb), and
K_d is the uranium desorption solid/liquid partition coefficient (L/kg).

Only adsorbed uranium mass in the portion of current uranium plume that has groundwater concentrations higher than C_{min} can cause future groundwater concentrations to exceed 20 ppb after terminating all the source loading and recovering the initial dissolved mass. For example, given a desorption K_d value of 30 L/kg which is a representative value in the South Field area, the C_{min} becomes 337 ppb. The only area in the Great Miami Aquifer that has groundwater concentrations higher than this C_{min} value is a roughly 7.5-acre plume close to the Inactive Fly Ash Pile (Plate E-79, Operable Unit 5 RI, DOE 1994). As can be seen from this example, although higher desorption K_d values may potentially prolong the aquifer restoration time due to lower desorption rates, they can reduce the size of plume that will require long-term operation of the groundwater extraction system. Therefore, after terminating all the source loading and recovering the initial dissolved mass, total pumping rate of the aquifer extraction system can be reduced and only focused on the smaller remaining plume which has significantly high adsorbed-phase concentrations.

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F.8.III.3.0 FLUSHING RATE AND CLEANUP TIME

To estimate additional time of extraction required after the initial dissolved phase uranium mass has been recovered, the second part of the sensitivity analysis consists of analytical model simulations to determine the relation between groundwater flushing rate and the required time to reach the groundwater cleanup level (i.e., 20 ppb). A 40-foot thick, 500 feet by 500 feet area of contaminated aquifer with 5 mg/kg of adsorbed-phase concentration was used in these simulations as the prolonged desorption source of uranium. This plume size and adsorbed-phase concentration are representative of the conditions found in the South Field area.

A mass-balance analysis of the contaminant flushing with 100 percent hydraulic efficiency through a volume of contaminated aquifer with contaminant mass partitioning and chemical or radioactive decay yields the following equation:

$$C_w = \frac{\left[1 + (SV_W + K_d W_s)(\lambda/Q_f)\right] C_{wo} \exp\left[- \frac{Q_f + (SV_W + K_d W_s)\lambda}{SV_W + K_d W_s} t \right]}{\left[1 + (SV_W + K_d W_s)(\lambda/Q_f)\right]} \qquad (2)$$

where:
- Q_f is the groundwater flushing rate (L/day),
- C_w is the groundwater concentration (ppb),
- C_{wo} is the initial groundwater concentration (ppb),
- S is the soil saturation fraction (dimensionless = 1),
- V_w is the void volume (L),
- K_d is the desorption solid/liquid partition coefficients (L/kg),
- W_s is the dry weight of soil in the specified volume (kg), and
- λ is the first-order chemical decay rate (day^{-1}).

Assuming C_{wo} = 5000 / K_d (ppb) and a soil bulk density of 1.6 g/cm^3, Eq. 2 was applied to determine the relation between groundwater flushing rate and the required time to reach the groundwater cleanup level (i.e., 20 ppb). Figure F.8.III-1 summarizes the results for 5 different desorption K_d values from 1.78 up to 30 L/kg and groundwater flushing rate between 25 gpm and 1500 gpm. The lower end of the flushing rate represents the natural groundwater flow rate through the contaminated aquifer volume.

Figure F.8.III-1 shows that it will require about 10 additional years to reach the cleanup level in the simulated volume with a groundwater flushing rate of 1500 gpm if the desorption K_d value is 30 L/kg. Although the additional time shown in Figure 2-1 is only about 1.5 years for the K_d of 1.78 L/kg case under the same flushing rate, the actual size of the overall uranium plume in the aquifer will be much larger than the simulated 500 feet by 500 feet area with this low K_d value. This is one of the reasons why the overall cleanup times for all the baseline simulations, which use a K_d value of 1.78 L/kg, are in the range of 25 to 30 years as described in Section 2.1.

Given the constant size of contaminated aquifer volume (i.e., 500 feet by 500 feet), Figure F.8.III-2 shows that the additional extraction time required will start to decrease if uranium K_d value exceeds about 100 L/kg. This is because more contaminant mass will remain bounded to the soil particles and can not desorb into dissolved phase. Three different flushing rates are presented in Figure F.8.III-2 to demonstrate the relation between groundwater flushing rate and the required time to reach the groundwater cleanup level. The maximum additional time required is about 15 years with a groundwater flushing rate of 1500 gpm regardless of the desorption K_d value.

F.8.III.4.0 OPERATIONAL CONSIDERATIONS

Because of the uncertainty associated with contaminant desorption characteristics, the FEMP will continue to investigate supporting technologies, such as re-injection and pulsed pumping, to enhance contaminant recovery and hydraulic flushing efficiencies and reduce the time needed to restore the aquifer. Re-injection would potentially involve pumping of extracted groundwater with concentrations below the cleanup level back into the aquifer to increase the rate of flow and create an enhanced local flushing effect in order to speed contaminant removal.

In general the overall time frame and cost of extraction and treatment to restore aquifer will not change significantly due to higher desorption K_d values. Because higher desorption K_d values will also result in smaller groundwater plumes. By adjusting the extraction operation, larger portion of the available extraction and treatment capacities can be focused in this smaller area to achieve higher groundwater flushing rates and therefore maintain the same cleanup time.

The uncertainties associated with the desorption characteristics of contaminants and hydraulic efficiency of groundwater extraction also indicate the importance of performance evaluation during the aquifer restoration. A monitoring and evaluation program should be in place to assess progress of the remediation effort.

F.8.III.5.0 REFERENCE

U.S. Department of Energy (DOE), 1994, "Remedial Investigation Report for Operable Unit 5 (Draft)," Fernald Environmental Management Project, Fernald, Ohio, Fernald Field Office.

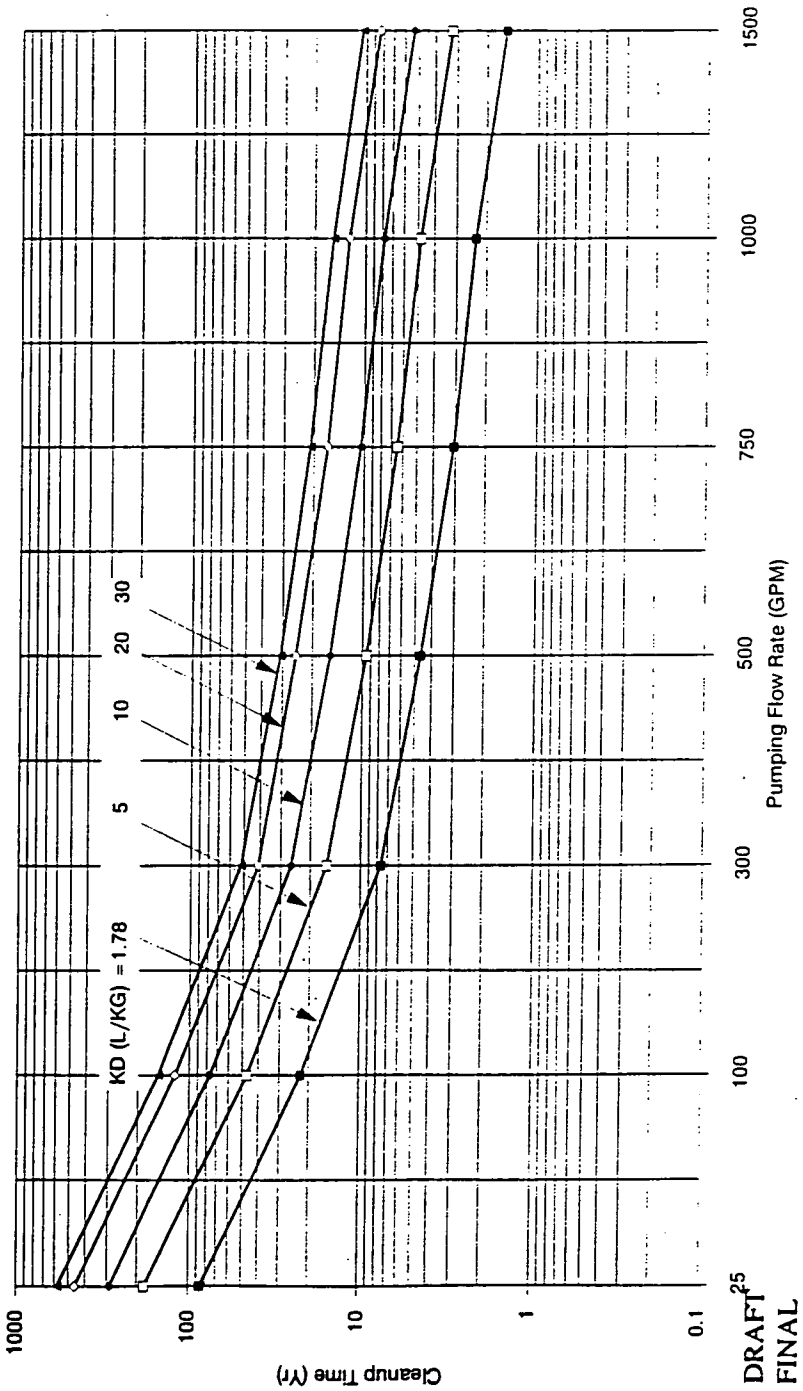

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FIGURE F.8.III-1 - RESULTS OF ANALYTICAL MODELING OF CLEANUP TIME VERSUS FLOW RATE FOR VARYING VALUES OF K_d

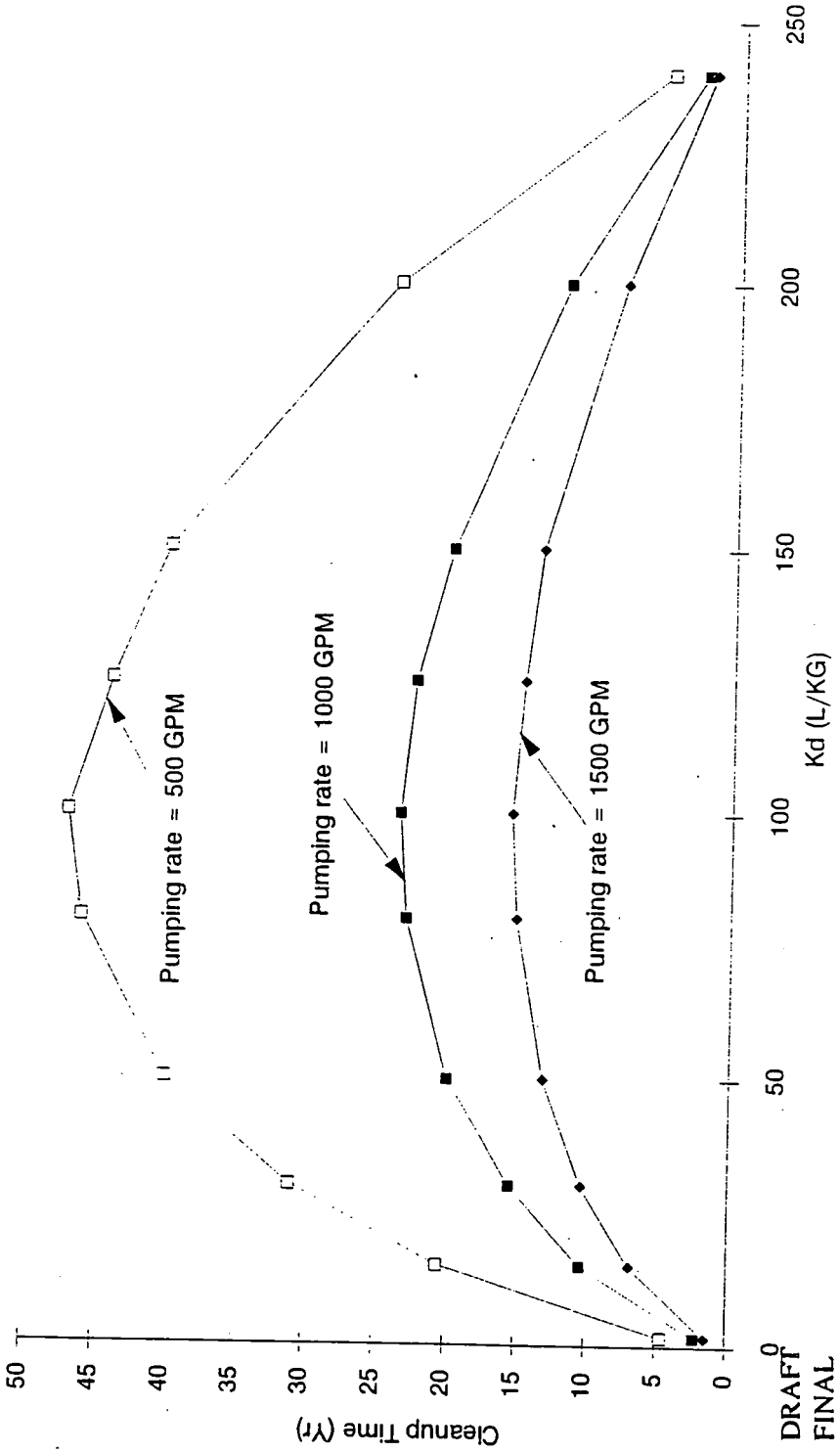

FIGURE F.8.III-2 - SUMMARY OF GEOCHEMICAL SENSITIVITY ANALYSIS RESULTS

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ATTACHMENT F.8.IV

GREAT MIAMI AQUIFER DESORPTION K_d

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F.8.IV.1.0 INTRODUCTION

This report describes testing which was done to measure desorption of uranium from GMA sediment samples collected in the southfield area of the FEMP. The sorption characteristics of the Great Miami Aquifer (GMA) sediments for uranium will affect the extraction of uranium from the groundwater and will substantially influence restoration times for any groundwater extraction remedy.

The partition coefficient (K_d) is used to describe the tendency of a contaminant to sorb to the soil from the ground water and desorb from the soil to the groundwater. K_d is defined as the ratio of the concentration of a contaminant in soil, ug/g, to the concentration of the contaminant in ground water, ug/ml. Desorption is frequently a longer process than adsorption.

The desorption tests described in this report were conducted using sediment collected from the Great Miami Aquifer during the installation of Monitoring Wells 2045, 2046, 2047, 2387, 2945, 2954 21191, 21192 and 3096 (Figure F.8.IV-1 and Table F.8.IV-1). The sediment samples were collected using split spoons from depths beneath the water table of the Great Miami Aquifer. With the exception of Monitoring Well 3096, all of these wells are located in an area of the Great Miami Aquifer that is contaminated with uranium (Table F.8.IV-2). Total uranium concentrations in this area range up to 2070 ug/l. Taking samples from this location maximizes the likelihood of obtaining sediments with high concentrations of adsorbed uranium. Monitoring Well 3096 is located upgradient of the FEMP site and comes from an area of the aquifer that is not contaminated with uranium (Table F.8.IV-2). Sediment samples from this well served to define background for the testing program.

Uncontaminated groundwater collected from Monitoring Well 3096 was used as the leaching medium for the desorption tests.

F.8.IV.2.0 SELECTION AND PREPARATION OF SAMPLES

Great Miami Aquifer Sediment Samples

Thirty-seven sediment samples (34 from an area where the groundwater is contaminated with uranium and three from an area where the groundwater is not contaminated with uranium) were retrieved from storage and the custody seals of the sample jars were inspected by the Site Characterization (SC) staff. All seals were found to be intact. The sediment samples were screened for radiation (ASL-A) in the FEMP Sample Processing Lab (SPL). No surface radiation was detected on the sample bottles. Each sediment sample was homogenized by quartering the sample and recombining sample quarters as prescribed in the SCQ Appendix K, Section K.5.1. The homogenization step and all subsequent sample handling processes were conducted with precleaned dedicated containers and equipment in order to decrease the chance of cross contamination.

Twenty grams of sediment was separated from the homogenized sample and placed in a clean container. This fraction was transferred by SMO personnel to the FEMP Environmental Processing and Monitoring Laboratory (EPML) for total uranium analysis and percent moisture determination (ASL B).

The total uranium analysis was performed using the bromopadap method which has a detection limit of 1 ppm total uranium. The percent moisture determination was made by weighing the sample fraction followed by drying at 110 C° for 18 hours and reweighing the sample fraction.

Two sediment samples were selected from samples with relatively large volumes of material, and an additional 20 gram sample fraction was collected from each. These fractions were also submitted for total uranium measurements and served as duplicate sediment samples for the bromopadap method.

The remaining volumes of sediment samples were transferred to the FEMP Laboratory Building for desorptive batch testing.

Background Groundwater Samples

Groundwater from the Great Miami Aquifer was collected from monitoring well 3096 located upgradient (west) of the FEMP (Figure F.8.IV-1). Groundwater in this area of the Great Miami Aquifer is not contaminated with uranium. One 250 ml sample and one 250 ml duplicate sample was sent to the FEMP Low Level Environmental Laboratory (LLEL) for total uranium analysis by KPA (ASL B). This method has a detection limit of 0.1 ppb. The remaining groundwater was taken in the FEMP Laboratory Building and used as the leaching medium for the desorptive batch test.

F.8.IV.3.0 TESTING PROCEDURE

The batch test procedure used is consistent with the procedure used during the OU5 K_1 Soil Sampling and Analysis Project (DOE July 1994).

Four hundred grams (dry weight equivalent) of each sediment sample was placed in a plastic vessel with 3500 mls of groundwater. If 400 grams (dry weight) of sediment was not available, than a soil to groundwater ratio (grams dry weight equivalent to milliliters) of 1 to 8.75 was maintained using as much of the sediment sample as was possible. The pH of groundwater used in the batch test was measured to the nearest 0.01 pH units. The bulk or gross weight required for each sample was calculated using the percent moisture determined prior to uranium analysis.

The vessel was placed on a mechanical rotator and rotated continuously during the test at 29 ± 2 rpm. The rpm of the rotator was verified prior to the start of the test.

Samples of leachate were periodically collected after the vessel had stopped rotating for a minimum 10 minutes or sufficient time to allow solids to settle. Twenty milliliters of leachate was decanted from the vessel and filtered through a 0.45 micron filter. Each sample was preserved with nitric acid to a pH less than 2. Samples were transferred to the LLEL for total uranium analysis at ASL B. Any solids which were removed during the leachate collection process were returned to the vessel. Clean groundwater was added back to the vessel to replace leachate removed during the sampling process.

Leachate samples were collected at approximately 72, 144, 168, 240, 288, 360, and 384 hours for total uranium analysis at the LLEL.

During each leachate collection period one vessel was selected at random and 20 ml duplicate leachate samples were also collected, preserved and sent to the LLEL for total uranium analysis.

F.8.IV.4.0 LAB RESULTS

Total Uranium in Sediments

Total uranium sediment samples are tabulated in Table F.8.IV-3. Uranium concentrations are given in Table F.8.IV-4. As mentioned above these measurements were taken using a bromopadap method that has a reported detection limit of 1 ppm for total uranium. The three sediment samples collected from Monitoring Well 3096 (upgradient of the FEMP) had measured uranium concentrations of 1.8 ug/g, 1.5 ug/g, and 1.5 ug/g, with an arithmetic average for the three samples of 1.6 ug/g. This average was used to represent background total uranium for the Great Miami Aquifer sediments. The other 34 sediment samples were all collected from an area of the Great Miami Aquifer that has elevated levels of uranium contamination in the groundwater. Measured total uranium concentrations range from 1.3 ug/g to 10.7 ug/g.

The highest concentration (10.7 ug/g) was reported from a sample collected from Monitoring Well 2945 from the depth interval of 47.5 feet to 49 feet bgs. Groundwater collected from this well has the highest measured total uranium concentration (2070 ppb).

Total uranium measurements were made on two duplicate sediment samples. The duplicate measurements were made on the samples collected from Monitoring Well 2387 at the depth interval of 60 feet to 61.5 feet bgs and from 65 feet to 66.5 feet bgs. For the shallow duplicate pair the results were 2.4 ug/g and 6 ug/g. For the deeper duplicate pair the result was 1.9 ug/g and 4.7 ug/g. The variance in results is attributed to the homogenization step used to prepare the sample. A very small amount of oxide going into one sample and not another could result in a large total uranium measurement difference at these low concentrations. With these duplicate results in mind, it is felt that the level of precision for this measurement turned out to be approximately 3 ug/g.

Percent Moisture in Sediments

The percent moisture of all of the sediment samples was also determined. Results are tabulated in Table F.8.IV-3. These percent moisture determinations were used to determine the dry wight of the sediment samples so that a ratio of sediment to groundwater of 1 to 8.75 could be determined. Percent moisture ranged from 1.15% to 13.83%.

Total Uranium and pH of Background Groundwater

The concentration of total uranium in the groundwater collected from Monitoring Well 3096 was .5 ppb. The pH was measured five different times as the water was collected. The five measurements were 6.89, 6.88, 6.93, 7.04 and 7.06.

Total Uranium in Leachate

Leachate was collected at the following approximate time intervals (72 hours, 144 hours, 168 hours, 240 hours, 288 hours, 360 hours, and 384 hours). Results (in ug/l) are tabulated in Table F.8.IV-4. The percent change between different time periods is also tabulated.

Testing for uranium at each time interval included testing of duplicate samples. Results are tabulated in Table F.8.IV-5. As the results indicate, the measurements are very consistent.

F.8.IV.5.0 DESORPTION K_d CALCULATIONS

K_d was calculated by dividing the concentration of uranium in the sediment (corrected for background) by the concentration of uranium in the leachate collected after 384 hours (16 days) had elapsed. The formula is as follows:

$$K_d = C_s' / C_l$$

K_d = sediment to liquid partition coefficient due to desorption
C_s' = Concentration of uranium in GMA sediment (minus background)
C_l = Concentration of uranium in test leachate (after 16 days)

The concentration of uranium in the GMA sediment was calculated by dividing the difference between the mass in the sediment and the mass in the leachate by the total mass of the soil.

$$C_s = (m_s - m_l) / M$$

$$m_s = C_o * M$$

$$m_l = C_l * V$$

C_s = Concentration of uranium in GMA sediment
m_s = Initial mass of uranium in GMA sediment
m_l = Mass of uranium in liquid at equilibrium
M = Total mass in GMA sediment
C_o = Initial concentration of uranium in GMA sediment
V = Total volume of liquid

$$C_s' = C_s - C_b$$

C_b = Background concentration of uranium in GMA sediment
C_s' = Concentration of uranium in GMA sediment (minus background)

Results of the K_d calculations are tabulated in Table F.8.IV-6.

F.8.IV.6.0 CONCLUSIONS

Four of the sediment samples has measured total uranium concentrations less than background resulting in negative K_d calculations. Excluding these four measurements, calculated K_d for the other 30 sediment samples ranged from 7.0 L/kg to 1307.0 L/kg. (Table F.8.IV-6) with an arithmetic average of 203.7 and a geometric average of 64.65. Linear regression of the total uranium concentration of the leachate verses the total uranium concentration of the sediment (minus background in the sediment) yields a slope of 14.9 with a Y intercept of 1.42 (Figure F.8.IV-2), Table F.8.IV-7) or a slope of 24.8 with a Y intercept of 0 (Figure F.8.IV-3, Table F.8.IV-8).

Sixteen of the 30 sediments produced leachates with concentrations of total uranium above 20 ug/l. Sediments capable of desorbing 20 ug/l of uranium into the groundwater are the sediments which would be targeted for remediation, in the current Proposed Plan, at the FEMP. Calculated K_d for these samples ranges from 7.9 L/kg to 100.9 L/kg with an arithmetic average of 32.64 L/kg and a geometric average of 25.43 L/kg. Linear regression of the total uranium concentration of the leachate verses the total uranium concentration of the sediment (minus background in the sediment) yields a slope of 17.8 with a Y intercept of .98 (Figure F.8.IV-4, Table F.8.IV-9) or a slope of 24.2 with a Y intercept of 0 (Figure F.8.IV-5, Table F.8.IV-10).

This range of K_d is consistent with the level of precision that has resulted in other studies of partition coefficients. "Estimated values of partition coefficients are often only precise to 3 to 5 orders of magnitude while values determined in the laboratory are generally accurate to within 1 or 2 orders of magnitude," EPA, 1988.

F.8.IV.7.0 REFERENCES

EPA, 1988, Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, Interim Final, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

DOE, 1994, Operable Unit 5, Post-RI Field and Laboratory Geochemical Study, Fernald Environmental Management Project, Cincinnati, Ohio.

TABLE F.8.IV-1

DEPTHS AND LITHOLOGY OF GMA SEDIMENT SAMPLES

Well #	Sample	Depth (feet bgs)	Description
2045	8946	25' - 26.5'	Grayish brown sand
	8949	40' - 41.5'	Grayish brown sand
		TD 45', WL 27.8', Screen 23' - 38'	
2046	08957	66' - 67.5'	Brown sand
	08958	71.5 - 73.0'	Brown sand
		TD 73', WL 58.5', Screen 53.4' - 68.4'	
2047	08965	50' - 51.5'	Brown sand & gravel
	08966	55' - 56.5'	Brown sand & gravel
	08967	60' - 61.5'	Brown sand & gravel
		TD 64', WL 50.4', Screen 45.3 - 60.3'	
2954	113215	49.5' - 51'	Brown sand
	113216	51' - 52.5'	Brown sand
	113217	52.5' - 54'	Brown sand
	113218	54' - 55.5'	Brown sand
	113219	55.5' - 57'	Brown sand
	113220	57' - 58.5'	Brown sand
	113221	58.5' - 60'	Brown sand
		TD 65', WL 53', Screen 47.0' - 62	
2945	110258	43' - 44.5	Brown sand
	110259	44.5' - 46'	Brown sand
	110260	46' - 47.5'	Brown sand
	110261	47.5' - 49'	Brown sand
	110262	49' - 50.5'	Brown sand
	110263	50.5' - 52'	Brown sand
	110264	52' - 53.5'	Brown sand
	110265	53.5' - 55'	Brown sand
		TD = 60' WL = 43.5' Screen = 38.5' - 53.5'	
2387	32567	45' - 46.5'	Brown gravel
	32568	50' - 51.5'	Brown sand
	32569	55' - 56.6'	Brown sand
	32570	60' - 61.5'	Brown sand
	32571	65' - 66.5'	Brown sand
		TD = 65' WL = 47' Screen = 46'- 61'	

TABLE F.8.IV-1
(Continued)

Well #	Sample	Depth (feet bgs)	Description
21192	55441	14' - 14.5'	Brown sand
	55450	18.5' - 19'	Brown sand
	55452	19.5' - 20'	Brown sand
		TD = 20' WL = 13.5' Screen = 10' - 20'	
21191	55402	15.5' - 16'	Brown sand
	55404	16.5' - 17'	Brown sand
	55406	17.5' - 18'	Brown sand
	55408	18.5' - 19'	Brown sand
		TD = 20' WL = 15' Screen = 9.5 - 19.5'	

TD = Total Well Depth
WL = Water Level at Time of Installation
Screen = Screen Interval

TABLE F.8.IV-2

TOTAL URANIUM IN GROUNDWATER CONCENTRATION IN μG/L

Well	Max	Conc in 1993
2045	462	380 NV
2046	907	423
2047	15	13.8
2954	1167	1107
2945	2070	2070
2387	492	329
21192	966	52.8*
21191	293	293*
3096	1.0	0.7

NV not validated

* Not collected in 1993, most recent to 1993

TABLE F.8.IV-3

TOTAL URANIUM AND % MOISTURE IN SEDIMENT SAMPLES

Well	Depth (ft.)	Total Uranium (ug/g)	% Moisture
2045	25 -26.5	4.6	7.91
2046	66 - 67.5	1.9	1.15
	71.5 - 73	2.0	9.78
2047	50 - 51.5	5.0	6.31
	55 - 56.5	5.9	4.78
	60 - 61.5	1.9	10.70
2954	49.5 - 51	4.2	5.91
	51 - 52.5	2.0	4.90
	52.5 - 54	3.3	10.12
	54 - 55.5	7.5	11.11
	55.5 - 57	4.6	12.50
	57 - 58.5	5.3	12.74
	58.5 - 60	3.6	13.83
2945	43 - 44.5	6.7	8.40
	44.5 - 46	7.8	8.49
	46 - 47.5	7.7	8.27
	47.5 - 49	10.7	7.83
	49 - 50.5	8.0	10.72
	50.5 - 52	6.0	11.51
	52 - 53.5	4.2	10.70
	53.5 - 55	5.0	7.04
2387	45 - 46.5	1.3	4.44
	50 - 51.5	2.8	6.31
	55 - 56.5	3.3	8.41
	60 - 61.5	2.4 (6)	8.96
	65 - 66.5	1.9 (4.7)	16.39
21192	14 - 14.5	1.3	10.63
	18.5 - 19	1.3	4.00
	19.5 - 20	2.9	5.78
21191	15.5 - 16	2.3	7.68
	16.5 - 17	5.1	9.98
	17.5 - 18	2.8	5.71
	18.5 - 19	2.7	7.76
Background			
3096	115 - 116.5'	1.8	10.59
	120 - 121.5'	1.5	8.32
	125 - 126.5'	1.5	8.09

NOTES: ( ) duplicate analysis

TABLE F.8.IV-4

PERCENT CHANGE BETWEEN LEACHATE CONCENTRATIONS AND SAMPLING TIMES

Well Number	Smple Number	Cl ug/l T=1	Cl ug/l T=2	Cl ug/l T=3	Cl ug/l T=4	Cl ug/l T=5	Cl ug/l T=6	Cl ug/l T=7	% CHG 1-2	% CHG 2-3	% CHG 3-4	% CHG 4-5	% CHG 5-6	% CHG 6-7
2045	8946	17	14	13	14	14	14	13	17.65	7.14	7.69	0.00	0.00	7.14
	8949	2.5	2.1	2.1	1.8	1.8	2	1.9	16.00	0.00	14.29	0.00	11.11	5.00
2046	8957	11	8.7	8.6	8.4	7.9	8.1	8	20.91	1.15	2.33	5.95	2.53	1.23
	8958	4.7	4.6	4.5	4.2	4.5	4.7	4.7	2.13	2.17	6.67	7.14	4.44	0.00
2047	8965	3.5	4.4	4.4	4.7	5.3	6.4	6.4	25.71	0.00	6.82	12.77	20.75	0.00
	8966	2.2	3.1	3.1	3.3	3.3	3.9	3.9	40.91	0.00	6.45	0.00	18.18	0.00
	8967	4.9	5.9	6.1	6.6	7.4	8	8.1	20.41	3.39	8.20	12.12	8.11	1.25
2954	113215	1.9	2.1	1.6	1.9	7.2	2.1	2.1	10.53	23.81	18.75	278.95	70.83	0.00
	113216	4.1	2	1.4	1.2	1	0.9	1	51.22	30.00	14.29	16.67	10.00	11.11
	113217	75	81	74	74	69	72	62	8.00	8.64	0.00	6.76	4.35	13.89
	113218	200	190	170	160	150	150	140	5.00	10.53	5.88	6.25	0.00	6.67
	113219	160	160	150	140	140	150	130	0.00	6.25	6.67	0.00	7.14	13.33
	113220	170	160	160	160	140	150	140	5.88	0.00	0.00	12.50	7.14	6.67
	113221	140	150	140	130	140	130	120	7.14	6.67	7.14	7.69	7.14	7.69
2945	110258	180	180	170	160	150	150	130	0.00	5.56	5.88	6.25	0.00	13.33
	110259	210	220	190	180	180	170	170	4.76	13.64	5.26	0.00	5.56	0.00
	110260	200	190	180	150	140	130	120	5.00	5.26	16.67	6.67	7.14	7.69
	110261	260	300	280	280	260	240	230	15.38	6.67	0.00	7.14	7.69	4.17
	110262	310	310	300	280	250	260	250	0.00	3.23	6.67	10.71	4.00	3.85
	110263	65	62	57	52	43	43	41	4.62	8.06	8.77	17.31	0.00	4.65
	110264	15	14	14	13	13	14	14	6.67	0.00	7.14	0.00	7.69	0.00
	110265	37	38	34	33	31	31	31	2.70	10.53	2.94	6.06	0.00	0.00
2387	32567	1.2	1.8	1.3	0.9	0.5	0.8	1	50.00	27.78	30.77	44.44	60.00	25.00
	32568	24	22	24	22	19	19	19	8.33	9.09	8.33	13.64	0.00	0.00
	32569	59	59	64	54	47	48	48	0.00	8.47	15.63	12.96	2.13	0.00
	32570	24	21	23	19	17	16	17	12.50	9.52	17.39	10.53	5.88	6.25
	32571	52	58	74	61	69	66	64	11.54	27.59	17.57	13.11	4.35	3.03
21192	55441	2.1	2.1	2.2	1.9	1.6	2.3	2.3	0.00	4.76	13.64	15.79	43.75	0.00
	55450	2.2	2	1.9	1.5	0.9	1.3	1.5	9.09	5.00	21.05	40.00	44.44	15.38
	55452	2.9	3.5	4.1	4.2	3.8	4.1	4.3	20.69	17.14	2.44	9.52	7.89	4.88
21191	55402	56	54	47	37	38	36	36	3.57	12.96	21.28	2.70	5.26	0.00
	55404	130	140	150	140	140	140	140	7.69	7.14	6.67	0.00	0.00	0.00
	55406	12	11	11	9.6	8.5	8.8	9	8.33	0.00	12.73	11.46	3.53	2.27
	55408	43	36	37	31	29	29	29	16.28	2.78	16.22	6.45	0.00	0.00

TABLE F.8.IV-5

RANDOM DUPLICATE RESULTS

Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7
#	#	#	#	#	#	#
63 (52/52)	62 (21/21)	61 (64/65)	60 (22/22)	58 (3.8/3.8)	56 (2.3/2.3)	57 (1.5/1.5)
	65 (2.1/2.2)	69 (3.1/3.1)	66 (8.4/8.7)	65 (1.8/1.8)	67 (4.7/4.7)	64 (13/13)

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004247

TABLE F.8.IV-6

CALCULATED K_d RESULTS

Well Number	Sample Number	Kato Lab ID	M g	y ml	C_o ug/g	C_t ug/L	m_s ug	m_l ug	C_s ug/g	C_s ug/g	K_d L/kg
2045	8946	64	400	3500	4.6	13	1840	45.50	4.486	2.886	222.0
	8949	65	400	3500	4.1	1.9	1640	6.65	4.083	2.483	1307.0
2046	8957	66	400	3500	1.9	8	760	28.00	1.830	0.230	28.7
	8958	67	399.57	3496	2.0	4.7	799.14	16.43	1.959	0.359	76.4
2047	8965	68	384.47	3364	5.0	6.4	1922.35	21.53	4.944	3.344	522.5
	8966	69	400	3500	5.9	3.9	2360	13.65	5.866	4.266	1093.8
	8967	70	400	3500	1.9	8.1	760	28.35	1.829	0.229	28.3
2954	113215	72	128.33	1123	4.2	2.1	538.986	2.36	4.182	2.582	1229.3
	113216	46	267.45	2253	2.0	1	534.9	2.25	1.992	0.392	391.6
	113217	47	288.85	2527	3.3	62	953.205	156.67	2.758	1.158	18.7
	113218	48	260.87	2283	7.5	140	1956.525	319.62	6.275	4.675	33.4
	113219	49	368.57	3225	4.6	130	1695.422	419.25	3.462	1.862	14.3
	113220	50	379.62	3322	5.3	140	2011.986	465.08	4.075	2.475	17.7
	113221	51	400	3500	3.6	120	1440	420.00	2.550	0.950	7.9
2945	110258	42	325.18	2845	6.7	130	2178.706	369.85	5.563	3.963	30.5
	110259	41	351.93	3079	7.8	170	2745.054	523.43	6.313	4.713	27.7
	110260	40	233.65	2044	7.7	120	1799.105	245.28	6.650	5.050	42.1
	110261	39	372.3	3258	10.7	230	3983.61	749.34	8.687	7.087	30.8
	110262	43	355.29	3109	8.0	250	2842.32	777.25	5.812	4.212	16.8
	110263	44	311.62	2727	6.0	41	1869.72	111.81	5.641	4.041	98.6
	110264	71	400	3500	4.2	14	1680	49.00	4.078	2.477	177.0
	110265	45	400	3500	5.0	31	2000	108.50	4.729	3.129	100.9
2387	32567	59	329.68	2885	1.3	1	428.584	2.89	1.291	-0.309	-308.8
	32568	60	400	3500	2.8	19	1120	66.50	2.634	1.034	54.4
	32569	61	400	3500	3.3	48	1320	168.00	2.880	1.280	26.7
	32570	62	400	3500	2.4	17	960	59.50	2.251	0.651	38.3
	32571	63	400	3500	1.9	64	760	224.00	1.340	-0.260	-4.1
21192	55441	56	242.51	2122	1.3	2.3	315.263	4.88	1.280	-0.320	-139.2
	55450	57	400	3500	1.3	1.5	520	5.25	1.287	-0.313	-208.8
	55452	58	182	1593	2.9	4.3	527.8	6.85	2.862	1.262	293.6
21191	55402	52	400	3500	2.3	36	920	126.00	1.985	0.385	10.7
	55404	53	372.27	3257	5.1	140	1898.577	455.98	3.875	2.275	16.3
	55406	54	358.18	3134	2.8	9	1002.904	28.21	2.721	1.121	124.6
	55408	55	390.48	3417	2.7	29	1054.296	99.09	2.446	0.846	29.2

TABLE F.8.IV-7

LINEAR REGRESSION OUTPUT TOTAL U IN LEACHATE VS. SEDIMENT FOR ALL 30 SAMPLES Y INTERCEPT = 1.42

Cw	Cs	*Observation*	*Predicted Y*	*Residuals*	*tdzd Residuals*
1	0.392	1	1.432	-1.040	-0.736
1.9	2.403	2	1.445	0.958	0.678
2.1	2.582	3	1.448	1.134	0.803
3.9	4.266	4	1.475	2.791	1.975
4.3	1.262	5	1.481	-0.219	-0.155
4.7	0.359	6	1.487	-1.128	-0.798
6.4	3.344	7	1.512	1.832	1.296
8	0.23	8	1.536	-1.306	-0.925
8.1	0.229	9	1.538	-1.309	-0.926
9	1.121	10	1.551	-0.430	-0.305
13	2.886	11	1.611	1.275	0.902
14	2.477	12	1.626	0.851	0.602
17	0.651	13	1.671	-1.020	-0.722
19	1.034	14	1.701	-0.667	-0.472
29	0.846	15	1.850	-1.004	-0.711
31	3.129	16	1.880	1.249	0.884
36	0.385	17	1.955	-1.570	-1.111
41	4.041	18	2.029	2.012	1.424
48	1.28	19	2.134	-0.854	-0.605
62	1.158	20	2.343	-1.185	-0.839
120	0.95	21	3.210	-2.260	-1.600
120	5.05	22	3.210	1.840	1.302
130	1.862	23	3.360	-1.498	-1.060
130	3.963	24	3.360	0.603	0.427
140	4.675	25	3.509	1.166	0.825
140	2.475	26	3.509	-1.034	-0.732
140	2.275	27	3.509	-1.234	-0.873
170	4.713	28	3.957	0.756	0.535
230	7.087	29	4.854	2.233	1.580
250	4.212	30	5.153	-0.941	-0.666

Regression Statistics

Multiple R	0.617
R Square	0.381
Adjusted R Square	0.359
Standard Error	1.413
Observations	30

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	34.367	34.367	17.216	0.0003
Residual	28	55.895	1.996		
Total	29	90.261			

	Coefficient	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.417	0.347	4.086	0.0003	0.707	2.127
x1	0.015	0.004	4.149	0.0003	0.008	0.022

TABLE F.8.IV-8

LINEAR REGRESSION OUTPUT TOTAL U IN LEACHATE VS. SEDIMENT FOR ALL 30 SAMPLES Y INTERCEPT = 0

Cw	Cs	*Observation*	*Predicted Y*	*Residuals*	*tdzd Residuals*
1	0.392	1	0.025	0.367	0.209
1.9	2.403	2	0.047	2.356	1.343
2.1	2.582	3	0.052	2.530	1.442
3.9	4.266	4	0.097	4.169	2.377
4.3	1.262	5	0.107	1.155	0.659
4.7	0.359	6	0.116	0.243	0.138
6.4	3.344	7	0.159	3.185	1.816
8	0.23	8	0.198	0.032	0.018
8.1	0.229	9	0.201	0.028	0.016
9	1.121	10	0.223	0.898	0.512
13	2.886	11	0.322	2.564	1.462
14	2.477	12	0.347	2.130	1.214
17	0.651	13	0.421	0.230	0.131
19	1.034	14	0.471	0.563	0.321
29	0.846	15	0.719	0.127	0.073
31	3.129	16	0.768	2.361	1.346
36	0.385	17	0.892	-0.507	-0.289
41	4.041	18	1.016	3.025	1.725
48	1.28	19	1.189	0.091	0.052
62	1.158	20	1.536	-0.378	-0.216
120	0.95	21	2.973	-2.023	-1.154
120	5.05	22	2.973	2.077	1.184
130	1.862	23	3.221	-1.359	-0.775
130	3.963	24	3.221	0.742	0.423
140	4.675	25	3.469	1.206	0.688
140	2.475	26	3.469	-0.994	-0.567
140	2.275	27	3.469	-1.194	-0.681
170	4.713	28	4.212	0.501	0.285
230	7.087	29	5.699	1.388	0.791
250	4.212	30	6.195	-1.983	-1.130

Regression Statistics

Multiple R	0.107
R Square	0.011
Adjusted R Square	-0.023
Standard Error	1.754
Observations	30

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	1.033	1.033	0.336	0.5670
Residual	29	89.229	3.077		
Total	30	90.261			

	Coefficient	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.000	#N/A	#N/A	#N/A	#N/A	#N/A
x1	0.025	0.003	7.448	0.0000	0.018	0.032

TABLE F.8.IV-9

LINEAR REGRESSION OUTPUT TOTAL U IN LEACHATE VS. SEDIMENT FOR LEACHATE > 20 ppb Y INTERCEPT = .98

Cw	Cs	*Observation*	*Predicted Y*	*Residuals*	*tdzd Residuals*
29	0.846	1	1.499	-0.653	-0.432
31	3.129	2	1.535	1.594	1.056
36	0.385	3	1.624	-1.239	-0.820
41	4.041	4	1.713	2.328	1.541
48	1.28	5	1.838	-0.558	-0.369
62	1.158	6	2.087	-0.929	-0.615
120	0.95	7	3.121	-2.171	-1.437
120	5.05	8	3.121	1.929	1.277
130	1.862	9	3.299	-1.437	-0.952
130	3.963	10	3.299	0.664	0.439
140	4.675	11	3.478	1.197	0.793
140	2.475	12	3.478	-1.003	-0.664
140	2.275	13	3.478	-1.203	-0.796
170	4.713	14	4.012	0.701	0.464
230	7.087	15	5.082	2.005	1.328
250	4.212	16	5.438	-1.226	-0.812

Regression Statistics

Multiple R	0.641
R Square	0.411
Adjusted R Square	0.369
Standard Error	1.510
Observations	16

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	22.331	22.331	9.789	0.0074
Residual	14	31.939	2.281		
Total	15	54.270			

	Coefficient	*tandard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.982	0.749	1.311	0.2096	-0.625	2.589
x1	0.018	0.006	3.129	0.0069	0.006	0.030

TABLE F.8.IV-10

LINEAR REGRESSION OUTPUT TOTAL U IN LEACHATE VS. SEDIMENT FOR LEACHATE > 20 ppb Y INTERCEPT = 0

Cw	Cs	*Observation*	*Predicted Y*	*Residuals*	*tdzd Residuals*
29	0.846	1	0.704	0.142	0.092
31	3.129	2	0.753	2.376	1.537
36	0.385	3	0.874	-0.489	-0.316
41	4.041	4	0.995	3.046	1.970
48	1.28	5	1.165	0.115	0.074
62	1.158	6	1.505	-0.347	-0.224
120	0.95	7	2.913	-1.963	-1.270
120	5.05	8	2.913	2.137	1.382
130	1.862	9	3.156	-1.294	-0.837
130	3.963	10	3.156	0.807	0.522
140	4.675	11	3.399	1.276	0.826
140	2.475	12	3.399	-0.924	-0.597
140	2.275	13	3.399	-1.124	-0.727
170	4.713	14	4.127	0.586	0.379
230	7.087	15	5.583	1.504	0.972
250	4.212	16	6.069	-1.857	-1.201

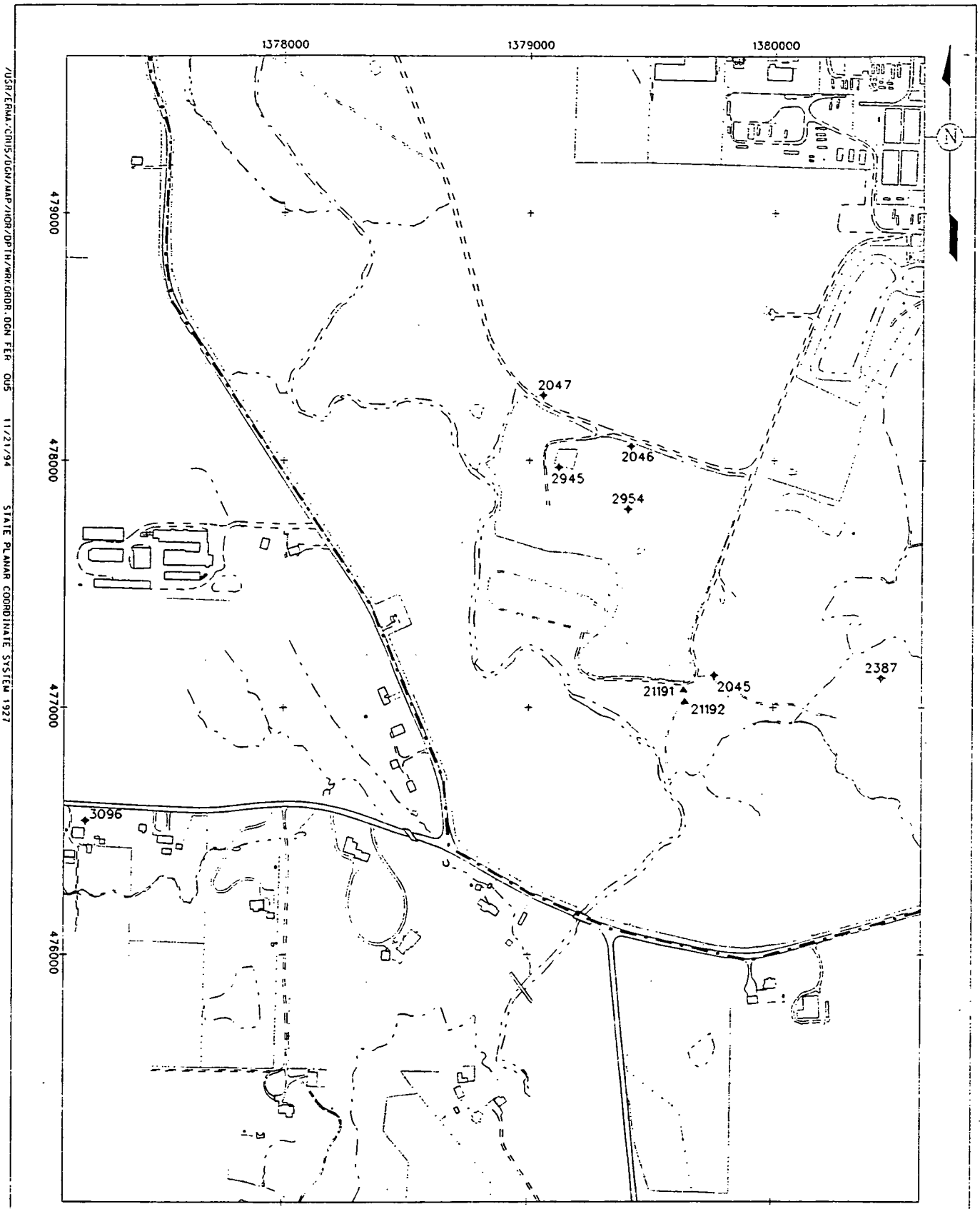
Regression Statistics

Multiple R	0.582
R Square	0.339
Adjusted R Square	0.273
Standard Error	1.546
Observations	16

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	18.411	18.411	7.701	0.0149
Residual	15	35.860	2.391		
Total	16	54.270			

	Coefficient	*tandard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.000	#N/A	#N/A	#N/A	#N/A	#N/A
x1	0.024	0.003	8.258	0.0000	0.018	0.031



LEGEND:

FEMP BOUNDARY

2954 MONITORING WELL

21191 PIEZOMETER

SCALE

550 275 0 550 FEET

DRAFT
FINAL

FIGURE F.8.IV-1. SAMPLING LOCATIONS

/USR/ERMA-CRIS/DGN/MAP/HOR/DPTH/WRK/ORDR.DGN FER 005 11/21/94 STATE PLANAR COORDINATE SYSTEM 1927

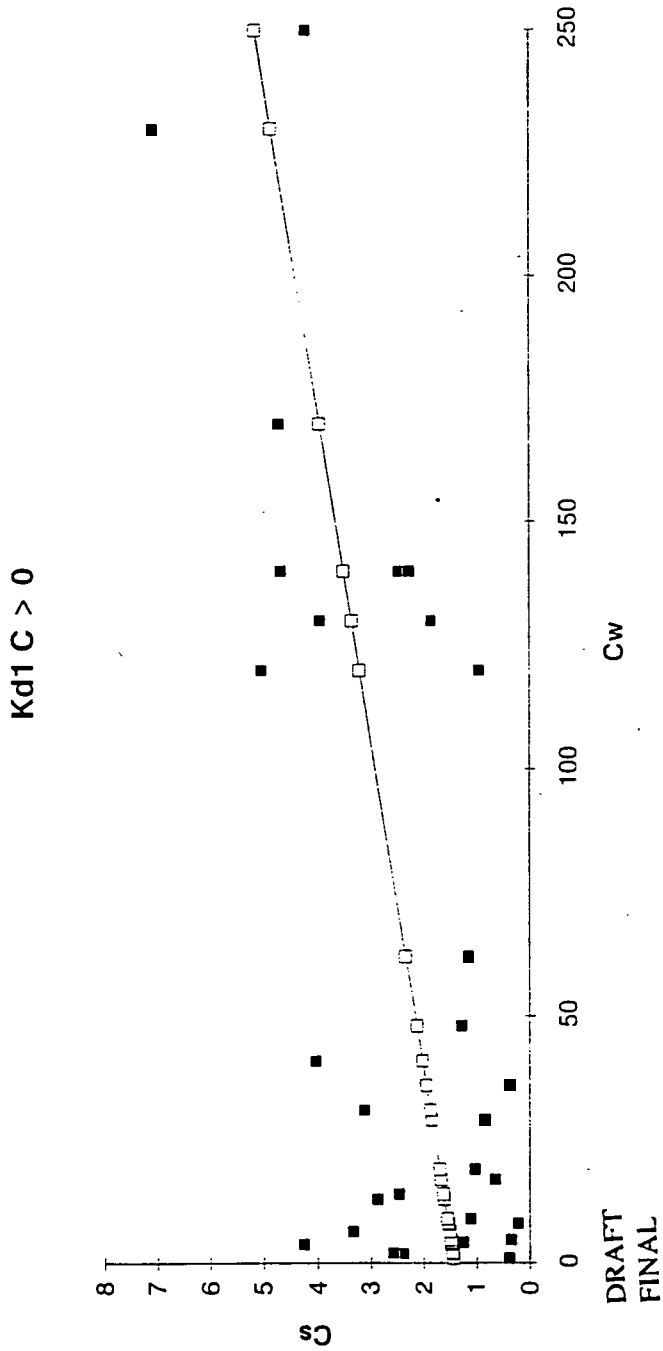


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FIGURE F.8.IV-2. LINEAR REGRESSION TOTAL URANIUM CONCENTRATION IN LEACHATE VS. SEDIMENT FOR ALL 30 SAMPLES Y INTERCEPT = 1.42

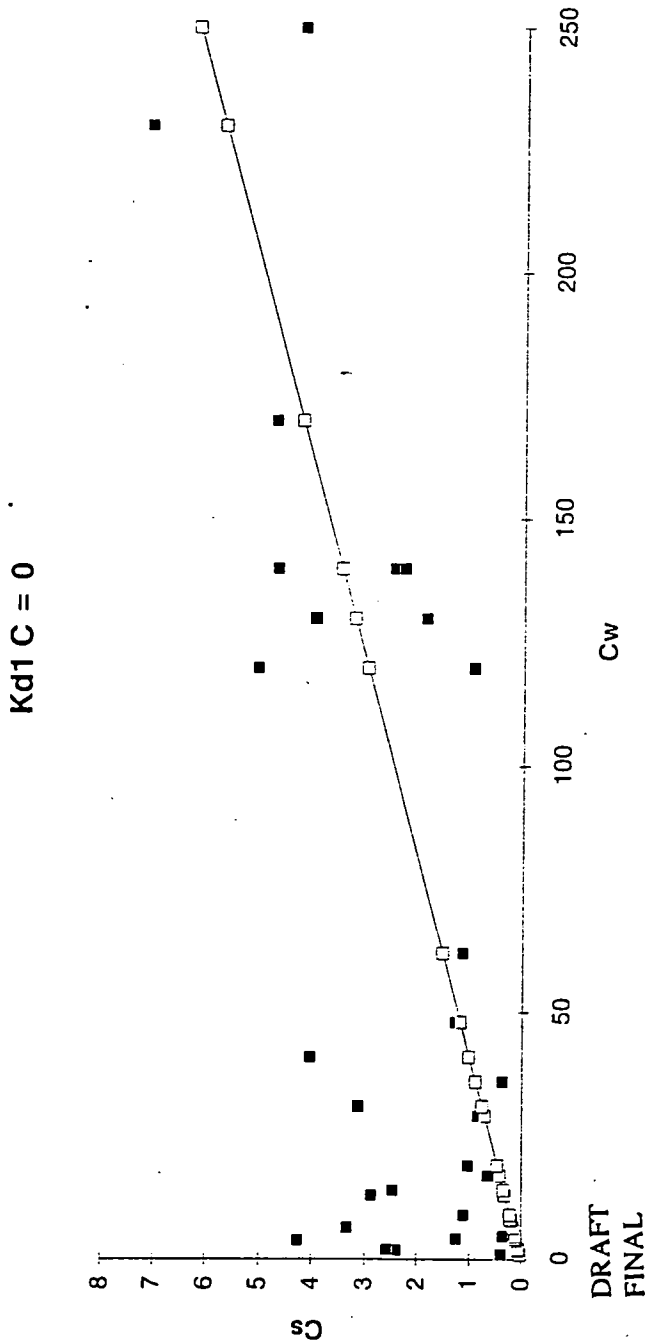

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FIGURE F.8.IV-3. LINEAR REGRESSION TOTAL URANIUM CONCENTRATION IN LEACHATE VS. SEDIMENT FOR ALL 30 SAMPLES Y INTERCEPT = 0

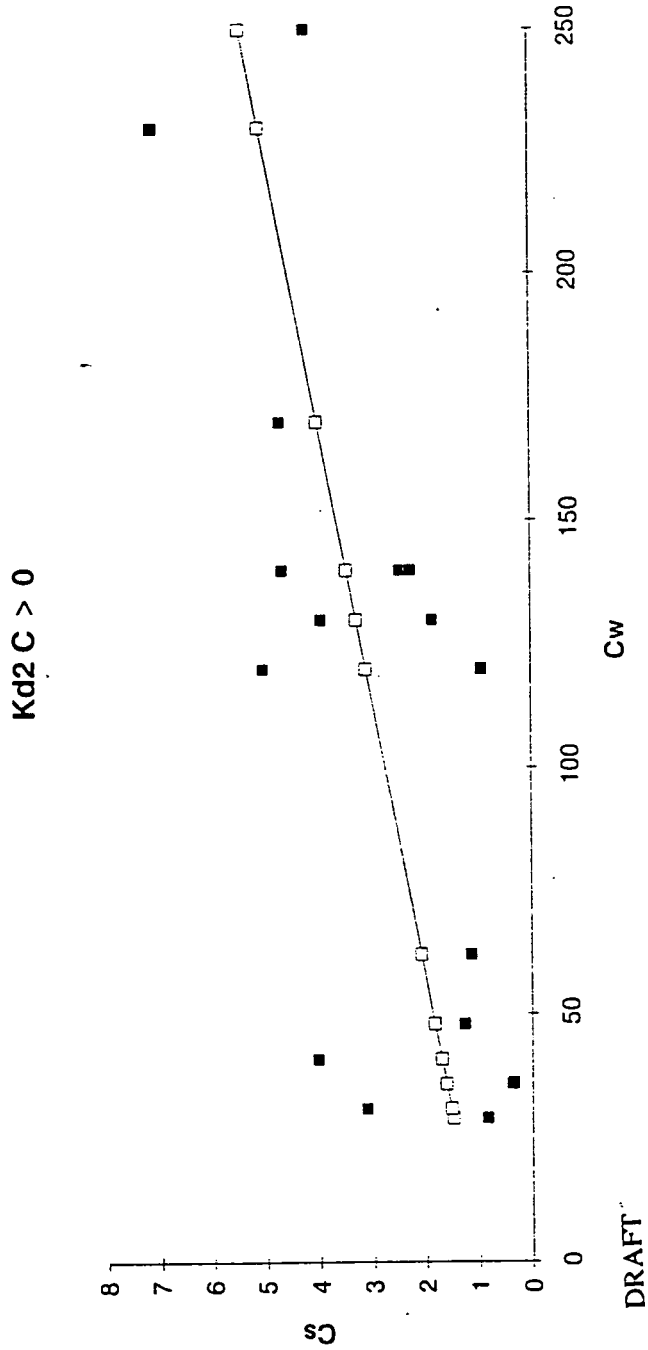

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FIGURE F.8.IV-4. LINEAR REGRESSION TOTAL URANIUM CONCENTRATION IN LEACHATE VS. SEDIMENT FOR LEACHATE > 20 ppb Y INTERCEPT = .98

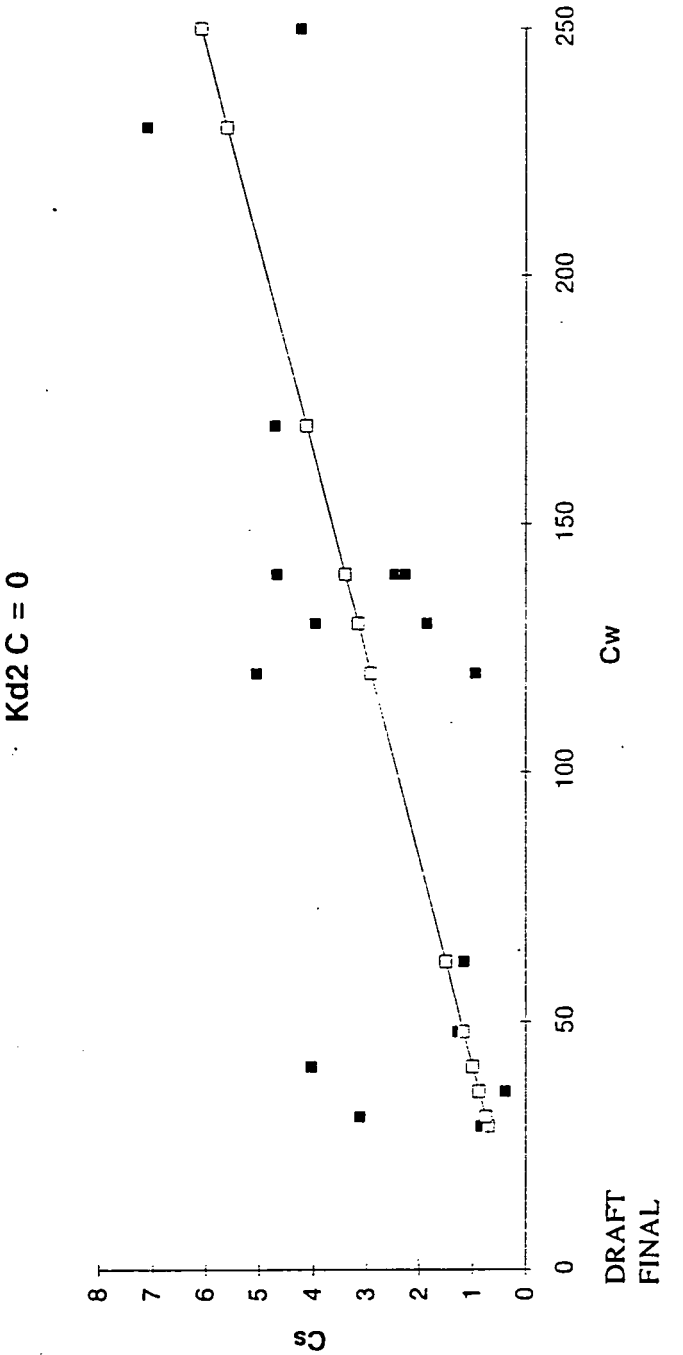

FIGURE F.8.IV-5. LINEAR REGRESSION OUTPUT TOTAL U IN LEACHATE VS. SEDIMENT FOR LEACHATE VS. SEDIMENT FOR LEACHATE > 20 ppb Y INTERCEPT = 0

Appendix G

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G.1.0 INTRODUCTION

This feasibility study (FS) short-term risk assessment presents estimations of risks associated with implementing those remedial actions which have passed the alternative screening process in Section 4.0. Chemical and radiological contributions to human health risks are assessed, as well as the mechanical and transportation hazards associated with remediation. This information is used to support the detailed analysis of alternatives in Section 5.0, as well as the comparative analysis of alternatives in Section 6.0 of this FS report. It also provides information on the constituents of concern (COCs) and environmental transport pathways that could impact public health and remediation workers.

The major objectives of this risk assessment are:

DOE

- To quantify remedial action short-term risks associated with the actual implementation of each alternative so that the impacts of remediation on public health and the environment can be compared among remedial alternatives (one of the nine criteria for evaluation of alternatives listed in the National Contingency Plan (EPA 1985a)
- To identify the major uncertainties of the risk estimates and their potential impact on the comparison of alternatives and the short-term effectiveness of the alternatives.

130 This risk assessment is performed in accordance with Risk Assessment Guidance for Superfund,
DOE Parts A and C (EPA 1989; EPA 1991). This risk assessment has used information from all five operable units to estimate the potential human health impacts resulting from the 22-year remediation of Operable Unit 5. Potential risks or exposures to workers and the general public due to contaminant releases during remedial actions are estimated and presented. The receptors investigated include:

- On-property remediation workers
- On-property nonremediation workers
- Off-property remediation workers transporting material for disposal
- Near-property public
- Public along transportation routes.

DOE Potential physical injuries and deaths (called mechanical hazards) for the remediation workers due to remedial activities such as construction, excavation, waste handling, and transportation are also evaluated. Injuries and fatalities resulting from transportation accidents are evaluated for the public along the transportation route.

The remedial alternatives evaluated in this short-term risk assessment define a unique combination of land use objectives, alternative technologies, and target receptors. Each remedial alternative is

intended to produce situations which meet one of the four land use objectives listed in the first column of Table G.1-1. The alternatives, listed in column 2 of this table, use the technologies presented in column 3 to achieve desired objectives for different sets of target receptors called cases. These cases are described in Section 2.0 of this FS. Case-specific information for each alternative is presented in columns 4 through 12 of Table G.1-1.

The organization of the remainder of this appendix is as follows:

- Section G.2.0 presents the exposure pathway analysis which addresses proposed remedial alternatives and potential exposures during remediation.
- Section G.3.0 presents the exposure and risk calculation methods for human health exposure pathways and mechanical hazard pathways. The discussion includes presentation of equations used to quantify impacts.
- Section G.4.0 presents the results of the human health and mechanical hazard risk assessment.
- Section G.5.0 analyzes the uncertainties associated with the risk assessment from remedial action design factors, COC analytical and toxicological data, exposure assumptions, and health and safety estimates. These factors can all contribute to the uncertainty of the risk analysis.
- Section G.6.0 presents a summary of the remedial action risk assessment.
- Section G.7.0 presents a bibliography listing references used in this evaluation.
- Attachment G.I presents a description of models used in the short-term risk assessment.
- Attachment G.II presents intermediate calculations which precede risk results.

TABLE G.1-1

DESCRIPTIONS OF ALTERNATIVES AFTER SCREENING

Land Use	Alternative	Technology	Case	On-Property Areas: Central Area Cleanup Level	On-Property Areas: Central Area Target Receptor	On-Property Areas: Border Area Cleanup Level	On-Property Areas: Border Area Target Receptor	Off-Property Cleanup Level	Off-Property Target Receptor	CPRG Cleanup Level	CPRG Target Receptor
Unrestricted land use for the entire site.	1	Excavation and Off-Site Disposal	1	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident
			2	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	PMCL	ARAR
Portions potentially released for restricted use while others remain as a Waste Management Area. Restrictions placed on groundwater use.	2A	Excavation and Placement in a covered On-Site Disposal Cell[a]	1	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident
			2	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	PMCL	ARAR
	2C	Excavation and Placement in a covered On-Site Consolidation Area[a]	1	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident	1.0×10^{-6}	Resident
			2	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	1.0×10^{-5}	Resident	PMCL	ARAR
Portions potentially released for restricted use while others remain as a Waste Management Area. Restrictions placed on groundwater use.	3A	Excavation and Placement in an On-Site Disposal Cell[a]	3	1.0×10^{-6}	Industrial	1.0×10^{-6}	Industrial	1.0×10^{-5}	Resident	PMCL	ARAR
			4	1.0×10^{-6}	Dev. Park	1.0×10^{-6}	Dev. Park	1.0×10^{-5}	Resident	PMCL	ARAR
			5	1.0×10^{-6}	Undev. Park	1.0×10^{-6}	Undev. Park	1.0×10^{-5}	Resident	PMCL	ARAR
			6	1.0×10^{-6}	Undev. Park	1.0×10^{-6}	Undev. Park	3.5×10^{-5} HI=1'	Resident	PMCL	ARAR
			7	1.0×10^{-6}	Undev. Park	ALARA	Undev. Park	3.5×10^{-5}, HI=1	Resident	PMCL	ARAR
	3C	Excavation and Placement in a covered On-site Consolidation Area[a]	3	1.0×10^{-6}	Industrial	1.0×10^{-6}	Industrial	1.0×10^{-5}	Resident	PMCL	ARAR

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TABLE G.1-1
(Continued)

Land Use	Alternative	Technology	Case	On-Property Areas: Central Area: Cleanup Level	On-Property Areas: Central Area: Target Receptor	On-Property Areas: Border Area: Cleanup Level	On-Property Areas: Border Area: Target Receptor	Off-Property: Cleanup Level	Off-Property: Target Receptor	CPRG: Cleanup Level	CPRG: Target Receptor
			4	1.0×10^{-6}	Dev. Park	1.0×10^{-6}	Dev. Park	1.0×10^{-5}	Resident	PMCL	ARAR
			5	1.0^{-6}	Undev. Park	1.0×10^{-6}	Undev. Park	1.0×10^{-5}	Resident	PMCL	ARAR
			6	1.0×10^{-6}	Undev. Park	1.0×10^{-6}	Undev. Park	3.5×10^{-5}, HI=1	Resident	PMCL	ARAR
			7	1.0×10^{-6}	Undev. Park	ALARA	Undev. Park	3.5×10^{-5}, HI=1	Resident	PMCL	ARAR
No sanctioned use of the property. Site envisioned as Waste Management Area in perpetuity.	4A	Excavation and Placement in an On-site Disposal Cell[a]	8	1.0×10^{-6}	Trespasser	1.0×10^{-6}	Trespasser	1.0×10^{-5}	Resident	PMCL	ARAR
			9	1.0×10^{-6}	Trespasser	1.0×10^{-6}	Trespasser	3.5×10^{-5}, HI=1	Resident	PMCL	ARAR
	4C	Excavation and Placement in a covered On-site Consolidation Area[a]	8	1.0×10^{-6}	Trespasser	1.0×10^{-6}	Trespasser	1.0×10^{-5}	Resident	PMCL	ARAR
			9	1.0×10^{-6}	Trespasser	1.0×10^{-6}	Trespasser	3.5×10^{-5}, HI=1	Resident	PMCL	ARAR

[a] Material exceeding waste acceptance criteria for on-site disposal is shipped to an approved off-property disposal facility.

G.2.0 EXPOSURE PATHWAY ANALYSIS

This section describes each of the remedial action alternatives and their respective components (Section G.2.1). This is followed by analyses of potential exposures and environmental transport mechanisms from Operable Unit 5 remedial activities (Section G.2.2). This exposure pathway analysis leads to the quantification of receptor exposure, which is described in Section G.3.0. The quantitative risk assessment results from these exposures are presented in Section G.4.0 where the risks from appropriate remedial alternative components are combined to yield the total remedial action risk for each remedial alternative.

G.2.1 PROPOSED REMEDIAL ALTERNATIVES

The number of possible remedial alternatives discussed in the FS is too large for practical quantitative evaluation of each alternative in the short-term risk assessment. Therefore, only those alternatives that pass alternative screening in Section 4.0 of the FS are quantitatively evaluated in the short-term risk assessment. These alternatives are comprised of various unique combinations of land use objectives, the types of individuals using the land, and the remedial technologies considered (Table G.1-1). These criteria in turn dictate the maximum allowable residual COC concentrations, defined as preliminary remediation levels (PRLs) that will ensure the protection of the envisioned receptor and land use combinations.

Once the allowable residual COC concentrations have been determined, both the volume of soil that must be removed to meet the clean up goals and the concentrations of COCs in the excavated soil can be estimated. The alternative- and case-specific information on the soil volume estimates presented in Table G.2-1 represent one of the most crucial pieces of data in the short-term risk assessment process because the magnitude of the mechanical hazards associated with implementing the alternatives are proportional to the volumes handled. Furthermore, the COC concentrations in the excavated soil determine the contaminant source terms which form the basis of the human health evaluation. To provide background information for the development of the conceptual exposure model for the short-term risk assessment, a brief description of each of the screened alternatives is presented in this section. Section 5.0 presents a detailed description of each alternative. The commonalities among alternatives are presented below (with exceptions noted where applicable) for the purpose of increasing the clarity of the alternative descriptions:

- On-property storm water, wastewater and perched groundwater recovered during soil excavation and treatment will be treated by the advanced wastewater treatment (AWWT) facility Phases I and II before discharge to the Great Miami River.

- Great Miami Aquifer groundwater exceeding the PRLs that are protective of the nearest potential groundwater user will be extracted, treated at a groundwater treatment facility (GTF), and discharged to the Great Miami River.

- Waste sludge generated by water-treatment processes will be dewatered and either shipped off site for disposal or buried on site, depending on its contents.

- Excavated areas will be backfilled first with available clean soil segregated during excavation and second with clean soil from on-site borrow areas. Backfilled areas will be covered with topsoil and reseeded.

- Soil and sediment exceeding the PRLs that are protective of the target receptor will be excavated and placed in either a covered on-site consolidation area, an on-site disposal cell, or an off-site disposal facility.

- All facilities and equipment involved in processing contaminated materials will be subject to decontamination and decommissioning operations before release for unrestricted use.

G.2.1.1 Description of the No-Action Alternative

The no-action alternative is provided as a basis for comparison only. This alternative assumes that no additional remediation is undertaken at the FEMP. The baseline risk assessment in the Operable Unit 5 Remedial Investigation (RI) Report (DOE 1995b) presents a quantitative evaluation of the No-Action Alternative.

G.2.1.2 Description of Alternative 1

Alternative 1 includes complete excavation of on- and off-property contaminated soil/sediment (including perched groundwater zones) exceeding PRLs for Land Use Objective 1 followed by disposal off-site. Clean material and topsoil would be used to backfill and revegetate the excavated areas. Spent treatment media (e.g., exhausted ion exchange resin and activated carbon) and concentrated contaminant residues would be cement stabilized and shipped off site for disposal.

G.2.1.3 Description of Alternative 2A

Alternative 2A includes complete excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objective 2 and segregation based on contaminant concentrations. Soil exceeding PRLs that are protective of the expanded trespasser, on- and off-property farmers, and Great Miami Aquifer would be placed in an on-property disposal facility. Soil with contaminant concentrations exceeding the waste acceptance criteria for the disposal facility would be shipped to an off-site disposal facility. Clean material and topsoil would be used to backfill and revegetate the excavated areas. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The on-property disposal facility would be maintained under continued federal ownership.

G.2.1.4 Description of Alternative 2C

Alternative 2C includes complete excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objection 2 and segregation based on contaminant concentrations. Soil exceeding PRLs which are protective of the expanded trespasser, on- and off-property farmers, and Great Miami Aquifer would be placed in an on-property consolidation area with an earthen cover. Soil with contaminant concentrations exceeding the waste acceptance criteria for the consolidation area would be shipped to an off-site disposal facility. Clean material and topsoil would be used to backfill and revegetate the excavated areas. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The consolidation area would be maintained under continued federal ownership.

G.2.1.5 Description of Alternative 3A

Alternative 3A includes complete excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objective 3 and segregation based on contaminant concentrations. Soil exceeding PRLs that are protective of the expanded trespasser, on- and off-property farmers, recreational users, and Great Miami Aquifer would be placed in an on-property disposal facility. Soil with contaminant concentrations exceeding the waste acceptance criteria for the disposal facility would be shipped to an off-site disposal facility. Clean material and topsoil would be used to backfill and revegetate the excavated areas. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The on-property disposal facility would be maintained under continued federal ownership.

G.2.1.6 Description of Alternative 3C

Alternative 3C includes complete excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objective 3 and segregation based on contaminant concentrations. Soil exceeding PRLs which are protective of the expanded trespasser, on- and off-property farmers, recreational user, and Great Miami Aquifer would be placed in an on-property consolidation area with an earthen cover. Soil with contaminant concentrations exceeding the waste acceptance criteria for the consolidation area would be shipped off-site to a disposal facility. Clean fill would be used to backfill the excavated areas. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The consolidation area would be maintained under continued federal ownership.

G.2.1.7 Description of Alternative 4A

Alternative 4A includes selective excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objective 4 which are protective of the expanded trespasser, off-property farmer, and Great Miami Aquifer. Excavated soil would be placed in an on-property disposal facility. Soil with contaminant concentrations exceeding the waste acceptance criteria for the disposal facility would be

shipped to an off-site disposal facility. Clean fill would be used to backfill excavated areas. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The entire FEMP property would be maintained under continued federal ownership.

G.2.1.8 Description of Alternative 4C

Alternative 4C includes selective excavation of soil (including perched groundwater zones) exceeding PRLs for Land Use Objective 4 which are protective of the expanded trespasser, off-property farmer, and Great Miami Aquifer. Excavated soil would be placed in an on-property consolidation area with an earthen cover. Soil with contaminant concentrations exceeding the waste acceptance criteria for the consolidation area would be shipped off-site to a disposal facility. Excavated areas would be backfilled with fill. Groundwater would be routinely sampled and analyzed to monitor the long-term effectiveness of the remedial actions. The entire FEMP property would be maintained under continued federal ownership.

G.2.2 EXPOSURES DURING REMEDIATION

Each of the remedial alternatives evaluated in this assessment contain operational components that may expose receptors to contaminated materials. This section identifies these major components and presents the conceptual models, methods, and parameters used to assess short-term exposures associated with implementing the remedial alternatives.

G.2.2.1 Operational Components of Remedial Alternatives

The Operable Unit 5 remedial alternatives that remain after screening encompass a range of technologies and operations. Each remedial alternative is made of a series of operational activities called remedial components that have varying degrees of physical hazards and exposure potential associated with them. Many alternatives share common remedial components. Major remedial components of each alternative that may contribute to contaminant release or mechanical hazards are grouped and summarized as follows:

	Major Remedial Component	Alternative Containing Component
1.	Excavation	1, 2A, 2C, 3A, 3C, 4A, 4C
2.	Off-site disposal	1, 2A, 2C, 3A, 3C, 4A, 4C,
3.	Consolidation with an earthen cover	2C, 3C, 4C
4.	On-property disposal facility	2A, 3A, 4A
5.	Backfilling	1, 2A, 2C, 3A, 3C, 4A, 4C
6.	Environmental monitoring	2A, 2C, 3A, 3C, 4A, 4C
7.	Great Miami Aquifer groundwater extraction	1, 2A, 2C, 3A, 3C, 4A, 4C
8.	Groundwater and wastewater treatment operations	1, 2A, 2C, 3A, 3C, 4A, 4C
9.	Contaminated soil interim storage	1, 2A, 2C, 3A, 3C, 4A, 4C

For simplicity, assessment of exposures associated with proposed remedial actions examines exposures related to the distinct operational components. These components are composed of different operations that have the potential for contributing to remedial action risks. Remedial components are described below.

G.2.2.1.1 Soil Excavation

The soil excavation component includes: contamination surveys of potential excavation areas; excavation of contaminated soil, sediment, and any associated perched groundwater; pre-treatment of soil containing wastes regulated under the Resource Conservation and Recovery Act (RCRA), polychlorinated biphenyls (PCBs), and petroleum products; segregation of excavated soil based on contaminant concentrations; storm water controls during excavation; certification of excavated areas; and hauling of contaminated soil while on site.

G.2.2.1.2 Off-Site Disposal

The off-site disposal component includes: construction of a staging facility and rail spur; unloading and stockpiling of bulk soil; loading of bulk soil into rail cars; transportation to an off-site disposal facility; off-site disposal; decontamination and decommissioning of the staging facility; and off-property disposal of decontamination and decommissioning debris.

G.2.2.1.3 Consolidation

The consolidation component includes: unloading and placement of bulk soil in lifts/piles with an earthen cover; security fencing; long-term maintenance; long-term groundwater monitoring; storm water controls.

G.2.2.1.4 On-Property Disposal Facility

The on-property disposal facility component includes: construction of staging facilities/areas for materials for the multilayer cap and liner, unloading and placement of soil/wastes in an engineered facility with an appropriate liner and cap; security fencing; long-term maintenance; long-term groundwater monitoring; storm water controls; decontamination and decommissioning of the staging facility; and off-site disposal of decontamination and decommissioning debris.

G.2.2.1.5 Backfill

The backfill component includes: procurement of fill material, placement of fill in excavated areas, topsoil placement, and revegetation.

G.2.2.1.6 Environmental Monitoring

The environmental monitoring component includes: installation of groundwater monitoring wells and surface water and air sampling stations; routine sampling and analysis; and long-term maintenance of wells.

G.2.2.1.7 Great Miami Aquifer Groundwater Extraction

The Great Miami Aquifer groundwater extraction component includes: installation of extraction wells, pumps, and piping; monitoring equipment; decontamination and decommissioning of groundwater recovery systems; and off-site disposal of decontamination and decommissioning debris.

G.2.2.1.8 Groundwater and Wastewater Treatment

Storm water, Fernald Environmental Management Project (FEMP) baseline wastewater, and FEMP remediation wastewater streams will be managed and treated by the storm water retention basin (SWRB) and AWWT facility. Extracted groundwater will be treated at the GTF. The water treatment component includes: equalization, multimedia filtration, carbon adsorption, and ion exchange treatment of groundwater and wastewater, as needed; dewatering of treatment slurries; stabilization of solid treatment wastes and spent media; packaging of stabilized wastes; and discharge of treated water to the Great Miami River. This component also includes maintenance and repair of the SWRB, and surface water drainage engineering controls to direct runoff areas of contamination to treatment facilities.

G.2.2.1.9 Contaminated Soil Interim Storage

The interim soil storage component employs a central storage facility to provide interim storage, staging, and packaging of small quantities of contaminated soil before off-site disposal.

G.2.2.2 Conceptual Model of Remedial Components

A conceptual model of the short-term risks associated with remedial actions is presented in Figure G.2-1. The conceptual model begins with the contaminated soil and water that are postulated as the primary sources of exposure. The conceptual model assumes remediation of the primary sources is accomplished as a result of implementing the various remedial components that make up each alternative. Each component has potential exposure pathways associated with it that may contribute to human health risks. In the conceptual model a determination is made whether each exposure pathway is quantitatively evaluated under each of the receptors listed. Figure G.2-1 includes a legend that indicates the basis for those pathways that are not quantitatively evaluated. The remaining subsections of G.2.2.2 discuss the sources, release mechanisms, transport pathways, potential receptors, and the impacts of engineering controls which make up the conceptual model.

G.2.2.2.1 Sources

Figure G.2-1 identifies sources of contamination within the boundaries of Operable Unit 5 which will be remediated. Operable Unit 5 remedial alternatives are designed to remove, reduce, and/or stabilize the contaminated material in these areas. In most cases, there will be some potential short-term exposures to workers or the general public from the remedial activities dealing with these sources. The Operable Unit 5 Remedial Investigation Report presents a detailed discussion of these potential sources.

Soil

Above-background concentrations of uranium isotopes are prevalent in surface soil across the former production area and portions of the administrative and laboratory areas and are among the potential sources of exposure during remedial operations. Other radiological and chemical constituents were also detected above background within the former processing areas. The occurrence of these other constituents was generally more localized and confined to areas exhibiting above-background concentrations of uranium. Above-background concentrations of uranium isotopes are also prevalent in surface soil across the FEMP site. These concentrations are generally lower than uranium concentrations in the former production area.

Perched Groundwater

Perched groundwater plumes are among the potential sources within Operable Unit 5 that impact short term risk. RI/FS field sampling has revealed the presence of three broadly contaminated areas within Operable Unit 5 where multiple contaminants are present above background in the perched groundwater:

- Production area (Area I plume)
- Sewage treatment plant area (Area II plume)
- Fire training area (Area VI plume).

With the possible exception of the eastern edge of the Area II plume in the sewage treatment plant area, none of the three perched groundwater plumes extend off site.

Great Miami Aquifer Groundwater

RI/FS field sampling has revealed the presence of six distinct plumes in the Great Miami Aquifer resulting from contaminant entry into the aquifer. These six potential sources of contaminated groundwater are designated as the waste storage area A plume, the waste storage area B plume, the Plant 6 area plume, and South Plumes A, B, and C.

Uranium-238, uranium-235/236, uranium-234 and some inorganic contaminants were detected above background in most of the plumes. Other contaminants including radionuclides, inorganics, and volatile

organic compounds (VOCs) are also present in the Great Miami Aquifer as isolated occurrences above background.

Surface Water and Sediment

Major drainage features include the storm sewer outfall ditch (SSOD), the pilot plant drainage ditch, Paddys Run, and the Great Miami River. Engineering controls are included in remedial alternatives under the water treatment component (Section G.2.2.1.8) to control all storm water runoff from areas of contamination and direct it to treatment facilities.

G.2.2.2.2 Potential Waste Release Mechanisms

The remedial alternatives discussed in this report are composed of a series of operations and may generate occupational or environmental releases of contaminants. This section describes the ways contaminated material may be inadvertently released to the environment by each operational component (Figure G.2-1). Table G.2-2 presents the basis for the release mechanisms for each component including the major operations involved, assumptions, exposure pathways, and receptors.

The engineering designs for remedial operation components specify use of diesel-powered remediation systems and equipment; therefore, associated emissions are of potential concern as waste releases. For example, exhausts will be produced, VOCs and other organics could be released in small quantities, and dusts will be resuspended from the operation of heavy equipment. These release mechanisms are evaluated as an integral part of remedial alternative components and are not evaluated separately.

Excavation

During excavation (alternative component #1 in Figure G.2-1), heavy equipment will remove contaminated media from surface and subsurface soils for ultimate treatment and disposal. This remedial activity may suspend dust or generate mists containing contaminants into the air, potentially resulting in inhalation exposure, cloud immersion external radiation exposure, and exposure from ingestion of contaminated food following deposition and contamination of the food chain. In addition, there is the external radiation pathway from the in situ soil. However, the external radiation pathway from immersion in a cloud and the food ingestion pathway following deposition of airborne contaminants are minor contributors and are not addressed further in the short-term risk assessment. The Operable Unit 5 RI/FS groundwater model divides the contaminated site into 33 source areas (Figure G.2-2). These same source areas were used to evaluate short-term effects of emissions from excavations.

Off-Property Waste Transportation

Following excavation, the material will be loaded into gondola rail cars and shipped directly by rail to a representative off-site disposal facility. The material may be a source of direct exposure from

penetrating radiation to remediation workers, truck drivers, train crews and individuals living along or sharing the transportation route. Members of the public may be exposed to direct radiation from contaminated material or inhale resuspended contaminants following a transportation accident.

Placement in On-Property Disposal Facility or Consolidation Area

Preparation of the disposal facility site involving staging of construction materials, construction of the fill layer beneath the facility, and construction of the layers will not result in potential for exposure. Subsequently, contaminated soil will be received and staged. During the staging period VOCs, radon, and resuspended dust may be released from the soil to the air. The engineering design includes air filtration devices to control releases from the soil and minimize potential exposure. Soil loading and unloading operations during filling of the disposal cell may potentially release contaminants into the air resulting in exposures, but it is anticipated that these releases would be mitigated by dust suppression technologies.

During on-property disposal, remediation workers may be exposed to direct radiation from uncapped contaminated material being placed in the disposal facility. Direct exposure to penetrating radiation to workers spending long periods near the open face of the facility could be a minor concern. However, direct radiation is expected to be negligible due to the low levels of radionuclides in much of the Operable Unit 5 soil.

Backfill

Following removal of contaminated material in Operable Unit 5, the areas will be backfilled with clean imported or treated soil. Because contaminant levels will be reduced to acceptable levels in the fill, remediation workers will not be exposed to soil contaminants. The exposed face of the soil being covered may be a brief potential source of direct radiation exposure if that soil is residually contaminated.

Groundwater Monitoring and Extraction

Groundwater monitoring activities and large-scale groundwater extraction operations will involve pumping water from the perched water zones and the Great Miami Aquifer. Potential exposures may result from releases of groundwater and entrained soil solids/sludge from the pumping and piping systems used. Groundwater released may result in emission of VOCs to the air. Potential direct exposure to penetrating radiation from radionuclide contaminants in groundwater could be of minor concern. Radionuclide contaminant concentrations in much of the groundwater are fairly low and the water itself provides shielding that will reduce the potential magnitude of exposure.

Groundwater and Wastewater Treatment

Groundwater and wastewater treatment operations will generate large quantities of processed water to be discharged and solids to be stabilized and transported to a disposal facility. Treatment processes may potentially result in exposures from releases of water and contaminated solid materials from treatment systems. Water released may result in emission of VOCs to the air. Potential direct exposure to penetrating radiation from radionuclide contaminants in water could be of minor concern. Radionuclide contaminant concentrations in much of the water are fairly low and the water itself provides shielding that will reduce the potential magnitude of exposure.

Off-Site Disposal

The on-site staging and loading operations before off-site disposal of contaminated soil, stabilized treatment residues, and contaminated debris from decontamination and decommissioning of remediation facilities may potentially result in releases to the air. Accordingly, the engineering design includes the use of dust collection measures on the mechanical soil conveyor used to load rail cars. Rail cars will be equipped with secured covers to isolate the material from wind, weather, and tampering.

Contaminated soil and other debris stockpiled at an interim storage and staging facility may serve as a source of direct exposure to penetrating radiation. However, direct radiation may be negligible due to the low levels of radionuclides in most Operable Unit 5 soil.

Decontamination and Decommissioning

Decontamination and decommissioning of equipment and buildings is an integral part of each component. During decontamination and decommissioning, equipment and other materials from remediation facilities must be demolished and decommissioned. Noncontaminated material poses no release mechanism and contaminated material will be decontaminated consistent with the waste management policy of the FEMP. The decontamination and decommissioning component includes a large variety of activities. Methods of decontaminating surfaces range from vacuum cleaning to high-pressure water sprays to acid mixtures designed to remove radioactive materials from surfaces. Each activity has its own set of advantages and disadvantages such that no one method is appropriate for all decontamination operations. Decommissioning includes the disassembly and removal of structures and equipment. The decontamination operations will be performed under conditions designed to control releases of contaminants, precluding potential exposure of receptors.

G.2.2.2.3 Potential Transport Mechanisms and Exposure Pathways

There are numerous potential exposure pathways during remedial operations by which receptors can come in contact with contaminants. These pathways include incidental ingestion and inhalation. Dermal contact may constitute an additional route of exposure to chemicals, while external exposures to

penetrating radiation may also occur in the case of radionuclides. In Figure G.2-1, the various combinations of exposure pathways and exposure media are tabulated. Each pathway and medium are considered for each of the receptors. Pathways identified as being complete, significant, and quantitatively evaluated are denoted with an "X," while those expected to result in no or insignificant exposure for a given receptor are noted. Those pathways which are possible but are mitigated by the use of personal protective equipment are also noted.

Air Exposure Pathways

A receptor exposure via air pathways begins with waste being disturbed or emitted from its source and transported by the ambient air, eventually reaching the receptor where it may be inhaled. Inhalation of airborne gases (such as emissions from diesel-powered equipment) and resuspended particulates is a typical example of this type of exposure.

The significance of the air exposure pathway depends on the different characteristics of each receptor's location and behavior. These pathways very often are receptor-specific. The significant air exposure pathways identified in this conceptual model include inhalation of gases and resuspended particulates.

Exposure Pathways Attributable to Dermal Contact

This group of pathways encompasses all of the receptor's activities that might result in direct contact with contaminated soil, sediment, or water during remedial operations. Potential sources of contamination include waste, soil, and sediment.

Exposure pathways via dermal contact included in the quantitative risk assessment are dermal contact with contaminated soil and sediment. As in the air exposure pathways described above, many dermal contact exposure routes are receptor-specific. The remedial operation areas are off-limits to the on-property nonremedial workers and to the off-property general public; consequently the likelihood that these receptors would have direct dermal contact with contaminated media is insignificant. Dermal contact pathways for the on-property remedial workers are mitigated by the use of personal protective equipment.

Ingestion Exposure Pathway

Direct ingestion of soil, sediment, and water are considered hypothetical plausible exposure routes in this study. Ingestion of substances containing contaminated soil can come from direct or indirect routes. For example, a receptor may inadvertently ingest contaminated soil or accidentally ingest water while working with contaminated effluent.

The remedial operation areas are off-limits to the on-property nonremedial workers and to the off-property general public, precluding such incidental ingestion exposure for these receptors. Incidental ingestion for the on-property remedial workers is mitigated by the use of personal protective equipment.

Exposure to External Penetrating Radiation

This pathway may be significant for receptors who are proximal to remedial operation work areas or transportation routes used to ship Operable Unit 5 wastes. Significant external radiation pathways identified for one or more of the receptors include exposure to radiation originating from contaminated soil and sediment. Due to the low concentrations of radionuclides in groundwater and the shielding afforded by the pipelines, equipment, and the water itself, measurable exposures from penetrating radiation are not expected from the extraction and processing of perched groundwater and groundwater from the aquifer. In addition, adherence to an approved health and safety plan will minimize direct radiation exposure during processing of wastewater and treatment water.

G.2.2.2.4 Potential Receptors

This remedial action risk assessment estimates potential health effects from exposures to contaminants that may be released during Operable Unit 5 remediation to five groups of individuals: on-property remediation and nonremediation workers, off-property remediation transport workers, the public along the transportation route, and the near-property public. These receptors were selected because they are thought to represent the types of humans that may be adversely impacted by implementation of the remedial alternatives evaluated in this study. Table G.2-3 illustrates which receptors may be exposed to hazards or adverse health effects as a direct result of the remedial alternative components.

On-Property Remediation Workers

On-property remediation workers may be at risk through their direct participation or involvement in remedial activities on the property. They may be exposed to contaminated materials, either through routine operations or accidents. Remediation workers may be impacted by mechanical hazards during relocation of contaminated soil or while constructing or operating remediation facilities or equipment.

On-Property Nonremediation Workers

On-property nonremediation workers include all other workers within the FEMP. These workers include, but are not limited to, the administrative and clerical staff of the Fernald Environmental Restoration Management Corporation (FERMCO) and its subcontractors. Nonremediation workers may be at potential risk from exposures to airborne contaminants released from remedial activities. They are not considered to be exposed to an increased level of mechanical hazards, and will be located too far away to receive significant direct radiation exposures from soil.

Off-Property Remediation Workers

Off-property remedial workers include, but are not limited to, truck drivers or train crew receptors who will transport the FEMP waste to any off-site disposal facilities. The magnitude of impacts to these receptors depends on the level of contaminants in the transported waste, the degree of shielding provided by transport containers, the proximity of workers to the waste, and the duration of transport, including stops.

Near-Property Public

For those scenarios where contaminants are dispersed in the air and carried beyond the FEMP site boundary, the near-property public will be defined as a hypothetical neighbor located at the fence line.

Public Along the Transportation Route

For transportation scenarios, the off-property general public are people who live along or share the transport route.

G.2.2.2.5 Impacts of Administrative and Engineering Controls on Potential Receptor Exposures

All on-property and off-property FEMP employees and its subcontractors will be working under a health and safety plan. This plan will control and restrict exposures through engineering and administrative controls, and the supervised use of personal protective equipment. The expected impacts of these protective measures on receptors are discussed below.

On-Property Remediation Worker

129 During remedial operations (i.e., excavation, consolidation, backfilling, transportation, etc.), engineering controls such as dust suppression technologies and enclosures will be used to protect the on-site remedial worker and lessen the potential to inhale contaminants. This study also assumes protective clothing will be worn by the workers to reduce the potential for dermal and ingestion exposures. Because these controls are assumed to effectively minimize dermal contact and ingestion, exposures from those pathways are not quantified in this assessment. This receptor may also be subjected to direct radiation and mechanical hazards.

On-Property Nonremediation Workers

The nonremediation worker may inhale airborne particulates and volatiles released from on-site remedial activities. However, the distance from the remediation work, the shielding provided by the buildings, and the low levels of contamination will combine to mitigate the direct radiation exposure pathway, leaving only inhalation of airborne contaminants as a viable pathway.

Off-Property Remediation Worker

The transportation worker will be protected from inhalation and direct contact exposures by the containers in which material will be shipped. Direct radiation exposures will be kept within regulated limits for workers through the distance, shielding, and time limits involved in transporting materials in dedicated-use shipments.

Near-Property Public

This receptor may be exposured via inhalation of air contaminated with site-related dust and gases, and from ingestion of home-grown food contaminated with dust from remedial operations. In the Operable Unit 5 RI Report, exposures via food pathways over a 1000-year study period are generally lower than concurrent inhalation exposures to radionuclides and organic chemicals, but can be an order of magnitude higher for certain metals like beryllium. A shorter study period like the 22-year scenario in the short-term risk assessment can be expected to further reduce the importance of the food pathways. Because the limiting exposure via airborne pathways for most constituents is inhalation, food pathway exposures will be qualitatively assessed unless an exposure to a COC results in an inhalation risk greater than 10^{-7} or its inhalation hazard index (HI) exceeds 0.1.

Public Along the Transportation Route

This group of people may be impacted by mechanical hazards or external exposure as the train or truck approaches them. Therefore, the mechanical hazards will be quantitatively evaluated. Also, the external exposure will be quantitatively evaluated for possible accident and incident-free scenarios.

TABLE G.2-1

SOIL VOLUME ESTIMATES[a]

Alternative/Case	Volume Excavated (yds^3)	Off-Site Disposal Volume (yds^3)
1/1	9,650,000	9,350,000
1/2	2,740,000	2,400,000
2A/1	9,650,000	50,000
2A/2	2,740,000	25,000
2C/1	9,650,000	9,350,000
2C/2	2,740,000	1,160,000
3A/3	2,390,000	25,000
3A/4	2,220,000	25,000
3A/5	2,190,000	25,000
3A/6	1,790,000	25,000
3A/7	1,800,000	25,000
3C/3	2,390,000	1,150,000
3C/4	2,220,000	1,130,000
3C/5	2,190,000	1,120,000
3C/6	1,790,000	1,120,000
3C/7	1,800,000	1,120,000
4A/8	2,190,000	25,000
4A/9	1,790,000	25,000
4C/8	2,190,000	1,120,000
4C/9	1,790,000	1,120,000

Source: Section 2.0 of the FS.

TABLE G.2-2

COMPONENT-LEVEL RELEASE MECHANISMS

Component	Major Operations	Assumptions	Potential Receptors[a] and Exposure Pathways[b]
1. Soil excavation	• Digging operations • Dewater soil from perched groundwater zones • Loading • Vehicle wheel washing • Transportation	• Engine emission and PM_{10}[c] calculations are based on equipment and operational requirements from Section 4.0 of the FS • Percentages of soil volume excavated by equipment type: - Hydraulic excavator (85 percent) - Backhoe loader (5 percent) - Skid loader (5 percent) - Wheel loader (5 percent) • Roads are not a source of contaminant resuspension because: - Truck loads will be covered - Wheels will be washed prior to exiting each component - Haul roads will be monitored and maintained in an uncontaminated condition • Emissions during unloading occur at the location of the receiving component and emission rates are quantified there using excavation parameters • Adherence to an approved health and safety plan will minimize direct exposure during equipment maintenance and upset conditions	• SRW - INH - DR - MH-C • SNW - INH • NP - INH
2. Off-site disposal	• Interim storage/staging • Loading • Vehicle wheel washing • Transportation • Unloading at disposal site	• Soil staging shed is affected by local wind variations • Soil staging pile is 3 meters high and footprint is based on excavation rate • Engine emission and PM_{10} calculations for soil staging operations and the staged soil pile are based on equipment and operational requirements from Section 4.0 of the FS. • No PM_{10} emissions during transport between loading and staging areas because loads will be covered or sealed • No off-site transport of decontamination and decommissioning waste streams because contamination levels will be minimal • Adherence to an approved health and safety plan will minimize direct exposure during equipment maintenance and upset conditions	• SRW - INH - DR - MH-C • SNW - INH • NP - INH • ORW - DR - MH-T • PT - DR - MH-T

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TABLE G.2-2
(Continued)

Component	Major Operations	Assumptions	Potential Receptors[a] and Exposure Pathways[b]
3. Consolidation	• Prepare/construct the area • Provide stormwater control • Construction of monitoring wells • Well sampling and maintenance	• Engine emission and PM_{10} calculations for consolidation operations are based on equipment and operational requirements from Section 4.0 of the FS. • Adherence to an approved health and safety plan will minimize direct exposure during well construction, sampling, equipment maintenance and upset conditions	• SRW - INH - DR - MH-C • SNW - INH • NP - INH
4. On-property disposal cell	• Cell construction • Waste placement • Leachate and stormwater management • Construction of monitoring wells • Well sampling and maintenance	• Engine emission and PM_{10} calculations for on-site disposal cell operations are based on equipment and operational requirements from Section 4.0 of the FS. • Adherence to an approved health and safety plan will minimize direct exposure during well construction, sampling, equipment maintenance and upset conditions	• SRW - INH - DR - MH-C • SNW - INH • NP - INH
5. Soil backfilling	• Import clean soil • Unloading • Compacting and grading	• Engine emission calculations for backfill operations are based on equipment and operational requirements from Section 4.0 of the FS. • Backfilling operations will not resuspend contaminants because backfilling involves clean materials	• SRW - INH - MH-C • SNW - INH • NP - INH
6. Environmental monitoring	• Construction of monitoring wells • Well sampling and maintenance • Well abandonment	• No inhalation exposure during well construction, sampling, and maintenance • Adherence to an approved health and safety plan will minimize direct exposure during well construction, sampling, equipment maintenance and upset conditions	• SRW - MH-C
7. Great Miami Aquifer extraction	• Construction of extraction well/pipeline • Extraction well pumping and maintenance	• No inhalation exposure during well and trench construction, well pumping and sampling, and maintenance • Adherence to an approved health and safety plan will minimize direct exposure during well and trench construction, sampling, equipment maintenance and upset conditions	• SRW - MH-C

TABLE G.2-2
(Continued)

Component	Major Operations	Assumptions	Potential Receptors[a] and Exposure Pathways[b]
8. Water treatment	• Lagoon and retention basin evaporation • Equalization, filtration, adsorption, ion exchange, effluent monitoring • Aeration • Resin regeneration and uranium precipitation • Sludge drying • Waste handling and disposal	• Potential inhalation source terms for groundwater treatment operations are based on equipment and operational requirements from Section 4.0 of the FS. • Adherence to an approved health and safety plan will minimize direct exposure during equipment maintenance and upset conditions	• SRW - DR - MH-C • SNW - INH • NP - INH
9. Soil interim storage at central storage facility	• Unloading soil from vehicles • Stockpiling soil • Loading soil to vehicles	• Potential inhalation source terms for interim soil storage operations are based on equipment and operational requirements from Section 4.0 of the FS. • Interim soil storage facility contains its maximum of 5000 cubic yards of contaminated soil • Adherence to an approved health and safety plan will minimize direct exposure during equipment maintenance and upset conditions • No engine emission or total suspended particulate emissions during loading and unloading operations (negligible in comparison to emissions from the interim storage pile itself)	• SRW - INH - DR - MH-C • SNW - INH • NP - INH

[a] SRW - On-property remediation worker
SNW - On-property nonremediation worker
NP - Near-property public
ORW - Off-property remediation worker
PT - Public along transportation route

[b] DR - Direct radiation exposure
INH - Inhalation exposure
MH-C - Mechanical hazard from construction operations
MH-T - Mechanical hazard from transportation operations

[c] PM_{10} - Particulates 10 microns

TABLE G.2-3
IMPACT OF REMEDIAL TECHNOLOGIES ON RECEPTOR SELECTION

Alt	Media	Remedial Technology	STRA Target Receptor[a]					Treatment	Disposal
			SRW	SNW	ORW	NP	PT		
No-Action	Soil, groundwater, sediment	None				b		None	None
1	Soil and sediment	Complete Excavation	X	X	X	X	X	None	Off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River
2A	Soil and sediment	Complete excavation and segregation based on contaminant concentration	X	X	X	X	X	None	On-site disposal cell or off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River
2C	Soil and sediment	Complete excavation and segregation based on contaminant concentration	X	X	X	X	X	None	On-site consolidation with earthen cover and off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River
3A	Soil and sediment	Complete excavation and segregation based on contaminant concentration	X	X	X	X	X	None	On-site disposal cell and off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River

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TABLE G.2-3
(Continued)

Alt	Media	Remedial Technology	STRA Target Receptor[a]					Treatment	Disposal
			SRW	SNW	ORW	NP	PT		
3C	Soil and sediment	Complete excavation and segregation based on contaminant concentration	X	X	X	X	X	None	On-site consolidation with earthen cover and off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River
4A	Soil	Selective excavation	X	X	X	X	X	None	On-site disposal cell or off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X						Discharge to Great Miami River
4C	Soil	Selective excavation	X	X	X	X	X	None	On-site consolidation with earthen cover and off-site disposal
	Perched water, process wastewater, and groundwater	Extraction	X					Advanced wastewater treatment	Discharge to Great Miami River

[a] Short-term risk assessment receptor code:
SRW - On-Site Remediation Worker
SNW - On-Site Nonremediation Worker
ORW - Off-Site Remediation Transportation Worker
NP - Near-Property Public
PT - Public Along Transportation Route
[b] Assessed as part of the OU5 Remedial Investigation Baseline Risk Assessment.

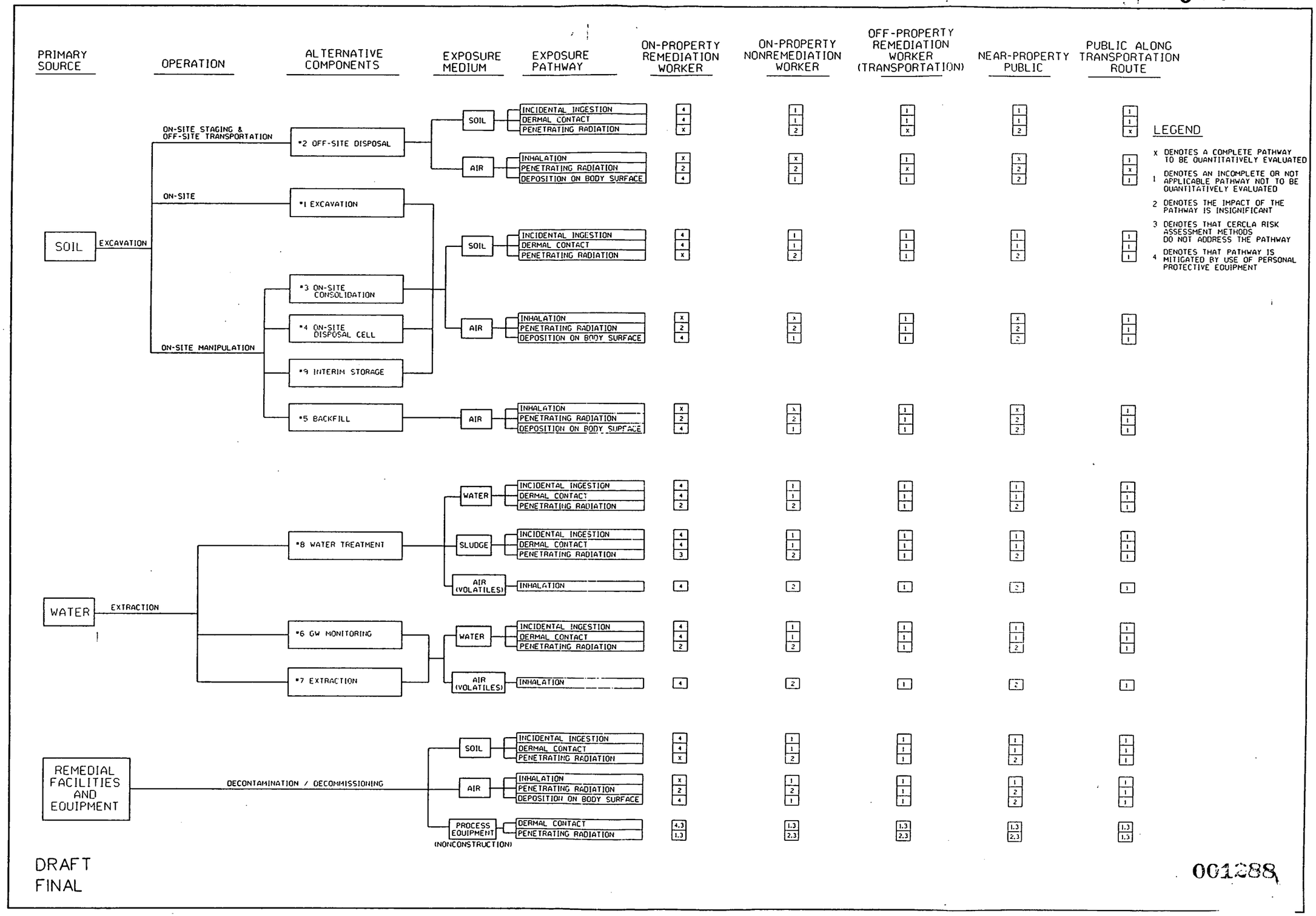

Figure G.2-1 - Conceptual Model of Short-Term Exposures Associated with Remedial Actions

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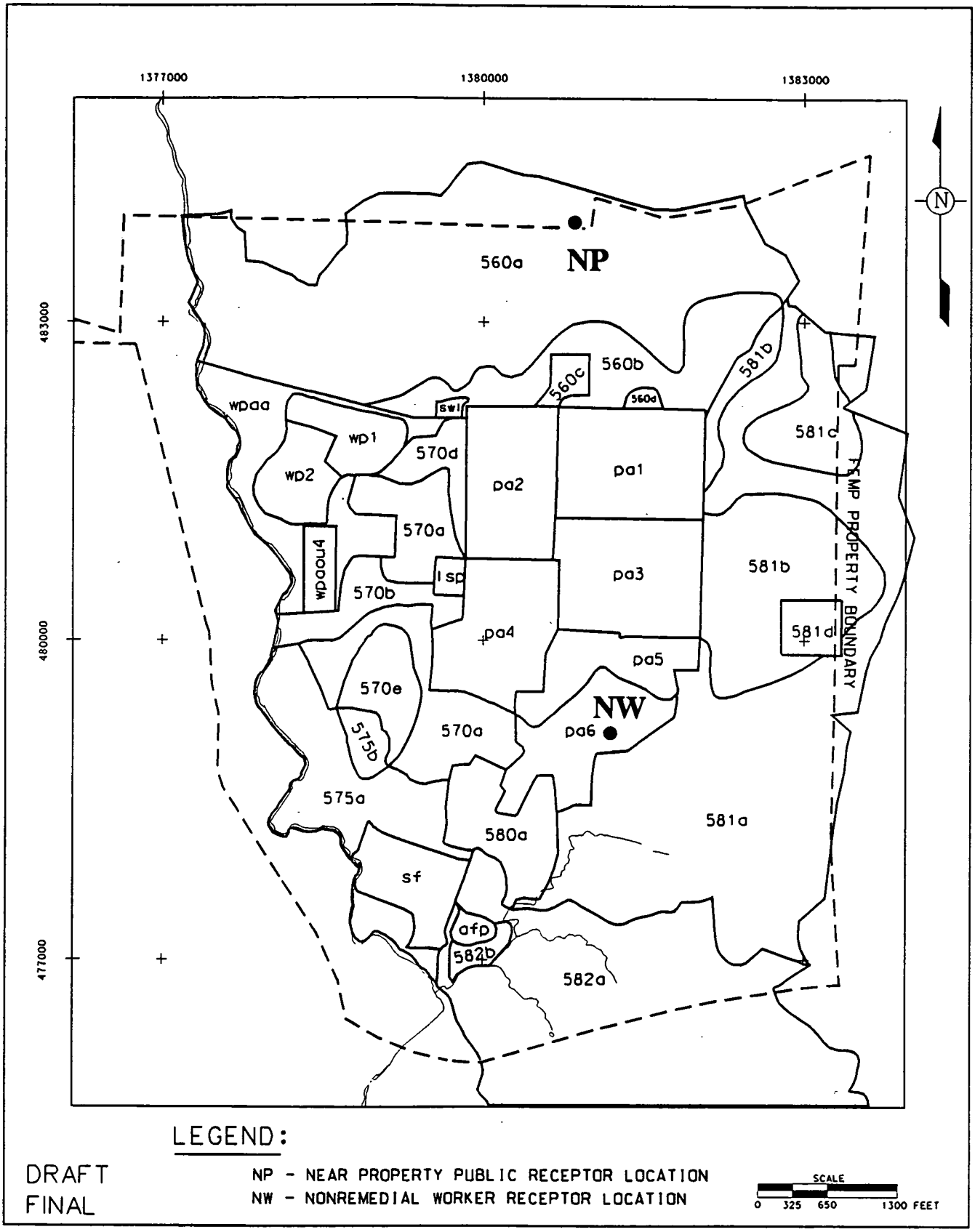

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FIGURE G.2-2. MAP OF THE 33 AREAS CONTAINING SOIL TO BE EXCAVATED

G.3.0 EXPOSURE AND RISK CALCULATIONS

The following section discusses the methods used to quantify the significant exposures and mechanical hazards anticipated during remedial operations. The discussion includes the selection of COCs, exposure assessment including determination of exposure point concentrations, intake assessment and dose assessment, human health risk characterization, and the estimation of mechanical hazards. Equations used to calculate risk, injuries, and fatalities are specified in corresponding text discussions. To increase readability, example parameter values and intermediate calculations and results are provided in Attachments G.I and G.II.

Figure G.3-1 shows the interactions between the proposed remedial operations and the kinds of process-related information required to evaluate the human health and mechanical hazards anticipated.

G.3.1 SELECTION OF CONSTITUENTS OF CONCERN

G.3.1.1 Constituents of Concern

Constituents of concern (COCs) were selected using information from several sources:

- The draft FS Reports for Operable Units 1 (DOE 1993a) and 2 (DOE 1994b),
- The Operable Unit 3 Work Plan (DOE 1992b),
- The final FS Report for Operable Unit 4 (DOE 1993b), and
- The draft Operable Unit 5 RI (DOE 1994a) and its baseline risk assessment

The Operable Unit 5 RI Report (DOE 1995b) and information from other operable units contributing material to Operable Unit 5 were used to prepare this exposure assessment according to applicable guidelines under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Whenever possible, COC identification was based on COCs selected in the Operable Unit 5 RI baseline risk assessment and from the estimated residual contaminants in the soil identified in the draft and final FS reports on other operable units. The final list of COCs selected for evaluation in this short-term risk assessment is presented in the discussion on exposure point concentrations below.

G.3.2 EXPOSURE ASSESSMENT

G.3.2.1 Exposure Point Concentrations

The Operable Unit 5 RI Report (DOE 1995b) presents a detailed discussion of the potential sources of exposure during remedial activities. Section G.2.2.2.1 in the conceptual model for short-term risk assessment discusses the sources within Operable Unit 5 that may potentially result in receptor exposures during remediation. Figure G.2-2 shows the 33 distinct source areas selected for evaluation.

Section 4.0 of the Operable Unit 5 FS states that remediation of FEMP soil will continue for 22 years. The maximum area actively excavated at any one time will be 0.5 acres to minimize contaminant releases. A representative source area contaminant concentration for each COC was used to calculate the exposure pathway risk from soil excavation activities in each of the 33 source areas. Representative concentrations were estimated by considering the results of a statistical analysis of the source area concentration data, as well as maps and process knowledge. The statistical analysis of the concentration data produced values for both the mean concentration and the 95 percent upper confidence limit on the mean concentration for the COCs in each of the 33 source areas. These sets of values were then compared to site maps from the Operable Unit 5 RI Report (DOE 1995b) showing the locations and results of individual sampling results. This comparison favored the use of the mean concentration to represent the level of contamination expected in the excavated soil. This is further supported by process knowledge. These average soil concentrations, which are listed in Table G.3-1, are used throughout the 22-year excavation period.

134 Table G.3-2 identifies potential exposure pathways and presents the subset of exposure pathways and receptors selected for quantification. The table is based on the conceptual model depicted in Figure G.2-1. The exposure pathways selected for quantitative evaluation for each receptor are indicated with shading in Table G.3-2. These pathways include direct exposure to penetrating radiation, inhalation of engine emissions, and inhalation of suspended particulates. Table G.3-3 presents the parameters used to quantify these exposure pathways.

Soil concentrations in Table G.3-1 are used to quantify exposures to penetrating radiation and to develop estimates of exposure point concentrations in air. A discussion of air transport modeling is presented in Attachment G.I.3. Air exposure point concentrations are used to quantify intake as described in the section below.

G.3.2.2 Intake Assessment

For each component, receptor intakes from inhalation are calculated using the respirable fraction (PM_{10}) of the contaminant concentration at the receptor, the receptor breathing rate, and the duration of time the receptor is exposed. In all cases involving nonradioactive chemicals, the intake is divided by the averaging time. In the case of carcinogens, the averaging time is 70 years. In the case of non-carcinogens, the averaging time is the duration of the component remedial activities.

The equations used to quantify intake via the inhalation pathway (EPA 1989b) are:

$$\text{(radionuclides) } I_a = (C_a)(IR)(ED)(EF)(ET) \qquad \text{(G.3-1)}$$

$$\text{(chemicals) } I_a = (C_a)(IR)(EF)(ED)(ET)/(BW)(AT) \qquad \text{(G.3-2)}$$

where

I_a	=	Intake from inhalation (pCi, radionuclides) (mg/kg-day, chemicals)
C_a	=	Concentration in air (pCi/m^3, radionuclides) (mg/m^3, chemicals)
IR	=	Inhalation rate (m^3/hr)
ET	=	Exposure time (hrs/day)
EF	=	Exposure frequency (day/yr)
ED	=	Exposure duration (yr)
BW	=	Body weight (kg)
AT	=	Averaging time (days); for noncarcinogens, AT equals (ED)(365 days/yr); for carcinogens, AT equals (70-year lifetime)(365 days/yr)

G.3.2.3 Dose Assessment

The method for estimating the dose from external exposure to radionuclides (DE) is presented below. DEs are estimated because they will be compared to pertinent radiation dose limits. DEs from external exposures to gamma-emitting radionuclides in planar and nonplanar geometries are calculated as:

$$DE = (EF)(ED)(ER)\ [(ET_{in})(1\text{-}SF_{in})+(ET_{out})(1\text{-}SF_{o})] \qquad \text{(G.3-3)}$$

where

DE	=	Dose from external source of gamma radiation (mSv)
EF	=	Exposure frequency (day/yr)
ED	=	Exposure duration (yr)
ER	=	Exposure rate (mSv/hr)
ET_{out}	=	Exposure time outdoors (hr/day)
S_o	=	Shielding factor while outdoors (unitless)
ET_i	=	Exposure time indoors (hr/day)
S_{in}	=	Shielding factor while indoors (unitless)

External gamma exposure rate (ER) is quantified for on-site remedial workers and off-site transportation workers using the MicroShield 4.2 software package. The MicroShield model is discussed in some detail in Attachment G.I.

G.3.3 HUMAN HEALTH RISK CHARACTERIZATION

Once the types and magnitudes of potential exposures have been estimated, the risks from these exposures can be quantified. This section presents the processes used to quantify the risks from the short term exposures from remedial actions.

G.3.3.1 Carcinogenic Risk

G.3.3.1.1 Calculation of Carcinogenic Risk Attributed to Intake of Chemicals

The risk attributed to postulated inhalation of chemical carcinogens is expressed as the probability of an individual developing cancer over a lifetime. At low doses, the risk of developing cancer is determined using the following equations from the Risk Assessment Work Plan Addendum (DOE 1992a).

$$\text{Risk} = (I_{ca})(SF) \qquad \text{(G.3-4)}$$

where

Risk = Risk of cancer incidence, expressed as a unitless probability
I_{ca} = Chronic daily inhalation intake of chemical averaged over 70 years (mg/kg-day)
SF = Slope factor $(\text{mg/kg-day})^{-1}$

G.3.3.1.2 Calculation of Carcinogenic Risk Attributed to Intake of Radionuclides

Cancer risks associated with the inhalation intake of a radionuclide are calculated using the slope factor methodology in DOE 1992a:

$$\text{Risk} = (I_{ra})(SF) \qquad \text{(G.3-5)}$$

where

Risk = Risk of cancer incidence, expressed as a unitless probability
I_{ra} = Lifetime intake of a radionuclide from inhalation (pCi)
SF = Radionuclide slope factor (pCi^{-1})

The slope factors used are the HEAST values for each particular radionuclide. The HEAST (EPA 1994) values are the "maximum likelihood estimates of the age-average lifetime total excess cancer risk per unit intake or exposure."

G.3.3.1.3 Risks Attributed to External Exposure from Soil

Since publication of the Risk Assessment Work Plan Addendum (DOE 1992a), EPA has published a new set of slope factors (EPA 1994). As a result of this change, risks resulting from external radiation exposures to soil must be calculated using an equation different from the one originally presented in the Risk Assessment Work Plan Addendum (DOE 1992a) and in Section G.3.2.3. The new equation is:

$$ILCR_e = (SF_{ext})(C_s)(ED)(EF)(CF)[(ET_{in})[(1-S_i)+(ET_{out})(1-S_o)] \qquad \text{(G.3-6)}$$

where

$ILCR_e$ = Incremental lifetime cancer risk (ILCR/lifetime)
C_s = concentration in surface soil (pCi/g)
SF_{ext} = HEAST slope factor (ILCR - g/pCi-y)

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ED = exposure duration (y/lifetime)
EF = exposure frequency (d/y)
ET_{in} = exposure time indoors on site (h/d)
ET_{out} = exposure time outdoors on site (h/d)
S_i = indoor shielding factor (0.5, from DOE 1992a)
S_o = outdoor shielding factor outdoors (0, assumes no shielding)
CF = 1/8760 y/h

Surface Soil Sources

External slope factors do not include contributions from decay products (radioactive progeny). In cases where the contributions from decay products are substantial, slope factors for the decay products are added to that of the parent.

Sources Other Than Surface Soil

Risk from external exposures to gamma-emitting radionuclides in forms other than surface soil may be calculated directly from the dose rate in the following manner (DOE 1992a):

$$\text{Risk} = (DE)(RC) \qquad \text{(G.3-7)}$$

where

Risk = Risk of cancer incidence, expressed as a unitless probability
DE = Dose from external gamma sources (mSv)
RC = Dose to cancer risk coefficient (mSv^{-1})

The value of the risk coefficient is 6.2×10^{-5} mSv^{-1} (EPA 1989a).

DOE G.3.3.1.4 Calculation of Risk from Multiple Constituents

For a given pathway with simultaneous exposure to several carcinogens, the following equation is used to sum cancer risks:

$$\text{Risk}_p = \text{Risk}(COC_1) + \text{Risk}(COC_2) + \ldots \text{Risk}(COC_i) \qquad \text{(G.3-8)}$$

where

Risk_p = Total pathway risk of cancer incidence
COC_i = Individual carcinogenic cancer incidence

G.3.3.2 Noncarcinogenic Effects from Intake of Toxicants

Toxicological hazards associated with the effects of noncarcinogenic hazardous chemicals are evaluated by comparing the intake to a reference dose. The ratio of intake over the reference dose is termed the Hazard Quotient (HQ) and is defined in EPA 1991 as:

$$HQ = I_{ca}/RfD \qquad (G.3\text{-}9)$$

where

HQ = Hazard Quotient (unitless)
I_{ca} = Inhalation intake of a chemical (mg/kg-day)
RfD = Reference dose (mg/kg-day)

Based on Section 4.0 of this FS Report, the exposure duration during remedial activities will last 22 years; therefore, chronic RfD values were used to determine the hazard quotient.

In the case of simultaneous exposure of a receptor to several chemicals, a Hazard Index (HI) is calculated as the sum of the HQs by:

$$HI = I_i/RfD_i + I_2/RfD_2 + \ldots I_i/RfD_i \qquad (G.3\text{-}10)$$

where

I_i = Intake for the ith toxicant
RfD_i = Reference dose for the ith toxicant

Hazard indices should be determined by assuming dose additivity for those chemicals acting by the same mechanism and inducing the same effects. Since we are assuming dose additivity, HQs for chemicals that affect the same target organ can be summed.

G.3.4 ESTIMATION OF MECHANICAL HAZARDS

There are mechanical hazards associated with all components of the remedial activities. They include construction injuries and fatalities as well as transportation injuries and fatalities. For the purposes of this report, an injury is defined as physical harm resulting in either time spent away from work because of injury or assignment to a less demanding job.

G.3.4.1 Transportation Risks

Analysis of the potential impacts in the Operable Unit 5 FS requires consideration of the radiation dose and risk to workers and to the public en route due to shipment of radioactive wastes for disposal to a representative waste disposal site.

This analysis includes two distinct cases for both truck and train; the incident-free transport and the transportation accident scenario. The analysis was performed using the Sandia National Laboratory (SNL) RADTRAN 4 Computer Code described in Attachment G.I.2.

The RADTRAN code uses hazard coefficients from the Risk Assessment Work Plan Addendum (DOE 1992a) supplied as input data. These coefficients are expressed per mile transported and are presented in Table G.3-4.

G.3.4.2 Occupational Mechanical Hazards

Mechanical hazards associated with construction operations are estimated for each alternative using the historical injury and fatality data discussed below. The construction work hazards are calculated in the following manner:

$$\text{Hazard} = (PH)(HC) \qquad \text{(G.3-11)}$$

where

Hazard = Injuries and fatalities, collective
PH = Person-hours of a specific remedial task
HC = Injury or fatality hazard coefficient (hazard/person-hour)

Table G.3-5 lists the total hours, by case, for major remedial components. These person-hour estimates were taken from the same engineering database used to assemble the cost estimate. They are derived from the engineering designs and volume estimates presented in Appendix L and Section 2.7 of this FS, respectively. The hazard coefficient is a fraction representing the average number of incidents expected to occur for each person-hour worked. The Risk Assessment Work Plan Addendum (DOE 1992a) lists hazard coefficients for operational worker activities. Recent U.S. Department of Labor, Bureau of Labor Statistics compilations of occupational injuries (DOL 1994a) and fatalities (DOL 1994b) have been reviewed and used to update the coefficients of mechanical hazards from remediation activities. These new coefficients are used in the short-term risk assessment and presented in Table G.3-6.

The injury and illness incidence rates from the survey of occupational injuries and illnesses (DOL 1994a) are used to derive injury hazard coefficients as described below (Equation G.3-12). The number of fatal occupational injuries listed in DOL 1994b are used to derive fatality hazard coefficients as described below (Equation G.3-13).

The injury rates presented in Table G.3-6 are derived in the following manner:

$$HC = (IR)/200000 \qquad \text{(G.3-12)}$$

where

HC = Injury hazard coefficient, Table G.3-6, $(\text{person-hr})^{-1}$
IR = Injury incidence rate, DOL 1994a Table 1, (total lost workday cases/100 full-time equivalents) assuming 100 full-time equivalents equals 40 hrs/wk for 50 wks/yr for 100 persons equals 200,000 person-hr/yr.

The summary report (DOL 1994a) provides results for the 1992 survey of occupational injuries and illnesses. The survey sampled 250,000 establishments and distinguishes between injuries plus illness and injuries alone, as well as lost-work-day cases and cases without lost work days. The short-term risk assessment hazard coefficients are derived from the rate of injuries alone classified as lost-work-time cases. The survey estimates of the incidence rates of nonfatal workplace injuries and illnesses are based on logs kept by private industry employees during the year (DOL 1994a). These records reflect both the year's injury and illness experience from each employer and the employer's understanding of which cases are work-related under the record-keeping guidelines of the U.S. DOL (DOL 1994a). The injury and illness incidence rates for a given year may also be influenced by changes in the economy, working conditions, work practices, worker experience and training, and the number of hours worked (DOL 1994a).

The fatality rates presented in Table G.3-6 are derived in the following manner:

$$HC = (F)/[(E)(2000)] \qquad \text{(G.3-13)}$$

where

HC = Fatality hazard coefficient, Table G.3-5, $(\text{person-hr})^{-1}$
F = Total fatalities, DOL 1994b Table A-4
E = 1992 annual average employment, DOL 1994a Table 1, assuming 40 hrs/wk for 50 wks/yr for each person equals 2000 person-hr/yr.

The summary report provides results for the 1992 Census of Fatal Occupational Injuries. The census compiles information on fatal work injuries occurring in all 50 states plus the District of Columbia. The goal of the census is to collect comprehensive data on all fatal injuries rather than a sample of fatal injuries (DOL 1994b). Multiple data sources are used in the census to obtain data on all fatal injuries, including death certificates, workers' compensation reports, and independent source documents (DOL 1994b). Fatality incidence from the census is expressed in the summary report (DOL 1994b) as fatality rate using employment estimates from the Current Population Survey. However, the Current Population Survey does not provide employment estimates for the specific industry categories needed in the short-term risk assessment; therefore, the employment estimates for the desired industry categories are obtained from the survey of occupational injuries and illnesses (DOL 1994a). These employment estimates are used as an approximation of the employment population sizes that would represent the 1992 Census of Fatal Occupational Injuries data if they were available and compiled as desired. Table G.3-6 presents these new hazard coefficients.

Comparison of the injury hazard coefficients in Table G.3-6 with the Risk Assessment Work Plan Addendum reveals that the coefficients are of approximately the same magnitude. However, comparison

of the fatality coefficients reveals that the values presented in Table G.3-6 are much lower. This is because the previous statistics included injuries and fatalities from dangerous trades that are not representative of projected activities at the FEMP, such as underground mining. This results in a corresponding decrease in the mechanical hazard fatalities for the remedial alternatives, and reflects the impacts of using more appropriate task-specific statistics.

TABLE G.3-1

EXPOSURE POINT CONCENTRATIONS IN SOIL

Contaminants of Concern (COCs)	Area									
	1sp	560a	560b	560c	560d	570a	570au	570b	570d	570e
Radionuclides (pCi/g)										
Cesium-137	2.00×10^{-1}	3.60×10^{-1}	3.60×10^{-1}	3.10×10^{-1}	4.80×10^{-1}	2.90×10^{-1}	2.90×10^{-1}	2.50×10^{-1}	2.50×10^{-1}	3.80×10^{-1}
Neptunium-237	2.00×10^{-1}	5.30×10^{-1}	5.00×10^{-1}	6.00×10^{-1}	2.10×10^{0}	4.40×10^{-1}	4.40×10^{-1}	1.60×10^{-1}	4.00×10^{-1}	6.00×10^{-1}
Plutonium-238	4.30×10^{-1}	3.50×10^{-1}	3.40×10^{-1}	6.00×10^{-1}	3.30×10^{0}	4.00×10^{-1}	4.00×10^{-1}	3.70×10^{-1}	3.50×10^{-1}	6.00×10^{-1}
Plutonium-239/240	2.00×10^{-1}	3.50×10^{-1}	3.30×10^{-1}	6.00×10^{-1}	4.50×10^{0}	3.50×10^{-1}	3.50×10^{-1}	6.10×10^{-1}	3.50×10^{-1}	6.00×10^{-1}
Radium-226	6.76×10^{0}	9.52×10^{-1}	2.99×10^{1}	9.00×10^{-1}	2.21×10^{3}	1.54×10^{0}	2.01×10^{0}	3.79×10^{0}	9.17×10^{-1}	9.00×10^{-1}
Radium-228	1.04×10^{0}	9.20×10^{-1}	8.50×10^{-1}	4.96×10^{0}	1.27×10^{1}	7.00×10^{-1}	7.00×10^{-1}	8.80×10^{-1}	6.50×10^{-1}	8.50×10^{-1}
Strontium-90	2.50×10^{-1}	7.11×10^{-1}	1.36×10^{0}	5.90×10^{-1}	1.61×10^{0}	3.25×10^{-1}	2.50×10^{-1}	2.50×10^{-1}	3.97×10^{-1}	2.50×10^{-1}
Technetium-99	1.13×10^{0}	1.13×10^{0}	1.86×10^{0}	9.85×10^{0}	1.11×10^{0}	6.80×10^{0}	1.13×10^{0}	1.01×10^{2}	1.60×10^{1}	1.13×10^{0}
Thorium-228	9.80×10^{-1}	1.41×10^{0}	1.05×10^{0}	5.23×10^{0}	1.84×10^{1}	9.00×10^{-1}	9.00×10^{-1}	3.37×10^{0}	1.53×10^{0}	1.15×10^{0}
Thorium-230	4.81×10^{0}	1.87×10^{0}	6.39×10^{0}	8.43×10^{0}	2.76×10^{1}	1.37×10^{1}	6.53×10^{1}	1.02×10^{2}	1.63×10^{1}	4.11×10^{0}
Thorium-232	2.76×10^{0}	1.01×10^{0}	1.93×10^{0}	7.03×10^{0}	5.31×10^{0}	1.02×10^{0}	1.36×10^{0}	1.89×10^{0}	1.03×10^{0}	1.87×10^{0}
Thorium-234	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uranium-234	7.45×10^{-4}	2.98×10^{-4}	1.56×10^{-3}	1.07×10^{-2}	2.46×10^{-3}	1.61×10^{-3}	1.30×10^{-3}	5.44×10^{-4}	3.38×10^{-3}	4.27×10^{-4}
Uranium-235/236	9.75×10^{-2}	3.90×10^{-2}	2.05×10^{-1}	1.40×10^{0}	3.21×10^{-1}	2.10×10^{-1}	1.70×10^{-1}	7.13×10^{-2}	4.42×10^{-1}	5.59×10^{-2}
Uranium-236	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uranium-238	1.35×10^{1}	5.42×10^{0}	2.84×10^{1}	1.94×10^{2}	4.46×10^{1}	2.92×10^{1}	2.36×10^{1}	9.90×10^{0}	6.14×10^{1}	7.76×10^{0}
Metals/Chemicals (mg/kg)										
1,1-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
1,1-Dichloroethene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
1,2,4,5-Tetrachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,2,4-Trichlorobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
1,2-Dichlorobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
1,2-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
1,2-Dichloroethene (Total)	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
1,3,5-Trinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,3-Dichlorobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
1,3-Dinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area									
	1sp	560a	560b	560c	560d	570a	570au	570b	570d	570e
Metals/Chemicals (mg/kg) (Continued)										
1,4-Dichlorobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-Benzyl Alcohol-4-chlorophenol	4.00×10^{-1}	0.00	0.00	0.00	0.00	4.00×10^{-1}	4.00×10^{-1}	4.00×10^{-1}	0.00	0.00
3,3'-Dichlorobenzidine	4.10×10^{-1}	6.20×10^{-1}	4.10×10^{-1}	2.03×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	6.00×10^{-1}	5.80×10^{-1}	0.00
3,3'-Dimethylbenzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-Methylphenol	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	2.00×10^{-1}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
4-Nitroaniline	9.80×10^{-1}	1.50×10^{0}	1.02×10^{0}	4.97×10^{0}	0.00	9.40×10^{-1}	9.40×10^{-1}	1.43×10^{0}	1.42×10^{0}	0.00
7,12-Dimethylbenz(a)anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	1.20×10^{0}	7.70×10^{0}	3.48×10^{0}	1.83×10^{0}	1.20×10^{0}	1.18×10^{1}	1.53×10^{1}	2.13×10^{1}	2.89×10^{1}	1.72×10^{1}
Alpha-chlordane	0.00	0.00	0.00	2.20×10^{-1}	0.00	0.00	0.00	5.00×10^{-2}	1.40×10^{-1}	0.00
Aroclor 1254	2.80×10^{-2}	8.58×10^{-2}	5.68×10^{-1}	1.20×10^{0}	6.11×10^{-1}	2.44×10^{-1}	4.56×10^{-2}	6.03×10^{-2}	5.90×10^{-1}	4.71×10^{-2}
Arsenic	6.40×10^{0}	4.22×10^{0}	5.69×10^{0}	6.05×10^{0}	6.80×10^{0}	7.84×10^{0}	6.30×10^{0}	6.26×10^{0}	6.40×10^{0}	6.20×10^{0}
Benzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Benzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(a)anthracene	6.10×10^{-1}	2.13×10^{-1}	8.05×10^{-1}	4.14×10^{0}	2.42×10^{0}	7.17×10^{-1}	3.38×10^{-1}	3.03×10^{-1}	3.85×10^{-1}	2.15×10^{-1}
Benzo(a)pyrene	3.70×10^{-1}	2.16×10^{-1}	1.01×10^{0}	5.25×10^{0}	3.18×10^{0}	6.76×10^{-1}	2.63×10^{-1}	2.49×10^{-1}	3.45×10^{-1}	2.15×10^{-1}
Benzo(b)fluoranthene	5.00×10^{-1}	2.03×10^{-1}	8.88×10^{-1}	5.25×10^{0}	2.79×10^{0}	3.11×10^{-1}	3.01×10^{-1}	2.74×10^{-1}	3.37×10^{-1}	2.10×10^{-1}
Benzo(g,h,i)perylene	4.10×10^{-1}	4.10×10^{-1}	2.50×10^{-1}	2.60×10^{-1}	0.00	5.00×10^{-1}	5.00×10^{-1}	2.90×10^{-1}	3.80×10^{-1}	0.00
Benzo(k)fluoranthene	4.50×10^{-1}	2.15×10^{-1}	1.00×10^{0}	5.34×10^{0}	3.16×10^{0}	5.09×10^{-1}	2.88×10^{-1}	2.67×10^{-1}	3.76×10^{-1}	2.15×10^{-1}
Benzoic acid	1.95×10^{0}	5.00×10^{-1}	1.50×10^{0}	7.50×10^{-1}	0.00	9.60×10^{-1}	9.60×10^{-1}	4.80×10^{-1}	1.66×10^{0}	0.00
Benzyl alcohol	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	3.80×10^{-1}	3.80×10^{-1}	0.00
Beryllium	1.39×10^{0}	5.46×10^{-1}	5.21×10^{-1}	4.98×10^{-1}	4.98×10^{-1}	6.28×10^{-1}	9.66×10^{-1}	8.34×10^{-1}	8.36×10^{-1}	4.89×10^{-1}
Bis(2-chloroethoxy)methane	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Bis(2-chloroethyl)ether	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Bis(2-chloroisopropyl)ether	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	2.10×10^{-1}	2.10×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Bis(2-ethylhexyl)phthalate	9.60×10^{-2}	5.18×10^{-1}	4.28×10^{-1}	8.80×10^{-1}	1.87×10^{0}	3.32×10^{-1}	1.60×10^{-1}	3.25×10^{-1}	3.17×10^{-1}	2.04×10^{-1}
Bis(chloromethyl)ether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromodichloromethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Bromomethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Cadmium	1.16×10^{0}	8.60×10^{-1}	3.05×10^{0}	2.94×10^{0}	0.00	8.10×10^{-1}	8.10×10^{-1}	2.64×10^{0}	3.90×10^{0}	0.00

TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area									
	1sp	560a	560b	560c	560d	570a	570au	570b	570d	570e
Metals/Chemicals (mg/kg) (Continued)										
Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorobenzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Chlorobenzilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloroform	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Chrysene	6.60×10^{-1}	2.03×10^{-1}	8.94×10^{-1}	5.00×10^{0}	2.79×10^{0}	8.42×10^{-1}	3.51×10^{-1}	3.10×10^{-1}	4.33×10^{-1}	2.10×10^{-1}
Dibenzo(a,h)anthracene	3.00×10^{-1}	7.35×10^{-2}	2.99×10^{-1}	1.72×10^{0}	9.22×10^{-1}	1.06×10^{-1}	1.45×10^{-1}	1.24×10^{-1}	1.15×10^{-1}	7.40×10^{-2}
Dibenzofuran	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	2.10×10^{-1}	2.10×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Dibromomethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dieldrin	0.00	1.00×10^{-2}	0.00	5.00×10^{-2}	0.00	0.00	0.00	1.00×10^{-2}	3.00×10^{-2}	0.00
Ethylbenzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00
Gamma-chlordane	0.00	0.00	0.00	2.20×10^{-1}	0.00	0.00	0.00	5.00×10^{-2}	1.40×10^{-1}	0.00
Hexachlorobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Indeno(1,2,3-cd)pyrene	3.70×10^{-1}	2.18×10^{-1}	7.74×10^{-1}	3.95×10^{0}	2.31×10^{0}	5.00×10^{-1}	2.67×10^{-1}	2.53×10^{-1}	2.86×10^{-1}	2.20×10^{-1}
Manganese	5.46×10^{2}	8.84×10^{2}	9.75×10^{2}	5.10×10^{2}	6.56×10^{2}	6.32×10^{2}	7.74×10^{2}	5.53×10^{2}	6.06×10^{2}	6.94×10^{2}
Mercury	5.50×10^{-2}	5.50×10^{-2}	5.64×10^{-2}	5.50×10^{-2}	5.50×10^{-2}	6.77×10^{-2}	5.50×10^{-2}	5.50×10^{-2}	7.11×10^{-2}	5.50×10^{-2}
Methylene chloride	1.00×10^{-3}	4.07×10^{-3}	2.12×10^{-2}	1.29×10^{-1}	1.00×10^{-3}	6.97×10^{-3}	1.62×10^{-2}	4.86×10^{-3}	7.00×10^{-3}	1.00×10^{-3}
N-Nitroso-di-n-propylamine	4.10×10^{-1}	2.00×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
Nitrobenzene	4.10×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	1.02×10^{0}	0.00	3.70×10^{-1}	3.70×10^{-1}	4.00×10^{-1}	3.80×10^{-1}	0.00
O-Dichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-Dimethylaminoazobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenanthrene	3.70×10^{-1}	2.12×10^{-1}	5.30×10^{-1}	2.30×10^{0}	1.34×10^{0}	3.31×10^{-1}	2.63×10^{-1}	2.49×10^{-1}	5.09×10^{-1}	2.15×10^{-1}
Silver	2.55×10^{-1}	2.07×10^{0}	2.85×10^{0}	3.77×10^{0}	3.60×10^{0}	1.63×10^{0}	1.37×10^{0}	5.22×10^{0}	4.56×10^{0}	2.05×10^{0}
Trans-1,2-dichloroethene(total)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichloroethene	3.40×10^{-2}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	4.30×10^{-3}	6.00×10^{-3}	9.11×10^{-3}	2.00×10^{-3}	3.73×10^{-3}
Uranium - total	4.06×10^{1}	1.63×10^{1}	8.52×10^{1}	5.82×10^{2}	1.34×10^{2}	8.76×10^{1}	7.07×10^{1}	2.97×10^{1}	1.84×10^{2}	2.33×10^{1}
Zinc	5.42×10^{1}	6.40×10^{1}	5.33×10^{1}	1.93×10^{2}	0.00	6.07×10^{1}	6.07×10^{1}	5.73×10^{1}	4.75×10^{1}	0.00

TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area									
	575a	575b	580a	581a	581b	581c	581d	582a	582b	afp
Radionuclides (pCi/g)										
Cesium-137	5.00×10^{-1}	1.05×10^{0}	3.50×10^{-1}	5.50×10^{-1}	3.90×10^{-1}	4.90×10^{-1}	2.50×10^{-1}	2.50×10^{-1}	3.90×10^{-1}	2.00×10^{-1}
Neptunium-237	4.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	5.50×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	1.78×10^{0}
Plutonium-238	4.00×10^{-1}	3.50×10^{-1}	4.00×10^{-1}	3.50×10^{-1}	3.50×10^{-1}	6.00×10^{-1}	7.50×10^{-1}	4.50×10^{-1}	6.00×10^{-1}	3.00×10^{-1}
Plutonium-239/240	4.00×10^{-1}	3.50×10^{-1}	4.00×10^{-1}	5.00×10^{-1}	4.00×10^{-1}	6.00×10^{-1}	7.50×10^{-1}	3.20×10^{-1}	6.00×10^{-1}	2.00×10^{-1}
Radium-226	7.93×10^{0}	1.82×10^{0}	1.86×10^{1}	1.07×10^{0}	2.01×10^{0}	9.00×10^{-1}	7.61×10^{0}	2.68×10^{0}	3.74×10^{0}	3.74×10^{0}
Radium-228	5.80×10^{-1}	7.80×10^{-1}	5.00×10^{-1}	7.20×10^{-1}	9.50×10^{-1}	9.00×10^{-1}	1.05×10^{0}	6.00×10^{-1}	7.90×10^{-1}	2.55×10^{0}
Strontium-90	2.50×10^{-1}	2.50×10^{-1}	3.11×10^{-1}	1.10×10^{0}	6.57×10^{-1}	6.20×10^{-1}	1.72×10^{0}	6.79×10^{-1}	1.45×10^{0}	1.60×10^{0}
Technecium-99	4.96×10^{0}	1.13×10^{0}	1.13×10^{0}	1.13×10^{0}	1.41×10^{0}	1.10×10^{0}	1.88×10^{1}	1.13×10^{0}	1.13×10^{0}	1.13×10^{0}
Thorium-228	4.50×10^{-1}	9.00×10^{-1}	8.50×10^{-1}	9.90×10^{-1}	1.58×10^{0}	1.02×10^{0}	1.61×10^{0}	8.20×10^{-1}	1.20×10^{0}	2.42×10^{0}
Thorium-230	7.17×10^{0}	1.77×10^{0}	1.40×10^{1}	3.46×10^{0}	2.46×10^{2}	2.27×10^{0}	2.32×10^{1}	1.41×10^{1}	3.03×10^{1}	2.84×10^{0}
Thorium-232	1.47×10^{0}	8.00×10^{-1}	8.73×10^{-1}	9.55×10^{-1}	1.26×10^{0}	1.14×10^{0}	1.64×10^{0}	1.54×10^{0}	2.81×10^{0}	2.81×10^{0}
Thorium-234	0.00	0.00	0.00	2.05×10^{0}	1.58×10^{1}	0.00	2.91×10^{2}	0.00	0.00	0.00
Uranium-234	3.90×10^{-4}	4.37×10^{-4}	2.39×10^{-4}	5.40×10^{-4}	1.51×10^{-3}	1.11×10^{-3}	2.51×10^{-3}	8.33×10^{-4}	4.70×10^{-4}	1.32×10^{-4}
Uranium-235/236	5.11×10^{-2}	5.72×10^{-2}	3.13×10^{-2}	7.06×10^{-2}	1.97×10^{-1}	1.45×10^{-1}	3.28×10^{-1}	1.09×10^{-1}	6.15×10^{-2}	1.73×10^{-2}
Uranium-236	0.00	0.00	0.00	6.00×10^{-2}	0.00	0.00	0.00	0.00	0.00	0.00
Uranium-238	7.10×10^{0}	7.95×10^{0}	4.34×10^{0}	9.81×10^{0}	2.74×10^{1}	2.02×10^{1}	4.56×10^{1}	1.51×10^{1}	8.54×10^{0}	2.40×10^{0}
Metals/Chemicals (mg/kg)										
1,1-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
1,1-Dichloroethene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
1,2,4,5-Tetrachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,2,4-Trichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
1,2-Dichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
1,2-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
1,2-Dichloroethene (Total)	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
1,3,5-Trinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,3-Dichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
1,3-Dinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,4-Dichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area									
	575a	575b	580a	581a	581b	581c	581d	582a	582b	afp
Metals/Chemicals (mg/kg) (Continued)										
2-Benzyl Alcohol-4-chlorophenol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.30×10^{-1}
3,3'-Dichlorobenzidine	5.90×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	8.20×10^{-1}	4.10×10^{-1}	8.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.60×10^{-1}
3,3'-Dimethylbenzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-Methylphenol	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	1.70×10^{0}	4.40×10^{-1}	4.40×10^{-1}
4-Nitroaniline	1.45×10^{0}	9.80×10^{-1}	1.00×10^{0}	2.00×10^{0}	1.00×10^{0}	2.00×10^{0}	9.50×10^{-1}	1.00×10^{0}	1.10×10^{0}	1.10×10^{0}
7,12-Dimethylbenz(a)anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	7.02×10^{0}	1.20×10^{0}	1.20×10^{0}	2.51×10^{0}	1.71×10^{0}	3.70×10^{0}	2.90×10^{0}	1.79×10^{0}	1.20×10^{0}	1.20×10^{0}
Alpha-chlordane	5.00×10^{-2}	0.00	0.00	0.00	0.00	1.00×10^{-1}	5.00×10^{-2}	0.00	0.00	0.00
Aroclor 1254	3.31×10^{-2}	7.64×10^{-2}	5.22×10^{-2}	2.00×10^{-1}	3.04×10^{-1}	1.53×10^{-1}	7.64×10^{-2}	2.20×10^{-2}	2.20×10^{-2}	2.20×10^{-2}
Arsenic	6.27×10^{0}	6.20×10^{0}	8.20×10^{0}	8.29×10^{0}	6.18×10^{0}	5.52×10^{0}	5.84×10^{0}	9.43×10^{0}	4.94×10^{1}	8.01×10^{1}
Benzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
Benzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(a)anthracene	1.66×10^{0}	2.15×10^{-1}	1.13×10^{0}	2.16×10^{-1}	2.21×10^{-1}	2.15×10^{-1}	3.40×10^{-1}	2.17×10^{-1}	2.15×10^{-1}	2.15×10^{-1}
Benzo(a)pyrene	1.61×10^{0}	2.15×10^{-1}	1.08×10^{0}	2.16×10^{-1}	2.26×10^{-1}	2.15×10^{-1}	4.57×10^{-1}	2.16×10^{-1}	2.15×10^{-1}	2.15×10^{-1}
Benzo(b)fluoranthene	3.77×10^{-1}	2.10×10^{-1}	2.84×10^{-1}	2.11×10^{-1}	2.34×10^{-1}	2.10×10^{-1}	7.40×10^{-1}	2.11×10^{-1}	2.10×10^{-1}	2.10×10^{-1}
Benzo(g,h,i)perylene	2.20×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	6.40×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Benzo(k)fluoranthene	1.04×10^{0}	2.15×10^{-1}	7.34×10^{-1}	2.16×10^{-1}	2.31×10^{-1}	2.15×10^{-1}	5.77×10^{-1}	2.16×10^{-1}	2.15×10^{-1}	2.15×10^{-1}
Benzoic acid	9.80×10^{-1}	9.80×10^{-1}	1.00×10^{0}	6.00×10^{-2}	7.00×10^{-2}	6.00×10^{-2}	2.90×10^{-1}	6.80×10^{-1}	1.20×10^{-1}	1.20×10^{0}
Benzyl alcohol	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.20×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.50×10^{-1}
Beryllium	1.06×10^{0}	6.33×10^{-1}	1.03×10^{0}	6.53×10^{-1}	9.26×10^{-1}	4.10×10^{-1}	8.87×10^{-1}	1.27×10^{0}	3.64×10^{0}	3.91×10^{0}
Bis(2-chloroethoxy)methane	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Bis(2-chloroethyl)ether	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Bis(2-chloroisopropyl)ether	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Bis(2-ethylhexyl)phthalate	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}
Bis(chloromethyl)ether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromodichloromethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
Bromomethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
Cadmium	3.35×10^{0}	1.20×10^{0}	1.30×10^{0}	4.90×10^{-1}	1.60×10^{0}	4.80×10^{-1}	1.43×10^{0}	7.50×10^{-1}	7.40×10^{-1}	5.80×10^{-1}
Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorobenzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}

TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area									
	575a	575b	580a	581a	581b	581c	581d	582a	582b	afp
Metals/Chemicals (mg/kg) (Continued)										
Chlorobenzilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloroform	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
Chrysene	2.00×10^{0}	2.10×10^{-1}	1.35×10^{0}	2.11×10^{-1}	2.16×10^{-1}	2.10×10^{-1}	3.37×10^{-1}	2.12×10^{-1}	2.10×10^{-1}	2.10×10^{-1}
Dibenzo(a,h)anthracene	1.36×10^{-1}	7.40×10^{-2}	1.05×10^{-1}	7.42×10^{-2}	7.89×10^{-2}	7.40×10^{-2}	1.83×10^{-1}	7.49×10^{-2}	7.40×10^{-2}	7.40×10^{-2}
Dibenzofuran	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Dibromomethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dieldrin	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	0.00	2.00×10^{-2}	1.00×10^{-2}	0.00	0.00	0.00
Ethylbenzene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}
Gamma-chlordane	5.00×10^{-2}	0.00	0.00	0.00	0.00	1.00×10^{-1}	5.00×10^{-2}	0.00	0.00	0.00
Hexachlorobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Indeno(1,2,3-cd)pyrene	1.06×10^{0}	2.20×10^{-1}	7.42×10^{-1}	2.20×10^{-1}	2.39×10^{-1}	2.20×10^{-1}	6.47×10^{-1}	2.21×10^{-1}	2.20×10^{-1}	2.20×10^{-1}
Manganese	9.57×10^{2}	1.15×10^{3}	5.88×10^{2}	8.23×10^{2}	1.06×10^{3}	7.15×10^{2}	1.15×10^{3}	4.52×10^{2}	4.18×10^{2}	4.18×10^{2}
Mercury	5.50×10^{-2}	5.50×10^{-2}	5.50×10^{-2}	1.28×10^{-1}	9.29×10^{-2}	5.50×10^{-2}	5.50×10^{-2}	5.79×10^{-2}	7.44×10^{-2}	2.30×10^{-1}
Methylene chloride	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.37×10^{-3}	5.62×10^{-3}	8.57×10^{-3}	6.33×10^{-3}	1.71×10^{-3}	1.67×10^{-2}	1.10×10^{-1}
N-Nitroso-di-n-propylamine	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
Nitrobenzene	4.00×10^{-1}	3.90×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.10×10^{-1}	4.40×10^{-1}	4.40×10^{-1}
O-Dichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-Dimethylaminoazobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenanthrene	4.03×10^{-1}	2.15×10^{-1}	3.25×10^{-1}	2.17×10^{-1}	2.13×10^{-1}	2.15×10^{-1}	1.62×10^{-1}	2.16×10^{-1}	2.15×10^{-1}	2.15×10^{-1}
Silver	6.30×10^{-1}	4.70×10^{-1}	4.72×10^{-1}	8.24×10^{-1}	1.02×10^{0}	1.41×10^{0}	4.80×10^{-1}	6.13×10^{-1}	4.74×10^{-1}	4.70×10^{-1}
Trans-1,2-dichloroethene(total)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichloroethene	2.05×10^{-3}	2.19×10^{-3}	2.35×10^{-3}	2.04×10^{-3}	2.14×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}
Uranium - total	2.13×10^{1}	2.38×10^{1}	1.30×10^{1}	2.94×10^{1}	8.22×10^{1}	6.05×10^{1}	1.37×10^{2}	4.54×10^{1}	2.56×10^{1}	7.20×10^{0}
Zinc	3.50×10^{1}	5.58×10^{1}	6.63×10^{1}	5.72×10^{1}	4.88×10^{1}	2.56×10^{1}	1.07×10^{2}	4.90×10^{1}	4.96×10^{1}	6.78×10^{1}

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TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area										
	Pa1	Pa2	Pa3	Pa4	Pa5	Pa6	sf	sw1	wp1	wp2	wpaa
Radionuclides (pCi/g)											
Cesium-137	2.40×10^{-1}	2.80×10^{-1}	2.10×10^{-1}	3.50×10^{-1}	2.20×10^{-1}	7.00×10^{-1}	2.40×10^{-1}	3.30×10^{-1}	5.43×10^{0}	5.30×10^{-1}	2.00×10^{-1}
Neptunium-237	5.40×10^{-1}	5.00×10^{-1}	1.03×10^{0}	6.00×10^{-1}	5.40×10^{-1}	6.00×10^{-1}	2.20×10^{-1}	1.80×10^{-1}	3.68×10^{0}	3.80×10^{-1}	4.90×10^{-1}
Plutonium-238	6.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	6.00×10^{-1}	3.30×10^{-1}	6.00×10^{-1}	2.20×10^{-1}	2.90×10^{-1}	1.22×10^{0}	4.60×10^{-1}	1.50×10^{-1}
Plutonium-239/240	6.00×10^{-1}	6.00×10^{-1}	7.30×10^{-1}	6.00×10^{-1}	4.10×10^{-1}	6.00×10^{-1}	4.00×10^{-1}	3.00×10^{-1}	3.67×10^{0}	4.80×10^{-1}	1.60×10^{-1}
Radium-226	7.72×10^{1}	2.38×10^{2}	9.00×10^{-1}	1.89×10^{0}	9.00×10^{-1}	1.10×10^{0}	1.29×10^{1}	0.00	9.67×10^{-1}	0.00	2.26×10^{0}
Radium-228	2.57×10^{0}	9.70×10^{-1}	6.60×10^{-1}	6.80×10^{-1}	6.60×10^{-1}	7.30×10^{-1}	1.26×10^{0}	1.17×10^{0}	1.47×10^{0}	8.20×10^{-1}	5.50×10^{-1}
Strontium-90	9.16×10^{-1}	5.47×10^{-1}	5.74×10^{-1}	3.51×10^{0}	2.50×10^{-1}	5.01×10^{-1}	2.50×10^{-1}	0.00	3.60×10^{-1}	0.00	4.44×10^{-1}
Technetium-99	1.10×10^{0}	3.38×10^{0}	7.50×10^{0}	2.33×10^{0}	1.13×10^{0}	1.13×10^{0}	1.19×10^{0}	0.00	1.64×10^{1}	0.00	1.14×10^{0}
Thorium-228	3.40×10^{0}	8.30×10^{-1}	1.05×10^{0}	9.20×10^{-1}	7.10×10^{-1}	8.80×10^{-1}	1.15×10^{0}	1.17×10^{0}	1.68×10^{1}	2.77×10^{1}	1.37×10^{0}
Thorium-230	1.45×10^{2}	5.95×10^{2}	1.06×10^{3}	4.71×10^{1}	1.77×10^{0}	2.16×10^{0}	1.81×10^{1}	0.00	3.68×10^{1}	0.00	1.54×10^{1}
Thorium-232	5.66×10^{0}	1.20×10^{1}	5.96×10^{0}	2.44×10^{1}	8.88×10^{-1}	8.88×10^{-1}	8.96×10^{-1}	0.00	5.42×10^{0}	0.00	9.10×10^{-1}
Thorium-234	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uranium-234	3.08×10^{-3}	2.72×10^{-3}	1.48×10^{-2}	2.85×10^{-2}	1.18×10^{-3}	8.52×10^{-4}	6.07×10^{-4}	0.00	7.84×10^{-3}	0.00	9.20×10^{-4}
Uranium-235/236	4.04×10^{-1}	3.56×10^{-1}	1.94×10^{0}	3.73×10^{0}	1.54×10^{-1}	1.12×10^{-1}	7.95×10^{-2}	0.00	1.03×10^{0}	0.00	1.20×10^{-1}
Uranium-236	2.62×10^{1}	2.60×10^{-1}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uranium-238	5.61×10^{1}	4.94×10^{1}	2.69×10^{2}	5.18×10^{2}	2.14×10^{1}	1.55×10^{1}	1.10×10^{1}	0.00	1.43×10^{2}	0.00	1.67×10^{1}
Metals/Chemicals (mg/kg)											
1,1-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	2.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	0.00
1,1-Dichloroethene	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	1.00×10^{-2}
1,2,4,5-Tetrachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.30×10^{-1}	0.00	0.00	0.00
1,2,4-Trichlorobenzene	3.70×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
1,2-Dichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
1,2-Dichloroethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.50×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	1.00×10^{-2}
1,2-Dichloroethene (Total)	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	1.00×10^{-1}	1.00×10^{-2}
1,3,5-Trinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.30×10^{-1}	0.00	0.00	0.00
1,3-Dichlorobenzene	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
1,3-Dinitrobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.30×10^{-1}	0.00	0.00	0.00
1,4-Dichlorobenzene	3.70×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
2,3,7,8-Tetrachlorodibenzo-p-dioxin	4.00×10^{-2}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area										
	Pa1	Pa2	Pa3	Pa4	Pa5	Pa6	sf	sw1	wp1	wp2	wpaa
Metals/Chemicals (mg/kg) (Continued)											
2-Benzyl Alcohol-4-chlorophenol	0.00	0.00	0.00	0.00	0.00	0.00	4.30×10^{-1}	4.00×10^{-1}	0.00	0.00	3.60×10^{-1}
3,3'-Dichlorobenzidine	6.20×10^{-1}	5.70×10^{-1}	6.00×10^{-1}	4.80×10^{-1}	4.80×10^{-1}	3.80×10^{-1}	5.20×10^{-1}	5.20×10^{-1}	1.11×10^{0}	5.90×10^{-1}	5.90×10^{-1}
3,3'-Dimethylbenzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15×10^{0}	0.00	0.00	0.00
4-Methylphenol	3.40×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	3.50×10^{-1}	3.50×10^{-1}	5.30×10^{-1}	4.10×10^{-1}	3.80×10^{-1}
4-Nitroaniline	1.48×10^{0}	1.41×10^{0}	1.44×10^{0}	1.17×10^{0}	1.17×10^{0}	9.50×10^{-1}	1.43×10^{0}	1.25×10^{0}	2.79×10^{0}	2.03×10^{0}	1.00×10^{2}
7,12-Dimethylbenz(a)anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29×10^{0}	0.00	0.00	0.00
Antimony	1.73×10^{0}	1.85×10^{1}	1.20×10^{0}	3.13×10^{0}	1.20×10^{0}	1.20×10^{0}	1.20×10^{0}	0.00	2.35×10^{1}	0.00	2.64×10^{1}
Alpha-chlordane	1.20×10^{-1}	5.00×10^{-2}	5.00×10^{-2}	0.00	2.00×10^{-2}	0.00	2.00×10^{-2}	2.00×10^{-2}	0.00	9.00×10^{-2}	1.50×10^{-1}
Aroclor 1254	5.14×10^{0}	2.60×10^{0}	1.84×10^{0}	3.24×10^{0}	9.20×10^{-2}	3.75×10^{-2}	4.43×10^{-2}	0.00	8.71×10^{-1}	0.00	1.36×10^{-1}
Arsenic	1.00×10^{1}	7.38×10^{0}	7.44×10^{0}	6.82×10^{0}	7.67×10^{0}	7.38×10^{0}	6.59×10^{0}	0.00	6.36×10^{0}	0.00	5.54×10^{0}
Benzene	1.00×10^{-2}	2.00×10^{-2}	1.00×10^{-1}	1.50×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	1.00×10^{-2}
Benzidine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00×10^{0}	0.00	0.00	0.00
Benzo(a)anthracene	6.05×10^{0}	1.67×10^{0}	3.75×10^{0}	9.89×10^{-1}	3.60×10^{-1}	2.43×10^{-1}	4.27×10^{0}	0.00	5.11×10^{-1}	0.00	2.22×10^{-1}
Benzo(a)pyrene	7.85×10^{0}	2.11×10^{0}	4.66×10^{0}	9.25×10^{-1}	3.42×10^{-1}	2.39×10^{-1}	4.07×10^{0}	0.00	4.57×10^{-1}	0.00	2.21×10^{-1}
Benzo(b)fluoranthene	7.22×10^{0}	1.95×10^{0}	7.45×10^{0}	3.98×10^{-1}	4.07×10^{-1}	2.48×10^{-1}	5.37×10^{-1}	0.00	4.32×10^{-1}	0.00	2.15×10^{-1}
Benzo(g,h,i)perylene	7.80×10^{-1}	3.20×10^{-1}	5.50×10^{-1}	2.70×10^{-1}	4.50×10^{-1}	8.00×10^{-2}	1.50×10^{-1}	1.90×10^{-1}	4.70×10^{-1}	4.10×10^{-1}	2.68×10^{0}
Benzo(k)fluoranthene	7.86×10^{0}	2.11×10^{0}	7.49×10^{-1}	6.55×10^{-1}	3.78×10^{-1}	2.46×10^{-1}	2.52×10^{0}	0.00	5.11×10^{-1}	0.00	2.22×10^{-1}
Benzoic acid	2.78×10^{0}	1.11×10^{0}	8.80×10^{-1}	1.00×10^{0}	1.17×10^{0}	9.50×10^{-1}	3.20×10^{-1}	1.38×10^{0}	2.29×10^{0}	2.04×10^{0}	9.20×10^{-1}
Benzyl alcohol	3.40×10^{-1}	3.80×10^{-1}	3.80×10^{-1}	3.90×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.10×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
Beryllium	1.16×10^{0}	9.56×10^{-1}	1.22×10^{0}	1.19×10^{0}	8.92×10^{-1}	5.54×10^{-1}	8.06×10^{-1}	0.00	6.41×10^{-1}	0.00	6.81×10^{-1}
Bis(2-chloroethoxy)methane	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
Bis(2-chloroethyl)ether	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
Bis(2-chloroisopropyl)ether	3.40×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
Bis(2-ethylhexyl)phthalate	1.64×10^{0}	3.89×10^{-1}	2.97×10^{-1}	3.00×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	0.00	6.14×10^{-1}	0.00	3.01×10^{-1}
Bis(chloromethyl)ether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.20×10^{-1}	0.00	0.00
Bromodichloromethane	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.50×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	1.00×10^{-2}
Bromomethane	1.00×10^{-2}	1.30×10^{-1}	1.00×10^{-2}	3.10×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	6.70×10^{-1}	1.80×10^{-1}	1.00×10^{-2}
Cadmium	1.10×10^{0}	8.54×10^{-1}	1.04×10^{0}	2.18×10^{0}	4.90×10^{-1}	1.54×10^{0}	1.09×10^{0}	2.82×10^{0}	2.02×10^{0}	1.62×10^{0}	8.77×10^{-1}
Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10×10^{-1}	5.80×10^{-1}	4.00×10^{-1}	0.00
Chlorobenzene	1.00×10^{-2}	1.00×10^{-2}	0.00	1.50×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	3.30×10^{-1}	9.00×10^{-2}	1.00×10^{-2}

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TABLE G.3-1
(Continued)

Contaminants of Concern (COCs)	Area										
	Pa1	Pa2	Pa3	Pa4	Pa5	Pa6	sf	sw1	wp1	wp2	wpaa
Metals/Chemicals (mg/kg) (Continued)											
Chlorobenzilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00×10^{-2}	0.00	0.00	0.00
Chloroform	3.00×10^{-2}	1.00×10^{-2}	2.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	2.00×10^{-2}	2.90×10^{-1}	6.00×10^{-2}	1.00×10^{-2}
Chrysene	7.22×10^{0}	1.96×10^{0}	3.59×10^{0}	1.19×10^{0}	3.98×10^{-1}	2.46×10^{-1}	5.27×10^{0}	0.00	6.06×10^{-1}	0.00	2.20×10^{-1}
Dibenzo(a,h)anthracene	2.29×10^{0}	6.26×10^{-1}	1.34×10^{0}	1.20×10^{-1}	1.00×10^{-1}	7.90×10^{-2}	2.11×10^{-1}	0.00	1.30×10^{-1}	0.00	7.54×10^{-2}
Dibenzofuran	2.20×10^{-1}	3.30×10^{-1}	3.10×10^{-1}	2.70×10^{-1}	3.20×10^{-1}	3.80×10^{-1}	3.20×10^{-1}	6.60×10^{-1}	4.70×10^{-1}	4.30×10^{-1}	1.44×10^{0}
Dibromomethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00×10^{-2}	0.00	0.00	0.00
Dieldrin	2.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	0.00	1.00×10^{-2}	0.00	1.00×10^{-2}	2.00×10^{-2}	1.20×10^{-1}	6.00×10^{-2}	3.00×10^{-2}
Ethylbenzene	5.00×10^{-2}	1.10×10^{-1}	1.10×10^{-1}	1.50×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	2.80×10^{-1}	3.00×10^{-2}	1.00×10^{-2}
Gamma-chlordane	1.20×10^{-1}	5.00×10^{-2}	5.00×10^{-2}	0.00	2.00×10^{-2}	0.00	3.00×10^{-2}	2.00×10^{-2}	0.00	9.00×10^{-2}	1.50×10^{-1}
Hexachlorobenzene	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
Indeno(1,2,3-cd)pyrene	5.69×10^{0}	1.56×10^{0}	2.56×10^{0}	6.57×10^{-1}	2.00×10^{-1}	2.16×10^{-1}	2.54×10^{0}	0.00	3.36×10^{-1}	0.00	2.23×10^{-1}
Manganese	5.73×10^{2}	6.18×10^{2}	5.58×10^{2}	5.85×10^{2}	9.15×10^{2}	8.17×10^{2}	7.51×10^{2}	0.00	5.92×10^{2}	0.00	6.72×10^{2}
Mercury	1.40×10^{-1}	1.27×10^{-1}	1.14×10^{-1}	1.35×10^{-1}	5.50×10^{-2}	7.95×10^{-2}	5.50×10^{-2}	0.00	5.50×10^{-2}	0.00	5.50×10^{-2}
Methylene chloride	5.01×10^{-3}	1.98×10^{-3}	2.24×10^{-3}	1.96×10^{-3}	1.00×10^{-3}	1.86×10^{-3}	1.00×10^{-3}	0.00	1.60×10^{-2}	0.00	2.26×10^{-3}
N-Nitroso-di-n-propylamine	3.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.50×10^{-1}	2.07×10^{1}
Nitrobenzene	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	3.80×10^{-1}	4.00×10^{-1}	3.90×10^{-1}	5.60×10^{-1}	4.60×10^{-1}	2.07×10^{1}
O-Dichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-Dimethylaminoazobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90×10^{0}	0.00	0.00	0.00
Phenanthrene	3.31×10^{0}	1.00×10^{0}	4.39×10^{0}	3.66×10^{-1}	5.04×10^{-1}	2.70×10^{-1}	7.05×10^{-1}	0.00	7.86×10^{-1}	0.00	2.29×10^{-1}
Silver	4.02×10^{0}	2.99×10^{0}	1.46×10^{0}	3.75×10^{0}	1.10×10^{0}	7.74×10^{-1}	2.28×10^{0}	0.00	6.23×10^{0}	0.00	5.10×10^{0}
Trans-1,2-dichloroethene(total)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20×10^{-1}	2.80×10^{-1}	0.00	0.00
Trichloroethene	3.95×10^{-3}	7.96×10^{-3}	7.53×10^{-3}	5.04×10^{-3}	3.00×10^{-3}	2.26×10^{-3}	2.00×10^{-3}	0.00	2.00×10^{-3}	0.00	2.00×10^{-3}
Uranium - total	1.68×10^{2}	1.48×10^{2}	8.06×10^{2}	1.55×10^{3}	6.41×10^{1}	4.65×10^{1}	3.31×10^{1}	0.00	4.28×10^{2}	0.00	5.02×10^{1}
Zinc	8.08×10^{1}	1.39×10^{2}	5.50×10^{1}	7.63×10^{1}	6.07×10^{1}	7.06×10^{1}	4.44×10^{1}	5.92×10^{1}	7.18×10^{1}	9.44×10^{1}	4.85×10^{1}

TABLE G.3-2

SHORT-TERM RISK ASSESSMENT EXPOSURE PATHWAY AND RECEPTOR MATRIX FOR OPERABLE UNIT 5

(Capitalization denotes emphasis on important entries.)

		Receptor[a]				
Component	**Pathway**	**SRW**	**SNW**	**ORW**	**NP**	**PT**
Excavation	Soil ingestion	ac[b]	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	Q	mp	n/a	mp	n/a
	Inhalation	QTP,QEE	QTP,QEE	n/a	QTP,QEE	n/a
	Deposition on body surface	ppe	mp	n/a	n/a	n/a
Off-site disposal	Soil ingestion	ac	n/a	ec	n/a	n/a
	Dermal contact	ppe	n/a	ec	n/a	QTA
	Direct exposure to penetrating radiation	Q	mp	Q	n/a	QTA
	Inhalation	QTP,QEE	QTP,QEE	ec	QTP,QEE	QTA
	Deposition on body surface	ppe	n/a	ec	n/a	QTA
Consolidation	Soil ingestion	ac	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	Q	mp	n/a	n/a	n/a
	Inhalation	QTP,QEE	QTP,QEE	n/a	QTP,QEE	n/a
	Deposition on body surface	ppe	n/a	n/a	n/a	n/a

TABLE G.3-2
(Continued)

Component	Pathway	Receptor[a]				
		SRW	SNW	ORW	NP	PT
On-site disposal facility	Soil ingestion	ac	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	Q	mp	n/a	n/a	n/a
	Inhalation	QTP,QEE	QTP,QEE	n/a	QTP,QEE	n/a
	Deposition on body surface	ppe	n/a	n/a	n/a	n/a
Soil backfill	Soil ingestion	n/a	n/a	n/a	n/a	n/a
	Dermal contact	n/a	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	n/a	n/a	n/a	n/a	n/a
	Inhalation	QEE	QEE	n/a	QEE	n/a
	Deposition on body surface	n/a	n/a	n/a	n/a	n/a
Groundwater monitoring	Water ingestion	ac	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	mp	n/a	n/a	n/a	n/a
	Inhalation	mp	mp	n/a	n/a	n/a
	Deposition on body surface	ppe	n/a	n/a	n/a	n/a
Great Miami Aquifer extraction	Water ingestion	ac,ec	n/a	n/a	n/a	n/a
	Dermal contact	ppe,ec	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	mp	n/a	n/a	n/a	n/a
	Inhalation	ec	mp	n/a	n/a	n/a
	Deposition on body surface	ec	n/a	n/a	n/a	n/a

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TABLE G.3-2
(Continued)

Component	Pathway	Receptor[a]				
		SRW	SNW	ORW	NP	PT
Water treatment	Water ingestion	ac	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	mp	n/a	n/a	n/a	n/a
	Inhalation	ec	mp	n/a	n/a	n/a
	Deposition on body surface	ec	n/a	n/a	n/a	n/a
Contaminated soil interim storage	Soil ingestion	ac	n/a	n/a	n/a	n/a
	Dermal contact	ppe	n/a	n/a	n/a	n/a
	Direct exposure to penetrating radiation	Q	mp	n/a	n/a	n/a
	Inhalation	QTP,QEE	QTP,QEE	n/a	QTP,QEE	n/a
	Deposition on body surface	ppe	n/a	n/a	n/a	n/a

[a] Receptor code:
SRW - On-site remedial worker
SNW - On-site nonremedial worker
ORW - Off-site remedial worker
NP - Near-property public
PT - Public along transportation route

[b] Key to table entries:
ac - Mitigated by administrative controls, not quantified
ec - Mitigated by engineering controls, not quantified
mp - Minor pathway, not quantified
n/a - Not applicable
ppe - Mitigated by personal protective equipment
Q - Quantified
QEE - Quantified for engine emissions
QTA - Quantified for transportation accidents only
QTP - Quantified for total suspended particulates

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TABLE G.3-3

EXPOSURE PARAMETERS USED IN SHORT-TERM RISK ASSESSMENT[a]

Exposure Route Parameter	Units	Receptors: Remediation Worker	Receptors: Nonremediation Worker	Receptors: Near Property Public: Carcinogenic Effects	Receptors: Near Property Public: Toxic Effects
Inhalation[b]					
Inhalation rate (IR)	(m^3/h)	2.5	0.83	0.83	0.5
Exposure time (ET)	(h/d)	8[c]	8	5.7	5.7
Exposure frequency (EF)	(d/y)	250	250	350	350
Exposure duration (ED)	(y/Life)	22	22	22	6
Averaging time for carcinogens (AT)	(d/Life)	25550	25550	25550	NA[d]
Averaging time for toxins (AT)	(d/Life)	8030	8030	NA	2190
Mass of receptor	(kg)	70	70	70	15
Direct radiation exposure[e]					
Dose rate (DR)	(mSv/h)	Varies[f]	NQ[g]	NQ	NQ
Indoor exposure time (ET)	(h/d)	0	NQ	NQ	NQ
Indoor shielding factor (S)	(unitless)	0.5	NQ	NQ	NQ
Outdoor exposure time (ET)	(h/d)	8	NQ	NQ	NQ
Outdoor shielding factor (S_o)	(unitless)	0	NQ	NQ	NQ
Exposure frequency (EF)	(d/y)	250	NQ	NQ	NQ
Exposure duration (ED)	(y/Life)	22	NQ	NQ	NQ

[a]All parameter values are taken from Table A.3-20 of the Operable Unit 5 Baseline Risk Assessment (DOE 1995d).
[b]Inhalation of radiologicals calculated using Equation G.3-1. Inhalation of chemicals calculated using Equation G.3-2.
[c]The remedial worker is assumed to be located in the prevailing downwind position for 8 hours a day. Since the wind blows in this direction for about 37 percent of the year, an exposure time of 3 hours was used for inhalation calculations.
[d]Not applicable.
[e]External dose from direct radiation exposure calculated using Equation G.3-3; incremental lifetime cancer risk attributed to direct radiation exposure from soil calculated using Equation G.3-7.
[f]Measured or calculated value dependent on the strength of the ambient radiation field.
[g]Not quantified

TABLE G.3-4

OCCUPATIONAL AND NONOCCUPATIONAL TRANSPORTATION INJURY AND FATALITY HAZARD COEFFICIENTS[a]

	Fatality Coefficient $(mile)^{-1}$	Injury Coefficient $(mile)^{-1}$
Train		
Off-Site Remediation Worker	4.6×10^{-8}	4.6×10^{-6}
Public Along Transportation Route[b]	1.8×10^{-6}	6.8×10^{-6}
Truck		
Off-Site Remediation Worker	2.1×10^{-9}	4.1×10^{-8}
Public Along Transportation Route	1.3×10^{-8}	1.2×10^{-7}

[a] (DOT 1988)
[b] The public includes passengers, off-duty workers, pedestrians, and drivers and passengers in other vehicles, etc.

TABLE G.3-5

ESTIMATES OF PERSON HOURS USED TO ASSESS RISKS FOR MECHANICAL HAZARDS TO ON-SITE REMEDIATION WORKERS

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	Excavation	3,571,050	1,025,627	-[a]	-	-	-	-	-	-
	Off-site Disposal	1,881,189	780,309	-	-	-	-	-	-	-
	Backfill	2,153,693	879,139	-	-	-	-	-	-	-
	GW Extraction	155,765	131,742	-	-	-	-	-	-	-
	GW Treatment	8,063,331	2,579,393	-	-	-	-	-	-	-
	Central Storage	309,206	309,206	-	-	-	-	-	-	-
	Sum:	**16,134,234**	**5,705,416**	-	-	-	-	-	-	-
2A	Excavation	3,571,050	1,025,627	-	-	-	-	-	-	-
	Disposal Facility	4,226,801	1,265,418	-	-	-	-	-	-	-
	Off-site Disposal	b	b	-	-	-	-	-	-	-
	Backfill	2,153,693	879,139	-	-	-	-	-	-	-
	GW Extraction	155,765	131,742	-	-	-	-	-	-	-
	GW Treatment	8,063,331	2,579,393	-	-	-	-	-	-	-
	Central Storage	309,206	309,206	-	-	-	-	-	-	-
	Sum:	**18,479,846**	**6,190,525**	-	-	-	-	-	-	-
2C	Excavation	3,571,050	1,025,627	-	-	-	-	-	-	-
	Disposal Facility	0	938,863	-	-	-	-	-	-	-
	Off-site Disposal	1,881,189	583,893	-	-	-	-	-	-	-
	Backfill	2,153,693	879,139	-	-	-	-	-	-	-
	GW Extraction	155,765	131,742	-	-	-	-	-	-	-
	GW Treatment	8,063,331	2,579,393	-	-	-	-	-	-	-
	Central Storage	309,206	309,206	-	-	-	-	-	-	-
	Sum:	**16,134,234**	**6,447,863**	-	-	-	-	-	-	-

TABLE G.3-5
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
3A	Excavation	-	-	896,699	826,709	823,025	675,678	679,361	-	-
	Disposal Facility	-	-	1,252,569	1,000,475	1,000,475	1,000,475	1,000,475	-	-
	Off-Site Disposal	-	-	b	b	b	b	b	-	-
	Backfill	-	-	791,982	355,781	360,861	690,390	674,305	-	-
	GW Extraction	-	-	131,742	131,742	131,742	131,742	131,742	-	-
	GW Treatment	-	-	2,579,393	2,579,393	2,579,393	2,579,393	2,579,393	-	-
	Central Storage	-	-	309,206	309,206	309,206	309,206	309,206	-	-
	Sum:	-	-	**5,961,591**	**5,203,306**	**5,204,702**	**5,386,884**	**5,374,482**	-	-
3C	Excavation	-	-	896,699	826,669	823,025	675,678	679,361	-	-
	Consolidation with Cover	-	-	927,770	612,712	612,712	612,712	612,712	-	-
	Off-site Disposal	-	-	582,309	579,141	577,557	577,557	577,557	-	-
	Backfill	-	-	791,982	355,781	360,861	690,360	674,305	-	-
	GW Extraction	-	-	131,742	131,742	131,742	131,742	131,742	-	-
	GW Treatment	-	-	2,579,393	2,579,393	2,579,393	2,579,393	2,579,393	-	-
	Central Storage	-	-	309,206	309,206	309,206	309,206	309,206	-	-
	Sum:	-	-	**6,219,101**	**5,394,644**	**5,399,496**	**5,576,648**	**5,564,276**	-	-
4A	Excavation	-	-	-	-	-	-	-	823,025	675,678
	Disposal Facility	-	-	-	-	-	-	-	1,000,475	1,000,475
	Off-site Disposal	-	-	-	-	-	-	-	b	b
	Backfill	-	-	-	-	-	-	-	355,781	693,777
	GW Extraction	-	-	-	-	-	-	-	131,742	131,742
	GW Treatment	-	-	-	-	-	-	-	2,579,393	2,579,393
	Central Storage	-	-	-	-	-	-	-	309,206	309,206
	Sum:	-	-	-	-	-	-	-	**5,199,622**	**5,390,271**

TABLE G.3-5
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
4C	Excavation	-	-	-	-	-	-	-	823,025	675,678
	Consolidation with Cover	-	-	-	-	-	-	-	612,712	612,712
	Off-site Disposal	-	-	-	-	-	-	-	577,557	577,557
	Backfill	-	-	-	-	-	-	-	355,781	693,777
	GW Extraction	-	-	-	-	-	-	-	131,742	131,742
	GW Treatment	-	-	-	-	-	-	-	2,579,393	2,579,393
	Central Storage	-	-	-	-	-	-	-	309,206	309,206
	Sum:	-	-	-	-	-	-	-	**5,389,416**	**5,580,065**

[a] NA - Not applicable.
[b] Included in Central Storage Operations.

TABLE G.3-6
OCCUPATIONAL INJURY[a] AND FATALITY[b] HAZARD COEFFICIENTS

Feasibility Study Component	Description of Occupation	SIC Code[c]	1992 Department of Labor Statistics: Annual Average Employment	Injury Coefficient $(person\text{-}hr)^{-1}$	Fatality Coefficient $(person\text{-}hr)^{-1}$
Excavation, Backfill, On-site Disposal, Loading for Off-site Disposal, and Central Storage Ops.	Heavy construction, except building contractors	16	711,200	2.7×10^{-5}	1.7×10^{-7}
GW Extraction	Special trade contractors	17	2,696,000	3.0×10^{-5}	9.1×10^{-8}
GW Treatment	Sanitary services	49	954,700	1.8×10^{-5}	4.5×10^{-8}

[a] DOL 1994a
[b] DOL 1994b
[c] SIC Standard Industrial Classification

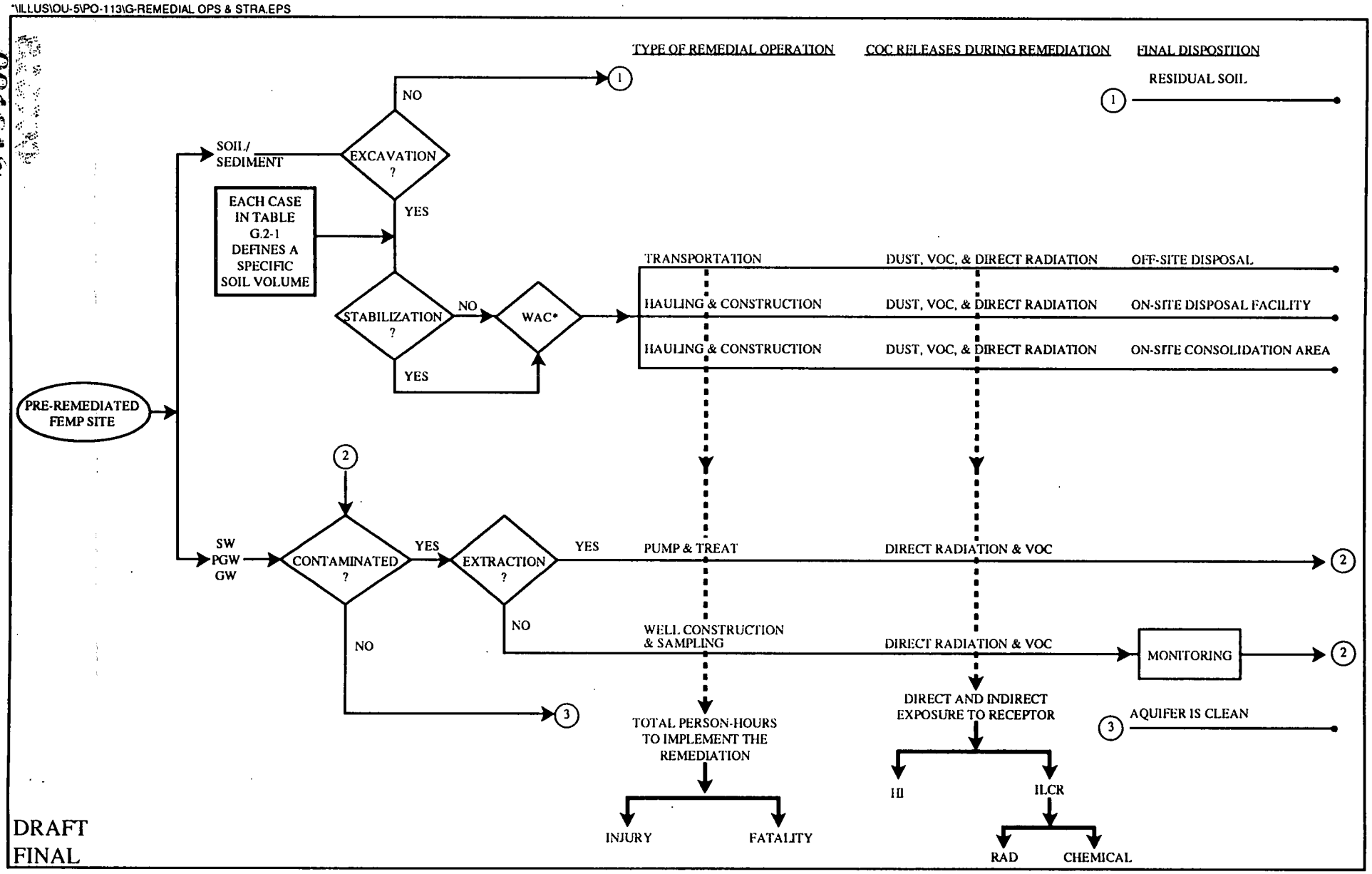

FIGURE G.3-1. INFLUENCE OF THE REMEDIAL OPERATIONS ON THE RISKS EVALUATED BY THE SHORT-TERM RISK ASSESSMENT

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G.4.0 RISK CHARACTERIZATION

Each remedial alternative involves a set of work activities, called components, in this study. These activities will produce varying degrees of mechanical hazard and human health risk. This section presents the results of the risk calculations by remedial action alternative. Sections G.2.1 and G.2.2 discussed the proposed remedial action alternatives and potential exposures during remediation, respectively. Mechanical hazards and cancer incidence risks are calculated using the remedial action components designed according to a particular remedial alternative as described in the Operable Unit 5 FS. Detailed example intermediate calculations are presented in Attachment G.II. Human health impacts from chemical and radiological carcinogens, as well as health effects from toxicants, are presented in Section G.4.1 for an on-site remediation worker, an on-site nonremediation worker, an off-site remediation worker, the near-property public, and the public along the transportation route for off-site disposal. Section G.4.2 contains estimates of mechanical hazards for these same five receptors. In addition, human health risks to the public and workers resulting from transportation accidents are also quantified.

To help the reader locate specific information, Table G.4-1 identifies the receptors that are quantitatively evaluated for specified pathways by listing the table number(s) on which the results are located.

G.4.1 HUMAN HEALTH IMPACTS OF REMEDIAL ACTIONS

This section contains the estimates of risk to human health from remedial activities. Results are presented for various components in tabular form, while the text discusses the salient points of these results. These health effects are estimated using methods and guidance as discussed in Section G.3.0.

G.4.1.1 Human Health Effects to the Near-Property Public

This receptor is postulated to be a farmer living just outside the site fence. The near-property public is potentially at risk through inhalation of contaminated dust, VOCs, and diesel exhaust. This pathway is quantitatively evaluated as described in Section G.3.0 and the results are shown by alternative and component in Table G.4-2. The cancer incidence calculations resulted in risks of less than 10^{-6} in all cases, while the companion toxic effects were well below an HI of 0.01. In addition, the radiocarcinogenic risks are consistently higher then the chemocarcinogenic risks in each case, and the highest carcinogenic risk sums are associated with Case 1 under Alternatives 1, 2A, and 2C.

The values in the table are for an individual member of the public. As an example, the calculated risk of cancer for this receptor in Case 1, Alternative 2A is 6.8×10^{-7} (Table G.4-2). This means that if Alternative 2A is implemented, the possibility that a member of the public would develop some form of cancer due to the off-site disposal is seven in ten million.

G.4.1.2 Human Health Effects to the On-Site Nonremediation Worker

This receptor is assumed to be an administrative person who works on the property for 8 hours per day, but does not participate directly with the remedial activities. The on-site nonremediation worker is potentially at risk through inhalation of contaminated resuspended dust, VOCs, and diesel engine exhaust. This pathway is quantitatively evaluated as described in Section G.3.0. The cancer incidence risk results for the on-site nonremediation worker are less than 10^{-6} in all cases (Table G.4-2). Toxic effect calculations indicate the HI from remedial activities would be well below 0.01 in all cases. The radiocarcinogenic risks are consistently higher than the chemocarcinogenic risks in each case. The highest carcinogenic risk sums are associated with Case 1 under Alternatives 1, 2A, and 2C.

G.4.1.3 Human Health Effects to the On-Site Remediation Worker

This receptor is potentially subject to human health risk from inhalation, dermal contact, incidental ingestion of soil, and external radiation exposure during participation in remedial tasks. Dermal contact and incidental ingestion of soil are assumed to be minimized by the application of administrative controls and an appropriate level of personal protective equipment. These controls will be stipulated by the health physics and industrial hygiene personnel monitoring the actions in accordance with 29 CFR 1910.120, 10 CFR 20, and 10 CFR 835. Exposures along the dermal and ingestion routes are not quantified because it is felt that they would be limited by these controls and therefore be much smaller than the exposures associated with the two pathways selected for quantification. Risks to the worker from external radiation exposure are quantified using Microshield computer software, as described in Attachment G.I, and Section G.3.0; inhalation risks are quantified using methods also described in Section G.3.0. Table G.4-3 lists inhalation and external radiation risk estimates for remediation workers involved with the four major remedial components considered. Human health risks from other components, such as water extraction, are considered to be much less than the risks from the four selected components and were not quantified. Because the same worker cannot participate in two different activities simultaneously, risks for each component are presented separately.

Toxic effect calculations indicate the HI from each component would be greater than 1.0. Within each component there is less than a factor of 3 variation in the calculated carcinogenic risk sum among the cases evaluated. Carcinogenic risks from inhalation are in the range of 10^{-4} to 10^{-3}. The results indicate that advanced levels of personal protective equipment may be appropriate under certain conditions. The radiocarcinogenic inhalation risks are consistently higher than the chemocarcinogenic inhalation risks. The cancer risk and HI results are of the same magnitude among the four remedial components presented in Table G.4-3.

G.4.1.4 Human Health Effects to the Off-Site Remediation Worker

This receptor is potentially subject to human health risks from external radiation exposure, as shown in Figure G.2-1. Risks to this worker from external radiation exposure are quantified using RADTRAN.

Attachment G.I.2 describes RADTRAN in detail and the last column in Table G.4-4 presents results for each alternative. The calculated risks shown for this receptor are individual risks associated with routine accident-free transportation. Risks from all cases are greater than the 10^{-6} point of departure.

G.4.1.5 Human Health Effects to the Public Along Transportation Route

The public along the route between the FEMP site and the off-site disposal location is potentially at risk to external radiation exposure. Carcinogenic risks from this pathway are quantitatively evaluated for the public as a group using RADTRAN, as described in Attachment G.I.2. The values shown for external radiological risks in Table G.4-4 are the calculated risks for each alternative. Risks calculated for all cases are in the 10^{-7} order of magnitude or lower for the public along the transportation route, assuming routine accident-free transportation.

G.4.1.6 Human Health Risks to Public and Workers from Transportation Accidents

This receptor group includes all persons who may be affected in the hypothetical situation of an accident. This includes the crew of the train (off-site remediation workers) and the public in the vicinity of the accident. Carcinogenic risks to individuals in these two groups are calculated by using RADTRAN and consider external radiation and inhalation hazards resulting from one accident. RADTRAN is described in detail Attachment G.I.2. The human health risk results from one such accident are below 10^{-6} in all cases (Table G.4-5).

G.4.2 MECHANICAL HAZARDS OF REMEDIAL ACTIONS

464 The mechanical hazards examined in this section include accidents resulting in injury or fatality to the on- and off-site remediation workers and the public along the transportation route. The hazards are examined collectively for each category of workers and collectively for the public along the transportation route for off-site disposal. These results represent the average number of injuries and fatalities that may be expected to occur over the 22-year period of remediation. Thus a fractional result of 0.5 in a table listing fatalities means that, on average, two such operations (or one operation twice the size) can be expected to produce one fatality.

G.4.2.1 On-Site Remediation Workers

The on-site remediation worker is subject to mechanical hazards by participating in remedial activities. For example, workers use machinery to excavate and relocate materials. As discussed in Section G.3.0, these hazards are linearly proportional to the person-hours required to perform the remedial action. Injuries and fatalities for the on-site remediation workers are presented by component in Tables G.4-6 and G.4-7, respectively for each alternative.

The projected incidence of injuries and fatalities is higher for Case 1 than for the other cases. Injuries and fatalities for specific components vary little between the remaining cases. However, Case 1

produces three to four times the number of injuries and fatalities as the other eight cases (Tables G.4-6 and G.4-7). The variation is due to the highly conservative criteria associated with Case 1, including the target receptor and cleanup level (Table G.1-1). These two criteria would require the excavation of the entire site and much of the surrounding property. Because the injuries and fatalities are directly proportional to the number of person-hours required to complete the remedial activities, greater excavated volumes lead to greater numbers of injuries and fatalities.

G.4.2.2 Off-Site Receptors

Transportation-related injuries and fatalities to off-site remediation workers and the public along the transportation route are calculated using the distance to a representative off-site disposal facility. This allows one to compare the results among the alternatives and cases. For this purpose, the actual disposal facility selected is irrelevant in that the ratios among the injury and fatality numbers would remain constant regardless of which disposal facility is selected.

Accidents include, but are not limited to, train derailments and collisions with motor vehicles. These possibilities are quantified using the method described in Section G.3.4. The results are linearly proportional to the round-trip miles required to transport the materials to the off-site disposal facility. A "round trip" is defined as the path/distance from the FEMP site to the representative disposal facility and back to the FEMP site. The round trips required to complete the off-site disposal for each alternative are shown in Table G.4-8. Results of the calculations do not include mileage during on-site hauling.

G.4.2.2.1 Off-Site Remediation Workers

The off-site remediation workers are postulated to be workers associated with the transportation of materials to the off-site disposal facility. Mechanical hazards to these workers are from potential accidents that occur during transportation. Results are shown in Table G.4-9 and include both injuries and fatalities to these workers.

The calculated collective injuries and fatalities for the workers due to off-site disposal do not vary significantly between most cases, the exceptions being Cases 1 and 2. The primary reason for this is that the volumes of soil designated for off-site disposal are significantly higher for these two cases, resulting in a greater number of round trips. In short, large volumes precipitate large numbers of round trips and, therefore, comparatively large numbers of injuries and fatalities. In these tables, worker fatalities are less than 1 (<1) per alternative for each case.

G.4.2.2.2 Public Along Transportation Route

Members of the public who live along the transportation route for off-site disposal are potentially subject to mechanical hazards from accidents during transportation. The results are linearly proportional to the miles required to transport the materials to the representative off-site disposal facility. Results are

presented in Table G.4-10 and include both injuries and fatalities to the public along the representative transport route.

For members of the public, calculated collective injuries and fatalities remain fairly constant between cases, with the obvious exception of Case 1, which ranges up to approximately 80 times higher than the other cases. As highlighted above, this is due to the significantly greater volumes of soil being disposed off site. As is true of other hazards calculated using this method, the greater the number of miles (i.e., round trips) required to perform the remedial action, the greater the number of injuries and fatalities.

TABLE G.4-1

SECTIONS DESCRIBING RECEPTORS QUANTITATIVELY EVALUATED FOR SPECIFIED PATHWAYS

Remedial Action Exposure Pathway	Type of Risk	On-Site Remediation Worker	On-Site Non-Remediation Worker	Off-Site Remediation Worker	Near-Property Public	Public Along Transportation Route	Public and Workers in Accident
Injuries and Fatalities from Mechanical Hazards During Remediation	Mechanical Risks (Calculated per Person-hour)	G.4.2.1	NA	NA	NA	NA	NA
	Transportation Risks (Calculated per Mile)	NA	NA	G.4.2.2.1	NA	G.4.2.2.2	NA
Inhalation of Contaminated Resuspended Dusts, VOCs, and Diesel Engine Exhaust	Radiological and Chemocarcinogenic Risk and HI	G.4.1.3	G.4.1.2	NA	G.4.1.1	NA	G.4.1.6
Direct Exposure to Penetrating Radiation	Surface Soil Risk	G.4.1.3	NA	NA	NA	NA	NA
	Routine - From Waste or Truck/Train	NA	NA	G.4.1.4	NA	G.4.1.5	NA
	Accident - From Waste or Truck/Train	NA	NA	G.4.1.6	NA	NA	G.4.1.6

TABLE G.4-2

PROJECTED HUMAN HEALTH EFFECTS OF PROPOSED REMEDIAL ACTION ON HYPOTHETICAL NONREMEDIATION WORKERS AND NEAR-PROPERTY PUBLIC

Alternative	Case	Health Effect	Nonremediation Worker	Near Property Public
1	1	Radiocarcinogenic Risk	8.1×10^{-7}	5.8×10^{-7}
		Chemocarcinogenic Risk	9.6×10^{-8}	7.3×10^{-8}
		Carcinogenic Sum	**9.0×10^{-7}**	**6.6×10^{-7}**
		Hazard Index	**6.5×10^{-3}**	**1.5×10^{-2}**
	2	Radiocarcinogenic Risk	4.5×10^{-7}	3.8×10^{-7}
		Chemocarcinogenic Risk	5.3×10^{-8}	4.4×10^{-8}
		Carcinogenic Sum	**5.1×10^{-7}**	**4.2×10^{-7}**
		Hazard Index	**2.9×10^{-3}**	**6.6×10^{-3}**
2A	1	Radiocarcinogenic Risk	8.1×10^{-7}	6.0×10^{-7}
		Chemocarcinogenic Risk	9.7×10^{-8}	7.4×10^{-8}
		Carcinogenic Sum	**9.0×10^{-7}**	**6.8×10^{-7}**
		Hazard Index	**6.3×10^{-3}**	**1.3×10^{-2}**
	2	Radiocarcinogenic Risk	4.6×10^{-7}	3.9×10^{-7}
		Chemocarcinogenic Risk	5.3×10^{-8}	4.6×10^{-8}
		Carcinogenic Sum	**5.1×10^{-7}**	**4.3×10^{-7}**
		Hazard Index	**2.9×10^{-3}**	**6.8×10^{-3}**
2C	1	Radiocarcinogenic Risk	8.1×10^{-7}	5.8×10^{-7}
		Chemocarcinogenic Risk	9.6×10^{-8}	7.2×10^{-8}
		Carcinogenic Sum	**9.0×10^{-7}**	**6.5×10^{-7}**
		Hazard Index	**6.3×10^{-3}**	**1.3×10^{-2}**
	2	Radiocarcinogenic Risk	4.6×10^{-7}	4.4×10^{-7}
		Chemocarcinogenic Risk	5.3×10^{-8}	5.2×10^{-8}
		Carcinogenic Sum	**5.1×10^{-7}**	**4.9×10^{-7}**
		Hazard Index	**2.9×10^{-3}**	**7.7×10^{-3}**
3A	3	Radiocarcinogenic Risk	3.8×10^{-7}	3.2×10^{-7}
		Chemocarcinogenic Risk	3.1×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**4.1×10^{-7}**	**3.4×10^{-7}**
		Hazard Index	**2.6×10^{-3}**	**5.8×10^{-3}**
	4	Radiocarcinogenic Risk	3.6×10^{-7}	3.0×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.1×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.2×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**4.8×10^{-3}**
	5	Radiocarcinogenic Risk	3.6×10^{-7}	3.0×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.1×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.2×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**4.8×10^{-3}**
	6	Radiocarcinogenic Risk	3.8×10^{-7}	3.2×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.4×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.1×10^{-3}**

Alternative	Case	Health Effect	Nonremediation Worker	Near Property Public
	7	Radiocarcinogenic Risk	3.8×10^{-7}	3.2×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.4×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.1×10^{-3}**
3C	3	Radiocarcinogenic Risk	3.8×10^{-7}	3.6×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.8×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.9×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**6.6×10^{-3}**
	4	Radiocarcinogenic Risk	3.6×10^{-7}	3.3×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.6×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**5.3×10^{-3}**
	5	Radiocarcinogenic Risk	3.6×10^{-7}	3.3×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.6×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**5.3×10^{-3}**
	6	Radiocarcinogenic Risk	3.8×10^{-7}	3.6×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.6×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.8×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.7×10^{-3}**
	7	Radiocarcinogenic Risk	3.8×10^{-7}	3.6×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.6×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.8×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.8×10^{-3}**
4A	8	Radiocarcinogenic Risk	3.6×10^{-7}	3.0×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.1×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.2×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**4.8×10^{-3}**
	9	Radiocarcinogenic Risk	3.8×10^{-7}	3.2×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.4×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.1×10^{-3}**
4C	8	Radiocarcinogenic Risk	3.6×10^{-7}	3.3×10^{-7}
		Chemocarcinogenic Risk	2.8×10^{-8}	2.4×10^{-8}
		Carcinogenic Sum	**3.9×10^{-7}**	**3.6×10^{-7}**
		Hazard Index	**2.3×10^{-3}**	**5.3×10^{-3}**
	9	Radiocarcinogenic Risk	3.8×10^{-7}	3.6×10^{-7}
		Chemocarcinogenic Risk	2.7×10^{-8}	2.6×10^{-8}
		Carcinogenic Sum	**4.0×10^{-7}**	**3.8×10^{-7}**
		Hazard Index	**2.4×10^{-3}**	**5.7×10^{-3}**

Note: The number of significant figures used is provided for comparative purposes, and does not reflect the accuracy of the results.

TABLE G.4-3

HUMAN HEALTH EFFECTS TO THE ON-SITE REMEDIATION WORKER PERFORMING THE FOUR REMEDIAL ACTIVITIES WITH THE GREATEST POTENTIAL TO PRODUCE DUST

Alternative	Case	Health Effect	Excavation	Loading for Off-site Disposal	On-site Disposal Consolidation	On-site Disposal Facility
1	1	Inhalation radiocarcinogenic risk	1.8×10^{-3}	3.9×10^{-3}	NA	NA
		Inhalation chemocarcinogenic risk	2.2×10^{-4}	4.8×10^{-4}	NA	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	NA
		Carcinogenic sum	**2.3×10^{-3}**	**4.6×10^{-3}**	NA	NA
		Hazard index	**1.3×10^{1}**	**2.9×10^{1}**	NA	NA
	2	Inhalation radiocarcinogenic risk	9.6×10^{-4}	2.4×10^{-3}	NA	NA
		Inhalation chemocarcinogenic risk	1.1×10^{-4}	2.9×10^{-4}	NA	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	NA
		Carcinogenic sum	**1.3×10^{-3}**	**2.9×10^{-3}**	NA	NA
		Hazard index	**5.8×10^{0}**	**1.5×10^{1}**	NA	NA
2a	1	Inhalation radiocarcinogenic risk	1.8×10^{-3}	3.9×10^{-3}	NA	1.6×10^{-3}
		Inhalation chemocarcinogenic risk	2.2×10^{-4}	4.8×10^{-4}	NA	1.9×10^{-4}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**2.3×10^{-3}**	**4.6×10^{-3}**	NA	**2.2×10^{-3}**
		Hazard index	**1.3×10^{1}**	**2.8×10^{1}**	NA	**1.1×10^{1}**
	2	Inhalation radiocarcinogenic risk	9.6×10^{-4}	2.4×10^{-3}	NA	1.0×10^{-3}
		Inhalation chemocarcinogenic risk	1.1×10^{-4}	2.9×10^{-4}	NA	1.2×10^{-4}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.3×10^{-3}**	**2.9×10^{-3}**	NA	**1.5×10^{-3}**
		Hazard index	**5.8×10^{0}**	**1.5×10^{1}**	NA	**6.0×10^{0}**

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Alternative	Case	Health Effect	Excavation	Loading for Off-site Disposal	On-site Disposal Consolidation	On-site Disposal Facility
2c	1	Inhalation radiocarcinogenic risk	1.8×10^{-3}	3.9×10^{-3}	NA	NA
		Inhalation chemocarcinogenic risk	2.2×10^{-4}	4.8×10^{-4}	NA	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	NA
		Carcinogenic sum	$\mathbf{2.3 \times 10^{-3}}$	$\mathbf{4.6 \times 10^{-3}}$	NA	NA
		Hazard index	$\mathbf{1.3 \times 10^{1}}$	$\mathbf{2.8 \times 10^{1}}$	NA	NA
	2	Inhalation radiocarcinogenic risk	9.6×10^{-4}	2.4×10^{-3}	8.4×10^{-4}	NA
		Inhalation chemocarcinogenic risk	1.1×10^{-4}	2.9×10^{-4}	9.9×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	$\mathbf{1.3 \times 10^{-3}}$	$\mathbf{2.9 \times 10^{-3}}$	$\mathbf{1.3 \times 10^{-3}}$	NA
		Hazard index	$\mathbf{5.8 \times 10^{0}}$	$\mathbf{1.5 \times 10^{1}}$	$\mathbf{5.0 \times 10^{0}}$	NA
3a	3	Inhalation radiocarcinogenic risk	8.2×10^{-4}	2.0×10^{-3}	NA	9.2×10^{-4}
		Inhalation chemocarcinogenic risk	6.5×10^{-5}	1.6×10^{-4}	NA	7.3×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	$\mathbf{1.2 \times 10^{-3}}$	$\mathbf{2.3 \times 10^{-3}}$	NA	$\mathbf{1.4 \times 10^{-3}}$
		Hazard index	$\mathbf{5.1 \times 10^{0}}$	$\mathbf{1.3 \times 10^{1}}$	NA	$\mathbf{5.7 \times 10^{0}}$
	4	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	NA	7.6×10^{-4}
		Inhalation chemocarcinogenic risk	5.9×10^{-5}	1.4×10^{-4}	NA	5.6×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	$\mathbf{1.1 \times 10^{-3}}$	$\mathbf{2.2 \times 10^{-3}}$	NA	$\mathbf{1.2 \times 10^{-3}}$
		Hazard index	$\mathbf{4.6 \times 10^{0}}$	$\mathbf{1.1 \times 10^{1}}$	NA	$\mathbf{4.4 \times 10^{0}}$

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TABLE G.4-3
(Continued)

Alternative	Case	Health Effect	Excavation	Loading for Off-site Disposal	On-site Disposal Consolidation	On-site Disposal Facility
3a (Cont'd)	5	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	NA	7.6×10^{-4}
		Inhalation chemocarcinogenic risk	5.9×10^{-5}	1.4×10^{-4}	NA	5.6×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.1×10^{-3}**	**2.2×10^{-3}**	NA	**1.2×10^{-3}**
		Hazard index	**4.6×10^{0}**	**1.1×10^{1}**	NA	**4.4×10^{0}**
	6	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	NA	9.4×10^{-4}
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	NA	6.9×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	NA	**1.4×10^{-3}**
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	NA	**5.5×10^{0}**
	7	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	NA	9.4×10^{-4}
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	NA	6.9×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	NA	**1.4×10^{-3}**
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	NA	**5.5×10^{0}**
3c	3	Inhalation radiocarcinogenic risk	8.2×10^{-4}	2.0×10^{-3}	7.7×10^{-4}	NA
		Inhalation chemocarcinogenic risk	6.5×10^{-5}	1.6×10^{-4}	6.1×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	**1.2×10^{-3}**	NA
		Hazard index	**5.1×10^{0}**	**1.3×10^{1}**	**4.8×10^{0}**	NA

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TABLE G.4-3
(Continued)

Alternative	Case	Health Effect	Excavation	Loading for Off-site Disposal	On-site Disposal Consolidation	On-site Disposal Facility
3c (Cont'd)	4	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	5.4×10^{-4}	NA
		Inhalation chemocarcinogenic risk	5.9×10^{-5}	1.4×10^{-4}	4.0×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.1×10^{-3}**	**2.2×10^{-3}**	**9.5×10^{-3}**	NA
		Hazard index	**4.6×10^{0}**	**1.1×10^{1}**	**3.1×10^{0}**	NA
	5	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	5.4×10^{-4}	NA
		Inhalation chemocarcinogenic risk	5.9×10^{-5}	1.4×10^{-4}	4.0×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.1×10^{-3}**	**2.2×10^{-3}**	**9.5×10^{-3}**	NA
		Hazard index	**4.6×10^{0}**	**1.1×10^{1}**	**3.1×10^{0}**	NA
	6	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	6.7×10^{-4}	NA
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	4.9×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.1×10^{-3}**	**2.3×10^{-3}**	**1.1×10^{-3}**	NA
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	**3.9×10^{0}**	NA
	7	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	6.7×10^{-4}	NA
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	4.9×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	**1.1×10^{-3}**	NA
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	**3.9×10^{0}**	NA

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TABLE G.4-3
(Continued)

Alternative	Case	Health Effect	Excavation	Loading for Off-site Disposal	On-site Disposal Consolidation	On-site Disposal Facility
4a	8	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	NA	7.6×10^{-4}
		Inhalation chemocarcinogenic risk	5.9×10^{-5}	1.4×10^{-4}	NA	5.6×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.1×10^{-3}**	**2.2×10^{-3}**	NA	**1.1×10^{-3}**
		Hazard index	**4.6×10^{0}**	**1.1×10^{1}**	NA	**4.4×10^{0}**
	9	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	NA	9.4×10^{-4}
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	NA	6.9×10^{-5}
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	NA	3.7×10^{-4}
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	NA	**1.2×10^{-3}**
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	NA	**5.5×10^{0}**
4c	8	Inhalation radiocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	5.4×10^{-4}	NA
		Inhalation chemocarcinogenic risk	8.0×10^{-4}	1.9×10^{-3}	5.4×10^{-4}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.1×10^{-3}**	**4.0×10^{-3}**	**1.5×10^{-3}**	NA
		Hazard index	**4.6×10^{0}**	**1.1×10^{1}**	**3.1×10^{0}**	NA
	9	Inhalation radiocarcinogenic risk	8.8×10^{-4}	2.0×10^{-3}	6.7×10^{-4}	NA
		Inhalation chemocarcinogenic risk	6.4×10^{-5}	1.5×10^{-4}	4.9×10^{-5}	NA
		External radiocarcinogenic risk	2.7×10^{-4}	1.8×10^{-4}	3.7×10^{-4}	NA
		Carcinogenic sum	**1.2×10^{-3}**	**2.3×10^{-3}**	**1.1×10^{-3}**	NA
		Hazard index	**5.1×10^{0}**	**1.2×10^{1}**	**3.9×10^{0}**	NA

Note: The number of significant figures used is provided for comparative purposes, and does not reflect the accuracy of the results. Sums may not equal the sum of the published numbers because of rounding.

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TABLE G.4-4

EXTERNAL RADIATION RISKS TO OFF-SITE RECEPTORS ASSOCIATED WITH ACCIDENT-FREE TRANSPORTATION

Alternative	Case	External Radiation Risks[a]	
		Public Along Transportation Route (ILCR)	Off-Site Remediation Workers (ILCR)
1	1	4.6×10^{-7}	6.9×10^{-5}
	2	1.1×10^{-7}	1.7×10^{-5}
2A	1	2.8×10^{-8}	4.3×10^{-4}
	2	1.4×10^{-8}	2.1×10^{-4}
2C	1	4.6×10^{-7}	6.9×10^{-5}
	2	8.6×10^{-8}	1.3×10^{-5}
3A	3	1.4×10^{-8}	2.1×10^{-4}
	4	1.4×10^{-8}	2.1×10^{-4}
	5	1.4×10^{-8}	2.1×10^{-4}
	6	1.4×10^{-8}	2.1×10^{-4}
	7	1.4×10^{-8}	2.1×10^{-4}
3C	3	8.5×10^{-8}	1.3×10^{-5}
	4	8.3×10^{-8}	1.3×10^{-5}
	5	8.3×10^{-8}	1.3×10^{-5}
	6	8.3×10^{-8}	1.3×10^{-5}
	7	8.3×10^{-8}	1.3×10^{-5}
4A	8	1.4×10^{-8}	2.1×10^{-4}
	9	1.4×10^{-8}	2.1×10^{-4}
4C	8	8.3×10^{-8}	1.3×10^{-5}
	9	8.3×10^{-8}	1.3×10^{-5}

[a]Only one form of transportation applies to each alternative. For Alternatives 2A, 3A, and 4A the off-site disposal is accomplished by truck. For all other alternatives listed, the off-site disposal is accomplished by gondola railcar.

TABLE G.4-5

CALCULATED CARCINOGENIC RISKS FROM ONE ACCIDENT INVOLVING RELEASE OF SOIL FROM CONTAINER

Alternative	Case	ILCR[a]
1	1	2.3×10^{-7}
	2	5.6×10^{-8}
2A	1	4.0×10^{-10}
	2	2.0×10^{-10}
2C	1	1.2×10^{-9}
	2	1.5×10^{-10}
3A	3	2.0×10^{-10}
	4	2.0×10^{-10}
	5	2.0×10^{-10}
	6	2.0×10^{-10}
	7	2.0×10^{-10}
3C	3	1.5×10^{-10}
	4	1.4×10^{-10}
	5	1.4×10^{-10}
	6	1.4×10^{-10}
	7	1.4×10^{-10}
4A	8	2.0×10^{-10}
	9	2.0×10^{-10}
4C	8	1.4×10^{-10}
	9	1.4×10^{-10}

[a]Only one form of transportation applies to each alternative. For Alternatives 2A, 3A, and 4A the off-site disposal is accomplished by truck. For all other alternatives listed, the off-site disposal is accomplished by gondola railcar.

TABLE G.4-6

CALCULATED COLLECTIVE INJURIES FROM MECHANICAL HAZARDS FOR ON-SITE REMEDIATION WORKERS

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	Excavation	96	28	-[a]	-	-	-	-	-	-
	Off-site Disposal	51	21	-	-	-	-	-	-	-
	Backfill	58	24	-	-	-	-	-	-	-
	GW Extraction	5	4	-	-	-	-	-	-	-
	GW Treatment	145	46	-	-	-	-	-	-	-
	Central Storage	8	8	-	-	-	-	-	-	-
	Sum:	**364[b]**	**131**	-	-	-	-	-	-	-
2A	Excavation	96	28	-	-	-	-	-	-	-
	Disposal Cell	114	34	-	-	-	-	-	-	-
	Off-site Disposal	c	c	-	-	-	-	-	-	-
	Backfill	58	24	-	-	-	-	-	-	-
	GW Extraction	5	4	-	-	-	-	-	-	-
	GW Treatment	145	46	-	-	-	-	-	-	-
	Central Storage	8	8	-	-	-	-	-	-	-
	Sum:	**427**	**144**	-	-	-	-	-	-	-
2C	Excavation	96	28	-	-	-	-	-	-	-
	Consolidation with Cover	0	25	-	-	-	-	-	-	-
	Off-site Disposal	51	16	-	-	-	-	-	-	-
	Backfill	58	24	-	-	-	-	-	-	-
	GW Extraction	5	4	-	-	-	-	-	-	-
	GW Treatment	145	46	-	-	-	-	-	-	-
	Central Storage	8	8	-	-	-	-	-	-	-
	Sum:	**364**	**151**	-	-	-	-	-	-	-

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TABLE G.4-6
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
3A	Excavation	-	-	24	22	22	18	18	-	-
	Disposal Cell	-	-	34	27	27	27	27	-	-
	Off-Site Disposal	-	-	b	b	b	b	b	-	-
	Backfill	-	-	21	10	10	19	18	-	-
	GW Extraction	-	-	4	4	4	4	4	-	-
	GW Treatment	-	-	46	46	46	46	46	-	-
	Central Storage	-	-	8	8	8	8	8	-	-
	Sum:	-	-	**138**	**118**	**118**	**123**	**122**	-	-
3C	Excavation	-	-	24	22	22	18	18	-	-
	Consolidation with Cover	-	-	25	17	17	17	17	-	-
	Off-site Disposal	-	-	16	16	16	16	16	-	-
	Backfill	-	-	21	10	10	19	18	-	-
	GW Extraction	-	-	4	4	4	4	4	-	-
	GW Treatment	-	-	46	46	46	46	46	-	-
	Central Storage	-	-	8	8	8	8	8	-	-
	Sum:	-	-	**145**	**123**	**123**	**128**	**127**	-	-
4A	Excavation	-	-	-	-	-	-	-	22	18
	Disposal Cell	-	-	-	-	-	-	-	27	27
	Off-site Disposal	-	-	-	-	-	-	-	b	b
	Backfill	-	-	-	-	-	-	-	10	19
	GW Extraction	-	-	-	-	-	-	-	4	4
	GW Treatment	-	-	-	-	-	-	-	46	46
	Central Storage	-	-	-	-	-	-	-	8	8
	Sum:	-	-	-	-	-	-	-	**118**	**123**

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TABLE G.4-6
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
4C	Excavation	-	-	-	-	-	-	-	22	18
	Consolidation with Cover	-	-	-	-	-	-	-	17	17
	Off-site Disposal	-	-	-	-	-	-	-	16	16
	Backfill	-	-	-	-	-	-	-	10	19
	GW Extraction	-	-	-	-	-	-	-	4	4
	GW Treatment	-	-	-	-	-	-	-	46	46
	Central Storage	-	-	-	-	-	-	-	8	8
	Sum:	-	-	-	-	-	-	-	**123**	**128**

[a]Not Applicable.
[b]Sums may not equal the sum of the published numbers because of rounding.
[b]Included in Central Storage Operations.

TABLE G.4-7

CALCULATED COLLECTIVE FATALITIES FROM MECHANICAL HAZARDS FOR ON-SITE REMEDIATION WORKERS

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	Excavation	0.61	0.17	-[a]	-	-	-	-	-	-
	Off-site Disposal	0.32	0.13	-	-	-	-	-	-	-
	Backfill	0.37	0.15	-	-	-	-	-	-	-
	GW Extraction	0.01	0.01	-	-	-	-	-	-	-
	GW Treatment	0.36	0.12	-	-	-	-	-	-	-
	Central Storage	0.05	0.05	-	-	-	-	-	-	-
	Sum:	**1.72[b]**	**0.64**	-	-	-	-	-	-	-
2A	Excavation	0.61	0.17	-	-	-	-	-	-	-
	Disposal Cell	0.72	0.22	-	-	-	-	-	-	-
	Off-site Disposal	c	c	-	-	-	-	-	-	-
	Backfill	0.37	0.15	-	-	-	-	-	-	-
	GW Extraction	0.01	0.01	-	-	-	-	-	-	-
	GW Treatment	0.36	0.12	-	-	-	-	-	-	-
	Central Storage	0.05	0.05	-	-	-	-	-	-	-
	Sum:	**2.12**	**0.72**	-	-	-	-	-	-	-
2C	Excavation	0.61	0.17	-	-	-	-	-	-	-
	Consolidation with Cover	0.00	0.16	-	-	-	-	-	-	-
	Off-site Disposal	0.32	0.10	-	-	-	-	-	-	-
	Backfill	0.37	0.15	-	-	-	-	-	-	-
	GW Extraction	0.01	0.01	-	-	-	-	-	-	-
	GW Treatment	0.36	0.12	-	-	-	-	-	-	-
	Central Storage	0.05	0.05	-	-	-	-	-	-	-
	Sum:	**1.72**	**0.76**	-	-	-	-	-	-	-

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TABLE G.4-7
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
3A	Excavation	-	-	0.15	0.14	0.14	0.11	0.12	-	-
	Disposal Cell	-	-	0.21	0.17	0.17	0.17	0.17	-	-
	Off-Site Disposal	-	-	b	b	b	b	b	-	-
	Backfill	-	-	0.13	0.06	0.06	0.12	0.11	-	-
	GW Extraction	-	-	0.01	0.01	0.01	0.01	0.01	-	-
	GW Treatment	-	-	0.12	0.12	0.12	0.12	0.12	-	-
	Central Storage	-	-	0.05	0.05	0.05	0.05	0.05	-	-
	Sum:	-	-	**0.68**	**0.55**	**0.55**	**0.58**	**0.58**	-	-
3C	Excavation	-	-	0.15	0.14	0.14	0.11	0.12	-	-
	Consolidation with Cover	-	-	0.16	0.10	0.10	0.10	0.10	-	-
	Off-site Disposal	-	-	0.10	0.10	0.10	0.10	0.10	-	-
	Backfill	-	-	0.13	0.06	0.06	0.12	0.11	-	-
	GW Extraction	-	-	0.01	0.01	0.01	0.01	0.01	-	-
	GW Treatment	-	-	0.12	0.12	0.12	0.12	0.12	-	-
	Central Storage	-	-	0.05	0.05	0.05	0.05	0.05	-	-
	Sum:	-	-	**0.72**	**0.58**	**0.58**	**0.62**	**0.61**	-	-
4A	Excavation	-	-	-	-	-	-	-	0.14	0.11
	Disposal Cell	-	-	-	-	-	-	-	0.17	0.17
	Off-site Disposal	-	-	-	-	-	-	-	b	b
	Backfill	-	-	-	-	-	-	-	0.06	0.12
	GW Extraction	-	-	-	-	-	-	-	0.01	0.01
	GW Treatment	-	-	-	-	-	-	-	0.12	0.12
	Central Storage	-	-	-	-	-	-	-	0.05	0.05
	Sum:	-	-	-	-	-	-	-	**0.55**	**0.58**

TABLE G.4-7
(Continued)

Alt	Process/Treatment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
4C	Excavation	-	-	-	-	-	-	-	0.14	0.11
	Consolidation with Cover	-	-	-	-	-	-	-	0.10	0.10
	Off-site Disposal	-	-	-	-	-	-	-	0.10	0.10
	Backfill	-	-	-	-	-	-	-	0.06	0.12
	GW Extraction	-	-	-	-	-	-	-	0.01	0.01
	GW Treatment	-	-	-	-	-	-	-	0.12	0.12
	Central Storage	-	-	-	-	-	-	-	0.05	0.05
	Sum:	-	-	-	-	-	-	-	**0.58**	**0.62**

[a] NA - Not applicable.
[b] Sums may not equal sum of column because of rounding errors.
[c] Included in Central Storage Operations.

TABLE G.4-8

TRANSPORTATION ROUND TRIPS TO THE REPRESENTATIVE OFF-SITE DISPOSAL FACILITY

	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6		Case 7		Case 8		Case 9	
Alternatives	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips	Mode	Trips
1	Train	3228	Train	782	-*	-	-	-	-	-	-	-	-	-	-	-	-	-
2A	Train	3376	Truck	1688	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2C	Train	182	Train	409	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3A	-	-	-	-	Truck	1688	Truck	1688	Truck	1688	Truck	1688	Truck	1688	-	-	-	-
3C	-	-	-	-	Train	405	Train	398	Train	395	Train	395	Train	395	-	-	-	-
4A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Truck	1688	Truck	1688
4C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Train	395	Train	395

* Not Applicable

TABLE G.4-9

OCCUPATIONAL INJURIES AND FATALITIES TO OFF-SITE REMEDIAL TRANSPORTATION WORKERS DURING TRANSPORT

Injuries

Alternative	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	58	15	NA	NA	NA	NA	NA	NA	NA
2A	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
2C	58	7	NA	NA	NA	NA	NA	NA	NA
3A	NA	NA	< 1	< 1	< 1	< 1	< 1	NA	NA
3C	NA	NA	7	7	7	7	7	NA	NA
4A	NA	NA	NA	NA	NA	NA	NA	< 1	< 1
4C	NA	NA	NA	NA	NA	NA	NA	7	7

Fatalities

Alternative	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
2A	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
2C	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
3A	NA	NA	< 1	< 1	< 1	< 1	< 1	NA	NA
3C	NA	NA	< 1	< 1	< 1	< 1	< 1	NA	NA
4A	NA	NA	NA	NA	NA	NA	NA	< 1	< 1
4C	NA	NA	NA	NA	NA	NA	NA	< 1	< 1

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TABLE G.4-10

TRANSPORTATION-RELATED INJURIES AND FATALITIES TO PUBLIC ALONG TRANSPORTATION ROUTE

Injuries

Alternative	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	86	22	NA	NA	NA	NA	NA	NA	NA
2A	2	< 1	NA	NA	NA	NA	NA	NA	NA
2C	86	11	NA	NA	NA	NA	NA	NA	NA
3A	NA	NA	< 1	< 1	< 1	< 1	< 1	NA	NA
3C	NA	NA	11	10	10	10	10	NA	NA
4A	NA	NA	NA	NA	NA	NA	NA	< 1	< 1
4C	NA	NA	NA	NA	NA	NA	NA	10	10

Fatalities

Alternative	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1	23	6	NA	NA	NA	NA	NA	NA	NA
2A	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
2C	23	23	NA	NA	NA	NA	NA	NA	NA
3A	NA	NA	< 1	< 1	< 1	< 1	< 1	NA	NA
3C	NA	NA	23	23	23	23	23	NA	NA
4A	NA	NA	NA	NA	NA	NA	NA	< 1	< 1
4C	NA	NA	NA	NA	NA	NA	NA	23	23

G.5.0 UNCERTAINTY ANALYSIS

G.5.1 INTRODUCTION

The short-term FS risk evaluation estimates risks to workers and the general public during the remedial action. Because the FS risk assessment assumes cleanup will continue to prescribed contaminant levels and must project across the entire period of remediation, results of the evaluation have some uncertainty with regard to future land use, PRLs, exposure patterns, exposed populations, and exposure concentrations. The uncertainty associated with these predictions influences the degree of confidence placed on these estimates by risk assessors and risk managers. This, in turn, affects the emphasis placed on these predictions by decision makers in the risk management process. This section contains a qualitative analysis of the uncertainties associated with the risk estimates produced by this study. The purpose of this analysis is to determine the reliability of risk estimates and place them in context with other information produced by the Operable Unit 5 FS.

G.5.2 PRINCIPAL SOURCES OF UNCERTAINTY

Uncertainties related to the risk analysis for the Operable Unit 5 FS risk assessment are complex, as this operable unit must consider and build from the assumptions and predictions for the remediation and residual contamination from the other operable units. Sources and characteristics of uncertainty examined in this section are summarized in Table G.5-1.

G.5.3 CUMULATIVE UNCERTAINTY

Numerous sources of uncertainty are identified for this remedial action risk assessment. Each of the factors is addressed in a fashion that ensures that the final estimate of the risk is quite conservative, meaning that while the magnitude of uncertainty is high, the likelihood that risks have been understated is very low.

TABLE G.5-1

UNCERTAINTIES ASSOCIATED WITH IMPLEMENTATION OF REMEDIAL ALTERNATIVES FOR OPERABLE UNIT 5

Potential Uncertainty	Source of Uncertainty		Magnitude[a]	Expected Direction[b]	Remark
Selection of COCs[c]	Adequacy of database		Low to Moderate	Unknown	COCs may be under-estimated. Principal constituents were identified.
Exposure assumptions	Selection and location of receptors		Low	Increases conservatism	Scenario based on current environmental setting.
	Volume of soil excavated		Low to Moderate	Increases conservatism	COCs may have a greater or lesser extent than expected.
	Engineering design		Low to Moderate	Unknown	Final engineering design is uncertain at this time.
	Person-hour estimates		Low to Moderate	Unknown	Receptor and task specific.
	Types and extent of D&D operations		Low	Unknown	Dependent on the D&D technologies selected in Advanced Design Phase.
Exposure pathways	Sources, release rates and pathways selected for quantification		Low to Moderate	Unknown	Receptor and exposure pathway specific.
	Determination of exposure factors		Low to Moderate	Increases conservatism	Receptor and exposure pathway specific.
Exposure point concentrations	Accuracy of predictive models		Moderate to High	Increases conservatism	Soil concentrations based on sampling program that was biased for radiological COCs. Air concentrations calculated by ISC ST and LT model.
Toxicological information	Dose-response assessment:	Chemical COCs	High	Increases conservatism	Dose-response based on animal data
	Dose-response assessment:	Uranium RfD[e]	Unknown	Unknown	RfD withdrawn, no new numbers available.

TABLE G.5-1 (Continued)

Potential Uncertainty	Source of Uncertainty		Magnitude[a]	Expected Direction[b]	Remark
Toxicological information (continued)	Dose-response assessment:	Radiological COCs - Internal	Moderate	Increases conservatism	Chronic, low-level dose-response relationship for humans extrapolated from large, acute doses to wartime Japanese. Supplementary data on specific radionuclides from therapeutic use at high concentrations. Ancillary data from animal studies.
	Dose-response assessment:	Radiological COCs - External	Moderate to High	Increases conservatism	Conservative assumptions made for external exposure
	Dose-response assessment:	Radionuclide slope factors	Low to Moderate	Unknown	March 1994 version of heast slope factors used
	Other Operable Unit COCs:	Dose-response for PAHs	Low	Increases conservatism	PAHs pose low risk
	Other Operable Unit COCs:	Dose-response for PCBs	Low	Increases conservatism	PCBs pose relatively low risk
	Other Operable Unit COCs:	Dose-response for dioxins/furans	Low	Increases conservatism	Furans/dioxins relatively low risk
Risk characterization	Additivity		Low to Moderate	Increases conservatism	Potential health effects driven by few COCs and few exposure pathways.
	Failure to consider antagonism		Unknown	Increases conservatism	Data unknown.
	Failure to consider synergism		Unknown	Decreases conservatism	Data unknown
Preliminary remediation goals	Modeling assumptions, toxicological information		High	Increased conservatism	High uncertainty from combining uncertainties in the modeling and risk characterization.
Overall			High	Increases conservatism	High uncertainty from combining biased parameter values having low, moderate or high uncertainties.

[a] Magnitude is assessed qualitatively based on professional judgment and includes the following:
- Low-impact risk by a factor of 10 or less.
- Moderate-impact risk by a factor of 10 to 100.
- High-impact risk by a factor of 100 or more.

[b] Direction is assessed qualitatively where an increased conservatism increases final health effects calculated in risk assessment.
[c] COC - Constituent of Concern
[d] D&D - Decontamination and Decommissioning
[e] RfD - Reference Dose

G.6.0 SUMMARY AND DISCUSSION

This summary includes a synopsis of the potential risks calculated for each remedial alternative, and presents analyses of significant trends associated with those risks. This section consists of three parts. Section G.6.1 briefly reviews the salient points of the short-term risk assessment. A brief comparison of the potential mechanical hazards and human health effects from various remedial actions to five receptors is discussed in Section G.6.2. The final section discusses the conclusions and recommendations of this study.

G.6.1 SUMMARY OF REMEDIAL ACTION RISKS

The short-term risk assessment considers potential health impacts to workers and the public from activities associated with the remedial actions that could be implemented for Operable Unit 5. Short-term risks are dependent on the future land-use objective selected for the site, because land use governs the soil volume removed and the level of contamination in the excavated material. The following land use objectives have been developed at the FEMP:

- Land Use Objective No. 1: Full unrestricted use of the property, including groundwater resources
- Land Use Objective No. 2: Continued federal ownership of portions on the sites, with maximum consolidation to free the majority of the property for unrestricted use, with unrestricted use of groundwater resources outside of the federally controlled area
- Land Use Objective No. 3: Continued federal ownership with maximum consolidation to free areas for use as an industrial site or park land, with unrestricted use of groundwater resources beyond the property boundaries
- Land Use Objective No. 4: Continued federal ownership with consolidation of contaminated materials. The entire property remains fallow with restricted access. Unrestricted use of groundwater resources beyond the property boundaries is allowed.

Three technologies were considered to offer a practical means to achieve these objectives: Off-site disposal, on-site consolidation under an earthen cover, and internment within an on-site engineered disposal facility. Seven alternatives combining these technologies and land uses survived remedy screening in Section 4.0 of the FS. These alternatives were examined in concert with nine unique combinations of critical receptors called cases. Twenty of these alternative case combinations were selected for detailed risk analysis. Based on an exposure pathway analysis of these alternative case combinations, five significant and relevant potential consequences from the activities were quantitatively evaluated:

- Physical hazards (injuries and fatalities)
- Radiological ILCR from inhalation

- Radiological ILCR from direct radiation
- Chemocarcinogenic ILCR from inhalation
- Chemical toxicity from inhalation.

Other exposure pathways were considered in the exposure assessment but eliminated from quantitative evaluation.

The following pathways were quantitatively evaluated for the specified receptors:

Receptor	Mechanical Hazards	Human Health Risks
On-site remediation worker	Injuries and fatalities	External radiation, inhalation
On-site nonremediation worker	NA	Inhalation
Off-site remediation worker	Injuries and fatalities	External radiation
Near-property public	NA	Inhalation
Public along transportation route	Injuries and fatalities	External radiation
Public and workers in accident	NA	External radiation

The types and magnitudes of these exposures and their consequences form the basis of the short-term risk characterization.

G.6.1.1 Physical Hazards

Physical hazards associated with implementing the proposed remedial actions can be grouped into two categories: on-site occupational accidents and off-site transportation accidents. The greatest estimated physical hazards are injuries to the on-site remediation workers (Figure G.6-1) and fatalities to the public along the transportation route (Figure G.6-2).

Between 400-550 reportable lost-time injuries would be anticipated for the Case 1 alternatives over the duration of the earthmoving and the groundwater pumping and treatment operations (27 and 70 years respectively). Calculated numbers of reportable lost-time injuries for all other alternative cases during the study period are between 100 and 200. About 23 public transportation fatalities were calculated for Alternative 1 and 2C's Case 1.

Figure G.6-3 and Figure G.6-4 present component-specific breakdowns of the occupational injuries and fatalities associated with each alternative's components for on-site remedial workers. For the on-site remediation worker, injury and fatality risks are collective risks for the entire work force. The risk

results are directly proportional to the person-hours. Therefore, alternatives with the greatest number of person-hours (Figure G.6-5) also have the greatest associated injury and fatality risks to the on-site remediation workers.

Calculated lost-time injuries and fatalities among off-site remediation workers are illustrated in Figures G.6-6. Off-site worker fatalities from mechanical hazards are less than one (< 1) for all cases. Figure G.6-7 depicts the injury and fatality risks for the public along the transportation route. Comparing the two figures illustrates that the off-site public along the transportation route is expected to experience a greater number of injuries and fatalities than the workers transporting the waste, although the trend among alternatives is the same. This is attributable to two facts. First, these injuries and fatalities are largely the predicted results of car-train accidents. Historically, passengers in automobiles involved in car-train accidents are injured or killed with greater frequency than the crew of the train. In addition, automobiles often have more than one passenger, so multiple injuries or fatalities to members of the public can result from one accident.

A second trend illustrated by Figures G.6-6 and G.6-7 is the lower number of fatalities and injuries among the public that are predicted for the "A" group of alternatives when compared to the "C" group of alternatives. This is because injuries and fatalities among the public and off-site remediation workers along the transportation route are related to the total volume of material being shipped off-site, the mode of transport (truck or rail), and the round-trip distance traveled to and from the off-site disposal facility. The on-site waste acceptance criteria are higher for the "A" group of alternatives, reducing the volume of material requiring off-site disposal. This in turn reduced the number of shipments required, which lowers the transportation risks.

G.6.1.2 Incremental Lifetime Cancer Risks

Carcinogenic risks to all receptors are dominated by the radiological components of the risks. Figure G.6-8 illustrates this for on-site remedial workers involved with excavation. This receptor and remedial component were chosen as an example because they are present in every alternative and case combination except the no-action alternative, and their estimated ILCRs (Figure G.6-9) are among the highest calculated in this study. Among the other receptors evaluated, the carcinogenic risks to the workers involved with the on-property operations supporting off-property disposal are higher, while risks to workers placing soil in the on-property consolidation area and the on-property disposal facility were lower than (but still within one order of magnitude of) the workers involved with excavation. Risks to the nonremedial site workers, the near-property public, the off-property remedial transportation workers, and the public along the transportation route are predicted to be several orders of magnitude less than the on-site remediation worker risks (Figures G.6-10 through G.6-11). In general, inhalation of radionuclides produces the most risk to the on-site remedial workers, followed by risks from external

radiation sources. Chemical carcinogenicity is estimated to be one to two orders of magnitude less than the radiological component, and hence contributes very little risk to the total.

G.6.1.2.1 Radiological ILCR from Inhalation

Estimated radiocarcinogenic ILCRs for on-site remedial workers who may inhale contaminated dust while performing various activities are generally in the 10^{-4} to 10^{-3} range. In all cases, the workers involved in excavation and the staging operations supporting off-site disposal exhibit the highest potential for exposure. This is because these operations are expected to exhibit the greatest potential to produce dust.

Worker risks are compared to specific worker health protection standards such as 10 CFR 835 and 29 CFR 1910. These regulations contain dose limits for radiation workers that allow up to 5 rem per year or 3×10^{-3} risk per year, assuming a risk coefficient of 6.2×10^{-7} $mrem^{-1}$. Similar risks are allowed for workers for chemical exposures. Other standards at U. S. Department of Energy (DOE) sites which are also applicable to the public and to nonremediation workers limit radiation doses from all nonmedical manmade sources up to 100 mrem/yr. This is approximately equal to a lifetime cancer risk of 6×10^{-5} per year of exposure.

Radiocarcinogenic ILCRs for the inhalation pathway are below 10^{-6} for the postulated on-site non-remediation workers and the hypothetical receptor representing the near-property public (Figure G.6-10). Radiocarcinogenic ILCRs for the inhalation pathway are higher for the nonremediation worker receptors than for the near-property public receptor because the worker is exposed to higher airborne concentrations due to proximity to the source.

G.6.1.2.2 Radiological ILCR from Direct Radiation

Three receptors are considered for the radiocarcinogenic ILCRs from direct radiation: 1) on-site remediation workers, 2) off-site remediation workers, and 3) public along the transportation route. The estimated excess lifetime cancer risks are higher for the on-site remediation workers than for the two other receptors (Figures G.6-8 and G.6-11). Off-site transportation of radioactive material is the only remedial activity during which the off-site remediation worker and the public along the transportation line are likely to be exposed to gamma radiation. These exposures will be generally shorter than for the on-site worker, and occur from a greater distance. Both of these considerations will lower their exposures significantly.

This assessment is quite conservative in that it assumes the on-site remedial worker is on site for 250 days/yr for 22 years and no credit is taken for shielding by the equipment used for excavation and handling material.

G.6.1.2.3 Chemocarcinogenic ILCR from Inhalation

Estimated chemically-induced ILCRs for remedial workers inhaling contaminated dust while performing various activities are generally in the 10^{-6} to 10^{-5} range. Workers involved in excavation and the staging operations supporting off-site disposal exhibit the highest potential for exposure. Again, this is attributable to the higher levels of dust expected from these activities.

Chemical ILCRs for the inhalation pathway are below 10^{-6} for the postulated on-site nonremediation workers and the hypothetical receptor representing the near-property public.

G.6.1.3 Chemical Toxicity

The HIs calculated for on-site remedial workers range from 3 for consolidation activities to almost 30 for operations associated with off-property disposal (Figure G.6-12). The HIs via the inhalation pathway are well below 0.02 for all receptors except the on-site remedial worker. They are well below the HI of 0.2 for any one constituent, and below the HI of 1.0 for all constituents acting on the same organ. Thus toxicity from airborne constituents should not be a major concern during remediation for any receptor except the on-site remedial worker.

G.6.2 COMPARATIVE ANALYSIS OF REMEDIAL ACTION RISKS

Several trends can be identified among the remedial alternatives. Probably the most striking aspect of the results of this study is the dominance of the transportation risks from the off-site disposal components of the "C" alternatives. These risks far exceed the risks from the next largest contributor - the accidents projected to occur during the performance of on-site remedial tasks. The smallest contributors to risk from remediation are the human health effects from calculated exposures to contaminated materials during remediation. This is particularly noteworthy because the reliability of the transportation risk estimates is greater than the reliability of the mechanical hazard predictions, which in turn is greater than the certainty of the human health predictions.

G.6.2.1 Trends in Predicted Transportation Risks

Two general trends are evident when considering the results of the transportation risk analysis for this study:

- In general, land uses with more stringent cleanup criteria produce higher transportation risks. For example, transportation risks from Land Use Objective 1 exceed the risks from Land Use Objectives 3 and 4.

- The "C" alternatives have lower on-site waste acceptance criteria and tend to produce higher transportation risks than the "A" alternatives for the same land use. This is because more material must be shipped off site, requiring more trips to the off-property disposal facility.

G.6.2.2 Trends in On-site Occupational Accidents

Three trends in the predicted average number of occupational accidents are evident:

- Land uses with more stringent cleanup criteria may be expected to produce more occupational accidents. For example, the predicted accident rate from Case 1 is three to four times higher than any other case.

- The "C" alternatives have slightly lower on-site accident rates but tend to produce higher transportation risks than the "A" alternatives for the same land use. This is because the time and effort required to build and seal a disposal facility are greater than those required to place material in a consolidation area. The lower waste acceptance criteria of the consolidation area requires that more material be shipped off-site. This increases the hazards for the public along the transportation route.

- Groundwater treatment operations are expected to induce a disproportionate number of injuries when compared with fatalities from the same operations than any other remedial component because these results include accidents from plant maintenance operations, as well as operational accidents.

G.6.2.3 Trends in Human Health Effects

Four trends are apparent when considering the impacts remediation actions may have on human health:

- Land uses with more stringent cleanup criteria may be expected to produce greater human health impacts. This is because a greater volume of material is being moved during the 22-year study period. This increases the dust resuspension rate and leads to higher exposures. This trend is particularly evident for excavation workers involved with Case 1 alternatives (Figure G.6-8).

- Inhalation of radionuclides imparts the greatest portion of the carcinogenic risks, while exposures to direct radiation produce the next largest contribution. Chemical carcinogens will not be important actors during remediation.

- Inhalation of chemical toxicants will not be an important contribution to human health impact in this remediation, except for the on-site remediation workers.

- Only the on-property remedial workers would incur risks exceeding 10^{-6}. This indicates these workers should be strictly monitored and follow an approved health and safety plan when working on this site.

G.6.3 SHORT-TERM CONCLUSIONS AND RECOMMENDATIONS

This short-term risk assessment attempts to evaluate risks involved with remediation of environmental media at the FEMP. A number of observations or conclusions follow from this analysis:

- A difference in short-term risks and predicted injuries and fatalities among different alternatives within the same land-use objective is evident. The predicted injuries and fatalities among alternatives is a function of person-hours needed to excavate, handle, treat, and/or dispose of soil that exceeds PRLs.

- The short-term risk assessment indicates the off-site transportation component is the major contributor to risks. Thus it is recommended that the final configuration of remedial technologies should be designed to minimize risks from off-site transportation.

- The short-term risk assessment portion of this FS indicates that the "A" group of alternatives is preferred over the "C" group because it reduces the impacts of off-site disposal on the public along the transportation route between the site and the disposal facility.

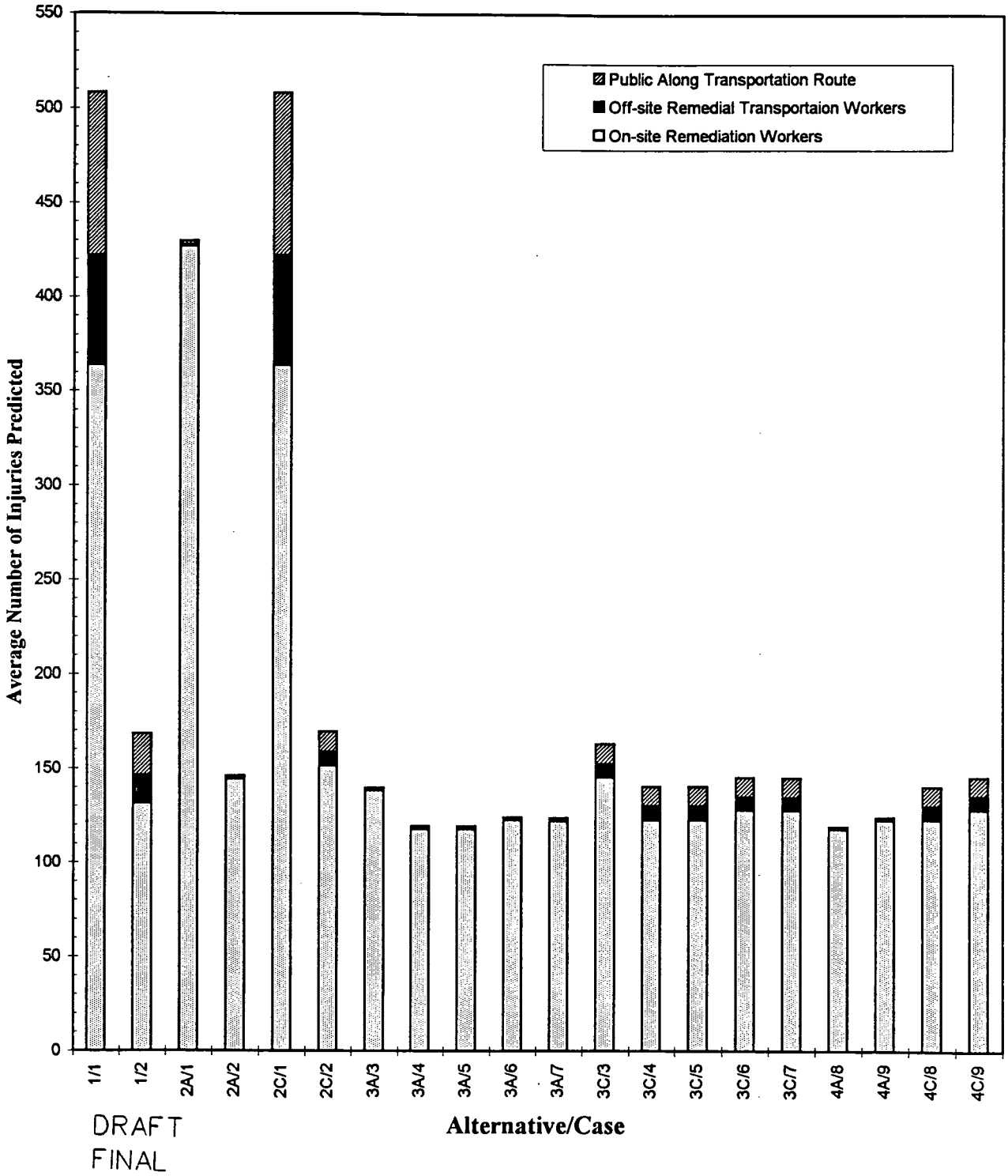

FIGURE G.6-1. PREDICTED INJURIES TO ALL RECEPTOR GROUPS FROM MECHANICAL HAZARDS. INCLUDING OFF-SITE TRANSPORTATION TO THE DISPOSAL FACILITY

A&A/mkb
* F&I-totals Chart 2

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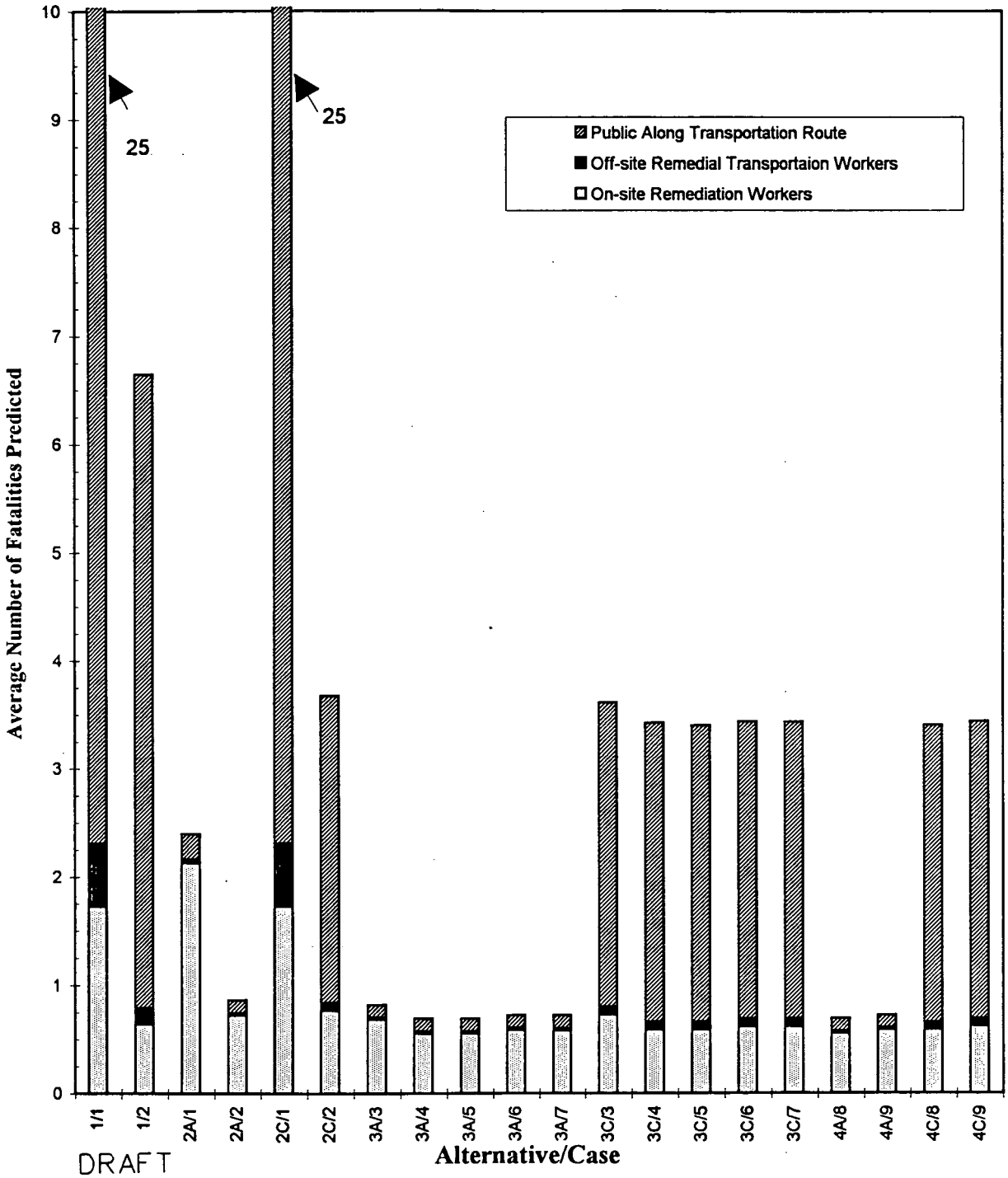

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FIGURE G.6-2. PREDICTED FATALITIES TO ALL RECEPTOR GROUPS FROM MECHANICAL HAZARDS, INCLUDING OFF-SITE TRANSPORTATION TO THE DISPOSAL FACILITY

A&A/mkb
* F&I-totals Chart 4

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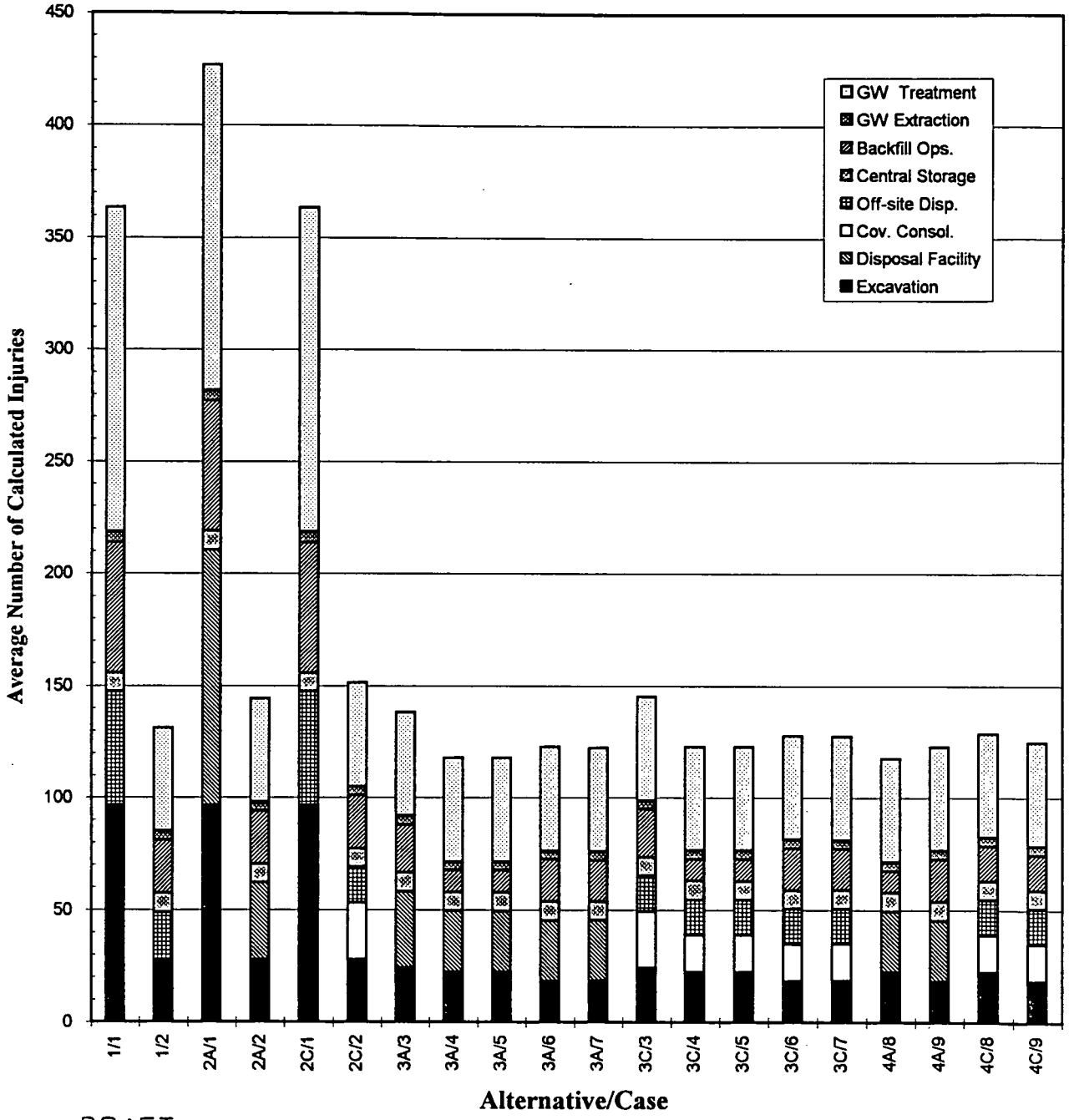

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FIGURE G.6-3. COMPONENT LEVEL COMPARISON OF ALTERNATIVE AND CASE SPECIFIC LOST TIME INJURIES CALCULATED FOR ON-SITE REMEDIAL WORKERS

A&A/mkb
*I-sw Chart 3

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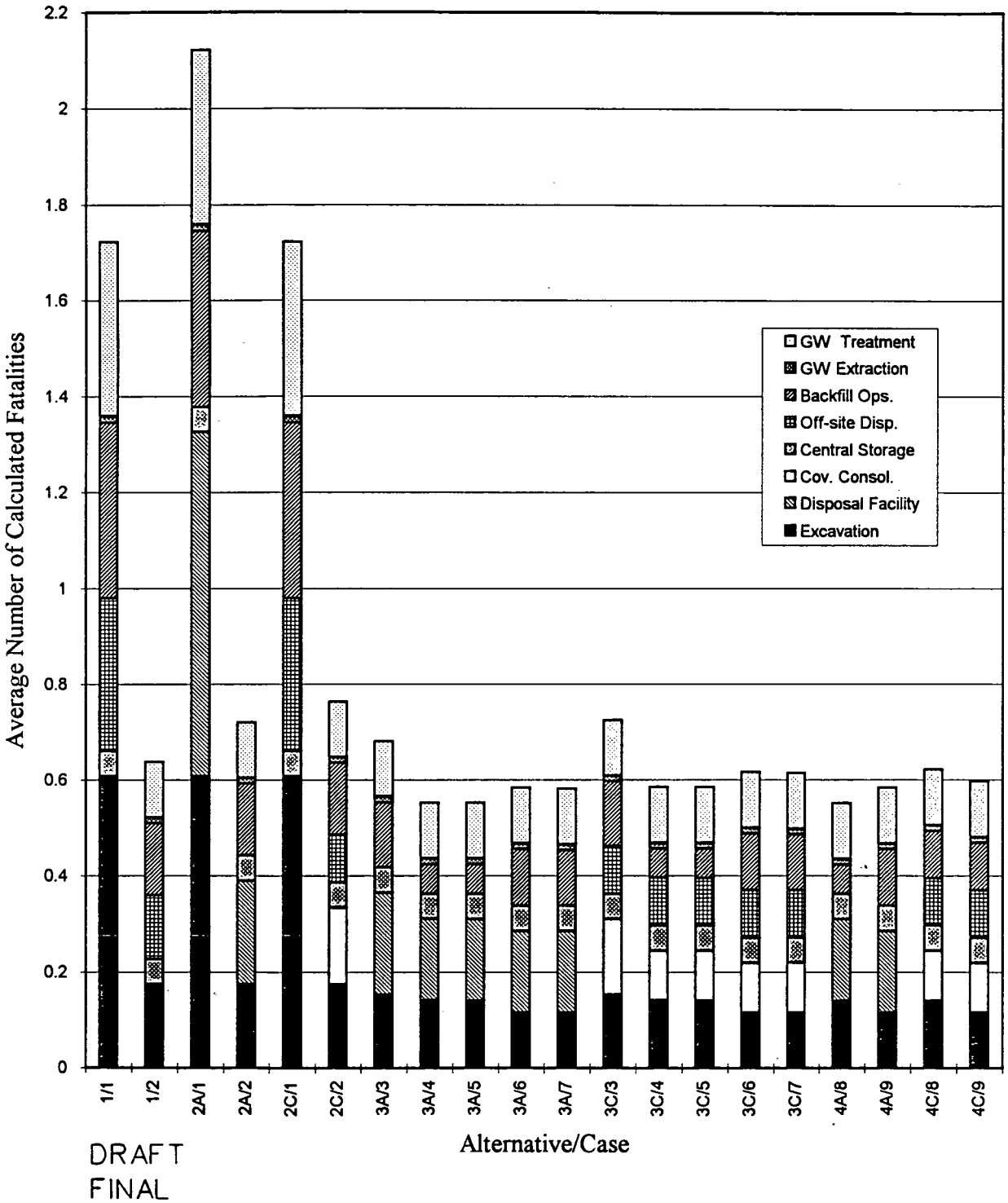

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FIGURE G.6-4. COMPONENT LEVEL COMPARISON OF ALTERNATIVE AND CASE SPECIFIC FATALITIES CALCULATED FOR ON-SITE REMEDIAL WORKERS

A&A/mkb
* F-sw Chart 2

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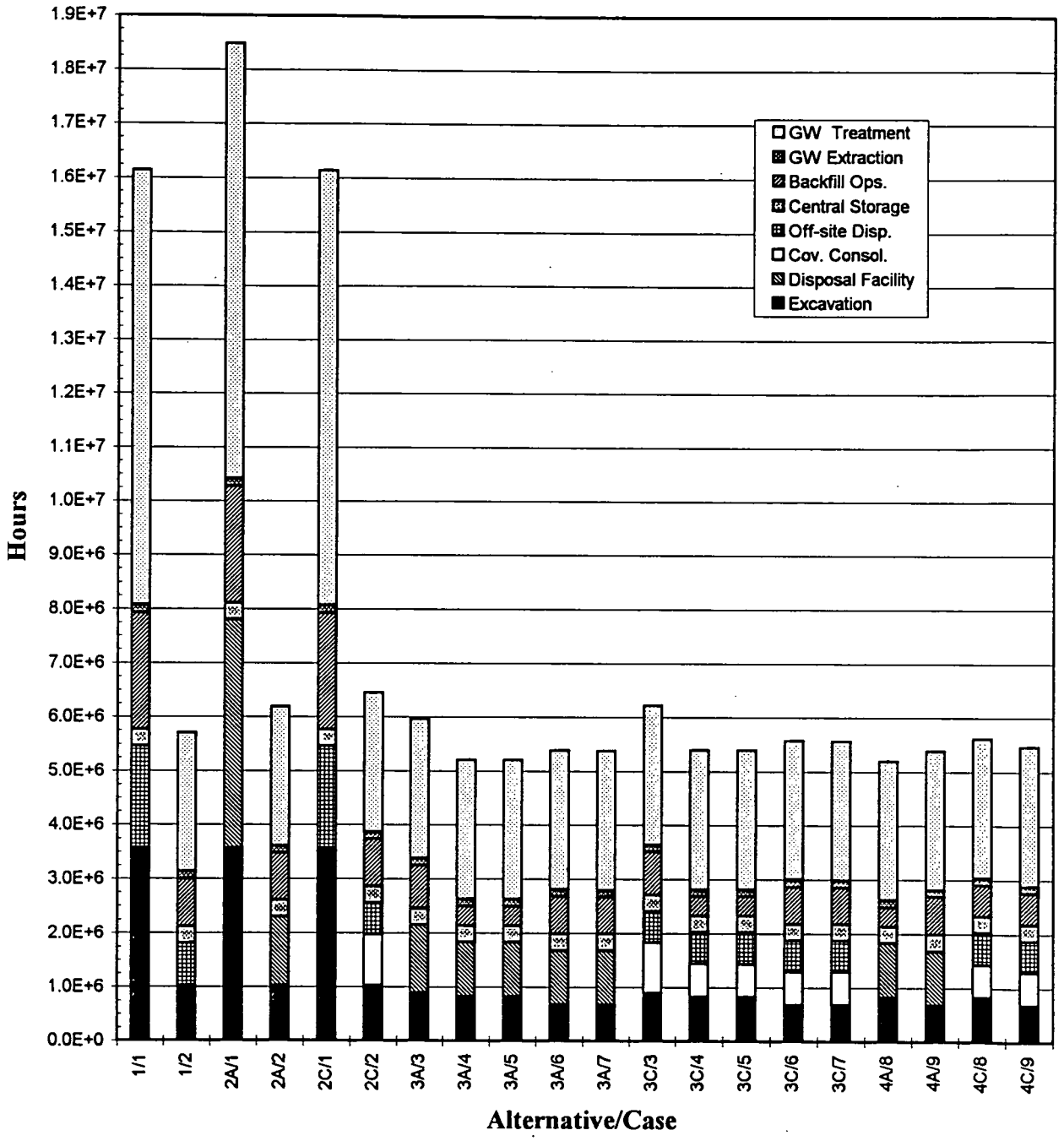

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FIGURE G.6-5. COMPONENT LEVEL COMPONENT SPECIFIC PERSON HOURS USED TO ESTIMATE INJURIES AND FATALTIES FOR ON-SITE REMEDIAL WORKERS

A&A/mkb
* H-sw Chart 2

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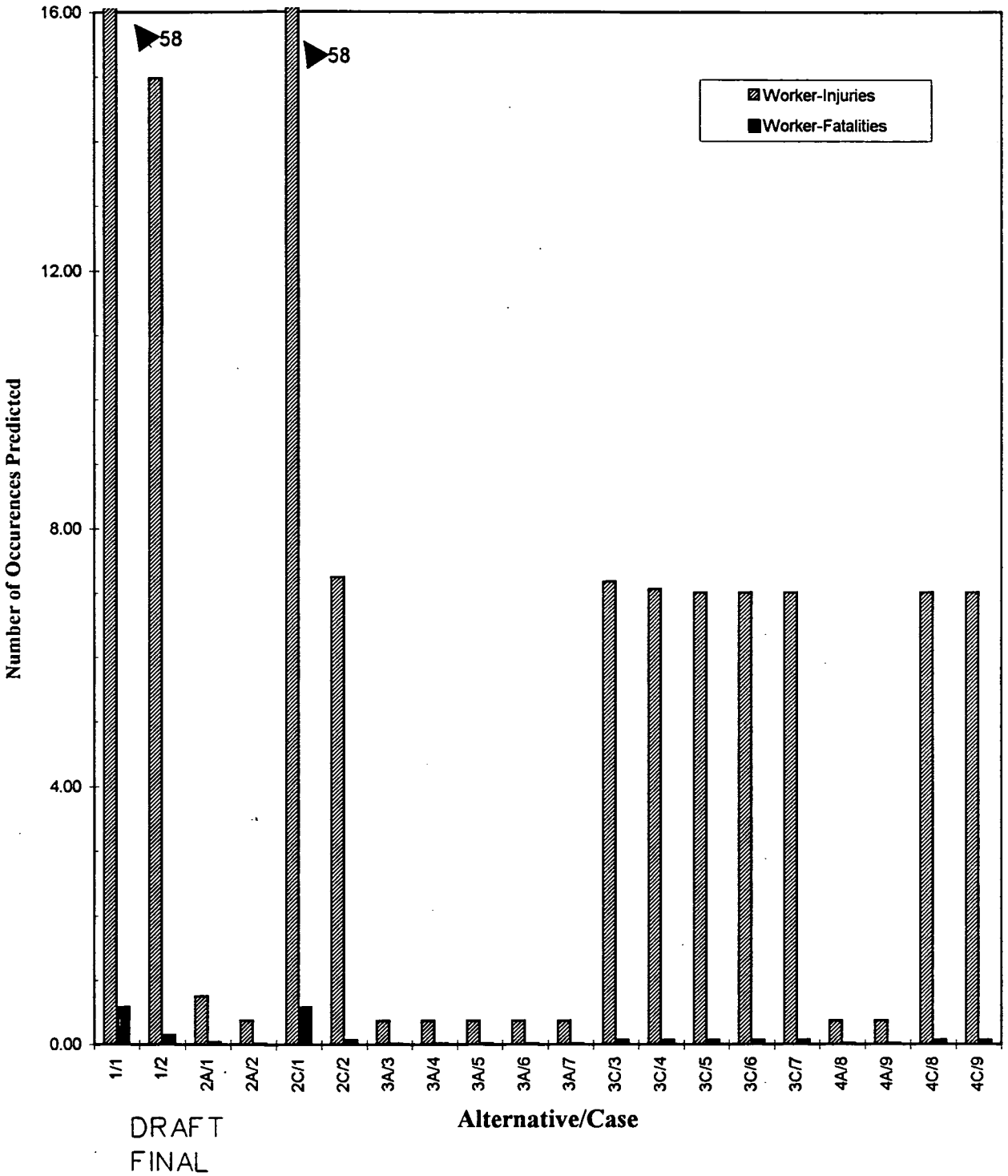

FIGURE G.6-6. TRANSPORTATION HAZARDS TO OFF-SITE REMEDAL TRANSPORTATION WORKERS FROM OFF-SITE DISPOSAL

A&A/mkb
* F&I-tw&tp Chart 13

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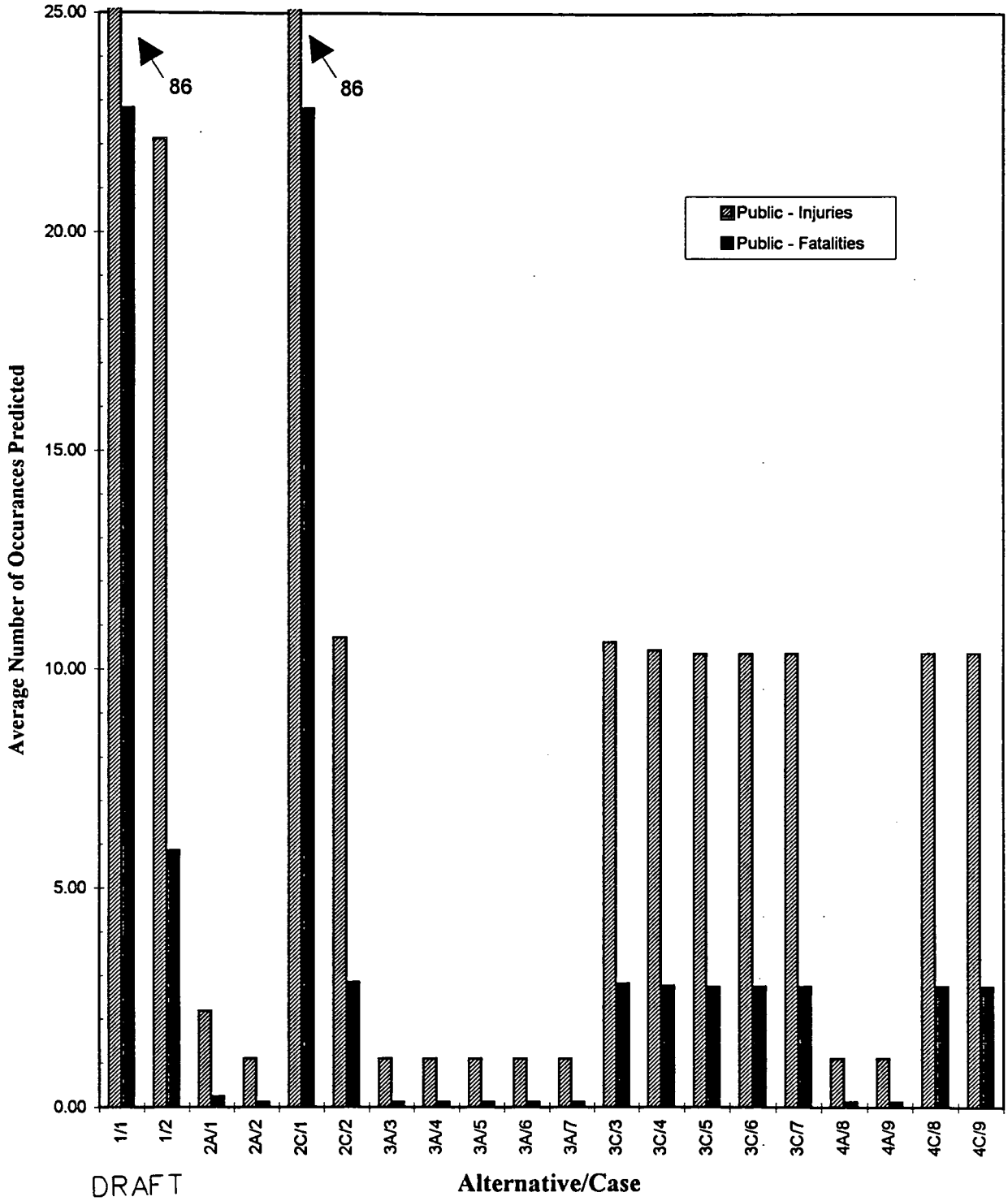

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FIGURE G.6-7. COMPARSON OF TRANSPORTATION HAZARDS TO THE PUBLIC BETWEEN FERNALD AND THE DISPOSAL SITE FROM OFF-SITE DISPOSAL

A&A/mkb
* F&I-tw&tp Chart 11

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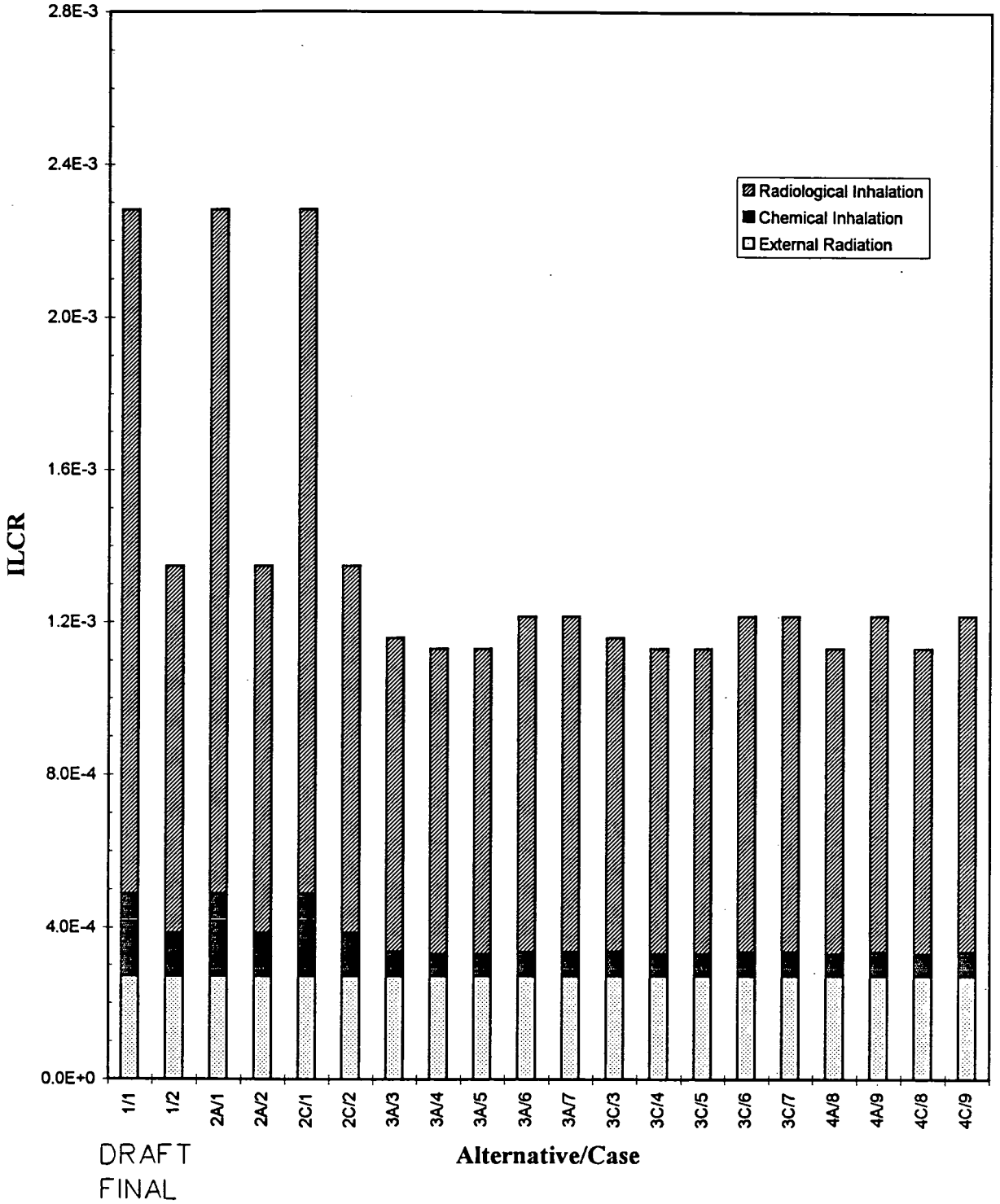

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FIGURE G.6-8. COMPARISON OF CARCINOGENIC EFFECTS CONTRIBUTING TO THE ILCR OF ON-SITE REMEDIAL WORKERS INVOLVED WITH EXCAVATION

A&A/mkb
* R-sw Chart 3

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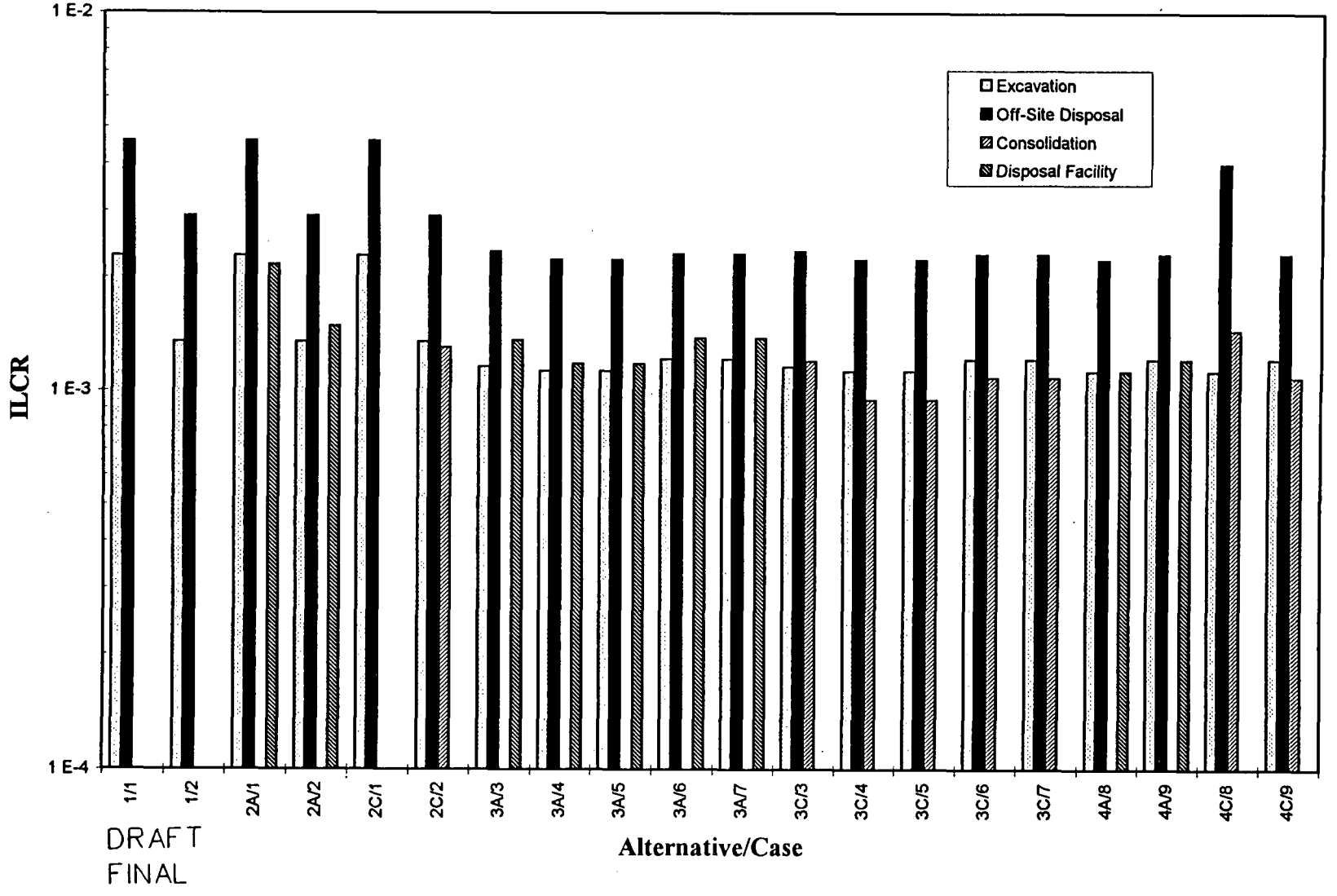

FIGURE G.6-9. COMPARISON OF COMPONENT LEVEL CARCINOGENIC RISK INFORMATION FOR ON-SITE REMEDIAL WORKERS BY ALTERNATIVE AND CASE

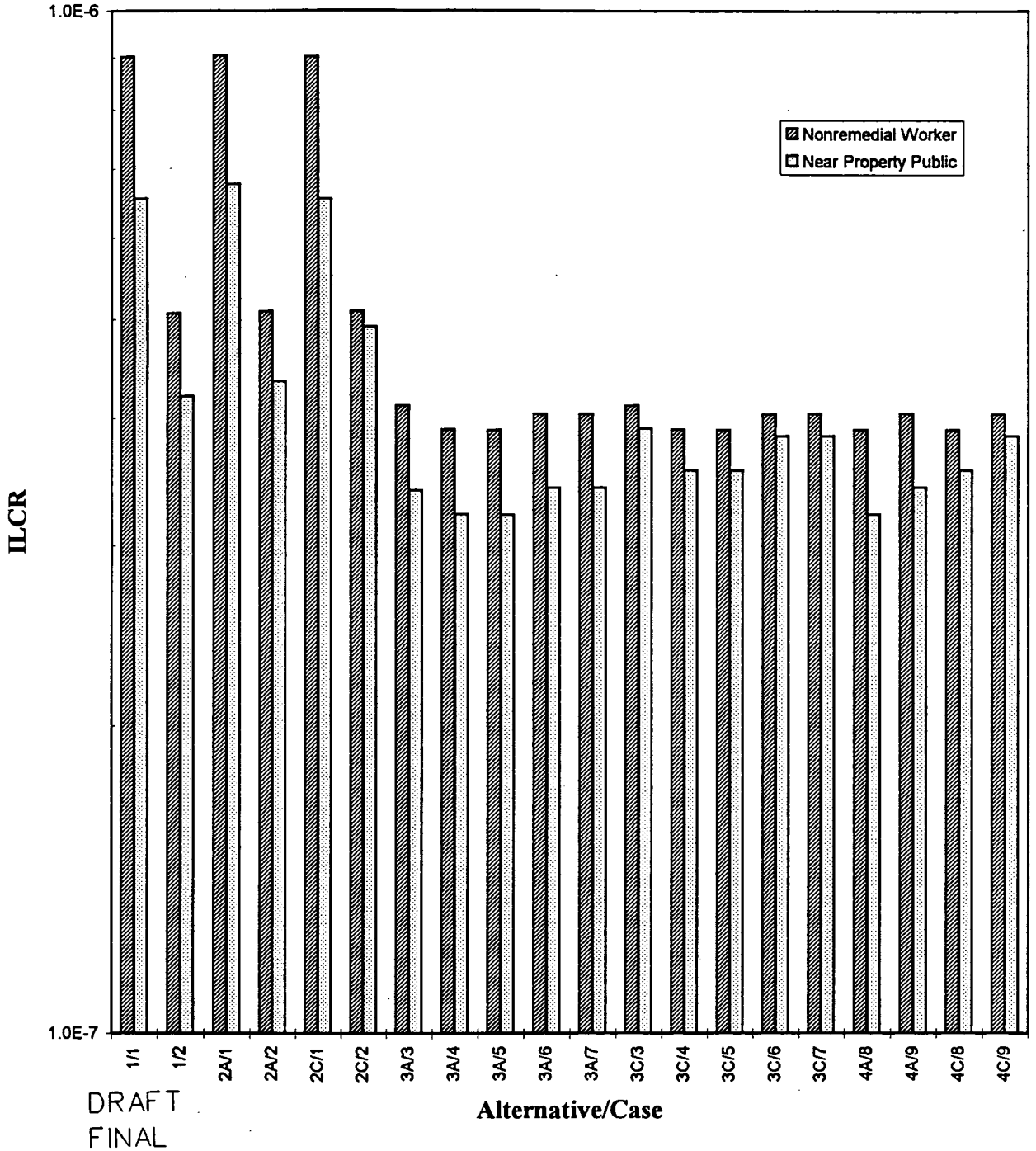

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FIGURE G.6-10. COMPARISON OF ALTERNATIVE AND CASE SPECIFIC RISK INFORMATION FOR ON-SITE NONREMEDIATION WORKERS AND THE NEAR PROPERTY PUBLIC

A&A/mkb
* R-sn&np Chart 2

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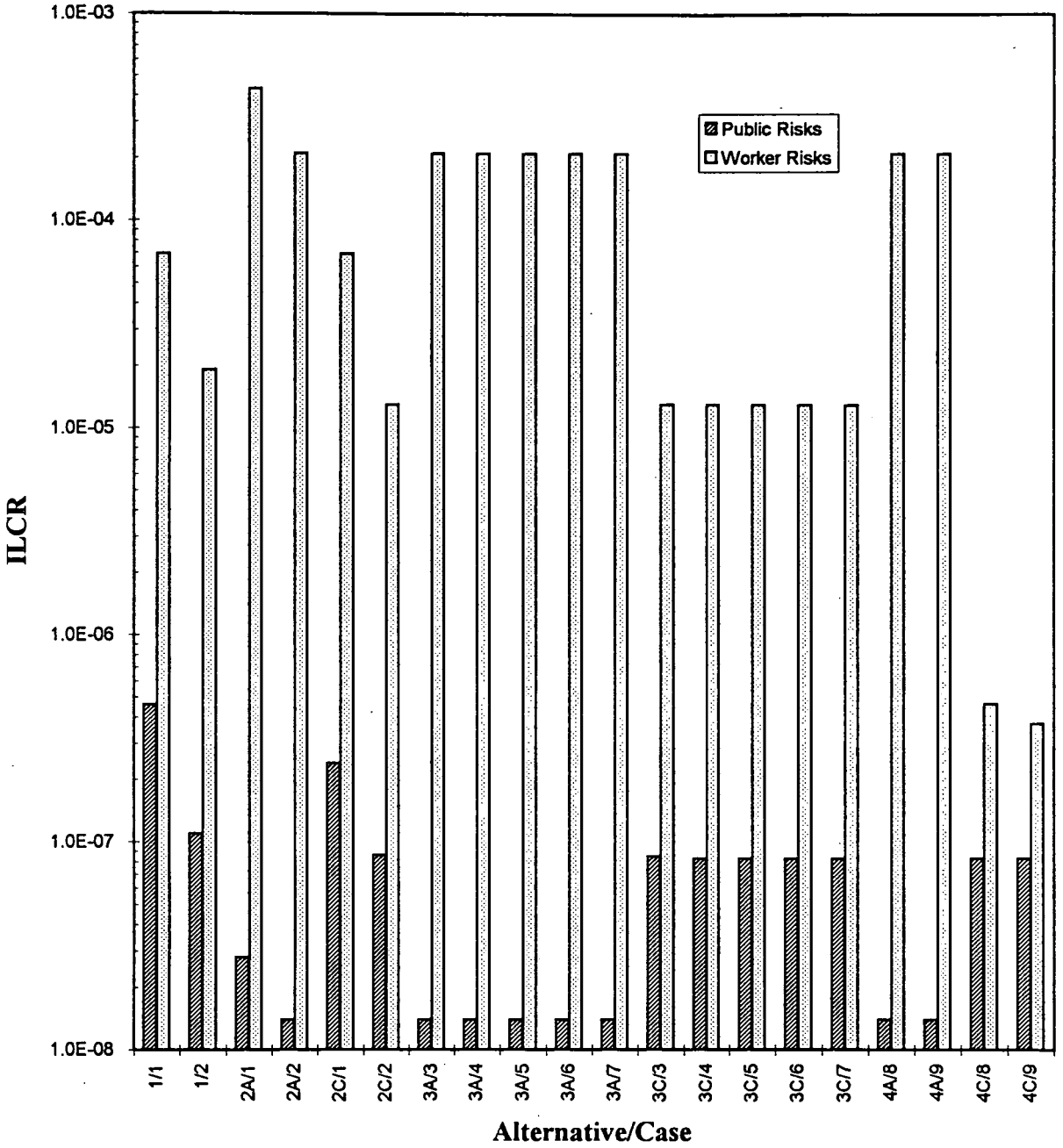

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FIGURE G.6-11. ALTERNATIVE AND CASE SPECIFIC CARCINOGENIC RISK INFORMATION FOR OFF-SITE REMEDIATION WORKERS AND THE PUBLIC ALONG THE TRANSPORTATION ROUTE ASSUMING NO ACCIDENTS OCCUR

A&A/mkb
* R-pt&tw Chart 3

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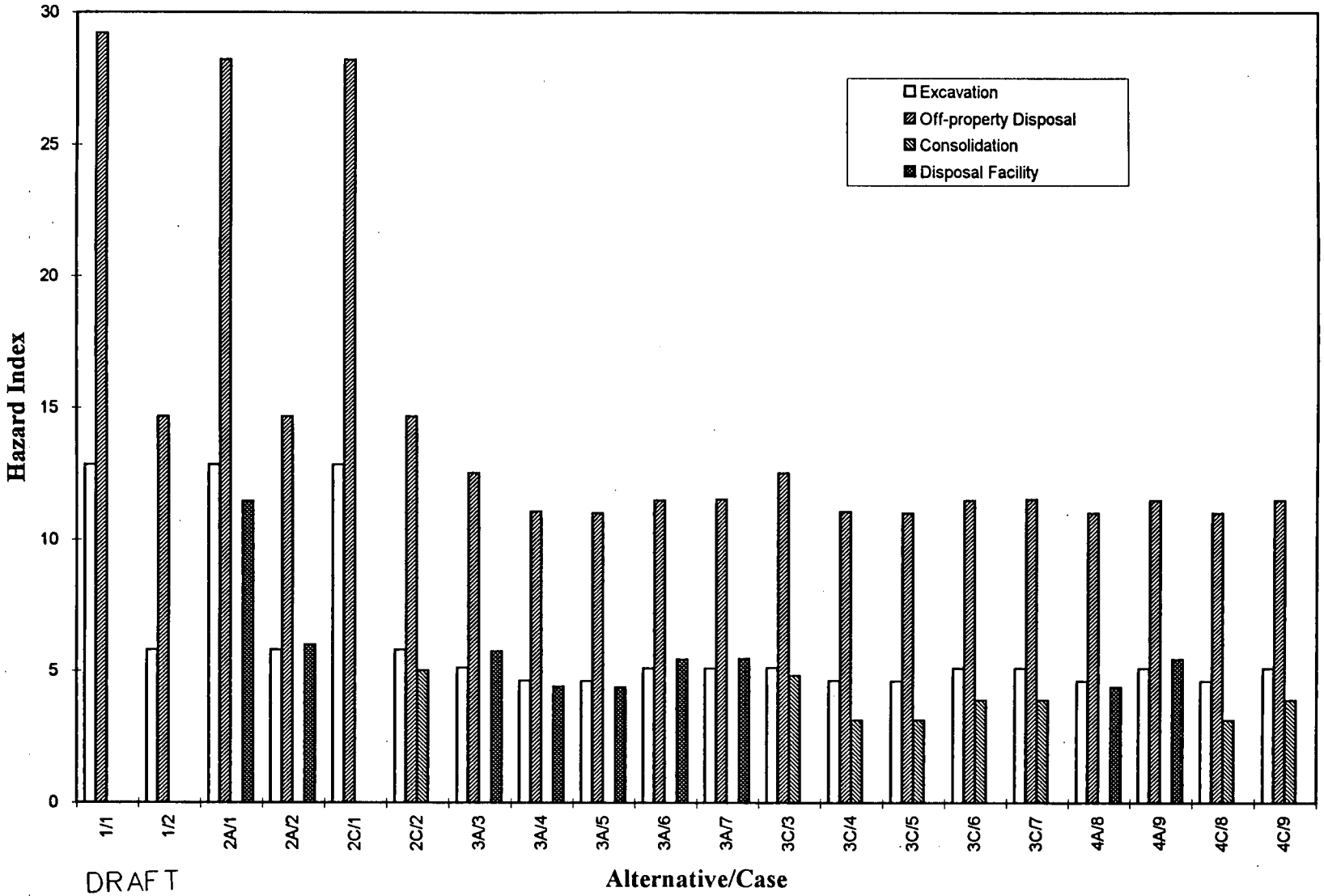

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FIGURE G.6-12. COMPARISON OF ALTERNATIVE AND CASE SPECIFIC TOXICITY INFORMATION FOR ON-SITE REMEDIAL WORKERS

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ATTACHMENT G.I

SHORT-TERM RISK ASSESSMENT MODELS

G.I.0 MODELS USED IN THE OU5 SHORT TERM RISK ASSESSMENT

Because of the nature of this short-term risk assessment, it is necessary to quantify future conditions and exposures that may occur during the remediation. This is typically done by using mathematical relationships that are thought to have some precognitive value. Many of these mathematical relationships have be encoded into computer models. Computer models are used in this study to predict:

- External radiation exposure for a variety of geometries and sources (MicroShield, Section G.I.1)
- Exposures relating to transportation accidents that result in a release of contaminated soil from its container (RADTRAN, Section G.I.2)
- Exposure concentrations of constituents in air at critical receptor locations (Near Term Box and Industrial Source Code Models, Section G.I.3).

This attachment describes these models and their use in the short-term human health risk assessment.

G.I.1 DIRECT RADIATION EXPOSURE

A number of risk assessment scenarios require the information on penetrating gamma radiation dose rates produced during proposed activities for which measured data on penetrating gamma radiation is not yet available. Direct radiation exposure is quantitatively evaluated via modeling when direct radiation exposure measurement data are not available. For example, modeling is used to estimate dose rates from waste shipments proposed as part of remedial alternatives that involve transportation of waste to a disposal facility. Modeling is also used to estimate radiation dose rates to remediation workers excavating asymmetric patches of waste material producing measurable gamma radiation fields.

Radiation dose rates for planar source geometries involving shielding materials and for nonplanar source geometries in Operable Unit 5 are modeled using MicroShield version 4.1 (™ Grove Engineering, Grove 1988). MicroShield was developed for use on personal computers by Grove Engineering (Grove 1988). It uses the same algorithms as ISOSHIELD, a mainframe code developed by Battelle Northwest Laboratories (Engle 1966). MicroShield methodology offers a tested approach for estimating the radiation dose rate to an individual from a variety of source geometries which may be tailored to suit operation-specific modeling needs.

MicroShield calculates the estimated dose rate from a given configuration in three forms: activity (photons/sec), gamma flux energy density (MeV/cm^2-sec), and dose rate (mrad/hr). The program

requires a moderate amount of input information to perform these analyses. Basic information requirements can be grouped into three categories:

- Source-Receptor Geometry: The exposure geometry is defined as the physical shape of the source (source geometry), the exposure point's orientation with respect to the source (receptor geometry). The receptor location is particularly important because the exposure rate decreases as the distance between the receptor and the source increases.

- Source Composition: The composition of the source is defined by the types of materials comprising the source and their densities, as well as the types and concentrations of nuclides in the source.

- Shielding: MicroShield uses information on materials between the source and the receptor (shielding) to calculate the degree to which the gamma rays emitted by the source are attenuated by the intervening material. In addition, the code uses information on the chemical and physical properties of the shielding and source materials to estimate any additional exposure caused by scattering phenomena (buildup).

Most input parameters are simple to determine, but care must be taken when determining the most appropriate source geometry and shielding configurations.

Section G.I.1.1 presents the geometries expected during remediation. Section G.I.1.2 includes a discussion of the sources evaluated. Exposure rates calculated by MicroShield are used directly to calculate expected doses to hypothetical receptors. Results are also used indirectly as input to the RADTRAN computer code used to calculate exposures associated with off-site transportation.

G.I.1.1 Geometries Evaluated

The source-receptor geometries evaluated in this study are illustrated in Figures G.I-1 through G.I-4. These geometries were selected because they correspond to the configurations of sources and receptors expected to occur during the actual implementation of the proposed remediation activities. Figure G.I-1 depicts two source receptor geometries that would occur during excavation of contaminated material, or placement of this material in lifts during on-site disposal or storage. These two geometries present the receptor locations where the maximum and minimum measurable exposure rates are likely to occur and can thus be used to estimate the dose to remediation workers involved with excavation and on-site disposal or storage operations. Figure G.I-2 shows the most likely position of a dump truck load of contaminated soil in relation to the truck's driver. Figure G.I-3 presents the geometries used to calculate package doses from containers filled with contaminated soil. Results from this last case provides information needed by RADTRAN (Section G.I.3) to calculate doses associated with off-site transportation.

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G.I.1.2 Sources Evaluated

Table G.I-1 contains the values of the MicroShield 4.1 input parameters used to characterize the physical attributes of sources evaluated in this study. Unit concentrations were selected for each radionuclide evaluated because the model predicts a linear relationship between the concentration of an isotope and its exposure rate. Thus the result can be scaled up or down, depending on the radionuclide's concentration in the source.

G.I.1.3 Receptor Specific Results

Table G.I-2 presents case-specific results for workers involved in excavation. Calculation methods are presented in footnotes f and g. It is worth noting that the risk to the individual worker remains constant (6×10^{-4}) among the cases because the parameters for the individual worker remain constant. For alternatives and cases requiring larger volumes of soil to be excavated the number of workers increases, but the level of effort for each worker remains constant.

Case-specific results for workers handling soil in the on-property disposal facility, the consolidation area, and the central storage facility are presented in Table G.I-3. Calculation methods are presented in footnotes f and g. Total risk results for this RME worker are within one order of magnitude, ranging from 1×10^{-4} to 8×10^{-4}. The location for this worker at the central storage facility differs from the location in other cases.

Table G.I-4 presents case-specific results for workers driving trucks used to haul soil from the excavation area to an on-property destination. Calculation methods are presented in footnotes f and g. As with worker risks associated with excavation, the level of effort for each worker remains constant. Therefore, the total risk results remain constant at 3×10^{-5}.

G.I.2 RADTRAN - TRANSPORTATION INJURIES AND FATALITIES, AND EXTERNAL RADIATION EXPOSURE

RADTRAN calculates direct radiation exposure and exposure through the inhalation pathway. Sections G.I.2.1 through G.I.2.4 overview the general description of RADTRAN. Section G.I.2.4 describes the incident-free transportation scenario. The results of the incident-free scenario for each alternative are summarized in Section G.5. Section G.I.2.5 describes transportation accident scenario. The results of the transportation accident scenario for each alternative are provided in Section G.4.

G.I.2.1 General Description

SNL developed the original RADTRAN code in 1977 in conjunction with the preparation of NUREG-0170, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes". The analytical capabilities of the code were expanded and refined in subsequent versions. RADTRAN 4 may be used to evaluate radiological consequences of incident-free transportation, and from potential vehicular accidents occurring during transportation.

The most current comprehensive description of the RADTRAN computer code is found in SNL (1986). Since 1986, a number of changes have been made to the code which do not greatly affect the RADTRAN model itself. However, user documents which describe the current (RADTRAN 4) model in detail have not been released. The following is a detailed description of the RADTRAN 3 model (SNL 1986).

The current version, RADTRAN 4, contains advances in the handling of route-related data and in the treatment of multiple-isotope materials. A route may be subdivided into segments with independent, user-assigned values for population density and other route-specific parameters ("route-specific" analysis). Regarding complex materials, RADTRAN 4 models the risk from transportation of multiple-isotope materials, and permits direct analysis of multiple-package shipments made up of dissimilar packages. RADTRAN 4 also calculates the maximum individual in-transit dose. An internal library containing parameters for more than 50 radioisotopes may be used. The user may independently define isotopes instead of, or in addition to, using the internal library. Also, an accident-severity category matrix allows up to 20 accident-severity categories to be analyzed in a single execution of the program.

Figure G.I-5 is a basic block diagram of the methodology used in RADTRAN. Two principal computations are performed by the code: computation of the radiological impact due to "incident-free" transport of radioactive material, and computation of the radiological impact of vehicular accidents involving radioactive material shipments. This figure illustrates the informational flow through the various submodels. Each of these submodels will be addressed briefly in this section.

Transportation of radioactive material involves a wide range of events with potential for environmental impact. To identify the source of these impacts, the sequence of events in a radioactive material shipment

must be considered. For most shipments, the material is first placed in a package meeting regulatory standards, the radiation exposure levels are noted, the package is labeled with the appropriate information, and a shipping bill is prepared The package is then loaded onto a truck or train that will take it directly to its ultimate destination.

RADTRAN allows the user to develop a shipment scenario specified by parameters such as material, material dispersion category, curie content, Transport Index, type of packaging, number of shipments, distance per shipment, and shipment mode. In RADTRAN 4, the required degree of specificity may be introduced into an analysis with user-defined parameter values. Since the vast majority of RADTRAN parameters are user-definable, the user has a great deal of flexibility in performing analyses.

RADTRAN 4 contains idealized mathematical models of transportation environments, formulated to yield conservative estimates of integrated population dose in a way that can be supported by available data. These models neglect features of the transportation environment that either do not affect the calculated risk values or reduce conservatism (i.e., the "divider width" of divided highways) and combine calculational simplicity with general conservatism. For example, all routes are modeled as infinitely long straight lines without grade or curves. This model also yields conservative estimates of integrated incident-free off-link and on-link doses for a moving source that are applicable to all routes by all modes. Similarly, all highway and rail links are treated as being one lane (or track) wide for the purpose of estimating distances to off-line population but as being two lanes wide (one lane or track in each direction) for the purpose of estimating on-line doses (overtaking vehicles on highways are treated separately). The first treatment is used to achieve symmetry (and, hence, mathematical simplicity) around the lane in which the shipment is located, and is also slightly conservative. The second treatment (one lane each direction) yields the smallest perpendicular distance to the traffic traveling in the opposite direction, which again is conservative. The latter treatment also means that all rail routes are modeled as having double tracks, which is another small increment of conservatism.

G.I.2.2 Overview of Calculational Models

Material Model

Parameters that define the materials are, for each isotope, the total number of curies per package, average total photon energy per disintegration, the rate at which released material is deposited on the ground, cloudshine dose factors, the physical character of the waste, half-life, and measures of the radiotoxicity of the dispersed material.

Transportation Model

The transportation model is subdivided into three sections: an accident rate section, a traffic pattern section, and a shipment information section. The accident rate section contains the accident rate for each mode of transportation, subdivided according to the severity of the accident and the population zone in which the accident is assumed to occur. The traffic pattern section contains the fraction of travel which

occurs on various types of roads, in various population zones, and under rush-hour and normal traffic conditions. The shipment information section contains the number of passengers or crew per vehicle, crew separation distances for various vehicle types, handling and storage times, and duration and number of stops.

Accident Severity and Package Release Model

The accident severity model divides all accidents into eight severity categories keyed to damaging environments and hence to the fractional release of material from packaging. These categories may be related to the fire, crush, impact, and puncture forces encountered in an accident or they may be related to other abnormal environments of specific interest to the user. The package release model combines the user-specified release fraction with the fraction of material which becomes airborne and the fraction of the airborne material which is of respirable size. These results are combined with the accident rates for each severity category, the distance per shipment, and the number of shipments to determine the expected release of each material in each population zone.

Meteorological Dispersion Model

The diffusion of the cloud of aerosolized debris released at the site of an accident must be described to estimate consequences. Basic dispersion calculations are not performed within RADTRAN. Instead, the user can provide either (1) a table of averaged time-integrated concentration (TIC) values with corresponding areas within which the TIC values are exceeded; or (2) fractional occurrences of Pasquill stability categories A through F in which case weighted averages of tabulated concentration and area values from within the code will be used.

Population Distribution Model

The population distribution model specifies population densities in three population zones: rural, suburban, and urban. In addition, numbers of exposed persons in certain specific areas such as pedestrian walkways, warehouses, and air terminals are specified.

Health Effects Model

The health effects model for RADTRAN is based on the model developed in the Reactor Safety Study. Neutron effects are included only in the incident-free and inhalation models. The radiotoxicity of the materials shipped is analyzed in terms of potential for producing early fatalities, early morbidities, latent cancer fatalities, and genetic effects. The analysis is based on the computed dose received by various organs.

G.I.2.3 Incident-Free Transportation Model

Despite requirements designed to minimize exposures, whenever radioactive material is transported, members of the general population are exposed to extremely small doses of external penetrating radiation from X-rays, gamma rays, and/or neutrons. In RADTRAN the general population is divided into eight

exposable population subgroups: crewmen, passengers, cargo handlers, flight attendants, warehouse personnel, people in the vicinity of the transporting vehicle while it is stopped, people surrounding the transport link on which the vehicle is moving, and people sharing the transport link with the vehicle. Total doses (in person-rem) are computed for each applicable subgroup shown in Figure G.I-6.

Rail Transportation

Common input parameters for rail transport are presented in Table G.I-5. Concentrations in soil being shipped off site are presented in Table G.I-6. The amount of soil shipped by rail to the disposal facility varies by alternative and case. To ease computations, an incident-free RADTRAN 4 run was setup with one shipment of 50 rail cars. Table G.I-7 identifies the total curie content found in a rail car. The total is based on the maximum net weight of a rail car times the exposure point concentrations for each radionuclide. The dose to the population subgroups is linear with respect to the number of shipments. Table G.4-8 identifies the number of shipments per alternative and case. Table G.I-8 presents the results for the single-shipment RADTRAN run. The results for each alternative are identified in Section G.4.

Truck Transportation

Common input parameters for B-25 box (truck) transport are presented in Table G.I-9. Concentrations in soil being shipped off site are presented in Table G.I-6. The amount of soil shipped by truck to the representative disposal facility varies by alternative and case. To ease computations, an incident-free RADTRAN 4 run was set up with one shipment of 6 B-25 boxes. Table G.I-7 identifies the total curie content found in a B-25 box. The total is based on the volume of a B-25 box times the exposure point concentration for each radionuclide. The dose to the population subgroups is linear with respect to the number of shipments. Table G.I-8 identified the number of shipments per alternative and case. Table G.I-8 presents the results for the single-shipment RADTRAN run. The results for each alternative are presented in Section G.4.

G.I.2.4 Model Outputs

The output of RADTRAN is expressed in terms of expected numbers of acute health effects, and economic consequences from transportation accidents, and dose in person-rem from incident-free transportation. Individual shipments are also analyzed for their contribution to the total radiological impact. The code has been developed in a generalized format to permit a wide variety of potential applications including analysis of existing radioactive material transport schemes; analysis of proposed alternative schemes such as mode shifts, packaging changes, or routing changes; and detailed consideration of transportation issues within specific sectors of the radioactive material industry.

Economic Model

Accidents involving radioactive material can result in economic impacts for surveillance, cleanup, evacuation, and long-term land-use denial. The calculational scheme that evaluates those costs does not include estimates of costs associated with litigation, government actions, and indirect corporate losses.

Costs can vary substantially depending on geographic location, property type, and decontamination techniques used. The RADTRAN model is intended to provide order-of-magnitude economic estimates rather than absolute site-specific economic impacts.

Radiological Impact Due to Accidents

The radiological impact from vehicular accidents is evaluated in terms of level of consequence, probability of occurrence, and level of risk. Radiological consequences which are evaluated include health effects and economic impacts and are shown in Figure G.I-6. Risk is evaluated in terms of the expected value of each of these effects. The expected value of risk is computed by forming the product of the probability of each specific accident and its particular level of consequence and summing these products over all accidents.

Radiological Impact Due to Incident-Free Transportation

The accumulation of relatively small doses which result from exposure of population to the radiation emitted by radioactive material packages is computed in RADTRAN by using the population distribution model, and the transportation model to compute the dose (in person-rem) to a set of specific population subgroups. Because of the low allowable external dose levels imposed by current regulations, no early effects are possible from incident-free transport.

G.I.2.5 Transportation Accident Model

Two factors are considered when evaluating impacts of accidents that involve vehicles carrying radioactive shipments: probability and consequence. The probability that an accident releasing radioactive material will occur can be described in terms of the expected number of accidents of a given severity for each transport mode, together with the package response to such an accident. The consequence of an accident is expressed in terms of the potential effects of the release of a specified quantity of radioactive material to the environment or the increased direct exposure of persons to ionizing radiation resulting from damaged package shielding. Transportation risk is defined as the product of probability and consequence.

Accident Severity Categories

The intensity of thermal and mechanical environments is responsible for the kind and degree of packaging damage and for the portion of the contained material which may be subsequently released. In this method accidents are assigned a severity category based upon the duration and temperature of fire occurring during the accident, and either impact speed (air transport), crush forces (for truck and van transport), or puncture impact speed (for rail transport). Eight categories are considered, with Category 1 used to represent the regulatory conditions of Type A packages, Category 2 to represent regulatory conditions for Type B packages, and higher categories designed for situations that exceed regulatory limits. Other methods for categorizing accident severity can be developed by the modeler.

Release and Dispersibility

The severity of an accident is related to the physical form of the material being transported. Compromising the integrity of a package containing a non-dispersible substance yields only potential direct radiation exposure from shielding loss. Breaching a package containing dispersible materials can produce five different exposure pathways (Figure G.I-7).

Transported materials are classified according to their dispersibility based on the shipment size and the chemical/physical properties of the material. The dispersion category in turn determines the fractions aerosolized and respirable. Figure G.I-8 shows the decision tree structure used to make this classification. If the material is flammable its dispersibility to make this category is 11. For nonflammables, the next level is determined by physical form: solid, liquid, or gas. Gases are Category 10, and liquids are either 8 or 9, depending upon the amount of material contained in one package. Large volumes are assigned to Category 8. Solids that are not dispersible are given Category 1, and dispersible solids go into Categories 2 through 7, depending on such other characteristics as the granular size and the amount of material involved. The Operable Unit 5 soil is modeled as Category 5, small loose powder.

RADTRAN uses four quantities which are dependent upon severity category: the accident severity fraction (n), the release fraction (RF), the aerosolization fraction (AER), and the respirable fraction (RESP). The severity fraction is a three-dimensional array which defines the probability that transport accidents for each of the allowable modes will occur in each of three population zones and each of the eight severity categories. Table G.I-10 identifies the default RADTRAN Accident Severity and Release Fractions used in the accident model.

The aerosolization fraction specifies the fraction of material released from a package in aerosol form. The aerosolized fraction used in the accident model was 0.1 and based on material dispersibility of 5 (solid-small loose powder). Only those particles less than approximately 10 microns in aerodynamic diameter pose an inhalation hazard. The respirable fraction is introduced to quantify this respirability fraction as a function of material dispersibility class and accident severity. The respirability fraction used in the accident model was 0.05 and based on material dispersibility of 5 (solid-small loose powder). In terms of ground contamination, all airborne particles are significant so the respirability fraction is not included.

Material Dispersal from Accidents

Airborne material released from the scene of an accident moves downwind under the influence of the winds and disperses according to the degree of turbulence in the atmosphere. Persons exposed to the aerosol cloud will inhale some of the radionuclides during cloud passage and have particles deposited in their lungs in proportion to the time integrated concentration of the aerosol, x. This is the source of the inhalation dose calculated in RADTRAN. Since groundshine, cloudshine, and ground deposit are also

proportional to the quantity x, the data for this parameter must either be input to RADTRAN or internal default data may be used.

In the RADTRAN model, lines connecting points of equal x take the shape of nested ellipses, as shown in Figure G.I-9 extending in the downwind direction from the release point. The ellipses having the highest values of x are in the middle of the pattern and all are concentric in the vicinity of the release point. The value of x at any point is directly proportional to the total mass of material released and inversely proportional to wind speed. Thus, most sources contain tabulations of xu/Q or x/Q versus distance or area enclosed in isopleths for various atmospheric stability classes (commonly Pasquill A-F, but other schemes are published). To differentiate one locale from another the relative frequency of occurrence of the classes must be specified to complete the description of the atmospheric dispersion potential of any accident (Pasquill 1961).

To use the x/Q tables in RADTRAN, the user must specify the frequency of occurrence of the Pasquill stability classes in the area of interest. This data can be obtained from national meteorological summaries or from stability wind roses that can be supplied from many localities by order from the National Weather Service's data bank in Asheville, NC.

Rail Transportation Results

Using the method described in this section and parameters for rail transport in Table G.I-10, results were calculated for a single shipment. These results are presented in Table G.I-11. These results were multiplied by the number of shipments to produce consequences associated with off-site disposal by rail for appropriate alternatives and cases. Those results are presented in Section G.4.

Truck Transportation Results

Using the method described in this section and parameters for truck transport in Table G.I-10, results were calculated for a single shipment. These results are presented in Table G.I-12. These results were multiplied by the number of shipments to produce consequences associated with off-site disposal by truck for appropriate alternatives and cases. Those results are presented in Section G.4.

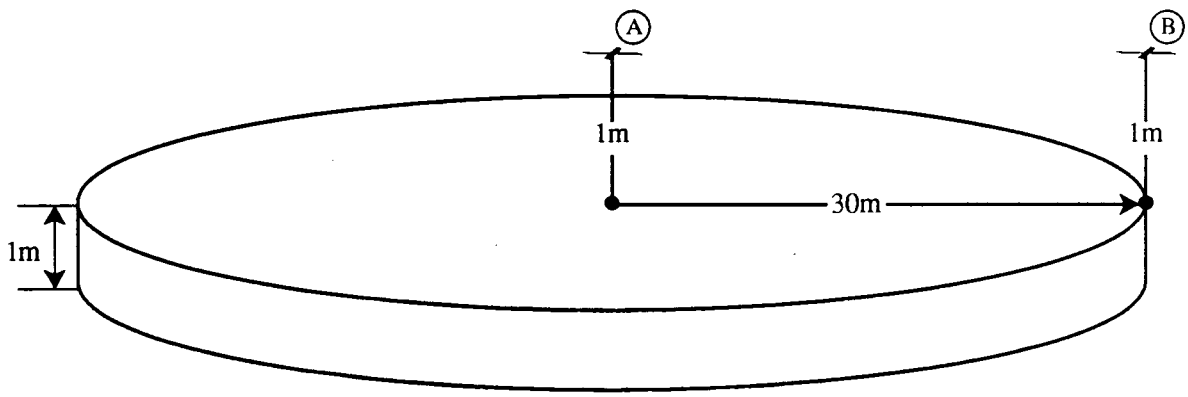

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FIGURE G.I-1. GEOMETRIES USED TO EVALUATE EXPOSURES TO REMEDIAL WORKERS EXCAVATING SOIL OR PLACING SOIL IN LIFTS WITHIN AN ON-PROPERTY DISPOSAL CELL

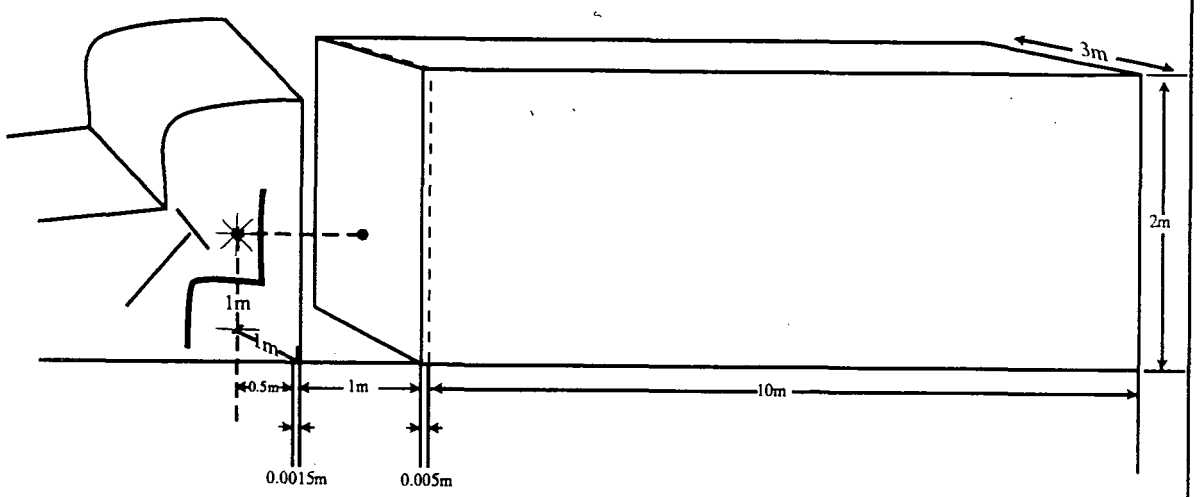

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FIGURE G.I-2. GEOMETRIES USED TO CALCULATE DOSE RATE TO DRIVER OF DUMP TRUCK HAULING CONTAMINATED SOIL

	B25 BOX	RAIL CAR
X END	1m	NA
Y END	0.6m	NA
Z END	0.6m	NA
X SIDE	1m	1m
Y SIDE	0.6m	1.8m
Z SIDE	0.9m	7.7m
L	1.8m	3.2m
W	1.2m	15m
H	1.2m	3.6m

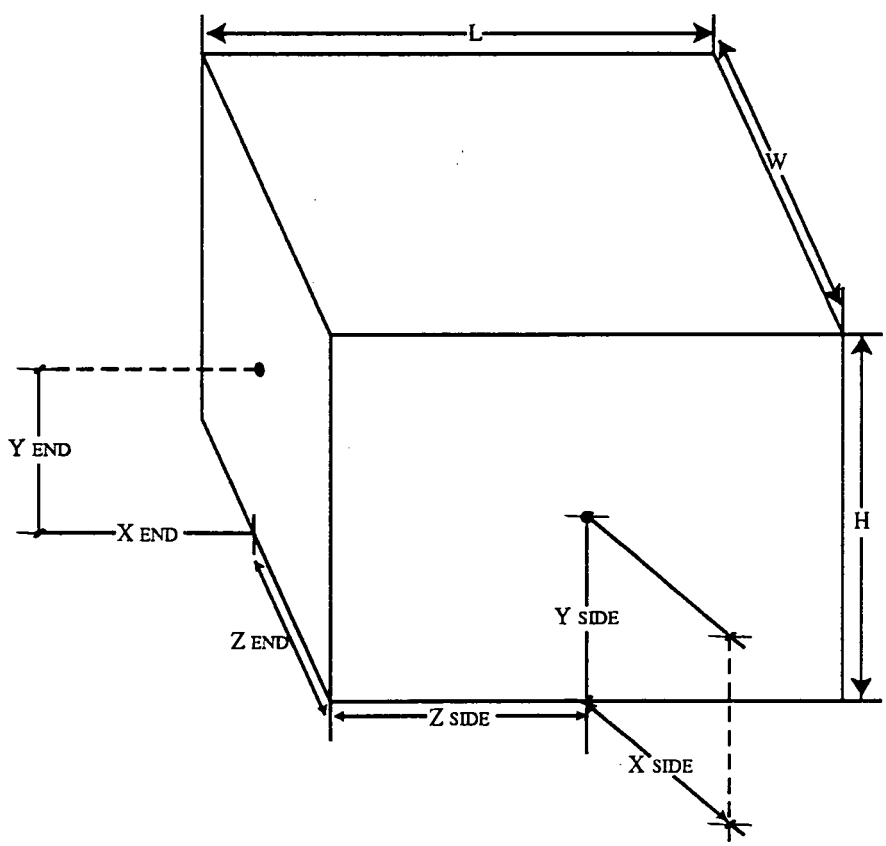

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FIGURE G.I-3. GEOMETRIES USED TO CALCULATE PACKAGE DOSE RATES USED AS INPUT TO RADTRAN CALCS

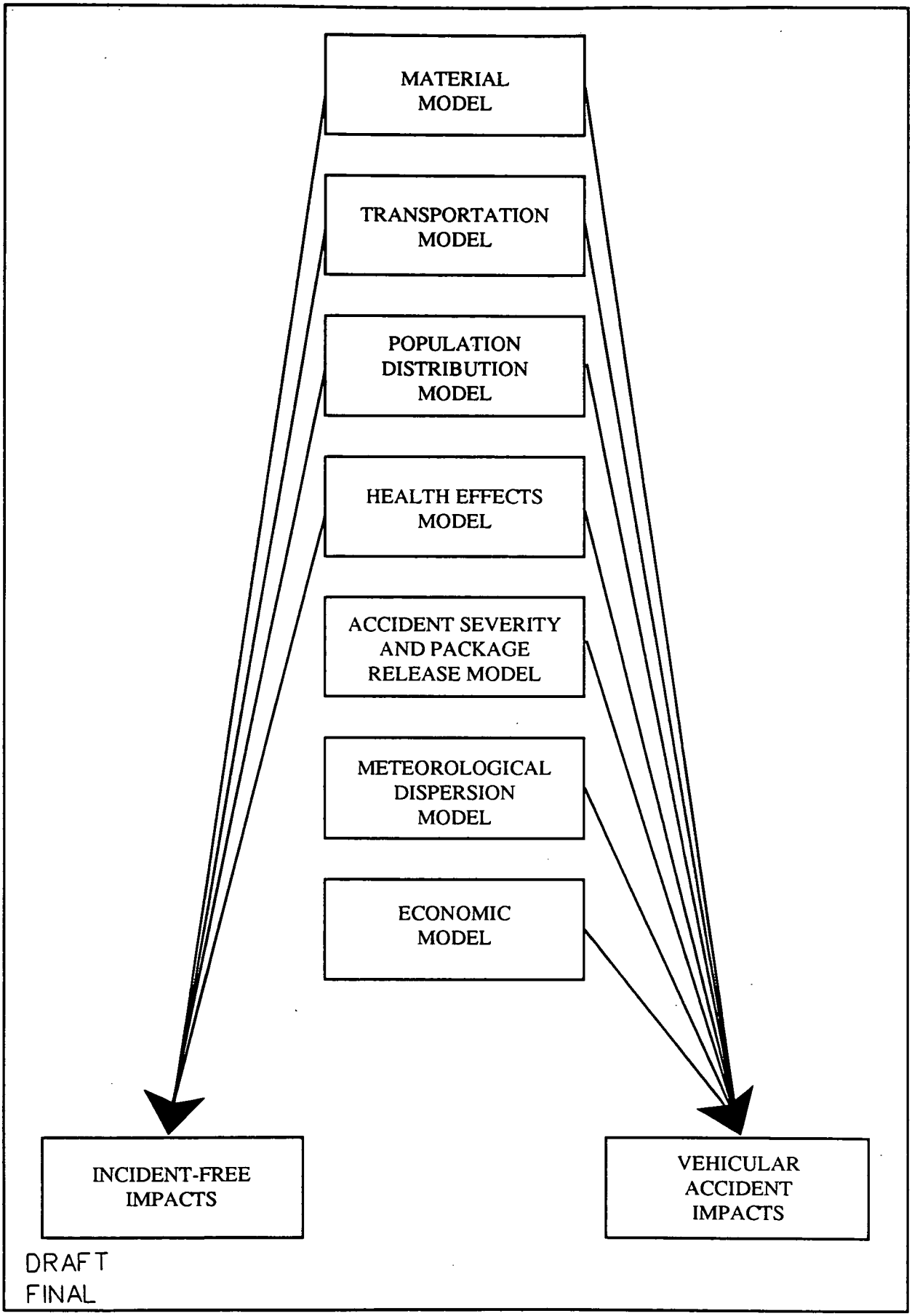

FIGURE G.I-4. RADTRAN METHODOLOGY

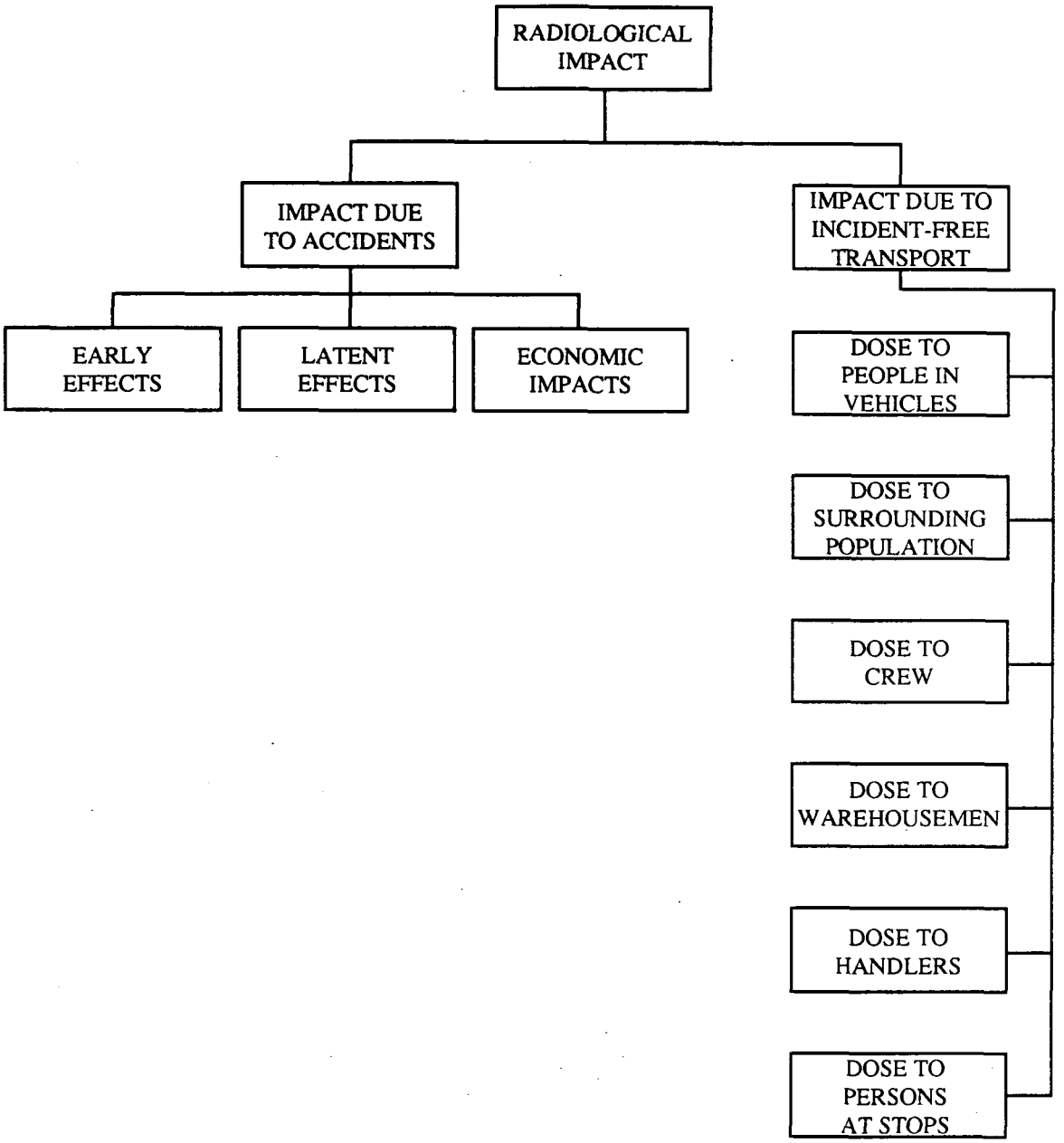

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FIGURE G.I-5. COMPONENTS OF RADIOLOGICAL IMPACT EVALUATED BY RADTRAN

*\ILLUS\OU-5\PO-113\ACCIDENT DOSE PATH.EPS

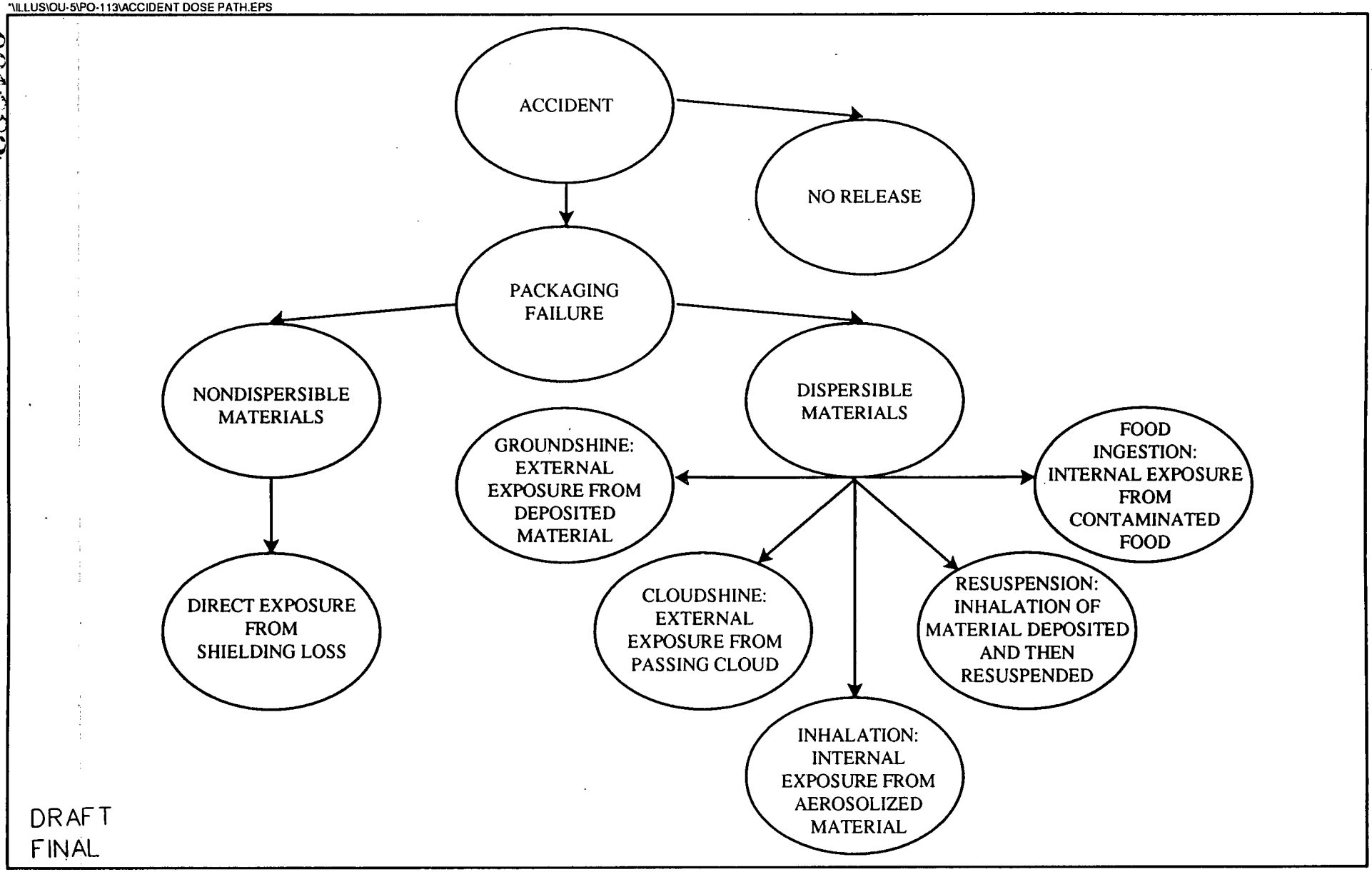

FIGURE G.I-6. ACCIDENT DOSE PATHWAYS MODELED IN RADTRAN

*\ILLUS\OU-5\PO-113\MATL DISPERSE CAT.EPS

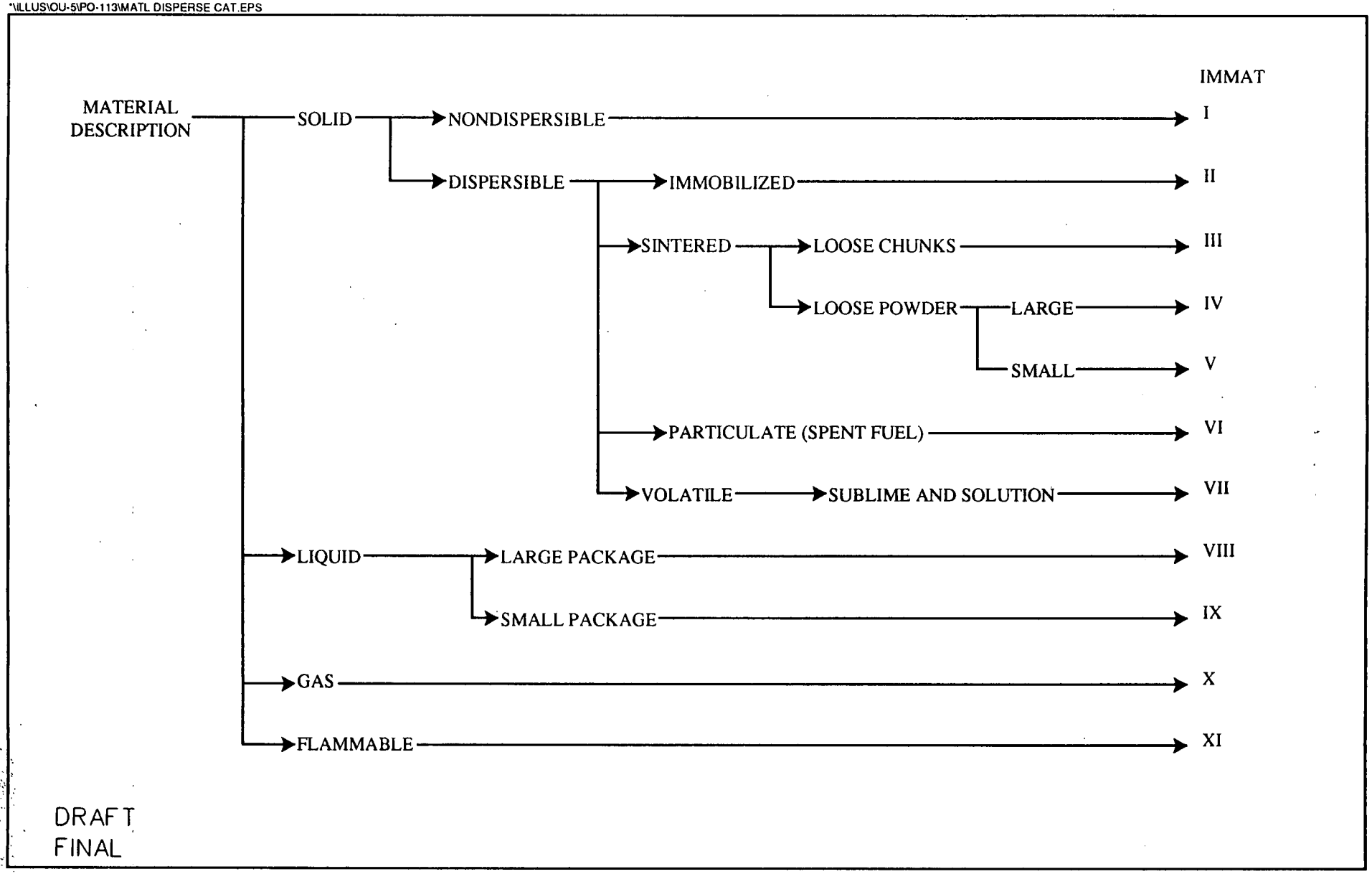

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FIGURE G.I-7. MATERIAL DISPERSIBILITY CATEGORIES

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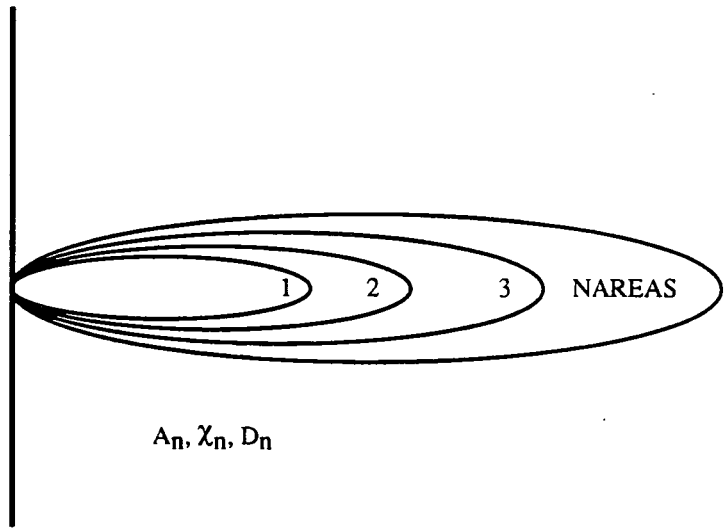
1229 6271



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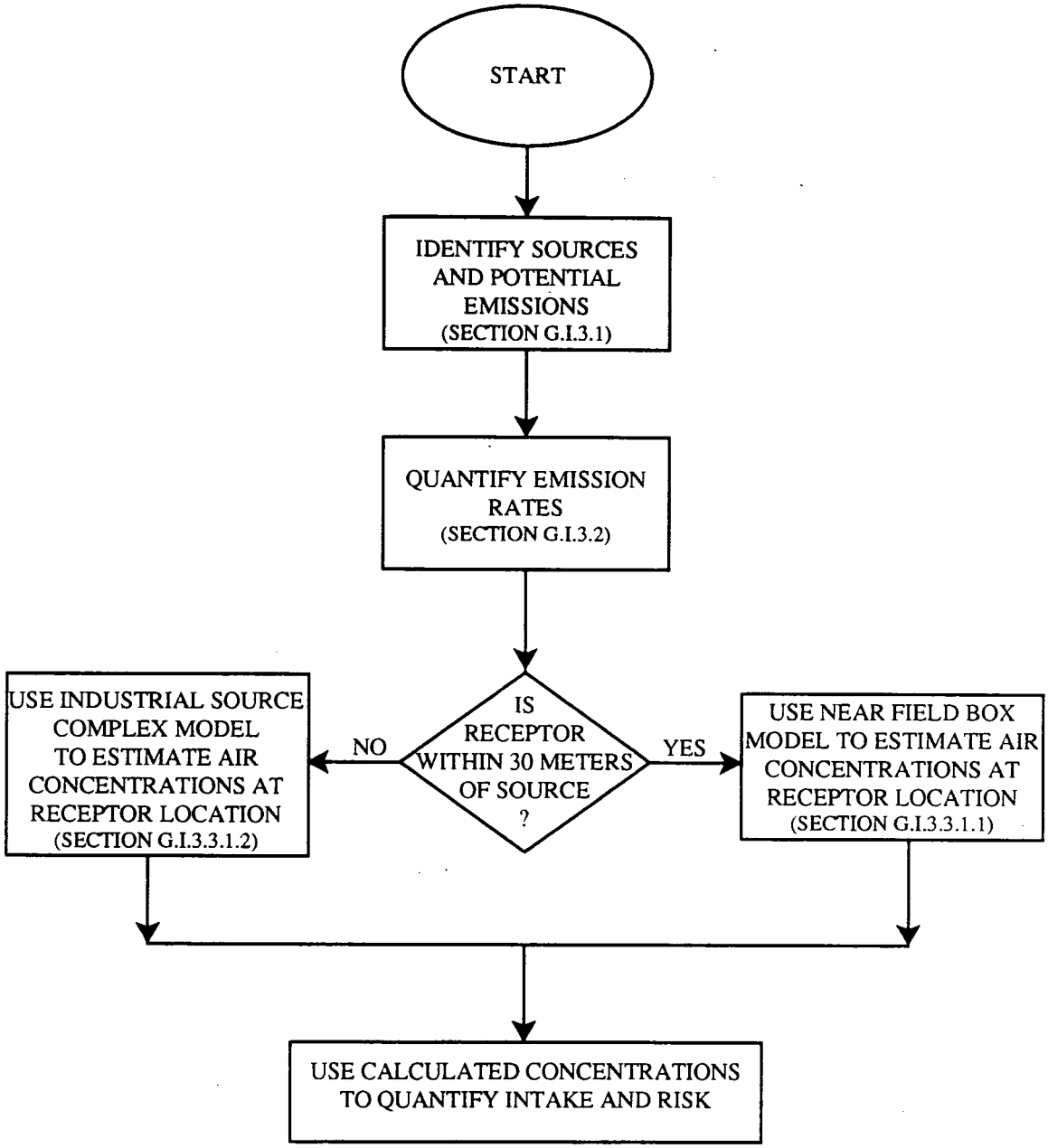
NOT TO SCALE

"ILLUS\OU-5\PO-113\TYP DOWNWIND.EPS

FIGURE G.I-8. TYPICAL DOWNWIND DISPERSION PATTERN ASSUMING GAUSSIAN DIFFUSION



"ILLUS\OU-5\PO-113\G-EST EXPOSURE PT.EPS

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FIGURE G.I-9. APPROACH USED TO ESTIMATE EXPOSURE POINT CONCENTRATIONS IN AIR

TABLE G.I-1
EXTERNAL GAMMA DOSE FROM A ONE HOUR EXPOSURE TO 1 pCi/g OF SELECTED RADIONUCLIDES[a] IN SIX GEOMETRIES

Geometry[b]	Cs137+d (mSv/h)	Ra226+ 8d (mSv/h)	Th232+10d (mSv/h)	U234 (mSv/h)	U235+7d (mSv/h)	U238+2d (mSv/h)
B25 Box (End)	1.75×10^{-7}	4.99×10^{-7}	2.65×10^{-6}	8.59×10^{-12}	3.34×10^{-7}	1.46×10^{-8}
B25 Box (Side)	6.67×10^{-7}	2.36×10^{-6}	3.56×10^{-6}	1.12×10^{-11}	4.44×10^{-7}	1.96×10^{-8}
Railroad Car (Side)	1.74×10^{-6}	6.66×10^{-6}	1.04×10^{-5}	8.34×10^{-12}	9.94×10^{-7}	6.72×10^{-6}
Soil Disc (Center)	3.98×10^{-6}	1.37×10^{-5}	2.08×10^{-5}	1.48×10^{-10}	3.23×10^{-6}	1.13×10^{-7}
Soil Disc (Edge)	1.91×10^{-6}	6.60×10^{-6}	1.00×10^{-5}	7.07×10^{-11}	1.54×10^{-6}	5.44×10^{-8}
Dump Truck (Cab)	6.25×10^{-7}	2.33×10^{-6}	3.59×10^{-6}	3.03×10^{-12}	3.66×10^{-7}	1.91×10^{-8}

[a] Includes the contribution from daughter products.

[b] These geometries are depicted in Figures G.I-1 through G.I-3.

TABLE G.I-2

WORK FORCE EXPOSURES AND RME WORKER RISKS FROM EXCAVATION OF CONTAMINATED SOIL

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi) At Center of Area	Unit Dose Rate[b] (mSv-g/h-pCi) 1m Beyond Edge of Area	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d] Center of Area (h/life)	Time an Individual Spends at Location During Remediation[d] 1m from Edge (h)	Size of Work Force[e] (Persons)	Dose to Work Force[f] (Persons-cSv)	Risks to RME Worker[g] (ILCR)
Case 1								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	82	1.5	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	82	8.4	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	82	10	7.8×10^{-5}
Th232+d	2.08E-05	1.00×10^{-5}	2.8	22000	22000	82	16	1.2×10^{-4}
Totals							36	2.7×10^{-4}
Case 2								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	24	0.4	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	24	2.5	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	24	3.0	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	24	4.6	1.2×10^{-4}
Totals							10	2.7×10^{-4}
Case 3								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	21	0.4	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	21	2.2	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	21	2.6	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	21	4.0	1.2×10^{-4}
Totals							9.2	2.7×10^{-4}
Case 4								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	19	0.3	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	19	2.0	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	19	2.4	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	19	3.6	1.2×10^{-4}
Totals							8.3	2.7×10^{-4}

TABLE G.I-2
(Continued)

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi) At Center of Area	Unit Dose Rate[b] (mSv-g/h-pCi) 1m Beyond Edge of Area	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d] Center of Area (h/life)	Time an Individual Spends at Location During Remediation[d] 1m from Edge (h)	Size of Work Force[e] (Persons)	Dose to Work Force[f] (Persons-cSv)	Risks to RME Worker[g] (ILCR)
Case 5								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	19	0.3	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	19	2.0	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	19	2.4	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	19	3.6	1.2×10^{-4}
Totals							8.3	2.7×10^{-4}
Case 6								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	16	0.3	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	16	1.6	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	16	2.0	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	16	3.0	1.2×10^{-4}
Totals							7.0	2.7×10^{-4}
Case 7								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	16	0.3	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	16	1.6	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	16	2.0	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	16	3.0	1.2×10^{-4}
Totals							7.0	2.7×10^{-4}
Case 8								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	19	0.3	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	19	2.0	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	19	2.4	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	19	3.6	1.2×10^{-4}
Totals							8.3	2.7×10^{-4}

TABLE G.I-2
(Continued)

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi)		Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d]		Size of Work Force[e] (Persons)	Dose to Work Force[f] (Persons-cSv)	Risks to RME Worker[g] (ILCR)
	At Center of Area	1m Beyond Edge of Area		Center of Area (h/life)	1m from Edge (h)			
Case 9								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	22000	22000	16	2.8	1.1×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	22000	22000	16	10.3	6.4×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	22000	22000	16	12.6	7.8×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	22000	22000	16	19.0	1.2×10^{-4}
Totals							44.6	2.7×10^{-4}

[a] U-234, Cs-137, and Th-230 are not included in this list because either their concentration or their gamma activities are low
[b] From Table G.I-1
[c] From Table G.2-5
[d] Assumed value
[e] # People = (Total Person hours from Table G.3-5)(22y)/(250d/y)/(8h/d)
[f] DOSE = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x 0.1 cSv/mSv x (Soil Conc, pCi/g) x (Number of Workers)
[g] Incremental lifetime cancer risk = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x (Soil Conc, pCi/g) x (6.2×10^{-5} r/mSv)

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TABLE G.I-3
WORK FORCE EXPOSURES AND RME WORKER RISKS FROM PLACEMENT AND HANDLING OF CONTAMINATED MATERIAL

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi) At Center of Area	Unit Dose Rate[b] (mSv-g/h-pCi) 1 m Beyond Edge of Area	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d] Center of Area (h)	Time an Individual Spends at Location During Remediation[d] 1m from Edge (h)	Size of Work Force[e] (Persons)	CEDE to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Disposal Cell: Case 1								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	97	2.3	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	97	13.4	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	97	16.5	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	97	24.8	1.6×10^{-4}
Totals							57.1	3.7×10^{-4}
Disposal Cell: Case 2								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	29	0.69	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	29	4.0	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	29	4.9	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	29	7.4	1.6×10^{-4}
Totals							17.1	3.7×10^{-4}
Disposal Cell: Case 3								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	29	0.69	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	29	4.0	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	29	4.9	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	29	7.4	1.6×10^{-4}
Totals							17.1	3.7×10^{-4}
Disposal Cell: Cases 4-9								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	23	0.55	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	23	3.2	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	23	3.9	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	23	5.9	1.6×10^{-4}
Totals							13.5	3.7×10^{-4}

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Table G.I-3
(Continued)

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi) At Center of Area	Unit Dose Rate[b] (mSv-g/h-pCi) 1 m Beyond Edge of Area	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d] Center of Area (h)	Time an Individual Spends at Location During Remediation[d] 1m from Edge (h)	Size of Work Force[e] (Persons)	CEDE to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Consolidation Area: Case 2								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	22	0.53	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	22	3.1	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	22	3.7	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	22	5.6	1.6×10^{-4}
Totals							13.0	3.7×10^{-4}
Consolidation Area: Case 3								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	22	0.53	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	22	3.1	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	22	3.7	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	22	5.6	1.6×10^{-4}
Totals							13.0	3.7×10^{-4}
Consolidation Area: Cases 4-9								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	44000	0	14	0.33	1.5×10^{-5}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	44000	0	14	1.9	8.6×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	44000	0	14	2.4	1.1×10^{-4}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	44000	0	14	3.6	1.6×10^{-4}
Totals							8.2	3.7×10^{-4}

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Table G.I-3
(Continued)

Radionuclides[a]	Unit Dose Rate[b] (mSv-g/h-pCi) At Center of Area	Unit Dose Rate[b] (mSv-g/h-pCi) 1 m Beyond Edge of Area	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Location During Remediation[d] Center of Area (h)	Time an Individual Spends at Location During Remediation[d] 1m from Edge (h)	Size of Work Force[e] (Persons)	CEDE to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Central Storage Operations: Cases 1-9								
U238+d	1.13×10^{-7}	5.44×10^{-8}	48	0	44000	8	0.09	7.1×10^{-6}
Ra226+d	1.37×10^{-5}	6.60×10^{-6}	2.3	0	44000	8	0.53	4.1×10^{-5}
U235+d	3.23×10^{-6}	1.54×10^{-6}	12	0	44000	8	0.65	5.0×10^{-5}
Th232+d	2.08×10^{-5}	1.00×10^{-5}	2.8	0	44000	8	1.0	7.6×10^{-5}
Totals							2.3	1.8×10^{-4}

[a] U-234, Cs-137, and Th-230 are not included in this list because either their concentration or their gamma activities are low.
[b] From Table G.I-1
[c] From Table G.2-5
[d] Assumed value
[e] # People = (Total Person hours from Table G.3-5)/(22y)(250d/y)/(8h/d)
[f] Committed effective dose equivalent = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x 0.1 cSv/mSv x (Soil Conc, pCi/g) x (Number of Workers)
[g] Incremental lifetime cancer risk = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x (Soil Conc, pCi/g) x (6.2×10^{-5} r/mSv)

TABLE G.I-4

WORK FORCE AND RME WORKER RISKS DURING HAULING OPERATIONS

Radionuclides[a]	Unit Dose Rate To Driver[b] (mSv-g/h-pCi)	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Driving A Full Truck[d] (h)	Size of Work Force[e] (Persons)	Dose to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Case 1						
U238+d	1.91×10^{-8}	48	22000	23	0.046	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	23	0.27	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	23	0.22	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	23	0.51	1.4×10^{-5}
Totals					1.0	2.8×10^{-5}
Case 2						
U238+d	1.91×10^{-8}	48	22000	6	0.013	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	6	0.076	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	6	0.063	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	6	0.14	1.4×10^{-5}
Totals					0.30	2.8×10^{-5}
Case 3						
U238+d	1.91×10^{-8}	48	22000	6	0.011	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	6	0.067	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	6	0.055	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	6	0.13	1.4×10^{-5}
Totals					0.26	2.8×10^{-5}

TABLE G.I-4
(Continued)

Radionuclides[a]	Unit Dose Rate To Driver[b] (mSv-g/h-pCi)	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Driving A Full Truck[d] (h)	Size of Work Force[e] (Persons)	Dose to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Case 4						
U238+d	1.91×10^{-8}	48	22000	5	0.011	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	5	0.062	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	5	0.051	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	5	0.12	1.4×10^{-5}
Totals					0.24	2.8×10^{-5}
Case 5						
U238+d	1.91×10^{-8}	48	22000	5	0.010	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	5	0.061	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	5	0.050	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	5	0.11	1.4×10^{-5}
Totals					0.24	2.8×10^{-5}
Case 6						
U238+d	1.91×10^{-8}	48	22000	4	0.0086	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	4	0.050	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	4	0.041	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	4	0.094	1.4×10^{-5}
Totals					0.19	2.8×10^{-5}
Case 7						
U238+d	1.91×10^{-8}	48	22000	4	0.0086	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	4	0.050	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	4	0.041	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	4	0.094	1.4×10^{-5}
Totals					0.19	2.8×10^{-5}

TABLE G.I-4
(Continued)

Radionuclides[a]	Unit Dose Rate To Driver[b] (mSv-g/h-pCi)	Average Soil Concentration[c] (pCi/g)	Time an Individual Spends at Driving A Full Truck[d] (h)	Size of Work Force[e] (Persons)	Dose to Work Force[f] (Person-cSv)	Risks to RME Worker[g] (ILCR)
Case 8						
U238+d	1.91×10^{-8}	48	22000	5	0.010	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	5	0.061	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	5	0.050	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	5	0.11	1.4×10^{-5}
Totals					0.24	2.8×10^{-5}
Case 9						
U238+d	1.91×10^{-8}	48	22000	4	0.0086	1.3×10^{-6}
Ra226+d	2.33×10^{-6}	2.3	22000	4	0.050	7.3×10^{-6}
U235+d	3.66×10^{-7}	12	22000	4	0.041	6.0×10^{-6}
Th232+d	3.59×10^{-6}	2.8	22000	4	0.094	1.4×10^{-5}
Totals					0.19	2.8×10^{-5}

[a] U-234, Cs-137, and Th-230 are not included in this list because either their concentration or their gamma activities are low.
[b] From Table G.I-1
[c] From Table G.2-5
[d] Assumed value
[e] # People = (Total Person hours from Table G.3-5)(22y)/(250d/y)/(8h/d)
[f] Committed effective dose equivalent = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x 0.1 cSv/mSv x (Soil Conc, pCi/g) x (Number of Workers)
[g] Incremental lifetime cancer risk = [(Dose rate at center, mSv-g/h-pCi)(Time at center, h) + (Dose rate at 1 m, mSv-g/h-pCi)(Time at 1m, h)] x (Soil Conc, pCi/g) x (6.2×10^{-5} r/mSv)

TABLE G.I-5

COMMON INPUT PARAMETERS FOR INCIDENT-FREE RADTRAN MODEL OF RAIL TRANSPORT

Parameter	Value	Units
Packages (Rail Cars) Per Shipment	50[a]	Rail Cars
Distance to Representative Disposal Facility	3098	km
Dose Rate at 1m (Transport Index)	0.0129[b]	mrem/hr
Travel in Rural Population Zone	82	% of total
Travel in Suburban Population Zone	14	% of total
Travel in Urban Population Zone	4	% of total
Velocity in Rural Population Zone	64	km/hr
Velocity in Suburban Population Zone	40	km/hr
Velocity in Urban Population Zone	24	km/hr
Number of Crewmen	5[c]	People
Distance from Source to Crew	25.1[d]	m
Number of Handlings	2	Unitless
Stop Time per Kilometer	0.033	hr/km
Minimum Stop Time per Trip	10	hr
Zero Stop Time per Trip	60	hr
Minimum Number of Rail Classifications/Inspections	2	Insp.
Persons Exposed While Stopped	100	People
Average Exposure Distance While Stopped	20	m
Storage Time per Shipment	8	hr
Number of Exposed Persons During Storage	20	hr
Average Exposure Distance While In Storage	100	m
Number of People per Vehicle on Link	5	People
Maximum Number of Trips per Crew	100	Trips
Fraction of Urban Travel During Rush Hour	0	Unitless
Fraction of Urban Travel on City Streets	1	Unitless
Fraction of Rural-Suburban Travel on Freeways	0	Unitless
Traffic Count Passing a Specific Point-Rural Zone	1	Cars/Time
Traffic Count Passing a Specific Point-Suburban Zone	5	Cars/Time
Traffic Count Passing a Specific Point-Urban Zone	5	Cars/Time

[a] The number of packages for determining the dose to crew members was reduced to 1 rail car. The contribution from the trailing 49 cars would be negligible due to self-shielding. RADTRAN 4 does not take self-shielding into consideration in calculating dose.

[b] The 1m dose rates were for bulk soil.

[c] The number of crew is per shipment. The number used for the duration of the project was not quantified. Additional crews would reduce individual risk over the life of the project.

[d] The distance from the source to crew is based on one diesel engine pulling the bulk soil cars. In reality, at least two diesels would be expected to pull 50 bulk soil cars. Also, shielding due to the diesel itself was not taken into consideration. RADTRAN 4 requires the user to increase this distance to account for shielding.

TABLE G.I-6

CONCENTRATIONS IN SOIL FOR OFF-SITE SHIPMENTS ASSOCIATED WITH REMEDIAL TECHNOLOGIES

Radionuclide	No Treatment[a]	On-Site Disposal Facility[b]	Consolidation with Earthen Cover[c]
Cesium-137	5.1×10^{-1}	1.0×10^{0}	1.0×10^{0}
Neptunium-226	6.8×10^{-1}	1.4×10^{0}	1.4×10^{0}
Plutonium 238	5.3×10^{-1}	1.1×10^{0}	1.1×10^{0}
Plutonium-239/240	6.4×10^{-1}	1.3×10^{0}	1.3×10^{0}
Radium-226	2.3×10^{0}	4.6×10^{0}	4.6×10^{0}
Radium-228	1.4×10^{0}	2.8×10^{0}	2.8×10^{0}
Strontium-90	6.9×10^{-1}	1.4×10^{0}	1.4×10^{0}
Technetium-99	6.1×10^{1}	1.2×10^{0}	1.2×10^{0}
Thorium-228	3.1×10^{0}	6.2×10^{0}	6.2×10^{0}
Thorium-230	7.3×10^{0}	1.5×10^{2}	1.5×10^{2}
Thorium-232	2.9×10^{0}	5.8×10^{0}	5.8×10^{0}
Thorium-234	8.8×10^{-3}	1.8×10^{1}	1.8×10^{1}
Uranium-234	4.8×10^{-3}	7.0×10^{-2}	1.5×10^{1}
Uranium-235/236	3.5×10^{-2}	3.1×10^{1}	6.8×10^{-1}
Uranium-238	4.8×10^{-1}	7.0×10^{2}	1.5×10^{1}

[a] Alternative 1
[b] Alternatives 2A, 3A, 4A
[c] Alternatives 2C, 3C, 4C

TABLE G.I-7
ACTIVITY (CURIES) PER RAILROAD GONDOLAS AND TRUCK

Radionuclide	Gondola Case 1	Gondola Cases 2-9	Truck - B-25 Box Case 2-9
Cs-137	4.6×10^{-5}	9.2×10^{-5}	3.1×10^{-6}
Np-237	6.1×10^{-5}	1.2×10^{-4}	4.1×10^{-6}
Pu-238	4.8×10^{-5}	9.7×10^{-5}	3.2×10^{-6}
Pu-239	5.8×10^{-5}	1.2×10^{-4}	3.9×10^{-6}
Pu-240	5.8×10^{-5}	1.2×10^{-4}	3.9×10^{-6}
Ra-226	6.9×10^{-4}	1.4×10^{-2}	4.6×10^{-4}
Sr-90	6.2×10^{-5}	1.2×10^{-4}	4.2×10^{-6}
Tc-99	5.5×10^{-4}	1.1×10^{-3}	3.7×10^{-5}
Th-228	2.8×10^{-4}	5.5×10^{-4}	1.8×10^{-5}
Th-230	6.6×10^{-3}	1.3×10^{-2}	4.4×10^{-4}
Th-232	2.6×10^{-4}	5.2×10^{-4}	1.7×10^{-5}
U-234	2.4×10^{-7}	4.8×10^{-7}	1.6×10^{-8}
U-235	3.2×10^{-5}	6.3×10^{-5}	2.1×10^{-6}
U-238	4.4×10^{-3}	8.8×10^{-3}	2.9×10^{-4}

TABLE G.I-8

INCIDENT-FREE SUMMARY FOR ONE SHIPMENT

Population Subgroup	Rail Transport Bulk Soil (person-rem)	Truck Transport Bulk Soil (person-rem)
Crew	6.4×10^{-6}	7.3×10^{-3}
Handlers	2.1×10^{-2}	1.9×10^{-3}
Public Along Route	2.4×10^{-3}	5.2×10^{-5}
Public Passing in Other Vehicles	2.7×10^{-4}	5.8×10^{-4}
Public Along Stops	3.9×10^{-3}	1.8×10^{-4}
Public in Storage Depots	4.4×10^{-4}	0
Total to Public	2.8×10^{-2}	2.7×10^{-3}
Total for All Population Subgroups	5.5×10^{-2}	1.0×10^{-2}

TABLE G.I-9

COMMON INPUT PARAMETERS FOR INCIDENT-FREE RADTRAN MODEL OF TRUCK TRANSPORT

Parameter	Value	Units
Packages Per Shipment	6[a]	B-25 boxes
Distance to Representative Disposal Facility	3300	km
Dose Rate at 1m (Transport Index)	0.018[b]	mrem/hr
Travel in Rural Population Zone	88.4	% of total
Travel in Suburban Population Zone	10.4	% of total
Travel in Urban Population Zone	1.2	% of total
Velocity in Rural Population Zone	44	km/hr
Velocity in Suburban Population Zone	20	km/hr
Velocity in Urban Population Zone	12	km/hr
Number of Crewmen	2[c]	People
Distance from source to crew	3.1	m
Number of Handlings	2	Unitless
Stop Time per Kilometer	0.011	hr/km
Minimum Stop Time per Trip	36.3	hr
Zero Stop Time per Trip	0	hr
Persons Exposed While Stopped	4	People
Average Exposure Distance While Stopped	20	m
Storage Time per Shipment	0	hr
Number of People per Vehicle on Route	2	People
Maximum Number of Trips per Crew	100	Trips
Fraction of Urban Travel During Rush Hour	0.08	Unitless
Fraction of Urban Travel on City Streets	0.06	Unitless
Fraction of Rural-Suburban Travel on Freeways	0.85	Unitless
Traffic Count Passing a Specific Point-Rural Zone	470	Cars/Time
Traffic Count Passing a Specific Point-Suburban Zone	780	Cars/Time
Traffic Count Passing a Specific Point-Urban Zone	2800	Cars/Time

[a] The number of packages for determining the dose to crew members is 6 B-25 boxes. This is a very conservative approach and does not take self-shielding into consideration in calculating dose.

[b] The 1m dose rates were for bulk soil.

[c] The number of crewmen is per shipment. The number used for the duration of the project was not quantified. Additional crews would reduce individual risk over the life of the project.

TABLE G.I-10

ACCIDENT SEVERITY AND RELEASE FRACTIONS BY POPULATION DISTRIBUTION AND SEVERITY GROUP

Severity Group	Accident Severity Fractions			Release Fraction
	Rural	Suburban	Urban	
Rail Transport				
1	3.6×10^{-1}	3.1×10^{-1}	5.7×10^{-1}	0
2	2.1×10^{-1}	1.9×10^{-1}	3.4×10^{-1}	1.0×10^{-1}
3	3.9×10^{-1}	4.5×10^{-1}	7.7×10^{-2}	2.0×10^{-1}
4	3.9×10^{-2}	4.5×10^{-2}	7.7×10^{-2}	3.0×10^{-1}
5	6.4×10^{-3}	3.4×10^{-3}	5.1×10^{-4}	4.0×10^{-1}
6	6.5×10^{-4}	1.6×10^{-4}	1.9×10^{-5}	5.0×10^{-1}
7	3.4×10^{-4}	3.8×10^{-5}	8.6×10^{-6}	6.0×10^{-1}
8	6.4×10^{-5}	3.1×10^{-6}	7.2×10^{-7}	1.0×10^{0}
Truck Transport				
1	4.6×10^{-1}	4.4×10^{-1}	5.8×10^{-1}	0
2	3.0×10^{-1}	2.9×10^{-1}	3.8×10^{-1}	1.0×10^{-2}
3	1.8×10^{-1}	2.2×10^{-1}	2.8×10^{-2}	2.0×10^{-2}
4	4.0×10^{-2}	5.1×10^{-2}	6.4×10^{-3}	4.0×10^{-2}
5	1.2×10^{-2}	6.6×10^{-3}	7.4×10^{-4}	8.0×10^{-2}
6	6.5×10^{-3}	1.7×10^{-3}	1.5×10^{-4}	1.6×10^{-1}
7	5.7×10^{-4}	6.7×10^{-5}	1.1×10^{-5}	3.2×10^{-1}
8	1.1×10^{-5}	5.9×10^{-6}	9.9×10^{-7}	6.4×10^{-1}

TABLE G.I-11
ACCIDENT SUMMARY FOR ONE RAIL SHIPMENT

Population Density	Severity Group	Expected No. of Accidents per Shipment	Consequences of One Shipment (person-rem)
Urban	1	1.1×10^{-3}	0
	2	6.4×10^{-4}	7.2×10^{1}
	3	1.4×10^{-4}	1.4×10^{2}
	4	1.4×10^{-4}	2.2×10^{2}
	5	9.6×10^{-7}	2.9×10^{2}
	6	3.5×10^{-8}	3.6×10^{2}
	7	1.6×10^{-8}	4.3×10^{2}
	8	1.3×10^{-9}	7.2×10^{2}
Urban Total		2.0×10^{-3}	2.2×10^{-3}
Suburban	1	2.6×10^{-4}	0
	2	1.6×10^{-4}	1.7×10^{1}
	3	3.7×10^{-4}	3.3×10^{1}
	4	3.7×10^{-5}	5.0×10^{1}
	5	2.8×10^{-6}	6.7×10^{1}
	6	1.4×10^{-7}	8.3×10^{1}
	7	3.1×10^{-8}	1.0×10^{2}
	8	2.6×10^{-9}	1.7×10^{2}
Suburban Total		8.3×10^{-4}	5.2×10^{2}
Rural	1	9.1×10^{-5}	0
	2	5.5×10^{-5}	3.1×10^{-1}
	3	9.8×10^{-5}	6.2×10^{-1}
	4	9.8×10^{-6}	9.3×10^{-1}
	5	1.6×10^{-6}	9.3×10^{-1}
	6	1.7×10^{-7}	1.3×10^{0}
	7	8.7×10^{-8}	1.6×10^{0}
	8	1.6×10^{-8}	1.9×10^{0}
Rural Total		2.6×10^{-4}	3.1×10^{0}
Overall Total		3.1×10^{-3}	2.7×10^{3}

TABLE G.I-12

ACCIDENT SUMMARY FOR ONE TRUCK SHIPMENT

Population Density	Severity Group	Expected No. of Accidents per Shipment	Consequences of One Shipment (person-rem)
Urban	1	3.1×10^{-4}	0
	2	2.0×10^{-4}	2.3×10^{-2}
	3	1.5×10^{-5}	4.5×10^{-2}
	4	3.4×10^{-6}	9.1×10^{-2}
	5	3.9×10^{-7}	1.8×10^{-1}
	6	8.0×10^{-8}	3.6×10^{-1}
	7	5.9×10^{-9}	7.3×10^{-1}
	8	5.3×10^{-10}	1.5×10^{-1}
Urban Total		5.3×10^{-4}	1.6×10^{0}
Suburban	1	3.4×10^{-4}	0
	2	2.3×10^{-4}	5.3×10^{-3}
	3	1.7×10^{-4}	1.1×10^{-2}
	4	4.0×10^{-5}	2.1×10^{-2}
	5	5.1×10^{-6}	4.3×10^{-2}
	6	1.3×10^{-6}	8.5×10^{-2}
	7	5.2×10^{-8}	1.7×10^{-1}
	8	4.6×10^{-9}	3.4×10^{-1}
Suburban Total		7.9×10^{-4}	6.8×10^{-1}
Rural	1	1.6×10^{-4}	0
	2	1.0×10^{-4}	1.0×10^{-4}
	3	6.2×10^{-5}	2.1×10^{-4}
	4	1.4×10^{-5}	4.2×10^{-4}
	5	4.1×10^{-6}	8.3×10^{-4}
	6	2.3×10^{-6}	1.7×10^{-3}
	7	2.0×10^{-7}	3.3×10^{-3}
	8	3.8×10^{-9}	6.6×10^{-3}
Rural Total		3.4×10^{-4}	1.3×10^{-2}
Overall Total		1.7×10^{-3}	2.3×10^{0}

TABLE G.I-13

EMISSION SOURCES ASSOCIATED WITH REMEDIAL ACTIVITIES

REMEDIAL COMPONENT		MAJOR OPERATIONS	EMISSION SOURCES
1.	Soil Excavation	Digging	Direct exposure (DE), Dermal contact (DC), Engine emissions (EE), Total suspended paticulate (TSP)[a]
		Loading	
		Vehicle Wheel Washing	DE, DC
		Transporation	DE, EE
2.	Off-Site Disposal	Vehicle Wheel Washing[b]	DE, DC, surface runoff
		Transportation	DE, EE
		Unloading at the Disposal Site	DE, DC, EE, TSP
3.	Consolidation Area	Prepare/Construct the Area	DE, EE, TSP
		Provide Stormwater Controls	DE, EE, TSP, DC
		Monitoring Well Constuction[b]	DE, DC, EE, TSP
		Well Sampling and Maintenance[b]	DE, DC
4.	On-Site Disposal Facility	Cell Construction	EE
		Waste Placement	DE, EE, DC, TSP
		Leachate and Stormwater Management	DE, DC
		Monitoring Well Constuction[b]	DE, DC, EE, TSP
		Well Sampling and Maintenance[b]	DE, DC
5.	Soil Backfill	Importing Clean Soils	EE[c]
		Unloading	EE
		Compacting and Grading	EE

TABLE G.I-13
(Continued)

REMEDIAL COMPONENT		MAJOR OPERATIONS	EMISSION SOURCES
6.	Groundwater Monitoring	Monitoring Well Constuction	DE, DC, EE, TSP
		Well Sampling and Maintenance	DE, DC
		Well Abandonment	DE, DC, EE, TSP
7.	GMA Extraction	Extraction Well/Pipeline Construction	DE, DC, EE, TSP
		Extraction Well Pumping & Maintenance	DE, DC, EE
8.	Water Treatment	Equalization, Filtration, Adsorption	DE, Evaporation, DC with spent material, acids, and caustic soda
		Ion Exchange, Effluent Monitoring	
		Resin Regeneration and U Precipitation	
		Waste Handling and Disposal	
		AWWT dewatering: filtration and drying	DE, TSP
		Aeration	DE, DC, Evaporation
		Lagoon and retention basin evaporation	
		Effluent filtration	
		Sludge drying	DE, DC, TSP
9.	Conatminated Soil Interim Storage	Unloading soil from vehicles	DE, DC, EE, TSP
		Stockpiling soils	DE, DC, EE, TSP
		Loading soils to vehicles	DE, DC, EE, TSP
10.	Decommission and Demolition[d]	Material segregation	DE, DC, EE, TSP
		Decontamination	DE, DC, EE, TSP
		Disposal of non-recoverable material	DE, DC, EE, TSP

[a] Denotes an optional operation. Such an operation may be required for a specific waste constituent. It can also be overlapped with a similar operation in another Remedial Component.
[b] TSP could result from wind blown and mechanical disturbance
[c] Earth moving operation on clean soils that have no detectable levels of COCs, therefore, exposures to COCs are not a concern.
[d] This activity is an integral part of many of the remedial components and is presented separately for ease of presentation.

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TABLE G.I-14

DIESEL ENGINE EMISSION RATES FOR MOBILE EQUIPMENT (kg/d)[a]

Equipment ID	Equipment Type	PM_{10}	So_2	No_2	VOC	CO	HCHO
A	Track-type tractor	50.7	82.3	570.70	55.06	157.01	12.4
B	Wheeled tractor	61.5	40.9	575.84	85.26	1622.77	13.5
C	Wheeled dozer, skid loader	75.0	158.0	1889.18	88.84	616.81	29.5
D	Scraper	184.0	210.0	1740.74	128.15	568.19	65.0
E	Motor grader	27.7	39.0	324.43	18.07	68.46	5.5
F	Wheeled Loader, backhoe loader	77.9	82.5	858.19	113.17	259.58	18.8
G	Track-type loader	26.4	34.4	375.22	44.55	91.15	4.0
H	Off-highway truck	116.0	206.0	1889.18	86.84	818.81	51.0
I	Roller, compactor	22.7	30.5	392.90	30.58	137.97	7.4
J	Miscellaneous, hydraulic excavator	63.2	64.7	767.30	69.35	306.37	13.9

[a] EPA 1985

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TABLE G.I-15

EQUATIONS USED TO CALCULATE EMISSIONS FROM MAJOR TASKS ASSOCIATED WITH REMEDIAL ACTIVITIES

Task	Units	Equation	Reference
Equipment-Related Releases			
PM_{10} Excavation Bulldozer, WL, SL, TL (moving dirt)	kg/hr	0.45*(silt^1.5)*(moist^-1.4)	EPA 1989
PM_{10} Excavation Backhoe, hydraulic excavator[b]	kg/m^3	0.0029*(drop^0.7)*(moist^-0.3)	EPA 1989
PM_{10} Grading	g/s	0.094*(silt^1.5)*(moist^-1.4)	EPA 1989
PM_{10} (k=.22)[a] Transport on Dry Ind. Roads, Med., and Heavy Vehicles	kg/km	k*(siltroad/12)^0.3	EPA 1989
TSP (k=1.0) and PM_{10} (k=0.35) (Load/Unload (TL), Conveyor Belts, and Dump (RT)[c,f]	g	k*0.0016*W*(U/2.2)^1.3*(moist/2)^-1.4	EPA 1993
Releases from Bare Soil			
TSP and PM_{10} Active Storage Piles (Wind Erosion)[d,e]	$g/day/m^2$	[1.9*(silt/15)*(365-predays)*(windfrac/15)]/235	EPA 1993
PM_{10} Consolidation Area Lift Construction	kg/hr	0.34*(silt^1.5)*(moist^-1.4)	Cowherd

a) k is the particle size multiplier
b) drop is the soil drop height of the equipment in meters
c) The mass of soil handled, W, is in kg/d
d) The number of days with precipitation >0.01 inch, Predays, is considered to be 100
e) The fraction of time the wind >5.4 m/s, Windfrac, based on site Met data is 2.53×10^{-2}
f) TL - Track Loader, SL - Skid Loader, WL - Wheel Loader, RT - Roll-off Truck

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TABLE G.I-16

PARAMETER VALUES USED TO QUANTIFY EMISSIONS ASSOCIATED WITH HANDLING CONTAMINATED SOIL

Parameter					
Name	Symbol	Units	Value	Range	Reference
Silt content					
Exposed ground	silt	%	15	5.1 - 21	EPA 1989, Table 28
Topsoil	silt	%	40		EPA 1989, Table 28
Sand	silt	%	10		EPA 1989, Table 28
Limestone	silt	%	2		EPA 1989, Table 28
Overburden pushed by bulldozer	silt	%	6.9	3.8 - 15.1	EPA 1989, Table 28
Overburden pushed by scraper	silt	%	16.4	7.2 - 25.2	EPA 1989, Table 28
Gravel road	silt	%	5		EPA 1989, Table 28
Dirt road	siltroad	%	28.5	5.8 - 68	EPA 1989, Table 28
Crushed limestone road	silt	%	9.5	7.7 - 13	EPA 1989, Table 28
Soil Density					
In place	rho_i	$tons/yd^3$	1.76		OU5 FS, Section 4.0
Excavated	rho_e	tons/yd	1.35		OU5 FS, Section 4.0
Moisture content	moist	%	20		OU5 FS, Section 4.0
Mass of soil handled	W	kg	a		FEMP joint frequency distribution for 5 years
Fraction of time wind speed >5.4 m/s	windfra	unitless	0.0253		
Particle size multiplier	k	unitless			
Drop					
Hydraulic Excavation	drop	m	2.3		
Backhoe/loader	drop	m	1.5		
Dump truck	drop	m	1.5		
Days with precipitation >0.01 inch	predays	d	100		EPA 1985, Figure 4-4

a Alternative/Case-specific

TABLE G.I-17

PARAMETER VALUES USED TO QUANTIFY EMISSION RATES FROM STATIONARY AREA SOURCES

Parameter	Units	Component 1	2	3	4
Near-by Receptors					
Width of source in direction of wind	m	45	80	427	427
Area of source	acre	0.5	1.6	45.1	45.1
Height of box	m	1.8	1.8	1.8	1.8
Average wind speed at ground Level	m/s	0.7	0.7	0.7	0.7
Distance Receptors					
Distance from source to Nonremedial Worker	m	varies	425	550	550
Distance from source to Near-Property Public	m	varies	425	350	350

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TABLE G.I-18

EXPOSURE POINT CONCENTRATIONS DURING EXCAVATION

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-RW comp 1																				
Cesium-137	1.2×10^{-3}	2.8×10^{-4}	1.2×10^{-3}	2.8×10^{-4}	1.2×10^{-3}	2.8×10^{-4}	2.6×10^{-4}	2.5×10^{-4}	2.5×10^{-4}	2.1×10^{-4}	2.1×10^{-4}	2.6×10^{-4}	2.5×10^{-4}	2.5×10^{-4}	2.1×10^{-4}	2.1×10^{-4}	2.5×10^{-4}	2.1×10^{-4}	2.5×10^{-4}	2.1×10^{-4}
Neptunium-237	1.9×10^{-3}	5.0×10^{-4}	1.9×10^{-3}	5.0×10^{-4}	1.9×10^{-3}	5.0×10^{-4}	4.6×10^{-4}	4.4×10^{-4}	4.4×10^{-4}	3.9×10^{-4}	3.9×10^{-4}	4.6×10^{-4}	4.4×10^{-4}	4.4×10^{-4}	3.9×10^{-4}	3.9×10^{-4}	4.4×10^{-4}	3.9×10^{-4}	4.4×10^{-4}	3.9×10^{-4}
Plutonium-238	1.3×10^{-3}	4.2×10^{-4}	1.3×10^{-3}	4.2×10^{-4}	1.3×10^{-3}	4.2×10^{-4}	3.7×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.7×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.4×10^{-4}
Plutonium-239/240	9.4×10^{-4}	4.1×10^{-4}	9.4×10^{-4}	4.1×10^{-4}	9.4×10^{-4}	4.1×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.4×10^{-4}	3.6×10^{-4}
Radium-226	5.9×10^{-2}	3.8×10^{-2}	5.9×10^{-2}	3.8×10^{-2}	5.9×10^{-2}	3.8×10^{-2}	2.1×10^{-2}	2.0×10^{-2}	2.0×10^{-2}	2.2×10^{-2}	2.2×10^{-2}	2.1×10^{-2}	2.0×10^{-2}	2.0×10^{-2}	2.2×10^{-2}	2.2×10^{-2}	2.0×10^{-2}	2.2×10^{-2}	2.0×10^{-2}	2.2×10^{-2}
Radium-228	2.6×10^{-3}	8.0×10^{-4}	2.6×10^{-3}	8.0×10^{-4}	2.6×10^{-3}	8.0×10^{-4}	6.6×10^{-4}	6.2×10^{-4}	6.1×10^{-4}	5.7×10^{-4}	5.8×10^{-4}	6.6×10^{-4}	6.2×10^{-4}	6.1×10^{-4}	5.7×10^{-4}	5.8×10^{-4}	6.1×10^{-4}	5.7×10^{-4}	6.1×10^{-4}	5.7×10^{-4}
Strontium-90	2.6×10^{-3}	1.1×10^{-3}	2.6×10^{-3}	1.1×10^{-3}	2.6×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.1×10^{-3}
Technetium-99	6.3×10^{-3}	2.6×10^{-3}	6.3×10^{-3}	2.6×10^{-3}	6.3×10^{-3}	2.6×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.3×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.3×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.3×10^{-3}	2.5×10^{-3}	2.3×10^{-3}	2.5×10^{-3}
Thorium-228	3.4×10^{-3}	1.0×10^{-3}	3.4×10^{-3}	1.0×10^{-3}	3.4×10^{-3}	1.0×10^{-3}	8.9×10^{-4}	8.2×10^{-4}	8.1×10^{-4}	7.6×10^{-4}	7.7×10^{-4}	8.9×10^{-4}	8.2×10^{-4}	8.1×10^{-4}	7.6×10^{-4}	7.7×10^{-4}	8.1×10^{-4}	7.6×10^{-4}	8.1×10^{-4}	7.6×10^{-4}
Thorium-230	3.3×10^{-1}	1.7×10^{-1}	3.3×10^{-1}	1.7×10^{-1}	3.3×10^{-1}	1.7×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.4×10^{-1}
Thorium-232	1.3×10^{-2}	7.3×10^{-3}	1.3×10^{-2}	7.3×10^{-3}	1.3×10^{-2}	7.3×10^{-3}	6.7×10^{-3}	6.6×10^{-3}	6.6×10^{-3}	7.2×10^{-3}	7.2×10^{-3}	6.7×10^{-3}	6.6×10^{-3}	6.6×10^{-3}	7.2×10^{-3}	7.2×10^{-3}	6.6×10^{-3}	7.2×10^{-3}	6.6×10^{-3}	7.2×10^{-3}
Thorium-234	1.9×10^{-2}	8.2×10^{-3}	1.9×10^{-2}	8.2×10^{-3}	1.9×10^{-2}	8.2×10^{-3}	8.6×10^{-3}	8.8×10^{-3}	8.8×10^{-3}	9.7×10^{-3}	9.7×10^{-3}	8.6×10^{-3}	8.8×10^{-3}	8.8×10^{-3}	9.7×10^{-3}	9.7×10^{-3}	8.8×10^{-3}	9.7×10^{-3}	8.8×10^{-3}	9.7×10^{-3}
Uranium-234	1.2×10^{-5}	7.3×10^{-6}	1.2×10^{-5}	7.3×10^{-6}	1.2×10^{-5}	7.3×10^{-6}	7.3×10^{-6}	7.2×10^{-6}	7.2×10^{-6}	8.0×10^{-6}	8.0×10^{-6}	7.3×10^{-6}	7.2×10^{-6}	7.2×10^{-6}	8.0×10^{-6}	8.0×10^{-6}	7.2×10^{-6}	8.0×10^{-6}	7.2×10^{-6}	8.0×10^{-6}
Uranium-235/236	1.6×10^{-3}	9.5×10^{-4}	1.6×10^{-3}	9.5×10^{-4}	1.6×10^{-3}	9.5×10^{-4}	9.6×10^{-4}	9.4×10^{-4}	9.4×10^{-4}	1.0×10^{-3}	1.0×10^{-3}	9.6×10^{-4}	9.4×10^{-4}	9.4×10^{-4}	1.0×10^{-3}	1.0×10^{-3}	9.4×10^{-4}	1.0×10^{-3}	9.4×10^{-4}	1.0×10^{-3}
Uranium-236	4.2×10^{-3}	2.2×10^{-3}	4.2×10^{-3}	2.2×10^{-3}	4.2×10^{-3}	2.2×10^{-3}	1.2×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.2×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	1.1×10^{-3}
Uranium-238	2.2×10^{-1}	1.3×10^{-1}	2.2×10^{-1}	1.3×10^{-1}	2.2×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.4×10^{-1}	1.3×10^{-1}	1.4×10^{-1}
Metals/Chemicals (mg/m3)-RW comp 2																				
1,1-DICHLOROETHANE	2.9×10^{-8}	6.6×10^{-9}	2.9×10^{-8}	6.6×10^{-9}	2.9×10^{-8}	6.6×10^{-9}	5.8×10^{-9}	5.3×10^{-9}	5.3×10^{-9}	4.2×10^{-9}	4.3×10^{-9}	5.8×10^{-9}	5.3×10^{-9}	5.3×10^{-9}	4.2×10^{-9}	4.3×10^{-9}	5.3×10^{-9}	4.2×10^{-9}	5.3×10^{-9}	4.2×10^{-9}
1,1-DICHLOROETHENE	3.2×10^{-8}	8.6×10^{-9}	3.2×10^{-8}	8.6×10^{-9}	3.2×10^{-8}	8.6×10^{-9}	7.9×10^{-9}	7.3×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	6.5×10^{-9}	7.9×10^{-9}	7.3×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	6.5×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	7.3×10^{-9}	6.5×10^{-9}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
1,2-DICHLOROBENZENE	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
1,2-DICHLOROETHANE	7.2×10^{-8}	3.5×10^{-8}	7.2×10^{-8}	3.5×10^{-8}	7.2×10^{-8}	3.5×10^{-8}	3.6×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.8×10^{-8}	3.6×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.8×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.5×10^{-8}	3.8×10^{-8}
1,2-DICHLOROETHENE (TOTAL)	3.2×10^{-8}	8.6×10^{-9}	3.2×10^{-8}	8.6×10^{-9}	3.2×10^{-8}	8.6×10^{-9}	7.9×10^{-9}	7.3×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	6.5×10^{-9}	7.9×10^{-9}	7.3×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	6.5×10^{-9}	7.3×10^{-9}	6.5×10^{-9}	7.3×10^{-9}	6.5×10^{-9}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	5.8×10^{-9}	3.3×10^{-9}	5.8×10^{-9}	3.3×10^{-9}	5.8×10^{-9}	3.3×10^{-9}	1.7×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.5×10^{-9}	1.7×10^{-9}	1.5×10^{-9}	1.7×10^{-9}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	3.2×10^{-8}	6.2×10^{-9}	3.2×10^{-8}	6.2×10^{-9}	3.2×10^{-8}	6.2×10^{-9}	6.6×10^{-9}	4.8×10^{-9}	4.7×10^{-9}	5.2×10^{-9}	5.3×10^{-9}	6.6×10^{-9}	4.8×10^{-9}	4.7×10^{-9}	5.2×10^{-9}	5.3×10^{-9}	4.7×10^{-9}	5.2×10^{-9}	4.7×10^{-9}	5.2×10^{-9}
3,3'-DICHLOROBENZIDINE	1.5×10^{-6}	4.5×10^{-7}	1.5×10^{-6}	4.5×10^{-7}	1.5×10^{-6}	4.5×10^{-7}	4.1×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	4.1×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	3.8×10^{-7}	3.6×10^{-7}	3.8×10^{-7}	3.6×10^{-7}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	9.1×10^{-7}	2.9×10^{-7}	9.1×10^{-7}	2.9×10^{-7}	9.1×10^{-7}	2.9×10^{-7}	2.7×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.7×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.5×10^{-7}

TABLE G.I-18
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
4-NITROANILINE	6.7×10^{-6}	1.5×10^{-6}	6.7×10^{-6}	1.5×10^{-6}	6.7×10^{-6}	1.5×10^{-6}	1.4×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.2×10^{-6}	1.4×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.2×10^{-6}	1.1×10^{-6}
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	9.0×10^{-6}	4.6×10^{-6}	9.0×10^{-6}	4.6×10^{-6}	9.0×10^{-6}	4.6×10^{-6}	3.4×10^{-6}	3.1×10^{-6}	3.1×10^{-6}	3.4×10^{-6}	3.4×10^{-6}	3.4×10^{-6}	3.1×10^{-6}	3.1×10^{-6}	3.4×10^{-6}	3.4×10^{-6}	3.1×10^{-6}	3.4×10^{-6}	3.1×10^{-6}	3.4×10^{-6}
ALPHA-CHLORDANE	8.6×10^{-8}	4.2×10^{-8}	8.6×10^{-8}	4.2×10^{-8}	8.6×10^{-8}	4.2×10^{-8}	3.5×10^{-8}	3.4×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.4×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.3×10^{-8}	3.5×10^{-8}
Aroclor 1254	2.5×10^{-6}	1.5×10^{-6}	2.5×10^{-6}	1.5×10^{-6}	2.5×10^{-6}	1.5×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.2×10^{-6}	1.3×10^{-6}	1.2×10^{-6}	1.3×10^{-6}
Arsenic	9.8×10^{-6}	4.6×10^{-6}	9.8×10^{-6}	4.6×10^{-6}	9.8×10^{-6}	4.6×10^{-6}	3.9×10^{-6}	3.6×10^{-6}	3.6×10^{-6}	4.0×10^{-6}	4.0×10^{-6}	3.9×10^{-6}	3.6×10^{-6}	3.6×10^{-6}	4.0×10^{-6}	4.0×10^{-6}	3.6×10^{-6}	4.0×10^{-6}	3.6×10^{-6}	4.0×10^{-6}
BENZENE	2.6×10^{-7}	5.5×10^{-8}	2.6×10^{-7}	5.5×10^{-8}	2.6×10^{-7}	5.5×10^{-8}	5.6×10^{-8}	5.6×10^{-8}	5.6×10^{-8}	4.5×10^{-8}	4.5×10^{-8}	5.6×10^{-8}	5.6×10^{-8}	5.6×10^{-8}	4.5×10^{-8}	4.5×10^{-8}	5.6×10^{-8}	4.5×10^{-8}	5.6×10^{-8}	4.5×10^{-8}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	2.3×10^{-6}	1.2×10^{-6}	2.3×10^{-6}	1.2×10^{-6}	2.3×10^{-6}	1.2×10^{-6}	8.9×10^{-7}	8.3×10^{-7}	8.2×10^{-7}	9.1×10^{-7}	9.1×10^{-7}	8.9×10^{-7}	8.3×10^{-7}	8.2×10^{-7}	9.1×10^{-7}	9.1×10^{-7}	8.2×10^{-7}	9.1×10^{-7}	8.2×10^{-7}	9.1×10^{-7}
Benzo(a)pyrene	2.8×10^{-6}	1.5×10^{-6}	2.8×10^{-6}	1.5×10^{-6}	2.8×10^{-6}	1.5×10^{-6}	1.1×10^{-6}	9.7×10^{-7}	9.7×10^{-7}	1.1×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.7×10^{-7}	9.7×10^{-7}	1.1×10^{-6}	1.1×10^{-6}	9.7×10^{-7}	1.1×10^{-6}	9.7×10^{-7}	1.1×10^{-6}
BENZO(B)FLUORANTHENE	3.0×10^{-6}	1.5×10^{-6}	3.0×10^{-6}	1.5×10^{-6}	3.0×10^{-6}	1.5×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.0×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.0×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.0×10^{-6}	1.2×10^{-6}	1.0×10^{-6}	1.2×10^{-6}
BENZO(G,H,I)PERYLENE	7.3×10^{-7}	3.0×10^{-7}	7.3×10^{-7}	3.0×10^{-7}	7.3×10^{-7}	3.0×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.6×10^{-7}
BENZO(K)FLUORANTHENE	2.2×10^{-6}	1.2×10^{-6}	2.2×10^{-6}	1.2×10^{-6}	2.2×10^{-6}	1.2×10^{-6}	7.7×10^{-7}	7.1×10^{-7}	7.0×10^{-7}	7.7×10^{-7}	7.7×10^{-7}	7.7×10^{-7}	7.1×10^{-7}	7.0×10^{-7}	7.7×10^{-7}	7.7×10^{-7}	7.0×10^{-7}	7.7×10^{-7}	7.0×10^{-7}	7.7×10^{-7}
BENZOIC ACID	1.8×10^{-6}	8.4×10^{-7}	1.8×10^{-6}	8.4×10^{-7}	1.8×10^{-6}	8.4×10^{-7}	6.8×10^{-7}	6.4×10^{-7}	6.4×10^{-7}	6.8×10^{-7}	6.8×10^{-7}	6.8×10^{-7}	6.4×10^{-7}	6.4×10^{-7}	6.8×10^{-7}	6.8×10^{-7}	6.4×10^{-7}	6.8×10^{-7}	6.4×10^{-7}	6.8×10^{-7}
BENZYL ALCOHOL	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.7×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.7×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}
Beryllium	1.3×10^{-6}	6.5×10^{-7}	1.3×10^{-6}	6.5×10^{-7}	1.3×10^{-6}	6.5×10^{-7}	5.7×10^{-7}	5.3×10^{-7}	5.3×10^{-7}	5.9×10^{-7}	5.9×10^{-7}	5.7×10^{-7}	5.3×10^{-7}	5.3×10^{-7}	5.9×10^{-7}	5.9×10^{-7}	5.3×10^{-7}	5.9×10^{-7}	5.3×10^{-7}	5.9×10^{-7}
BIS(2-CHLOROETHOXY)METHANE	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
BIS(2-CHLOROETHYL)ETHER	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.4×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}
BIS(2-CHLOROISOPROPYL) ETHER	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	1.9×10^{-6}	4.0×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.8×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}
Bis(2-ethylhexyl)phthalate	6.0×10^{-7}	3.1×10^{-7}	6.0×10^{-7}	3.1×10^{-7}	6.0×10^{-7}	3.1×10^{-7}	2.2×10^{-7}	2.0×10^{-7}	2.0×10^{-7}	2.2×10^{-7}	2.2×10^{-7}	2.2×10^{-7}	2.0×10^{-7}	2.0×10^{-7}	2.2×10^{-7}	2.2×10^{-7}	2.0×10^{-7}	2.2×10^{-7}	2.0×10^{-7}	2.2×10^{-7}
BIS(CHLOROMETHYL)ETHER	1.9×10^{-9}	8.0×10^{-10}	1.9×10^{-9}	8.0×10^{-10}	1.9×10^{-9}	8.0×10^{-10}	8.5×10^{-10}	4.4×10^{-10}	4.4×10^{-10}	4.9×10^{-10}	4.9×10^{-10}	8.5×10^{-10}	4.4×10^{-10}	4.4×10^{-10}	4.9×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.9×10^{-10}
BROMODICHLOROMETHANE	7.2×10^{-8}	3.5×10^{-8}	7.2×10^{-8}	3.5×10^{-8}	7.2×10^{-8}	3.5×10^{-8}	3.6×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.8×10^{-8}	3.6×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.8×10^{-8}	3.5×10^{-8}	3.8×10^{-8}	3.5×10^{-8}	3.8×10^{-8}
BROMOMETHANE	1.4×10^{-7}	8.1×10^{-8}	1.4×10^{-7}	8.1×10^{-8}	1.4×10^{-7}	8.1×10^{-8}	7.6×10^{-8}	7.5×10^{-8}	7.5×10^{-8}	8.2×10^{-8}	8.2×10^{-8}	7.6×10^{-8}	7.5×10^{-8}	7.5×10^{-8}	8.2×10^{-8}	8.2×10^{-8}	7.5×10^{-8}	8.2×10^{-8}	7.5×10^{-8}	8.2×10^{-8}
CADMIUM	9.2×10^{-6}	1.6×10^{-6}	9.2×10^{-6}	1.6×10^{-6}	9.2×10^{-6}	1.6×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.5×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.5×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	1.5×10^{-6}	1.0×10^{-6}	1.5×10^{-6}	1.0×10^{-6}
CHLORDANE	1.6×10^{-9}	6.5×10^{-10}	1.6×10^{-9}	6.5×10^{-10}	1.6×10^{-9}	6.5×10^{-10}	6.9×10^{-10}	3.6×10^{-10}	3.6×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	6.9×10^{-10}	3.6×10^{-10}	3.6×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	3.6×10^{-10}	3.9×10^{-10}	3.6×10^{-10}	3.9×10^{-10}
CHLOROBENZENE	4.5×10^{-7}	6.3×10^{-8}	4.5×10^{-7}	6.3×10^{-8}	4.5×10^{-7}	6.3×10^{-8}	6.5×10^{-8}	6.6×10^{-8}	6.6×10^{-8}	3.7×10^{-8}	3.7×10^{-8}	6.5×10^{-8}	6.6×10^{-8}	6.6×10^{-8}	3.7×10^{-8}	3.7×10^{-8}	6.6×10^{-8}	3.7×10^{-8}	6.6×10^{-8}	3.7×10^{-8}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	3.7×10^{-8}	1.1×10^{-8}	3.7×10^{-8}	1.1×10^{-8}	3.7×10^{-8}	1.1×10^{-8}	9.3×10^{-9}	8.7×10^{-9}	8.7×10^{-9}	8.0×10^{-9}	8.0×10^{-9}	9.3×10^{-9}	8.7×10^{-9}	8.7×10^{-9}	8.0×10^{-9}	8.0×10^{-9}	8.7×10^{-9}	8.0×10^{-9}	8.7×10^{-9}	8.0×10^{-9}
Chrysene	2.6×10^{-6}	1.4×10^{-6}	2.6×10^{-6}	1.4×10^{-6}	2.6×10^{-6}	1.4×10^{-6}	1.0×10^{-6}	9.2×10^{-7}	9.2×10^{-7}	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	9.2×10^{-7}	9.2×10^{-7}	1.0×10^{-6}	1.0×10^{-6}	9.2×10^{-7}	1.0×10^{-6}	9.2×10^{-7}	1.0×10^{-6}
DIBENZO(A,H)ANTHRACENE	1.5×10^{-6}	4.8×10^{-7}	1.5×10^{-6}	4.8×10^{-7}	1.5×10^{-6}	4.8×10^{-7}	3.6×10^{-7}	3.4×10^{-7}	3.4×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.6×10^{-7}	3.4×10^{-7}	3.4×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.4×10^{-7}	3.1×10^{-7}	3.4×10^{-7}	3.1×10^{-7}
DIBENZOFURAN	1.2×10^{-6}	2.8×10^{-7}	1.2×10^{-6}	2.8×10^{-7}	1.2×10^{-6}	2.8×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.0×10^{-7}	2.1×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.0×10^{-7}	2.1×10^{-7}	2.4×10^{-7}	2.0×10^{-7}	2.4×10^{-7}	2.0×10^{-7}
DIBROMOMETHANE	8.1×10^{-10}	7.6×10^{-10}	8.1×10^{-10}	7.6×10^{-10}	8.1×10^{-10}	7.6×10^{-10}	8.1×10^{-10}	8.4×10^{-10}	8.4×10^{-10}	9.3×10^{-10}	9.3×10^{-10}	8.1×10^{-10}	8.4×10^{-10}	8.4×10^{-10}	9.3×10^{-10}	9.3×10^{-10}	8.4×10^{-10}	9.3×10^{-10}	8.4×10^{-10}	9.3×10^{-10}
DIELDRIN	1.5×10^{-8}	8.1×10^{-9}	1.5×10^{-8}	8.1×10^{-9}	1.5×10^{-8}	8.1×10^{-9}	6.9×10^{-9}	6.4×10^{-9}	6.4×10^{-9}	7.1×10^{-9}	7.1×10^{-9}	6.9×10^{-9}	6.4×10^{-9}	6.4×10^{-9}	7.1×10^{-9}	7.1×10^{-9}	6.4×10^{-9}	7.1×10^{-9}	6.4×10^{-9}	7.1×10^{-9}
ETHYLBENZENE	9.4×10^{-8}	5.6×10^{-8}	9.4×10^{-8}	5.6×10^{-8}	9.4×10^{-8}	5.6×10^{-8}	4.9×10^{-8}	4.8×10^{-8}	4.8×10^{-8}	5.3×10^{-8}	5.3×10^{-8}	4.9×10^{-8}	4.8×10^{-8}	4.8×10^{-8}	5.3×10^{-8}	5.3×10^{-8}	4.8×10^{-8}	5.3×10^{-8}	4.8×10^{-8}	5.3×10^{-8}
GAMMA-CHLORDANE	8.6×10^{-8}	4.2×10^{-8}	8.6×10^{-8}	4.2×10^{-8}	8.6×10^{-8}	4.2×10^{-8}	3.5×10^{-8}	3.4×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.4×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.5×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	3.3×10^{-8}	3.5×10^{-8}
HEXACHLOROBENZENE	2.4×10^{-6}	4.4×10^{-7}	2.4×10^{-6}	4.4×10^{-7}	2.4×10^{-6}	4.4×10^{-7}	4.2×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	4.2×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.1×10^{-7}
INDENO(1,2,3-CD)PYRENE	2.0×10^{-6}	1.1×10^{-6}	2.0×10^{-6}	1.1×10^{-6}	2.0×10^{-6}	1.1×10^{-6}	7.5×10^{-7}	7.0×10^{-7}	6.9×10^{-7}	7.6×10^{-7}	7.6×10^{-7}	7.5×10^{-7}	7.0×10^{-7}	6.9×10^{-7}	7.6×10^{-7}	7.6×10^{-7}	6.9×10^{-7}	7.6×10^{-7}	6.9×10^{-7}	7.6×10^{-7}

TABLE G.I-18
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Manganese	9.4×10^{-4}	4.2×10^{-4}	9.4×10^{-4}	4.2×10^{-4}	9.4×10^{-4}	4.2×10^{-4}	3.7×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.7×10^{-4}	3.7×10^{-4}	3.7×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.7×10^{-4}	3.7×10^{-4}	3.4×10^{-4}	3.7×10^{-4}	3.4×10^{-4}	3.7×10^{-4}
Mercury	1.4×10^{-7}	7.2×10^{-8}	1.4×10^{-7}	7.2×10^{-8}	1.4×10^{-7}	7.2×10^{-8}	6.1×10^{-8}	5.7×10^{-8}	5.7×10^{-8}	6.3×10^{-8}	6.3×10^{-8}	6.1×10^{-8}	5.7×10^{-8}	5.7×10^{-8}	6.3×10^{-8}	6.3×10^{-8}	5.7×10^{-8}	6.3×10^{-8}	5.7×10^{-8}	6.3×10^{-8}
METHYLENE CHIORIDE	2.3×10^{-7}	2.0×10^{-8}	2.3×10^{-7}	2.0×10^{-8}	2.3×10^{-7}	2.0×10^{-8}	2.1×10^{-8}	2.1×10^{-8}	2.1×10^{-8}	2.6×10^{-9}	2.7×10^{-9}	2.1×10^{-8}	2.1×10^{-8}	2.1×10^{-8}	2.6×10^{-9}	2.7×10^{-9}	2.1×10^{-8}	2.6×10^{-9}	2.1×10^{-8}	2.6×10^{-9}
N-NITROSO-DI-N-PROPYLAMINE	1.8×10^{-6}	3.9×10^{-7}	1.8×10^{-6}	3.9×10^{-7}	1.8×10^{-6}	3.9×10^{-7}	3.7×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.7×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.0×10^{-7}
NITROBENZENE	2.4×10^{-6}	4.4×10^{-7}	2.4×10^{-6}	4.4×10^{-7}	2.4×10^{-6}	4.4×10^{-7}	4.2×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	4.2×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.1×10^{-7}	3.8×10^{-7}	3.1×10^{-7}
O-DICHLOROBENZENE	1.3×10^{-6}	9.5×10^{-8}	1.3×10^{-6}	9.5×10^{-8}	1.3×10^{-6}	9.5×10^{-8}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	2.9×10^{-10}	2.9×10^{-10}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	2.9×10^{-10}	2.9×10^{-10}	1.0×10^{-7}	2.9×10^{-10}	1.0×10^{-7}	2.9×10^{-10}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	1.7×10^{-6}	8.1×10^{-7}	1.7×10^{-6}	8.1×10^{-7}	1.7×10^{-6}	8.1×10^{-7}	6.3×10^{-7}	5.9×10^{-7}	5.9×10^{-7}	6.5×10^{-7}	6.5×10^{-7}	6.3×10^{-7}	5.9×10^{-7}	5.9×10^{-7}	6.5×10^{-7}	6.5×10^{-7}	5.9×10^{-7}	6.5×10^{-7}	5.9×10^{-7}	6.5×10^{-7}
SILVER	3.5×10^{-6}	1.9×10^{-6}	3.5×10^{-6}	1.9×10^{-6}	3.5×10^{-6}	1.9×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.5×10^{-6}	1.6×10^{-6}	1.6×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.5×10^{-6}	1.6×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.6×10^{-6}	1.5×10^{-6}	1.6×10^{-6}
TRANS-1,2-DICHLOROETHENE (TOTAL)	7.5×10^{-10}	3.1×10^{-10}	7.5×10^{-10}	3.1×10^{-10}	7.5×10^{-10}	3.1×10^{-10}	3.3×10^{-10}	1.7×10^{-10}	1.7×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	3.3×10^{-10}	1.7×10^{-10}	1.7×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	1.7×10^{-10}	1.9×10^{-10}	1.7×10^{-10}	1.9×10^{-10}
Trichloroethene	6.1×10^{-9}	3.2×10^{-9}	6.1×10^{-9}	3.2×10^{-9}	6.1×10^{-9}	3.2×10^{-9}	2.6×10^{-9}	2.5×10^{-9}	2.5×10^{-9}	2.8×10^{-9}	2.8×10^{-9}	2.6×10^{-9}	2.5×10^{-9}	2.5×10^{-9}	2.8×10^{-9}	2.8×10^{-9}	2.5×10^{-9}	2.8×10^{-9}	2.5×10^{-9}	2.8×10^{-9}
URANIUM, TOTAL	6.7×10^{-4}	4.0×10^{-4}	6.7×10^{-4}	4.0×10^{-4}	6.7×10^{-4}	4.0×10^{-4}	4.0×10^{-4}	3.9×10^{-4}	3.9×10^{-4}	4.3×10^{-4}	4.3×10^{-4}	4.0×10^{-4}	3.9×10^{-4}	3.9×10^{-4}	4.3×10^{-4}	4.3×10^{-4}	3.9×10^{-4}	4.3×10^{-4}	3.9×10^{-4}	4.3×10^{-4}
ZINC	2.1×10^{-4}	6.5×10^{-5}	2.1×10^{-4}	6.5×10^{-5}	2.1×10^{-4}	6.5×10^{-5}	5.5×10^{-5}	5.3×10^{-5}	5.3×10^{-5}	4.9×10^{-5}	4.9×10^{-5}	5.5×10^{-5}	5.3×10^{-5}	5.3×10^{-5}	4.9×10^{-5}	4.9×10^{-5}	5.3×10^{-5}	4.9×10^{-5}	5.3×10^{-5}	4.9×10^{-5}

TABLE G.I-19

EXPOSURE POINT CONCENTRATIONS IN THE VICINITY OF THE CENTRAL STORAGE/OFF-PROPERTY SHIPPING FACILITY DURING OPERATIONS

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-RW comp 2																				
Cesium-137	2.5×10^{-3}	7.1×10^{-4}	2.5×10^{-3}	7.1×10^{-4}	2.5×10^{-3}	7.1×10^{-4}	6.4×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	4.7×10^{-4}	4.7×10^{-4}	6.4×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	4.7×10^{-4}	4.7×10^{-4}	5.9×10^{-4}	4.7×10^{-4}	5.9×10^{-4}	4.7×10^{-4}
Neptunium-237	4.2×10^{-3}	1.3×10^{-3}	4.2×10^{-3}	1.3×10^{-3}	4.2×10^{-3}	1.3×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	8.9×10^{-4}	8.9×10^{-4}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	8.9×10^{-4}	8.9×10^{-4}	1.1×10^{-3}	8.9×10^{-4}	1.1×10^{-3}	8.9×10^{-4}
Plutonium-238	2.9×10^{-3}	1.1×10^{-3}	2.9×10^{-3}	1.1×10^{-3}	2.9×10^{-3}	1.1×10^{-3}	9.1×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	7.6×10^{-4}	7.7×10^{-4}	9.1×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	7.6×10^{-4}	7.7×10^{-4}	8.5×10^{-4}	7.6×10^{-4}	8.5×10^{-4}	7.6×10^{-4}
Plutonium-239/240	2.1×10^{-3}	1.0×10^{-3}	2.1×10^{-3}	1.0×10^{-3}	2.1×10^{-3}	1.0×10^{-3}	8.8×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.8×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}	8.1×10^{-4}
Radium-226	1.3×10^{-1}	9.7×10^{-2}	1.3×10^{-1}	9.7×10^{-2}	1.3×10^{-1}	9.7×10^{-2}	5.1×10^{-2}	4.8×10^{-2}	4.8×10^{-2}	5.0×10^{-2}	5.0×10^{-2}	5.1×10^{-2}	4.8×10^{-2}	4.8×10^{-2}	5.0×10^{-2}	5.0×10^{-2}	4.8×10^{-2}	5.0×10^{-2}	4.8×10^{-2}	5.0×10^{-2}
Radium-228	5.7×10^{-3}	2.0×10^{-3}	5.7×10^{-3}	2.0×10^{-3}	5.7×10^{-3}	2.0×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.3×10^{-3}	1.3×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.3×10^{-3}	1.3×10^{-3}	1.5×10^{-3}	1.3×10^{-3}	1.5×10^{-3}	1.3×10^{-3}
Strontium-90	5.8×10^{-3}	2.8×10^{-3}	5.8×10^{-3}	2.8×10^{-3}	5.8×10^{-3}	2.8×10^{-3}	2.6×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.6×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.5×10^{-3}	2.4×10^{-3}	2.5×10^{-3}	2.4×10^{-3}
Technetium-99	1.4×10^{-2}	6.7×10^{-3}	1.4×10^{-2}	6.7×10^{-3}	1.4×10^{-2}	6.7×10^{-3}	6.0×10^{-3}	5.5×10^{-3}	5.5×10^{-3}	5.7×10^{-3}	5.7×10^{-3}	6.0×10^{-3}	5.5×10^{-3}	5.5×10^{-3}	5.7×10^{-3}	5.7×10^{-3}	5.5×10^{-3}	5.7×10^{-3}	5.5×10^{-3}	5.7×10^{-3}
Thorium-228	7.5×10^{-3}	2.6×10^{-3}	7.5×10^{-3}	2.6×10^{-3}	7.5×10^{-3}	2.6×10^{-3}	2.2×10^{-3}	2.0×10^{-3}	1.9×10^{-3}	1.7×10^{-3}	1.7×10^{-3}	2.2×10^{-3}	2.0×10^{-3}	1.9×10^{-3}	1.7×10^{-3}	1.7×10^{-3}	1.9×10^{-3}	1.7×10^{-3}	1.9×10^{-3}	1.7×10^{-3}
Thorium-230	7.3×10^{-1}	4.3×10^{-1}	7.3×10^{-1}	4.3×10^{-1}	7.3×10^{-1}	4.3×10^{-1}	3.2×10^{-1}	3.0×10^{-1}	3.0×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.2×10^{-1}	3.0×10^{-1}	3.0×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.0×10^{-1}	3.1×10^{-1}	3.0×10^{-1}	3.1×10^{-1}
Thorium-232	2.8×10^{-2}	1.9×10^{-2}	2.8×10^{-2}	1.9×10^{-2}	2.8×10^{-2}	1.9×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}	1.6×10^{-2}
Thorium-234	4.2×10^{-2}	2.1×10^{-2}	4.2×10^{-2}	2.1×10^{-2}	4.2×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	2.2×10^{-2}	2.2×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	2.2×10^{-2}	2.2×10^{-2}	2.1×10^{-2}	2.2×10^{-2}	2.1×10^{-2}	2.2×10^{-2}
Uranium-234	2.7×10^{-5}	1.8×10^{-5}	2.7×10^{-5}	1.8×10^{-5}	2.7×10^{-5}	1.8×10^{-5}	1.8×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.8×10^{-5}	1.8×10^{-5}	1.8×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.8×10^{-5}	1.8×10^{-5}	1.7×10^{-5}	1.8×10^{-5}	1.7×10^{-5}	1.8×10^{-5}
Uranium-235/236	3.5×10^{-3}	2.4×10^{-3}	3.5×10^{-3}	2.4×10^{-3}	3.5×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.3×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.3×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.4×10^{-3}	2.3×10^{-3}	2.4×10^{-3}
Uranium-236	9.3×10^{-3}	5.6×10^{-3}	9.3×10^{-3}	5.6×10^{-3}	9.3×10^{-3}	5.6×10^{-3}	2.8×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.8×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}
Uranium-238	4.9×10^{-1}	3.4×10^{-1}	4.9×10^{-1}	3.4×10^{-1}	4.9×10^{-1}	3.4×10^{-1}	3.3×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.3×10^{-1}	3.3×10^{-1}	3.3×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.3×10^{-1}	3.3×10^{-1}	3.1×10^{-1}	3.3×10^{-1}	3.1×10^{-1}	3.3×10^{-1}
Metals/Chemicals (mg/m3)-RW comp 2																				
1,1-DICHLOROETHANE	1.1×10^{-13}	3.0×10^{-14}	1.1×10^{-13}	3.0×10^{-14}	1.1×10^{-13}	3.0×10^{-14}	2.5×10^{-14}	2.2×10^{-14}	2.2×10^{-14}	1.7×10^{-14}	1.7×10^{-14}	2.5×10^{-14}	2.2×10^{-14}	2.2×10^{-14}	1.7×10^{-14}	1.7×10^{-14}	2.2×10^{-14}	1.7×10^{-14}	2.2×10^{-14}	1.7×10^{-14}
1,1-DICHLOROETHENE	1.3×10^{-13}	3.9×10^{-14}	1.3×10^{-13}	3.9×10^{-14}	1.3×10^{-13}	3.9×10^{-14}	3.4×10^{-14}	3.1×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	2.6×10^{-14}	3.4×10^{-14}	3.1×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	2.6×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	3.1×10^{-14}	2.6×10^{-14}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
1,2-DICHLOROBENZENE	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
1,2-DICHLOROETHANE	2.8×10^{-13}	1.6×10^{-13}	2.8×10^{-13}	1.6×10^{-13}	2.8×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.6×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}
1,2-DICHLOROETHENE (TOTAL)	1.3×10^{-13}	3.9×10^{-14}	1.3×10^{-13}	3.9×10^{-14}	1.3×10^{-13}	3.9×10^{-14}	3.4×10^{-14}	3.1×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	2.6×10^{-14}	3.4×10^{-14}	3.1×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	2.6×10^{-14}	3.1×10^{-14}	2.6×10^{-14}	3.1×10^{-14}	2.6×10^{-14}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	2.3×10^{-14}	1.5×10^{-14}	2.3×10^{-14}	1.5×10^{-14}	2.3×10^{-14}	1.5×10^{-14}	7.4×10^{-15}	6.5×10^{-15}	6.5×10^{-15}	6.7×10^{-15}	6.7×10^{-15}	7.4×10^{-15}	6.5×10^{-15}	6.5×10^{-15}	6.7×10^{-15}	6.7×10^{-15}	6.5×10^{-15}	6.7×10^{-15}	6.5×10^{-15}	6.7×10^{-15}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	1.2×10^{-13}	2.8×10^{-14}	1.2×10^{-13}	2.8×10^{-14}	1.2×10^{-13}	2.8×10^{-14}	2.9×10^{-14}	2.0×10^{-14}	2.0×10^{-14}	2.1×10^{-14}	2.1×10^{-14}	2.9×10^{-14}	2.0×10^{-14}	2.0×10^{-14}	2.1×10^{-14}	2.1×10^{-14}	2.0×10^{-14}	2.1×10^{-14}	2.0×10^{-14}	2.1×10^{-14}
3,3'-DICHLOROBENZIDINE	5.9×10^{-12}	2.0×10^{-12}	5.9×10^{-12}	2.0×10^{-12}	5.9×10^{-12}	2.0×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.6×10^{-12}	1.4×10^{-12}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	3.5×10^{-12}	1.3×10^{-12}	3.5×10^{-12}	1.3×10^{-12}	3.5×10^{-12}	1.3×10^{-12}	1.2×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	9.9×10^{-13}	1.0×10^{-12}	1.2×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	9.9×10^{-13}	1.0×10^{-12}	1.1×10^{-12}	9.9×10^{-13}	1.1×10^{-12}	9.9×10^{-13}
4-NITROANILINE	2.6×10^{-11}	6.6×10^{-12}	2.6×10^{-11}	6.6×10^{-12}	2.6×10^{-11}	6.6×10^{-12}	6.0×10^{-12}	5.0×10^{-12}	5.0×10^{-12}	4.6×10^{-12}	4.6×10^{-12}	6.0×10^{-12}	5.0×10^{-12}	5.0×10^{-12}	4.6×10^{-12}	4.6×10^{-12}	5.0×10^{-12}	4.6×10^{-12}	5.0×10^{-12}	4.6×10^{-12}

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TABLE G.I-19
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	3.5×10^{-11}	2.1×10^{-11}	3.5×10^{-11}	2.1×10^{-11}	3.5×10^{-11}	2.1×10^{-11}	1.5×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.5×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.4×10^{-11}
ALPHA-CHLORDANE	3.4×10^{-13}	1.9×10^{-13}	3.4×10^{-13}	1.9×10^{-13}	3.4×10^{-13}	1.9×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}
Aroclor 1254	9.9×10^{-12}	6.8×10^{-12}	9.9×10^{-12}	6.8×10^{-12}	9.9×10^{-12}	6.8×10^{-12}	5.2×10^{-12}	4.9×10^{-12}	4.9×10^{-12}	5.1×10^{-12}	5.1×10^{-12}	5.2×10^{-12}	4.9×10^{-12}	4.9×10^{-12}	5.1×10^{-12}	5.1×10^{-12}	4.9×10^{-12}	5.1×10^{-12}	4.9×10^{-12}	5.1×10^{-12}
Arsenic	3.8×10^{-11}	2.1×10^{-11}	3.8×10^{-11}	2.1×10^{-11}	3.8×10^{-11}	2.1×10^{-11}	1.7×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.7×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.5×10^{-11}	1.6×10^{-11}	1.5×10^{-11}	1.6×10^{-11}
BENZENE	1.0×10^{-12}	2.5×10^{-13}	1.0×10^{-12}	2.5×10^{-13}	1.0×10^{-12}	2.5×10^{-13}	2.5×10^{-13}	2.4×10^{-13}	2.4×10^{-13}	1.8×10^{-13}	1.8×10^{-13}	2.5×10^{-13}	2.4×10^{-13}	2.4×10^{-13}	1.8×10^{-13}	1.8×10^{-13}	2.4×10^{-13}	1.8×10^{-13}	2.4×10^{-13}	1.8×10^{-13}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	9.0×10^{-12}	5.5×10^{-12}	9.0×10^{-12}	5.5×10^{-12}	9.0×10^{-12}	5.5×10^{-12}	3.9×10^{-12}	3.5×10^{-12}	3.5×10^{-12}	3.7×10^{-12}	3.7×10^{-12}	3.9×10^{-12}	3.5×10^{-12}	3.5×10^{-12}	3.7×10^{-12}	3.7×10^{-12}	3.5×10^{-12}	3.7×10^{-12}	3.5×10^{-12}	3.7×10^{-12}
Benzo(a)pyrene	1.1×10^{-11}	6.6×10^{-12}	1.1×10^{-11}	6.6×10^{-12}	1.1×10^{-11}	6.6×10^{-12}	4.6×10^{-12}	4.1×10^{-12}	4.1×10^{-12}	4.3×10^{-12}	4.3×10^{-12}	4.6×10^{-12}	4.1×10^{-12}	4.1×10^{-12}	4.3×10^{-12}	4.3×10^{-12}	4.1×10^{-12}	4.3×10^{-12}	4.1×10^{-12}	4.3×10^{-12}
BENZO(B)FLUORANTHENE	1.2×10^{-11}	6.8×10^{-12}	1.2×10^{-11}	6.8×10^{-12}	1.2×10^{-11}	6.8×10^{-12}	4.9×10^{-12}	4.5×10^{-12}	4.5×10^{-12}	4.6×10^{-12}	4.7×10^{-12}	4.9×10^{-12}	4.5×10^{-12}	4.5×10^{-12}	4.6×10^{-12}	4.7×10^{-12}	4.5×10^{-12}	4.6×10^{-12}	4.5×10^{-12}	4.6×10^{-12}
BENZO(G,H,I)PERYLENE	2.9×10^{-12}	1.4×10^{-12}	2.9×10^{-12}	1.4×10^{-12}	2.9×10^{-12}	1.4×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}
BENZO(K)FLUORANTHENE	8.6×10^{-12}	5.4×10^{-12}	8.6×10^{-12}	5.4×10^{-12}	8.6×10^{-12}	5.4×10^{-12}	3.3×10^{-12}	3.0×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	3.3×10^{-12}	3.0×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.0×10^{-12}	3.1×10^{-12}
BENZOIC ACID	7.0×10^{-12}	3.8×10^{-12}	7.0×10^{-12}	3.8×10^{-12}	7.0×10^{-12}	3.8×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.8×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.8×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.7×10^{-12}
BENZYL ALCOHOL	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
Beryllium	5.2×10^{-12}	2.9×10^{-12}	5.2×10^{-12}	2.9×10^{-12}	5.2×10^{-12}	2.9×10^{-12}	2.5×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.5×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.3×10^{-12}	2.4×10^{-12}	2.3×10^{-12}	2.4×10^{-12}
BIS(2-CHLOROETHOXY)METHANE	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
BIS(2-CHLOROETHYL)ETHER	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
BIS(2-CHLOROISOPROPYL) ETHER	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	7.3×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
Bis(2-ethylhexyl)phthalate	2.4×10^{-12}	1.4×10^{-12}	2.4×10^{-12}	1.4×10^{-12}	2.4×10^{-12}	1.4×10^{-12}	9.7×10^{-13}	8.5×10^{-13}	8.5×10^{-13}	8.9×10^{-13}	8.9×10^{-13}	9.7×10^{-13}	8.5×10^{-13}	8.5×10^{-13}	8.9×10^{-13}	8.9×10^{-13}	8.5×10^{-13}	8.9×10^{-13}	8.5×10^{-13}	8.9×10^{-13}
BIS(CHLOROMETHYL)ETHER	7.6×10^{-15}	3.6×10^{-15}	7.6×10^{-15}	3.6×10^{-15}	7.6×10^{-15}	3.6×10^{-15}	3.7×10^{-15}	1.9×10^{-15}	1.9×10^{-15}	2.0×10^{-15}	2.0×10^{-15}	3.7×10^{-15}	1.9×10^{-15}	1.9×10^{-15}	2.0×10^{-15}	2.0×10^{-15}	1.9×10^{-15}	2.0×10^{-15}	1.9×10^{-15}	2.0×10^{-15}
BROMODICHLOROMETHANE	2.8×10^{-13}	1.6×10^{-13}	2.8×10^{-13}	1.6×10^{-13}	2.8×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.6×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.5×10^{-13}
BROMOMETHANE	5.5×10^{-13}	3.6×10^{-13}	5.5×10^{-13}	3.6×10^{-13}	5.5×10^{-13}	3.6×10^{-13}	3.3×10^{-13}	3.2×10^{-13}	3.2×10^{-13}	3.3×10^{-13}	3.3×10^{-13}	3.3×10^{-13}	3.2×10^{-13}	3.2×10^{-13}	3.3×10^{-13}	3.3×10^{-13}	3.2×10^{-13}	3.3×10^{-13}	3.2×10^{-13}	3.3×10^{-13}
CADMIUM	3.6×10^{-11}	7.3×10^{-12}	3.6×10^{-11}	7.3×10^{-12}	3.6×10^{-11}	7.3×10^{-12}	6.9×10^{-12}	6.5×10^{-12}	6.5×10^{-12}	4.2×10^{-12}	4.2×10^{-12}	6.9×10^{-12}	6.5×10^{-12}	6.5×10^{-12}	4.2×10^{-12}	4.2×10^{-12}	6.5×10^{-12}	4.2×10^{-12}	6.5×10^{-12}	4.2×10^{-12}
CHLORDANE	6.1×10^{-15}	2.9×10^{-15}	6.1×10^{-15}	2.9×10^{-15}	6.1×10^{-15}	2.9×10^{-15}	3.0×10^{-15}	1.5×10^{-15}	1.5×10^{-15}	1.6×10^{-15}	1.6×10^{-15}	3.0×10^{-15}	1.5×10^{-15}	1.5×10^{-15}	1.6×10^{-15}	1.6×10^{-15}	1.5×10^{-15}	1.6×10^{-15}	1.5×10^{-15}	1.6×10^{-15}
CHLOROBENZENE	1.8×10^{-12}	2.8×10^{-13}	1.8×10^{-12}	2.8×10^{-13}	1.8×10^{-12}	2.8×10^{-13}	2.8×10^{-13}	2.8×10^{-13}	2.8×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	2.8×10^{-13}	2.8×10^{-13}	2.8×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	2.8×10^{-13}	1.5×10^{-13}	2.8×10^{-13}	1.5×10^{-13}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	1.4×10^{-13}	4.9×10^{-14}	1.4×10^{-13}	4.9×10^{-14}	1.4×10^{-13}	4.9×10^{-14}	4.1×10^{-14}	3.7×10^{-14}	3.7×10^{-14}	3.2×10^{-14}	3.2×10^{-14}	4.1×10^{-14}	3.7×10^{-14}	3.7×10^{-14}	3.2×10^{-14}	3.2×10^{-14}	3.7×10^{-14}	3.2×10^{-14}	3.7×10^{-14}	3.2×10^{-14}
Chrysene	1.0×10^{-11}	6.2×10^{-12}	1.0×10^{-11}	6.2×10^{-12}	1.0×10^{-11}	6.2×10^{-12}	4.3×10^{-12}	3.9×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	4.1×10^{-12}	4.3×10^{-12}	3.9×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	4.1×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	3.9×10^{-12}	4.1×10^{-12}
DIBENZO(A,H)ANTHRACENE	5.8×10^{-12}	2.1×10^{-12}	5.8×10^{-12}	2.1×10^{-12}	5.8×10^{-12}	2.1×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.3×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.3×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
DIBENZOFURAN	4.6×10^{-12}	1.2×10^{-12}	4.6×10^{-12}	1.2×10^{-12}	4.6×10^{-12}	1.2×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	8.2×10^{-13}	8.3×10^{-13}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	8.2×10^{-13}	8.3×10^{-13}	1.0×10^{-12}	8.2×10^{-13}	1.0×10^{-12}	8.2×10^{-13}
DIBROMOMETHANE	3.2×10^{-15}	3.4×10^{-15}	3.2×10^{-15}	3.4×10^{-15}	3.2×10^{-15}	3.4×10^{-15}	3.5×10^{-15}	3.6×10^{-15}	3.6×10^{-15}	3.7×10^{-15}	3.7×10^{-15}	3.5×10^{-15}	3.6×10^{-15}	3.6×10^{-15}	3.7×10^{-15}	3.7×10^{-15}	3.6×10^{-15}	3.7×10^{-15}	3.6×10^{-15}	3.7×10^{-15}
DIELDRIN	5.8×10^{-14}	3.6×10^{-14}	5.8×10^{-14}	3.6×10^{-14}	5.8×10^{-14}	3.6×10^{-14}	3.0×10^{-14}	2.7×10^{-14}	2.7×10^{-14}	2.8×10^{-14}	2.9×10^{-14}	3.0×10^{-14}	2.7×10^{-14}	2.7×10^{-14}	2.8×10^{-14}	2.9×10^{-14}	2.7×10^{-14}	2.8×10^{-14}	2.7×10^{-14}	2.8×10^{-14}
ETHYLBENZENE	3.7×10^{-13}	2.5×10^{-13}	3.7×10^{-13}	2.5×10^{-13}	3.7×10^{-13}	2.5×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}
GAMMA-CHLORDANE	3.4×10^{-13}	1.9×10^{-13}	3.4×10^{-13}	1.9×10^{-13}	3.4×10^{-13}	1.9×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}	1.4×10^{-13}
HEXACHLOROBENZENE	9.4×10^{-12}	2.0×10^{-12}	9.4×10^{-12}	2.0×10^{-12}	9.4×10^{-12}	2.0×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.2×10^{-12}
INDENO(1,2,3-CD)PYRENE	7.9×10^{-12}	4.8×10^{-12}	7.9×10^{-12}	4.8×10^{-12}	7.9×10^{-12}	4.8×10^{-12}	3.3×10^{-12}	3.0×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	3.3×10^{-12}	3.0×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	3.0×10^{-12}	3.1×10^{-12}	3.0×10^{-12}	3.1×10^{-12}
Manganese	3.7×10^{-9}	1.9×10^{-9}	3.7×10^{-9}	1.9×10^{-9}	3.7×10^{-9}	1.9×10^{-9}	1.6×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.6×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.5×10^{-9}
Mercury	5.5×10^{-13}	3.2×10^{-13}	5.5×10^{-13}	3.2×10^{-13}	5.5×10^{-13}	3.2×10^{-13}	2.6×10^{-13}	2.4×10^{-13}	2.4×10^{-13}	2.5×10^{-13}	2.5×10^{-13}	2.6×10^{-13}	2.4×10^{-13}	2.4×10^{-13}	2.5×10^{-13}	2.5×10^{-13}	2.4×10^{-13}	2.5×10^{-13}	2.4×10^{-13}	2.5×10^{-13}

TABLE G.I-19
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
METHYLENE CHIORIDE	9.0×10^{-13}	9.0×10^{-14}	9.0×10^{-13}	9.0×10^{-14}	9.0×10^{-13}	9.0×10^{-14}	9.0×10^{-14}	8.9×10^{-14}	8.8×10^{-14}	1.0×10^{-14}	1.1×10^{-14}	9.0×10^{-14}	8.9×10^{-14}	8.8×10^{-14}	1.0×10^{-14}	1.1×10^{-14}	8.8×10^{-14}	1.0×10^{-14}	8.8×10^{-14}	1.0×10^{-14}
N-NITROSO-DI-N-PROPYLAMINE	7.2×10^{-12}	1.8×10^{-12}	7.2×10^{-12}	1.8×10^{-12}	7.2×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}	1.4×10^{-12}	1.2×10^{-12}
NITROBENZENE	9.4×10^{-12}	2.0×10^{-12}	9.4×10^{-12}	2.0×10^{-12}	9.4×10^{-12}	2.0×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.2×10^{-12}	1.6×10^{-12}	1.2×10^{-12}
O-DICHLOROBENZENE	5.0×10^{-12}	4.3×10^{-13}	5.0×10^{-12}	4.3×10^{-13}	5.0×10^{-12}	4.3×10^{-13}	4.4×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	1.2×10^{-15}	1.2×10^{-15}	4.4×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	1.2×10^{-15}	1.2×10^{-15}	4.5×10^{-13}	1.2×10^{-15}	4.5×10^{-13}	1.2×10^{-15}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	6.5×10^{-12}	3.6×10^{-12}	6.5×10^{-12}	3.6×10^{-12}	6.5×10^{-12}	3.6×10^{-12}	2.7×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	2.7×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	2.5×10^{-12}	2.6×10^{-12}	2.5×10^{-12}	2.6×10^{-12}
SILVER	1.4×10^{-11}	8.5×10^{-12}	1.4×10^{-11}	8.5×10^{-12}	1.4×10^{-11}	8.5×10^{-12}	6.9×10^{-12}	6.3×10^{-12}	6.3×10^{-12}	6.6×10^{-12}	6.6×10^{-12}	6.9×10^{-12}	6.3×10^{-12}	6.3×10^{-12}	6.6×10^{-12}	6.6×10^{-12}	6.3×10^{-12}	6.6×10^{-12}	6.3×10^{-12}	6.6×10^{-12}
TRANS-1,2-DICHLOROETHENE (TOTAL)	2.9×10^{-15}	1.4×10^{-15}	2.9×10^{-15}	1.4×10^{-15}	2.9×10^{-15}	1.4×10^{-15}	1.4×10^{-15}	7.3×10^{-16}	7.3×10^{-16}	7.6×10^{-16}	7.6×10^{-16}	1.4×10^{-15}	7.3×10^{-16}	7.3×10^{-16}	7.6×10^{-16}	7.6×10^{-16}	7.3×10^{-16}	7.6×10^{-16}	7.3×10^{-16}	7.6×10^{-16}
Trichloroethene	2.4×10^{-14}	1.4×10^{-14}	2.4×10^{-14}	1.4×10^{-14}	2.4×10^{-14}	1.4×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.1×10^{-14}
URANIUM, TOTAL	2.6×10^{-9}	1.8×10^{-9}	2.6×10^{-9}	1.8×10^{-9}	2.6×10^{-9}	1.8×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.7×10^{-9}
ZINC	8.4×10^{-10}	2.9×10^{-10}	8.4×10^{-10}	2.9×10^{-10}	8.4×10^{-10}	2.9×10^{-10}	2.4×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	2.0×10^{-10}	2.0×10^{-10}	2.4×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	2.0×10^{-10}	2.0×10^{-10}	2.2×10^{-10}	2.0×10^{-10}	2.2×10^{-10}	2.0×10^{-10}

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TABLE G.I-20

EXPOSURE POINT AIR CONCENTRATIONS IN THE VICINITY OF THE CONSOLIDATION AREA DURING OPERATION

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-RW comp 3																				
Cesium-137	0.0	0.0	0.0	0.0	0.0	2.4×10^{-4}	0.0	0.0	0.0	0.0	0.0	2.5×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	0.0	0.0	1.7×10^{-4}	1.6×10^{-4}
Neptunium-237	0.0	0.0	0.0	0.0	0.0	4.3×10^{-4}	0.0	0.0	0.0	0.0	0.0	4.4×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	0.0	0.0	3.0×10^{-4}	3.0×10^{-4}
Plutonium-238	0.0	0.0	0.0	0.0	0.0	3.6×10^{-4}	0.0	0.0	0.0	0.0	0.0	3.5×10^{-4}	2.4×10^{-4}	2.4×10^{-4}	2.6×10^{-4}	2.6×10^{-4}	0.0	0.0	2.4×10^{-4}	2.6×10^{-4}
Plutonium-239/240	0.0	0.0	0.0	0.0	0.0	3.5×10^{-4}	0.0	0.0	0.0	0.0	0.0	3.4×10^{-4}	2.3×10^{-4}	2.3×10^{-4}	2.7×10^{-4}	2.7×10^{-4}	0.0	0.0	2.3×10^{-4}	2.7×10^{-4}
Radium-226	0.0	0.0	0.0	0.0	0.0	3.3×10^{-2}	0.0	0.0	0.0	0.0	0.0	1.9×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	0.0	0.0	1.4×10^{-2}	1.7×10^{-2}
Radium-228	0.0	0.0	0.0	0.0	0.0	7.0×10^{-4}	0.0	0.0	0.0	0.0	0.0	6.2×10^{-4}	4.2×10^{-4}	4.2×10^{-4}	4.4×10^{-4}	4.4×10^{-4}	0.0	0.0	4.2×10^{-4}	4.4×10^{-4}
Strontium-90	0.0	0.0	0.0	0.0	0.0	9.5×10^{-4}	0.0	0.0	0.0	0.0	0.0	1.0×10^{-3}	7.1×10^{-4}	7.1×10^{-4}	8.2×10^{-4}	8.2×10^{-4}	0.0	0.0	7.1×10^{-4}	8.2×10^{-4}
Technetium-99	0.0	0.0	0.0	0.0	0.0	2.3×10^{-3}	0.0	0.0	0.0	0.0	0.0	2.3×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.9×10^{-3}	1.9×10^{-3}	0.0	0.0	1.5×10^{-3}	1.9×10^{-3}
Thorium-228	0.0	0.0	0.0	0.0	0.0	9.0×10^{-4}	0.0	0.0	0.0	0.0	0.0	8.4×10^{-4}	5.5×10^{-4}	5.5×10^{-4}	5.8×10^{-4}	5.9×10^{-4}	0.0	0.0	5.5×10^{-4}	5.8×10^{-4}
Thorium-230	0.0	0.0	0.0	0.0	0.0	1.5×10^{-1}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-1}	8.5×10^{-2}	8.5×10^{-2}	1.1×10^{-1}	1.1×10^{-1}	0.0	0.0	8.5×10^{-2}	1.1×10^{-1}
Thorium-232	0.0	0.0	0.0	0.0	0.0	6.4×10^{-3}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-3}	4.4×10^{-3}	4.5×10^{-3}	5.5×10^{-3}	5.5×10^{-3}	0.0	0.0	4.5×10^{-3}	5.5×10^{-3}
Thorium-234	0.0	0.0	0.0	0.0	0.0	7.1×10^{-3}	0.0	0.0	0.0	0.0	0.0	8.1×10^{-3}	6.0×10^{-3}	6.0×10^{-3}	7.4×10^{-3}	7.4×10^{-3}	0.0	0.0	6.0×10^{-3}	7.4×10^{-3}
Uranium-234	0.0	0.0	0.0	0.0	0.0	6.3×10^{-6}	0.0	0.0	0.0	0.0	0.0	6.9×10^{-6}	4.9×10^{-6}	4.9×10^{-6}	6.1×10^{-6}	6.1×10^{-6}	0.0	0.0	4.9×10^{-6}	6.1×10^{-6}
Uranium-235/236	0.0	0.0	0.0	0.0	0.0	8.3×10^{-4}	0.0	0.0	0.0	0.0	0.0	9.0×10^{-4}	6.4×10^{-4}	6.4×10^{-4}	8.0×10^{-4}	8.0×10^{-4}	0.0	0.0	6.4×10^{-4}	8.0×10^{-4}
Uranium-236	0.0	0.0	0.0	0.0	0.0	1.9×10^{-3}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-3}	7.0×10^{-4}	7.1×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	0.0	0.0	7.1×10^{-4}	8.5×10^{-4}
Uranium-238	0.0	0.0	0.0	0.0	0.0	1.1×10^{-1}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-1}	8.9×10^{-2}	8.9×10^{-2}	1.1×10^{-1}	1.1×10^{-1}	0.0	0.0	8.9×10^{-2}	1.1×10^{-1}
Metals/Chemicals (mg/m3)-RW comp 3																				
1,1-DICHLOROETHANE	0.0	0.0	0.0	0.0	0.0	1.0×10^{-14}	0.0	0.0	0.0	0.0	0.0	9.7×10^{-15}	6.3×10^{-15}	6.3×10^{-15}	5.8×10^{-15}	5.8×10^{-15}	0.0	0.0	6.3×10^{-15}	5.8×10^{-15}
1,1-DICHLOROETHENE	0.0	0.0	0.0	0.0	0.0	1.3×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-14}	8.8×10^{-15}	8.8×10^{-15}	8.8×10^{-15}	8.8×10^{-15}	0.0	0.0	8.8×10^{-15}	8.8×10^{-15}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
1,2-DICHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
1,2-DICHLOROETHANE	0.0	0.0	0.0	0.0	0.0	5.4×10^{-14}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-14}	4.3×10^{-14}	4.3×10^{-14}	5.1×10^{-14}	5.1×10^{-14}	0.0	0.0	4.3×10^{-14}	5.1×10^{-14}
1,2-DICHLOROETHENE (TOTAL)	0.0	0.0	0.0	0.0	0.0	1.3×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-14}	8.8×10^{-15}	8.8×10^{-15}	8.8×10^{-15}	8.8×10^{-15}	0.0	0.0	8.8×10^{-15}	8.8×10^{-15}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	0.0	0.0	0.0	0.0	0.0	5.0×10^{-15}	0.0	0.0	0.0	0.0	0.0	2.8×10^{-15}	1.8×10^{-15}	1.8×10^{-15}	2.3×10^{-15}	2.3×10^{-15}	0.0	0.0	1.8×10^{-15}	2.3×10^{-15}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	0.0	0.0	0.0	0.0	0.0	9.6×10^{-15}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-14}	5.7×10^{-15}	5.7×10^{-15}	7.1×10^{-15}	7.2×10^{-15}	0.0	0.0	5.7×10^{-15}	7.1×10^{-15}
3,3'-DICHLOROBENZIDINE	0.0	0.0	0.0	0.0	0.0	7.0×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.8×10^{-13}	4.6×10^{-13}	4.6×10^{-13}	4.9×10^{-13}	4.9×10^{-13}	0.0	0.0	4.6×10^{-13}	4.9×10^{-13}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	0.0	0.0	0.0	0.0	0.0	4.5×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.5×10^{-13}	3.0×10^{-13}	3.0×10^{-13}	3.4×10^{-13}	3.4×10^{-13}	0.0	0.0	3.0×10^{-13}	3.4×10^{-13}
4-NITROANILINE	0.0	0.0	0.0	0.0	0.0	2.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.3×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	0.0	0.0	1.4×10^{-12}	1.6×10^{-12}

TABLE G.I-20
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	0.0	0.0	0.0	0.0	0.0	7.1×10^{-12}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-12}	3.7×10^{-12}	3.7×10^{-12}	4.6×10^{-12}	4.6×10^{-12}	0.0	0.0	3.7×10^{-12}	4.6×10^{-12}
ALPHA-CHLORDANE	0.0	0.0	0.0	0.0	0.0	6.4×10^{-14}	0.0	0.0	0.0	0.0	0.0	5.8×10^{-14}	4.0×10^{-14}	4.0×10^{-14}	4.8×10^{-14}	4.8×10^{-14}	0.0	0.0	4.0×10^{-14}	4.8×10^{-14}
Aroclor 1254	0.0	0.0	0.0	0.0	0.0	2.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.0×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	0.0	0.0	1.4×10^{-12}	1.7×10^{-12}
Arsenic	0.0	0.0	0.0	0.0	0.0	7.2×10^{-12}	0.0	0.0	0.0	0.0	0.0	6.6×10^{-12}	4.4×10^{-12}	4.4×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	0.0	0.0	4.4×10^{-12}	5.4×10^{-12}
BENZENE	0.0	0.0	0.0	0.0	0.0	8.5×10^{-14}	0.0	0.0	0.0	0.0	0.0	9.4×10^{-14}	6.7×10^{-14}	6.8×10^{-14}	6.1×10^{-14}	6.1×10^{-14}	0.0	0.0	6.8×10^{-14}	6.1×10^{-14}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	1.9×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.5×10^{-12}	1.0×10^{-12}	9.9×10^{-13}	1.2×10^{-12}	1.2×10^{-12}	0.0	0.0	9.9×10^{-13}	1.2×10^{-12}
Benzo(a)pyrene	0.0	0.0	0.0	0.0	0.0	2.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.8×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	0.0	0.0	1.2×10^{-12}	1.5×10^{-12}
BENZO(B)FLUORANTHENE	0.0	0.0	0.0	0.0	0.0	2.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.9×10^{-12}	1.3×10^{-12}	1.3×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	0.0	0.0	1.3×10^{-12}	1.6×10^{-12}
BENZO(G,H,I)PERYLENE	0.0	0.0	0.0	0.0	0.0	4.6×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.3×10^{-13}	2.9×10^{-13}	2.9×10^{-13}	3.5×10^{-13}	3.5×10^{-13}	0.0	0.0	2.9×10^{-13}	3.5×10^{-13}
BENZO(K)FLUORANTHENE	0.0	0.0	0.0	0.0	0.0	1.8×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-12}	8.5×10^{-13}	8.5×10^{-13}	1.0×10^{-12}	1.1×10^{-12}	0.0	0.0	8.5×10^{-13}	1.0×10^{-12}
BENZOIC ACID	0.0	0.0	0.0	0.0	0.0	1.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-12}	7.7×10^{-13}	7.7×10^{-13}	9.3×10^{-13}	9.3×10^{-13}	0.0	0.0	7.7×10^{-13}	9.3×10^{-13}
BENZYL ALCOHOL	0.0	0.0	0.0	0.0	0.0	6.1×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	0.0	0.0	4.0×10^{-13}	4.1×10^{-13}
Beryllium	0.0	0.0	0.0	0.0	0.0	1.0×10^{-12}	0.0	0.0	0.0	0.0	0.0	9.5×10^{-13}	6.4×10^{-13}	6.4×10^{-13}	8.0×10^{-13}	8.0×10^{-13}	0.0	0.0	6.4×10^{-13}	8.0×10^{-13}
BIS(2-CHLOROETHOXY)METHANE	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
BIS(2-CHLOROETHYL)ETHER	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.0×10^{-13}	4.2×10^{-13}
BIS(2-CHLOROISOPROPYL) ETHER	0.0	0.0	0.0	0.0	0.0	6.1×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	0.0	0.0	4.0×10^{-13}	4.1×10^{-13}
Bis(2-ethylhexyl)phthalate	0.0	0.0	0.0	0.0	0.0	4.7×10^{-13}	0.0	0.0	0.0	0.0	0.0	3.7×10^{-13}	2.4×10^{-13}	2.4×10^{-13}	3.0×10^{-13}	3.0×10^{-13}	0.0	0.0	2.4×10^{-13}	3.0×10^{-13}
BIS(CHLOROMETHYL)ETHER	0.0	0.0	0.0	0.0	0.0	1.2×10^{-15}	0.0	0.0	0.0	0.0	0.0	1.4×10^{-15}	5.3×10^{-16}	5.3×10^{-16}	6.7×10^{-16}	6.6×10^{-16}	0.0	0.0	5.3×10^{-16}	6.7×10^{-16}
BROMODICHLOROMETHANE	0.0	0.0	0.0	0.0	0.0	5.4×10^{-14}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-14}	4.3×10^{-14}	4.3×10^{-14}	5.1×10^{-14}	5.1×10^{-14}	0.0	0.0	4.3×10^{-14}	5.1×10^{-14}
BROMOMETHANE	0.0	0.0	0.0	0.0	0.0	1.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-13}	9.1×10^{-14}	9.1×10^{-14}	1.1×10^{-13}	1.1×10^{-13}	0.0	0.0	9.1×10^{-14}	1.1×10^{-13}
CADMIUM	0.0	0.0	0.0	0.0	0.0	2.5×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.6×10^{-12}	1.8×10^{-12}	1.8×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	0.0	0.0	1.8×10^{-12}	1.4×10^{-12}
CHLORDANE	0.0	0.0	0.0	0.0	0.0	1.0×10^{-15}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-15}	4.3×10^{-16}	4.3×10^{-16}	5.4×10^{-16}	5.3×10^{-16}	0.0	0.0	4.3×10^{-16}	5.4×10^{-16}
CHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	9.7×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-13}	7.9×10^{-14}	8.0×10^{-14}	5.0×10^{-14}	5.0×10^{-14}	0.0	0.0	8.0×10^{-14}	5.0×10^{-14}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	0.0	0.0	0.0	0.0	0.0	1.7×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.6×10^{-14}	1.0×10^{-14}	1.0×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	0.0	0.0	1.0×10^{-14}	1.1×10^{-14}
Chrysene	0.0	0.0	0.0	0.0	0.0	2.1×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.7×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	0.0	0.0	1.1×10^{-12}	1.4×10^{-12}
DIBENZO(A,H)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	7.4×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.1×10^{-13}	4.2×10^{-13}
DIBENZOFURAN	0.0	0.0	0.0	0.0	0.0	4.3×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.3×10^{-13}	2.9×10^{-13}	2.9×10^{-13}	2.8×10^{-13}	2.8×10^{-13}	0.0	0.0	2.9×10^{-13}	2.8×10^{-13}
DIBROMOMETHANE	0.0	0.0	0.0	0.0	0.0	1.2×10^{-15}	0.0	0.0	0.0	0.0	0.0	1.4×10^{-15}	1.0×10^{-15}	1.0×10^{-15}	1.3×10^{-15}	1.3×10^{-15}	0.0	0.0	1.0×10^{-15}	1.3×10^{-15}
DIELDRIN	0.0	0.0	0.0	0.0	0.0	1.2×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-14}	7.7×10^{-15}	7.7×10^{-15}	9.6×10^{-15}	9.6×10^{-15}	0.0	0.0	7.7×10^{-15}	9.6×10^{-15}
ETHYLBENZENE	0.0	0.0	0.0	0.0	0.0	8.6×10^{-14}	0.0	0.0	0.0	0.0	0.0	8.3×10^{-14}	5.8×10^{-14}	5.8×10^{-14}	7.3×10^{-14}	7.2×10^{-14}	0.0	0.0	5.8×10^{-14}	7.3×10^{-14}
GAMMA-CHLORDANE	0.0	0.0	0.0	0.0	0.0	6.4×10^{-14}	0.0	0.0	0.0	0.0	0.0	5.8×10^{-14}	4.0×10^{-14}	4.0×10^{-14}	4.8×10^{-14}	4.8×10^{-14}	0.0	0.0	4.0×10^{-14}	4.8×10^{-14}
HEXACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	6.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	7.1×10^{-13}	4.6×10^{-13}	4.6×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.6×10^{-13}	4.2×10^{-13}
INDENO(1,2,3-CD)PYRENE	0.0	0.0	0.0	0.0	0.0	1.6×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-12}	8.4×10^{-13}	8.4×10^{-13}	1.0×10^{-12}	1.0×10^{-12}	0.0	0.0	8.4×10^{-13}	1.0×10^{-12}
Manganese	0.0	0.0	0.0	0.0	0.0	6.5×10^{-10}	0.0	0.0	0.0	0.0	0.0	6.3×10^{-10}	4.1×10^{-10}	4.1×10^{-10}	5.1×10^{-10}	5.1×10^{-10}	0.0	0.0	4.1×10^{-10}	5.1×10^{-10}
Mercury	0.0	0.0	0.0	0.0	0.0	1.1×10^{-13}	0.0	0.0	0.0	0.0	0.0	1.0×10^{-13}	6.9×10^{-14}	6.9×10^{-14}	8.6×10^{-14}	8.6×10^{-14}	0.0	0.0	6.9×10^{-14}	8.6×10^{-14}
METHYLENE CHIORIDE	0.0	0.0	0.0	0.0	0.0	3.1×10^{-14}	0.0	0.0	0.0	0.0	0.0	3.4×10^{-14}	2.5×10^{-14}	2.5×10^{-14}	3.5×10^{-15}	3.7×10^{-15}	0.0	0.0	2.5×10^{-14}	3.5×10^{-15}

TABLE G.I-20
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	0.0	0.0	0.0	0.0	0.0	6.0×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.2×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	0.0	0.0	4.0×10^{-13}	4.1×10^{-13}
NITROBENZENE	0.0	0.0	0.0	0.0	0.0	6.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	7.1×10^{-13}	4.6×10^{-13}	4.6×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	4.6×10^{-13}	4.2×10^{-13}
O-DICHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	1.5×10^{-13}	0.0	0.0	0.0	0.0	0.0	1.7×10^{-13}	1.3×10^{-13}	1.3×10^{-13}	3.9×10^{-16}	3.9×10^{-16}	0.0	0.0	1.3×10^{-13}	3.9×10^{-16}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	0.0	0.0	0.0	0.0	0.0	1.2×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-12}	7.1×10^{-13}	7.1×10^{-13}	8.8×10^{-13}	8.8×10^{-13}	0.0	0.0	7.1×10^{-13}	8.8×10^{-13}
SILVER	0.0	0.0	0.0	0.0	0.0	2.9×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.7×10^{-12}	1.8×10^{-12}	1.8×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	0.0	0.0	1.8×10^{-12}	2.2×10^{-12}
TRANS-1,2-DICHLOROETHENE (TOTAL)	0.0	0.0	0.0	0.0	0.0	4.8×10^{-16}	0.0	0.0	0.0	0.0	0.0	5.5×10^{-16}	2.1×10^{-16}	2.1×10^{-16}	2.6×10^{-16}	2.6×10^{-16}	0.0	0.0	2.1×10^{-16}	2.6×10^{-16}
Trichloroethene	0.0	0.0	0.0	0.0	0.0	4.9×10^{-15}	0.0	0.0	0.0	0.0	0.0	4.4×10^{-15}	3.0×10^{-15}	3.0×10^{-15}	3.8×10^{-15}	3.8×10^{-15}	0.0	0.0	3.0×10^{-15}	3.8×10^{-15}
URANIUM, TOTAL	0.0	0.0	0.0	0.0	0.0	6.1×10^{-10}	0.0	0.0	0.0	0.0	0.0	6.7×10^{-10}	4.7×10^{-10}	4.7×10^{-10}	5.9×10^{-10}	5.9×10^{-10}	0.0	0.0	4.7×10^{-10}	5.9×10^{-10}
ZINC	0.0	0.0	0.0	0.0	0.0	1.0×10^{-10}	0.0	0.0	0.0	0.0	0.0	9.3×10^{-11}	6.4×10^{-11}	6.4×10^{-11}	6.6×10^{-11}	6.6×10^{-11}	0.0	0.0	6.4×10^{-11}	6.6×10^{-11}

FEMPCRUS\APXS\APP-GI\ATTACH\TABGI-2013/22/95, 10:16am

FER\CRU5\APX\APP-G\ATTACHT\ABGI-22\3/22/95, 10:21am

TABLE G.I-22

EXPOSURE POINT AIR CONCENTRATIONS FOR ON-SITE NONREMEDIATION WORKERS DURING OPERATIONS

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-nrw																				
Cesium-137	1.4×10^{-6}	3.8×10^{-7}	1.4×10^{-6}	3.8×10^{-7}	1.4×10^{-6}	3.8×10^{-7}	3.5×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	3.5×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	3.2×10^{-7}	2.6×10^{-7}
Neptunium-237	2.3×10^{-6}	6.8×10^{-7}	2.3×10^{-6}	6.8×10^{-7}	2.3×10^{-6}	6.8×10^{-7}	6.2×10^{-7}	5.7×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	4.9×10^{-7}	6.2×10^{-7}	5.7×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	4.9×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	5.7×10^{-7}	4.9×10^{-7}
Plutonium-238	1.6×10^{-6}	5.7×10^{-7}	1.6×10^{-6}	5.7×10^{-7}	1.6×10^{-6}	5.7×10^{-7}	5.0×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.2×10^{-7}	5.0×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.2×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.6×10^{-7}	4.2×10^{-7}
Plutonium-239/240	1.2×10^{-6}	5.5×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	4.8×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.8×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}
Radium-226	6.9×10^{-5}	4.9×10^{-5}	6.9×10^{-5}	4.9×10^{-5}	6.9×10^{-5}	4.9×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.6×10^{-5}
Radium-228	3.1×10^{-6}	1.1×10^{-6}	3.1×10^{-6}	1.1×10^{-6}	3.1×10^{-6}	1.1×10^{-6}	8.9×10^{-7}	8.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	7.1×10^{-7}	8.9×10^{-7}	8.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	7.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}
Strontium-90	3.2×10^{-6}	1.5×10^{-6}	3.2×10^{-6}	1.5×10^{-6}	3.2×10^{-6}	1.5×10^{-6}	1.4×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.4×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}
Technetium-99	8.1×10^{-6}	3.6×10^{-6}	8.1×10^{-6}	3.6×10^{-6}	8.1×10^{-6}	3.6×10^{-6}	3.3×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.2×10^{-6}	3.3×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.2×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.0×10^{-6}	3.1×10^{-6}
Thorium-228	4.1×10^{-6}	1.4×10^{-6}	4.1×10^{-6}	1.4×10^{-6}	4.1×10^{-6}	1.4×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.4×10^{-7}	9.5×10^{-7}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.4×10^{-7}	9.5×10^{-7}	1.1×10^{-6}	9.4×10^{-7}	1.1×10^{-6}	9.4×10^{-7}
Thorium-230	4.2×10^{-4}	2.2×10^{-4}	4.2×10^{-4}	2.2×10^{-4}	4.2×10^{-4}	2.2×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}
Thorium-232	1.5×10^{-5}	9.6×10^{-6}	1.5×10^{-5}	9.7×10^{-6}	1.5×10^{-5}	9.7×10^{-6}	8.6×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	8.6×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.3×10^{-6}	8.5×10^{-6}
Thorium-234	2.8×10^{-5}	1.3×10^{-5}	2.8×10^{-5}	1.3×10^{-5}	2.8×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.4×10^{-5}
Uranium-234	1.5×10^{-8}	9.6×10^{-9}	1.5×10^{-8}	9.7×10^{-9}	1.5×10^{-8}	9.7×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.5×10^{-9}
Uranium-235/236	2.0×10^{-6}	1.3×10^{-6}	2.0×10^{-6}	1.3×10^{-6}	2.0×10^{-6}	1.3×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
Uranium-236	5.1×10^{-6}	2.8×10^{-6}	5.1×10^{-6}	2.8×10^{-6}	5.1×10^{-6}	2.8×10^{-6}	1.5×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.5×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}
Uranium-238	2.7×10^{-4}	1.8×10^{-4}	2.7×10^{-4}	1.8×10^{-4}	2.7×10^{-4}	1.8×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}
Metals/Chemicals (mg/m3)-nrw																				
1,1-DICHLOROETHANE	3.5×10^{-11}	9.0×10^{-12}	3.5×10^{-11}	9.0×10^{-12}	3.5×10^{-11}	9.0×10^{-12}	7.8×10^{-12}	6.9×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	7.8×10^{-12}	6.9×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	6.9×10^{-12}	5.4×10^{-12}
1,1-DICHLOROETHENE	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,2-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,2-DICHLOROETHANE	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}
1,2-DICHLOROETHENE (TOTAL)	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	7.1×10^{-12}	4.1×10^{-12}	7.1×10^{-12}	4.2×10^{-12}	7.1×10^{-12}	4.2×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	2.0×10^{-12}	1.9×10^{-12}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	3.7×10^{-11}	8.4×10^{-12}	3.7×10^{-11}	8.4×10^{-12}	3.7×10^{-11}	8.4×10^{-12}	8.7×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.4×10^{-12}	8.7×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.4×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.0×10^{-12}	6.3×10^{-12}
3,3'-DICHLOROBENZIDINE	1.8×10^{-9}	6.1×10^{-10}	1.8×10^{-9}	6.1×10^{-10}	1.8×10^{-9}	6.1×10^{-10}	5.4×10^{-10}	5.0×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.5×10^{-10}	5.4×10^{-10}	5.0×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.5×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.9×10^{-10}	4.4×10^{-10}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	1.1×10^{-9}	4.0×10^{-10}	1.1×10^{-9}	4.0×10^{-10}	1.1×10^{-9}	4.0×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.3×10^{-10}	3.1×10^{-10}
4-NITROANILINE	7.8×10^{-9}	2.0×10^{-9}	7.8×10^{-9}	2.0×10^{-9}	7.8×10^{-9}	2.0×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.4×10^{-9}

TABLE G.I-22
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	1.1×10^{-8}	6.0×10^{-9}	1.1×10^{-8}	6.0×10^{-9}	1.1×10^{-8}	6.0×10^{-9}	4.4×10^{-9}	3.9×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	4.0×10^{-9}	4.4×10^{-9}	3.9×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	4.0×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	3.9×10^{-9}	4.0×10^{-9}
ALPHA-CHLORDANE	1.0×10^{-10}	5.4×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}
Aroclor 1254	3.1×10^{-9}	2.0×10^{-9}	3.1×10^{-9}	2.0×10^{-9}	3.1×10^{-9}	2.0×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}
Arsenic	1.3×10^{-8}	6.4×10^{-9}	1.3×10^{-8}	6.4×10^{-9}	1.3×10^{-8}	6.4×10^{-9}	5.4×10^{-9}	4.8×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	5.0×10^{-9}	5.4×10^{-9}	4.8×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	5.0×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	4.8×10^{-9}	5.0×10^{-9}
BENZENE	3.0×10^{-10}	7.3×10^{-11}	3.0×10^{-10}	7.3×10^{-11}	3.0×10^{-10}	7.3×10^{-11}	7.2×10^{-11}	7.0×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	5.4×10^{-11}	7.2×10^{-11}	7.0×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	5.4×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	7.0×10^{-11}	5.4×10^{-11}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	2.9×10^{-9}	1.6×10^{-9}	2.9×10^{-9}	1.6×10^{-9}	2.9×10^{-9}	1.6×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}
Benzo(a)pyrene	3.5×10^{-9}	1.9×10^{-9}	3.5×10^{-9}	1.9×10^{-9}	3.5×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.3×10^{-9}
BENZO(B)FLUORANTHENE	3.9×10^{-9}	2.0×10^{-9}	3.9×10^{-9}	2.0×10^{-9}	3.9×10^{-9}	2.0×10^{-9}	1.5×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.3×10^{-9}	1.4×10^{-9}
BENZO(G,H,I)PERYLENE	9.4×10^{-10}	4.1×10^{-10}	9.4×10^{-10}	4.1×10^{-10}	9.4×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}
BENZO(K)FLUORANTHENE	2.7×10^{-9}	1.6×10^{-9}	2.7×10^{-9}	1.6×10^{-9}	2.7×10^{-9}	1.6×10^{-9}	1.0×10^{-9}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.1×10^{-10}	1.0×10^{-9}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}
BENZOIC ACID	2.2×10^{-9}	1.1×10^{-9}	2.2×10^{-9}	1.1×10^{-9}	2.2×10^{-9}	1.1×10^{-9}	9.0×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	9.0×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}
BENZYL ALCOHOL	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}
Beryllium	1.7×10^{-9}	8.9×10^{-10}	1.7×10^{-9}	8.9×10^{-10}	1.7×10^{-9}	8.9×10^{-10}	7.6×10^{-10}	7.0×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.3×10^{-10}	7.6×10^{-10}	7.0×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.3×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.0×10^{-10}	7.3×10^{-10}
BIS(2-CHLOROETHOXY)METHANE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
BIS(2-CHLOROETHYL)ETHER	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
BIS(2-CHLOROISOPROPYL) ETHER	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.8×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}
Bis(2-ethylhexyl)phthalate	7.6×10^{-10}	4.1×10^{-10}	7.6×10^{-10}	4.1×10^{-10}	7.6×10^{-10}	4.1×10^{-10}	3.0×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	3.0×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.6×10^{-10}	2.7×10^{-10}
BIS(CHLOROMETHYL)ETHER	2.1×10^{-12}	1.0×10^{-12}	2.1×10^{-12}	1.0×10^{-12}	2.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	5.3×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.5×10^{-13}	1.0×10^{-12}	5.3×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.5×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.3×10^{-13}	5.5×10^{-13}
BROMODICHLOROMETHANE	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}
BROMOMETHANE	1.6×10^{-10}	1.1×10^{-10}	1.6×10^{-10}	1.1×10^{-10}	1.6×10^{-10}	1.1×10^{-10}	9.8×10^{-11}	9.5×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.8×10^{-11}
CADMIUM	1.1×10^{-8}	2.1×10^{-9}	1.1×10^{-8}	2.1×10^{-9}	1.1×10^{-8}	2.1×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.3×10^{-9}
CHLORDANE	1.7×10^{-12}	8.2×10^{-13}	1.7×10^{-12}	8.2×10^{-13}	1.7×10^{-12}	8.2×10^{-13}	8.4×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	8.4×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.3×10^{-13}	4.5×10^{-13}
CHLOROBENZENE	5.0×10^{-10}	8.2×10^{-11}	5.1×10^{-10}	8.2×10^{-11}	5.0×10^{-10}	8.2×10^{-11}	8.3×10^{-11}	8.2×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	8.3×10^{-11}	8.2×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	8.2×10^{-11}	4.5×10^{-11}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	4.4×10^{-11}	1.4×10^{-11}	4.4×10^{-11}	1.4×10^{-11}	4.4×10^{-11}	1.4×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.9×10^{-12}	9.9×10^{-12}	1.2×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.8×10^{-12}	9.9×10^{-12}	1.1×10^{-11}	9.9×10^{-12}	1.1×10^{-11}	9.8×10^{-12}
Chrysene	3.2×10^{-9}	1.8×10^{-9}	3.2×10^{-9}	1.8×10^{-9}	3.2×10^{-9}	1.8×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}
DIBENZO(A,H)ANTHRACENE	1.8×10^{-9}	6.2×10^{-10}	1.8×10^{-9}	6.2×10^{-10}	1.8×10^{-9}	6.2×10^{-10}	4.6×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.6×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}
DIBENZOFURAN	1.4×10^{-9}	3.8×10^{-10}	1.4×10^{-9}	3.8×10^{-10}	1.4×10^{-9}	3.8×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	3.1×10^{-10}	2.6×10^{-10}
DIBROMOMETHANE	9.2×10^{-13}	9.9×10^{-13}	9.2×10^{-13}	1.0×10^{-12}	9.2×10^{-13}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.1×10^{-12}
DIELDRIN	1.8×10^{-11}	1.1×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	9.0×10^{-12}	8.2×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.5×10^{-12}	9.0×10^{-12}	8.2×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.5×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.2×10^{-12}	8.5×10^{-12}
ETHYLBENZENE	1.1×10^{-10}	7.3×10^{-11}	1.1×10^{-10}	7.4×10^{-11}	1.1×10^{-10}	7.4×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.3×10^{-11}
GAMMA-CHLORDANE	1.0×10^{-10}	5.4×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}
HEXACHLOROBENZENE	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}
INDENO(1,2,3-CD)PYRENE	2.5×10^{-9}	1.4×10^{-9}	2.5×10^{-9}	1.4×10^{-9}	2.5×10^{-9}	1.4×10^{-9}	9.8×10^{-10}	8.9×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.8×10^{-10}	8.9×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	9.0×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	8.9×10^{-10}	9.0×10^{-10}
Manganese	1.3×10^{-6}	6.0×10^{-7}	1.3×10^{-6}	6.0×10^{-7}	1.3×10^{-6}	6.0×10^{-7}	5.2×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	5.2×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.6×10^{-7}	4.8×10^{-7}
Mercury	1.8×10^{-10}	9.7×10^{-11}	1.8×10^{-10}	9.7×10^{-11}	1.8×10^{-10}	9.7×10^{-11}	8.1×10^{-11}	7.5×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.8×10^{-11}	8.1×10^{-11}	7.5×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.8×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.5×10^{-11}	7.8×10^{-11}
METHYLENE CHIORIDE	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	3.2×10^{-12}	3.3×10^{-12}	2.6×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	3.2×10^{-12}	3.3×10^{-12}	2.5×10^{-11}	3.2×10^{-12}	2.5×10^{-11}	3.2×10^{-12}

TABLE G.I-22
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}
NITROBENZENE	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}
O-DICHLOROBENZENE	1.4×10^{-9}	1.2×10^{-10}	1.4×10^{-9}	1.2×10^{-10}	1.4×10^{-9}	1.2×10^{-10}	1.2×10^{-10}	1.3×10^{-10}	1.3×10^{-10}	3.3×10^{-13}	3.3×10^{-13}	1.2×10^{-10}	1.3×10^{-10}	1.3×10^{-10}	3.3×10^{-13}	3.3×10^{-13}	1.3×10^{-10}	3.3×10^{-13}	1.3×10^{-10}	3.3×10^{-13}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	2.1×10^{-9}	1.1×10^{-9}	2.1×10^{-9}	1.1×10^{-9}	2.1×10^{-9}	1.1×10^{-9}	8.2×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.7×10^{-10}	8.2×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.7×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.5×10^{-10}	7.7×10^{-10}
SILVER	4.3×10^{-9}	2.5×10^{-9}	4.3×10^{-9}	2.5×10^{-9}	4.3×10^{-9}	2.5×10^{-9}	2.1×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	2.0×10^{-9}	2.1×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	2.0×10^{-9}
TRANS-1,2-DICHLOROETHENE (TOTAL)	8.3×10^{-13}	3.9×10^{-13}	8.3×10^{-13}	4.0×10^{-13}	8.3×10^{-13}	4.0×10^{-13}	4.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.2×10^{-13}	4.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.2×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.1×10^{-13}	2.2×10^{-13}
Trichloroethene	7.8×10^{-12}	4.3×10^{-12}	7.8×10^{-12}	4.3×10^{-12}	7.8×10^{-12}	4.3×10^{-12}	3.5×10^{-12}	3.2×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.4×10^{-12}	3.5×10^{-12}	3.2×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.4×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.2×10^{-12}	3.4×10^{-12}
URANIUM, TOTAL	8.2×10^{-7}	5.3×10^{-7}	8.2×10^{-7}	5.3×10^{-7}	8.2×10^{-7}	5.3×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.2×10^{-7}
ZINC	2.6×10^{-7}	8.7×10^{-8}	2.6×10^{-7}	8.8×10^{-8}	2.6×10^{-7}	8.8×10^{-8}	7.3×10^{-8}	6.9×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.0×10^{-8}	7.3×10^{-8}	6.9×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.0×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.8×10^{-8}	6.0×10^{-8}

TABLE G.I-23

EXPOSURE POINT AIR CONCENTRATIONS IN THE VICINITY OF THE HYPOTHETICAL NEAR-PROPERTY PUBLIC RECEPTOR

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-npp																				
Cesium-137	9.4×10^{-7}	2.8×10^{-7}	9.7×10^{-7}	2.9×10^{-7}	9.4×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.3×10^{-7}	2.3×10^{-7}	1.9×10^{-7}	1.9×10^{-7}	3.0×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	2.2×10^{-7}	2.2×10^{-7}	2.3×10^{-7}	1.9×10^{-7}	2.5×10^{-7}	2.2×10^{-7}
Neptunium-237	1.5×10^{-6}	4.9×10^{-7}	1.6×10^{-6}	5.1×10^{-7}	1.5×10^{-6}	5.8×10^{-7}	4.6×10^{-7}	4.1×10^{-7}	4.1×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	5.2×10^{-7}	4.5×10^{-7}	4.5×10^{-7}	4.0×10^{-7}	4.1×10^{-7}	4.1×10^{-7}	3.6×10^{-7}	4.5×10^{-7}	4.0×10^{-7}
Plutonium-238	1.1×10^{-6}	4.2×10^{-7}	1.1×10^{-6}	4.3×10^{-7}	1.1×10^{-6}	4.9×10^{-7}	3.7×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	4.2×10^{-7}	3.7×10^{-7}	3.7×10^{-7}	3.5×10^{-7}	3.5×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	3.7×10^{-7}	3.5×10^{-7}
Plutonium-239/240	8.0×10^{-7}	4.1×10^{-7}	8.3×10^{-7}	4.2×10^{-7}	8.0×10^{-7}	4.7×10^{-7}	3.5×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	3.3×10^{-7}	3.3×10^{-7}	4.1×10^{-7}	3.5×10^{-7}	3.5×10^{-7}	3.7×10^{-7}	3.7×10^{-7}	3.2×10^{-7}	3.3×10^{-7}	3.5×10^{-7}	3.7×10^{-7}
Radium-226	5.1×10^{-5}	4.2×10^{-5}	5.3×10^{-5}	4.3×10^{-5}	5.1×10^{-5}	4.8×10^{-5}	2.2×10^{-5}	2.2×10^{-5}	2.2×10^{-5}	2.3×10^{-5}	2.3×10^{-5}	2.5×10^{-5}	2.4×10^{-5}	2.4×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.2×10^{-5}	2.3×10^{-5}	2.4×10^{-5}	2.6×10^{-5}
Radium-228	2.2×10^{-6}	8.1×10^{-7}	2.2×10^{-6}	8.4×10^{-7}	2.2×10^{-6}	9.5×10^{-7}	6.6×10^{-7}	5.8×10^{-7}	5.8×10^{-7}	5.3×10^{-7}	5.3×10^{-7}	7.6×10^{-7}	6.4×10^{-7}	6.4×10^{-7}	6.0×10^{-7}	6.0×10^{-7}	5.8×10^{-7}	5.3×10^{-7}	6.4×10^{-7}	6.0×10^{-7}
Strontium-90	2.2×10^{-6}	1.1×10^{-6}	2.3×10^{-6}	1.1×10^{-6}	2.2×10^{-6}	1.3×10^{-6}	1.0×10^{-6}	9.8×10^{-7}	9.8×10^{-7}	9.8×10^{-7}	9.8×10^{-7}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.8×10^{-7}	9.8×10^{-7}	1.1×10^{-6}	1.1×10^{-6}
Technetium-99	5.1×10^{-6}	2.5×10^{-6}	5.3×10^{-6}	2.6×10^{-6}	5.1×10^{-6}	3.0×10^{-6}	2.3×10^{-6}	2.1×10^{-6}	2.1×10^{-6}	2.2×10^{-6}	2.2×10^{-6}	2.7×10^{-6}	2.3×10^{-6}	2.3×10^{-6}	2.5×10^{-6}	2.5×10^{-6}	2.1×10^{-6}	2.2×10^{-6}	2.3×10^{-6}	2.5×10^{-6}
Thorium-228	2.9×10^{-6}	1.1×10^{-6}	3.0×10^{-6}	1.1×10^{-6}	2.9×10^{-6}	1.2×10^{-6}	8.9×10^{-7}	7.6×10^{-7}	7.6×10^{-7}	7.0×10^{-7}	7.1×10^{-7}	1.0×10^{-6}	8.5×10^{-7}	8.4×10^{-7}	7.9×10^{-7}	7.9×10^{-7}	7.6×10^{-7}	7.0×10^{-7}	8.4×10^{-7}	7.9×10^{-7}
Thorium-230	2.7×10^{-4}	1.7×10^{-4}	2.8×10^{-4}	1.8×10^{-4}	2.7×10^{-4}	2.0×10^{-4}	1.3×10^{-4}	1.2×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	1.3×10^{-4}	1.5×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	1.4×10^{-4}	1.5×10^{-4}
Thorium-232	1.1×10^{-5}	7.3×10^{-6}	1.1×10^{-5}	7.5×10^{-6}	1.1×10^{-5}	8.5×10^{-6}	6.6×10^{-6}	6.3×10^{-6}	6.3×10^{-6}	6.6×10^{-6}	6.6×10^{-6}	7.6×10^{-6}	7.0×10^{-6}	7.0×10^{-6}	7.4×10^{-6}	7.4×10^{-6}	6.3×10^{-6}	6.6×10^{-6}	7.0×10^{-6}	7.4×10^{-6}
Thorium-234	1.4×10^{-5}	7.1×10^{-6}	1.5×10^{-5}	7.4×10^{-6}	1.4×10^{-5}	8.5×10^{-6}	7.6×10^{-6}	7.6×10^{-6}	7.6×10^{-6}	7.9×10^{-6}	7.9×10^{-6}	8.9×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	9.0×10^{-6}	9.0×10^{-6}	7.6×10^{-6}	7.9×10^{-6}	8.5×10^{-6}	9.0×10^{-6}
Uranium-234	1.0×10^{-8}	7.0×10^{-9}	1.1×10^{-8}	7.2×10^{-9}	1.0×10^{-8}	8.2×10^{-9}	7.1×10^{-9}	6.8×10^{-9}	6.8×10^{-9}	7.2×10^{-9}	7.2×10^{-9}	8.2×10^{-9}	7.5×10^{-9}	7.5×10^{-9}	8.1×10^{-9}	8.1×10^{-9}	6.8×10^{-9}	7.2×10^{-9}	7.5×10^{-9}	8.1×10^{-9}
Uranium-235/236	1.4×10^{-6}	9.2×10^{-7}	1.4×10^{-6}	9.5×10^{-7}	1.4×10^{-6}	1.1×10^{-6}	9.3×10^{-7}	8.9×10^{-7}	8.9×10^{-7}	9.4×10^{-7}	9.4×10^{-7}	1.1×10^{-6}	9.9×10^{-7}	9.9×10^{-7}	1.1×10^{-6}	1.1×10^{-6}	8.9×10^{-7}	9.4×10^{-7}	9.9×10^{-7}	1.1×10^{-6}
Uranium-236	3.6×10^{-6}	2.2×10^{-6}	3.7×10^{-6}	2.3×10^{-6}	3.6×10^{-6}	2.6×10^{-6}	1.1×10^{-6}	9.7×10^{-7}	9.7×10^{-7}	1.1×10^{-6}	1.1×10^{-6}	1.3×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	9.7×10^{-7}	1.1×10^{-6}	1.1×10^{-6}	1.2×10^{-6}
Uranium-238	1.9×10^{-4}	1.3×10^{-4}	1.9×10^{-4}	1.3×10^{-4}	1.9×10^{-4}	1.5×10^{-4}	1.3×10^{-4}	1.2×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	1.3×10^{-4}	1.5×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	1.4×10^{-4}	1.5×10^{-4}
Metals/Chemicals (mg/m3)-npp																				
1,1-DICHLOROETHANE	2.4×10^{-11}	6.7×10^{-12}	2.5×10^{-11}	6.9×10^{-12}	2.4×10^{-11}	7.8×10^{-12}	5.8×10^{-12}	4.9×10^{-12}	4.9×10^{-12}	3.9×10^{-12}	3.9×10^{-12}	6.6×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	4.4×10^{-12}	4.4×10^{-12}	4.9×10^{-12}	3.9×10^{-12}	5.4×10^{-12}	4.4×10^{-12}
1,1-DICHLOROETHENE	2.6×10^{-11}	8.5×10^{-12}	2.7×10^{-11}	8.8×10^{-12}	2.6×10^{-11}	1.0×10^{-11}	7.8×10^{-12}	6.8×10^{-12}	6.8×10^{-12}	6.0×10^{-12}	6.0×10^{-12}	8.9×10^{-12}	7.5×10^{-12}	7.5×10^{-12}	6.7×10^{-12}	6.7×10^{-12}	6.8×10^{-12}	6.0×10^{-12}	7.5×10^{-12}	6.7×10^{-12}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
1,2-DICHLOROBENZENE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
1,2-DICHLOROETHANE	6.1×10^{-11}	3.4×10^{-11}	6.3×10^{-11}	3.5×10^{-11}	6.1×10^{-11}	4.0×10^{-11}	3.5×10^{-11}	3.3×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	4.0×10^{-11}	3.7×10^{-11}	3.7×10^{-11}	3.9×10^{-11}	3.8×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.7×10^{-11}	3.9×10^{-11}
1,2-DICHLOROETHENE (TOTAL)	2.6×10^{-11}	8.5×10^{-12}	2.7×10^{-11}	8.8×10^{-12}	2.6×10^{-11}	1.0×10^{-11}	7.8×10^{-12}	6.8×10^{-12}	6.8×10^{-12}	6.0×10^{-12}	6.0×10^{-12}	8.9×10^{-12}	7.5×10^{-12}	7.5×10^{-12}	6.7×10^{-12}	6.7×10^{-12}	6.8×10^{-12}	6.0×10^{-12}	7.5×10^{-12}	6.7×10^{-12}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	4.9×10^{-12}	3.3×10^{-12}	5.1×10^{-12}	3.4×10^{-12}	4.9×10^{-12}	3.8×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.9×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.8×10^{-12}	1.8×10^{-12}	1.4×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.8×10^{-12}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	2.4×10^{-11}	5.3×10^{-12}	2.5×10^{-11}	5.5×10^{-12}	2.4×10^{-11}	6.3×10^{-12}	5.6×10^{-12}	4.0×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	4.2×10^{-12}	6.6×10^{-12}	4.5×10^{-12}	4.4×10^{-12}	4.7×10^{-12}	4.8×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	4.4×10^{-12}	4.7×10^{-12}
3,3'-DICHLOROBENZIDINE	1.3×10^{-9}	4.5×10^{-10}	1.3×10^{-9}	4.7×10^{-10}	1.3×10^{-9}	5.3×10^{-10}	4.1×10^{-10}	3.6×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	3.3×10^{-10}	4.7×10^{-10}	4.0×10^{-10}	4.0×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	4.0×10^{-10}	3.7×10^{-10}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	7.7×10^{-10}	3.0×10^{-10}	7.9×10^{-10}	3.1×10^{-10}	7.7×10^{-10}	3.5×10^{-10}	2.7×10^{-10}	2.4×10^{-10}	2.4×10^{-10}	2.3×10^{-10}	2.3×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.4×10^{-10}	2.3×10^{-10}	2.6×10^{-10}	2.6×10^{-10}
4-NITROANILINE	5.6×10^{-9}	1.5×10^{-9}	5.8×10^{-9}	1.5×10^{-9}	5.6×10^{-9}	1.7×10^{-9}	1.4×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.6×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.2×10^{-9}	1.2×10^{-9}

TABLE G.I-23
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	8.5×10^{-9}	5.0×10^{-9}	8.7×10^{-9}	5.1×10^{-9}	8.5×10^{-9}	5.7×10^{-9}	3.7×10^{-9}	3.1×10^{-9}	3.1×10^{-9}	3.3×10^{-9}	3.3×10^{-9}	4.2×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	3.1×10^{-9}	3.3×10^{-9}	3.4×10^{-9}	3.7×10^{-9}
ALPHA-CHLORDANE	7.0×10^{-11}	4.0×10^{-11}	7.2×10^{-11}	4.2×10^{-11}	7.0×10^{-11}	4.7×10^{-11}	3.3×10^{-11}	3.1×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.2×10^{-11}	3.8×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	3.6×10^{-11}	3.6×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.4×10^{-11}	3.6×10^{-11}
Aroclor 1254	2.2×10^{-9}	1.5×10^{-9}	2.2×10^{-9}	1.6×10^{-9}	2.2×10^{-9}	1.8×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}
Arsenic	8.5×10^{-9}	4.7×10^{-9}	8.8×10^{-9}	4.8×10^{-9}	8.5×10^{-9}	5.5×10^{-9}	3.9×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	4.5×10^{-9}	3.8×10^{-9}	3.8×10^{-9}	4.1×10^{-9}	4.1×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.8×10^{-9}	4.1×10^{-9}
BENZENE	2.0×10^{-10}	5.2×10^{-11}	2.1×10^{-10}	5.4×10^{-11}	2.0×10^{-10}	6.1×10^{-11}	5.3×10^{-11}	5.1×10^{-11}	5.1×10^{-11}	4.1×10^{-11}	4.1×10^{-11}	6.2×10^{-11}	5.7×10^{-11}	5.7×10^{-11}	4.6×10^{-11}	4.6×10^{-11}	5.1×10^{-11}	4.1×10^{-11}	5.7×10^{-11}	4.6×10^{-11}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	1.9×10^{-9}	1.2×10^{-9}	2.0×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	8.7×10^{-10}	7.9×10^{-10}	7.8×10^{-10}	8.5×10^{-10}	8.5×10^{-10}	1.0×10^{-9}	8.7×10^{-10}	8.7×10^{-10}	9.5×10^{-10}	9.5×10^{-10}	7.8×10^{-10}	8.5×10^{-10}	8.7×10^{-10}	9.5×10^{-10}
Benzo(a)pyrene	2.3×10^{-9}	1.5×10^{-9}	2.4×10^{-9}	1.5×10^{-9}	2.3×10^{-9}	1.7×10^{-9}	1.0×10^{-9}	9.3×10^{-10}	9.2×10^{-10}	1.0×10^{-9}	1.0×10^{-9}	1.2×10^{-9}	1.0×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	9.2×10^{-10}	1.0×10^{-9}	1.0×10^{-9}	1.1×10^{-9}
BENZO(B)FLUORANTHENE	2.5×10^{-9}	1.5×10^{-9}	2.6×10^{-9}	1.5×10^{-9}	2.5×10^{-9}	1.8×10^{-9}	1.1×10^{-9}	9.9×10^{-10}	9.9×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	1.3×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	9.9×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}
BENZO(G,H,I)PERYLENE	6.5×10^{-10}	3.0×10^{-10}	6.7×10^{-10}	3.1×10^{-10}	6.5×10^{-10}	3.5×10^{-10}	2.6×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	2.3×10^{-10}	2.4×10^{-10}	3.0×10^{-10}	2.5×10^{-10}	2.5×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.2×10^{-10}	2.3×10^{-10}	2.5×10^{-10}	2.6×10^{-10}
BENZO(K)FLUORANTHENE	1.9×10^{-9}	1.2×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	7.6×10^{-10}	6.8×10^{-10}	6.8×10^{-10}	7.3×10^{-10}	7.4×10^{-10}	8.7×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	8.2×10^{-10}	8.2×10^{-10}	6.8×10^{-10}	7.3×10^{-10}	7.5×10^{-10}	8.2×10^{-10}
BENZOIC ACID	1.5×10^{-9}	8.5×10^{-10}	1.6×10^{-9}	8.7×10^{-10}	1.5×10^{-9}	9.9×10^{-10}	6.7×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	6.3×10^{-10}	6.3×10^{-10}	7.7×10^{-10}	6.7×10^{-10}	6.7×10^{-10}	7.1×10^{-10}	7.1×10^{-10}	6.1×10^{-10}	6.3×10^{-10}	6.7×10^{-10}	7.1×10^{-10}
BENZYL ALCOHOL	1.5×10^{-9}	3.9×10^{-10}	1.6×10^{-9}	4.0×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.2×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
Beryllium	1.2×10^{-9}	6.6×10^{-10}	1.2×10^{-9}	6.8×10^{-10}	1.2×10^{-9}	7.7×10^{-10}	5.6×10^{-10}	5.1×10^{-10}	5.1×10^{-10}	5.4×10^{-10}	5.4×10^{-10}	6.5×10^{-10}	5.6×10^{-10}	5.6×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	5.1×10^{-10}	5.4×10^{-10}	5.6×10^{-10}	6.1×10^{-10}
BIS(2-CHLOROETHOXY)METHANE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
BIS(2-CHLOROETHYL)ETHER	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
BIS(2-CHLOROISOPROPYL) ETHER	1.5×10^{-9}	3.9×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.2×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
Bis(2-ethylhexyl)phthalate	5.7×10^{-10}	3.2×10^{-10}	5.9×10^{-10}	3.3×10^{-10}	5.7×10^{-10}	3.7×10^{-10}	2.3×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.7×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.3×10^{-10}	2.4×10^{-10}	1.9×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.3×10^{-10}
BIS(CHLOROMETHYL)ETHER	1.6×10^{-12}	7.6×10^{-13}	1.7×10^{-12}	7.8×10^{-13}	1.6×10^{-12}	8.9×10^{-13}	8.1×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	9.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	4.9×10^{-13}	4.9×10^{-13}	4.1×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.9×10^{-13}
BROMODICHLOROMETHANE	6.1×10^{-11}	3.4×10^{-11}	6.3×10^{-11}	3.5×10^{-11}	6.1×10^{-11}	4.0×10^{-11}	3.5×10^{-11}	3.3×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	4.0×10^{-11}	3.7×10^{-11}	3.7×10^{-11}	3.9×10^{-11}	3.8×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.7×10^{-11}	3.9×10^{-11}
BROMOMETHANE	1.2×10^{-10}	8.0×10^{-11}	1.2×10^{-10}	8.3×10^{-11}	1.2×10^{-10}	9.4×10^{-11}	7.5×10^{-11}	7.2×10^{-11}	7.2×10^{-11}	7.6×10^{-11}	7.6×10^{-11}	8.6×10^{-11}	8.0×10^{-11}	8.0×10^{-11}	8.5×10^{-11}	8.5×10^{-11}	7.2×10^{-11}	7.6×10^{-11}	8.0×10^{-11}	8.5×10^{-11}
CADMIUM	7.2×10^{-9}	1.5×10^{-9}	7.5×10^{-9}	1.6×10^{-9}	7.2×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	9.4×10^{-10}	9.4×10^{-10}	1.7×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.4×10^{-9}	9.4×10^{-10}	1.5×10^{-9}	1.1×10^{-9}
CHLORDANE	1.3×10^{-12}	6.1×10^{-13}	1.3×10^{-12}	6.3×10^{-13}	1.3×10^{-12}	7.2×10^{-13}	6.5×10^{-13}	3.3×10^{-13}	3.3×10^{-13}	3.5×10^{-13}	3.5×10^{-13}	7.5×10^{-13}	3.7×10^{-13}	3.7×10^{-13}	3.9×10^{-13}	3.9×10^{-13}	3.3×10^{-13}	3.5×10^{-13}	3.7×10^{-13}	3.9×10^{-13}
CHLOROBENZENE	3.5×10^{-10}	5.8×10^{-11}	3.6×10^{-10}	6.0×10^{-11}	3.5×10^{-10}	6.8×10^{-11}	6.0×10^{-11}	5.9×10^{-11}	5.9×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	7.0×10^{-11}	6.6×10^{-11}	6.6×10^{-11}	3.8×10^{-11}	3.8×10^{-11}	5.9×10^{-11}	3.4×10^{-11}	6.6×10^{-11}	3.8×10^{-11}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	3.0×10^{-11}	1.1×10^{-11}	3.1×10^{-11}	1.1×10^{-11}	3.0×10^{-11}	1.3×10^{-11}	9.1×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	7.4×10^{-12}	7.4×10^{-12}	1.1×10^{-11}	8.9×10^{-12}	8.9×10^{-12}	8.3×10^{-12}	8.3×10^{-12}	8.1×10^{-12}	7.4×10^{-12}	8.9×10^{-12}	8.3×10^{-12}
Chrysene	2.2×10^{-9}	1.4×10^{-9}	2.3×10^{-9}	1.4×10^{-9}	2.2×10^{-9}	1.6×10^{-9}	9.8×10^{-10}	8.8×10^{-10}	8.8×10^{-10}	9.5×10^{-10}	9.5×10^{-10}	1.1×10^{-9}	9.7×10^{-10}	9.7×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	8.8×10^{-10}	9.5×10^{-10}	9.7×10^{-10}	1.1×10^{-9}
DIBENZO(A,H)ANTHRACENE	1.2×10^{-9}	4.7×10^{-10}	1.2×10^{-9}	4.9×10^{-10}	1.2×10^{-9}	5.5×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.9×10^{-10}	2.9×10^{-10}	4.0×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	2.9×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
DIBENZOFURAN	9.8×10^{-10}	2.8×10^{-10}	1.0×10^{-9}	2.9×10^{-10}	9.8×10^{-10}	3.2×10^{-10}	2.6×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	2.9×10^{-10}	2.5×10^{-10}	2.5×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.2×10^{-10}	1.9×10^{-10}	2.5×10^{-10}	2.1×10^{-10}
DIBROMOMETHANE	6.5×10^{-13}	7.0×10^{-13}	6.7×10^{-13}	7.3×10^{-13}	6.5×10^{-13}	8.3×10^{-13}	7.5×10^{-13}	7.6×10^{-13}	7.6×10^{-13}	8.1×10^{-13}	8.1×10^{-13}	8.7×10^{-13}	8.5×10^{-13}	8.5×10^{-13}	9.1×10^{-13}	9.1×10^{-13}	7.6×10^{-13}	8.1×10^{-13}	8.5×10^{-13}	9.1×10^{-13}
DIELDRIN	1.3×10^{-11}	8.2×10^{-12}	1.4×10^{-11}	8.4×10^{-12}	1.3×10^{-11}	9.5×10^{-12}	6.9×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.4×10^{-12}	6.5×10^{-12}	7.9×10^{-12}	6.7×10^{-12}	6.7×10^{-12}	7.2×10^{-12}	7.3×10^{-12}	6.0×10^{-12}	6.4×10^{-12}	6.7×10^{-12}	7.2×10^{-12}
ETHYLBENZENE	8.1×10^{-11}	5.6×10^{-11}	8.3×10^{-11}	5.8×10^{-11}	8.1×10^{-11}	6.6×10^{-11}	4.9×10^{-11}	4.6×10^{-11}	4.6×10^{-11}	4.9×10^{-11}	4.9×10^{-11}	5.6×10^{-11}	5.1×10^{-11}	5.1×10^{-11}	5.6×10^{-11}	5.5×10^{-11}	4.6×10^{-11}	4.9×10^{-11}	5.1×10^{-11}	5.6×10^{-11}
GAMMA-CHLORDANE	7.0×10^{-11}	4.0×10^{-11}	7.2×10^{-11}	4.2×10^{-11}	7.0×10^{-11}	4.7×10^{-11}	3.3×10^{-11}	3.1×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.2×10^{-11}	3.8×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	3.6×10^{-11}	3.6×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.4×10^{-11}	3.6×10^{-11}
HEXACHLOROBENZENE	1.9×10^{-9}	4.3×10^{-10}	2.0×10^{-9}	4.5×10^{-10}	1.9×10^{-9}	5.1×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.7×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	3.9×10^{-10}	3.2×10^{-10}
INDENO(1,2,3-CD)PYRENE	1.7×10^{-9}	1.1×10^{-9}	1.8×10^{-9}	1.1×10^{-9}	1.7×10^{-9}	1.2×10^{-9}	7.4×10^{-10}	6.6×10^{-10}	6.6×10^{-10}	7.1×10^{-10}	7.1×10^{-10}	8.5×10^{-10}	7.4×10^{-10}	7.3×10^{-10}	8.0×10^{-10}	8.0×10^{-10}	6.6×10^{-10}	7.1×10^{-10}	7.3×10^{-10}	8.0×10^{-10}
Manganese	8.7×10^{-7}	4.4×10^{-7}	9.0×10^{-7}	4.6×10^{-7}	8.7×10^{-7}	5.1×10^{-7}	3.9×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	3.4×10^{-7}	3.4×10^{-7}	4.4×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	3.8×10^{-7}	3.9×10^{-7}	3.2×10^{-7}	3.4×10^{-7}	3.6×10^{-7}	3.8×10^{-7}
Mercury	1.2×10^{-10}	7.3×10^{-11}	1.3×10^{-10}	7.5×10^{-11}	1.2×10^{-10}	8.5×10^{-11}	6.1×10^{-11}	5.5×10^{-11}	5.5×10^{-11}	5.8×10^{-11}	5.8×10^{-11}	7.0×10^{-11}	6.1×10^{-11}	6.0×10^{-11}	6.5×10^{-11}	6.6×10^{-11}	5.5×10^{-11}	5.8×10^{-11}	6.0×10^{-11}	6.5×10^{-11}
METHYLENE CHLORIDE	1.7×10^{-10}	1.8×10^{-11}	1.8×10^{-10}	1.8×10^{-11}	1.7×10^{-10}	2.1×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	2.3×10^{-12}	2.4×10^{-12}	2.1×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	2.6×10^{-12}	2.7×10^{-12}	1.8×10^{-11}	2.3×10^{-12}	2.0×10^{-11}	2.6×10^{-12}

TABLE G.I-23
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	1.5×10^{-9}	3.8×10^{-10}	1.5×10^{-9}	3.9×10^{-10}	1.5×10^{-9}	4.5×10^{-10}	3.6×10^{-10}	3.1×10^{-10}	3.0×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	4.1×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.0×10^{-10}	2.7×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
NITROBENZENE	1.9×10^{-9}	4.3×10^{-10}	2.0×10^{-9}	4.5×10^{-10}	1.9×10^{-9}	5.1×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.7×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	3.9×10^{-10}	3.2×10^{-10}
O-DICHLOROBENZENE	9.6×10^{-10}	8.2×10^{-11}	1.0×10^{-9}	8.5×10^{-11}	9.6×10^{-10}	9.8×10^{-11}	8.8×10^{-11}	8.9×10^{-11}	8.9×10^{-11}	2.3×10^{-13}	2.3×10^{-13}	1.0×10^{-10}	9.9×10^{-11}	9.9×10^{-11}	2.7×10^{-13}	2.7×10^{-13}	8.9×10^{-11}	2.3×10^{-13}	9.9×10^{-11}	2.7×10^{-13}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	1.4×10^{-9}	8.0×10^{-10}	1.4×10^{-9}	8.3×10^{-10}	1.4×10^{-9}	9.4×10^{-10}	6.1×10^{-10}	5.5×10^{-10}	5.5×10^{-10}	5.9×10^{-10}	6.0×10^{-10}	7.1×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	6.7×10^{-10}	6.7×10^{-10}	5.5×10^{-10}	5.9×10^{-10}	6.1×10^{-10}	6.7×10^{-10}
SILVER	3.2×10^{-9}	1.9×10^{-9}	3.3×10^{-9}	2.0×10^{-9}	3.2×10^{-9}	2.3×10^{-9}	1.6×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.9×10^{-9}	1.6×10^{-9}	1.6×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.6×10^{-9}	1.7×10^{-9}
TRANS-1,2-DICHLOROETHENE (TOTAL)	6.3×10^{-13}	2.9×10^{-13}	6.5×10^{-13}	3.0×10^{-13}	6.3×10^{-13}	3.5×10^{-13}	3.1×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	1.7×10^{-13}	1.7×10^{-13}	3.6×10^{-13}	1.8×10^{-13}	1.8×10^{-13}	1.9×10^{-13}	1.9×10^{-13}	1.6×10^{-13}	1.7×10^{-13}	1.8×10^{-13}	1.9×10^{-13}
Trichloroethene	5.3×10^{-12}	3.3×10^{-12}	5.5×10^{-12}	3.4×10^{-12}	5.3×10^{-12}	3.8×10^{-12}	2.6×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.9×10^{-12}	2.9×10^{-12}	2.4×10^{-12}	2.6×10^{-12}	2.7×10^{-12}	2.9×10^{-12}
URANIUM, TOTAL	5.6×10^{-7}	3.8×10^{-7}	5.8×10^{-7}	4.0×10^{-7}	5.6×10^{-7}	4.5×10^{-7}	3.9×10^{-7}	3.7×10^{-7}	3.7×10^{-7}	3.9×10^{-7}	3.9×10^{-7}	4.5×10^{-7}	4.1×10^{-7}	4.1×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	3.7×10^{-7}	3.9×10^{-7}	4.1×10^{-7}	4.4×10^{-7}
ZINC	1.8×10^{-7}	6.6×10^{-8}	1.8×10^{-7}	6.8×10^{-8}	1.8×10^{-7}	7.7×10^{-8}	5.5×10^{-8}	5.0×10^{-8}	5.0×10^{-8}	4.6×10^{-8}	4.6×10^{-8}	6.3×10^{-8}	5.6×10^{-8}	5.5×10^{-8}	5.1×10^{-8}	5.1×10^{-8}	5.0×10^{-8}	4.6×10^{-8}	5.5×10^{-8}	5.1×10^{-8}

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TABLE G.I-21

EXPOSURE POINT AIR CONCENTRATIONS IN THE VICINITY OF THE DISPOSAL CELL DURING OPERATION

	Alt 1		Alt 2A*		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)- rw comp 4																				
Cesium-137	0.0	0.0	1.0×10^{-3}	2.9×10^{-4}	0.0	0.0	3.0×10^{-4}	2.3×10^{-4}	2.3×10^{-4}	2.2×10^{-4}	2.2×10^{-4}	0.0	0.0	0.0	0.0	0.0	2.3×10^{-4}	2.2×10^{-4}	0.0	0.0
Neptunium-237	0.0	0.0	1.7×10^{-3}	5.2×10^{-4}	0.0	0.0	5.2×10^{-4}	4.2×10^{-4}	4.2×10^{-4}	4.2×10^{-4}	4.2×10^{-4}	0.0	0.0	0.0	0.0	0.0	4.2×10^{-4}	4.2×10^{-4}	0.0	0.0
Plutonium-238	0.0	0.0	1.2×10^{-3}	4.3×10^{-4}	0.0	0.0	4.2×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	3.6×10^{-4}	3.6×10^{-4}	0.0	0.0	0.0	0.0	0.0	3.4×10^{-4}	3.6×10^{-4}	0.0	0.0
Plutonium-239/240	0.0	0.0	8.4×10^{-4}	4.2×10^{-4}	0.0	0.0	4.0×10^{-4}	3.2×10^{-4}	3.2×10^{-4}	3.8×10^{-4}	3.8×10^{-4}	0.0	0.0	0.0	0.0	0.0	3.2×10^{-4}	3.8×10^{-4}	0.0	0.0
Radium-226	0.0	0.0	5.3×10^{-2}	3.9×10^{-2}	0.0	0.0	2.3×10^{-2}	1.9×10^{-2}	1.9×10^{-2}	2.4×10^{-2}	2.4×10^{-2}	0.0	0.0	0.0	0.0	0.0	1.9×10^{-2}	2.4×10^{-2}	0.0	0.0
Radium-228	0.0	0.0	2.3×10^{-3}	8.3×10^{-4}	0.0	0.0	7.4×10^{-4}	5.9×10^{-4}	5.8×10^{-4}	6.1×10^{-4}	6.2×10^{-4}	0.0	0.0	0.0	0.0	0.0	5.8×10^{-4}	6.1×10^{-4}	0.0	0.0
Strontium-90	0.0	0.0	2.3×10^{-3}	1.1×10^{-3}	0.0	0.0	1.2×10^{-3}	9.9×10^{-4}	9.9×10^{-4}	1.2×10^{-3}	1.2×10^{-3}	0.0	0.0	0.0	0.0	0.0	9.9×10^{-4}	1.2×10^{-3}	0.0	0.0
Technetium-99	0.0	0.0	5.6×10^{-3}	2.7×10^{-3}	0.0	0.0	2.7×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	2.7×10^{-3}	2.7×10^{-3}	0.0	0.0	0.0	0.0	0.0	2.2×10^{-3}	2.7×10^{-3}	0.0	0.0
Thorium-228	0.0	0.0	3.0×10^{-3}	1.1×10^{-3}	0.0	0.0	1.0×10^{-3}	7.8×10^{-4}	7.7×10^{-4}	8.2×10^{-4}	8.2×10^{-4}	0.0	0.0	0.0	0.0	0.0	7.7×10^{-4}	8.2×10^{-4}	0.0	0.0
Thorium-230	0.0	0.0	3.0×10^{-1}	1.7×10^{-1}	0.0	0.0	1.5×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.5×10^{-1}	1.5×10^{-1}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-1}	1.5×10^{-1}	0.0	0.0
Thorium-232	0.0	0.0	1.1×10^{-2}	7.6×10^{-3}	0.0	0.0	7.5×10^{-3}	6.2×10^{-3}	6.2×10^{-3}	7.7×10^{-3}	7.7×10^{-3}	0.0	0.0	0.0	0.0	0.0	6.2×10^{-3}	7.7×10^{-3}	0.0	0.0
Thorium-234	0.0	0.0	1.7×10^{-2}	8.4×10^{-3}	0.0	0.0	9.7×10^{-3}	8.4×10^{-3}	8.4×10^{-3}	1.0×10^{-2}	1.0×10^{-2}	0.0	0.0	0.0	0.0	0.0	8.4×10^{-3}	1.0×10^{-2}	0.0	0.0
Uranium-234	0.0	0.0	1.1×10^{-5}	7.5×10^{-6}	0.0	0.0	8.2×10^{-6}	6.9×10^{-6}	6.8×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	0.0	0.0	0.0	0.0	0.0	6.8×10^{-6}	8.5×10^{-6}	0.0	0.0
Uranium-235/236	0.0	0.0	1.4×10^{-3}	9.8×10^{-4}	0.0	0.0	1.1×10^{-3}	9.0×10^{-4}	9.0×10^{-4}	1.1×10^{-3}	1.1×10^{-3}	0.0	0.0	0.0	0.0	0.0	9.0×10^{-4}	1.1×10^{-3}	0.0	0.0
Uranium-236	0.0	0.0	3.8×10^{-3}	2.3×10^{-3}	0.0	0.0	1.3×10^{-3}	9.9×10^{-4}	9.9×10^{-4}	1.2×10^{-3}	1.2×10^{-3}	0.0	0.0	0.0	0.0	0.0	9.9×10^{-4}	1.2×10^{-3}	0.0	0.0
Uranium-238	0.0	0.0	2.0×10^{-1}	1.4×10^{-1}	0.0	0.0	1.5×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.6×10^{-1}	1.6×10^{-1}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-1}	1.6×10^{-1}	0.0	0.0
Metals/Chemicals (mg/m3)-comp 4																				
1,1-DICHLOROETHANE	0.0	0.0	4.6×10^{-14}	1.2×10^{-14}	0.0	0.0	1.2×10^{-14}	8.9×10^{-15}	8.9×10^{-15}	8.1×10^{-15}	8.1×10^{-15}	0.0	0.0	0.0	0.0	0.0	8.9×10^{-15}	8.1×10^{-15}	0.0	0.0
1,1-DICHLOROETHENE	0.0	0.0	5.1×10^{-14}	1.6×10^{-14}	0.0	0.0	1.6×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-14}	1.2×10^{-14}	0.0	0.0
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.6×10^{-13}	5.8×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-13}	5.8×10^{-13}	0.0	0.0
1,2-DICHLOROBENZENE	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.7×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-13}	5.9×10^{-13}	0.0	0.0
1,2-DICHLOROETHANE	0.0	0.0	1.1×10^{-13}	6.5×10^{-14}	0.0	0.0	7.2×10^{-14}	6.0×10^{-14}	6.0×10^{-14}	7.2×10^{-14}	7.2×10^{-14}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-14}	7.2×10^{-14}	0.0	0.0
1,2-DICHLOROETHENE (TOTAL)	0.0	0.0	5.1×10^{-14}	1.6×10^{-14}	0.0	0.0	1.6×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	1.2×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-14}	1.2×10^{-14}	0.0	0.0
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.7×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-13}	5.9×10^{-13}	0.0	0.0
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.6×10^{-13}	5.8×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-13}	5.8×10^{-13}	0.0	0.0
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	0.0	0.0	9.2×10^{-15}	6.0×10^{-15}	0.0	0.0	3.4×10^{-15}	2.6×10^{-15}	2.6×10^{-15}	3.2×10^{-15}	3.2×10^{-15}	0.0	0.0	0.0	0.0	0.0	2.6×10^{-15}	3.2×10^{-15}	0.0	0.0
2-BENZYL ALCOHOL-4-CHLOROPHENOL	0.0	0.0	5.1×10^{-14}	1.1×10^{-14}	0.0	0.0	1.3×10^{-14}	8.1×10^{-15}	7.9×10^{-15}	9.9×10^{-15}	1.0×10^{-14}	0.0	0.0	0.0	0.0	0.0	7.9×10^{-15}	9.9×10^{-15}	0.0	0.0
3,3'-DICHLOROBENZIDINE	0.0	0.0	2.4×10^{-12}	8.3×10^{-13}	0.0	0.0	8.1×10^{-13}	6.5×10^{-13}	6.4×10^{-13}	6.8×10^{-13}	6.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	6.8×10^{-13}	0.0	0.0
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	0.0	0.0	1.4×10^{-12}	5.4×10^{-13}	0.0	0.0	5.3×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	4.7×10^{-13}	4.7×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.2×10^{-13}	4.7×10^{-13}	0.0	0.0
4-NITROANILINE	0.0	0.0	1.1×10^{-11}	2.7×10^{-12}	0.0	0.0	2.8×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.0×10^{-12}	2.2×10^{-12}	0.0	0.0

TABLE G.I-21
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	0.0	0.0	1.4×10^{-11}	8.4×10^{-12}	0.0	0.0	6.8×10^{-12}	5.2×10^{-12}	5.2×10^{-12}	6.5×10^{-12}	6.5×10^{-12}	0.0	0.0	0.0	0.0	0.0	5.2×10^{-12}	6.5×10^{-12}	0.0	0.0
ALPHA-CHLORDANE	0.0	0.0	1.4×10^{-13}	7.6×10^{-14}	0.0	0.0	7.0×10^{-14}	5.7×10^{-14}	5.6×10^{-14}	6.7×10^{-14}	6.8×10^{-14}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-14}	6.7×10^{-14}	0.0	0.0
Aroclor 1254	0.0	0.0	4.0×10^{-12}	2.8×10^{-12}	0.0	0.0	2.4×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.9×10^{-12}	2.4×10^{-12}	0.0	0.0
Arsenic	0.0	0.0	1.6×10^{-11}	8.5×10^{-12}	0.0	0.0	7.8×10^{-12}	6.1×10^{-12}	6.1×10^{-12}	7.6×10^{-12}	7.6×10^{-12}	0.0	0.0	0.0	0.0	0.0	6.1×10^{-12}	7.6×10^{-12}	0.0	0.0
BENZENE	0.0	0.0	4.1×10^{-13}	1.0×10^{-13}	0.0	0.0	1.1×10^{-13}	9.5×10^{-14}	9.5×10^{-14}	8.5×10^{-14}	8.5×10^{-14}	0.0	0.0	0.0	0.0	0.0	9.5×10^{-14}	8.5×10^{-14}	0.0	0.0
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	0.0	0.0	3.7×10^{-12}	2.2×10^{-12}	0.0	0.0	1.8×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.4×10^{-12}	1.7×10^{-12}	0.0	0.0
Benzo(a)pyrene	0.0	0.0	4.4×10^{-12}	2.7×10^{-12}	0.0	0.0	2.1×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	2.0×10^{-12}	2.1×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.6×10^{-12}	2.0×10^{-12}	0.0	0.0
BENZO(B)FLUORANTHENE	0.0	0.0	4.8×10^{-12}	2.8×10^{-12}	0.0	0.0	2.2×10^{-12}	1.8×10^{-12}	1.8×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.8×10^{-12}	2.2×10^{-12}	0.0	0.0
BENZO(G,H,I)PERYLENE	0.0	0.0	1.2×10^{-12}	5.5×10^{-13}	0.0	0.0	5.2×10^{-13}	4.0×10^{-13}	4.0×10^{-13}	4.9×10^{-13}	4.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.0×10^{-13}	4.9×10^{-13}	0.0	0.0
BENZO(K)FLUORANTHENE	0.0	0.0	3.5×10^{-12}	2.2×10^{-12}	0.0	0.0	1.5×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-12}	1.5×10^{-12}	0.0	0.0
BENZOIC ACID	0.0	0.0	2.8×10^{-12}	1.5×10^{-12}	0.0	0.0	1.4×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.3×10^{-12}	1.3×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-12}	1.3×10^{-12}	0.0	0.0
BENZYL ALCOHOL	0.0	0.0	2.9×10^{-12}	7.3×10^{-13}	0.0	0.0	7.5×10^{-13}	5.6×10^{-13}	5.6×10^{-13}	5.8×10^{-13}	5.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-13}	5.8×10^{-13}	0.0	0.0
Beryllium	0.0	0.0	2.1×10^{-12}	1.2×10^{-12}	0.0	0.0	1.1×10^{-12}	9.0×10^{-13}	9.0×10^{-13}	1.1×10^{-12}	1.1×10^{-12}	0.0	0.0	0.0	0.0	0.0	9.0×10^{-13}	1.1×10^{-12}	0.0	0.0
BIS(2-CHLOROETHOXY)METHANE	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.7×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-13}	5.9×10^{-13}	0.0	0.0
BIS(2-CHLOROETHYL)ETHER	0.0	0.0	3.0×10^{-12}	7.4×10^{-13}	0.0	0.0	7.6×10^{-13}	5.7×10^{-13}	5.7×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-13}	5.9×10^{-13}	0.0	0.0
BIS(2-CHLOROISOPROPYL) ETHER	0.0	0.0	2.9×10^{-12}	7.3×10^{-13}	0.0	0.0	7.5×10^{-13}	5.6×10^{-13}	5.6×10^{-13}	5.8×10^{-13}	5.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-13}	5.8×10^{-13}	0.0	0.0
Bis(2-ethylhexyl)phthalate	0.0	0.0	9.6×10^{-13}	5.6×10^{-13}	0.0	0.0	4.4×10^{-13}	3.4×10^{-13}	3.4×10^{-13}	4.2×10^{-13}	4.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	3.4×10^{-13}	4.2×10^{-13}	0.0	0.0
BIS(CHLOROMETHYL)ETHER	0.0	0.0	3.1×10^{-15}	1.5×10^{-15}	0.0	0.0	1.7×10^{-15}	7.5×10^{-16}	7.5×10^{-16}	9.3×10^{-16}	9.3×10^{-16}	0.0	0.0	0.0	0.0	0.0	7.5×10^{-16}	9.3×10^{-16}	0.0	0.0
BROMODICHLOROMETHANE	0.0	0.0	1.1×10^{-13}	6.5×10^{-14}	0.0	0.0	7.2×10^{-14}	6.0×10^{-14}	6.0×10^{-14}	7.2×10^{-14}	7.2×10^{-14}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-14}	7.2×10^{-14}	0.0	0.0
BROMOMETHANE	0.0	0.0	2.2×10^{-13}	1.5×10^{-13}	0.0	0.0	1.5×10^{-13}	1.3×10^{-13}	1.3×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	0.0	0.0	0.0	0.0	0.0	1.3×10^{-13}	1.6×10^{-13}	0.0	0.0
CADMIUM	0.0	0.0	1.5×10^{-11}	3.0×10^{-12}	0.0	0.0	3.1×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.6×10^{-12}	2.0×10^{-12}	0.0	0.0
CHLORDANE	0.0	0.0	2.5×10^{-15}	1.2×10^{-15}	0.0	0.0	1.4×10^{-15}	6.0×10^{-16}	6.0×10^{-16}	7.5×10^{-16}	7.5×10^{-16}	0.0	0.0	0.0	0.0	0.0	6.0×10^{-16}	7.5×10^{-16}	0.0	0.0
CHLOROBENZENE	0.0	0.0	7.1×10^{-13}	1.2×10^{-13}	0.0	0.0	1.3×10^{-13}	1.1×10^{-13}	1.1×10^{-13}	7.1×10^{-14}	7.1×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-13}	7.1×10^{-14}	0.0	0.0
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	0.0	0.0	5.8×10^{-14}	2.0×10^{-14}	0.0	0.0	1.9×10^{-14}	1.5×10^{-14}	1.5×10^{-14}	1.5×10^{-14}	1.5×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.5×10^{-14}	1.5×10^{-14}	0.0	0.0
Chrysene	0.0	0.0	4.1×10^{-12}	2.5×10^{-12}	0.0	0.0	2.0×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.6×10^{-12}	1.9×10^{-12}	0.0	0.0
DIBENZO(A,H)ANTHRACENE	0.0	0.0	2.4×10^{-12}	8.8×10^{-13}	0.0	0.0	7.1×10^{-13}	5.7×10^{-13}	5.7×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-13}	5.9×10^{-13}	0.0	0.0
DIBENZOFURAN	0.0	0.0	1.9×10^{-12}	5.1×10^{-13}	0.0	0.0	5.2×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	3.9×10^{-13}	3.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	4.1×10^{-13}	3.9×10^{-13}	0.0	0.0
DIBROMOMETHANE	0.0	0.0	1.3×10^{-15}	1.4×10^{-15}	0.0	0.0	1.6×10^{-15}	1.4×10^{-15}	1.4×10^{-15}	1.8×10^{-15}	1.8×10^{-15}	0.0	0.0	0.0	0.0	0.0	1.4×10^{-15}	1.8×10^{-15}	0.0	0.0
DIELDRIN	0.0	0.0	2.3×10^{-14}	1.5×10^{-14}	0.0	0.0	1.4×10^{-14}	1.1×10^{-14}	1.1×10^{-14}	1.3×10^{-14}	1.4×10^{-14}	0.0	0.0	0.0	0.0	0.0	1.1×10^{-14}	1.3×10^{-14}	0.0	0.0
ETHYLBENZENE	0.0	0.0	1.5×10^{-13}	1.0×10^{-13}	0.0	0.0	9.8×10^{-14}	8.1×10^{-14}	8.1×10^{-14}	1.0×10^{-13}	1.0×10^{-13}	0.0	0.0	0.0	0.0	0.0	8.1×10^{-14}	1.0×10^{-13}	0.0	0.0
GAMMA-CHLORDANE	0.0	0.0	1.4×10^{-13}	7.6×10^{-14}	0.0	0.0	7.0×10^{-14}	5.7×10^{-14}	5.6×10^{-14}	6.7×10^{-14}	6.8×10^{-14}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-14}	6.7×10^{-14}	0.0	0.0
HEXACHLOROBENZENE	0.0	0.0	3.8×10^{-12}	8.2×10^{-13}	0.0	0.0	8.4×10^{-13}	6.4×10^{-13}	6.4×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	5.9×10^{-13}	0.0	0.0
INDENO(1,2,3-CD)PYRENE	0.0	0.0	3.2×10^{-12}	1.9×10^{-12}	0.0	0.0	1.5×10^{-12}	1.2×10^{-12}	1.2×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	0.0	0.0	0.0	0.0	0.0	1.2×10^{-12}	1.5×10^{-12}	0.0	0.0
Manganese	0.0	0.0	1.5×10^{-9}	7.8×10^{-10}	0.0	0.0	7.5×10^{-10}	5.7×10^{-10}	5.7×10^{-10}	7.1×10^{-10}	7.1×10^{-10}	0.0	0.0	0.0	0.0	0.0	5.7×10^{-10}	7.1×10^{-10}	0.0	0.0
Mercury	0.0	0.0	2.2×10^{-13}	1.3×10^{-13}	0.0	0.0	1.2×10^{-13}	9.7×10^{-14}	9.6×10^{-14}	1.2×10^{-13}	1.2×10^{-13}	0.0	0.0	0.0	0.0	0.0	9.6×10^{-14}	1.2×10^{-13}	0.0	0.0
METHYLENE CHIORIDE	0.0	0.0	3.7×10^{-13}	3.7×10^{-14}	0.0	0.0	4.1×10^{-14}	3.5×10^{-14}	3.5×10^{-14}	4.9×10^{-15}	5.2×10^{-15}	0.0	0.0	0.0	0.0	0.0	3.5×10^{-14}	4.9×10^{-15}	0.0	0.0

TABLE G.I-21
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	0.0	0.0	2.9×10^{-12}	7.2×10^{-13}	0.0	0.0	7.4×10^{-13}	5.6×10^{-13}	5.6×10^{-13}	5.7×10^{-13}	5.8×10^{-13}	0.0	0.0	0.0	0.0	0.0	5.6×10^{-13}	5.7×10^{-13}	0.0	0.0
NITROBENZENE	0.0	0.0	3.8×10^{-12}	8.2×10^{-13}	0.0	0.0	8.4×10^{-13}	6.4×10^{-13}	6.4×10^{-13}	5.9×10^{-13}	5.9×10^{-13}	0.0	0.0	0.0	0.0	0.0	6.4×10^{-13}	5.9×10^{-13}	0.0	0.0
O-DICHLOROBENZENE	0.0	0.0	2.0×10^{-12}	1.8×10^{-13}	0.0	0.0	2.0×10^{-13}	1.8×10^{-13}	1.8×10^{-13}	5.5×10^{-16}	5.5×10^{-16}	0.0	0.0	0.0	0.0	0.0	1.8×10^{-13}	5.5×10^{-16}	0.0	0.0
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	0.0	0.0	2.6×10^{-12}	1.5×10^{-12}	0.0	0.0	1.3×10^{-12}	9.9×10^{-13}	9.9×10^{-13}	1.2×10^{-12}	1.2×10^{-12}	0.0	0.0	0.0	0.0	0.0	9.9×10^{-13}	1.2×10^{-12}	0.0	0.0
SILVER	0.0	0.0	5.6×10^{-12}	3.5×10^{-12}	0.0	0.0	3.2×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	0.0	0.0	0.0	0.0	0.0	2.5×10^{-12}	3.1×10^{-12}	0.0	0.0
TRANS-1,2-DICHLOROETHENE (TOTAL)	0.0	0.0	1.2×10^{-15}	5.7×10^{-16}	0.0	0.0	6.6×10^{-16}	2.9×10^{-16}	2.9×10^{-16}	3.6×10^{-16}	3.6×10^{-16}	0.0	0.0	0.0	0.0	0.0	2.9×10^{-16}	3.6×10^{-16}	0.0	0.0
Trichloroethene	0.0	0.0	9.7×10^{-15}	5.9×10^{-15}	0.0	0.0	5.2×10^{-15}	4.2×10^{-15}	4.2×10^{-15}	5.3×10^{-15}	5.3×10^{-15}	0.0	0.0	0.0	0.0	0.0	4.2×10^{-15}	5.3×10^{-15}	0.0	0.0
URANIUM, TOTAL	0.0	0.0	1.1×10^{-9}	7.3×10^{-10}	0.0	0.0	8.0×10^{-10}	6.6×10^{-10}	6.6×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	0.0	0.0	0.0	0.0	0.0	6.6×10^{-10}	8.3×10^{-10}	0.0	0.0
ZINC	0.0	0.0	3.4×10^{-10}	1.2×10^{-10}	0.0	0.0	1.1×10^{-10}	9.0×10^{-11}	8.9×10^{-11}	9.3×10^{-11}	9.3×10^{-11}	0.0	0.0	0.0	0.0	0.0	8.9×10^{-11}	9.3×10^{-11}	0.0	0.0

TABLE G.I-22

EXPOSURE POINT AIR CONCENTRATIONS FOR ON-SITE NONREMEDIATION WORKERS DURING OPERATIONS

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-nrw																				
Cesium-137	1.4×10^{-6}	3.8×10^{-7}	1.4×10^{-6}	3.8×10^{-7}	1.4×10^{-6}	3.8×10^{-7}	3.5×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	3.5×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	3.2×10^{-7}	2.6×10^{-7}
Neptunium-237	2.3×10^{-6}	6.8×10^{-7}	2.3×10^{-6}	6.8×10^{-7}	2.3×10^{-6}	6.8×10^{-7}	6.2×10^{-7}	5.7×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	4.9×10^{-7}	6.2×10^{-7}	5.7×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	4.9×10^{-7}	5.7×10^{-7}	4.9×10^{-7}	5.7×10^{-7}	4.9×10^{-7}
Plutonium-238	1.6×10^{-6}	5.7×10^{-7}	1.6×10^{-6}	5.7×10^{-7}	1.6×10^{-6}	5.7×10^{-7}	5.0×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.2×10^{-7}	5.0×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.2×10^{-7}	4.6×10^{-7}	4.2×10^{-7}	4.6×10^{-7}	4.2×10^{-7}
Plutonium-239/240	1.2×10^{-6}	5.5×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	4.8×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.8×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	4.4×10^{-7}
Radium-226	6.9×10^{-5}	4.9×10^{-5}	6.9×10^{-5}	4.9×10^{-5}	6.9×10^{-5}	4.9×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.5×10^{-5}	2.6×10^{-5}
Radium-228	3.1×10^{-6}	1.1×10^{-6}	3.1×10^{-6}	1.1×10^{-6}	3.1×10^{-6}	1.1×10^{-6}	8.9×10^{-7}	8.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	7.1×10^{-7}	8.9×10^{-7}	8.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	7.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}	8.0×10^{-7}	7.1×10^{-7}
Strontium-90	3.2×10^{-6}	1.5×10^{-6}	3.2×10^{-6}	1.5×10^{-6}	3.2×10^{-6}	1.5×10^{-6}	1.4×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.4×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}
Technetium-99	8.1×10^{-6}	3.6×10^{-6}	8.1×10^{-6}	3.6×10^{-6}	8.1×10^{-6}	3.6×10^{-6}	3.3×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.2×10^{-6}	3.3×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.2×10^{-6}	3.0×10^{-6}	3.1×10^{-6}	3.0×10^{-6}	3.1×10^{-6}
Thorium-228	4.1×10^{-6}	1.4×10^{-6}	4.1×10^{-6}	1.4×10^{-6}	4.1×10^{-6}	1.4×10^{-6}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.4×10^{-7}	9.5×10^{-7}	1.2×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	9.4×10^{-7}	9.5×10^{-7}	1.1×10^{-6}	9.4×10^{-7}	1.1×10^{-6}	9.4×10^{-7}
Thorium-230	4.2×10^{-4}	2.2×10^{-4}	4.2×10^{-4}	2.2×10^{-4}	4.2×10^{-4}	2.2×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}
Thorium-232	1.5×10^{-5}	9.6×10^{-6}	1.5×10^{-5}	9.7×10^{-6}	1.5×10^{-5}	9.7×10^{-6}	8.6×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	8.6×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.5×10^{-6}	8.3×10^{-6}	8.5×10^{-6}	8.3×10^{-6}	8.5×10^{-6}
Thorium-234	2.8×10^{-5}	1.3×10^{-5}	2.8×10^{-5}	1.3×10^{-5}	2.8×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.4×10^{-5}	1.3×10^{-5}	1.4×10^{-5}
Uranium-234	1.5×10^{-8}	9.6×10^{-9}	1.5×10^{-8}	9.7×10^{-9}	1.5×10^{-8}	9.7×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.5×10^{-9}	9.1×10^{-9}	9.5×10^{-9}
Uranium-235/236	2.0×10^{-6}	1.3×10^{-6}	2.0×10^{-6}	1.3×10^{-6}	2.0×10^{-6}	1.3×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
Uranium-236	5.1×10^{-6}	2.8×10^{-6}	5.1×10^{-6}	2.8×10^{-6}	5.1×10^{-6}	2.8×10^{-6}	1.5×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.5×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-6}
Uranium-238	2.7×10^{-4}	1.8×10^{-4}	2.7×10^{-4}	1.8×10^{-4}	2.7×10^{-4}	1.8×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}
Metals/Chemicals (mg/m3)-nrw																				
1,1-DICHLOROETHANE	3.5×10^{-11}	9.0×10^{-12}	3.5×10^{-11}	9.0×10^{-12}	3.5×10^{-11}	9.0×10^{-12}	7.8×10^{-12}	6.9×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	7.8×10^{-12}	6.9×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	6.9×10^{-12}	5.4×10^{-12}	6.9×10^{-12}	5.4×10^{-12}
1,1-DICHLOROETHENE	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,2-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,2-DICHLOROETHANE	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}
1,2-DICHLOROETHENE (TOTAL)	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	3.9×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	1.0×10^{-11}	9.5×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}	9.5×10^{-12}	8.1×10^{-12}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	7.1×10^{-12}	4.1×10^{-12}	7.1×10^{-12}	4.2×10^{-12}	7.1×10^{-12}	4.2×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	2.0×10^{-12}	1.9×10^{-12}	2.0×10^{-12}	1.9×10^{-12}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	3.7×10^{-11}	8.4×10^{-12}	3.7×10^{-11}	8.4×10^{-12}	3.7×10^{-11}	8.4×10^{-12}	8.7×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.4×10^{-12}	8.7×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.4×10^{-12}	6.0×10^{-12}	6.3×10^{-12}	6.0×10^{-12}	6.3×10^{-12}
3,3'-DICHLOROBENZIDINE	1.8×10^{-9}	6.1×10^{-10}	1.8×10^{-9}	6.1×10^{-10}	1.8×10^{-9}	6.1×10^{-10}	5.4×10^{-10}	5.0×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.5×10^{-10}	5.4×10^{-10}	5.0×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.5×10^{-10}	4.9×10^{-10}	4.4×10^{-10}	4.9×10^{-10}	4.4×10^{-10}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	1.1×10^{-9}	4.0×10^{-10}	1.1×10^{-9}	4.0×10^{-10}	1.1×10^{-9}	4.0×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.6×10^{-10}	3.3×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	3.3×10^{-10}	3.1×10^{-10}
4-NITROANILINE	7.8×10^{-9}	2.0×10^{-9}	7.8×10^{-9}	2.0×10^{-9}	7.8×10^{-9}	2.0×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.4×10^{-9}

F:\R\CRU5\APXS\APP-G\ATTACH\TABGI-22\3/22/95, 2:36pm

TABLE G.I-22
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	1.1×10^{-8}	6.0×10^{-9}	1.1×10^{-8}	6.0×10^{-9}	1.1×10^{-8}	6.0×10^{-9}	4.4×10^{-9}	3.9×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	4.0×10^{-9}	4.4×10^{-9}	3.9×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	4.0×10^{-9}	3.9×10^{-9}	4.0×10^{-9}	3.9×10^{-9}	4.0×10^{-9}
ALPHA-CHLORDANE	1.0×10^{-10}	5.4×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}
Aroclor 1254	3.1×10^{-9}	2.0×10^{-9}	3.1×10^{-9}	2.0×10^{-9}	3.1×10^{-9}	2.0×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.5×10^{-9}
Arsenic	1.3×10^{-8}	6.4×10^{-9}	1.3×10^{-8}	6.4×10^{-9}	1.3×10^{-8}	6.4×10^{-9}	5.4×10^{-9}	4.8×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	5.0×10^{-9}	5.4×10^{-9}	4.8×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	5.0×10^{-9}	4.8×10^{-9}	5.0×10^{-9}	4.8×10^{-9}	5.0×10^{-9}
BENZENE	3.0×10^{-10}	7.3×10^{-11}	3.0×10^{-10}	7.3×10^{-11}	3.0×10^{-10}	7.3×10^{-11}	7.2×10^{-11}	7.0×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	5.4×10^{-11}	7.2×10^{-11}	7.0×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	5.4×10^{-11}	7.0×10^{-11}	5.4×10^{-11}	7.0×10^{-11}	5.4×10^{-11}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	2.9×10^{-9}	1.6×10^{-9}	2.9×10^{-9}	1.6×10^{-9}	2.9×10^{-9}	1.6×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.0×10^{-9}	1.1×10^{-9}
Benzo(a)pyrene	3.5×10^{-9}	1.9×10^{-9}	3.5×10^{-9}	1.9×10^{-9}	3.5×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.3×10^{-9}
BENZO(B)FLUORANTHENE	3.9×10^{-9}	2.0×10^{-9}	3.9×10^{-9}	2.0×10^{-9}	3.9×10^{-9}	2.0×10^{-9}	1.5×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.3×10^{-9}	1.4×10^{-9}	1.3×10^{-9}	1.4×10^{-9}
BENZO(G,H,I)PERYLENE	9.4×10^{-10}	4.1×10^{-10}	9.4×10^{-10}	4.1×10^{-10}	9.4×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.2×10^{-10}
BENZO(K)FLUORANTHENE	2.7×10^{-9}	1.6×10^{-9}	2.7×10^{-9}	1.6×10^{-9}	2.7×10^{-9}	1.6×10^{-9}	1.0×10^{-9}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.1×10^{-10}	1.0×10^{-9}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.0×10^{-10}	9.1×10^{-10}
BENZOIC ACID	2.2×10^{-9}	1.1×10^{-9}	2.2×10^{-9}	1.1×10^{-9}	2.2×10^{-9}	1.1×10^{-9}	9.0×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	9.0×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}	8.3×10^{-10}
BENZYL ALCOHOL	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}
Beryllium	1.7×10^{-9}	8.9×10^{-10}	1.7×10^{-9}	8.9×10^{-10}	1.7×10^{-9}	8.9×10^{-10}	7.6×10^{-10}	7.0×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.3×10^{-10}	7.6×10^{-10}	7.0×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.3×10^{-10}	7.0×10^{-10}	7.3×10^{-10}	7.0×10^{-10}	7.3×10^{-10}
BIS(2-CHLOROETHOXY)METHANE	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
BIS(2-CHLOROETHYL)ETHER	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	2.2×10^{-9}	5.4×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.0×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.8×10^{-10}
BIS(2-CHLOROISOPROPYL) ETHER	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.8×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.8×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}
Bis(2-ethylhexyl)phthalate	7.6×10^{-10}	4.1×10^{-10}	7.6×10^{-10}	4.1×10^{-10}	7.6×10^{-10}	4.1×10^{-10}	3.0×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	3.0×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	2.6×10^{-10}	2.7×10^{-10}	2.6×10^{-10}	2.7×10^{-10}
BIS(CHLOROMETHYL)ETHER	2.1×10^{-12}	1.0×10^{-12}	2.1×10^{-12}	1.0×10^{-12}	2.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	5.3×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.5×10^{-13}	1.0×10^{-12}	5.3×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.5×10^{-13}	5.3×10^{-13}	5.5×10^{-13}	5.3×10^{-13}	5.5×10^{-13}
BROMODICHLOROMETHANE	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	8.5×10^{-11}	4.7×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.7×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	4.5×10^{-11}
BROMOMETHANE	1.6×10^{-10}	1.1×10^{-10}	1.6×10^{-10}	1.1×10^{-10}	1.6×10^{-10}	1.1×10^{-10}	9.8×10^{-11}	9.5×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.8×10^{-11}	9.5×10^{-11}	9.8×10^{-11}
CADMIUM	1.1×10^{-8}	2.1×10^{-9}	1.1×10^{-8}	2.1×10^{-9}	1.1×10^{-8}	2.1×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.3×10^{-9}
CHLORDANE	1.7×10^{-12}	8.2×10^{-13}	1.7×10^{-12}	8.2×10^{-13}	1.7×10^{-12}	8.2×10^{-13}	8.4×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	8.4×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.3×10^{-13}	4.5×10^{-13}
CHLOROBENZENE	5.0×10^{-10}	8.2×10^{-11}	5.1×10^{-10}	8.2×10^{-11}	5.0×10^{-10}	8.2×10^{-11}	8.3×10^{-11}	8.2×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	8.3×10^{-11}	8.2×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	4.5×10^{-11}	8.2×10^{-11}	4.5×10^{-11}	8.2×10^{-11}	4.5×10^{-11}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	4.4×10^{-11}	1.4×10^{-11}	4.4×10^{-11}	1.4×10^{-11}	4.4×10^{-11}	1.4×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.9×10^{-12}	9.9×10^{-12}	1.2×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.8×10^{-12}	9.9×10^{-12}	1.1×10^{-11}	9.9×10^{-12}	1.1×10^{-11}	9.8×10^{-12}
Chrysene	3.2×10^{-9}	1.8×10^{-9}	3.2×10^{-9}	1.8×10^{-9}	3.2×10^{-9}	1.8×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.2×10^{-9}
DIBENZO(A,H)ANTHRACENE	1.8×10^{-9}	6.2×10^{-10}	1.8×10^{-9}	6.2×10^{-10}	1.8×10^{-9}	6.2×10^{-10}	4.6×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.6×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	4.3×10^{-10}	3.7×10^{-10}
DIBENZOFURAN	1.4×10^{-9}	3.8×10^{-10}	1.4×10^{-9}	3.8×10^{-10}	1.4×10^{-9}	3.8×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	3.1×10^{-10}	2.6×10^{-10}	3.1×10^{-10}	2.6×10^{-10}
DIBROMOMETHANE	9.2×10^{-13}	9.9×10^{-13}	9.2×10^{-13}	1.0×10^{-12}	9.2×10^{-13}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.1×10^{-12}	1.0×10^{-12}	1.1×10^{-12}
DIELDRIN	1.8×10^{-11}	1.1×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	9.0×10^{-12}	8.2×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.5×10^{-12}	9.0×10^{-12}	8.2×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.5×10^{-12}	8.2×10^{-12}	8.5×10^{-12}	8.2×10^{-12}	8.5×10^{-12}
ETHYLBENZENE	1.1×10^{-10}	7.3×10^{-11}	1.1×10^{-10}	7.4×10^{-11}	1.1×10^{-10}	7.4×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.3×10^{-11}	6.1×10^{-11}	6.3×10^{-11}
GAMMA-CHLORDANE	1.0×10^{-10}	5.4×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	1.0×10^{-10}	5.5×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.5×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}
HEXACHLOROBENZENE	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}
INDENO(1,2,3-CD)PYRENE	2.5×10^{-9}	1.4×10^{-9}	2.5×10^{-9}	1.4×10^{-9}	2.5×10^{-9}	1.4×10^{-9}	9.8×10^{-10}	8.9×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	9.1×10^{-10}	9.8×10^{-10}	8.9×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	9.0×10^{-10}	8.9×10^{-10}	9.0×10^{-10}	8.9×10^{-10}	9.0×10^{-10}
Manganese	1.3×10^{-6}	6.0×10^{-7}	1.3×10^{-6}	6.0×10^{-7}	1.3×10^{-6}	6.0×10^{-7}	5.2×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	5.2×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	4.6×10^{-7}	4.8×10^{-7}	4.6×10^{-7}	4.8×10^{-7}
Mercury	1.8×10^{-10}	9.7×10^{-11}	1.8×10^{-10}	9.7×10^{-11}	1.8×10^{-10}	9.7×10^{-11}	8.1×10^{-11}	7.5×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.8×10^{-11}	8.1×10^{-11}	7.5×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.8×10^{-11}	7.5×10^{-11}	7.8×10^{-11}	7.5×10^{-11}	7.8×10^{-11}
METHYLENE CHlORIDE	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-10}	2.6×10^{-11}	2.6×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	3.2×10^{-12}	3.3×10^{-12}	2.6×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	3.2×10^{-12}	3.3×10^{-12}	2.5×10^{-11}	3.2×10^{-12}	2.5×10^{-11}	3.2×10^{-12}

TABLE G.I-22
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	2.2×10^{-9}	5.3×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.9×10^{-10}	4.3×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}	4.2×10^{-10}	3.7×10^{-10}
NITROBENZENE	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	2.8×10^{-9}	5.9×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	5.5×10^{-10}	4.9×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}	4.8×10^{-10}	3.8×10^{-10}
O-DICHLOROBENZENE	1.4×10^{-9}	1.2×10^{-10}	1.4×10^{-9}	1.2×10^{-10}	1.4×10^{-9}	1.2×10^{-10}	1.2×10^{-10}	1.3×10^{-10}	1.3×10^{-10}	3.3×10^{-13}	3.3×10^{-13}	1.2×10^{-10}	1.3×10^{-10}	1.3×10^{-10}	3.3×10^{-13}	3.3×10^{-13}	1.3×10^{-10}	3.3×10^{-13}	1.3×10^{-10}	3.3×10^{-13}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	2.1×10^{-9}	1.1×10^{-9}	2.1×10^{-9}	1.1×10^{-9}	2.1×10^{-9}	1.1×10^{-9}	8.2×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.7×10^{-10}	8.2×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.7×10^{-10}	7.5×10^{-10}	7.7×10^{-10}	7.5×10^{-10}	7.7×10^{-10}
SILVER	4.3×10^{-9}	2.5×10^{-9}	4.3×10^{-9}	2.5×10^{-9}	4.3×10^{-9}	2.5×10^{-9}	2.1×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	2.0×10^{-9}	2.1×10^{-9}	1.9×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	2.0×10^{-9}	1.9×10^{-9}	2.0×10^{-9}
TRANS-1,2-DICHLOROETHENE (TOTAL)	8.3×10^{-13}	3.9×10^{-13}	8.3×10^{-13}	4.0×10^{-13}	8.3×10^{-13}	4.0×10^{-13}	4.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.2×10^{-13}	4.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.2×10^{-13}	2.1×10^{-13}	2.2×10^{-13}	2.1×10^{-13}	2.2×10^{-13}
Trichloroethene	7.8×10^{-12}	4.3×10^{-12}	7.8×10^{-12}	4.3×10^{-12}	7.8×10^{-12}	4.3×10^{-12}	3.5×10^{-12}	3.2×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.4×10^{-12}	3.5×10^{-12}	3.2×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.4×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.2×10^{-12}	3.4×10^{-12}
URANIUM, TOTAL	8.2×10^{-7}	5.3×10^{-7}	8.2×10^{-7}	5.3×10^{-7}	8.2×10^{-7}	5.3×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.2×10^{-7}	5.0×10^{-7}	5.2×10^{-7}
ZINC	2.6×10^{-7}	8.7×10^{-8}	2.6×10^{-7}	8.8×10^{-8}	2.6×10^{-7}	8.8×10^{-8}	7.3×10^{-8}	6.9×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.0×10^{-8}	7.3×10^{-8}	6.9×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.0×10^{-8}	6.8×10^{-8}	6.0×10^{-8}	6.8×10^{-8}	6.0×10^{-8}

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TABLE G.I-23

EXPOSURE POINT AIR CONCENTRATIONS IN THE VICINITY OF THE HYPOTHETICAL NEAR-PROPERTY PUBLIC RECEPTOR

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
Radionuclides (pCi/m3)-npp																				
Cesium-137	9.4 x 10^{-7}	2.8 x 10^{-7}	9.7 x 10^{-7}	2.9 x 10^{-7}	9.4 x 10^{-7}	3.2 x 10^{-7}	2.6 x 10^{-7}	2.3 x 10^{-7}	2.3 x 10^{-7}	1.9 x 10^{-7}	1.9 x 10^{-7}	3.0 x 10^{-7}	2.5 x 10^{-7}	2.5 x 10^{-7}	2.2 x 10^{-7}	2.2 x 10^{-7}	2.3 x 10^{-7}	1.9 x 10^{-7}	2.5 x 10^{-7}	2.2 x 10^{-7}
Neptunium-237	1.5 x 10^{-6}	4.9 x 10^{-7}	1.6 x 10^{-6}	5.1 x 10^{-7}	1.5 x 10^{-6}	5.8 x 10^{-7}	4.6 x 10^{-7}	4.1 x 10^{-7}	4.1 x 10^{-7}	3.6 x 10^{-7}	3.6 x 10^{-7}	5.2 x 10^{-7}	4.5 x 10^{-7}	4.5 x 10^{-7}	4.0 x 10^{-7}	4.1 x 10^{-7}	4.1 x 10^{-7}	3.6 x 10^{-7}	4.5 x 10^{-7}	4.0 x 10^{-7}
Plutonium-238	1.1 x 10^{-6}	4.2 x 10^{-7}	1.1 x 10^{-6}	4.3 x 10^{-7}	1.1 x 10^{-6}	4.9 x 10^{-7}	3.7 x 10^{-7}	3.3 x 10^{-7}	3.3 x 10^{-7}	3.1 x 10^{-7}	3.1 x 10^{-7}	4.2 x 10^{-7}	3.7 x 10^{-7}	3.7 x 10^{-7}	3.5 x 10^{-7}	3.5 x 10^{-7}	3.3 x 10^{-7}	3.1 x 10^{-7}	3.7 x 10^{-7}	3.5 x 10^{-7}
Plutonium-239/240	8.0 x 10^{-7}	4.1 x 10^{-7}	8.3 x 10^{-7}	4.2 x 10^{-7}	8.0 x 10^{-7}	4.7 x 10^{-7}	3.5 x 10^{-7}	3.2 x 10^{-7}	3.2 x 10^{-7}	3.3 x 10^{-7}	3.3 x 10^{-7}	4.1 x 10^{-7}	3.5 x 10^{-7}	3.5 x 10^{-7}	3.7 x 10^{-7}	3.7 x 10^{-7}	3.2 x 10^{-7}	3.3 x 10^{-7}	3.5 x 10^{-7}	3.7 x 10^{-7}
Radium-226	5.1 x 10^{-5}	4.2 x 10^{-5}	5.3 x 10^{-5}	4.3 x 10^{-5}	5.1 x 10^{-5}	4.8 x 10^{-5}	2.2 x 10^{-5}	2.2 x 10^{-5}	2.2 x 10^{-5}	2.3 x 10^{-5}	2.3 x 10^{-5}	2.5 x 10^{-5}	2.4 x 10^{-5}	2.4 x 10^{-5}	2.6 x 10^{-5}	2.6 x 10^{-5}	2.2 x 10^{-5}	2.3 x 10^{-5}	2.4 x 10^{-5}	2.6 x 10^{-5}
Radium-228	2.2 x 10^{-6}	8.1 x 10^{-7}	2.2 x 10^{-6}	8.4 x 10^{-7}	2.2 x 10^{-6}	9.5 x 10^{-7}	6.6 x 10^{-7}	5.8 x 10^{-7}	5.8 x 10^{-7}	5.3 x 10^{-7}	5.3 x 10^{-7}	7.6 x 10^{-7}	6.4 x 10^{-7}	6.4 x 10^{-7}	6.0 x 10^{-7}	6.0 x 10^{-7}	5.8 x 10^{-7}	5.3 x 10^{-7}	6.4 x 10^{-7}	6.0 x 10^{-7}
Strontium-90	2.2 x 10^{-6}	1.1 x 10^{-6}	2.3 x 10^{-6}	1.1 x 10^{-6}	2.2 x 10^{-6}	1.3 x 10^{-6}	1.0 x 10^{-6}	9.8 x 10^{-7}	9.8 x 10^{-7}	9.8 x 10^{-7}	9.8 x 10^{-7}	1.2 x 10^{-6}	1.1 x 10^{-6}	1.1 x 10^{-6}	1.1 x 10^{-6}	1.1 x 10^{-6}	9.8 x 10^{-7}	9.8 x 10^{-7}	1.1 x 10^{-6}	1.1 x 10^{-6}
Technetium-99	5.1 x 10^{-6}	2.5 x 10^{-6}	5.3 x 10^{-6}	2.6 x 10^{-6}	5.1 x 10^{-6}	3.0 x 10^{-6}	2.3 x 10^{-6}	2.1 x 10^{-6}	2.1 x 10^{-6}	2.2 x 10^{-6}	2.2 x 10^{-6}	2.7 x 10^{-6}	2.3 x 10^{-6}	2.3 x 10^{-6}	2.5 x 10^{-6}	2.5 x 10^{-6}	2.1 x 10^{-6}	2.2 x 10^{-6}	2.3 x 10^{-6}	2.5 x 10^{-6}
Thorium-228	2.9 x 10^{-6}	1.1 x 10^{-6}	3.0 x 10^{-6}	1.1 x 10^{-6}	2.9 x 10^{-6}	1.2 x 10^{-6}	8.9 x 10^{-7}	7.6 x 10^{-7}	7.6 x 10^{-7}	7.0 x 10^{-7}	7.1 x 10^{-7}	1.0 x 10^{-6}	8.5 x 10^{-7}	8.4 x 10^{-7}	7.9 x 10^{-7}	7.9 x 10^{-7}	7.6 x 10^{-7}	7.0 x 10^{-7}	8.4 x 10^{-7}	7.9 x 10^{-7}
Thorium-230	2.7 x 10^{-4}	1.7 x 10^{-4}	2.8 x 10^{-4}	1.8 x 10^{-4}	2.7 x 10^{-4}	2.0 x 10^{-4}	1.3 x 10^{-4}	1.2 x 10^{-4}	1.2 x 10^{-4}	1.3 x 10^{-4}	1.3 x 10^{-4}	1.5 x 10^{-4}	1.4 x 10^{-4}	1.4 x 10^{-4}	1.5 x 10^{-4}	1.5 x 10^{-4}	1.2 x 10^{-4}	1.3 x 10^{-4}	1.4 x 10^{-4}	1.5 x 10^{-4}
Thorium-232	1.1 x 10^{-5}	7.3 x 10^{-6}	1.1 x 10^{-5}	7.5 x 10^{-6}	1.1 x 10^{-5}	8.5 x 10^{-6}	6.6 x 10^{-6}	6.3 x 10^{-6}	6.3 x 10^{-6}	6.6 x 10^{-6}	6.6 x 10^{-6}	7.6 x 10^{-6}	7.0 x 10^{-6}	7.0 x 10^{-6}	7.4 x 10^{-6}	7.4 x 10^{-6}	6.3 x 10^{-6}	6.6 x 10^{-6}	7.0 x 10^{-6}	7.4 x 10^{-6}
Thorium-234	1.4 x 10^{-5}	7.1 x 10^{-6}	1.5 x 10^{-5}	7.4 x 10^{-6}	1.4 x 10^{-5}	8.5 x 10^{-6}	7.6 x 10^{-6}	7.6 x 10^{-6}	7.6 x 10^{-6}	7.9 x 10^{-6}	7.9 x 10^{-6}	8.9 x 10^{-6}	8.5 x 10^{-6}	8.5 x 10^{-6}	9.0 x 10^{-6}	9.0 x 10^{-6}	7.6 x 10^{-6}	7.9 x 10^{-6}	8.5 x 10^{-6}	9.0 x 10^{-6}
Uranium-234	1.0 x 10^{-8}	7.0 x 10^{-9}	1.1 x 10^{-8}	7.2 x 10^{-9}	1.0 x 10^{-8}	8.2 x 10^{-9}	7.1 x 10^{-9}	6.8 x 10^{-9}	6.8 x 10^{-9}	7.2 x 10^{-9}	7.2 x 10^{-9}	8.2 x 10^{-9}	7.5 x 10^{-9}	7.5 x 10^{-9}	8.1 x 10^{-9}	8.1 x 10^{-9}	6.8 x 10^{-9}	7.2 x 10^{-9}	7.5 x 10^{-9}	8.1 x 10^{-9}
Uranium-235/236	1.4 x 10^{-6}	9.2 x 10^{-7}	1.4 x 10^{-6}	9.5 x 10^{-7}	1.4 x 10^{-6}	1.1 x 10^{-6}	9.3 x 10^{-7}	8.9 x 10^{-7}	8.9 x 10^{-7}	9.4 x 10^{-7}	9.4 x 10^{-7}	1.1 x 10^{-6}	9.9 x 10^{-7}	9.9 x 10^{-7}	1.1 x 10^{-6}	1.1 x 10^{-6}	8.9 x 10^{-7}	9.4 x 10^{-7}	9.9 x 10^{-7}	1.1 x 10^{-6}
Uranium-236	3.6 x 10^{-6}	2.2 x 10^{-6}	3.7 x 10^{-6}	2.3 x 10^{-6}	3.6 x 10^{-6}	2.6 x 10^{-6}	1.1 x 10^{-6}	9.7 x 10^{-7}	9.7 x 10^{-7}	1.1 x 10^{-6}	1.1 x 10^{-6}	1.3 x 10^{-6}	1.1 x 10^{-6}	1.1 x 10^{-6}	1.2 x 10^{-6}	1.2 x 10^{-6}	9.7 x 10^{-7}	1.1 x 10^{-6}	1.1 x 10^{-6}	1.2 x 10^{-6}
Uranium-238	1.9 x 10^{-4}	1.3 x 10^{-4}	1.9 x 10^{-4}	1.3 x 10^{-4}	1.9 x 10^{-4}	1.5 x 10^{-4}	1.3 x 10^{-4}	1.2 x 10^{-4}	1.2 x 10^{-4}	1.3 x 10^{-4}	1.3 x 10^{-4}	1.5 x 10^{-4}	1.4 x 10^{-4}	1.4 x 10^{-4}	1.5 x 10^{-4}	1.5 x 10^{-4}	1.2 x 10^{-4}	1.3 x 10^{-4}	1.4 x 10^{-4}	1.5 x 10^{-4}
Metals/Chemicals (mg/m3)-npp																				
1,1-DICHLOROETHANE	2.4 x 10^{-11}	6.7 x 10^{-12}	2.5 x 10^{-11}	6.9 x 10^{-12}	2.4 x 10^{-11}	7.8 x 10^{-12}	5.8 x 10^{-12}	4.9 x 10^{-12}	4.9 x 10^{-12}	3.9 x 10^{-12}	3.9 x 10^{-12}	6.6 x 10^{-12}	5.4 x 10^{-12}	5.4 x 10^{-12}	4.4 x 10^{-12}	4.4 x 10^{-12}	4.9 x 10^{-12}	3.9 x 10^{-12}	5.4 x 10^{-12}	4.4 x 10^{-12}
1,1-DICHLOROETHENE	2.6 x 10^{-11}	8.5 x 10^{-12}	2.7 x 10^{-11}	8.8 x 10^{-12}	2.6 x 10^{-11}	1.0 x 10^{-11}	7.8 x 10^{-12}	6.8 x 10^{-12}	6.8 x 10^{-12}	6.0 x 10^{-12}	6.0 x 10^{-12}	8.9 x 10^{-12}	7.5 x 10^{-12}	7.5 x 10^{-12}	6.7 x 10^{-12}	6.7 x 10^{-12}	6.8 x 10^{-12}	6.0 x 10^{-12}	7.5 x 10^{-12}	6.7 x 10^{-12}
1,2,4,5-TETRACHLOROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2,4-TRICHLOROBENZENE	1.5 x 10^{-9}	4.0 x 10^{-10}	1.6 x 10^{-9}	4.1 x 10^{-10}	1.5 x 10^{-9}	4.6 x 10^{-10}	3.7 x 10^{-10}	3.1 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	2.8 x 10^{-10}	4.3 x 10^{-10}	3.5 x 10^{-10}	3.4 x 10^{-10}	3.1 x 10^{-10}	3.2 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	3.4 x 10^{-10}	3.1 x 10^{-10}
1,2-DICHLOROBENZENE	1.5 x 10^{-9}	4.0 x 10^{-10}	1.6 x 10^{-9}	4.1 x 10^{-10}	1.5 x 10^{-9}	4.7 x 10^{-10}	3.7 x 10^{-10}	3.1 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	2.8 x 10^{-10}	4.3 x 10^{-10}	3.5 x 10^{-10}	3.5 x 10^{-10}	3.2 x 10^{-10}	3.2 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	3.5 x 10^{-10}	3.2 x 10^{-10}
1,2-DICHLOROETHANE	6.1 x 10^{-11}	3.4 x 10^{-11}	6.3 x 10^{-11}	3.5 x 10^{-11}	6.1 x 10^{-11}	4.0 x 10^{-11}	3.5 x 10^{-11}	3.3 x 10^{-11}	3.3 x 10^{-11}	3.4 x 10^{-11}	3.4 x 10^{-11}	4.0 x 10^{-11}	3.7 x 10^{-11}	3.7 x 10^{-11}	3.9 x 10^{-11}	3.8 x 10^{-11}	3.3 x 10^{-11}	3.4 x 10^{-11}	3.7 x 10^{-11}	3.9 x 10^{-11}
1,2-DICHLOROETHENE (TOTAL)	2.6 x 10^{-11}	8.5 x 10^{-12}	2.7 x 10^{-11}	8.8 x 10^{-12}	2.6 x 10^{-11}	1.0 x 10^{-11}	7.8 x 10^{-12}	6.8 x 10^{-12}	6.8 x 10^{-12}	6.0 x 10^{-12}	6.0 x 10^{-12}	8.9 x 10^{-12}	7.5 x 10^{-12}	7.5 x 10^{-12}	6.7 x 10^{-12}	6.7 x 10^{-12}	6.8 x 10^{-12}	6.0 x 10^{-12}	7.5 x 10^{-12}	6.7 x 10^{-12}
1,3,5-TRINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-DICHLOROBENZENE	1.5 x 10^{-9}	4.0 x 10^{-10}	1.6 x 10^{-9}	4.1 x 10^{-10}	1.5 x 10^{-9}	4.7 x 10^{-10}	3.7 x 10^{-10}	3.1 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	2.8 x 10^{-10}	4.3 x 10^{-10}	3.5 x 10^{-10}	3.5 x 10^{-10}	3.2 x 10^{-10}	3.2 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	3.5 x 10^{-10}	3.2 x 10^{-10}
1,3-DINITROBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-DICHLOROBENZENE	1.5 x 10^{-9}	4.0 x 10^{-10}	1.6 x 10^{-9}	4.1 x 10^{-10}	1.5 x 10^{-9}	4.6 x 10^{-10}	3.7 x 10^{-10}	3.1 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	2.8 x 10^{-10}	4.3 x 10^{-10}	3.5 x 10^{-10}	3.4 x 10^{-10}	3.1 x 10^{-10}	3.2 x 10^{-10}	3.1 x 10^{-10}	2.8 x 10^{-10}	3.4 x 10^{-10}	3.1 x 10^{-10}
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	4.9 x 10^{-12}	3.3 x 10^{-12}	5.1 x 10^{-12}	3.4 x 10^{-12}	4.9 x 10^{-12}	3.8 x 10^{-12}	1.6 x 10^{-12}	1.4 x 10^{-12}	1.4 x 10^{-12}	1.6 x 10^{-12}	1.6 x 10^{-12}	1.9 x 10^{-12}	1.6 x 10^{-12}	1.6 x 10^{-12}	1.8 x 10^{-12}	1.8 x 10^{-12}	1.4 x 10^{-12}	1.6 x 10^{-12}	1.6 x 10^{-12}	1.8 x 10^{-12}
2-BENZYL ALCOHOL-4-CHLOROPHENOL	2.4 x 10^{-11}	5.3 x 10^{-12}	2.5 x 10^{-11}	5.5 x 10^{-12}	2.4 x 10^{-11}	6.3 x 10^{-12}	5.6 x 10^{-12}	4.0 x 10^{-12}	3.9 x 10^{-12}	4.1 x 10^{-12}	4.2 x 10^{-12}	6.6 x 10^{-12}	4.5 x 10^{-12}	4.4 x 10^{-12}	4.7 x 10^{-12}	4.8 x 10^{-12}	3.9 x 10^{-12}	4.1 x 10^{-12}	4.4 x 10^{-12}	4.7 x 10^{-12}
3,3'-DICHLOROBENZIDINE	1.3 x 10^{-9}	4.5 x 10^{-10}	1.3 x 10^{-9}	4.7 x 10^{-10}	1.3 x 10^{-9}	5.3 x 10^{-10}	4.1 x 10^{-10}	3.6 x 10^{-10}	3.6 x 10^{-10}	3.3 x 10^{-10}	3.3 x 10^{-10}	4.7 x 10^{-10}	4.0 x 10^{-10}	4.0 x 10^{-10}	3.7 x 10^{-10}	3.7 x 10^{-10}	3.6 x 10^{-10}	3.3 x 10^{-10}	4.0 x 10^{-10}	3.7 x 10^{-10}
3,3'-DIMETHYLBENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-METHYLPHENOL	7.7 x 10^{-10}	3.0 x 10^{-10}	7.9 x 10^{-10}	3.1 x 10^{-10}	7.7 x 10^{-10}	3.5 x 10^{-10}	2.7 x 10^{-10}	2.4 x 10^{-10}	2.4 x 10^{-10}	2.3 x 10^{-10}	2.3 x 10^{-10}	3.1 x 10^{-10}	2.6 x 10^{-10}	2.6 x 10^{-10}	2.6 x 10^{-10}	2.6 x 10^{-10}	2.4 x 10^{-10}	2.3 x 10^{-10}	2.6 x 10^{-10}	2.6 x 10^{-10}
4-NITROANILINE	5.6 x 10^{-9}	1.5 x 10^{-9}	5.8 x 10^{-9}	1.5 x 10^{-9}	5.6 x 10^{-9}	1.7 x 10^{-9}	1.4 x 10^{-9}	1.1 x 10^{-9}	1.1 x 10^{-9}	1.0 x 10^{-9}	1.1 x 10^{-9}	1.6 x 10^{-9}	1.2 x 10^{-9}	1.2 x 10^{-9}	1.2 x 10^{-9}	1.2 x 10^{-9}	1.1 x 10^{-9}	1.0 x 10^{-9}	1.2 x 10^{-9}	1.2 x 10^{-9}

TABLE G.I-23
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
7,12-DIMETHYLBENZ(A)ANTHRACENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	8.5×10^{-9}	5.0×10^{-9}	8.7×10^{-9}	5.1×10^{-9}	8.5×10^{-9}	5.7×10^{-9}	3.7×10^{-9}	3.1×10^{-9}	3.1×10^{-9}	3.3×10^{-9}	3.3×10^{-9}	4.2×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	3.1×10^{-9}	3.3×10^{-9}	3.4×10^{-9}	3.7×10^{-9}
ALPHA-CHLORDANE	7.0×10^{-11}	4.0×10^{-11}	7.2×10^{-11}	4.2×10^{-11}	7.0×10^{-11}	4.7×10^{-11}	3.3×10^{-11}	3.1×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.2×10^{-11}	3.8×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	3.6×10^{-11}	3.6×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.4×10^{-11}	3.6×10^{-11}
Aroclor 1254	2.2×10^{-9}	1.5×10^{-9}	2.2×10^{-9}	1.6×10^{-9}	2.2×10^{-9}	1.8×10^{-9}	1.2×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}	1.3×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	1.3×10^{-9}
Arsenic	8.5×10^{-9}	4.7×10^{-9}	8.8×10^{-9}	4.8×10^{-9}	8.5×10^{-9}	5.5×10^{-9}	3.9×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	4.5×10^{-9}	3.8×10^{-9}	3.8×10^{-9}	4.1×10^{-9}	4.1×10^{-9}	3.4×10^{-9}	3.7×10^{-9}	3.8×10^{-9}	4.1×10^{-9}
BENZENE	2.0×10^{-10}	5.2×10^{-11}	2.1×10^{-10}	5.4×10^{-11}	2.0×10^{-10}	6.1×10^{-11}	5.3×10^{-11}	5.1×10^{-11}	5.1×10^{-11}	4.1×10^{-11}	4.1×10^{-11}	6.2×10^{-11}	5.7×10^{-11}	5.7×10^{-11}	4.6×10^{-11}	4.6×10^{-11}	5.1×10^{-11}	4.1×10^{-11}	5.7×10^{-11}	4.6×10^{-11}
BENZIDINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BENZO(A)ANTHRACENE	1.9×10^{-9}	1.2×10^{-9}	2.0×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	8.7×10^{-10}	7.9×10^{-10}	7.8×10^{-10}	8.5×10^{-10}	8.5×10^{-10}	1.0×10^{-9}	8.7×10^{-10}	8.7×10^{-10}	9.5×10^{-10}	9.5×10^{-10}	7.8×10^{-10}	8.5×10^{-10}	8.7×10^{-10}	9.5×10^{-10}
Benzo(a)pyrene	2.3×10^{-9}	1.5×10^{-9}	2.4×10^{-9}	1.5×10^{-9}	2.3×10^{-9}	1.7×10^{-9}	1.0×10^{-9}	9.3×10^{-10}	9.2×10^{-10}	1.0×10^{-9}	1.0×10^{-9}	1.2×10^{-9}	1.0×10^{-9}	1.0×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	9.2×10^{-10}	1.0×10^{-9}	1.0×10^{-9}	1.1×10^{-9}
BENZO(B)FLUORANTHENE	2.5×10^{-9}	1.5×10^{-9}	2.6×10^{-9}	1.5×10^{-9}	2.5×10^{-9}	1.8×10^{-9}	1.1×10^{-9}	9.9×10^{-10}	9.9×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	1.3×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}	1.2×10^{-9}	9.9×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	1.2×10^{-9}
BENZO(G,H,I)PERYLENE	6.5×10^{-10}	3.0×10^{-10}	6.7×10^{-10}	3.1×10^{-10}	6.5×10^{-10}	3.5×10^{-10}	2.6×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	2.3×10^{-10}	2.4×10^{-10}	3.0×10^{-10}	2.5×10^{-10}	2.5×10^{-10}	2.6×10^{-10}	2.6×10^{-10}	2.2×10^{-10}	2.3×10^{-10}	2.5×10^{-10}	2.6×10^{-10}
BENZO(K)FLUORANTHENE	1.9×10^{-9}	1.2×10^{-9}	1.9×10^{-9}	1.3×10^{-9}	1.9×10^{-9}	1.4×10^{-9}	7.6×10^{-10}	6.8×10^{-10}	6.8×10^{-10}	7.3×10^{-10}	7.4×10^{-10}	8.7×10^{-10}	7.5×10^{-10}	7.5×10^{-10}	8.2×10^{-10}	8.2×10^{-10}	6.8×10^{-10}	7.3×10^{-10}	7.5×10^{-10}	8.2×10^{-10}
BENZOIC ACID	1.5×10^{-9}	8.5×10^{-10}	1.6×10^{-9}	8.7×10^{-10}	1.5×10^{-9}	9.9×10^{-10}	6.7×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	6.3×10^{-10}	6.3×10^{-10}	7.7×10^{-10}	6.7×10^{-10}	6.7×10^{-10}	7.1×10^{-10}	7.1×10^{-10}	6.1×10^{-10}	6.3×10^{-10}	6.7×10^{-10}	7.1×10^{-10}
BENZYL ALCOHOL	1.5×10^{-9}	3.9×10^{-10}	1.6×10^{-9}	4.0×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.2×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
Beryllium	1.2×10^{-9}	6.6×10^{-10}	1.2×10^{-9}	6.8×10^{-10}	1.2×10^{-9}	7.7×10^{-10}	5.6×10^{-10}	5.1×10^{-10}	5.1×10^{-10}	5.4×10^{-10}	5.4×10^{-10}	6.5×10^{-10}	5.6×10^{-10}	5.6×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	5.1×10^{-10}	5.4×10^{-10}	5.6×10^{-10}	6.1×10^{-10}
BIS(2-CHLOROETHOXY)METHANE	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
BIS(2-CHLOROETHYL)ETHER	1.5×10^{-9}	4.0×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.7×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.3×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
BIS(2-CHLOROISOPROPYL) ETHER	1.5×10^{-9}	3.9×10^{-10}	1.6×10^{-9}	4.1×10^{-10}	1.5×10^{-9}	4.6×10^{-10}	3.7×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.2×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.8×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
Bis(2-ethylhexyl)phthalate	5.7×10^{-10}	3.2×10^{-10}	5.9×10^{-10}	3.3×10^{-10}	5.7×10^{-10}	3.7×10^{-10}	2.3×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.7×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.3×10^{-10}	2.4×10^{-10}	1.9×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.3×10^{-10}
BIS(CHLOROMETHYL)ETHER	1.6×10^{-12}	7.6×10^{-13}	1.7×10^{-12}	7.8×10^{-13}	1.6×10^{-12}	8.9×10^{-13}	8.1×10^{-13}	4.1×10^{-13}	4.1×10^{-13}	4.3×10^{-13}	4.3×10^{-13}	9.3×10^{-13}	4.5×10^{-13}	4.5×10^{-13}	4.9×10^{-13}	4.9×10^{-13}	4.1×10^{-13}	4.3×10^{-13}	4.5×10^{-13}	4.9×10^{-13}
BROMODICHLOROMETHANE	6.1×10^{-11}	3.4×10^{-11}	6.3×10^{-11}	3.5×10^{-11}	6.1×10^{-11}	4.0×10^{-11}	3.5×10^{-11}	3.3×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	4.0×10^{-11}	3.7×10^{-11}	3.7×10^{-11}	3.9×10^{-11}	3.8×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	3.7×10^{-11}	3.9×10^{-11}
BROMOMETHANE	1.2×10^{-10}	8.0×10^{-11}	1.2×10^{-10}	8.3×10^{-11}	1.2×10^{-10}	9.4×10^{-11}	7.5×10^{-11}	7.2×10^{-11}	7.2×10^{-11}	7.6×10^{-11}	7.6×10^{-11}	8.6×10^{-11}	8.0×10^{-11}	8.0×10^{-11}	8.5×10^{-11}	8.5×10^{-11}	7.2×10^{-11}	7.6×10^{-11}	8.0×10^{-11}	8.5×10^{-11}
CADMIUM	7.2×10^{-9}	1.5×10^{-9}	7.5×10^{-9}	1.6×10^{-9}	7.2×10^{-9}	1.8×10^{-9}	1.5×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	9.4×10^{-10}	9.4×10^{-10}	1.7×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	$1:4 \times 10^{-9}$	9.4×10^{-10}	1.5×10^{-9}	1.1×10^{-9}
CHLORDANE	1.3×10^{-12}	6.1×10^{-13}	1.3×10^{-12}	6.3×10^{-13}	1.3×10^{-12}	7.2×10^{-13}	6.5×10^{-13}	3.3×10^{-13}	3.3×10^{-13}	3.5×10^{-13}	3.5×10^{-13}	7.5×10^{-13}	3.7×10^{-13}	3.7×10^{-13}	3.9×10^{-13}	3.9×10^{-13}	3.3×10^{-13}	3.5×10^{-13}	3.7×10^{-13}	3.9×10^{-13}
CHLOROBENZENE	3.5×10^{-10}	5.8×10^{-11}	3.6×10^{-10}	6.0×10^{-11}	3.5×10^{-10}	6.8×10^{-11}	6.0×10^{-11}	5.9×10^{-11}	5.9×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	7.0×10^{-11}	6.6×10^{-11}	6.6×10^{-11}	3.8×10^{-11}	3.8×10^{-11}	5.9×10^{-11}	3.4×10^{-11}	6.6×10^{-11}	3.8×10^{-11}
CHLOROBENZILATE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	3.0×10^{-11}	1.1×10^{-11}	3.1×10^{-11}	1.1×10^{-11}	3.0×10^{-11}	1.3×10^{-11}	9.1×10^{-12}	8.1×10^{-12}	8.1×10^{-12}	7.4×10^{-12}	7.4×10^{-12}	1.1×10^{-11}	8.9×10^{-12}	8.9×10^{-12}	8.3×10^{-12}	8.3×10^{-12}	8.1×10^{-12}	7.4×10^{-12}	8.9×10^{-12}	8.3×10^{-12}
Chrysene	2.2×10^{-9}	1.4×10^{-9}	2.3×10^{-9}	1.4×10^{-9}	2.2×10^{-9}	1.6×10^{-9}	9.8×10^{-10}	8.8×10^{-10}	8.8×10^{-10}	9.5×10^{-10}	9.5×10^{-10}	1.1×10^{-9}	9.7×10^{-10}	9.7×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	8.8×10^{-10}	9.5×10^{-10}	9.7×10^{-10}	1.1×10^{-9}
DIBENZO(A,H)ANTHRACENE	1.2×10^{-9}	4.7×10^{-10}	1.2×10^{-9}	4.9×10^{-10}	1.2×10^{-9}	5.5×10^{-10}	3.4×10^{-10}	3.2×10^{-10}	3.1×10^{-10}	2.9×10^{-10}	2.9×10^{-10}	4.0×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	3.2×10^{-10}	3.3×10^{-10}	3.1×10^{-10}	2.9×10^{-10}	3.5×10^{-10}	3.2×10^{-10}
DIBENZOFURAN	9.8×10^{-10}	2.8×10^{-10}	1.0×10^{-9}	2.9×10^{-10}	9.8×10^{-10}	3.2×10^{-10}	2.6×10^{-10}	2.3×10^{-10}	2.2×10^{-10}	1.9×10^{-10}	1.9×10^{-10}	2.9×10^{-10}	2.5×10^{-10}	2.5×10^{-10}	2.1×10^{-10}	2.1×10^{-10}	2.2×10^{-10}	1.9×10^{-10}	2.5×10^{-10}	2.1×10^{-10}
DIBROMOMETHANE	6.5×10^{-13}	7.0×10^{-13}	6.7×10^{-13}	7.3×10^{-13}	6.5×10^{-13}	8.3×10^{-13}	7.5×10^{-13}	7.6×10^{-13}	7.6×10^{-13}	8.1×10^{-13}	8.1×10^{-13}	8.7×10^{-13}	8.5×10^{-13}	8.5×10^{-13}	9.1×10^{-13}	9.1×10^{-13}	7.6×10^{-13}	8.1×10^{-13}	8.5×10^{-13}	9.1×10^{-13}
DIELDRIN	1.3×10^{-11}	8.2×10^{-12}	1.4×10^{-11}	8.4×10^{-12}	1.3×10^{-11}	9.5×10^{-12}	6.9×10^{-12}	6.1×10^{-12}	6.0×10^{-12}	6.4×10^{-12}	6.5×10^{-12}	7.9×10^{-12}	6.7×10^{-12}	6.7×10^{-12}	7.2×10^{-12}	7.3×10^{-12}	6.0×10^{-12}	6.4×10^{-12}	6.7×10^{-12}	7.2×10^{-12}
ETHYLBENZENE	8.1×10^{-11}	5.6×10^{-11}	8.3×10^{-11}	5.8×10^{-11}	8.1×10^{-11}	6.6×10^{-11}	4.9×10^{-11}	4.6×10^{-11}	4.6×10^{-11}	4.9×10^{-11}	4.9×10^{-11}	5.6×10^{-11}	5.1×10^{-11}	5.1×10^{-11}	5.6×10^{-11}	5.5×10^{-11}	4.6×10^{-11}	4.9×10^{-11}	5.1×10^{-11}	5.6×10^{-11}
GAMMA-CHLORDANE	7.0×10^{-11}	4.0×10^{-11}	7.2×10^{-11}	4.2×10^{-11}	7.0×10^{-11}	4.7×10^{-11}	3.3×10^{-11}	3.1×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.2×10^{-11}	3.8×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	3.6×10^{-11}	3.6×10^{-11}	3.1×10^{-11}	3.2×10^{-11}	3.4×10^{-11}	3.6×10^{-11}
HEXACHLOROBENZENE	1.9×10^{-9}	4.3×10^{-10}	2.0×10^{-9}	4.5×10^{-10}	1.9×10^{-9}	5.1×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.7×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	3.9×10^{-10}	3.2×10^{-10}
INDENO(1,2,3-CD)PYRENE	1.7×10^{-9}	1.1×10^{-9}	1.8×10^{-9}	1.1×10^{-9}	1.7×10^{-9}	1.2×10^{-9}	7.4×10^{-10}	6.6×10^{-10}	6.6×10^{-10}	7.1×10^{-10}	7.1×10^{-10}	8.5×10^{-10}	7.4×10^{-10}	7.3×10^{-10}	8.0×10^{-10}	8.0×10^{-10}	6.6×10^{-10}	7.1×10^{-10}	7.3×10^{-10}	8.0×10^{-10}
Manganese	8.7×10^{-7}	4.4×10^{-7}	9.0×10^{-7}	4.6×10^{-7}	8.7×10^{-7}	5.1×10^{-7}	3.9×10^{-7}	3.2×10^{-7}	3.2×10^{-7}	3.4×10^{-7}	3.4×10^{-7}	4.4×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	3.8×10^{-7}	3.9×10^{-7}	3.2×10^{-7}	3.4×10^{-7}	3.6×10^{-7}	3.8×10^{-7}
Mercury	1.2×10^{-10}	7.3×10^{-11}	1.3×10^{-10}	7.5×10^{-11}	1.2×10^{-10}	8.5×10^{-11}	6.1×10^{-11}	5.5×10^{-11}	5.5×10^{-11}	5.8×10^{-11}	5.8×10^{-11}	7.0×10^{-11}	6.1×10^{-11}	6.0×10^{-11}	6.5×10^{-11}	6.6×10^{-11}	5.5×10^{-11}	5.8×10^{-11}	6.0×10^{-11}	6.5×10^{-11}
METHYLENE CHIORIDE	1.7×10^{-10}	1.8×10^{-11}	1.8×10^{-10}	1.8×10^{-11}	1.7×10^{-10}	2.1×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	2.3×10^{-12}	2.4×10^{-12}	2.1×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	2.6×10^{-12}	2.7×10^{-12}	1.8×10^{-11}	2.3×10^{-12}	2.0×10^{-11}	2.6×10^{-12}

TABLE G.I-23
(Continued)

	Alt 1		Alt 2A		Alt 2C		Alt 3A					Alt 3C					Alt 4A		Alt 4C	
Contaminants of Concern (COCs)	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 8	Case 9
N-NITROSO-DI-N-PROPYLAMINE	1.5×10^{-9}	3.8×10^{-10}	1.5×10^{-9}	3.9×10^{-10}	1.5×10^{-9}	4.5×10^{-10}	3.6×10^{-10}	3.1×10^{-10}	3.0×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	4.1×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	3.0×10^{-10}	2.7×10^{-10}	3.4×10^{-10}	3.1×10^{-10}
NITROBENZENE	1.9×10^{-9}	4.3×10^{-10}	2.0×10^{-9}	4.5×10^{-10}	1.9×10^{-9}	5.1×10^{-10}	4.1×10^{-10}	3.5×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	2.8×10^{-10}	4.7×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	3.9×10^{-10}	3.2×10^{-10}
O-DICHLOROBENZENE	9.6×10^{-10}	8.2×10^{-11}	1.0×10^{-9}	8.5×10^{-11}	9.6×10^{-10}	9.8×10^{-11}	8.8×10^{-11}	8.9×10^{-11}	8.9×10^{-11}	2.3×10^{-13}	2.3×10^{-13}	1.0×10^{-10}	9.9×10^{-11}	9.9×10^{-11}	2.7×10^{-13}	2.7×10^{-13}	8.9×10^{-11}	2.3×10^{-13}	9.9×10^{-11}	2.7×10^{-13}
P-DIMETHYLAMINOAZOBENZENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenanthrene	1.4×10^{-9}	8.0×10^{-10}	1.4×10^{-9}	8.3×10^{-10}	1.4×10^{-9}	9.4×10^{-10}	6.1×10^{-10}	5.5×10^{-10}	5.5×10^{-10}	5.9×10^{-10}	6.0×10^{-10}	7.1×10^{-10}	6.1×10^{-10}	6.1×10^{-10}	6.7×10^{-10}	6.7×10^{-10}	5.5×10^{-10}	5.9×10^{-10}	6.1×10^{-10}	6.7×10^{-10}
SILVER	3.2×10^{-9}	1.9×10^{-9}	3.3×10^{-9}	2.0×10^{-9}	3.2×10^{-9}	2.3×10^{-9}	1.6×10^{-9}	1.4×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.5×10^{-9}	1.9×10^{-9}	1.6×10^{-9}	1.6×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.4×10^{-9}	1.5×10^{-9}	1.6×10^{-9}	1.7×10^{-9}
TRANS-1,2-DICHLOROETHENE (TOTAL)	6.3×10^{-13}	2.9×10^{-13}	6.5×10^{-13}	3.0×10^{-13}	6.3×10^{-13}	3.5×10^{-13}	3.1×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	1.7×10^{-13}	1.7×10^{-13}	3.6×10^{-13}	1.8×10^{-13}	1.8×10^{-13}	1.9×10^{-13}	1.9×10^{-13}	1.6×10^{-13}	1.7×10^{-13}	1.8×10^{-13}	1.9×10^{-13}
Trichloroethene	5.3×10^{-12}	3.3×10^{-12}	5.5×10^{-12}	3.4×10^{-12}	5.3×10^{-12}	3.8×10^{-12}	2.6×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.9×10^{-12}	2.9×10^{-12}	2.4×10^{-12}	2.6×10^{-12}	2.7×10^{-12}	2.9×10^{-12}
URANIUM, TOTAL	5.6×10^{-7}	3.8×10^{-7}	5.8×10^{-7}	4.0×10^{-7}	5.6×10^{-7}	4.5×10^{-7}	3.9×10^{-7}	3.7×10^{-7}	3.7×10^{-7}	3.9×10^{-7}	3.9×10^{-7}	4.5×10^{-7}	4.1×10^{-7}	4.1×10^{-7}	4.4×10^{-7}	4.4×10^{-7}	3.7×10^{-7}	3.9×10^{-7}	4.1×10^{-7}	4.4×10^{-7}
ZINC	1.8×10^{-7}	6.6×10^{-8}	1.8×10^{-7}	6.8×10^{-8}	1.8×10^{-7}	7.7×10^{-8}	5.5×10^{-8}	5.0×10^{-8}	5.0×10^{-8}	4.6×10^{-8}	4.6×10^{-8}	6.3×10^{-8}	5.6×10^{-8}	5.5×10^{-8}	5.1×10^{-8}	5.1×10^{-8}	5.0×10^{-8}	4.6×10^{-8}	5.5×10^{-8}	5.1×10^{-8}

ATTACHMENT G.II
SAMPLE OUTPUT FROM MODELS AND SPREADSHEETS USED IN THE OPERABLE UNIT 5 SHORT TERM RISK ASSESSMENT

EXAMPLE OF MICROSHIELD v4.10 OUTPUT

MicroShield 4.10 - Serial #4.10-00627
Auxier & Associates

Page : 1
DOS File: U8DISK00.MS4
Run Date: October 31, 1994
Run Time: 1:12 a.m. Monday
Duration: 0:00:14

File Ref: 0115FS ST01
Date: 11/02/94
By: M Bellantoni
Checked: R Collins

Case Title: U238+3d, 1pCi/g soil; 1m thick Disk: r=30m, x=Center (00m)

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet and inches	
Dose point coordinate X:	0.0	0.0	.0
Dose point coordinate Y:	200.0	6.0	6.7
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	100.0	3.0	3.4
Cylinder radius:	3000.0	98.0	5.1
Air Gap:	100.0	3.0	3.4

Source Volume: 2.82743e+9 cm^3 99849.9 cu ft. 1.72541e+8 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Air Gap
Air		0.00122
Concrete	1.7	

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	60
Y Direction (axial)	10

SOURCE NUCLIDES

Nuclide	curies	microCi/cm^3	Nuclide	curies	microCi/cm^3
Bi-210	0.0000e+000	0.0000e+000	Bi-214	0.0000e+000	0.0000e+000
Pa-234	7.6906e-006	2.7200e-009	Pa-234m	4.8066e-003	1.7000e-006
Pb-210	0.0000e+000	0.0000e+000	Pb-214	0.0000e+000	0.0000e+000
Po-210	0.0000e+000	0.0000e+000	Po-214	0.0000e+000	0.0000e+000
Po-218	0.0000e+000	0.0000e+000	Ra-226	0.0000e+000	0.0000e+000
Rn-222	0.0000e+000	0.0000e+000	Th-230	0.0000e+000	0.0000e+000
Th-234	4.8066e-003	1.7000e-006	U-234	0.0000e+000	0.0000e+000
U-238	4.8066e-003	1.7000e-006			

Page : 2
DOS File: U8DISK00.MS4
Run Date: October 31, 1994
Run Time: 1:12 a.m. Monday
Title : U238+3d, 1pCi/g soil; 1m thick Disk: r=30m, x=Center (00m)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.1	6.193e+005	3.053e-005	9.979e-005	4.671e-008	1.527e-007
0.15	8.971e+004	8.414e-006	2.916e-005	1.386e-008	4.802e-008
0.2	6.002e+004	8.556e-006	2.894e-005	1.510e-008	5.107e-008
0.3	2.067e+004	5.274e-006	1.633e-005	1.000e-008	3.098e-008
0.4	1.747e+004	6.767e-006	1.932e-005	1.319e-008	3.765e-008
0.5	2.595e+004	1.393e-005	3.723e-005	2.734e-008	7.308e-008
0.6	1.060e+005	7.447e-005	1.879e-004	1.454e-007	3.667e-007
0.8	5.904e+005	6.376e-004	1.476e-003	1.213e-006	2.807e-006
1.0	1.888e+006	2.858e-003	6.215e-003	5.267e-006	1.146e-005
1.5	3.982e+004	1.123e-004	2.197e-004	1.890e-007	3.696e-007
2.0	5.137e+003	2.253e-005	4.146e-005	3.485e-008	6.411e-008
TOTAL:	3.462e+006	3.778e-003	8.371e-003	6.975e-006	1.546e-005

MicroShield 4.10 - Serial #4.10-00627
Licensed to Auxier & Associates
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: U8DISK00.MS4
Case Title: U238+3d, 1pCi/g soil; 1m thick Disk: r=30m, x=Center (00m)
This case was run on Monday, October 31, 1994 at 1:12 a.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	4.331e-003	1.005e-002
Photon Energy Fluence Rate	MeV/cm²/sec	3.778e-003	8.371e-003
Exposure Rate in Air	mR/hr	6.975e-006	1.546e-005
Absorbed Dose Rate in Air	mGy/hr	6.090e-008	1.349e-007
"	mrad/hr	6.090e-006	1.349e-005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	7.043e-008	1.565e-007
o Opposed "	"	5.872e-008	1.300e-007
o Rotational "	"	5.872e-008	1.300e-007
o Isotropic "	"	5.209e-008	1.154e-007
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	7.522e-008	1.670e-007
o Opposed "	"	7.177e-008	1.592e-007
o Rotational "	"	7.177e-008	1.592e-007
o Isotropic "	"	5.561e-008	1.232e-007
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	6.302e-008	1.399e-007
o Posterior/Anterior "	"	5.699e-008	1.264e-007
o Lateral "	"	4.390e-008	9.716e-008
o Rotational "	"	5.109e-008	1.132e-007
o Isotropic "	"	4.440e-008	9.833e-008

001138

EXAMPLE OF RADTRAN OUTPUT

RUN DATE: [7-NOV-94 AT 17:47:29] PAGE 1

```
RRRR    AAA   DDDD   TTTTT  RRRR    AAA   N   N
R   R  A   A  D   D    T    R   R  A   A  NN  N
R   R  A   A  D   D    T    R   R  A   A  N N N
RRRR   A   A  D   D    T    RRRR   A   A  N  NN
R R    AAAAA  D   D    T    R R    AAAAA  N   N
R  R   A   A  D   D    T    R  R   A   A  N   N
R   R  A   A  DDDD     T    R   R  A   A  N   N
```

```
    4
4   4
4   4
44444
    4
    4
    4
```

RADTRAN 4.0.16 VERSION DATE: APRIL 12,1994

MODE DESCRIPTIONS

NUMBER	NAME	CHARACTERIZATION
1	TRUCK	LONG HAUL VEHICLE
2	RAIL	COMMERCIAL TRAIN
3	BARGE	INLAND VESSEL
4	SHIP	OPEN SEA VESSEL
5	CARGO AIR	CARGO AIRCRAFT
6	PASS AIR	PASSENGER AIRCRAFT
7	P-VAN	PASSENGER VAN
8	CVAN-T	COMMERCIAL VAN
9	CVAN-R	COMMERCIAL VAN
10	CVAN-CA	COMMERCIAL VAN

001440

ECHO CHECK

```
&& Edited Nov 7, 1994
&&  RADTRAN 4 RUN
&&  SHIPMENT OF one truck loaded with B-25 boxes of ou-5 soil
&& six boxes with twice average concentration of case 1
&&  truck SHIPMENT
&&  PRIMARY ROUTE
&&  FERNALD  OH TO THE ENVIROCARE CLIVE UT
&&  1 SHIPMENT
&& Package Dose Rate to 0.0410 mrem/hr
&& U234, U235 and U238 adjusted for on-site cell WAC (1044ppm U)
TITLE RUN NUMBER 8 INPUT
FORM UNIT
DIMEN 14 8 1 10 10
PARM 1 3 3 3 1
POPDEN     6.00    308.0   2168.0
PACKAGE
   LABGRP
      SOIL
SHIPMENT
   LABISO
      CS137       NP237       PU238       PU239       PU240       RA226
       SR90       TC99       TH228       TH230       TH232
       U234       U235       U238
NORMAL
   NMODE=1
      8.840E-01  1.040E-01  1.200E-02  5.500E+01  2.500E+01
1.500E+01
      2.000E+00  3.100E+00  2.000E+00  1.100E-02  0.000E+00
0.000E+00
      0.000E+00  4.000E+00  2.000E+01  0.000E+00  2.000E+01
1.000E+02
      2.000E+00  8.000E-02  6.000E-02  8.500E-01  4.700E+02
7.800E+02
      2.800E+03
ACCIDENT
   ARATMZ
       NMODE=1   1.400E-07    2.700E-06    1.600E-05
   SEVFRC
     NPOP=1
       NMODE=1
       4.6E-01  3.0E-01  1.8E-01  4.0E-02  1.2E-02  6.58E-03
       5.7E-04  1.1E-05
     NPOP=2
       NMODE=1
       4.4E-01  2.9E-01  2.2E-01  5.1E-02  6.6E-03  1.7E-03
       6.7E-05  5.9E-06
     NPOP=3
       NMODE=1
       5.8E-01  3.8E-01  2.8E-02  6.4E-03  7.4E-04  1.5E-04
       1.1E-05  9.9E-07
RELEASE
```

RUN DATE: [7-NOV-94 AT 17:47:29] PAGE 3

RUN NUMBER 8 INPUT

```
   RFRAC
     GROUP=1
       0.0  0.01  0.02  0.04  0.08  0.16  0.32  0.64

   PSPROB  0.0  0.0  0.0  0.0  0.0  1.0
DEFINE    CS137
            1.10E+04  5.98E-01  9.64E-02  3.19E+04  4.61E+04
0.00E+00
            0.00E+00  1.80E-03  2.00E+00  3.26E+04  2.90E+04
DEFINE    NP237
            7.81E+08  3.13E-02  3.52E-03  5.40E+08  4.01E+06
0.00E+00
            0.00E+00  1.80E-03  3.00E+00  7.07E+07  6.93E+08
DEFINE    PU238
            3.20E+04  1.60E-03  1.38E-05  3.92E+08  3.85E+06
0.00E+00
            0.00E+00  1.80E-03  3.00E+00  1.18E+09  2.54E+08
DEFINE    PU239
            8.81E+06  6.00E-04  1.27E-05  4.29E+08  4.31E+06
0.00E+00
            0.00E+00  1.80E-03  3.00E+00  1.19E+09  2.85E+08
DEFINE    PU240
            2.39E+06  1.73E-03  1.37E-05  4.29E+08  4.30E+06
0.00E+00
            0.00E+00  1.80E-03  3.00E+00  4.20E+08  1.10E+06
DEFINE    RA226
          5.84E+05  1.07E-01  2.96E-01  3.18E+07  1.38E+06 0.00E+00

            0.00E+00 1.80E-03  3.00E+00  6.08E+07  2.56E+06
DEFINE    SR90
          1.04E+04  0.00E+00  0.00E+00  2.48E+05  1.41E+05 0.00E+00

            0.00E+00 1.80E-03  2.00E+00  5.53E+04  1.14E+06
DEFINE    TC99
          7.77E+07  0.00E+00  8.09E-08  8.33E+03  1.45E+03 0.00E+00

            0.00E+00 1.80E-03  2.00E+00  6.25E+04  1.55E+02
DEFINE    TH228
          6.97E+02  2.90E-03  2.80E-01  3.45E+08  6.52E+05 0.00E+00

            0.00E+00 1.80E-03  3.00E+00  2.03E+09  2.95E+07
DEFINE    TH230
          2.92E+07  1.30E-03  5.99E-05  3.26E+08  5.25E+05 0.00E+00

            0.00E+00 1.80E-03  3.00E+00  1.08E+08  2.46E+08
DEFINE    TH232
          5.11E+12  1.10E-03  1.52E-01  1.64E+09  1.18E+06 0.00E+00

            0.00E+00 1.80E-03  3.00E+00  2.00E+09  2.51E+08
DEFINE    U234
          9.13E+07  1.40E-03  2.37E-05  1.30E+08  1.05E+06 0.00E+00
```

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```
            0.00E+00 1.80E-03  3.00E+00  1.10E+09  2.58E+05
DEFINE    U235
          2.59E+11  1.52E-01  2.85E-02  8.13E+09  6.04E+06 0.00E+00

      0.00E+00 1.80E-03  3.00E+00  2.89E+09  5.05E+08
DEFINE    U238
          1.64E+12  1.10E-03  3.59E-03  1.19E+07  9.60E+05 0.00E+00

            0.00E+00 1.80E-03  3.00E+00  9.78E+08  2.88E+05
EOF
ISOTOPES  1 1     6.00  0.0410  1.00   0.00  OU5SOIL
        CS137  3.08E-06     SOIL   5
        NP237  4.09E-06     SOIL   5
        PU238  3.22E-06     SOIL   5
        PU239  3.89E-06     SOIL   5
        PU240  3.89E-06     SOIL   5
        RA226  4.63E-04     SOIL   5
         SR90  4.15E-06     SOIL   5
         TC99  3.66E-05     SOIL   5
        TH228  1.84E-05     SOIL   5
        TH230  4.42E-04     SOIL   5
        TH232  1.74E-05     SOIL   5
         U234  2.15E-03     SOIL   5
         U235  9.50E-05     SOIL   5
         U238  2.08E-03     SOIL   5
DISTKM
         NMODE=1    2776.0
PKGSIZ
         OU5SOIL    1.22
EOF
```

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ZONE	POPULATION DENSITY (PERSONS PER SQ KM)
RURAL	6.
SUBURBAN	308.
URBAN	2168.

PACKAGE CHARACTERISTICS

FOR MATERIAL	DIMENSION (METERS)	EFFECTIVE DIMENSION	K(0) METERS SQ.
OU5SOIL	1.220E+00	1.220E+00	2.592E+00

K(0) IS TI TO DOSE RATE CONVERSION FACTOR

PACKAGE HANDLING THRESHOLDS (METERS)
PKGSZ1= 5.000E-01
PKGSZ2= 1.000E+00
PACKAGES .LE. PKGSZ1 ARE HAND CARRIED
PACKAGES .GT. PKGSZ1 AND .LE. PKGSZ2 ARE HANDLED BY SMALL EQUIPMENT
PACKAGES .GT. PKGSZ2 ARE HANDLED BY HEAVY EQUIPMENT

MATERIAL CHARACTERISTICS

MATERIAL	FRACTION OF GAMMA	FRACTION OF NEUTRON
OU5SOIL	1.000E+00	0.000E+00

001444

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MODE CHARACTERISTICS

MODE	DISTANCE TRAVELED	EXCLUSIVE USE	NUMBER OF SHIPMENTS	MATERIALS	TRANSPORT INDEX (TI)	PACKAGES/ SHIPMENT
TRUCK	2.78E+03	NO	1.00E+00			
				OU5SOIL	4.10E-02	6.00E+00

BUILDING SHIELDING OPTION= 3
(1=TOTAL SHIELDING, 2=PARTIAL SHIELDING, 3=NO SHIELDING)

RPD= 6.000E+00
(RATIO OF PEDESTRIAN DENSITY (PEDESTRIAN/KM SQ OF SIDEWALK)
TO POPULATION DENSITY (PEOPLE/KM SQ IN URBAN AREAS)

RR = 1.000E+00
(TRANSMISSION FACTOR FOR RURAL AREAS)

RS = 1.000E+00
(TRANSMISSION FACTOR FOR SUBURBAN AREAS)

RU = 1.000E+00
(TRANSMISSION FACTOR FOR URBAN AREAS)

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NO		DNORML INPUT TRUCK
1	FRACTION OF TRAVEL IN RURAL POPULATION ZONE	8.840E-01
2	FRACTION OF TRAVEL IN SUBURBAN POPULATION ZONE	1.040E-01
3	FRACTION OF TRAVEL IN URBAN POPULATION ZONE	1.200E-02
4	VELOCITY IN RURAL POPULATION ZONE (KILOMETERS/HOUR)	5.500E+01
5	VELOCITY IN SUBURBAN POP. ZONE (KILOMETERS/HOUR)	2.500E+01
6	VELOCITY IN URBAN POPULATION ZONE (KILOMETERS/HOUR)	1.500E+01
7	NUMBER OF CREWMEN	2.000E+00
8	DISTANCE FROM SOURCE TO CREW (METERS)	3.100E+00
9	NUMBER OF HANDLINGS	2.000E+00
10	STOP TIME PER KM (HR/KM)	1.100E-02
11	MINIMUM STOP TIME PER TRIP (HR)	0.000E+00
12	ZERO STOP TIME PER TRIP (HR)	0.000E+00
13	MINIMUM NUMBER OF RAIL CLASSIFICATIONS/INSPECTIONS	0.000E+00
14	PERSONS EXPOSED WHILE STOPPED	4.000E+00
15	AVERAGE EXPOSURE DISTANCE WHILE STOPPED (METERS)	2.000E+01
16	STORAGE TIME PER SHIPMENT (HR)	0.000E+00
17	NUMBER OF EXPOSED PERSONS DURING STORAGE	2.000E+01
18	AVERAGE EXPOSURE DISTANCE WHILE IN STORAGE (METERS)	1.000E+02
19	NUMBER OF PEOPLE PER VEHICLE ON LINK	2.000E+00
20	FRACTION OF URBAN TRAVEL DURING RUSH HOUR TRAFFIC	8.000E-02
21	FRACTION OF URBAN TRAVEL ON CITY STREETS	6.000E-02
22	FRACTION OF RURAL-SUBURBAN TRAVEL ON FREEWAYS	8.500E-01
23	*TRAFFIC COUNT PASSING A SPECIFIC POINT-RURAL ZONE	4.700E+02
24	*TRAFFIC COUNT PASSING A SPECIFIC POINT-SUBURBAN ZONE	7.800E+02
25	*TRAFFIC COUNT PASSING A SPECIFIC POINT-URBAN ZONE	2.800E+03

*(ONE WAY VEHICLES/HR)

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ISOTOPE RELATED DATA

NUCLIDE	CURIES PER PKG	RELEASE GROUP	RESUSP FACTOR	LUNG TYPE	DISPERS. CATEGORY	1YR INHAL LUNG	REM/CI MARROW
OU5SOIL							
CS137	3.08E-06	SOIL	1.79E+00	2	5	3.26E+04	2.90E+04
NP237	4.09E-06	SOIL	1.82E+00	3	5	7.07E+07	6.93E+08
PU238	3.22E-06	SOIL	1.81E+00	3	5	1.18E+09	2.54E+08
PU239	3.89E-06	SOIL	1.82E+00	3	5	1.19E+09	2.85E+08
PU240	3.89E-06	SOIL	1.82E+00	3	5	4.20E+08	1.10E+06
RA226	4.63E-04	SOIL	1.82E+00	3	5	6.08E+07	2.56E+06
SR90	4.15E-06	SOIL	1.79E+00	2	5	5.53E+04	1.14E+06
TC99	3.66E-05	SOIL	1.82E+00	2	5	6.25E+04	1.55E+02
TH228	1.84E-05	SOIL	1.54E+00	3	5	2.03E+09	2.95E+07
TH230	4.42E-04	SOIL	1.82E+00	3	5	1.08E+08	2.46E+08
TH232	1.74E-05	SOIL	1.82E+00	3	5	2.00E+09	2.51E+08
U234	2.15E-03	SOIL	1.82E+00	3	5	1.10E+09	2.58E+05
U235	9.50E-05	SOIL	1.82E+00	3	5	2.89E+09	5.05E+08
U238	2.08E-03	SOIL	1.82E+00	3	5	9.78E+08	2.88E+05

NUCLIDE	HALF LIFE	GAMMA ENERGY	CLOUD FACTOR	TRANSFER CROPS	TRANSFER SOIL	DEPOS SPEED
OU5SOIL						
CS137	1.10E+04	5.98E-01	9.64E-02	0.00E+00	0.00E+00	1.80E-03
NP237	7.81E+08	3.13E-02	3.52E-03	0.00E+00	0.00E+00	1.80E-03
PU238	3.20E+04	1.60E-03	1.38E-05	0.00E+00	0.00E+00	1.80E-03
PU239	8.81E+06	6.00E-04	1.27E-05	0.00E+00	0.00E+00	1.80E-03
PU240	2.39E+06	1.73E-03	1.37E-05	0.00E+00	0.00E+00	1.80E-03
RA226	5.84E+05	1.07E-01	2.96E-01	0.00E+00	0.00E+00	1.80E-03
SR90	1.04E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.80E-03
TC99	7.77E+07	0.00E+00	8.09E-08	0.00E+00	0.00E+00	1.80E-03
TH228	6.97E+02	2.90E-03	2.80E-01	0.00E+00	0.00E+00	1.80E-03
TH230	2.92E+07	1.30E-03	5.99E-05	0.00E+00	0.00E+00	1.80E-03
TH232	5.11E+12	1.10E-03	1.52E-01	0.00E+00	0.00E+00	1.80E-03
U234	9.13E+07	1.40E-03	2.37E-05	0.00E+00	0.00E+00	1.80E-03
U235	2.59E+11	1.52E-01	2.85E-02	0.00E+00	0.00E+00	1.80E-03
U238	1.64E+12	1.10E-03	3.59E-03	0.00E+00	0.00E+00	1.80E-03

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ISOTOPE RELATED DATA

NUCLIDE	50-YR EFFECTIVE REM/CI INHALE	INGEST
OU5SOIL		
CS137	3.19E+04	4.61E+04
NP237	5.40E+08	4.01E+06
PU238	3.92E+08	3.85E+06
PU239	4.29E+08	4.31E+06
PU240	4.29E+08	4.30E+06
RA226	3.18E+07	1.38E+06
SR90	2.48E+05	1.41E+05
TC99	8.33E+03	1.45E+03
TH228	3.45E+08	6.52E+05
TH230	3.26E+08	5.25E+05
TH232	1.64E+09	1.18E+06
U234	1.30E+08	1.05E+06
U235	8.13E+09	6.04E+06
U238	1.19E+07	9.60E+05

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RELEASE RELATED DATA

ACCIDENT RATES (PER KM)

MODE	RURAL	SUBURBAN	URBAN
TRUCK	1.400E-07	2.700E-06	1.600E-05

RELEASE FRACTIONS

GROUP	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	1.00E-02	2.00E-02	4.00E-02	8.00E-02	1.60E-01	3.20E-01

GROUP	SEVER: 8
1	6.40E-01

ACCIDENT SEVERITY FRACTIONS
FOR TRUCK

ZONE	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	4.60E-01	3.00E-01	1.80E-01	4.00E-02	1.20E-02	6.58E-03	5.70E-04
2	4.40E-01	2.90E-01	2.20E-01	5.10E-02	6.60E-03	1.70E-03	6.70E-05
3	5.80E-01	3.80E-01	2.80E-02	6.40E-03	7.40E-04	1.50E-04	1.10E-05

ZONE	SEVER: 8
1	1.10E-05
2	5.90E-06
3	9.90E-07

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AEROSOLIZED FRACTION OF RELEASED MATERIAL

DISP CAT	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
3	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
4	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
5	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
6	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
7	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
8	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
9	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
10	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
11	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

DISP CAT	SEVER: 8
1	0.00E+00
2	1.00E-06
3	1.00E-02
4	5.00E-02
5	1.00E-01
6	1.00E+00
7	1.00E+00
8	1.00E+00
9	1.00E+00
10	1.00E+00
11	1.00E+00

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FRACTION OF AEROSOLS BELOW 10 MICRONS AED

DISP CAT	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
3	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
4	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
5	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
6	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
7	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
8	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
9	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
10	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
11	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

DISP CAT	SEVER: 8
1	0.00E+00
2	5.00E-02
3	5.00E-02
4	5.00E-02
5	5.00E-02
6	5.00E-02
7	1.00E+00
8	1.00E+00
9	1.00E+00
10	1.00E+00
11	1.00E+00

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COST RELATED DATA

EMERGENCY RESPONSE COST

	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	SEVER: 8
1	0.00E+00

ON-SCENE COSTS
(RF=RELEASE FRACTION)

RF=0.	0.<RF<=.01	.01<RF<=0.1	.1<RF<=1.
0.	0.	0.	0.

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HEALTH RELATED DATA

EARLY FATALITY PROBABILITIES

DOSE(REM)	LUNG-1	LUNG-2	LUNG-3	MARROW
100000.000	1.000E+00	1.000E+00	1.000E+00	1.000E+00
80000.000	1.000E+00	8.500E-01	8.000E-01	1.000E+00
70000.000	1.000E+00	8.000E-01	5.000E-01	1.000E+00
40000.000	1.000E+00	7.000E-01	0.000E+00	1.000E+00
30000.000	1.000E+00	5.000E-01	0.000E+00	1.000E+00
25000.000	1.000E+00	2.000E-01	0.000E+00	1.000E+00
20000.000	1.000E+00	8.000E-02	0.000E+00	1.000E+00
10000.000	6.000E-01	0.000E+00	0.000E+00	1.000E+00
8000.000	1.000E-01	0.000E+00	0.000E+00	1.000E+00
6000.000	6.000E-02	0.000E+00	0.000E+00	1.000E+00
4000.000	3.000E-02	0.000E+00	0.000E+00	1.000E+00
3000.000	0.000E+00	0.000E+00	0.000E+00	1.000E+00
2000.000	0.000E+00	0.000E+00	0.000E+00	1.000E+00
1000.000	0.000E+00	0.000E+00	0.000E+00	1.000E+00
800.000	0.000E+00	0.000E+00	0.000E+00	9.960E-01
700.000	0.000E+00	0.000E+00	0.000E+00	9.000E-01
600.000	0.000E+00	0.000E+00	0.000E+00	4.000E-01
500.000	0.000E+00	0.000E+00	0.000E+00	5.000E-02
400.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
300.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
100.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
75.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
50.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
30.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.100	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.010	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.010	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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METEOROLOGICAL DATA BASED ON PASQUILL CATEGORIES

PROB. A	PROB. B	PROB. C	PROB. D	PROB. E	PROB. F
0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

AREA (M SQ)	*PASQUILL CATEGORY A	B	C	D	E	F
4.60E+02	6.00E-03	4.00E-03	4.00E-03	4.30E-03	9.60E-03	6.20E-02
1.50E+03	1.70E-03	1.30E-03	1.10E-03	1.30E-03	3.20E-03	1.80E-02
3.90E+03	8.40E-04	5.50E-04	5.70E-04	6.50E-04	1.60E-03	8.40E-03
1.30E+04	1.70E-04	1.30E-04	1.30E-04	1.80E-04	4.00E-04	2.00E-03
3.00E+04	7.80E-05	6.00E-05	6.70E-05	9.50E-05	2.10E-04	9.20E-04
6.90E+04	2.80E-05	2.70E-05	3.00E-05	4.30E-05	1.40E-04	4.40E-04
1.80E+05	8.00E-06	1.00E-05	1.00E-05	1.80E-05	4.40E-05	2.00E-04
4.50E+05	2.20E-06	3.50E-06	5.00E-06	8.50E-06	2.10E-05	1.00E-04
8.60E+05	9.00E-07	1.60E-06	2.80E-06	5.00E-06	1.20E-05	6.20E-05
2.60E+06	1.40E-07	4.10E-07	1.00E-06	1.90E-06	4.80E-06	2.60E-05
4.50E+06	7.00E-08	2.20E-07	6.00E-07	1.30E-06	3.60E-06	1.90E-05
1.70E+07	1.10E-08	5.00E-08	1.70E-07	4.00E-07	1.40E-06	8.40E-06
2.20E+07	7.76E-09	3.20E-08	1.30E-07	3.00E-07	1.20E-06	7.00E-06
5.50E+07	2.24E-09	1.10E-08	5.70E-08	1.50E-07	6.00E-07	4.00E-06
1.80E+08	4.50E-10	2.50E-09	1.70E-08	5.50E-08	2.80E-07	2.00E-06
5.00E+08	1.13E-10	7.24E-10	6.32E-09	2.41E-08	1.38E-07	1.09E-06
8.00E+08	5.96E-11	4.09E-10	4.01E-09	1.65E-08	9.97E-08	8.22E-07
1.40E+09	2.76E-11	2.08E-10	2.33E-09	1.05E-08	6.77E-08	5.89E-07

* DILUTION FACTOR UNITS ARE (CI-SEC/M**3/CI-RELEASED)

NON-DISPERSAL ACCIDENT INPUT

RADIST(M) RURAL	SUBURBAN	URBAN
3.050E+00	3.050E+00	3.050E+00
6.100E+00	6.100E+00	6.100E+00
9.100E+00	9.100E+00	9.100E+00
1.220E+01	1.220E+01	1.220E+01
1.520E+01	1.520E+01	1.520E+01
3.050E+01	3.050E+01	3.050E+01
6.100E+01	6.100E+01	6.100E+01
9.140E+01	9.140E+01	9.140E+01
1.524E+02	1.524E+02	1.524E+02
3.050E+02	3.050E+02	3.050E+02

BUILDING DOSE FACTOR	= 8.600E-03
FRACTION OF LAND UNDER CULTIVATION	= 5.000E-01
CONTAMINATION CLEAN UP LEVEL (UCI/M**2)	= 2.000E-01
BREATHING RATE (M**3/SEC)	= 3.300E-04

OC1454

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RUN NUMBER 8 INPUT

REGULATORY CHECKS

RUN DATE: [7-NOV-94 AT 17:47:29] PAGE 17

RUN NUMBER 8 INPUT

CALCULATIONAL INFORMATION FOR MODE TRUCK AND PASQUILL CATEGORY F

IN CALCULATING THE DEPLETION OF CS137 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF NP237 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF PU238 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF PU239 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF PU240 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF RA226 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF SR90 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF TC99 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF TH228 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF TH230 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF TH232 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF U234 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF U235 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

IN CALCULATING THE DEPLETION OF U238 THE CONCENTRATION
IN AREA 16 HAS BECOME NEGATIVE. THE CONTAMINATION AND
CONCENTRATIONS IN AREAS 16 AND LARGER HAVE BEEN SET TO 0.0.

001456

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RUN NUMBER 8 INPUT

PASQUILL CATEGORY F
MODE TRUCK

1-YEAR LUNG DOSE - INHALATION PATHWAY
BDF = 1 (REM)

AREA #	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	2.97E-02	5.93E-02	1.19E-01	2.37E-01	4.75E-01	9.49E-01
2	0.00E+00	8.59E-03	1.72E-02	3.44E-02	6.88E-02	1.38E-01	2.75E-01
3	0.00E+00	3.76E-03	7.52E-03	1.50E-02	3.01E-02	6.02E-02	1.20E-01
4	0.00E+00	8.47E-04	1.69E-03	3.39E-03	6.77E-03	1.35E-02	2.71E-02
5	0.00E+00	3.63E-04	7.25E-04	1.45E-03	2.90E-03	5.80E-03	1.16E-02
6	0.00E+00	1.66E-04	3.32E-04	6.64E-04	1.33E-03	2.65E-03	5.31E-03
7	0.00E+00	7.20E-05	1.44E-04	2.88E-04	5.76E-04	1.15E-03	2.30E-03
8	0.00E+00	3.38E-05	6.76E-05	1.35E-04	2.71E-04	5.41E-04	1.08E-03
9	0.00E+00	1.95E-05	3.90E-05	7.79E-05	1.56E-04	3.12E-04	6.23E-04
10	0.00E+00	7.68E-06	1.54E-05	3.07E-05	6.14E-05	1.23E-04	2.46E-04
11	0.00E+00	4.88E-06	9.76E-06	1.95E-05	3.91E-05	7.81E-05	1.56E-04
12	0.00E+00	1.98E-06	3.97E-06	7.94E-06	1.59E-05	3.17E-05	6.35E-05
13	0.00E+00	1.16E-06	2.33E-06	4.66E-06	9.31E-06	1.86E-05	3.72E-05
14	0.00E+00	6.10E-07	1.22E-06	2.44E-06	4.88E-06	9.77E-06	1.95E-05
15	0.00E+00	2.05E-07	4.10E-07	8.21E-07	1.64E-06	3.28E-06	6.56E-06
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

AREA #	SEVER: 8
1	1.90E+00
2	5.50E-01
3	2.41E-01
4	5.42E-02
5	2.32E-02
6	1.06E-02
7	4.61E-03
8	2.16E-03
9	1.25E-03
10	4.91E-04
11	3.12E-04
12	1.27E-04
13	7.45E-05
14	3.91E-05
15	1.31E-05
16	0.00E+00
17	0.00E+00
18	0.00E+00

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RUN NUMBER 8 INPUT

1-YEAR MARROW DOSE - INHALATION PATHWAY
BDF = 1 (REM)

AREA #	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	1.04E-03	2.07E-03	4.14E-03	8.29E-03	1.66E-02	3.31E-02
2	0.00E+00	3.00E-04	6.00E-04	1.20E-03	2.40E-03	4.80E-03	9.60E-03
3	0.00E+00	1.31E-04	2.63E-04	5.25E-04	1.05E-03	2.10E-03	4.20E-03
4	0.00E+00	2.96E-05	5.91E-05	1.18E-04	2.37E-04	4.73E-04	9.46E-04
5	0.00E+00	1.27E-05	2.53E-05	5.06E-05	1.01E-04	2.03E-04	4.05E-04
6	0.00E+00	5.79E-06	1.16E-05	2.32E-05	4.63E-05	9.27E-05	1.85E-04
7	0.00E+00	2.51E-06	5.03E-06	1.01E-05	2.01E-05	4.02E-05	8.05E-05
8	0.00E+00	1.18E-06	2.36E-06	4.72E-06	9.45E-06	1.89E-05	3.78E-05
9	0.00E+00	6.80E-07	1.36E-06	2.72E-06	5.44E-06	1.09E-05	2.18E-05
10	0.00E+00	2.68E-07	5.36E-07	1.07E-06	2.14E-06	4.29E-06	8.58E-06
11	0.00E+00	1.70E-07	3.41E-07	6.82E-07	1.36E-06	2.73E-06	5.46E-06
12	0.00E+00	6.93E-08	1.39E-07	2.77E-07	5.54E-07	1.11E-06	2.22E-06
13	0.00E+00	4.06E-08	8.13E-08	1.63E-07	3.25E-07	6.50E-07	1.30E-06
14	0.00E+00	2.13E-08	4.26E-08	8.52E-08	1.70E-07	3.41E-07	6.82E-07
15	0.00E+00	7.16E-09	1.43E-08	2.86E-08	5.73E-08	1.15E-07	2.29E-07
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

AREA #	SEVER: 8
1	6.63E-02
2	1.92E-02
3	8.40E-03
4	1.89E-03
5	8.10E-04
6	3.71E-04
7	1.61E-04
8	7.56E-05
9	4.35E-05
10	1.72E-05
11	1.09E-05
12	4.43E-06
13	2.60E-06
14	1.36E-06
15	4.58E-07
16	0.00E+00
17	0.00E+00
18	0.00E+00

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RUN NUMBER 8 INPUT

PASQUILL CATEGORY F
MODE TRUCK

GROUND SURFACE CONTAMINATION TABLE (MICRO CI/M**2)
BEFORE CLEANUP

AREA #	SEVER: 1	SEVER: 2	SEVER: 3	SEVER: 4	SEVER: 5	SEVER: 6	SEVER: 7
1	0.00E+00	3.57E-03	7.13E-03	1.43E-02	2.85E-02	5.70E-02	1.14E-01
2	0.00E+00	1.03E-03	2.07E-03	4.13E-03	8.26E-03	1.65E-02	3.31E-02
3	0.00E+00	4.52E-04	9.04E-04	1.81E-03	3.62E-03	7.23E-03	1.45E-02
4	0.00E+00	1.02E-04	2.04E-04	4.07E-04	8.14E-04	1.63E-03	3.26E-03
5	0.00E+00	4.36E-05	8.72E-05	1.74E-04	3.49E-04	6.97E-04	1.39E-03
6	0.00E+00	1.99E-05	3.99E-05	7.98E-05	1.60E-04	3.19E-04	6.38E-04
7	0.00E+00	8.66E-06	1.73E-05	3.46E-05	6.93E-05	1.39E-04	2.77E-04
8	0.00E+00	4.07E-06	8.13E-06	1.63E-05	3.25E-05	6.51E-05	1.30E-04
9	0.00E+00	2.34E-06	4.68E-06	9.37E-06	1.87E-05	3.75E-05	7.49E-05
10	0.00E+00	9.23E-07	1.85E-06	3.69E-06	7.38E-06	1.48E-05	2.95E-05
11	0.00E+00	5.87E-07	1.17E-06	2.35E-06	4.70E-06	9.39E-06	1.88E-05
12	0.00E+00	2.39E-07	4.77E-07	9.54E-07	1.91E-06	3.82E-06	7.63E-06
13	0.00E+00	1.40E-07	2.80E-07	5.60E-07	1.12E-06	2.24E-06	4.48E-06
14	0.00E+00	7.34E-08	1.47E-07	2.93E-07	5.87E-07	1.17E-06	2.35E-06
15	0.00E+00	2.47E-08	4.93E-08	9.86E-08	1.97E-07	3.95E-07	7.89E-07
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

AREA #	SEVER: 8
1	2.28E-01
2	6.61E-02
3	2.89E-02
4	6.51E-03
5	2.79E-03
6	1.28E-03
7	5.54E-04
8	2.60E-04
9	1.50E-04
10	5.91E-05
11	3.76E-05
12	1.53E-05
13	8.95E-06
14	4.70E-06
15	1.58E-06
16	0.00E+00
17	0.00E+00
18	0.00E+00

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INCIDENT-FREE SUMMARY
******** **** *******

INCIDENT-FREE POPULATION EXPOSURE IN PERSON-REM

	PASSENGR	CREW	HANDLERS	OFF LINK	ON LINK	STOPS	STORAGE	TOTALS
LINK 1	0.00E+00	7.81E-03	1.98E-03	5.52E-05	6.15E-04	1.95E-04	0.00E+00	1.07E-02
TOTALS:	0.00E+00	7.81E-03	1.98E-03	5.52E-05	6.15E-04	1.95E-04	0.00E+00	1.07E-02

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE

LINK 1 2.44E-09 REM

001650

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INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 1
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	DOSE RATE (TRANSPORT INDEX)	1.066E-04
2	NUMBER OF SHIPMENTS	1.066E-04
3	PACKAGES PER SHIPMENT	1.066E-04
4	K ZERO	9.665E-05
5	DISTANCE TRAVELED	8.675E-05
6	NUMBER OF CREW MEMBERS	7.810E-05
7	FRACTION OF TRAVEL - RURAL	6.272E-05
8	PERSONS EXPOSED PER HANDLING	1.980E-05
9	EXPOSURE TIME FOR HANDLERS	1.980E-05
10	NUMBER OF HANDLINGS	1.980E-05
11	FRACTION OF TRAVEL - SUBURBAN	1.786E-05
12	NUMBER OF PEOPLE PER VEHICLE	6.149E-06
13	FRACTION OF TRAVEL - URBAN	4.227E-06
14	TRAFFIC COUNT - RURAL	2.998E-06
15	TRAFFIC COUNT - SUBURBAN	2.136E-06
16	STOP TIME	1.947E-06
17	PERSONS EXPOSED WHILE STOPPED	1.947E-06
18	FRACTION OF RUSH HOUR TRAVEL	1.221E-06
19	TRAFFIC COUNT - URBAN	1.015E-06
20	FRACTION OF TRAVEL ON CITY STREETS	7.582E-07
21	POPULATION DENSITY - SUBURBAN	2.757E-07
22	POPULATION DENSITY - URBAN	2.407E-07
23	POPULATION DENSITY - RURAL	3.567E-08
24	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
25	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
26	RATIO OF PEDESTRIAN DENSITY (RPD)	0.000E+00
27	URBAN SHIELDING FACTOR (RU)	0.000E+00
28	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
29	STORAGE TIME PER SHIPMENT	0.000E+00
30	STORAGE EXPOSURE DISTANCE	0.000E+00
31	RURAL SHIELDING FACTOR (RR)	0.000E+00
32	EXPOSURE DISTANCE WHILE STOPPED	-3.894E-06
33	VELOCITY - URBAN	-4.483E-06
34	FRACTION OF TRAVEL ON FREEWAYS	-1.158E-05
35	VELOCITY - SUBURBAN	-1.853E-05
36	HANDLER EXPOSURE DISTANCE	-1.980E-05
37	VELOCITY - RURAL	-6.794E-05
38	DISTANCE FROM SOURCE TO CREW	-1.562E-04

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER

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ACCIDENT SUMMARY
******** *******

NUMBER OF EXPECTED ACCIDENTS -- MODE TRUCK

CATEGORY	RURAL	SUBURB	URBAN
1	1.58E-04	3.43E-04	3.09E-04
2	1.03E-04	2.26E-04	2.03E-04
3	6.18E-05	1.71E-04	1.49E-05
4	1.37E-05	3.98E-05	3.41E-06
5	4.12E-06	5.14E-06	3.94E-07
6	2.26E-06	1.33E-06	7.99E-08
7	1.96E-07	5.22E-08	5.86E-09
8	3.78E-09	4.60E-09	5.28E-10

EARLY FATALITY CONSEQUENCES -- MODE TRUCK

CATEGORY	RURAL	SUBURB	URBAN
1	0.00E+00	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00	0.00E+00
4	0.00E+00	0.00E+00	0.00E+00
5	0.00E+00	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00
7	0.00E+00	0.00E+00	0.00E+00
8	0.00E+00	0.00E+00	0.00E+00

ECONOMIC CONSEQUENCES -- MODE TRUCK

CATEGORY	RURAL	SUBURB	URBAN
1	0.00E+00	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00	0.00E+00
4	0.00E+00	0.00E+00	0.00E+00
5	0.00E+00	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00
7	0.00E+00	0.00E+00	0.00E+00
8	0.00E+00	0.00E+00	0.00E+00

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RADIOLOGICAL CONSEQUENCES -- MODE TRUCK
50 YEAR POPULATION DOSE IN PERSON REM

CATEGORY	RURAL	SUBURB	URBAN
1	0.00E+00	0.00E+00	0.00E+00
2	5.93E-04	3.04E-02	1.29E-01
3	1.19E-03	6.08E-02	2.59E-01
4	2.37E-03	1.22E-01	5.18E-01
5	4.74E-03	2.43E-01	1.04E+00
6	9.48E-03	4.87E-01	2.07E+00
7	1.90E-02	9.73E-01	4.14E+00
8	3.79E-02	1.95E+00	8.28E+00

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EXPECTED VALUES OF POPULATION RISK IN PERSON REM

OU5SOIL	GROUND	INHALED	RESUSPD	CLOUDSH	*INGESTION	TOTAL
CS137	4.67E-09	2.39E-12	1.90E-12	4.37E-13	0.00E+00	4.67E-09
NP237	5.17E-10	5.36E-08	4.41E-08	2.12E-14	0.00E+00	9.83E-08
PU238	1.75E-11	3.07E-08	2.49E-08	6.54E-17	0.00E+00	5.56E-08
PU239	9.42E-12	4.05E-08	3.33E-08	7.27E-17	0.00E+00	7.39E-08
PU240	2.71E-11	4.05E-08	3.33E-08	7.85E-17	0.00E+00	7.39E-08
RA226	1.98E-07	3.58E-07	2.94E-07	2.02E-10	0.00E+00	8.50E-07
SR90	0.00E+00	2.50E-11	1.98E-11	0.00E+00	0.00E+00	4.48E-11
TC99	0.00E+00	7.41E-12	6.09E-12	4.36E-18	0.00E+00	1.35E-11
TH228	1.89E-11	1.54E-07	8.29E-08	7.58E-12	0.00E+00	2.37E-07
TH230	2.32E-09	3.50E-06	2.88E-06	3.90E-14	0.00E+00	6.38E-06
TH232	7.73E-11	6.93E-07	5.68E-07	3.89E-12	0.00E+00	1.26E-06
U234	1.22E-08	6.79E-06	5.58E-06	7.50E-14	0.00E+00	1.24E-05
U235	5.83E-08	1.88E-05	1.54E-05	3.99E-12	0.00E+00	3.42E-05
U238	9.24E-09	6.01E-07	4.92E-07	1.10E-11	0.00E+00	1.10E-06
TOTALS:	2.86E-07	3.10E-05	2.55E-05	2.29E-10	0.00E+00	5.68E-05

* NOTE THAT INGESTION RISK IS A SOCIETAL RISK;
THE USER MAY WISH TO TREAT THIS VALUE SEPARATELY.

RUN DATE: [7-NOV-94 AT 17:47:29] PAGE 26

RUN NUMBER 8 INPUT

EXPECTED RISK VALUES - OTHER

LINK	ECON $$	EARLY FATALITY
1	0.00E+00	0.00E+00
TOTAL	0.00E+00	0.00E+00

TOTAL EXPOSED POPULATION: INCIDENT-FREE

TRUCK RURAL	2.36E+04	PERSONS
TRUCK SUBURBAN	1.42E+05	PERSONS
TRUCK URBAN	1.16E+05	PERSONS
TOTAL	2.81E+05	PERSONS

PASQUILL CATEGORY A
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	0.00E+00	PERSONS
TRUCK SUBURBAN	0.00E+00	PERSONS
TRUCK URBAN	0.00E+00	PERSONS

RUN DATE: [7-NOV-94 AT 17:47:29] PAGE 27

RUN NUMBER 8 INPUT

PASQUILL CATEGORY B
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	0.00E+00	PERSONS
TRUCK SUBURBAN	0.00E+00	PERSONS
TRUCK URBAN	0.00E+00	PERSONS

PASQUILL CATEGORY C
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	0.00E+00	PERSONS
TRUCK SUBURBAN	0.00E+00	PERSONS
TRUCK URBAN	0.00E+00	PERSONS

PASQUILL CATEGORY D
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	0.00E+00	PERSONS
TRUCK SUBURBAN	0.00E+00	PERSONS
TRUCK URBAN	0.00E+00	PERSONS

PASQUILL CATEGORY E
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	0.00E+00	PERSONS
TRUCK SUBURBAN	0.00E+00	PERSONS
TRUCK URBAN	0.00E+00	PERSONS

PASQUILL CATEGORY F
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

TRUCK RURAL	1.08E+03	PERSONS
TRUCK SUBURBAN	5.54E+04	PERSONS
TRUCK URBAN	3.90E+05	PERSONS

END OF RUN

001466

EXAMPLES OF INDUSTRIAL SOURCE COMPLEX LONG-TERM AND SHORT-TERM MODEL OUTPUTS

```
CO STARTING
   TITLEONE  Long Term Dispersion Factors for PO113 Risk Assessment
   TITLETWO  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92
   MODELOPT  RURAL CONC
   AVERTIME  ANNUAL
   POLLUTID  Other
   TERRHGTS  FLAT
   FLAGPOLE  1.5
   RUNORNOT  RUN
   ERRORFIL  C:\ISC\ERRORS.OUT
CO FINISHED

SO STARTING
** Excavation of 1/2 acre = 45m x 45m
**
** Parameters for LOCATION are SW Corner coordinates for area of excavation
** Parameters for SRCEPARAM are emission rate, stack height, length of side
**
   LOCATION  582a     AREA 1562 1753
   SRCPARAM  582a     1.0 0.0 45.0
   LOCATION  582b     AREA 1219 2096
   SRCPARAM  582b     1.0 0.0 45.0
   LOCATION  afp      AREA 1219 2134
   SRCPARAM  afp      1.0 0.0 45.0
   LOCATION  sf       AREA 1181 2362
   SRCPARAM  sf       1.0 0.0 45.0
   LOCATION  580a     AREA 1448 2324
   SRCPARAM  580a     1.0 0.0 45.0
   LOCATION  581a     AREA 2057 2096
   SRCPARAM  581a     1.0 0.0 45.0
   LOCATION  575a     AREA 1029 2743
   SRCPARAM  575a     1.0 0.0 45.0
   LOCATION  575b     AREA 1257 2781
   SRCPARAM  575b     1.0 0.0 45.0
   LOCATION  570e     AREA 1372 2896
   SRCPARAM  570e     1.0 0.0 45.0
   LOCATION  570a     AREA 1448 2667
   SRCPARAM  570a     1.0 0.0 45.0
   LOCATION  Pa6      AREA 1829 2477
   SRCPARAM  Pa6      1.0 0.0 45.0
   LOCATION  Pa5      AREA 1981 2629
   SRCPARAM  Pa5      1.0 0.0 45.0
   LOCATION  Pa4      AREA 1753 2858
   SRCPARAM  Pa4      1.0 0.0 45.0
   LOCATION  Pa3      AREA 2134 2819
   SRCPARAM  Pa3      1.0 0.0 45.0
   LOCATION  Pa2      AREA 1943 3200
   SRCPARAM  Pa2      1.0 0.0 45.0
   LOCATION  Pa1      AREA 2286 3086
   SRCPARAM  Pa1      1.0 0.0 45.0
   LOCATION  581d     AREA 2515 2438
   SRCPARAM  581d     1.0 0.0 45.0
   LOCATION  581b     AREA 2438 2629
   SRCPARAM  581b     1.0 0.0 45.0
   LOCATION  581c     AREA 2819 2934
   SRCPARAM  581c     1.0 0.0 45.0
   LOCATION  560d     AREA 2438 3239
   SRCPARAM  560d     1.0 0.0 45.0
   LOCATION  560b     AREA 2400 3315
   SRCPARAM  560b     1.0 0.0 45.0
   LOCATION  560c     AREA 2248 3391
   SRCPARAM  560c     1.0 0.0 45.0
   LOCATION  560a     AREA 2210 3734
   SRCPARAM  560a     1.0 0.0 45.0
   LOCATION  570b     AREA 1448 3162
   SRCPARAM  570b     1.0 0.0 45.0
   LOCATION  1sp      AREA 1715 3086
   SRCPARAM  1sp      1.0 0.0 45.0
   LOCATION  570au    AREA 1715 3277
   SRCPARAM  570au    1.0 0.0 45.0
   LOCATION  570d     AREA 1867 3391
   SRCPARAM  570d     1.0 0.0 45.0
   LOCATION  sw1      AREA 1943 3505
   SRCPARAM  sw1      1.0 0.0 45.0
   LOCATION  wp1      AREA 1676 3543
   SRCPARAM  wp1      1.0 0.0 45.0
```

```
   LOCATION  wp2      AREA 1448 3505
   SRCPARAM  wp2      1.0 0.0 45.0
   LOCATION  wpaa     AREA 1219 3620
   SRCPARAM  wpaa     1.0 0.0 45.0
   LOCATION  wpaou4   AREA 1372 3277
   SRCPARAM  wpaou4   1.0 0.0 45.0

   EMISUNIT  1 Grams/Sec Grams/M**3
** Source Group will change each run until all source groups are ran
   SRCGROUP  caselong all
   SRCGROUP  case582a 582a
   SRCGROUP  case582b 582b

SO FINISHED

RE STARTING
** FEMP PROPERTY LINE RECEPTORS (36 total)
RE DISCCART 800 2134
RE DISCCART 838 2362
RE DISCCART 838 2591
RE DISCCART 838 2819
RE DISCCART 914 3048
RE DISCCART 1029 3277
RE DISCCART 1067 3505
RE DISCCART 1181 3810
RE DISCCART 1257 4191
RE DISCCART 1410 4420
RE DISCCART 1791 4191
RE DISCCART 2019 4039
RE DISCCART 2172 3962
RE DISCCART 2400 3810
RE DISCCART 2591 3810
RE DISCCART 2858 3620
RE DISCCART 3048 3543
**
** The Following Receptor is NE Corner
RE DISCCART 3315 3505
**
RE DISCCART 3239 3391
RE DISCCART 3162 3277
RE DISCCART 3086 3162
RE DISCCART 3010 3048
RE DISCCART 2858 2858
RE DISCCART 2743 2705
RE DISCCART 2629 2477
RE DISCCART 2515 2286
RE DISCCART 2400 2096
RE DISCCART 2286 1905
RE DISCCART 2172 1715
RE DISCCART 2057 1486
RE DISCCART 1791 1638
RE DISCCART 1638 1676
RE DISCCART 1448 1715
RE DISCCART 1219 1791
RE DISCCART 1029 1867
RE DISCCART 914 1981
RE DISCCART 3315 4420
**
** The following Receptor is Non-Remedial Worker (50,61)
RE DISCCART 1906 2326
**
** The following Receptors Represent Near Public Property Receptors
** NPPR1 (60 112)
RE DISCCART 2286 4267
** NPPR2 (66 111)
RE DISCCART 2515 4229
** NPPR3 (69 109)
RE DISCCART 2629 4153
** NPPR4 (75 106)
RE DISCCART 2858 4039
** NPPR5 (80 103)
RE DISCCART 3048 3924
** NPPR6 (85 99)
RE DISCCART 3239 3772
** NPPR7 (87 79)
RE DISCCART 3315 3010
```

```
** NPPR8 (87 74)
RE DISCCART 3315 2819
** NPPR9 (84 69)
RE DISCCART 3200 2629
** NPPR10 (81 62)
RE DISCCART 3086 2362
** NPPR11 (77 57)
RE DISCCART 2934 2172
** NPPR12 (72 51)
RE DISCCART 2743 1943
** NPPR13 (67 46)
RE DISCCART 2553 1753
** NPPR14 (63 39)
RE DISCCART 2400 1486
** NPPR15 (60 34)
RE DISCCART 2286 1295
** NPPR16 (56 29)
RE DISCCART 2134 1105
** NPPR17 (49 26)
RE DISCCART 1867 991
** NPPR18 (41 29)
RE DISCCART 1562 1105
** NPPR19 (32 34)
RE DISCCART 1219 1295
** NPPR20 (26 38)
RE DISCCART 991 1448
** NPPR21 (17 46)
RE DISCCART 648 1753
** NPPR22 (14 53)
RE DISCCART 533 2019
** NPPR23 (14 63)
RE DISCCART 533 2400
** NPPR24 (14 71)
RE DISCCART 533 2705
** NPPR25 (15 81)
RE DISCCART 572 3086
** NPPR26 (20 89)
RE DISCCART 762 3391
** NPPR27 (24 96)
RE DISCCART 914 3658
** NPPR28 (26 106)
RE DISCCART 991 4039
**
** Center of Site Receptor  (49,78)
RE DISCCART 1867 2972
**
** Receptor Grid Code Follows: Receptor Point on Every 4th Block of Sketch
RE GRIDCART CAR1 STA
** max allowabe receptor = 500  (isc default)
** 125ft x 125ft block = 38m x38m
** X = 0 -> 3315 meters; Y = 0 -> 4420 meters (area of sketch)
** receptor grid: x = 760 -> 3344, y = 1140 -> 4484 (area of concern)
** Receptor grid with source point every 152 m (500 ft) (4 blocks)
**                    Xinit Xnum Xdelta Yinit Ynum Ydelta
**                    ----- ---- ------ ----- ---- ------
**
           CAR1 XYINC 760 18 152 1140 23 152
           CAR1 END

RE FINISHED

ME STARTING
   INPUTFIL  C:\isc\weather\jfd87_92.out
   ANEMHGHT  10.0
**
   SURFDATA  00000  0000  FEMP-STANDARD-JFD
   UAIRDATA  13840  1987  DAYTON
   STARDATA ANNUAL
**
** Stability Class  A    B    C    D    E    F
**                 ---  ---  ---  ---  ---  ---
   AVETEMPS ANNUAL 290. 289. 288. 283. 283. 283.
**
** Wind Speed Class   1     2     3     4     5     6
**                   ----  ----  ----  ----  ----  ----
   AVEMIXHT ANNUAL A 1823. 1991. 1791. 1695. 1629. 2313.
```


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```
    AVEMIXHT ANNUAL B 1215. 1327. 1194. 1130. 1086. 1542.
    AVEMIXHT ANNUAL C 1215. 1327. 1194. 1130. 1086. 1542.
    AVEMIXHT ANNUAL D 1215. 1327. 1194. 1130. 1086. 1542.
    AVEMIXHT ANNUAL E 5000. 5000. 5000. 5000. 5000. 5000.
    AVEMIXHT ANNUAL F 5000. 5000. 5000. 5000. 5000. 5000.

ME FINISHED

OU STARTING
   RECTABLE  SRCGRP INDSRC
   MAXTABLE  10 INDSRC SRCGRP
   PLOTFILE ANNUAL caselong all.plt
   PLOTFILE ANNUAL case582a 582a.plt
   PLOTFILE ANNUAL case582b 582b.plt

OU FINISHED


*** Message Summary For ISC2 Model Setup ***

--------- Summary of Total Messages --------

A Total of          0 Fatal Error Message(s)
A Total of         68 Warning Message(s)
A Total of          0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
RE W228   94 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   95 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   96 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   97 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   98 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   99 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  100 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  101 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  102 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  103 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  104 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  105 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  106 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  107 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  108 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  109 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  110 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  113 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  115 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  116 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  117 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  118 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  119 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  120 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  121 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  122 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  123 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  124 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  125 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  126 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  127 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  128 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  129 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  130 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  131 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  132 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  133 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  136 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  140 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  142 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  144 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  146 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  148 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  150 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
```

```
RE W228  152 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  154 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  156 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  158 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  160 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  162 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  164 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  166 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  168 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  170 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  172 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  174 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  176 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  178 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  180 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  182 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  184 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  186 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  188 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  190 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  192 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  194 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  197 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W216  210 RECART: FLAG Input Inconsistent With Option: Defaults Used CAR1

************************************
*** SETUP Finishes Successfully ***
************************************
```


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```
*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:39
                                                                                                                PAGE   1
 *** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                                        ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

**Model Is Setup For Calculation of Average CONCentration Values.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Default Wind Profile Exponents.
          5. Default Vertical Potential Temperature Gradients.

**Model Assumes Receptors on FLAT Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                          Seasons/Quarters:  0  0  0  0
                                                and Annual:  1

**Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                          Seasons/Quarters:  0  0  0  0
                                                and Annual:  1

**This Run Includes:   32 Source(s);      3 Source Group(s); and    481 Receptor(s)

**The Model Assumes A Pollutant Type of:  OTHER

**Model Set To Continue RUNning After the Setup Testing.

 Output Options Selected:
        Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
        Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
        Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =    1.0000
                 Output Units   = GRAMS/M**3

**Input Runstream File: C:\isc\testcase\longterm\long1.in       ;  **Output Print File: C:\isc\testcase\longterm\long1.out
**Error Message File: C:\ISC\ERRORS.OUT
```

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 2

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS /METER**2)	COORD (SW CORNER) X (METERS)	Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	WIDTH OF AREA (METERS)	EMISSION RATE SCALAR VARY BY
582A	0	.10000E+01	1562.0	1753.0	.0	.00	45.00	
582B	0	.10000E+01	1219.0	2096.0	.0	.00	45.00	
AFP	0	.10000E+01	1219.0	2134.0	.0	.00	45.00	
SF	0	.10000E+01	1181.0	2362.0	.0	.00	45.00	
580A	0	.10000E+01	1448.0	2324.0	.0	.00	45.00	
581A	0	.10000E+01	2057.0	2096.0	.0	.00	45.00	
575A	0	.10000E+01	1029.0	2743.0	.0	.00	45.00	
575B	0	.10000E+01	1257.0	2781.0	.0	.00	45.00	
570E	0	.10000E+01	1372.0	2896.0	.0	.00	45.00	
570A	0	.10000E+01	1448.0	2667.0	.0	.00	45.00	
PA6	0	.10000E+01	1829.0	2477.0	.0	.00	45.00	
PA5	0	.10000E+01	1981.0	2629.0	.0	.00	45.00	
PA4	0	.10000E+01	1753.0	2858.0	.0	.00	45.00	
PA3	0	.10000E+01	2134.0	2819.0	.0	.00	45.00	
PA2	0	.10000E+01	1943.0	3200.0	.0	.00	45.00	
PA1	0	.10000E+01	2286.0	3086.0	.0	.00	45.00	
581D	0	.10000E+01	2515.0	2438.0	.0	.00	45.00	
581B	0	.10000E+01	2438.0	2629.0	.0	.00	45.00	
581C	0	.10000E+01	2819.0	2934.0	.0	.00	45.00	
560D	0	.10000E+01	2438.0	3239.0	.0	.00	45.00	
560B	0	.10000E+01	2400.0	3315.0	.0	.00	45.00	
560C	0	.10000E+01	2248.0	3391.0	.0	.00	45.00	
560A	0	.10000E+01	2210.0	3734.0	.0	.00	45.00	
570B	0	.10000E+01	1448.0	3162.0	.0	.00	45.00	
1SP	0	.10000E+01	1715.0	3086.0	.0	.00	45.00	
570AU	0	.10000E+01	1715.0	3277.0	.0	.00	45.00	
570D	0	.10000E+01	1867.0	3391.0	.0	.00	45.00	
SW1	0	.10000E+01	1943.0	3505.0	.0	.00	45.00	
WP1	0	.10000E+01	1676.0	3543.0	.0	.00	45.00	
WP2	0	.10000E+01	1448.0	3505.0	.0	.00	45.00	
WPAA	0	.10000E+01	1219.0	3620.0	.0	.00	45.00	
WPAOU4	0	.10000E+01	1372.0	3277.0	.0	.00	45.00	

```
*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***    19:43:39
                                                                                                              PAGE   3
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                                   *** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID                                                  SOURCE IDs

 CASELONG

 CASE582A  582A    ,

 CASE582B  582B    ,
```

```
*** ISCLT2 - VERSION 92062 ***   ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***   09/29/94
                                 ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***   19:43:39
                                                                                                            PAGE  4

*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                                  *** GRIDDED RECEPTOR NETWORK SUMMARY ***

                              *** NETWORK ID: CAR1     ;  NETWORK TYPE: GRIDCART ***

                                     *** X-COORDINATES OF GRID ***
                                              (METERS)

     760.0,    912.0,   1064.0,   1216.0,   1368.0,   1520.0,   1672.0,   1824.0,   1976.0,   2128.0,
    2280.0,   2432.0,   2584.0,   2736.0,   2888.0,   3040.0,   3192.0,   3344.0,

                                     *** Y-COORDINATES OF GRID ***
                                              (METERS)

    1140.0,   1292.0,   1444.0,   1596.0,   1748.0,   1900.0,   2052.0,   2204.0,   2356.0,   2508.0,
    2660.0,   2812.0,   2964.0,   3116.0,   3268.0,   3420.0,   3572.0,   3724.0,   3876.0,   4028.0,
    4180.0,   4332.0,   4484.0,
```

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 5

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 760.00	912.00	1064.00	1216.00	1368.00	1520.00	1672.00	1824.00	1976.00
4484.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4332.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4028.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3876.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3724.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3572.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3420.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3268.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3116.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2964.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2812.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2660.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2508.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2356.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2204.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2052.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1900.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1748.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1596.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1444.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1292.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 2128.00	2280.00	2432.00	2584.00	2736.00	2888.00	3040.00	3192.00	3344.00
4484.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4332.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
4028.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3876.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3724.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3572.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3420.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3268.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3116.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2964.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2812.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2660.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2508.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2356.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2204.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2052.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1900.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1748.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1596.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1444.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1292.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92          ***    19:43:39
                                                                                                              PAGE   7
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** DISCRETE CARTESIAN RECEPTORS ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

(800.0,	2134.0,	.0,	1.5);	(838.0,	2362.0,	.0,	1.5);
(838.0,	2591.0,	.0,	1.5);	(838.0,	2819.0,	.0,	1.5);
(914.0,	3048.0,	.0,	1.5);	(1029.0,	3277.0,	.0,	1.5);
(1067.0,	3505.0,	.0,	1.5);	(1181.0,	3810.0,	.0,	1.5);
(1257.0,	4191.0,	.0,	1.5);	(1410.0,	4420.0,	.0,	1.5);
(1791.0,	4191.0,	.0,	1.5);	(2019.0,	4039.0,	.0,	1.5);
(2172.0,	3962.0,	.0,	1.5);	(2400.0,	3810.0,	.0,	1.5);
(2591.0,	3810.0,	.0,	1.5);	(2858.0,	3620.0,	.0,	1.5);
(3048.0,	3543.0,	.0,	1.5);	(3315.0,	3505.0,	.0,	1.5);
(3239.0,	3391.0,	.0,	1.5);	(3162.0,	3277.0,	.0,	1.5);
(3086.0,	3162.0,	.0,	1.5);	(3010.0,	3048.0,	.0,	1.5);
(2858.0,	2858.0,	.0,	1.5);	(2743.0,	2705.0,	.0,	1.5);
(2629.0,	2477.0,	.0,	1.5);	(2515.0,	2286.0,	.0,	1.5);
(2400.0,	2096.0,	.0,	1.5);	(2286.0,	1905.0,	.0,	1.5);
(2172.0,	1715.0,	.0,	1.5);	(2057.0,	1486.0,	.0,	1.5);
(1791.0,	1638.0,	.0,	1.5);	(1638.0,	1676.0,	.0,	1.5);
(1448.0,	1715.0,	.0,	1.5);	(1219.0,	1791.0,	.0,	1.5);
(1029.0,	1867.0,	.0,	1.5);	(914.0,	1981.0,	.0,	1.5);
(3315.0,	4420.0,	.0,	1.5);	(1906.0,	2326.0,	.0,	1.5);
(2286.0,	4267.0,	.0,	1.5);	(2515.0,	4229.0,	.0,	1.5);
(2629.0,	4153.0,	.0,	1.5);	(2858.0,	4039.0,	.0,	1.5);
(3048.0,	3924.0,	.0,	1.5);	(3239.0,	3772.0,	.0,	1.5);
(3315.0,	3010.0,	.0,	1.5);	(3315.0,	2819.0,	.0,	1.5);
(3200.0,	2629.0,	.0,	1.5);	(3086.0,	2362.0,	.0,	1.5);
(2934.0,	2172.0,	.0,	1.5);	(2743.0,	1943.0,	.0,	1.5);
(2553.0,	1753.0,	.0,	1.5);	(2400.0,	1486.0,	.0,	1.5);
(2286.0,	1295.0,	.0,	1.5);	(2134.0,	1105.0,	.0,	1.5);
(1867.0,	991.0,	.0,	1.5);	(1562.0,	1105.0,	.0,	1.5);
(1219.0,	1295.0,	.0,	1.5);	(991.0,	1448.0,	.0,	1.5);
(648.0,	1753.0,	.0,	1.5);	(533.0,	2019.0,	.0,	1.5);
(533.0,	2400.0,	.0,	1.5);	(533.0,	2705.0,	.0,	1.5);
(572.0,	3086.0,	.0,	1.5);	(762.0,	3391.0,	.0,	1.5);
(914.0,	3658.0,	.0,	1.5);	(991.0,	4039.0,	.0,	1.5);
(1867.0,	2972.0,	.0,	1.5);				

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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:3
                                                                                                               PAGE  8

*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                            * SOURCE-RECEPTOR COMBINATIONS LESS THAN 1.0 METER OR 3*ZLB *
                                  IN DISTANCE.  CALCULATIONS MAY NOT BE PERFORMED.

                             SOURCE          - - RECEPTOR LOCATION - -          DISTANCE
                               ID            XR (METERS)   YR (METERS)          (METERS)
                           - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

                             560C               2280.0        3420.0            -13.88
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*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 9

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01
F	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	290.0000	289.0000	288.0000	283.0000	283.0000	283.0000

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1823.0000	1991.0000	1791.0000	1695.0000	1629.0000	2313.0000
STABILITY CATEGORY B	1215.0000	1327.0000	1194.0000	1130.0000	1086.0000	1542.0000
STABILITY CATEGORY C	1215.0000	1327.0000	1194.0000	1130.0000	1086.0000	1542.0000
STABILITY CATEGORY D	1215.0000	1327.0000	1194.0000	1130.0000	1086.0000	1542.0000
STABILITY CATEGORY E	5000.0000	5000.0000	5000.0000	5000.0000	5000.0000	5000.0000
STABILITY CATEGORY F	5000.0000	5000.0000	5000.0000	5000.0000	5000.0000	5000.0000

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\isc\weather\jfd87_92.out FORMAT: (6F10.0)
SURFACE STATION NO.: 0 UPPER AIR STATION NO.: 13840
NAME: FEMP-STANDARD-JFD NAME: DAYTON
YEAR: 0 YEAR: 1987

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00026300	.00090400	.00090400	.00005800	.00000000	.00000000
22.500	.00029200	.00154600	.00067100	.00000000	.00000000	.00000000
45.000	.00081700	.00288800	.00119600	.00002900	.00000000	.00000000
67.500	.00143000	.00443400	.00204200	.00011700	.00000000	.00000000
90.000	.00105000	.00201300	.00020400	.00014600	.00000000	.00000000
112.500	.00070000	.00081700	.00005800	.00000000	.00000000	.00000000
135.000	.00046700	.00043800	.00000000	.00000000	.00000000	.00000000
157.500	.00058300	.00055400	.00000000	.00000000	.00000000	.00000000
180.000	.00070000	.00157500	.00119600	.00000000	.00000000	.00000000
202.500	.00102100	.00434700	.00379300	.00014600	.00000000	.00000000
225.000	.00128400	.00507600	.00475500	.00055400	.00000000	.00000000
247.500	.00175000	.00475500	.00364700	.00020400	.00000000	.00000000
270.000	.00099200	.00388000	.00326700	.00046700	.00000000	.00000000
292.500	.00061300	.00180900	.00262600	.00052500	.00000000	.00000000
315.000	.00058300	.00157500	.00140000	.00011700	.00000000	.00000000
337.500	.00035000	.00131300	.00128400	.00005800	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00002900	.00081700	.00070000	.00011700	.00000000	.00000000
22.500	.00011700	.00052500	.00049600	.00005800	.00000000	.00000000
45.000	.00035000	.00096300	.00061300	.00005800	.00000000	.00000000
67.500	.00032100	.00145900	.00055400	.00014600	.00000000	.00000000
90.000	.00046700	.00067100	.00017500	.00002900	.00000000	.00000000
112.500	.00026300	.00026300	.00002900	.00000000	.00000000	.00000000
135.000	.00023300	.00020400	.00002900	.00000000	.00000000	.00000000
157.500	.00026300	.00046700	.00008800	.00002900	.00000000	.00000000
180.000	.00040800	.00113800	.00032100	.00000000	.00000000	.00000000
202.500	.00052500	.00154600	.00131300	.00017500	.00000000	.00000000
225.000	.00061300	.00204200	.00207100	.00023300	.00000000	.00000000
247.500	.00061300	.00169200	.00128400	.00017500	.00000000	.00000000
270.000	.00067100	.00116700	.00122500	.00014600	.00000000	.00000000
292.500	.00023300	.00078800	.00087500	.00020400	.00000000	.00000000
315.000	.00026300	.00067100	.00102100	.00020400	.00000000	.00000000
337.500	.00014600	.00064200	.00090400	.00008800	.00000000	.00000000

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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***    19:43:39
                                                                                                              PAGE  12

*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

        *** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

        FILE: C:\isc\weather\jfd87_92.out              FORMAT: (6F10.0)
        SURFACE STATION NO.:      0                    UPPER AIR STATION NO.:  13840
                     NAME: FEMP-STANDARD-JFD                          NAME: DAYTON
                     YEAR:      0                                     YEAR:   1987
```

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00020400	.00084600	.00107900	.00023300	.00000000	.00000000
22.500	.00017500	.00131300	.00072900	.00005800	.00000000	.00000000
45.000	.00040800	.00148800	.00102100	.00008800	.00000000	.00000000
67.500	.00070000	.00172100	.00043800	.00026300	.00000000	.00000000
90.000	.00105000	.00087500	.00020400	.00005800	.00000000	.00000000
112.500	.00067100	.00058300	.00005800	.00000000	.00000000	.00000000
135.000	.00032100	.00046700	.00008800	.00000000	.00000000	.00000000
157.500	.00014600	.00046700	.00005800	.00005800	.00000000	.00000000
180.000	.00032100	.00116700	.00055400	.00005800	.00000000	.00000000
202.500	.00055400	.00175000	.00157500	.00005800	.00002900	.00000000
225.000	.00090400	.00274200	.00175000	.00017500	.00000000	.00000000
247.500	.00075900	.00242100	.00125400	.00020400	.00000000	.00000000
270.000	.00078800	.00128400	.00113800	.00032100	.00000000	.00000000
292.500	.00032100	.00134200	.00125400	.00020400	.00000000	.00000000
315.000	.00023300	.00134200	.00113800	.00011700	.00002900	.00000000
337.500	.00023300	.00107900	.00096300	.00002900	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00210100	.00872300	.00921900	.00107900	.00000000	.00000000
22.500	.00283000	.01053200	.00825600	.00113800	.00000000	.00000000
45.000	.00446400	.01342000	.00749800	.00049600	.00000000	.00000000
67.500	.00633100	.01782500	.00916100	.00204200	.00000000	.00000000
90.000	.00449300	.00612700	.00107900	.00008800	.00000000	.00000000
112.500	.00323800	.00297600	.00011700	.00000000	.00000000	.00000000
135.000	.00262600	.00262600	.00035000	.00000000	.00000000	.00000000
157.500	.00280100	.00361800	.00110900	.00020400	.00000000	.00000000
180.000	.00306300	.00659300	.00288800	.00032100	.00000000	.00000000
202.500	.00580600	.01409100	.00743900	.00180900	.00000000	.00000000
225.000	.00784800	.01447000	.00802300	.00105000	.00005800	.00000000
247.500	.00837300	.01120300	.00627200	.00116700	.00000000	.00000000
270.000	.00706000	.01155300	.00948200	.00143000	.00000000	.00000000
292.500	.00478500	.01041500	.01061900	.00154600	.00000000	.00000000
315.000	.00373400	.00904400	.00726400	.00096300	.00008800	.00000000
337.500	.00297600	.00884000	.00563100	.00105000	.00005800	.00000000

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 13

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\isc\weather\jfd87_92.out FORMAT: (6F10.0)
SURFACE STATION NO.: 0 UPPER AIR STATION NO.: 13840
NAME: FEMP-STANDARD-JFD NAME: DAYTON
YEAR: 0 YEAR: 1987

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00361800	.00388000	.00075900	.00002900	.00000000	.00000000
22.500	.00259600	.00309200	.00078800	.00017500	.00000000	.00000000
45.000	.00297600	.00347200	.00043800	.00000000	.00000000	.00000000
67.500	.00869400	.00921900	.00180900	.00000000	.00000000	.00000000
90.000	.00819800	.00274200	.00023300	.00000000	.00000000	.00000000
112.500	.00478500	.00125400	.00014600	.00000000	.00000000	.00000000
135.000	.00484300	.00172100	.00029200	.00000000	.00000000	.00000000
157.500	.00557200	.00341300	.00128400	.00020400	.00000000	.00000000
180.000	.00697300	.00767300	.00335500	.00064200	.00000000	.00000000
202.500	.01158200	.01403300	.00679800	.00169200	.00000000	.00000000
225.000	.01849600	.01826300	.00741000	.00067100	.00000000	.00000000
247.500	.01779600	.01032800	.00329700	.00064200	.00000000	.00000000
270.000	.01248600	.01000700	.00414300	.00014600	.00000000	.00000000
292.500	.00948200	.00761400	.00329700	.00058300	.00000000	.00000000
315.000	.00834400	.00466800	.00110900	.00017500	.00000000	.00000000
337.500	.00621400	.00382200	.00107900	.00026300	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00498800	.00011700	.00000000	.00000000	.00000000	.00000000
22.500	.00525100	.00008800	.00002900	.00000000	.00000000	.00000000
45.000	.00507600	.00011700	.00000000	.00000000	.00000000	.00000000
67.500	.00910200	.00160500	.00011700	.00000000	.00000000	.00000000
90.000	.01336100	.00090400	.00000000	.00000000	.00000000	.00000000
112.500	.00892700	.00005800	.00000000	.00000000	.00000000	.00000000
135.000	.00592200	.00032100	.00000000	.00000000	.00000000	.00000000
157.500	.00545600	.00017500	.00000000	.00000000	.00000000	.00000000
180.000	.00700200	.00046700	.00000000	.00000000	.00000000	.00000000
202.500	.01181500	.00119600	.00026300	.00000000	.00000000	.00000000
225.000	.01957600	.00210100	.00002900	.00000000	.00000000	.00000000
247.500	.02681100	.00186700	.00005800	.00000000	.00000000	.00000000
270.000	.02975700	.00067100	.00002900	.00000000	.00000000	.00000000
292.500	.02931900	.00023300	.00002900	.00000000	.00000000	.00000000
315.000	.02278500	.00075800	.00005800	.00000000	.00000000	.00000000
337.500	.01152300	.00087600	.00005800	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99996

Pages 14 through 109 of this computer printout contain dispersion results for each model grid node. Since these nodes do not correspond with actual receptors, their dispersion results have omitted from this report to conserve space. The printout resumes on the following page and presents results for the selected receptor locations.

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 110

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASELONG ***
INCLUDING SOURCE(S):

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 760.00	912.00	1064.00	1216.00	1368.00	1520.00	1672.00	1824.00	1976.00
4484.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4332.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4180.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4028.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3876.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3724.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3572.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3420.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3268.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3116.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2964.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2812.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2660.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2508.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2356.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2204.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2052.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1900.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1748.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1596.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1444.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1292.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1140.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
PAGE 111

*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASELONG ***
INCLUDING SOURCE(S):

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 2128.00	2280.00	2432.00	2584.00	2736.00	2888.00	3040.00	3192.00	3344.00
4484.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4332.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4180.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
4028.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3876.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3724.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3572.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3420.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3268.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
3116.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2964.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2812.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2660.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2508.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2356.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2204.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
2052.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1900.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1748.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1596.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1444.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
1292.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000
1140.00	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASELONG ***
INCLUDING SOURCE(S):

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF OTHER IN GRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
800.00	2134.00	.000000	838.00	2362.00	.000000
838.00	2591.00	.000000	838.00	2819.00	.000000
914.00	3048.00	.000000	1029.00	3277.00	.000000
1067.00	3505.00	.000000	1181.00	3810.00	.000000
1257.00	4191.00	.000000	1410.00	4420.00	.000000
1791.00	4191.00	.000000	2019.00	4039.00	.000000
2172.00	3962.00	.000000	2400.00	3810.00	.000000
2591.00	3810.00	.000000	2858.00	3620.00	.000000
3048.00	3543.00	.000000	3315.00	3505.00	.000000
3239.00	3391.00	.000000	3162.00	3277.00	.000000
3086.00	3162.00	.000000	3010.00	3048.00	.000000
2858.00	2858.00	.000000	2743.00	2705.00	.000000
2629.00	2477.00	.000000	2515.00	2286.00	.000000
2400.00	2096.00	.000000	2286.00	1905.00	.000000
2172.00	1715.00	.000000	2057.00	1486.00	.000000
1791.00	1638.00	.000000	1638.00	1676.00	.000000
1448.00	1715.00	.000000	1219.00	1791.00	.000000
1029.00	1867.00	.000000	914.00	1981.00	.000000
3315.00	4420.00	.000000	1906.00	2326.00	.000000
2286.00	4267.00	.000000	2515.00	4229.00	.000000
2629.00	4153.00	.000000	2858.00	4039.00	.000000
3048.00	3924.00	.000000	3239.00	3772.00	.000000
3315.00	3010.00	.000000	3315.00	2819.00	.000000
3200.00	2629.00	.000000	3086.00	2362.00	.000000
2934.00	2172.00	.000000	2743.00	1943.00	.000000
2553.00	1753.00	.000000	2400.00	1486.00	.000000
2286.00	1295.00	.000000	2134.00	1105.00	.000000
1867.00	991.00	.000000	1562.00	1105.00	.000000
1219.00	1295.00	.000000	991.00	1448.00	.000000
648.00	1753.00	.000000	533.00	2019.00	.000000
533.00	2400.00	.000000	533.00	2705.00	.000000
572.00	3086.00	.000000	762.00	3391.00	.000000
914.00	3658.00	.000000	991.00	4039.00	.000000
1867.00	2972.00	.000000			

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582A ***
INCLUDING SOURCE(S): 582A ,

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 760.00	912.00	1064.00	1216.00	1368.00	1520.00	1672.00	1824.00	1976.00
4484.00	.000547	.000588	.000628	.000666	.000701	.000733	.000833	.000913	.000984
4332.00	.000584	.000632	.000679	.000723	.000764	.000801	.000917	.001008	.001089
4180.00	.000625	.000682	.000736	.000788	.000837	.000880	.001014	.001120	.001212
4028.00	.000670	.000737	.000802	.000864	.000921	.000972	.001130	.001254	.001359
3876.00	.000723	.000798	.000877	.000951	.001021	.001082	.001269	.001414	.001536
3724.00	.000796	.000868	.000963	.001054	.001139	.001214	.001440	.001611	.001751
3572.00	.000835	.000947	.001066	.001181	.001287	.001380	.001656	.001862	.002026
3420.00	.000933	.001087	.001188	.001334	.001468	.001585	.001929	.002180	.002374
3268.00	.001047	.001132	.001330	.001519	.001694	.001845	.002281	.002592	.002822
3116.00	.001181	.001295	.001531	.001747	.001980	.002182	.002748	.003139	.003411
2964.00	.001337	.001493	.001742	.002030	.002352	.002629	.003386	.003886	.004206
2812.00	.001517	.001733	.001954	.002384	.002847	.003245	.004293	.004944	.005542
2660.00	.001742	.002020	.002348	.003088	.003549	.004165	.005702	.006548	.007850
2508.00	.002067	.002395	.002872	.003433	.004598	.005625	.008034	.009170	.010533
2356.00	.002525	.002967	.003617	.004524	.006619	.008119	.012248	.016812	.015077
2204.00	.003047	.003794	.004754	.006260	.008946	.012926	.020980	.025926	.024257
2052.00	.004189	.005755	.006434	.009143	.013827	.024266	.052328	.051845	.033694
1900.00	.005315	.007157	.010332	.017328	.028805	.074849	.198253	.094710	.045926
1748.00	.006863	.009735	.015184	.027211	.062942	.350261	.461997	.104930	.048634
1596.00	.006876	.009617	.014960	.023511	.034583	.049107	.076224	.056053	.038613
1444.00	.006964	.007985	.009933	.012767	.013394	.016239	.021864	.025234	.022975
1292.00	.004955	.005685	.006587	.006667	.008929	.008971	.011361	.014441	.013
1140.00	.003707	.004058	.004038	.004724	.005338	.005709	.007020	.008616	.00

001490

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582A ***
INCLUDING SOURCE(S): 582A ,

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 2128.00	2280.00	2432.00	2584.00	2736.00	2888.00	3040.00	3192.00	3344.00
4484.00	.001046	.001097	.001139	.001172	.001253	.001264	.001277	.001280	.001276
4332.00	.001158	.001214	.001259	.001293	.001373	.001392	.001400	.001397	.001387
4180.00	.001289	.001351	.001399	.001528	.001524	.001539	.001540	.001530	.001511
4028.00	.001446	.001514	.001564	.001674	.001700	.001708	.001700	.001681	.001652
3876.00	.001633	.001708	.001838	.001885	.001904	.001902	.001883	.001850	.001809
3724.00	.001862	.001942	.002113	.002136	.002143	.002126	.002091	.002042	.001984
3572.00	.002148	.002246	.002412	.002435	.002424	.002386	.002328	.002258	.002229
3420.00	.002510	.002818	.002802	.002798	.002754	.002686	.002600	.002564	.002399
3268.00	.002972	.003260	.003284	.003241	.003153	.003036	.002989	.002777	.002584
3116.00	.003894	.003909	.003882	.003778	.003626	.003553	.003265	.003011	.002777
2964.00	.004727	.004744	.004629	.004430	.004329	.003933	.003578	.003256	.002974
2812.00	.005934	.005828	.005564	.005420	.004855	.004355	.003907	.003512	.003171
2660.00	.007601	.007247	.007033	.006180	.005441	.004796	.004241	.003767	.003362
2508.00	.009985	.009586	.008199	.007034	.006052	.005237	.004563	.004004	.003735
2356.00	.014290	.011596	.009514	.007911	.006646	.005747	.005054	.004227	.003713
2204.00	.018213	.013929	.010847	.009329	.007235	.006022	.005123	.004416	.003849
2052.00	.022777	.017740	.012060	.009417	.007614	.006297	.005305	.004539	.003935
1900.00	.026254	.017650	.012811	.009788	.007822	.006419	.005378	.004584	.003962
1748.00	.028155	.018502	.013268	.010064	.007999	.006540	.005466	.004649	.004012
1596.00	.023301	.015920	.011796	.009144	.007378	.006098	.005138	.004399	.003817
1444.00	.016892	.013214	.011007	.008349	.006865	.005750	.004893	.004220	.003682
1292.00	.012591	.010288	.008479	.007110	.006551	.005293	.004567	.003981	.003502
1140.00	.008332	.008099	.007012	.006100	.005312	.004646	.004216	.003779	.003287

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582A ***
INCLUDING SOURCE(S): 582A ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF OTHER IN GRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
800.00	2134.00	.003768	838.00	2362.00	.002717
838.00	2591.00	.001988	838.00	2819.00	.001616
914.00	3048.00	.001381	1029.00	3277.00	.001278
1067.00	3505.00	.001120	1181.00	3810.00	.000976
1257.00	4191.00	.000797	1410.00	4420.00	.000736
1791.00	4191.00	.001090	2019.00	4039.00	.001374
2172.00	3962.00	.001545	2400.00	3810.00	.001919
2591.00	3810.00	.001990	2858.00	3620.00	.002307
3048.00	3543.00	.002374	3315.00	3505.00	.002405
3239.00	3391.00	.002586	3162.00	3277.00	.002803
3086.00	3162.00	.003103	3010.00	3048.00	.003462
2858.00	2858.00	.004312	2743.00	2705.00	.005235
2629.00	2477.00	.006885	2515.00	2286.00	.009069
2400.00	2096.00	.013358	2286.00	1905.00	.017379
2172.00	1715.00	.022630	2057.00	1486.00	.021263
1791.00	1638.00	.074571	1638.00	1676.00	.201065
1448.00	1715.00	.121440	1219.00	1791.00	.026251
1029.00	1867.00	.010057	914.00	1981.00	.006185
3315.00	4420.00	.001323	1906.00	2326.00	.016914
2286.00	4267.00	.001272	2515.00	4229.00	.001372
2629.00	4153.00	.001534	2858.00	4039.00	.001694
3048.00	3924.00	.001821	3239.00	3772.00	.001964
3315.00	3010.00	.002963	3315.00	2819.00	.003222
3200.00	2629.00	.003793	3086.00	2362.00	.004747
2934.00	2172.00	.005787	2743.00	1943.00	.007716
2553.00	1753.00	.010719	2400.00	1486.00	.011538
2286.00	1295.00	.010257	2134.00	1105.00	.007732
1867.00	991.00	.005598	1562.00	1105.00	.005894
1219.00	1295.00	.006745	991.00	1448.00	.009026
648.00	1753.00	.005534	533.00	2019.00	.003247
533.00	2400.00	.001921	533.00	2705.00	.001403
572.00	3086.00	.001062	762.00	3391.00	.000954
914.00	3658.00	.000902	991.00	4039.00	.000766
1867.00	2972.00	.003947			

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582B ***
INCLUDING SOURCE(S): 582B ,

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 760.00	912.00	1064.00	1216.00	1368.00	1520.00	1672.00	1824.00	1976.00
4484.00	.000767	.000820	.000869	.000954	.001072	.001178	.001269	.001345	.001404
4332.00	.000837	.000901	.000960	.001059	.001198	.001322	.001426	.001510	.001575
4180.00	.000918	.000995	.001066	.001186	.001350	.001495	.001615	.001709	.001779
4028.00	.001013	.001109	.001196	.001341	.001540	.001711	.001848	.001952	.002026
3876.00	.001128	.001248	.001357	.001536	.001780	.001985	.002144	.002258	.002531
3724.00	.001263	.001416	.001556	.001781	.002085	.002334	.002520	.002644	.002888
3572.00	.001423	.001623	.001805	.002097	.002481	.002787	.003004	.003352	.003423
3420.00	.001614	.001881	.002126	.002512	.003012	.003393	.003644	.004091	.004101
3268.00	.001963	.002206	.002549	.003078	.003744	.004226	.004596	.005014	.004969
3116.00	.002107	.002624	.003122	.003882	.004799	.005413	.006464	.006293	.006087
2964.00	.002563	.003371	.003976	.005144	.006484	.007242	.008263	.008034	.007532
2812.00	.003195	.003994	.005274	.007223	.009297	.011977	.011379	.010489	.009901
2660.00	.004095	.005197	.007488	.011054	.014514	.017615	.016129	.014846	.011522
2508.00	.005507	.007450	.012172	.019249	.028621	.028817	.025416	.017935	.013546
2356.00	.008213	.011291	.018098	.042279	.071021	.055039	.032425	.024433	.015316
2204.00	.012562	.021372	.049611	.193448	.229651	.082333	.038848	.023876	.016301
2052.00	.016838	.031072	.087020	.274537	.216456	.071597	.037024	.022872	.015694
1900.00	.016055	.020373	.028030	.038109	.052276	.042787	.028893	.021032	.014193
1748.00	.009278	.010835	.013616	.016278	.021448	.020903	.019283	.014658	.011457
1596.00	.005762	.006382	.007656	.009026	.010223	.012372	.011582	.011122	.009233
1444.00	.003932	.004502	.004929	.005760	.006532	.008428	.008009	.007536	.007365
1292.00	.003021	.003567	.003572	.004036	.004560	.004912	.005704	.005669	.005401
1140.00	.002398	.002550	.002720	.003005	.003372	.003680	.004346	.004366	.004301

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582B ***
INCLUDING SOURCE(S): 582B ,

*** NETWORK ID: CAR1 ; NETWORK TYPE: GRIDCART ***

** CONC OF OTHER IN GRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 2128.00	2280.00	2432.00	2584.00	2736.00	2888.00	3040.00	3192.00	3344.00
4484.00	.001449	.001546	.001572	.001581	.001577	.001563	.001539	.001511	.001479
4332.00	.001672	.001733	.001752	.001754	.001740	.001715	.001681	.001641	.001598
4180.00	.001937	.001952	.001962	.001952	.001925	.001887	.001839	.001785	.001765
4028.00	.002186	.002211	.002207	.002180	.002136	.002080	.002015	.001989	.001858
3876.00	.002512	.002519	.002494	.002444	.002376	.002296	.002264	.002102	.001977
3724.00	.002918	.002893	.002831	.002748	.002648	.002606	.002404	.002247	.002100
3572.00	.003417	.003347	.003235	.003099	.003043	.002783	.002583	.002397	.002226
3420.00	.004032	.003893	.003712	.003623	.003271	.003008	.002768	.002549	.002352
3268.00	.004796	.004551	.004424	.003939	.003570	.003240	.002955	.002701	.002476
3116.00	.005743	.005554	.004859	.004340	.003881	.003481	.003139	.002848	.002593
2964.00	.007232	.006179	.005411	.004751	.004191	.003715	.003315	.003029	.002772
2812.00	.008181	.006970	.005970	.005152	.004481	.004122	.003485	.003113	.002805
2660.00	.009372	.007752	.006540	.005817	.004751	.004135	.003633	.003222	.002889
2508.00	.011147	.008644	.006969	.005844	.004976	.004294	.003747	.003302	.002949
2356.00	.011486	.009011	.007306	.006058	.005117	.004389	.003812	.003348	.002980
2204.00	.011953	.009235	.007426	.006124	.005153	.004407	.003821	.003351	.002979
2052.00	.011560	.008964	.007229	.005976	.005038	.004316	.003748	.003291	.002930
1900.00	.010735	.008475	.006909	.005756	.004881	.004200	.003660	.003222	.002875
1748.00	.010184	.007708	.006405	.005410	.004634	.004019	.003522	.003116	.002792
1596.00	.007745	.006569	.005862	.005082	.004318	.003784	.003345	.002981	.002686
1444.00	.006448	.005655	.004962	.004369	.003866	.003665	.003137	.002824	.0025
1292.00	.005346	.004810	.004328	.003888	.003496	.003152	.002854	.002707	.002
1140.00	.004114	.004088	.003746	.003432	.003136	.002865	.002626	.002417	.0022

*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: CASE582B ***
INCLUDING SOURCE(S): 582B ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF OTHER IN GRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
800.00	2134.00	.019214	838.00	2362.00	.009126
838.00	2591.00	.005207	838.00	2819.00	.003486
914.00	3048.00	.002859	1029.00	3277.00	.002447
1067.00	3505.00	.001940	1181.00	3810.00	.001519
1257.00	4191.00	.001250	1410.00	4420.00	.001155
1791.00	4191.00	.001676	2019.00	4039.00	.002134
2172.00	3962.00	.002328	2400.00	3810.00	.002644
2591.00	3810.00	.002567	2858.00	3620.00	.002752
3048.00	3543.00	.002607	3315.00	3505.00	.002315
3239.00	3391.00	.002514	3162.00	3277.00	.002740
3086.00	3162.00	.002996	3010.00	3048.00	.003287
2858.00	2858.00	.003964	2743.00	2705.00	.004747
2629.00	2477.00	.005612	2515.00	2286.00	.006643
2400.00	2096.00	.008001	2286.00	1905.00	.008424
2172.00	1715.00	.008990	2057.00	1486.00	.007248
1791.00	1638.00	.012446	1638.00	1676.00	.015888
1448.00	1715.00	.019620	1219.00	1791.00	.020379
1029.00	1867.00	.021959	914.00	1981.00	.033361
3315.00	4420.00	.001535	1906.00	2326.00	.018160
2286.00	4267.00	.001823	2515.00	4229.00	.001890
2629.00	4153.00	.001983	2858.00	4039.00	.002076
3048.00	3924.00	.002246	3239.00	3772.00	.002157
3315.00	3010.00	.002771	3315.00	2819.00	.002855
3200.00	2629.00	.003222	3086.00	2362.00	.003660
2934.00	2172.00	.004209	2743.00	1943.00	.004900
2553.00	1753.00	.005607	2400.00	1486.00	.005292
2286.00	1295.00	.004806	2134.00	1105.00	.003925
1867.00	991.00	.003462	1562.00	1105.00	.003517
1219.00	1295.00	.004106	991.00	1448.00	.005049
648.00	1753.00	.008222	533.00	2019.00	.008821
533.00	2400.00	.005278	533.00	2705.00	.002829
572.00	3086.00	.001862	762.00	3391.00	.001669
914.00	3658.00	.001503	991.00	4039.00	.001145
1867.00	2972.00	.007812			

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*** ISCLT2 - VERSION 92062 ***     ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                   ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:39
                                                                                                                 PAGE 119
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 582A ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.461997	AT (	1672.00,	1748.00)	GC	6.	.104930	AT (	1824.00,	1748.00)	GC
2.	.350261	AT (	1520.00,	1748.00)	GC	7.	.094710	AT (	1824.00,	1900.00)	GC
3.	.201065	AT (	1638.00,	1676.00)	DC	8.	.076224	AT (	1672.00,	1596.00)	GC
4.	.198253	AT (	1672.00,	1900.00)	GC	9.	.074849	AT (	1520.00,	1900.00)	GC
5.	.121440	AT (	1448.00,	1715.00)	DC	10.	.074571	AT (	1791.00,	1638.00)	DC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 582B ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.274537	AT (	1216.00,	2052.00)	GC	6.	.082333	AT (	1520.00,	2204.00)	GC
2.	.229651	AT (	1368.00,	2204.00)	GC	7.	.071597	AT (	1520.00,	2052.00)	GC
3.	.216456	AT (	1368.00,	2052.00)	GC	8.	.071021	AT (	1368.00,	2356.00)	GC
4.	.193448	AT (	1216.00,	2204.00)	GC	9.	.055039	AT (	1520.00,	2356.00)	GC
5.	.087020	AT (	1064.00,	2052.00)	GC	10.	.052276	AT (	1368.00,	1900.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: AFP ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.409961	AT (	1216.00,	2204.00)	GC	6.	.077865	AT (	1520.00,	2204.00)	GC
2.	.287221	AT (	1368.00,	2204.00)	GC	7.	.074968	AT (	1520.00,	2052.00)	GC
3.	.146726	AT (	1368.00,	2052.00)	GC	8.	.064604	AT (	1064.00,	2052.00)	GC
4.	.128201	AT (	1216.00,	2052.00)	GC	9.	.059428	AT (	1064.00,	2204.00)	GC
5.	.086344	AT (	1368.00,	2356.00)	GC	10.	.057712	AT (	1520.00,	2356.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: SF ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.512474	AT (	1216.00,	2356.00)	GC	6.	.076539	AT (	1368.00,	2204.00)	GC
2.	.187605	AT (	1368.00,	2356.00)	GC	7.	.069847	AT (	1520.00,	2508.00)	GC
3.	.167843	AT (	1216.00,	2508.00)	GC	8.	.068028	AT (	1520.00,	2356.00)	GC
4.	.134701	AT (	1368.00,	2508.00)	GC	9.	.059662	AT (	1216.00,	2204.00)	GC
5.	.126546	AT (	1064.00,	2356.00)	GC	10.	.052639	AT (	1368.00,	2660.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 *** *** Long Term Dispersion Factors for PO113 Risk Assessment *** 09/29/94
*** ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92 *** 19:43:39
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*** MODELING OPTIONS USED: CONC RURAL FLAT FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 580A ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	1.143686	AT (	1520.00,	2356.00)	GC	6.	.095737	AT (	1672.00,	2508.00)	GC
2.	.182949	AT (	1368.00,	2356.00)	GC	7.	.075836	AT (	1672.00,	2204.00)	GC
3.	.153186	AT (	1672.00,	2356.00)	GC	8.	.062939	AT (	1824.00,	2356.00)	GC
4.	.127890	AT (	1520.00,	2508.00)	GC	9.	.061491	AT (	1368.00,	2204.00)	GC
5.	.106908	AT (	1520.00,	2204.00)	GC	10.	.054473	AT (	1824.00,	2508.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 581A ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.366523	AT (	2128.00,	2052.00)	GC	6.	.078277	AT (	1976.00,	2204.00)	GC
2.	.361223	AT (	2128.00,	2204.00)	GC	7.	.068834	AT (	2400.00,	2096.00)	DC
3.	.147403	AT (	1976.00,	2052.00)	GC	8.	.067021	AT (	2280.00,	2356.00)	GC
4.	.144992	AT (	2280.00,	2204.00)	GC	9.	.058702	AT (	2286.00,	1905.00)	DC
5.	.125997	AT (	2280.00,	2052.00)	GC	10.	.055897	AT (	2280.00,	1900.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 575A ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.776211	AT (	1064.00,	2812.00)	GC	6.	.084136	AT (	912.00,	2812.00)	GC
2.	.193165	AT (	1216.00,	2812.00)	GC	7.	.077075	AT (	912.00,	2660.00)	GC
3.	.158528	AT (	1064.00,	2660.00)	GC	8.	.071519	AT (	1064.00,	2964.00)	GC
4.	.120001	AT (	1216.00,	2660.00)	GC	9.	.064621	AT (	1368.00,	2812.00)	GC
5.	.090525	AT (	1216.00,	2964.00)	GC	10.	.060040	AT (	1368.00,	2660.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 575B ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.536308	AT (	1368.00,	2812.00)	GC	6.	.075007	AT (	1520.00,	2964.00)	GC
2.	.358552	AT (	1216.00,	2812.00)	GC	7.	.067588	AT (	1216.00,	2660.00)	GC
3.	.129375	AT (	1368.00,	2964.00)	GC	8.	.066335	AT (	1520.00,	2660.00)	GC
4.	.117404	AT (	1520.00,	2812.00)	GC	9.	.063441	AT (	1064.00,	2812.00)	GC
5.	.107533	AT (	1368.00,	2660.00)	GC	10.	.057646	AT (	1216.00,	2964.00)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:39
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*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 570E ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.421086	AT (	1368.00,	2964.00)	GC	6.	.079157	AT (	1672.00,	2964.00)	GC
2.	.293041	AT (	1520.00,	2964.00)	GC	7.	.075500	AT (	1672.00,	2812.00)	GC
3.	.145768	AT (	1520.00,	2812.00)	GC	8.	.063035	AT (	1216.00,	2812.00)	GC
4.	.124139	AT (	1368.00,	2812.00)	GC	9.	.060265	AT (	1216.00,	2964.00)	GC
5.	.087646	AT (	1520.00,	3116.00)	GC	10.	.058243	AT (	1672.00,	3116.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 570A ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.795701	AT (	1520.00,	2660.00)	GC	6.	.068704	AT (	1672.00,	2508.00)	GC
2.	.206156	AT (	1520.00,	2812.00)	GC	7.	.067573	AT (	1520.00,	2508.00)	GC
3.	.193886	AT (	1368.00,	2660.00)	GC	8.	.056798	AT (	1824.00,	2660.00)	GC
4.	.133201	AT (	1672.00,	2660.00)	GC	9.	.056287	AT (	1824.00,	2812.00)	GC
5.	.109523	AT (	1672.00,	2812.00)	GC	10.	.054555	AT (	1368.00,	2812.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA6 ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.369806	AT (	1824.00,	2508.00)	GC	6.	.083066	AT (	1672.00,	2508.00)	GC
2.	.318101	AT (	1976.00,	2508.00)	GC	7.	.077749	AT (	1824.00,	2356.00)	GC
3.	.127875	AT (	1976.00,	2660.00)	GC	8.	.076634	AT (	1906.00,	2326.00)	DC
4.	.109655	AT (	1976.00,	2356.00)	GC	9.	.076562	AT (	1824.00,	2660.00)	GC
5.	.094180	AT (	2128.00,	2508.00)	GC	10.	.066485	AT (	2128.00,	2660.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA5 ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.369806	AT (	1976.00,	2660.00)	GC	6.	.083066	AT (	1824.00,	2660.00)	GC
2.	.318101	AT (	2128.00,	2660.00)	GC	7.	.077749	AT (	1976.00,	2508.00)	GC
3.	.127875	AT (	2128.00,	2812.00)	GC	8.	.076562	AT (	1976.00,	2812.00)	GC
4.	.109655	AT (	2128.00,	2508.00)	GC	9.	.066485	AT (	2280.00,	2812.00)	GC
5.	.094180	AT (	2280.00,	2660.00)	GC	10.	.061747	AT (	2280.00,	2508.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:39
                                                                                                                PAGE 122
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA4 ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.372254	AT (	1824.00,	2964.00)	GC	6.	.126160	AT (	1976.00,	2812.00)	GC
2.	.348388	AT (	1824.00,	2812.00)	GC	7.	.080383	AT (	1672.00,	2964.00)	GC
3.	.285102	AT (	1867.00,	2972.00)	DC	8.	.068123	AT (	1976.00,	3116.00)	GC
4.	.146926	AT (	1976.00,	2964.00)	GC	9.	.055254	AT (	1824.00,	3116.00)	GC
5.	.144285	AT (	1672.00,	2812.00)	GC	10.	.054921	AT (	1976.00,	2660.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA3 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.546880	AT (	2128.00,	2812.00)	GC	6.	.083839	AT (	2432.00,	2812.00)	GC
2.	.288320	AT (	2280.00,	2812.00)	GC	7.	.083773	AT (	1976.00,	2812.00)	GC
3.	.189671	AT (	2280.00,	2964.00)	GC	8.	.069577	AT (	2280.00,	2660.00)	GC
4.	.113784	AT (	2128.00,	2964.00)	GC	9.	.059806	AT (	2280.00,	3116.00)	GC
5.	.084741	AT (	2432.00,	2964.00)	GC	10.	.053393	AT (	2432.00,	3116.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA2 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.786743	AT (	1976.00,	3268.00)	GC	6.	.083643	AT (	1824.00,	3268.00)	GC
2.	.197629	AT (	2128.00,	3268.00)	GC	7.	.075498	AT (	1824.00,	3116.00)	GC
3.	.154243	AT (	1976.00,	3116.00)	GC	8.	.072093	AT (	1976.00,	3420.00)	GC
4.	.120165	AT (	2128.00,	3116.00)	GC	9.	.065576	AT (	2280.00,	3268.00)	GC
5.	.091195	AT (	2128.00,	3420.00)	GC	10.	.060781	AT (	2280.00,	3116.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: PA1 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.365286	AT (	2280.00,	3116.00)	GC	6.	.083085	AT (	2128.00,	3116.00)	GC
2.	.321926	AT (	2432.00,	3116.00)	GC	7.	.076557	AT (	2280.00,	3268.00)	GC
3.	.129160	AT (	2432.00,	3268.00)	GC	8.	.076514	AT (	2280.00,	2964.00)	GC
4.	.108301	AT (	2432.00,	2964.00)	GC	9.	.067106	AT (	2584.00,	3268.00)	GC
5.	.095071	AT (	2584.00,	3116.00)	GC	10.	.061393	AT (	2584.00,	2964.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***      19:43:39
                                                                                                                PAGE 123
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 581D ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.742718	AT (	2584.00,	2508.00)	GC	6.	.106279	AT (	2736.00,	2356.00)	GC
2.	.492228	AT (	2629.00,	2477.00)	DC	7.	.096069	AT (	2432.00,	2356.00)	GC
3.	.184507	AT (	2584.00,	2356.00)	GC	8.	.090618	AT (	2736.00,	2660.00)	GC
4.	.139341	AT (	2736.00,	2508.00)	GC	9.	.080998	AT (	2584.00,	2660.00)	GC
5.	.117474	AT (	2432.00,	2508.00)	GC	10.	.063686	AT (	2743.00,	2705.00)	DC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 581B ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.363879	AT (	2432.00,	2660.00)	GC	6.	.082405	AT (	2280.00,	2660.00)	GC
2.	.322175	AT (	2584.00,	2660.00)	GC	7.	.081328	AT (	2629.00,	2477.00)	DC
3.	.127752	AT (	2584.00,	2812.00)	GC	8.	.077416	AT (	2432.00,	2508.00)	GC
4.	.109565	AT (	2584.00,	2508.00)	GC	9.	.075798	AT (	2432.00,	2812.00)	GC
5.	.094725	AT (	2736.00,	2660.00)	GC	10.	.075389	AT (	2743.00,	2705.00)	DC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 581C ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	1.115515	AT (	2888.00,	2964.00)	GC	6.	.129043	AT (	2888.00,	3116.00)	GC
2.	.180315	AT (	2858.00,	2858.00)	DC	7.	.103559	AT (	2888.00,	2812.00)	GC
3.	.179163	AT (	2736.00,	2964.00)	GC	8.	.098063	AT (	3040.00,	3116.00)	GC
4.	.161997	AT (	3010.00,	3048.00)	DC	9.	.076992	AT (	3040.00,	2812.00)	GC
5.	.157987	AT (	3040.00,	2964.00)	GC	10.	.068815	AT (	3086.00,	3162.00)	DC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 560D ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.321626	AT (	2584.00,	3268.00)	GC	6.	.083760	AT (	2280.00,	3268.00)	GC
2.	.290311	AT (	2432.00,	3268.00)	GC	7.	.077327	AT (	2432.00,	3420.00)	GC
3.	.130581	AT (	2584.00,	3420.00)	GC	8.	.075625	AT (	2432.00,	3116.00)	GC
4.	.107048	AT (	2584.00,	3116.00)	GC	9.	.067571	AT (	2736.00,	3420.00)	GC
5.	.095414	AT (	2736.00,	3268.00)	GC	10.	.060906	AT (	2736.00,	3116.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***    19:43:39
                                                                                                              PAGE 124
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR SOURCE:  560B     ***

                       ** CONC OF OTHER    IN GRAMS/M**3                                  **

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .335166 AT (    2432.00,    3268.00)  GC         6.       .064824 AT (    2584.00,    3572.00)  GC
  2.       .325771 AT (    2432.00,    3420.00)  GC         7.       .064522 AT (    2736.00,    3420.00)  GC
  3.       .180634 AT (    2584.00,    3420.00)  GC         8.       .060934 AT (    2280.00,    3420.00)  GC
  4.       .170566 AT (    2584.00,    3268.00)  GC         9.       .059350 AT (    2736.00,    3268.00)  GC
  5.       .107262 AT (    2280.00,    3268.00)  GC        10.       .054905 AT (    2432.00,    3572.00)  GC

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR SOURCE:  560C     ***

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .213636 AT (    2432.00,    3420.00)  GC         6.       .084457 AT (    2280.00,    3268.00)  GC
  2.       .127546 AT (    2432.00,    3572.00)  GC         7.       .077458 AT (    2584.00,    3420.00)  GC
  3.       .116560 AT (    2128.00,    3420.00)  GC         8.       .061407 AT (    2584.00,    3572.00)  GC
  4.       .100212 AT (    2280.00,    3572.00)  GC         9.       .058532 AT (    2128.00,    3268.00)  GC
  5.       .097462 AT (    2432.00,    3268.00)  GC        10.       .055996 AT (    2584.00,    3268.00)  GC

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR SOURCE:  560A     ***

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .778214 AT (    2280.00,    3724.00)  GC         6.       .113063 AT (    2432.00,    3876.00)  GC
  2.       .213034 AT (    2280.00,    3876.00)  GC         7.       .068848 AT (    2432.00,    3572.00)  GC
  3.       .188322 AT (    2400.00,    3810.00)  DC         8.       .064632 AT (    2280.00,    3572.00)  GC
  4.       .187863 AT (    2128.00,    3724.00)  GC         9.       .056566 AT (    2584.00,    3876.00)  GC
  5.       .133587 AT (    2432.00,    3724.00)  GC        10.       .056427 AT (    2584.00,    3724.00)  GC

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR SOURCE:  570B     ***

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .371039 AT (    1520.00,    3268.00)  GC         6.       .080936 AT (    1368.00,    3268.00)  GC
  2.       .348112 AT (    1520.00,    3116.00)  GC         7.       .068193 AT (    1672.00,    3420.00)  GC
  3.       .146215 AT (    1672.00,    3268.00)  GC         8.       .055820 AT (    1520.00,    3420.00)  GC
  4.       .145388 AT (    1368.00,    3116.00)  GC         9.       .054992 AT (    1672.00,    2964.00)  GC
  5.       .125166 AT (    1672.00,    3116.00)  GC        10.       .052650 AT (    1824.00,    3268.00)  GC

*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92          ***    19:43:39
                                                                                                              PAGE 125

*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 1SP ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.556536	AT (	1824.00,	3116.00)	GC	6.	.105699	AT (	1824.00,	2964.00)	GC
2.	.347341	AT (	1672.00,	3116.00)	GC	7.	.075884	AT (	1976.00,	3268.00)	GC
3.	.131464	AT (	1824.00,	3268.00)	GC	8.	.066149	AT (	1672.00,	2964.00)	GC
4.	.119411	AT (	1976.00,	3116.00)	GC	9.	.065930	AT (	1976.00,	2964.00)	GC
5.	.118840	AT (	1867.00,	2972.00)	DC	10.	.063040	AT (	1520.00,	3116.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 570AU ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.460077	AT (	1824.00,	3268.00)	GC	6.	.077500	AT (	1672.00,	3420.00)	GC
2.	.329035	AT (	1672.00,	3268.00)	GC	7.	.074489	AT (	1824.00,	3116.00)	GC
3.	.208351	AT (	1824.00,	3420.00)	GC	8.	.061759	AT (	1520.00,	3268.00)	GC
4.	.102832	AT (	1976.00,	3268.00)	GC	9.	.055926	AT (	1976.00,	3116.00)	GC
5.	.097658	AT (	1976.00,	3420.00)	GC	10.	.053789	AT (	1824.00,	3572.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: 570D ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.558859	AT (	1976.00,	3420.00)	GC	6.	.076114	AT (	2128.00,	3572.00)	GC
2.	.349937	AT (	1824.00,	3420.00)	GC	7.	.065705	AT (	1824.00,	3268.00)	GC
3.	.132364	AT (	1976.00,	3572.00)	GC	8.	.065296	AT (	2128.00,	3268.00)	GC
4.	.119873	AT (	2128.00,	3420.00)	GC	9.	.063518	AT (	1672.00,	3420.00)	GC
5.	.104215	AT (	1976.00,	3268.00)	GC	10.	.058469	AT (	1824.00,	3572.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: SW1 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.805188	AT (	1976.00,	3572.00)	GC	6.	.084711	AT (	1824.00,	3572.00)	GC
2.	.198165	AT (	2128.00,	3572.00)	GC	7.	.074665	AT (	1824.00,	3420.00)	GC
3.	.151826	AT (	1976.00,	3420.00)	GC	8.	.072661	AT (	1976.00,	3724.00)	GC
4.	.119053	AT (	2128.00,	3420.00)	GC	9.	.065903	AT (	2280.00,	3572.00)	GC
5.	.092052	AT (	2128.00,	3724.00)	GC	10.	.060836	AT (	2280.00,	3420.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***      09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92          ***      19:43:39
                                                                                                                 PAGE 126
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL
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*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: WP1 ***

** CONC OF OTHER IN GRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.313522	AT (	1824.00,	3572.00)	GC	6.	.085115	AT (	1520.00,	3572.00)	GC
2.	.298753	AT (	1672.00,	3572.00)	GC	7.	.078886	AT (	1672.00,	3724.00)	GC
3.	.130787	AT (	1824.00,	3724.00)	GC	8.	.076255	AT (	1672.00,	3420.00)	GC
4.	.107251	AT (	1824.00,	3420.00)	GC	9.	.067243	AT (	1976.00,	3724.00)	GC
5.	.094318	AT (	1976.00,	3572.00)	GC	10.	.060652	AT (	1976.00,	3420.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: WP2 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.762352	AT (	1520.00,	3572.00)	GC	6.	.093500	AT (	1368.00,	3420.00)	GC
2.	.174749	AT (	1520.00,	3420.00)	GC	7.	.090088	AT (	1672.00,	3724.00)	GC
3.	.136243	AT (	1672.00,	3572.00)	GC	8.	.085567	AT (	1520.00,	3724.00)	GC
4.	.128885	AT (	1368.00,	3572.00)	GC	9.	.054995	AT (	1824.00,	3572.00)	GC
5.	.102355	AT (	1672.00,	3420.00)	GC	10.	.049749	AT (	1216.00,	3420.00)	GC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: WPAA ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.252104	AT (	1216.00,	3572.00)	GC	6.	.081437	AT (	1520.00,	3724.00)	GC
2.	.236495	AT (	1368.00,	3724.00)	GC	7.	.072455	AT (	1368.00,	3876.00)	GC
3.	.209119	AT (	1368.00,	3572.00)	GC	8.	.072141	AT (	1520.00,	3572.00)	GC
4.	.207225	AT (	1216.00,	3724.00)	GC	9.	.055243	AT (	1520.00,	3876.00)	GC
5.	.087299	AT (	1064.00,	3572.00)	GC	10.	.054484	AT (	1181.00,	3810.00)	DC

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: WPAOU4 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.534936	AT (	1368.00,	3268.00)	GC	6.	.085116	AT (	1672.00,	3420.00)	GC
2.	.278846	AT (	1520.00,	3268.00)	GC	7.	.081919	AT (	1672.00,	3268.00)	GC
3.	.187848	AT (	1520.00,	3420.00)	GC	8.	.068152	AT (	1520.00,	3116.00)	GC
4.	.119082	AT (	1368.00,	3420.00)	GC	9.	.060057	AT (	1520.00,	3572.00)	GC
5.	.085353	AT (	1216.00,	3268.00)	GC	10.	.053049	AT (	1672.00,	3572.00)	GC

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*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
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*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for P0113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***    19:43:39
                                                                                                              PAGE 127

*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR GROUP:  CASELONG ***
                      INCLUDING SOURCE(S):

                        ** CONC OF OTHER    IN GRAMS/M**3                          **

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .000000 AT (        .00,        .00)             6.       .000000 AT (        .00,        .00)
  2.       .000000 AT (        .00,        .00)             7.       .000000 AT (        .00,        .00)
  3.       .000000 AT (        .00,        .00)             8.       .000000 AT (        .00,        .00)
  4.       .000000 AT (        .00,        .00)             9.       .000000 AT (        .00,        .00)
  5.       .000000 AT (        .00,        .00)            10.       .000000 AT (        .00,        .00)

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR GROUP:  CASE582A ***
                      INCLUDING SOURCE(S):      582A    ,

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .461997 AT (    1672.00,    1748.00)  GC          6.       .104930 AT (    1824.00,    1748.00)  GC
  2.       .350261 AT (    1520.00,    1748.00)  GC          7.       .094710 AT (    1824.00,    1900.00)  GC
  3.       .201065 AT (    1638.00,    1676.00)  DC          8.       .076224 AT (    1672.00,    1596.00)  GC
  4.       .198253 AT (    1672.00,    1900.00)  GC          9.       .074849 AT (    1520.00,    1900.00)  GC
  5.       .121440 AT (    1448.00,    1715.00)  DC         10.       .074571 AT (    1791.00,    1638.00)  DC

                  *** THE MAXIMUM   10  ANNUAL  AVERAGE CONCENTRATION    VALUES FOR GROUP:  CASE582B ***
                      INCLUDING SOURCE(S):      582B    ,

RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  1.       .274537 AT (    1216.00,    2052.00)  GC          6.       .082333 AT (    1520.00,    2204.00)  GC
  2.       .229651 AT (    1368.00,    2204.00)  GC          7.       .071597 AT (    1520.00,    2052.00)  GC
  3.       .216456 AT (    1368.00,    2052.00)  GC          8.       .071021 AT (    1368.00,    2356.00)  GC
  4.       .193448 AT (    1216.00,    2204.00)  GC          9.       .055039 AT (    1520.00,    2356.00)  GC
  5.       .087020 AT (    1064.00,    2052.00)  GC         10.       .052276 AT (    1368.00,    1900.00)  GC

*** RECEPTOR TYPES:  GC = GRIDCART
                     GP = GRIDPOLR
                     DC = DISCCART
                     DP = DISCPOLR
                     BD = BOUNDARY
```

```
*** ISCLT2 - VERSION 92062 ***    ***  Long Term Dispersion Factors for PO113 Risk Assessment          ***    09/29/94
                                  ***  ORIGIN AT 0,0 - Meteorlogical data based on JFD '88-'92         ***    19:43:39
                                                                                                              PAGE 128
*** MODELING OPTIONS USED:  CONC   RURAL  FLAT   FLGPOL

*** Message Summary For ISC2 Model Execution ***

 --------- Summary of Total Messages --------

A Total of          0 Fatal Error Message(s)
A Total of         68 Warning Message(s)
A Total of          0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
             ***  NONE  ***


   ********   WARNING MESSAGES   ********
RE W228   94 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   95 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   96 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   97 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   98 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228   99 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  100 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  101 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  102 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  103 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  104 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  105 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  106 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  107 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  108 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  109 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  110 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  113 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  115 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  116 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  117 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  118 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  119 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  120 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  121 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  122 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  123 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  124 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  125 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  126 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  127 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  128 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  129 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  130 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  131 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  132 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  133 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  136 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  140 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  142 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  144 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  146 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  148 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  150 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  152 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
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RE W228  156 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  158 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  160 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  162 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  164 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  166 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  168 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  170 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  172 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  174 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
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RE W228  176 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  178 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  180 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  182 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  184 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  186 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  188 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  190 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  192 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  194 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W228  197 DISCAR: Default(s) Used for Missing Parameters on Keyword  DISCCART
RE W216  210 RECART: FLAG Input Inconsistent With Option: Defaults Used CAR1

   ************************************
   *** ISCLT2 Finishes Successfully ***
   ************************************
```


001506

```
   STARTING
   TITLEONE  Short Term Dispersion Factors for PO113 Risk Assessment
   TITLETWO  CASE 1 - Meteorlogical data based on 1988 FEMP Hourly Data
   MODELOPT  RURAL CONC MSGPRO
   AVERTIME  PERIOD
   POLLUTID  Other
   TERRHGTS  FLAT
   FLAGPOLE  1.5
   RUNORNOT  RUN
   ERRORFIL  C:\ISC\ERRORS.OUT
CO FINISHED

SO STARTING
**
** excavation of 1/2 acre = 45m x 45m
**
** parameters for LOCATION are SW Corner coordinates for area of excavation
** parameters for SRCEPARAM are emission rate, stack height, length of side
**
   LOCATION  582a     AREA 1562 1753
   SRCPARAM  582a     1.0    0.0   45.0
   LOCATION  582b     AREA 1219 2096
   SRCPARAM  582b     1.0    0.0   45.0
   LOCATION  afp      AREA 1219 2134
   SRCPARAM  afp      1.0    0.0    45.0
   LOCATION  sf       AREA 1181 2362
   SRCPARAM  sf       1.0    0.0    45.0
   LOCATION  580a     AREA 1448 2324
   SRCPARAM  580a     1.0    0.0    45.0
   LOCATION  581a     AREA 2057 2096
   SRCPARAM  581a     1.0    0.0    45.0
   LOCATION  575a     AREA 1029 2743
   SRCPARAM  575a     1.0    0.0    45.0
   LOCATION  575b     AREA 1257 2781
   SRCPARAM  575b     1.0    0.0    45.0
   LOCATION  570e     AREA 1372 2896
   SRCPARAM  570e     1.0    0.0    45.0
   LOCATION  570a     AREA 1448 2667
   SRCPARAM  570a     1.0    0.0    45.0
   LOCATION  Pa6      AREA 1829 2477
   SRCPARAM  Pa6      1.0    0.0    45.0
   LOCATION  Pa5      AREA 1981 2629
   SRCPARAM  Pa5      1.0    0.0    45.0
   LOCATION  Pa4      AREA 1753 2858
   SRCPARAM  Pa4      1.0    0.0    45.0
   LOCATION  Pa3      AREA 2134 2819
   SRCPARAM  Pa3      1.0    0.0    45.0
   LOCATION  Pa2      AREA 1943 3200
   SRCPARAM  Pa2      1.0    0.0    45.0
   LOCATION  Pa1      AREA 2286 3086
   SRCPARAM  Pa1      1.0    0.0    45.0
   LOCATION  581d     AREA 2515 2438
   SRCPARAM  581d     1.0    0.0    45.0
   LOCATION  581b     AREA 2438 2629
   SRCPARAM  581b     1.0    0.0    45.0
   LOCATION  581c     AREA 2819 2934
   SRCPARAM  581c     1.0    0.0    45.0
   LOCATION  560d     AREA 2438 3239
   SRCPARAM  560d     1.0    0.0    45.0
   LOCATION  560b     AREA 2400 3315
   SRCPARAM  560b     1.0    0.0    45.0
   LOCATION  560c     AREA 2248 3391
   SRCPARAM  560c     1.0    0.0    45.0
   LOCATION  560a     AREA 2210 3734
   SRCPARAM  560a     1.0    0.0    45.0
   LOCATION  570b     AREA 1448 3162
   SRCPARAM  570b     1.0    0.0    45.0
   LOCATION  1sp      AREA 1715 3086
   SRCPARAM  1sp      1.0    0.0    45.0
   LOCATION  570au    AREA 1715 3277
   SRCPARAM  570au    1.0    0.0    45.0
   LOCATION  570d     AREA 1867 3391
   SRCPARAM  570d     1.0    0.0    45.0
   LOCATION  sw1      AREA 1943 3505
   SRCPARAM  sw1      1.0    0.0    45.0
   LOCATION  wp1      AREA 1676 3543
```

```
   SRCPARAM  wp1      1.0    0.0    45.0
   LOCATION  wp2      AREA 1448 3505
   SRCPARAM  wp2      1.0    0.0    45.0
   LOCATION  wpaa     AREA 1219 3620
   SRCPARAM  wpaa     1.0    0.0    45.0
   LOCATION  wpaou4   AREA 1372 3277
   SRCPARAM  wpaou4   1.0    0.0    45.0
   LOCATION  z1       AREA 953 2248
   SRCPARAM  z1       1.0    0.0    45.0

   EMISUNIT  1e3 Grams/Sec milligrams/M**3
** Source Group will change each run until all source groups are ran
   SRCGROUP  case1 582a

SO FINISHED

RE STARTING
** FEMP PROPERTY LINE RECEPTORS (36 total)
RE DISCCART 800 2134
RE DISCCART 838 2362
RE DISCCART 838 2591
RE DISCCART 838 2819
RE DISCCART 914 3048
RE DISCCART 1029 3277
RE DISCCART 1067 3505
RE DISCCART 1181 3810
RE DISCCART 1257 4191
RE DISCCART 1410 4420
RE DISCCART 1791 4191
RE DISCCART 2019 4039
RE DISCCART 2172 3962
RE DISCCART 2400 3810
RE DISCCART 2591 3810
RE DISCCART 2858 3620
RE DISCCART 3086 3543
**
** The Following Receptor is NE Corner
RE DISCCART 3315 3505
**
RE DISCCART 3239 3391
RE DISCCART 3162 3277
RE DISCCART 3086 3162
RE DISCCART 3010 3048
RE DISCCART 2858 2858
RE DISCCART 2743 2705
RE DISCCART 2629 2477
RE DISCCART 2515 2286
RE DISCCART 2400 2096
RE DISCCART 2286 1905
RE DISCCART 2172 1715
RE DISCCART 2057 1486
RE DISCCART 1791 1638
RE DISCCART 1638 1676
RE DISCCART 1448 1715
RE DISCCART 1219 1791
RE DISCCART 1029 1867
RE DISCCART 914 1981
**
** The following Receptor is Non-Remedial Worker (50,61)
RE DISCCART 1906 2326
**
** The following Receptors Represent Near Public Property Receptors
** NPPR1 (60 112)
RE DISCCART 2286 4267
** NPPR2 (66 111)
RE DISCCART 2515 4229
** NPPR3 (69 109)
RE DISCCART 2629 4153
** NPPR4 (75 106)
RE DISCCART 2858 4039
** NPPR5 (80 103)
RE DISCCART 3048 3924
** NPPR6 (85 99)
RE DISCCART 3239 3772
** NPPR7 (87 79)
RE DISCCART 3315 3010
```

```
** NPPR8 (87 74)
RE DISCCART 3315 2819
** NPPR9 (84 69)
RE DISCCART 3200 2629
** NPPR10 (81 62)
RE DISCCART 3086 2362
** NPPR11 (77 57)
RE DISCCART 2934 2172
** NPPR12 (72 51)
RE DISCCART 2743 1943
** NPPR13 (67 46)
RE DISCCART 2553 1753
** NPPR14 (63 39)
RE DISCCART 2400 1486
** NPPR15 (60 34)
RE DISCCART 2286 1295
** NPPR16 (56 29)
RE DISCCART 2134 1105
** NPPR17 (49 26)
RE DISCCART 1867 991
** NPPR18 (41 29)
RE DISCCART 1562 1105
** NPPR19 (32 34)
RE DISCCART 1219 1295
** NPPR20 (26 38)
RE DISCCART 991 1448
** NPPR21 (17 46)
RE DISCCART 648 1753
** NPPR22 (14 53)
RE DISCCART 533 2019
** NPPR23 (14 63)
RE DISCCART 533 2400
** NPPR24 (14 71)
RE DISCCART 533 2705
** NPPR25 (15 81)
RE DISCCART 572 3086
** NPPR26 (20 89)
RE DISCCART 762 3391
** NPPR27 (24 96)
RE DISCCART 914 3658
** NPPR28 (26 106)
RE DISCCART 991 4039

** Receptor Grid Code Follows: Receptor Point on Every 4th Block of Sketch
RE GRIDCART CAR1 STA
** max allowable receptors = 500  (isc default)
** 125ft x 125ft block = 38m x38m
** X = 0 -> 3315 meters; Y = 0 -> 4420 meters (area of sketch)
** receptor grid: x = 760 -> 3344, y = 1140 -> 4484 (area of concern)
** Receptor grid with source point every 152 m (500 ft) (4 blocks)
**                          Xinit Xnum Xdelta Yinit Ynum Ydelta
**                          ----- ---- ------ ----- ---- ------
            CAR1 XYINC 760 18 152 1140 23 152
            CAR1 END

RE FINISHED

ME STARTING
   INPUTFIL  C:\isc\weather\HR1988.MET
   ANEMHGHT  10.0
**
** The following code will be used to change time period 1/3/6/9 months
**
** Input parameters to average over less than entire year
** parameters stryr strtmn strtdy (strthr) endyr endmn enddy (endhr)
**             ----- ------ ------ -------- ----- ----- ----- -------
   STARTEND    88     06     01        1      88    08    31     24
**
   SURFDATA  22222  1988  FEMP
   UAIRDATA  33333  1988  FEMP
ME FINISHED

OU STARTING
   RECTABLE  ALLAVE first
   POSTFILE  PERIOD  CASE1 PLOT CASE1.OUT 21
OU FINISHED
```

```
* ISCST2 (92062):  Short Term Dispersion Factors for PO113 Risk Assessment
* MODELING OPTIONS USED:
*  CONC   RURAL  FLAT   FLGPOL                                    MSGPRO
*         POST/PLOT FILE OF PERIOD VALUES FOR SOURCE GROUP: CASE1
*         FOR A TOTAL OF   479 RECEPTORS.
*         FORMAT: (3(1X,F13.5),1X,F8.2,2X,A6,2X,A8,2X,I8)
*        X            Y            CONC       ZELEV    AVE      GRP       NUM HRS
*
```

X	Y	CONC	ZELEV	AVE	GRP	NUM HRS
800.00000	2134.00000	23.73944	.00	PERIOD	CASE1	2208
838.00000	2362.00000	12.53900	.00	PERIOD	CASE1	2208
838.00000	2591.00000	8.22415	.00	PERIOD	CASE1	2208
838.00000	2819.00000	5.24597	.00	PERIOD	CASE1	2208
914.00000	3048.00000	2.51961	.00	PERIOD	CASE1	2208
1029.00000	3277.00000	1.22575	.00	PERIOD	CASE1	2208
1067.00000	3505.00000	.95882	.00	PERIOD	CASE1	2208
1181.00000	3810.00000	1.04278	.00	PERIOD	CASE1	2208
1257.00000	4191.00000	1.19273	.00	PERIOD	CASE1	2208
1410.00000	4420.00000	.86979	.00	PERIOD	CASE1	2208
1791.00000	4191.00000	1.08437	.00	PERIOD	CASE1	2208
2019.00000	4039.00000	.71649	.00	PERIOD	CASE1	2208
2172.00000	3962.00000	1.00947	.00	PERIOD	CASE1	2208
2400.00000	3810.00000	.79373	.00	PERIOD	CASE1	2208
2591.00000	3810.00000	.68468	.00	PERIOD	CASE1	2208
2858.00000	3620.00000	.95031	.00	PERIOD	CASE1	2208
3086.00000	3543.00000	1.59765	.00	PERIOD	CASE1	2208
3315.00000	3505.00000	.76500	.00	PERIOD	CASE1	2208
3239.00000	3391.00000	.76105	.00	PERIOD	CASE1	2208
3162.00000	3277.00000	.77073	.00	PERIOD	CASE1	2208
3086.00000	3162.00000	.79468	.00	PERIOD	CASE1	2208
3010.00000	3048.00000	.84562	.00	PERIOD	CASE1	2208
2858.00000	2858.00000	1.04218	.00	PERIOD	CASE1	2208
2743.00000	2705.00000	1.36656	.00	PERIOD	CASE1	2208
2629.00000	2477.00000	3.01009	.00	PERIOD	CASE1	2208
2515.00000	2286.00000	4.81753	.00	PERIOD	CASE1	2208
2400.00000	2096.00000	7.43071	.00	PERIOD	CASE1	2208
2286.00000	1905.00000	9.46200	.00	PERIOD	CASE1	2208
2172.00000	1715.00000	11.86008	.00	PERIOD	CASE1	2208
2057.00000	1486.00000	9.84409	.00	PERIOD	CASE1	2208
1791.00000	1638.00000	45.24384	.00	PERIOD	CASE1	2208
1638.00000	1676.00000	166.93770	.00	PERIOD	CASE1	2208
1448.00000	1715.00000	676.70530	.00	PERIOD	CASE1	2208
1219.00000	1791.00000	125.71090	.00	PERIOD	CASE1	2208
1029.00000	1867.00000	49.87220	.00	PERIOD	CASE1	2208
914.00000	1981.00000	36.49903	.00	PERIOD	CASE1	2208
1906.00000	2326.00000	8.67787	.00	PERIOD	CASE1	2208
2286.00000	4267.00000	.85855	.00	PERIOD	CASE1	2208
2515.00000	4229.00000	.61436	.00	PERIOD	CASE1	2208
2629.00000	4153.00000	.56125	.00	PERIOD	CASE1	2208
2858.00000	4039.00000	.91846	.00	PERIOD	CASE1	2208
3048.00000	3924.00000	.71663	.00	PERIOD	CASE1	2208
3239.00000	3772.00000	1.34595	.00	PERIOD	CASE1	2208
3315.00000	3010.00000	1.15873	.00	PERIOD	CASE1	2208
3315.00000	2819.00000	1.47315	.00	PERIOD	CASE1	2208
3200.00000	2629.00000	2.02607	.00	PERIOD	CASE1	2208
3086.00000	2362.00000	2.76786	.00	PERIOD	CASE1	2208
2934.00000	2172.00000	2.36828	.00	PERIOD	CASE1	2208
2743.00000	1943.00000	4.45947	.00	PERIOD	CASE1	2208
2553.00000	1753.00000	6.24275	.00	PERIOD	CASE1	2208
2400.00000	1486.00000	4.95119	.00	PERIOD	CASE1	2208
2286.00000	1295.00000	6.04294	.00	PERIOD	CASE1	2208
2134.00000	1105.00000	4.76077	.00	PERIOD	CASE1	2208
1867.00000	991.00000	5.49231	.00	PERIOD	CASE1	2208
1562.00000	1105.00000	12.11326	.00	PERIOD	CASE1	2208
1219.00000	1295.00000	47.09748	.00	PERIOD	CASE1	2208
991.00000	1448.00000	48.02004	.00	PERIOD	CASE1	2208
648.00000	1753.00000	25.57181	.00	PERIOD	CASE1	2208
533.00000	2019.00000	17.68324	.00	PERIOD	CASE1	2208
533.00000	2400.00000	9.89364	.00	PERIOD	CASE1	2208
533.00000	2705.00000	5.60054	.00	PERIOD	CASE1	2208
572.00000	3086.00000	4.15655	.00	PERIOD	CASE1	2208
762.00000	3391.00000	1.76725	.00	PERIOD	CASE1	2208
914.00000	3658.00000	.80787	.00	PERIOD	CASE1	2208
991.00000	4039.00000	.58134	.00	PERIOD	CASE1	2208
760.00000	1140.00000	27.61322	.00	PERIOD	CASE1	2208
912.00000	1140.00000	21.27034	.00	PERIOD	CASE1	2208
1064.00000	1140.00000	26.07050	.00	PERIOD	CASE1	2208

1216.00000	1140.00000	22.57822	.00	PERIOD	CASE1	2208
1368.00000	1140.00000	32.03160	.00	PERIOD	CASE1	2208
1520.00000	1140.00000	15.55452	.00	PERIOD	CASE1	2208
1672.00000	1140.00000	12.44790	.00	PERIOD	CASE1	2208
1824.00000	1140.00000	8.54767	.00	PERIOD	CASE1	2208
1976.00000	1140.00000	6.68103	.00	PERIOD	CASE1	2208
2128.00000	1140.00000	5.57377	.00	PERIOD	CASE1	2208
2280.00000	1140.00000	4.97103	.00	PERIOD	CASE1	2208
2432.00000	1140.00000	4.53737	.00	PERIOD	CASE1	2208
2584.00000	1140.00000	2.79586	.00	PERIOD	CASE1	2208
2736.00000	1140.00000	2.24424	.00	PERIOD	CASE1	2208
2888.00000	1140.00000	2.06640	.00	PERIOD	CASE1	2208
3040.00000	1140.00000	1.98309	.00	PERIOD	CASE1	2208
3192.00000	1140.00000	1.88243	.00	PERIOD	CASE1	2208
3344.00000	1140.00000	1.44868	.00	PERIOD	CASE1	2208
760.00000	1292.00000	26.60176	.00	PERIOD	CASE1	2208
912.00000	1292.00000	36.58637	.00	PERIOD	CASE1	2208
1064.00000	1292.00000	35.05567	.00	PERIOD	CASE1	2208
1216.00000	1292.00000	46.46553	.00	PERIOD	CASE1	2208
1368.00000	1292.00000	42.94142	.00	PERIOD	CASE1	2208
1520.00000	1292.00000	28.58329	.00	PERIOD	CASE1	2208
1672.00000	1292.00000	22.67636	.00	PERIOD	CASE1	2208
1824.00000	1292.00000	12.25181	.00	PERIOD	CASE1	2208
1976.00000	1292.00000	8.33048	.00	PERIOD	CASE1	2208
2128.00000	1292.00000	7.54043	.00	PERIOD	CASE1	2208
2280.00000	1292.00000	6.25728	.00	PERIOD	CASE1	2208
2432.00000	1292.00000	3.51215	.00	PERIOD	CASE1	2208
2584.00000	1292.00000	3.19797	.00	PERIOD	CASE1	2208
2736.00000	1292.00000	3.08352	.00	PERIOD	CASE1	2208
2888.00000	1292.00000	2.47088	.00	PERIOD	CASE1	2208
3040.00000	1292.00000	1.70378	.00	PERIOD	CASE1	2208
3192.00000	1292.00000	1.47006	.00	PERIOD	CASE1	2208
3344.00000	1292.00000	1.42306	.00	PERIOD	CASE1	2208
760.00000	1444.00000	34.04935	.00	PERIOD	CASE1	2208
912.00000	1444.00000	39.64331	.00	PERIOD	CASE1	2208
1064.00000	1444.00000	54.68439	.00	PERIOD	CASE1	2208
1216.00000	1444.00000	72.89014	.00	PERIOD	CASE1	2208
1368.00000	1444.00000	85.68475	.00	PERIOD	CASE1	2208
1520.00000	1444.00000	60.02610	.00	PERIOD	CASE1	2208
1672.00000	1444.00000	32.10220	.00	PERIOD	CASE1	2208
1824.00000	1444.00000	20.01149	.00	PERIOD	CASE1	2208
1976.00000	1444.00000	14.07052	.00	PERIOD	CASE1	2208
2128.00000	1444.00000	7.54934	.00	PERIOD	CASE1	2208
2280.00000	1444.00000	5.97410	.00	PERIOD	CASE1	2208
2432.00000	1444.00000	5.17285	.00	PERIOD	CASE1	2208
2584.00000	1444.00000	3.20111	.00	PERIOD	CASE1	2208
2736.00000	1444.00000	2.67791	.00	PERIOD	CASE1	2208
2888.00000	1444.00000	2.48322	.00	PERIOD	CASE1	2208
3040.00000	1444.00000	2.19138	.00	PERIOD	CASE1	2208
3192.00000	1444.00000	1.89993	.00	PERIOD	CASE1	2208
3344.00000	1444.00000	1.66366	.00	PERIOD	CASE1	2208
760.00000	1596.00000	27.30354	.00	PERIOD	CASE1	2208
912.00000	1596.00000	43.98046	.00	PERIOD	CASE1	2208
1064.00000	1596.00000	85.24845	.00	PERIOD	CASE1	2208
1216.00000	1596.00000	114.95590	.00	PERIOD	CASE1	2208
1368.00000	1596.00000	217.64140	.00	PERIOD	CASE1	2208
1520.00000	1596.00000	238.00370	.00	PERIOD	CASE1	2208
1672.00000	1596.00000	67.16314	.00	PERIOD	CASE1	2208
1824.00000	1596.00000	35.71920	.00	PERIOD	CASE1	2208
1976.00000	1596.00000	17.14165	.00	PERIOD	CASE1	2208
2128.00000	1596.00000	9.49282	.00	PERIOD	CASE1	2208
2280.00000	1596.00000	6.89221	.00	PERIOD	CASE1	2208
2432.00000	1596.00000	5.41503	.00	PERIOD	CASE1	2208
2584.00000	1596.00000	4.26935	.00	PERIOD	CASE1	2208
2736.00000	1596.00000	3.54994	.00	PERIOD	CASE1	2208
2888.00000	1596.00000	3.00254	.00	PERIOD	CASE1	2208
3040.00000	1596.00000	2.55264	.00	PERIOD	CASE1	2208
3192.00000	1596.00000	2.19022	.00	PERIOD	CASE1	2208
3344.00000	1596.00000	1.90273	.00	PERIOD	CASE1	2208
760.00000	1748.00000	32.34498	.00	PERIOD	CASE1	2208
912.00000	1748.00000	46.07392	.00	PERIOD	CASE1	2208
1064.00000	1748.00000	71.82563	.00	PERIOD	CASE1	2208
1216.00000	1748.00000	124.62200	.00	PERIOD	CASE1	2208
1368.00000	1748.00000	293.07970	.00	PERIOD	CASE1	2208
1520.00000	1748.00000	2065.08400	.00	PERIOD	CASE1	2208
1672.00000	1748.00000	231.61990	.00	PERIOD	CASE1	2208

1824.00000	1748.00000	56.41545	.00	PERIOD	CASE1	2208
1976.00000	1748.00000	26.06326	.00	PERIOD	CASE1	2208
2128.00000	1748.00000	15.28996	.00	PERIOD	CASE1	2208
2280.00000	1748.00000	10.24181	.00	PERIOD	CASE1	2208
2432.00000	1748.00000	7.50652	.00	PERIOD	CASE1	2208
2584.00000	1748.00000	5.79831	.00	PERIOD	CASE1	2208
2736.00000	1748.00000	4.68959	.00	PERIOD	CASE1	2208
2888.00000	1748.00000	3.88990	.00	PERIOD	CASE1	2208
3040.00000	1748.00000	3.29057	.00	PERIOD	CASE1	2208
3192.00000	1748.00000	2.82785	.00	PERIOD	CASE1	2208
3344.00000	1748.00000	2.46196	.00	PERIOD	CASE1	2208
760.00000	1900.00000	26.34158	.00	PERIOD	CASE1	2208
912.00000	1900.00000	33.47956	.00	PERIOD	CASE1	2208
1064.00000	1900.00000	58.50497	.00	PERIOD	CASE1	2208
1216.00000	1900.00000	95.73817	.00	PERIOD	CASE1	2208
1368.00000	1900.00000	163.79550	.00	PERIOD	CASE1	2208
1520.00000	1900.00000	139.76400	.00	PERIOD	CASE1	2208
1672.00000	1900.00000	117.29450	.00	PERIOD	CASE1	2208
1824.00000	1900.00000	52.00755	.00	PERIOD	CASE1	2208
1976.00000	1900.00000	22.09452	.00	PERIOD	CASE1	2208
2128.00000	1900.00000	12.63413	.00	PERIOD	CASE1	2208
2280.00000	1900.00000	9.75605	.00	PERIOD	CASE1	2208
2432.00000	1900.00000	7.46531	.00	PERIOD	CASE1	2208
2584.00000	1900.00000	5.84846	.00	PERIOD	CASE1	2208
2736.00000	1900.00000	4.82203	.00	PERIOD	CASE1	2208
2888.00000	1900.00000	4.11552	.00	PERIOD	CASE1	2208
3040.00000	1900.00000	3.58349	.00	PERIOD	CASE1	2208
3192.00000	1900.00000	3.15071	.00	PERIOD	CASE1	2208
3344.00000	1900.00000	2.78482	.00	PERIOD	CASE1	2208
760.00000	2052.00000	22.81647	.00	PERIOD	CASE1	2208
912.00000	2052.00000	31.41105	.00	PERIOD	CASE1	2208
1064.00000	2052.00000	37.92333	.00	PERIOD	CASE1	2208
1216.00000	2052.00000	46.81163	.00	PERIOD	CASE1	2208
1368.00000	2052.00000	57.27205	.00	PERIOD	CASE1	2208
1520.00000	2052.00000	27.51616	.00	PERIOD	CASE1	2208
1672.00000	2052.00000	30.72514	.00	PERIOD	CASE1	2208
1824.00000	2052.00000	30.93390	.00	PERIOD	CASE1	2208
1976.00000	2052.00000	14.03425	.00	PERIOD	CASE1	2208
2128.00000	2052.00000	12.78620	.00	PERIOD	CASE1	2208
2280.00000	2052.00000	9.75220	.00	PERIOD	CASE1	2208
2432.00000	2052.00000	5.65861	.00	PERIOD	CASE1	2208
2584.00000	2052.00000	3.83532	.00	PERIOD	CASE1	2208
2736.00000	2052.00000	3.28140	.00	PERIOD	CASE1	2208
2888.00000	2052.00000	3.04409	.00	PERIOD	CASE1	2208
3040.00000	2052.00000	2.77923	.00	PERIOD	CASE1	2208
3192.00000	2052.00000	2.49504	.00	PERIOD	CASE1	2208
3344.00000	2052.00000	2.22291	.00	PERIOD	CASE1	2208
760.00000	2204.00000	17.98634	.00	PERIOD	CASE1	2208
912.00000	2204.00000	20.85449	.00	PERIOD	CASE1	2208
1064.00000	2204.00000	20.76347	.00	PERIOD	CASE1	2208
1216.00000	2204.00000	27.94419	.00	PERIOD	CASE1	2208
1368.00000	2204.00000	16.92406	.00	PERIOD	CASE1	2208
1520.00000	2204.00000	18.57015	.00	PERIOD	CASE1	2208
1672.00000	2204.00000	13.03796	.00	PERIOD	CASE1	2208
1824.00000	2204.00000	12.95519	.00	PERIOD	CASE1	2208
1976.00000	2204.00000	12.97379	.00	PERIOD	CASE1	2208
2128.00000	2204.00000	5.46732	.00	PERIOD	CASE1	2208
2280.00000	2204.00000	6.56208	.00	PERIOD	CASE1	2208
2432.00000	2204.00000	5.89688	.00	PERIOD	CASE1	2208
2584.00000	2204.00000	5.23589	.00	PERIOD	CASE1	2208
2736.00000	2204.00000	4.04301	.00	PERIOD	CASE1	2208
2888.00000	2204.00000	2.77469	.00	PERIOD	CASE1	2208
3040.00000	2204.00000	2.09224	.00	PERIOD	CASE1	2208
3192.00000	2204.00000	1.74743	.00	PERIOD	CASE1	2208
3344.00000	2204.00000	1.60667	.00	PERIOD	CASE1	2208
760.00000	2356.00000	13.46280	.00	PERIOD	CASE1	2208
912.00000	2356.00000	12.15899	.00	PERIOD	CASE1	2208
1064.00000	2356.00000	15.56257	.00	PERIOD	CASE1	2208
1216.00000	2356.00000	9.30261	.00	PERIOD	CASE1	2208
1368.00000	2356.00000	6.82695	.00	PERIOD	CASE1	2208
1520.00000	2356.00000	12.18072	.00	PERIOD	CASE1	2208
1672.00000	2356.00000	7.21554	.00	PERIOD	CASE1	2208
1824.00000	2356.00000	6.36498	.00	PERIOD	CASE1	2208
1976.00000	2356.00000	6.80112	.00	PERIOD	CASE1	2208
2128.00000	2356.00000	6.86320	.00	PERIOD	CASE1	2208
2280.00000	2356.00000	2.98534	.00	PERIOD	CASE1	2208

2432.00000	2356.00000	4.06975	.00	PERIOD	CASE1	2208
2584.00000	2356.00000	3.93245	.00	PERIOD	CASE1	2208
2736.00000	2356.00000	3.55785	.00	PERIOD	CASE1	2208
2888.00000	2356.00000	3.27645	.00	PERIOD	CASE1	2208
3040.00000	2356.00000	2.93725	.00	PERIOD	CASE1	2208
3192.00000	2356.00000	2.26147	.00	PERIOD	CASE1	2208
3344.00000	2356.00000	1.70049	.00	PERIOD	CASE1	2208
760.00000	2508.00000	8.20717	.00	PERIOD	CASE1	2208
912.00000	2508.00000	9.65934	.00	PERIOD	CASE1	2208
1064.00000	2508.00000	9.09363	.00	PERIOD	CASE1	2208
1216.00000	2508.00000	6.70206	.00	PERIOD	CASE1	2208
1368.00000	2508.00000	3.91833	.00	PERIOD	CASE1	2208
1520.00000	2508.00000	7.93754	.00	PERIOD	CASE1	2208
1672.00000	2508.00000	5.61879	.00	PERIOD	CASE1	2208
1824.00000	2508.00000	5.98456	.00	PERIOD	CASE1	2208
1976.00000	2508.00000	4.92892	.00	PERIOD	CASE1	2208
2128.00000	2508.00000	5.62079	.00	PERIOD	CASE1	2208
2280.00000	2508.00000	4.24757	.00	PERIOD	CASE1	2208
2432.00000	2508.00000	2.03022	.00	PERIOD	CASE1	2208
2584.00000	2508.00000	2.51749	.00	PERIOD	CASE1	2208
2736.00000	2508.00000	2.68417	.00	PERIOD	CASE1	2208
2888.00000	2508.00000	2.71952	.00	PERIOD	CASE1	2208
3040.00000	2508.00000	2.42278	.00	PERIOD	CASE1	2208
3192.00000	2508.00000	2.25780	.00	PERIOD	CASE1	2208
3344.00000	2508.00000	2.15596	.00	PERIOD	CASE1	2208
760.00000	2660.00000	6.61168	.00	PERIOD	CASE1	2208
912.00000	2660.00000	7.70586	.00	PERIOD	CASE1	2208
1064.00000	2660.00000	4.16540	.00	PERIOD	CASE1	2208
1216.00000	2660.00000	4.44613	.00	PERIOD	CASE1	2208
1368.00000	2660.00000	3.09924	.00	PERIOD	CASE1	2208
1520.00000	2660.00000	5.34507	.00	PERIOD	CASE1	2208
1672.00000	2660.00000	4.80625	.00	PERIOD	CASE1	2208
1824.00000	2660.00000	4.43981	.00	PERIOD	CASE1	2208
1976.00000	2660.00000	2.78749	.00	PERIOD	CASE1	2208
2128.00000	2660.00000	3.60916	.00	PERIOD	CASE1	2208
2280.00000	2660.00000	4.74131	.00	PERIOD	CASE1	2208
2432.00000	2660.00000	2.95705	.00	PERIOD	CASE1	2208
2584.00000	2660.00000	1.52804	.00	PERIOD	CASE1	2208
2736.00000	2660.00000	1.61676	.00	PERIOD	CASE1	2208
2888.00000	2660.00000	2.08157	.00	PERIOD	CASE1	2208
3040.00000	2660.00000	1.92967	.00	PERIOD	CASE1	2208
3192.00000	2660.00000	1.99508	.00	PERIOD	CASE1	2208
3344.00000	2660.00000	1.77437	.00	PERIOD	CASE1	2208
760.00000	2812.00000	6.44815	.00	PERIOD	CASE1	2208
912.00000	2812.00000	3.53258	.00	PERIOD	CASE1	2208
1064.00000	2812.00000	3.75453	.00	PERIOD	CASE1	2208
1216.00000	2812.00000	2.21683	.00	PERIOD	CASE1	2208
1368.00000	2812.00000	2.96299	.00	PERIOD	CASE1	2208
1520.00000	2812.00000	3.78156	.00	PERIOD	CASE1	2208
1672.00000	2812.00000	4.13068	.00	PERIOD	CASE1	2208
1824.00000	2812.00000	3.05313	.00	PERIOD	CASE1	2208
1976.00000	2812.00000	2.56987	.00	PERIOD	CASE1	2208
2128.00000	2812.00000	2.59085	.00	PERIOD	CASE1	2208
2280.00000	2812.00000	2.37805	.00	PERIOD	CASE1	2208
2432.00000	2812.00000	3.80910	.00	PERIOD	CASE1	2208
2584.00000	2812.00000	2.19286	.00	PERIOD	CASE1	2208
2736.00000	2812.00000	1.21071	.00	PERIOD	CASE1	2208
2888.00000	2812.00000	1.15257	.00	PERIOD	CASE1	2208
3040.00000	2812.00000	1.53780	.00	PERIOD	CASE1	2208
3192.00000	2812.00000	1.53898	.00	PERIOD	CASE1	2208
3344.00000	2812.00000	1.51526	.00	PERIOD	CASE1	2208
760.00000	2964.00000	3.83532	.00	PERIOD	CASE1	2208
912.00000	2964.00000	2.68090	.00	PERIOD	CASE1	2208
1064.00000	2964.00000	3.17866	.00	PERIOD	CASE1	2208
1216.00000	2964.00000	1.78881	.00	PERIOD	CASE1	2208
1368.00000	2964.00000	2.74716	.00	PERIOD	CASE1	2208
1520.00000	2964.00000	2.81836	.00	PERIOD	CASE1	2208
1672.00000	2964.00000	3.52356	.00	PERIOD	CASE1	2208
1824.00000	2964.00000	2.16636	.00	PERIOD	CASE1	2208
1976.00000	2964.00000	2.69057	.00	PERIOD	CASE1	2208
2128.00000	2964.00000	1.63591	.00	PERIOD	CASE1	2208
2280.00000	2964.00000	2.50210	.00	PERIOD	CASE1	2208
2432.00000	2964.00000	2.19189	.00	PERIOD	CASE1	2208
2584.00000	2964.00000	3.02853	.00	PERIOD	CASE1	2208
2736.00000	2964.00000	1.70098	.00	PERIOD	CASE1	2208
2888.00000	2964.00000	.99259	.00	PERIOD	CASE1	2208

3040.00000	2964.00000	.89129	.00	PERIOD	CASE1	2208
3192.00000	2964.00000	1.11012	.00	PERIOD	CASE1	2208
3344.00000	2964.00000	1.29868	.00	PERIOD	CASE1	2208
760.00000	3116.00000	2.02158	.00	PERIOD	CASE1	2208
912.00000	3116.00000	2.46328	.00	PERIOD	CASE1	2208
1064.00000	3116.00000	1.71126	.00	PERIOD	CASE1	2208
1216.00000	3116.00000	1.37634	.00	PERIOD	CASE1	2208
1368.00000	3116.00000	2.57213	.00	PERIOD	CASE1	2208
1520.00000	3116.00000	2.18067	.00	PERIOD	CASE1	2208
1672.00000	3116.00000	2.97190	.00	PERIOD	CASE1	2208
1824.00000	3116.00000	1.60969	.00	PERIOD	CASE1	2208
1976.00000	3116.00000	2.36320	.00	PERIOD	CASE1	2208
2128.00000	3116.00000	1.55434	.00	PERIOD	CASE1	2208
2280.00000	3116.00000	1.62577	.00	PERIOD	CASE1	2208
2432.00000	3116.00000	1.66763	.00	PERIOD	CASE1	2208
2584.00000	3116.00000	2.12020	.00	PERIOD	CASE1	2208
2736.00000	3116.00000	2.42365	.00	PERIOD	CASE1	2208
2888.00000	3116.00000	1.36438	.00	PERIOD	CASE1	2208
3040.00000	3116.00000	.83404	.00	PERIOD	CASE1	2208
3192.00000	3116.00000	.72597	.00	PERIOD	CASE1	2208
3344.00000	3116.00000	.83015	.00	PERIOD	CASE1	2208
760.00000	3268.00000	1.88611	.00	PERIOD	CASE1	2208
912.00000	3268.00000	2.30686	.00	PERIOD	CASE1	2208
1064.00000	3268.00000	1.19807	.00	PERIOD	CASE1	2208
1216.00000	3268.00000	1.26314	.00	PERIOD	CASE1	2208
1368.00000	3268.00000	2.40818	.00	PERIOD	CASE1	2208
1520.00000	3268.00000	1.74054	.00	PERIOD	CASE1	2208
1672.00000	3268.00000	2.49632	.00	PERIOD	CASE1	2208
1824.00000	3268.00000	1.31766	.00	PERIOD	CASE1	2208
1976.00000	3268.00000	1.83820	.00	PERIOD	CASE1	2208
2128.00000	3268.00000	1.49551	.00	PERIOD	CASE1	2208
2280.00000	3268.00000	1.09569	.00	PERIOD	CASE1	2208
2432.00000	3268.00000	1.76660	.00	PERIOD	CASE1	2208
2584.00000	3268.00000	1.27958	.00	PERIOD	CASE1	2208
2736.00000	3268.00000	1.96658	.00	PERIOD	CASE1	2208
2888.00000	3268.00000	1.96253	.00	PERIOD	CASE1	2208
3040.00000	3268.00000	1.12483	.00	PERIOD	CASE1	2208
3192.00000	3268.00000	.71514	.00	PERIOD	CASE1	2208
3344.00000	3268.00000	.61128	.00	PERIOD	CASE1	2208
760.00000	3420.00000	1.76131	.00	PERIOD	CASE1	2208
912.00000	3420.00000	1.51335	.00	PERIOD	CASE1	2208
1064.00000	3420.00000	1.07169	.00	PERIOD	CASE1	2208
1216.00000	3420.00000	1.27325	.00	PERIOD	CASE1	2208
1368.00000	3420.00000	2.21154	.00	PERIOD	CASE1	2208
1520.00000	3420.00000	1.42507	.00	PERIOD	CASE1	2208
1672.00000	3420.00000	2.10006	.00	PERIOD	CASE1	2208
1824.00000	3420.00000	1.16726	.00	PERIOD	CASE1	2208
1976.00000	3420.00000	1.47475	.00	PERIOD	CASE1	2208
2128.00000	3420.00000	1.59713	.00	PERIOD	CASE1	2208
2280.00000	3420.00000	1.07078	.00	PERIOD	CASE1	2208
2432.00000	3420.00000	1.12555	.00	PERIOD	CASE1	2208
2584.00000	3420.00000	1.35974	.00	PERIOD	CASE1	2208
2736.00000	3420.00000	1.19772	.00	PERIOD	CASE1	2208
2888.00000	3420.00000	1.77249	.00	PERIOD	CASE1	2208
3040.00000	3420.00000	1.61893	.00	PERIOD	CASE1	2208
3192.00000	3420.00000	.94791	.00	PERIOD	CASE1	2208
3344.00000	3420.00000	.62235	.00	PERIOD	CASE1	2208
760.00000	3572.00000	1.72901	.00	PERIOD	CASE1	2208
912.00000	3572.00000	.92361	.00	PERIOD	CASE1	2208
1064.00000	3572.00000	.87297	.00	PERIOD	CASE1	2208
1216.00000	3572.00000	1.23332	.00	PERIOD	CASE1	2208
1368.00000	3572.00000	1.98985	.00	PERIOD	CASE1	2208
1520.00000	3572.00000	1.19141	.00	PERIOD	CASE1	2208
1672.00000	3572.00000	1.77569	.00	PERIOD	CASE1	2208
1824.00000	3572.00000	1.07982	.00	PERIOD	CASE1	2208
1976.00000	3572.00000	1.19369	.00	PERIOD	CASE1	2208
2128.00000	3572.00000	1.50011	.00	PERIOD	CASE1	2208
2280.00000	3572.00000	.99587	.00	PERIOD	CASE1	2208
2432.00000	3572.00000	.79636	.00	PERIOD	CASE1	2208
2584.00000	3572.00000	1.28511	.00	PERIOD	CASE1	2208
2736.00000	3572.00000	.98562	.00	PERIOD	CASE1	2208
2888.00000	3572.00000	1.19223	.00	PERIOD	CASE1	2208
3040.00000	3572.00000	1.57839	.00	PERIOD	CASE1	2208
3192.00000	3572.00000	1.35284	.00	PERIOD	CASE1	2208
3344.00000	3572.00000	.81195	.00	PERIOD	CASE1	2208
760.00000	3724.00000	1.32430	.00	PERIOD	CASE1	2208

912.00000	3724.00000	.77690	.00	PERIOD	CASE1	2208
1064.00000	3724.00000	.73447	.00	PERIOD	CASE1	2208
1216.00000	3724.00000	1.16880	.00	PERIOD	CASE1	2208
1368.00000	3724.00000	1.76492	.00	PERIOD	CASE1	2208
1520.00000	3724.00000	1.01341	.00	PERIOD	CASE1	2208
1672.00000	3724.00000	1.51201	.00	PERIOD	CASE1	2208
1824.00000	3724.00000	1.02289	.00	PERIOD	CASE1	2208
1976.00000	3724.00000	.95888	.00	PERIOD	CASE1	2208
2128.00000	3724.00000	1.25336	.00	PERIOD	CASE1	2208
2280.00000	3724.00000	1.01047	.00	PERIOD	CASE1	2208
2432.00000	3724.00000	.78342	.00	PERIOD	CASE1	2208
2584.00000	3724.00000	.83592	.00	PERIOD	CASE1	2208
2736.00000	3724.00000	1.12786	.00	PERIOD	CASE1	2208
2888.00000	3724.00000	.82145	.00	PERIOD	CASE1	2208
3040.00000	3724.00000	1.17262	.00	PERIOD	CASE1	2208
3192.00000	3724.00000	1.39855	.00	PERIOD	CASE1	2208
3344.00000	3724.00000	1.14471	.00	PERIOD	CASE1	2208
760.00000	3876.00000	.84456	.00	PERIOD	CASE1	2208
912.00000	3876.00000	.72969	.00	PERIOD	CASE1	2208
1064.00000	3876.00000	.71204	.00	PERIOD	CASE1	2208
1216.00000	3876.00000	1.12428	.00	PERIOD	CASE1	2208
1368.00000	3876.00000	1.55938	.00	PERIOD	CASE1	2208
1520.00000	3876.00000	.87737	.00	PERIOD	CASE1	2208
1672.00000	3876.00000	1.30279	.00	PERIOD	CASE1	2208
1824.00000	3876.00000	.98684	.00	PERIOD	CASE1	2208
1976.00000	3876.00000	.78493	.00	PERIOD	CASE1	2208
2128.00000	3876.00000	1.04495	.00	PERIOD	CASE1	2208
2280.00000	3876.00000	1.08278	.00	PERIOD	CASE1	2208
2432.00000	3876.00000	.75143	.00	PERIOD	CASE1	2208
2584.00000	3876.00000	.61544	.00	PERIOD	CASE1	2208
2736.00000	3876.00000	.97325	.00	PERIOD	CASE1	2208
2888.00000	3876.00000	.85397	.00	PERIOD	CASE1	2208
3040.00000	3876.00000	.77722	.00	PERIOD	CASE1	2208
3192.00000	3876.00000	1.12446	.00	PERIOD	CASE1	2208
3344.00000	3876.00000	1.23841	.00	PERIOD	CASE1	2208
760.00000	4028.00000	.61022	.00	PERIOD	CASE1	2208
912.00000	4028.00000	.63086	.00	PERIOD	CASE1	2208
1064.00000	4028.00000	.72988	.00	PERIOD	CASE1	2208
1216.00000	4028.00000	1.09554	.00	PERIOD	CASE1	2208
1368.00000	4028.00000	1.37378	.00	PERIOD	CASE1	2208
1520.00000	4028.00000	.76934	.00	PERIOD	CASE1	2208
1672.00000	4028.00000	1.13240	.00	PERIOD	CASE1	2208
1824.00000	4028.00000	.96008	.00	PERIOD	CASE1	2208
1976.00000	4028.00000	.66858	.00	PERIOD	CASE1	2208
2128.00000	4028.00000	.89759	.00	PERIOD	CASE1	2208
2280.00000	4028.00000	1.05527	.00	PERIOD	CASE1	2208
2432.00000	4028.00000	.71394	.00	PERIOD	CASE1	2208
2584.00000	4028.00000	.60041	.00	PERIOD	CASE1	2208
2736.00000	4028.00000	.65145	.00	PERIOD	CASE1	2208
2888.00000	4028.00000	.93181	.00	PERIOD	CASE1	2208
3040.00000	4028.00000	.66779	.00	PERIOD	CASE1	2208
3192.00000	4028.00000	.77494	.00	PERIOD	CASE1	2208
3344.00000	4028.00000	1.05714	.00	PERIOD	CASE1	2208
760.00000	4180.00000	.56029	.00	PERIOD	CASE1	2208
912.00000	4180.00000	.52788	.00	PERIOD	CASE1	2208
1064.00000	4180.00000	.73073	.00	PERIOD	CASE1	2208
1216.00000	4180.00000	1.07011	.00	PERIOD	CASE1	2208
1368.00000	4180.00000	1.20987	.00	PERIOD	CASE1	2208
1520.00000	4180.00000	.68145	.00	PERIOD	CASE1	2208
1672.00000	4180.00000	.99182	.00	PERIOD	CASE1	2208
1824.00000	4180.00000	.93610	.00	PERIOD	CASE1	2208
1976.00000	4180.00000	.59583	.00	PERIOD	CASE1	2208
2128.00000	4180.00000	.77613	.00	PERIOD	CASE1	2208
2280.00000	4180.00000	.93116	.00	PERIOD	CASE1	2208
2432.00000	4180.00000	.74643	.00	PERIOD	CASE1	2208
2584.00000	4180.00000	.59442	.00	PERIOD	CASE1	2208
2736.00000	4180.00000	.49390	.00	PERIOD	CASE1	2208
2888.00000	4180.00000	.75996	.00	PERIOD	CASE1	2208
3040.00000	4180.00000	.75782	.00	PERIOD	CASE1	2208
3192.00000	4180.00000	.58183	.00	PERIOD	CASE1	2208
3344.00000	4180.00000	.77633	.00	PERIOD	CASE1	2208
760.00000	4332.00000	.53856	.00	PERIOD	CASE1	2208
912.00000	4332.00000	.47519	.00	PERIOD	CASE1	2208
1064.00000	4332.00000	.70966	.00	PERIOD	CASE1	2208
1216.00000	4332.00000	1.03869	.00	PERIOD	CASE1	2208
1368.00000	4332.00000	1.06745	.00	PERIOD	CASE1	2208

1520.00000	4332.00000	.60887	.00	PERIOD	CASE1	2208
1672.00000	4332.00000	.87506	.00	PERIOD	CASE1	2208
1824.00000	4332.00000	.91094	.00	PERIOD	CASE1	2208
1976.00000	4332.00000	.55002	.00	PERIOD	CASE1	2208
2128.00000	4332.00000	.66481	.00	PERIOD	CASE1	2208
2280.00000	4332.00000	.79648	.00	PERIOD	CASE1	2208
2432.00000	4332.00000	.79655	.00	PERIOD	CASE1	2208
2584.00000	4332.00000	.55824	.00	PERIOD	CASE1	2208
2736.00000	4332.00000	.47641	.00	PERIOD	CASE1	2208
2888.00000	4332.00000	.52477	.00	PERIOD	CASE1	2208
3040.00000	4332.00000	.77021	.00	PERIOD	CASE1	2208
3192.00000	4332.00000	.59256	.00	PERIOD	CASE1	2208
3344.00000	4332.00000	.55423	.00	PERIOD	CASE1	2208
760.00000	4484.00000	.48419	.00	PERIOD	CASE1	2208
912.00000	4484.00000	.47074	.00	PERIOD	CASE1	2208
1064.00000	4484.00000	.68245	.00	PERIOD	CASE1	2208
1216.00000	4484.00000	.99832	.00	PERIOD	CASE1	2208
1368.00000	4484.00000	.94481	.00	PERIOD	CASE1	2208
1520.00000	4484.00000	.54813	.00	PERIOD	CASE1	2208
1672.00000	4484.00000	.77738	.00	PERIOD	CASE1	2208
1824.00000	4484.00000	.88256	.00	PERIOD	CASE1	2208
1976.00000	4484.00000	.51907	.00	PERIOD	CASE1	2208
2128.00000	4484.00000	.56622	.00	PERIOD	CASE1	2208
2280.00000	4484.00000	.69369	.00	PERIOD	CASE1	2208
2432.00000	4484.00000	.79069	.00	PERIOD	CASE1	2208
2584.00000	4484.00000	.54831	.00	PERIOD	CASE1	2208
2736.00000	4484.00000	.48111	.00	PERIOD	CASE1	2208
2888.00000	4484.00000	.40769	.00	PERIOD	CASE1	2208
3040.00000	4484.00000	.61035	.00	PERIOD	CASE1	2208
3192.00000	4484.00000	.67217	.00	PERIOD	CASE1	2208
3344.00000	4484.00000	.49006	.00	PERIOD	CASE1	2208

EXAMPLES OF INTERMEDIATE SPREADSHEET RESULTS USED TO CALCULATE INHALATION EXPOSURES

INTERMEDIATE RESULTS FOR CONSOLIDATION OPERATIONS

Consolidation Unit Length (ft)	8.00E+02
Consolidation Area (m^2)	5.95E+04

Soil Volume	
cubic yards	4.77E+05
cubic meters	3.65E+05

Calculated Soil Mass	
tons	8.40E+05
kg	7.62E+08

Schedule		
	Delivery	Processing
Hours/shift	8	8
Shifts/day	1	1
Days/week	5	5
Weeks/year	52	52
Hours/year	2080	2080
Years	22	22

Calculated Soil Delivery Rate	
(m^3/hr)	8.0
(m^3/day)	63.8
(kg/hr)	16650.2
(kg/day)	133201.9
(ton/hr)	18.4
(ton/day)	146.8

Calculated Soil Processing Rate	
(yd^3/day)	83.42657343
(m^3/hr)	8.0
(m^3/day)	63.8
(kg/hr)	16650.2
(kg/day)	133201.9
(ton/hr)	18.4
(ton/day)	146.8

Calculated Active Storage Pile	
tons per 2 days	293.7
cubic yards	217.5
cubic meters	166.4
Height (m)	3.0
Area (m^2)	55.5

Notes

ge pile is based on stockpiling enough soil to process for 2 days.
an assumption used to calculate the surface area of the pile.

SOURCE:

Equipment Specific Input for Emissions Calculations

Equipment	Equipment ID	Model Number	HP	Quantity	Maximum Depth (m)	Ave. Drop Height (m)	Use per Shift (%)	Hours per day Each	Hours per Year Each
Roll-off Truck (40 ton capacity)				see notes			100	8	2080
Backhoe Loader	F	*	*	1	3.05	1.53	50	4	1040
Dump Truck	H	*	*	1	n/a	n/a	100	8	2080
Bulldozer	C	CAT D8	*	1	0.61	0.92	100	8	2080
Motor Grader	E	*	*	1	n/a	n/a	100	8	2080
Compactor	I	CAT 825C	*	1	n/a	n/a	100	8	2080

Notes:

1) The equipment identified above was taken from Parsons 1994.
2) Information that was unavailable is identified with '*'.
3) Parameters that are not applicable are identified as 'n/a'.
4) The quantites and Use per Shift (%) were developed from discussions with Parsons' Engineering personnel.
5) The maximum depths and average drop heights are assumptions.
6) The hours per year each was based on the schedule for excavation and the expected use per shift.
7) The engine emissions for the roll-off truck are calculated in the excavation component.

Maximum Engine Emissions (kg/day)						
Equipment	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Backhoe Loader	0.31	0.33	3.43	0.45	1.04	0.08
Dump truck	0.93	1.65	15.11	0.69	6.53	0.41
Bulldozer	0.60	1.26	15.11	0.69	6.53	0.24
Motor Grader	0.22	0.31	2.60	0.14	0.55	0.04
Compactor	0.18	0.24	3.14	0.24	1.10	0.06
Totals	**2.24**	**3.80**	**39.40**	**2.23**	**15.76**	**0.82**

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4.

Annually Averaged Engine Emissions (kg/day)						
Equipment	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Backhoe Loader	0.04	0.04	0.41	0.05	0.12	0.01
Dump truck	0.22	0.39	3.59	0.16	1.55	0.10
Bulldozer	0.14	0.30	3.59	0.16	1.55	0.06
Motor Grader	0.05	0.07	0.62	0.03	0.13	0.01
Compactor	0.04	0.06	0.75	0.06	0.26	0.01
Totals	**0.50**	**0.86**	**8.95**	**0.48**	**3.62**	**0.19**

Notes

1) The maximum engine emissions is based on the type of equipment, the hours per day the equipment is used, and the number being used.

2) The annually averaged engine emissions adjusts the maximum emissions by the ratio of the hours per year a piece of equipment is used to the number of hours in a year (8760).

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4. Results are averaged over year (hrs per year/8760).

Major Operations - PM_{10} Emissions							Emissions (kg/day)	
Equipment	Prepare Area - Dumping (kg/day)	Prepare Area - Active Storage Pile (kg/day)	Construct Area - (kg/day)	Uncovered Consolidation Area (kg/day)	Provide Stormwater Controls (kg/day)	Construction (wells) (kg/day)	Maximum	Annually Averaged
Roll-off Truck (40 ton capacity)	1.66	n/a	n/a	n/a	n/a	n/a	1.66	0.39
Supply Storage Pile	n/a	1.85E-06	n/a	n/a	n/a	n/a	0.00	0.00
Backhoe Loader	n/a	n/a	0.40	n/a	n/a	n/a	0.40	0.05
Dump Truck	n/a	n/a	0.17	n/a	n/a	n/a	0.17	0.04
Bulldozer	n/a	n/a	1.99	n/a	n/a	n/a	1.99	0.47
Motor Grader	n/a	n/a	1.50	n/a	n/a	n/a	1.50	0.36
Compactor	n/a	n/a	n/a	n/a	n/a	n/a	0.00	0.00
Consolidation Area Pile	n/a	n/a	n/a	1.99E-03	n/a	n/a	0.00	0.00
Totals	**1.66**	**0.00**	**4.06**	**0.00**	**0.00**	**0.00**	**5.71**	**1.31**

Notes:

1) The roll-off trucks will be covered prior to soil transport soil. In addition, the wheels will be washed prior to leaving a component. The roads are not expected to be contaminated and are not a resuspension problem.

2) The unloading operation occurs at the storage pile. The emission rate is based on the volume delivered to this component. This is due to the fact that components may split the excavated soil volumes (based on alternative)

of the process of Preparation/Construction of the Consolidation Area:

dumps a load of soil onto a preparation area storage pile.

oe loader loads a consolidation area dump truck.

livers and dumps the dirt to the working consolidation area

s the dirt around the working consolidation area as needed

der grades the soil in the working consolidation area.

r compacts the soil in the working consolidation area

lidation pile is uncovered until the end of the day.

ll not be a source of PM_{10} emissions at the consolidation area.

xpected to be a source of PM_{10} emissions at the consolidation area.

INTERMEDIATE RESULTS FOR OFF-SITE DISPOSAL OPERATIONS

Soil Volume	
cubic yards	1.12E+06
cubic meters	8.57E+05

Calculated Soil Mass	
tons	1.97E+06
kg	1.79E+09

Schedule	Delivery	Processing
Hours/shift	8	8
Shifts/day	1	1
Days/week	5	5
Weeks/year	52	52
Hours/year	2080	2080
Years	22	22

Calculated Soil Delivery Rate	
(m^3/hr)	18.7
(m^3/day)	149.8
(kg/hr)	39071.5
(kg/day)	312572.4
(ton/hr)	43.1
(ton/day)	344.6

Calculated Loading Rate	
m^3/hr	18.7
yd^3/hr	24.5
yd^3/day	195.8
tons/hr	43.1
tons/day	344.6
Gondolas/day	3.4

Calculated Active Storage Pile	
tons	689.11
cubic yards	510.45
cubic meters	390.49
Height (m)	3.00
Area (m^2)	130.16

Notes

e pile is based on stockpiling enough soil to process for 2 days.
an assumption used to calculate the surface area of the pile.

Equipment Specific Input for Emissions Calculations									
Equipment	Equipment ID	Model Number	HP	Quantity	Maximum Depth (m)	Ave. Drop Height (m)	Use per Shift (%)	Hours per day Each	Hours per Year Each
Roll-off Truck (40 ton capacity)				see notes			100	8	2080
Track Loader	G	CAT 963	150	2	0.61	1.53	100	8	2080
Hydraulic Excavator	J	CAT E300B	206	1	6.1	2.29	100	8	2080
Track Mobile	J	*	*	1	n/a	n/a	100	8	2080

Notes:
1) The equipment identified above was taken from Parsons 1994.
2) Information that was unavailable is identified with '*'.
3) Parameters that are not applicable are identified as 'n/a'.
4) The quantites and Use per Shift (%) were developed from discussions with Parsons' Engineering personnel.
5) The maximum depths and average drop heights are assumptions.
6) The hours per year each was based on the schedule for excavation and the expected use per shift.

Equipment	Maximum Engine Emissions (kg/day)					
	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Track Loader	0.42	0.55	6.00	0.71	1.46	0.06
Hydraulic Excavator	0.51	0.52	6.14	0.55	2.45	0.11
Track Mobile	0.51	0.52	6.14	0.55	2.45	0.11
Totals	**1.43**	**1.59**	**18.28**	**1.82**	**6.36**	**0.29**

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4.

Equipment	Annually Averaged Engine Emissions (kg/day)					
	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Track Loader	0.10	0.13	1.43	0.17	0.35	0.02
Hydraulic Excavator	0.12	0.12	1.46	0.13	0.58	0.03
Track Mobile	0.12	0.12	1.46	0.13	0.58	0.03
Totals	**0.34**	**0.38**	**4.34**	**0.43**	**1.51**	**0.07**

Notes

1) The maximum engine emissions is based on the type of equipment, the hours per day the equipment is used, and the number being used.

2) The annually averaged engine emissions adjusts the maximum emissions by the ratio of the hours per year a piece of equipment is used to the number of hours in a year (8760).

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4. Results averaged over year (hrs per year/8760).

Equipment	Major Operations - PM_{10} Emissions					Emissions (kg/day)	
	Interim Staging - (kg/day)	Interim Storage (active storage pile) (kg/day)	Loading (kg/day)	Transportation (kg/day)	Unloading at disposal site (kg/day)	Maximum	Average
Roll-off Truck (40 ton capacity)	5.60	n/a	n/a	n/a	n/a	5.60	1.33
Track Loader	1.99	n/a	n/a	n/a	n/a	1.99	0.47
Hydraulic Excavator	1.81	n/a	n/a	n/a	n/a	1.81	0.43
Storage Pile	n/a	4.35E-06	n/a	n/a	n/a	0.00	0.00
Rail Cars	n/a	n/a	0.00	n/a	n/a	0.00	0.00
Track Mobile	n/a	n/a	n/a	0.00	n/a	0.00	0.00
Totals	**9.40**	**0.00**	**0.00**	**0.00**	**0.00**	**9.40**	**2.23**

Notes

1) Interim Staging consists of the following steps:
   a) The roll-off truck dumps the soil onto an active storage pile.
   b) A track loader moves the dirt over to a stationary hydraulic excavator.
   c) The hydraulic excavator drops the soil onto a conveyor system.
2) The roll-off trucks will be covered prior to soil transport soil. In addition, the wheels will be washed prior to leaving a component. The roads are not expected to be contaminated and are not a resuspension problem.
3) The unloading operation occurs at the storage pile. The emission rate is based on the volume delivered to this component. This is due to the fact that components may split the excavated soil volumes (based on alternative)
4) There is no expected PM_{10} emissions for the transportation of waste (track mobiles) from the loading area since gondolas and sealand containers will be covered, blocks shrink-wrapped or sprayed with epoxy.
5) The PM10 emssions associated with the unloading of rail cars at Envirocare is not quantified in this calculation.

INTERMEDIATE RESULTS FOR EXCAVATION OPERATIONS

Total Soil Volume To Be Excavated	
cubic yards	1.61E+06
cubic meters	1.23E+06

Calculated Soil Mass	
tons	2.84E+06
kg	2.58E+09

Schedule for Excavation	
Hours/shift	8
Shifts/day	1
Days/week	5
Weeks/year	52
Hours/year	2080
Years	22

Calculated Excavation Rate	
yd3/day	282.13
(m^3/hr)	27.0
(m^3/day)	215.8
(kg/hr)	56308.1
(kg/day)	450465.0
(ton/day)	496.6

On-site transport of soil	
Max.distance to dropoff (ft)	7000
Round trip (km)	4.27
Number of trips per day using 40 ton trucks	12.4

Equipment Specific Input for Emissions Calculations

Equipment	Equipment ID	Model Number	HP	Quantity	Maximum Depth (m)	Ave. Drop Height (m)	Use per Shift (%)	Hours per day Each	Hours per Year Each
Hydraulic Excavator	J	CAT E300B	206	1	6.1	2.29	100	8	2080
Backhoe Loader	F	Cat 428 Series II	70	1	3.05	1.53	50	4	1040
Skid Loader	C	Bobcat 843	*	1	0.61	0.92	50	4	1040
Track Loader	G	CAT 963	150	1	0.61	1.53	100	8	2080
Roll-off Truck (40 ton capacity)	H	*	*	3	n/a	1.53	100	8	2080
Wheel Loader	F	CAT 966C	*	1	0.61	1.53	50	4	1040

Notes:

1) The equipment identified above was taken from Parsons 1994.
2) Information that was unavailable is identified with '*'.
3) Parameters that are not applicable are identified as 'n/a'.
4) The quantites and Use per Shift (%) were developed from discussions with Parsons' Engineering personnel.
5) The maximum depths and average drop heights are assumptions.
6) The hours per year each was based on the schedule for excavation and the expected use per shift.

Maximum Engine Emissions (kg/day)						
Equipment	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Hydraulic Excavator	0.51	0.52	6.14	0.55	2.45	0.11
Backhoe Loader	0.31	0.33	3.43	0.45	1.04	0.08
Skid Loader	0.30	0.63	7.56	0.35	3.27	0.12
Track Loader	0.21	0.28	3.00	0.36	0.73	0.03
Roll-off Truck (40 ton capacity)	2.78	4.94	45.34	2.08	19.60	1.22
Wheel Loader	0.31	0.33	3.43	0.45	1.04	0.08
Totals	**4.42**	**7.03**	**68.90**	**4.25**	**28.13**	**1.64**

m Table H.III.4-3, Equipment IDs, and Hours per Day from Table H.III.6-4.

Equipment	Annually Averaged Engine Emissions (kg/day)					
	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Hydraulic Excavator	0.12	0.12	1.46	0.13	0.58	0.03
Backhoe Loader	0.04	0.04	0.41	0.05	0.12	0.01
Skid Loader	0.04	0.08	0.90	0.04	0.39	0.01
Track Loader	0.05	0.07	0.71	0.08	0.17	0.01
Roll-off Truck (40 ton capacity)	0.66	1.17	10.77	0.49	4.65	0.29
Wheel Loader	0.04	0.04	0.41	0.05	0.12	0.01
Totals	**0.94**	**1.52**	**14.65**	**0.86**	**6.04**	**0.36**

Notes

1) The maximum engine emissions is based on the type of equipment, the hours per day the equipment is used, and the number being used.

2) The annually averaged engine emissions adjusts the maximum emissions by the ratio of the hours per year a piece of equipment is used to the number of hours in a year (8760).

.4-3, Equipment IDs, and Hours per Day from Table H.III.6-4. Results are averaged over year (Hrs per year /8760).

Major Operations - PM_{10} Emissions							Emissions (kg/day)	
Equipment	Digging (kg/day)	RCRA Waste (thermal desorption)	RCRA Waste (soil washing)	Loading (kg/day)	Transportation (kg/day)	Unloading (kg/day)	Maximum	Annually Averaged
Hydraulic Excavator	1.54	n/a	n/a	n/a	n/a	n/a	1.54	0.37
Backhoe Loader	0.07	n/a	n/a	0.03	n/a	n/a	0.10	0.01
Skid Loader	1.00	n/a	n/a	0.03	n/a	n/a	1.02	0.12
Track Loader	n/a	n/a	n/a	0.48	n/a	n/a	0.48	0.11
Roll-off Truck (40 ton capacity)	n/a	n/a	n/a	n/a	n/a	n/a	0.00	0.00
Wheel Loader	1.00	n/a	n/a	0.03	n/a	n/a	1.02	0.12
Totals	**3.60**	n/a	n/a	**0.56**	n/a	n/a	**4.16**	**0.73**

Notes:

1) Based on the OU5 Remedial Alternative Engineering Study, the hydraulic excavator will be primarily used for digging. The backhoe/loader, skid loader, and wheel loader will supplement the hydraulic excavator.

2) For calculation purposes, the following percentages were assigned to the digging equipment:

Hydraulic Excavator	85%
Backhoe Loader	5%
Skid Loader	5%
Wheel Loader	5%

3) Based on the OU5 Remedial Alternative Engineering Study, the track loader will be primarily used for loading. The backhoe/loader, skid loader, and wheel loader will supplement the track loader.

4) For calculation purposes, the following percentages were assigned to the loading equipment:

Track Loader	85%
Backhoe Loader	5%
Skid Loader	5%
Wheel Loader	5%

5) The roll-off trucks will be covered prior to soil transport soil. In addition, the wheels will be washed prior to leaving a component. The roads are not expected to be contaminated and are not a resuspension problem.

6) The unloading operation occurs at a different component and will be quantified elsewhere. Based on the OU5 Remedial Alternative Engineering Study, the roll-off truck will be primarily used for unloading.

7) For calculation purposes, the following percentage was assigned to the unloading equipment:

Roll-off Truck	100%

INTERMEDIATE RESULTS FOR ON-SITE DISPOSAL CELL OPERATIONS

Cell Subunit Length (ft)	0.00E+00
Cell Subunit Area (m^2)	0.00E+00

Soil Volume	
cubic yards	0.00E+00
cubic meters	0.00E+00

Calculated Soil Mass	
tons	0.00E+00
kg	0.00E+00

Schedule		
	Delivery	Processing
Hours/shift	8	8
Shifts/day	1	1
Days/week	5	5
Weeks/year	52	52
Hours/year	2080	2080
Years	22	22

Calculated Soil Delivery Rate	
(m^3/hr)	0.0
(m^3/day)	0.0
(kg/hr)	0.0
(kg/day)	0.0
(ton/hr)	0.0
(ton/day)	0.0

Calculated Soil Processing Rate	
(yd^3/day)	0
(m^3/hr)	0.0
(m^3/day)	0.0
(kg/hr)	0.0
(kg/day)	0.0
(ton/hr)	0.0
(ton/day)	0.0

Calculated Active Storage Pile	
tons per 2 days	0.0
cubic yards	0.0
cubic meters	0.0
Height (m)	3.0
Area (m^2)	0.0

Notes

e pile is based on stockpiling enough soil to process for 2 days.
an assumption used to calculate the surface area of the pile.

SOURCE:

Equipment Specific Input for Emissions Calculations

Equipment	Equipment ID	Model Number	HP	Quantity	Maximum Depth (m)	Ave. Drop Height (m)	Use per Shift (%)	Hours per day Each	Hours per Year Each
Roll-off Truck (40 ton capacity)				see notes			100	8	2080
Wheel Loader	F	CAT 950F	*	1	0.61	1.53	75	6	1560
Dump Truck	H	CAT 769C	*	1	n/a	1.53	100	8	2080
Small Bulldozer	C	D3C LGP series II	*	1	0.61	0.92	100	8	2080
Water Truck (2000 gal)	H	*	*	1	n/a	n/a	50	4	1040
Soil Stabilizier	J	CAT SS-250	*	1	n/a	n/a	100	8	2080
Motor Grader	E	CAT 12G	*	1	n/a	n/a	100	8	2080
Compactor (sheep's foot) + blade	I	CAT 850B	*	1	n/a	n/a	100	8	2080
Smooth Drum Roller	I	CAT CS-433B	*	1	n/a	n/a	100	8	2080

Notes:
1) The equipment identified above was taken from Parsons 1994.
2) Information that was unavailable is identified with "*".
3) Parameters that are not applicable are identified as 'n/a'.
4) The quantites and Use per Shift (%) were developed from discussions with Parsons' Engineering personnel.
5) The maximum depths and average drop heights are assumptions.
6) The hours per year each was based on the schedule for excavation and the expected use per shift.

Equipment	Maximum Engine Emissions (kg/day)					
	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Wheel Loader	0.47	0.50	5.15	0.68	1.56	0.11
Dump Truck	1.86	3.30	30.23	1.39	13.07	0.82
Small Bulldozer	0.60	1.26	15.11	0.69	6.53	0.24
Water Truck (2000 gal)	0.46	0.82	7.56	0.35	3.27	0.20
Soil Stabilizier	0.51	0.52	6.14	0.55	2.45	0.11
Motor Grader	0.22	0.31	2.60	0.14	0.55	0.04
Compactor (sheep's foot) + blade	0.18	0.24	3.14	0.24	1.10	0.06
Smooth Drum Roller	0.18	0.24	3.14	0.24	1.10	0.06
Totals	**4.48**	**7.20**	**73.07**	**4.30**	**29.63**	**1.84**

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4.

Annually Averaged Engine Emissions (kg/day)						
Equipment	PM_{10}	SO_2	NO_2	VOC	CO	HCHO
Wheel Loader	0.08	0.09	0.92	0.12	0.28	0.02
Dump Truck	0.44	0.78	7.18	0.33	3.10	0.19
Small Bulldozer	0.14	0.30	3.59	0.16	1.55	0.06
Water Truck (2000 gal)	0.06	0.10	0.90	0.04	0.39	0.02
Soil Stabilizer	0.12	0.12	1.46	0.13	0.58	0.03
Motor Grader	0.05	0.07	0.62	0.03	0.13	0.01
Compactor (sheep's foot) + blade	0.04	0.06	0.75	0.06	0.26	0.01
Smooth Drum Roller	0.04	0.06	0.75	0.06	0.26	0.01
Totals	**0.98**	**1.68**	**16.15**	**0.94**	**6.56**	**0.36**

Notes

1) The maximum engine emissions is based on the type of equipment, the hours per day the equipment is used, and the number being used.

2) The annually averaged engine emissions adjusts the maximum emissions by the ratio of the hours per year a piece of equipment is used to the number of hours in a year (8760).

SOURCE: Calculated using values from Table H.III.4-3, Equipment IDs and hours per day from Table H.III.6-4. Results averaged over year (hrs per year/8760).

Major Operations - PM_{10} Emissions							Emissions (kg/day)	
Equipment	Receiving Area - Dumping (kg/day)	Receiving Area - Active Storage Pile (kg/day)	Construct Cell - (kg/day)	Uncovered Cell (kg/day)	Provide Stormwater Controls (kg/day)	Construction (wells) (kg/day)	Maximum	Annually Averaged
Roll-off Truck (40 ton capacity)	0.00	n/a	n/a	n/a	n/a	n/a	0.00	0.00
Supply Storage Pile	n/a	0.00E+00	n/a	n/a	n/a	n/a	0.00	0.00
Wheel Loader	n/a	n/a	0.00	n/a	n/a	n/a	0.00	0.00
Small Bulldozer	n/a	n/a	1.99	n/a	n/a	n/a	1.99	0.47
Motor Grader	n/a	n/a	1.50	n/a	n/a	n/a	1.50	0.36
Compactor	n/a	n/a	n/a	n/a	n/a	n/a	0.00	0.00
Cell Subunit Pile	n/a	n/a	n/a	0.00E+00	n/a	n/a	0.00	0.00
Totals	**0.00**	**0.00**	**3.49**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Notes:

1) The roll-off trucks will be covered prior to soil transport soil. In addition, the wheels will be washed prior to leaving a component. The roads are not expected to be contaminated and are not a resuspension problem.

2) The unloading operation occurs at the storage pile. The emission rate is based on the volume delivered to this component. This is due to the fact that components may split the excavated soil volumes (based on alternative)

s are typical of the process of the Construct Cell segment.

dumps a load of soil onto a receiving area storage pile.

wheel loader delivers the soil to to the cell.

er moves the dirt around the cell subunit as needed

otor grader grades the soil in the cell subunit.

mpactor compacts the soil in the cell subunit.

ll subunit is uncovered until the end of the day.

trols will not be a source of PM_{10} emissions at the cell.

is not expected to be a source of PM_{10} emissions at the cell.

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