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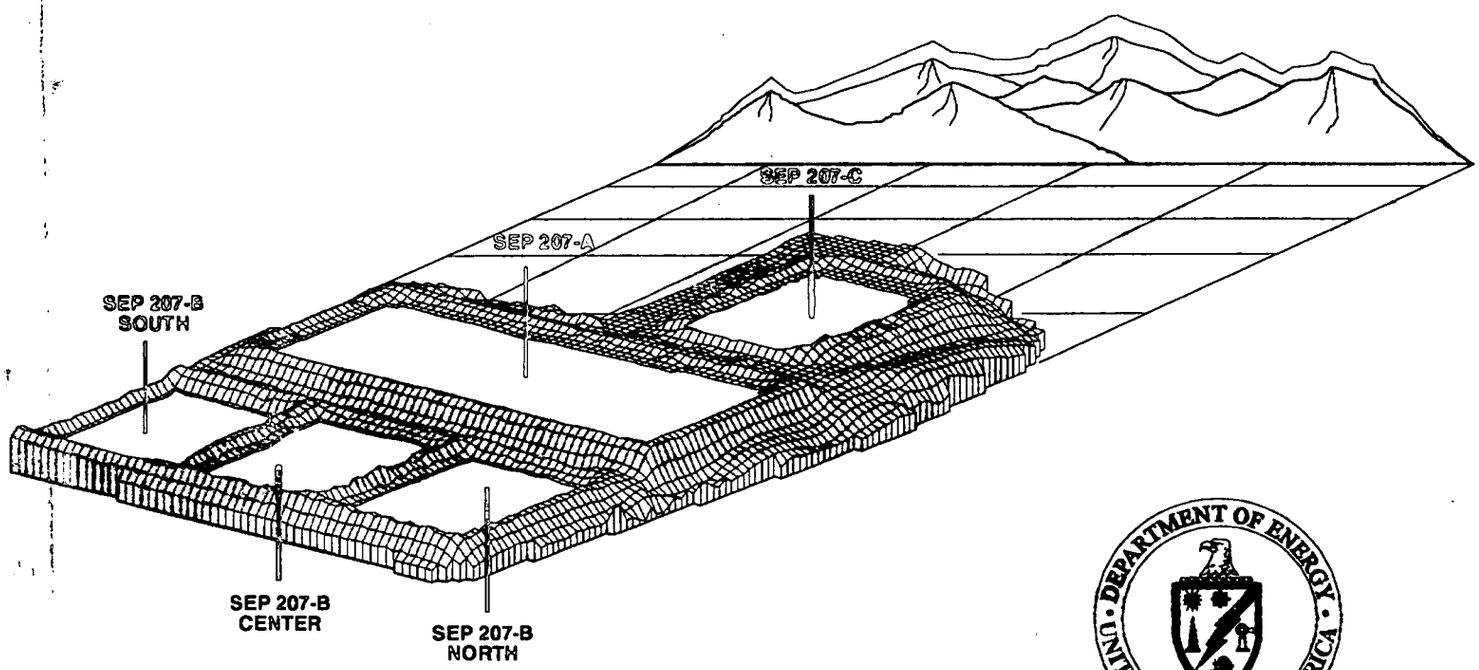
OU4 Solar Evaporation Ponds Interim Measure/Interim Remedial Action Environmental Assessment Decision Document

U.S. Department of Energy
Rocky Flats Plant
Golden, Colorado

May 1994

Revision: Draft Proposed

Part III



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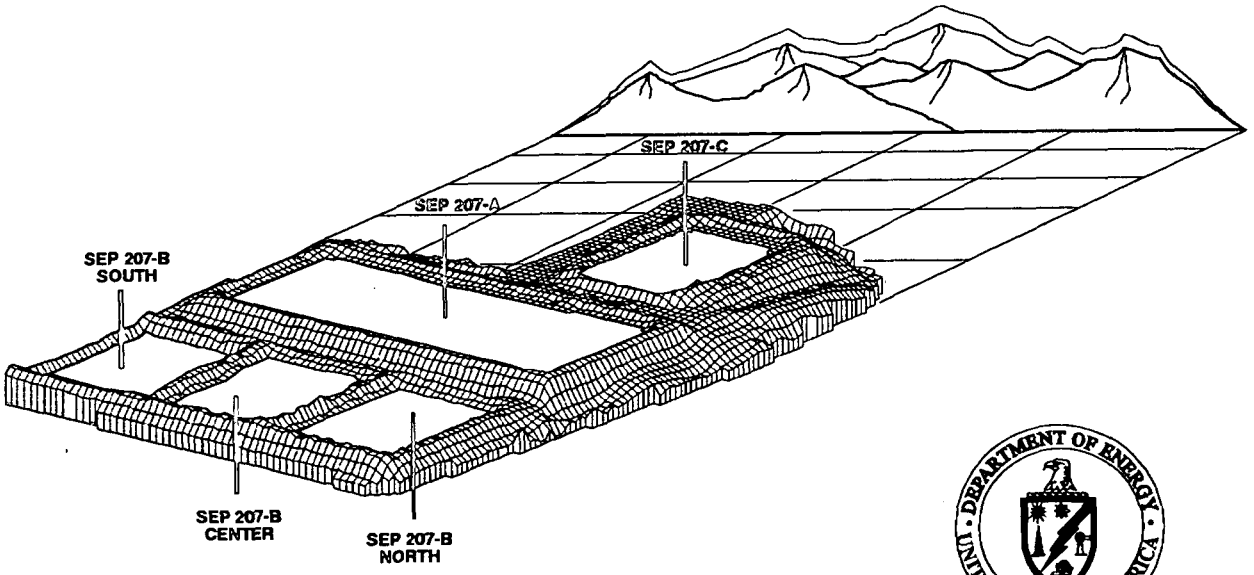

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DOCUMENT ORGANIZATION

Operable Unit 4 Solar Evaporation Pond Interim Measure/Interim Remedial Action - Environmental Assessment Decision Document

Part I	-	Executive Summary and Introduction
Part II	-	Operable Unit 4 Phase I RCRA Facility Investigation/Remedial Investigation Report
		Volume 1 - Sections 1 through 7 (Figures for Section 3 are in Volume 2)
		Volume 2 - Section 3 Figures
		Volume 3 - Appendices A through G
		Volume 4 - Appendices H through L
		Volume 5 - Appendices M through O
		Volume 6 - Appendices P through Q
		Volume 7 - Appendices R through V
		Volume 8 - Appendices W through Z
Part III	-	Interim Measure/Interim Remedial Action Design Analysis
Part IV	-	Recommended Interim Measure/Interim Remedial Action Alternative
Part V	-	Post-Closure Monitoring and Assessment Plan

OPERABLE UNIT 4 SOLAR EVAPORATION POND INTERIM MEASURES/INTERIM REMEDIAL ACTION - ENVIRONMENTAL ASSESSMENT DECISION DOCUMENT

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OPERABLE UNIT NO. 4
LIST OF ACRONYMS AND ABBREVIATIONS

ADT	Average Daily Traffic
AG	aboveground
AIP	Agreement in Principle
ANOVA	analysis of variance
APEN	Air Pollution Emission Notice
AR	Treatability Studies Annual Reports
ARAR(s)	Applicable or Relevant and Appropriate Requirement(s)
ARF	Airborn Release Fraction
ASTM	American Society for Testing and Materials
ATM-m^3/mole	Atmospheres per cubic meter per mole
ATSDR	Agency for Toxic Substance and Disease Registry
BDL	Below (analytical) Detection Limit
bgs	below ground surface
BRA	Baseline Risk Assessment
BTEX	benzene, toluene, ethylbenzene, and xylene
CAD/FAD	Corrective Action Decision/Final Action Decision
CAMU	Corrective Action Management Unit
CAP	Cement Asbestos Pipe
CCR	Colorado Code of Regulations
CD	Consolidated-Drained
CDH	Colorado Department of Health
CDOT	Colorado Department of Transportation
CEC	Cation Exchange Capacity
CE	Cognizant Engineer
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHWA	Colorado Hazardous Waste Act
CI	Cast Iron
CLP	Contract Laboratory Program
CLT	Comprehensive list of technologies/process options
cm^2	square centimeters
cm/day	centimeters per day
cm/sec	centimeters per second
CMP	corrugated metal pipe
CMS/FS	Corrective Measures Study/Feasibility Study
COC(s)	contaminants of concern
COEM	Conduct of Engineering Manual
COL	colluvium

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cpm	counts per minute
CRDL	contract-required detection limit
CRQL	contract-required quantitation limit
CSI	Construction Specified Institute
CU	Consolidated-Undrained
DCF	Dose Conversion Factor
DCG	Derived Concentration Guide
DCN	document change notice
°C	degrees Celsius
DOE	United States Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
dpm/kg	disintegrations per minute per kilogram
DQO	data quality objective
DQR	data quality requirement
EA	environmental assessment
ECD	electron capture detector
EE	Environmental Evaluation
EIS	Environmental Impact Statement
EM	Electromagnetic
EMD	Environmental Management Division
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	Environmental Safety and Health
°F	degrees Fahrenheit
FDC	Frequency domain capacitance
FFCA	Federal Facilities Compliance Agreement
FID	Flame Ionization Detector
FIDLER	Field Instrument for the detection of low energy radiation
FML	flexible membrane liner
FO	field operations
FR	Federal Register
FRP	Fiberglass Reinforced Plastic
FS	Feasibility Study
FSP	Field Sampling Plan
ft/ft	feet per foot
ft msl	feet above mean sea level
ft/yr	feet per year

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g/cm^3	grams per cubic centimeter
GC/FID	gas chromograph/flame ionization detector
GCL	geosynthetic clay liners
GIS	Geographic Information System
gpm	gallons per minute
GPR	ground-penetrating radar
GRA	General Response Action
GRRASP	General Radiochemistry and Routine Analytical Services Protocols
HEAST	Health Effects Assessment Summary Table
HELP	Hydrologic Evaluation of Landfill Performance
HEPA	High-Efficiency Particulate Air
HHEM	Human Health Evaluation Manual
HHRA	Human Health Risk Assessment
HHS	Human Health Standard
HM	hot measurement
HQ	hazard quotient
HSU	hydrostratigraphic unit
IAG	Interagency Agreement
ICP	Inductively Coupled Plasma Arc Method
ICR	Incremental Cancer Risk
IDL	instrument detection limit
IDM	Investigation-Derived Material
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IRIS	Integrated Risk Information System
ITPH	interceptor trench pump house
ITS	interceptor trench system
K	hydraulic conductivity
KAL	Cretaceous Arapahoe/Laramie
KS	Kolmogorov-Smirnov
LDR	land disposal restriction
LHSU	lower hydrostratigraphic unit
LOEL	Lowest Observed Effect
m	meter
MCL	maximum contaminant level
MEPAS	Multimedia Exposure Pathway Asessment System
mg/kg	milligrams per kilogram

μg/kg	micrograms per kilogram
μg/L	micrograms per liter
mg/L	milligrams per liter
m/yr	meters per year
MHz	megahertz
mph	miles per hour
MTR	Minimum Technology Requirement
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NOEL	No Observed Effect
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NSC	Non-safety Class
NTGS	National Technical Guidance Series
NTS	Nevada Test Site
O&M	operations & maintenance
OPWL(s)	original process waste line(s)
OU	Operable Unit
OU4	Operable Unit 4
PA	Protected Area
PAH	Polynuclear or Polycyclic Aromatic Hydrocarbon
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCBs	polychlorinated biphenyls
pCi/L	picocuries per liter
PCOC(s)	potential contaminant(s) of concern
PCE	Tetrachloroethene
pH	negative log hydronium ion concentration moles per liter (potential of hydrogen)
PID	Photoionization Detector
PM1O	particulate matter less than 10 microns
PMR	Power Modification Request
PNA	polynuclear aromatic hydrocarbons
PNL	Pacific Northwest Laboratory
PP	proposed plan
PPCD	DOE's Plan for Prevention of Contaminant Dispersion
PPE	personal protective equipment
PQAP	Project Quality Assurance Program Plan
PRG(s)	preliminary remediation goal(s)

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PSZ	Perimeter Security Zone
PVC	polyvinyl chloride
QA	quality assurance
QAA	Quality Assurance Addendum
QAP	Quality Assurance Plan
QAPjP	Quality Assurance Project Plan
QC	quality control
QHA	Quality Assurance Addendum
RA	remedial action
RAAMP	Radiological Ambient Air Monitoring Program
RAGS	Risk Assessment Guidance for Superfund
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act
RF	Respirable Fraction
RFA	Rocky Flats Alluvium
RfC	reference concentration
RfD	reference dose
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RL	reporting limit
ROD	Record of Decision
ROI	Radiological operating instruction
RQD	Rock Quality Designation
RSP	Respirable Suspended Particulates
SAP	Sampling and Analysis
SAS	Special Analytical Service
SCS	Soil Conservation Service
SEP(s)	Solar Evaporation Pond(s)
SF	slope factor
SOP	Standard Operating Procedure
SOW	Statement of Work
SPT	Standard Penetration Test
SS	Stainless Steel
SSH&SP	Site-Specific Health and Safety Plan
STL	Steel
STP	Sewage Treatment Plant
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit

TAL	Target Analyte List
TBC	to-be-considered documents
TCA-1,1,1	Trichloroethane
TCE	Trichloroethene
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TDR	Time domain reflectometry
TDS	total dissolved solids
TICs	tentatively identified compounds
TMTS	Temporary Modular Tank System
TOC	total organic carbon
TSDF	Treatment, Storage, or Disposal Facility
TSP	Treatability Studies Plan
TSS	total suspended solids
UCL	upper confidence level
UG	underground
UHSU	upper hydrostratigraphic unit
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
UTL	upper threshold limit
UV	ultraviolet
VCP	Vitrified Clay Pipe
VFA	Valley Fill Alluvium
VOC	volatile organic compound
WARP	Well Abandonment and Replacement Program
WCS	weathered bedrock
WQPL	water quality parameters list
WRS	Wilcoxon Rank Sum
ZPA	Zero Period Acceleration

PART III
INTERIM MEASURE/INTERIM REMEDIAL ACTION DECISION ANALYSIS

The Interagency Agreement (IAG), Statement of Work, Section I.B.11.b., prescribes a two-phase approach for the closure and cleanup of Resource Conservation and Recovery Act (RCRA) Interim Status units at Rocky Flats Plant (RFP). As such, the intent of the IAG is that the U.S. Department of Energy (DOE) will first close the Solar Evaporation Ponds (SEPs) to eliminate the continued or threatened release of contaminants from the SEPs then, as necessary, perform corrective action(s) to mitigate prior releases from the SEPs. Under the first phase of the effort, DOE was required to conduct a characterization of the "sources/soils" of the SEPs. Consequently, the requirements for closure are interpreted to mean that DOE will close the ponds in a manner that will prevent further degradation of the environment by including contaminated soils, as well as SEP structures, into the closure action. Various alternatives can be implemented to successfully close and remediate Operable Unit 4 (OU4). In determining the most appropriate alternative, the following factors were considered:

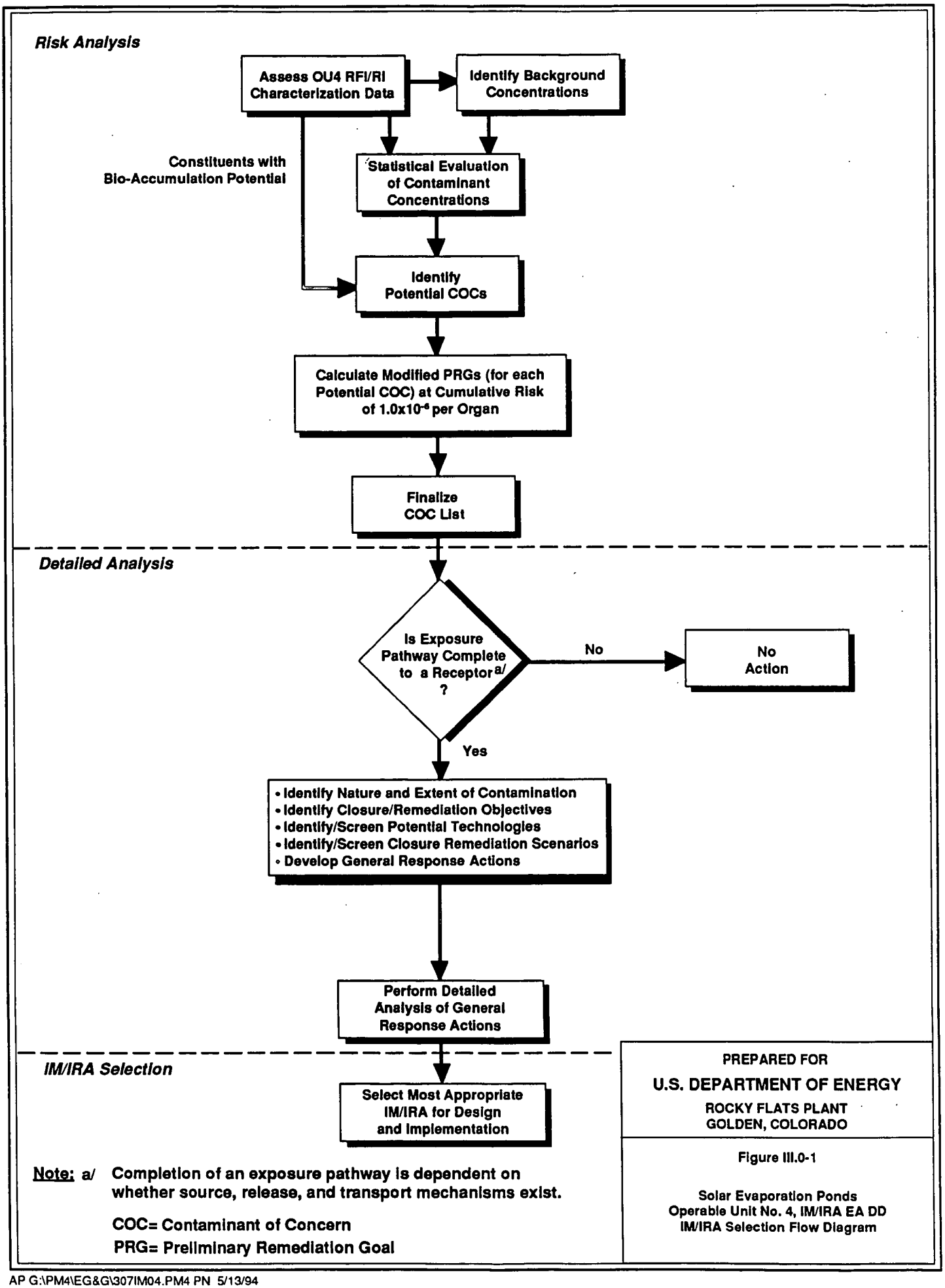
- The nature and extent of contamination present;
- The closure/remediation objectives established for the IM/IRA;
- The cleanup levels determined to be protective of human health and the environment; and
- The evaluation criteria used to compare acceptable alternatives.

Figure III.0-1 is the overall flow diagram depicting the organization of Part III and the activities involved in selecting an appropriate interim measure/interim remedial action (IM/IRA). Of the decision factors listed above, the nature and extent of contamination was presented in Part II of this Decision Document. Section III.1 presents the closure/remediation objectives that the IM/IRA is to achieve. Section III.2 discusses the methodology for establishing the OU4 cleanup levels and provides the cleanup levels (e.g., PRGs) for the contaminants of concern (COCs). Section III.3 identifies those process options deemed to be appropriate for the closure/remediation of OU4 and groups them into general response actions (GRAs) to allow comparison of the credible alternatives. Section III.4 delineates the evaluation criteria used to compare the GRAs to determine the GRA's suitability for implementation. Section III.5 provides the results of the detailed analysis of the IM/IRA selection process. A justification for the selected IM/IRA is presented in Section III.6.

III.1 REMEDIAL ACTION OBJECTIVES

As stated above, the purpose of the OU4 IM/IRA program is to close the SEPs and remediate contaminated soils. Specific technical closure/remediation objectives are:

- Protect human health and the environment from further risks resulting from unmitigated direct exposure to contaminants found in soils, surface water runoff, or air, in a manner consistent with the National Contingency Plan (NCP),



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Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA, and the IAG;

- Minimize the need for long-term maintenance;
- Provide a closure system that will be the long-term remedy for OU4 and, to the greatest extent practicable, be consistent with and expected to meet the requirements for ground water protection (developed during the subsequent hydrogeological investigations);
- Minimize the impact to surrounding RFP facilities, operations, and utilities;
- Minimize the impact upon the stability of the hillside north of the SEPs, which has the potential for slumping;
- Provide a closure/remediation system that will comply with the CDH- and EPA-approved applicable or relevant and appropriate requirements (ARARs), unless a waiver is justified;
- Minimize impacts to the interceptor trench system (ITS);
- Be cost-effective, and within the congressionally approved funding limitations;
- Utilize permanent solutions and alternative (i.e., innovative) treatment technologies or resource recovery technologies to the maximum extent practicable;
- Meet the schedule milestones specified in the IAG;
- Minimize the generation of waste;
- Minimize the spread of contaminants during implementation; and
- Integrate closure activities for RCRA Units 21 and 48.

The selected GRA will be designed to achieve the remedial action objectives to the maximum extent practicable.

III.2 RISK ANALYSIS

Results of the risk analysis are used to assess the ability of the GRAs to meet the first remedial action objective: protection of the human health and the environment. This section presents the methods used to evaluate the risks posed by contaminants at the SEPs.

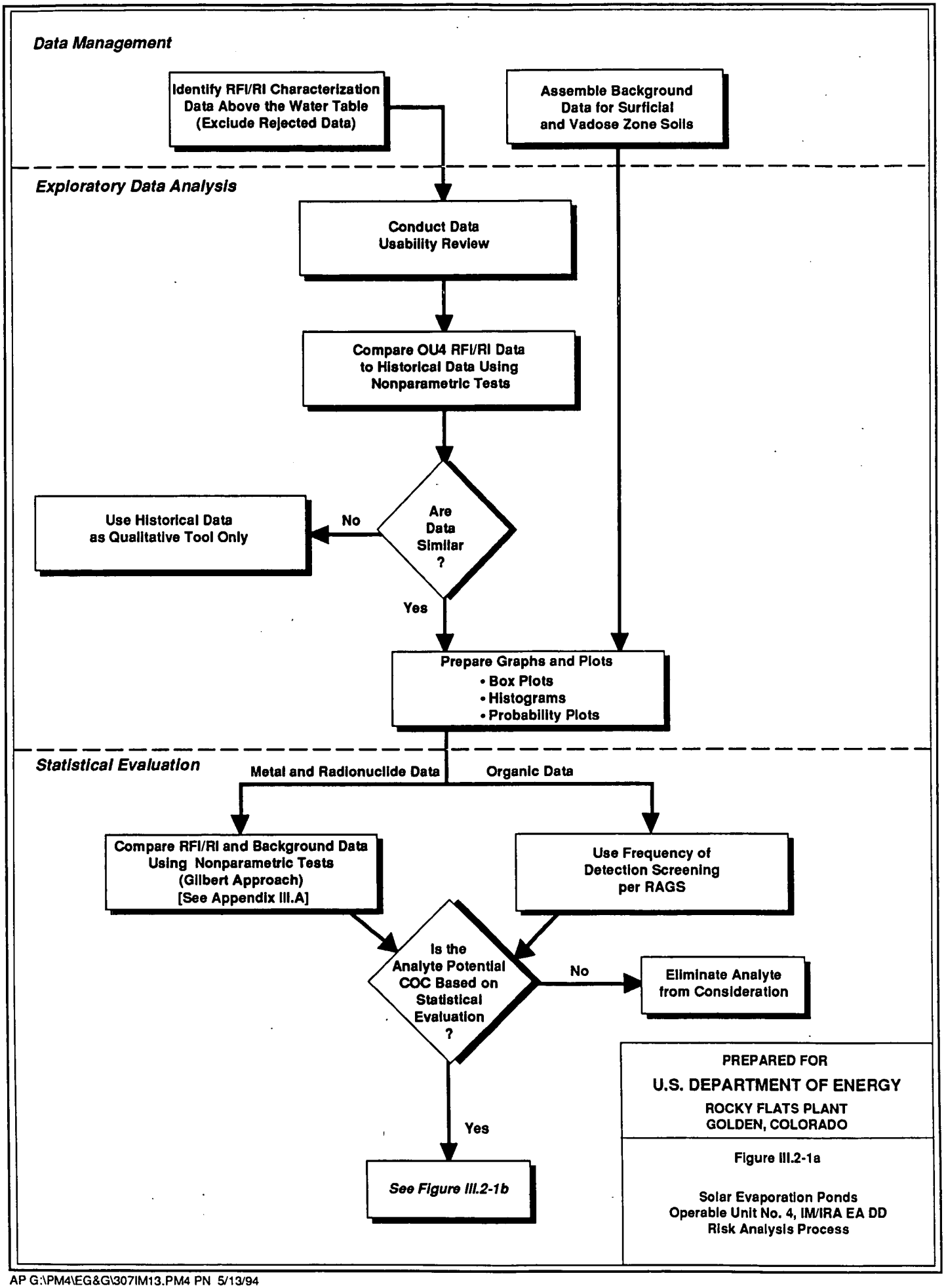
Data from characterization activities at the SEPs were used to identify COCs in surficial and vadose zone soil. The goal of this analysis was to define the nature and extent of contamination in these media that may pose a risk to human health and the environment and to assist in identifying and selecting an appropriate IM/IRA alternative for the site. All steps of the risk analysis, completed in support of the IM/IRA for OU4, were developed in concert with the CDH and the EPA. The risk analysis includes several new statistical techniques suggested by Gilbert (1993), which were slightly revised to support risk analysis and modified human health intake equations based on guidance from the CDH (1993). The statistical techniques suggested by Gilbert are described in Part II, Section 3. Details concerning the results of the statistical evaluation are provided in Appendix III.A.

Using the previously mentioned statistical techniques, risk assessment concentrations for each potential COC were developed following EPA *Risk Assessment Guidance for Superfund (RAGS)* (EPA 1991). These values are compared to PRGs (Subsection III.2.3). The final result is a determination of which contaminants exceed the human health protective PRGs on an OU4 site specific basis. These results are used in defining potential general response actions and in the selection of a preferred alternative.

The following sections briefly identify the PCOCs, define long-term target concentrations that are protective of human health, and present the final list of COCs that will be used to evaluate technologies appropriate for the site. Section III.2.1 presents the PCOCs that were developed statistically in Part II (Section 3). Subsection III.2.2 describes the development of risk-based preliminary remediation goals (PRGs) used in defining long-term target potential COC concentrations that minimize potential risks to human health. Subsection III.2.3 summarizes the methods used to define the final list of COCs for consideration during selection and implementation of remedial technologies for OU4. Subsection III.2.3 also defines the general areas within OU4 that may pose a risk to human health and the environment based on existing data. Several appendices, III.A, III.B, and III.C, contain detailed information concerning statistical evaluations, risk-based PRGs, and COCs. Figure III.2-1 schematically illustrates the approach used to identify PCOCs and determine risk-based PRGs. Figure III.2-1 also defines the approach for developing the final list of COCs and extent of contamination to be considered when evaluating the applicability and effectiveness of remedial alternatives for OU4.

III.2.1 Identification of Potential Contaminants of Concern

The statistical analysis of the OU4 RFI/RI data to determine the potential contaminants of concern (PCOCs) is presented in Part II of this IM/IRA-EA decision document. Figure III.2.1 presents the strategy to determine the final COCs based on calculating PRGs for comparison to the OU4 RFI/RI results. Table III.2-1 presents the list of PCOCs developed using the strategy described in Part II. Calcium, potassium, and silicon were eliminated as PCOCs because they are essential human nutrients (EPA, 1989). Sulfide was eliminated as a PCOC because it is a naturally occurring ubiquitous anion. Gross alpha and beta were also eliminated as PCOCs because this type of radiation is included in all of the other radioisotopes



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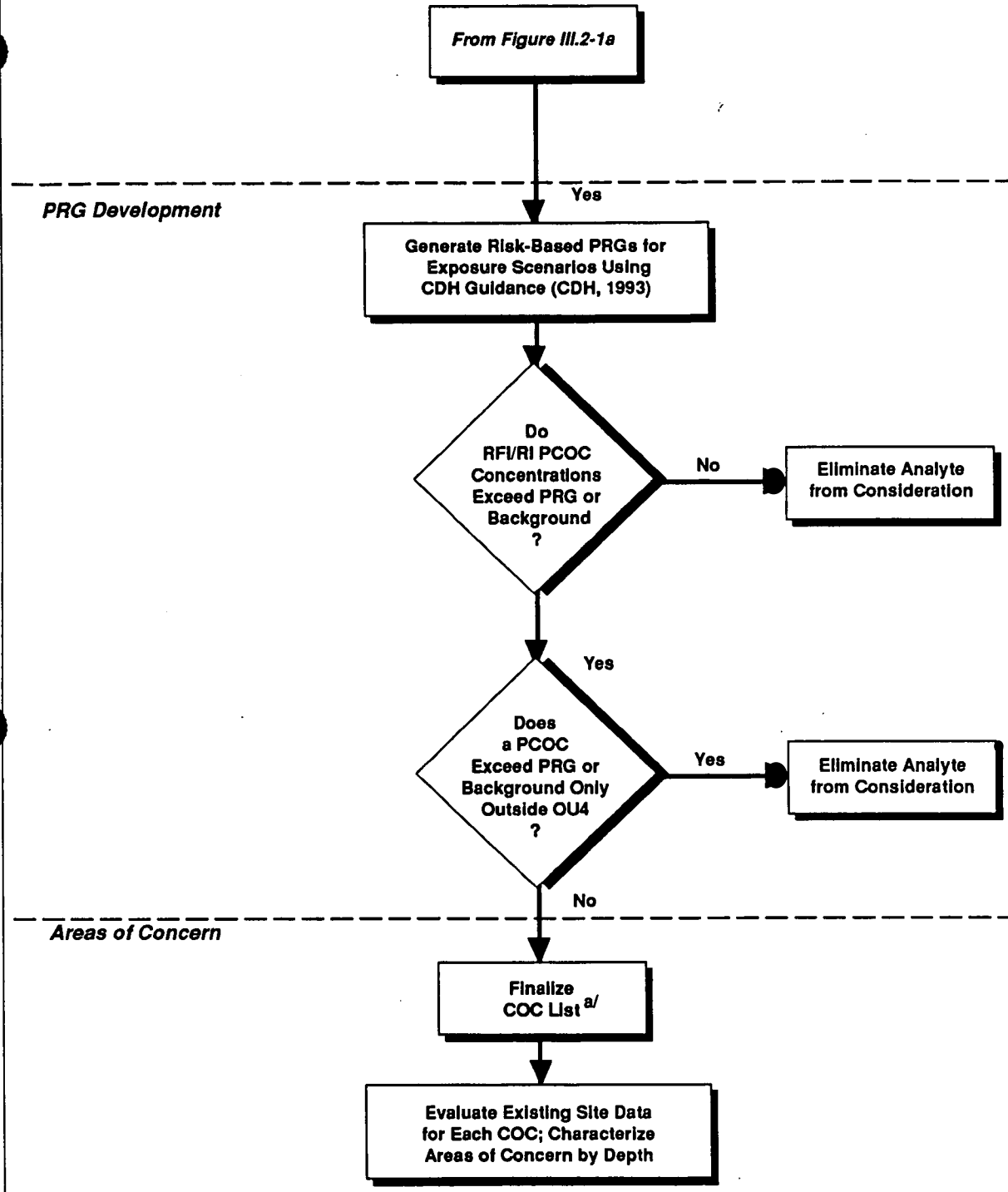

Note: a/ PRGs may need to be recalculated based upon the results of the location screen.

COC = Contaminant of Concern
PCOC = Potential COC
PRG = Preliminary Remediation Goal

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Figure III.2-1b

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Risk Analysis Process

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TABLE III.2-1
LIST OF THE POTENTIAL CONTAMINANTS OF CONCERN FOR THE OU 4 IM/IRA

Surficial Soil	Vadose Zone Soil
Radionuclides	**Radionuclides**
Americium-241	Americium-241
Cesium-134	Cesium-134
Gross alpha	Cesium-137
Plutonium-239,240	Gross beta
Tritium	Plutonium-239,240
Uranium-233,234	Radium-226
Uranium-235	Strontium-89,90
Uranium-238	Tritium
	Uranium-233,234
	Uranium-235
	Uranium-238
Metals/Inorganics	**Metals/Inorganics**
Beryllium	Barium
Cadmium	Cadmium
Calcium a/	Calcium a/
Mercury	Lithium
Nitrate/Nitrite	Manganese
Silicon a/	Nitrate/Nitrite
Silver	Potassium a/
Sodium	Sodium
	Sulfide a/
	Zinc
Organics	**Organics**
Benzo(a)anthracene	2-butanone
Benzo(a)pyrene	Acetone
Benzo(b)fluoranthene	Bis(2-ethylhexyl)phthalate
Benzo(ghi)perylene	Chloroform
Benzo(k)fluoranthene	Di-n-butyl phthalate
Bis(2-ethylhexyl)phthalate	Methylene chloride
Chrysene	Toluene
Di-n-butyl phthalate	Cyanide
Fluoranthene	
Indeno(1,2,3-cd)pyrene	
Phenanthrene	
Pyrene	
Aroclor-1254	

Footnotes:
a/ Chemical later eliminated as an essential human nutrient or naturally occurring anion.

in the COC list. None of the PCOCs were determined to exceed PRGs or background outside OU4.

III.2.2 Development Preliminary Remediation Goals

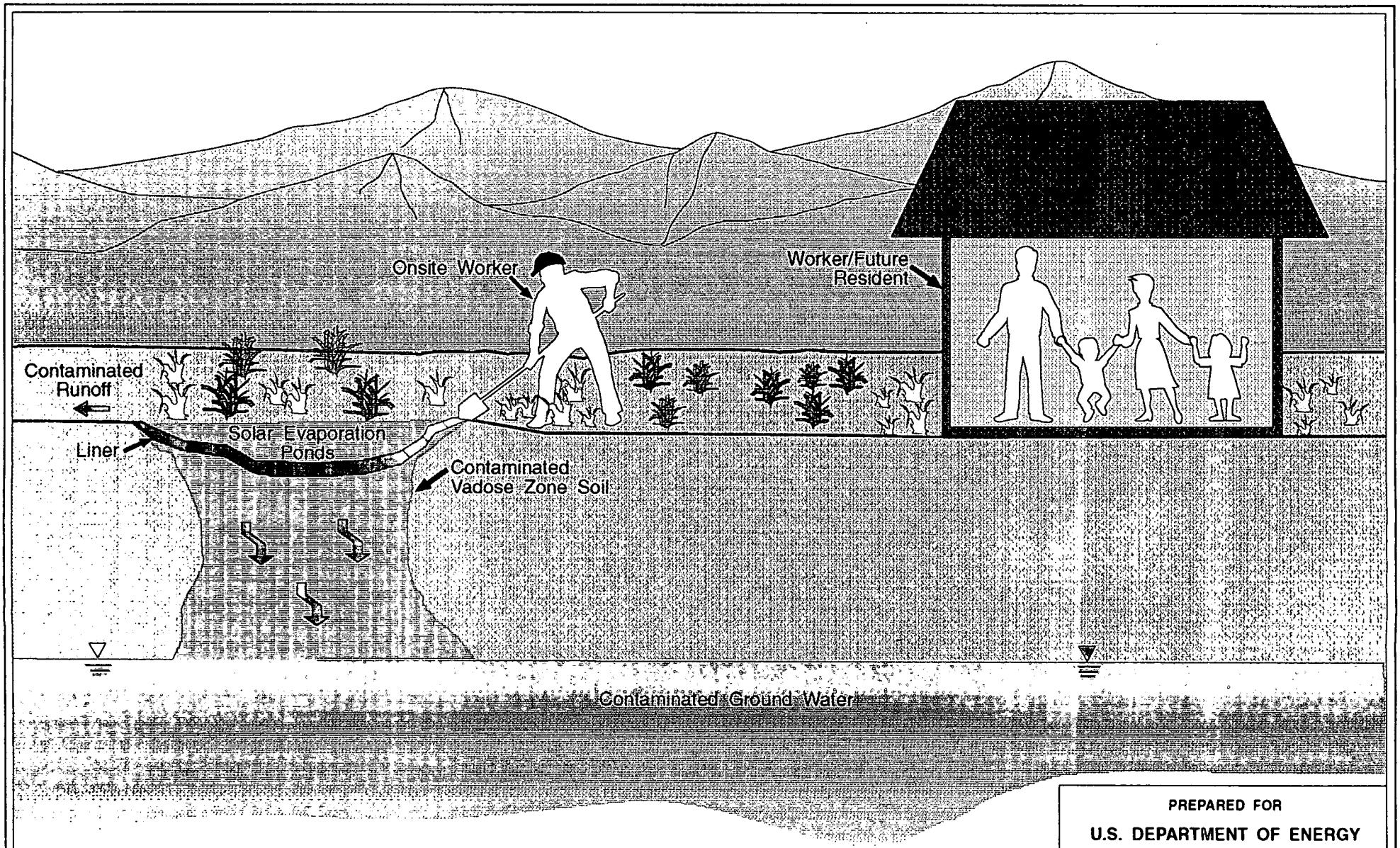
The following sections present the methods for calculation of PRGs for soils and an evaluation of cross-media contamination to assess the potential for soils to be a source of ground water contamination.

III.2.2.1 Soil Preliminary Remediation Goals

Risk-based PRGs for human health were calculated for the PCOCs based on an evaluation of exposure pathways and chemical toxicity. Risk-based PRGs are concentration goals for individual chemicals for specific environmental media and land use combinations which are protective of public health. Ecological PRGs were not included in this evaluation. The rationale for this decision is that OU4 has been defined as a potential source of contaminants, rather than as a point of impact for contaminants (DOE, 1992). OU4 is a highly disturbed industrial area that does not have the ecological attributes of the surrounding region. Because the OU4 area has been characterized previously as containing few ecological attributes within its own boundaries, humans are likely to be the primary receptors of concern. Further, risk-based PRGs for humans are generally more conservative than those values typically developed to be protective of ecological resources given the target media. Even though no quantification of risks to ecological receptors at OU4 was completed, a qualitative discussion of ecologic impacts is included as part of the alternatives evaluation at the end of this section. For the OU4 IM/IRA, the media of concern are surface soils [0 to 3 inches below ground surface (bgs)] and subsurface or vadose zone soils (3 inches bgs to mean historic seasonal high ground water elevation). Soils deeper than the mean historic seasonal high ground water elevation are seasonally or typically saturated and may be a source of ground water contamination. Due to the saturation potential, these soils will be addressed in the follow-on hydrogeologic investigations (Phase II). PRGs provide target concentrations for use during analysis and selection of remedial alternatives. They are not intended to replace the baseline evaluation that will be completed under the follow-on hydrogeological studies for OU4.

III.2.2.1.1 Pathways of Exposure

Two potential future land use scenarios were considered in the development of PRGs: residential and commercial. Residential land use is considered improbable at the RFP. However, this scenario is required by the State of Colorado to establish clean closure requirements under RCRA. A residential scenario is also the most conservative potential future land use. Commercial/industrial land use is considered to be the most probable future land use at the RFP and was therefore considered in developing PRGs for OU4. Figure III.2-2 presents a conceptual exposure assessment model.



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U.S. DEPARTMENT OF ENERGY

ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure III.2-2

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Conceptual Exposure Assessment Model

DE30722A-IM/IRA-EA

Under the residential land use scenario, potential future receptors could be exposed to contaminated surface soils through incidental ingestion, dermal contact, and inhalation of contaminated soil particulates. Only those chemicals not considered volatile (e.g., Henry's Law constant less than 10^{-5} atmospheres per mole per cubic meter [atm-m^3/mole]) were considered for potential inhalation of contaminated soil particles. Inhalation of volatile organic compounds (VOCs) was considered to be an insignificant pathway given the lack of VOCs in the surficial soils and the limited numbers of and low concentrations of VOCs in vadose zone soils at OU4. Ingestion of fruits and vegetables was also considered an insignificant pathway in developing PRGs for the residential scenario due to the improbability of subsistence farming or gardening in the SEP area. Therefore, this pathway was not used to screen the GRAs. However, this potential exposure pathway may be considered in the baseline risk assessment to be completed as part of the additional hydrogeological investigation, if necessary. Both adults and children were considered as receptors in the residential scenario.

Under the commercial/industrial land use scenario, only short-term use of the site during construction (remediation) was considered. Worker exposure was considered for incidental ingestion of soils, dermal contact, and inhalation of contaminated particulates. Longer term exposure of industrial/commercial workers was not retained in the final PRG evaluation because it was not relevant for PRG comparisons. The residential PRGs would have primacy over the commercial/industrial worker PRGs. The latter calculation was, therefore, not retained in this evaluation.

Exposure parameters for organic and inorganic PCOCs under the residential and construction worker scenarios were taken from the State of Colorado's *Interim Final Policy and Guidance on Risk Assessments for Corrective Action at RCRA Facilities* (CDH, 1993). For radionuclides exposure parameters were taken from the *RAGS, Part B* (RAGS) (EPA, 1991c).

Intake equations were taken from RAGS Part B and modified. For the residential scenario, the RAGS equation for residential soil PRGs was modified to include intake from dermal exposure and from inhalation of particulates. The equations were also modified to separate intakes for adults and children according to the CDH guidance (CDH, 1993). For the construction worker scenario, the RAGS equation for commercial/industrial soil PRGs was modified both to include dermal exposure and to adjust intake factors to correspond to the CDH guidance (CDH, 1993). For radionuclides, the RAGS equation was modified slightly according to the EPA revisions to the RAGS guidance (EPA, 1993e), which adjust for the new external toxicity values provided in the *Health Effects Assessment Summary Table* (HEAST) (EPA, 1993c). These parameters and equations used to calculate PRGs are listed in Appendix III.B.

III.2.2.1.2 Toxicity Assessment

Toxicity information used to calculate risk-based PRGs included the reference dose (RfD), the reference concentration (RfC) for evaluating noncarcinogenic effects, the slope factor (SF), and unit risk for evaluating potential carcinogenic effects. Values were obtained from the

Integrated Risk Information System (IRIS) (Micromedix, Inc., 1993). If values were not available from the IRIS, then the HEAST (EPA, 1993c) was consulted. For polynuclear aromatics (PNAs) not listed in the IRIS or the HEAST, toxicity values were calculated using the *Provisional Guidance for Quantitative Risk Assessment for Polycyclic Aromatic Hydrocarbons* (EPA, 1993d). In addition to toxicity values, information on toxic endpoints (i.e., critical effects or target organs) was also obtained from the IRIS or the HEAST for the PCOCs. Toxicity information for organic and inorganic chemicals is summarized in Table III.B-7 and toxicity information for radionuclides is summarized in Table III.B-8 in Appendix III.B. Complete toxicological profiles for each PCOC are contained in Appendix III.C.

Only oral and inhalation values have been derived by the EPA and are listed in the IRIS or the HEAST. The EPA has not developed toxicity values for dermal exposure due to the lack of scientific studies to quantify dermal toxicity and carcinogenic potential for the vast majority of priority pollutants. In the absence of dermal reference toxicity values, the EPA has suggested that in some cases it is appropriate to modify an oral RfD so it can be used to estimate the hazard incurred by dermal exposure (EPA, 1989d). This requires that the observed toxic endpoints are the same for both oral and dermal exposures and that a quantitative estimate exists for both dermal and oral absorption of the chemical. This information is generally not available for most priority pollutants. Oral toxicity values are nevertheless often used to quantify risk associated with dermal exposure. As a consequence, any valuation of the contribution of dermal exposure to the overall hazard should be viewed as highly tentative at best. Oral absorption factors for the PCOCs were taken from appropriate Agency for Toxic Substance and Disease Registry (ATSDR) Profiles as a conservative estimate of oral absorption. When ATSDR Profiles were not available or when information on the extent of absorption was not located, the following default values were determined by adopting absorption factors from similar chemicals: 0.2 for metals and inorganics; 0.90 for VOCs; 0.50 for phthalates; and 0.20 for PNAs.

III.2.2.1.3 Calculation of Preliminary Remediation Goals

PRGs were calculated for each of the two future scenarios: residential and construction (remediation). For residential land use, PRGs were calculated for PCOCs in surficial soils only. For the construction worker scenario, PRGs were calculated for PCOCs in vadose zone soils only because vadose zone soil is a medium that construction workers are likely to contact. Calculations were based on exposure assumptions identified in Section III.2.2.1.1 and on toxicity information discussed in Section III.2.2.1.2. For carcinogens, PRGs were calculated to correspond to a cumulative individual risk level of a one-in-one-million chance (1.0×10^{-6}) of developing cancer. Cumulative individual risks were considered by dividing the target risk level (1.0×10^{-6}) by the number of carcinogens affecting the same target organ. For example, if five carcinogens affect the liver, the PRG for each of those five carcinogens corresponds to a target risk level of $10^{-6}/5$ or 2×10^{-7}. Similarly, for noncarcinogens, PRGs correspond to an adjusted target hazard index based on the critical effect of the PCOC to account for cumulative exposure from multiple chemicals. PRGs and other chemical-specific statistics for each of the exposure scenarios considered are presented in Table III.2-2.

TABLE III.2-2

RFI/RI CHARACTERIZATION, BACKGROUND, AND PRELIMINARY REMEDIATION GOAL INFORMATION
POTENTIAL CONTAMINANTS OF CONCERN
LISTED BY CARCINOGENS, NONCARCINOGENS, AND RADIONUCLIDES

Potential Contaminant of Concern (PCOC)	Surficial Soil (0-3" bgs(1))			Vadose Zone Soil (3" bgs to water table)		
	OU4 95% UCL (RFI/RI) (2)	95% UCL (Background) (4)	PRG (Future Resident) (7)	OU4 95% UCL (RFI/RI) (2)	95% UCL (Background) (4)	PRG (Construction Worker) (8)
CARCINOGENS						
METALS/INORGANICS						
Beryllium (mg/kg)	3.98	0.92	1.93E-03		Not PCOC	
Cadmium (mg/kg)	172.1	0.64	1.91E+03	163.06	2.3	1.10E+05
VOCs (8)						
Chloroform (ug/kg)		Not PCOC		12.5	--	9.84E+04
Methylene chloride (ug/kg)		Not PCOC		30.56	--	7.89E+04
SEMIVOCs						
Benzo(a)anthracene (ug/kg)	830.29	--	7.40E+00		Not PCOC	
Benzo(a)pyrene (ug/kg)	881.44	--	7.40E-01		Not PCOC	
Benzo(b)fluoranthene (ug/kg)	371.31	--	7.40E+00		Not PCOC	
Benzo(k)fluoranthene (ug/kg)	422.5	--	7.40E+01		Not PCOC	
Bis(2-ethylhexyl)phthalate (ug/kg)	8129.91	--	2.69E+03	220	--	5.00E+04
Chrysene (ug/kg)	946.1	--	1.37E+02		Not PCOC	
Indeno(1,2,3-cd)pyrene (ug/kg)	712.54	--	7.40E+00		Not PCOC	
OTHER						
Aroclor-1254 (ug/kg)	3251.4	--	1.19E+01		Not PCOC	
NONCARCINOGENS						
METALS/INORGANICS						
Barium (mg/kg)		Not PCOC		108.4	93.87	6.99E+03
Beryllium (mg/kg)	3.98	0.92	1.23E+01		Not PCOC	
Cadmium (mg/kg)	172.1	0.64	5.96E-01	163.06	2.3	1.88E+01
Manganese (mg/kg)		Not PCOC		238.92	190.5	3.47E+02
Mercury (mg/kg)	0.17	0.03	1.85E-01		Not PCOC	
Nitrate (mg/kg)	595.62	1.11	1.58E+04	1873.4	7.1	3.18E+05
Nitrite (mg/kg)	595.62	1.11	9.88E+02	1873.4	7.1	1.99E+04
Silver (mg/kg)	2.19	0.58	1.48E+02		Not PCOC	
Strontium(mg/kg)		Not PCOC				1.19E+05
Uranium (mg/kg)			1.85E+00			6.17E+01
Zinc (mg/kg)		Not PCOC		4.74	23.64	6.37E+04
VOCs						
2-butanone (ug/kg)		Not PCOC		29	--	4.77E+07
Acetone (ug/kg)		Not PCOC		69.92	--	5.96E+06
Chloroform (ug/kg)		Not PCOC		12.5	--	6.43E+05
Methylene chloride (ug/kg)		Not PCOC		30.56	--	3.80E+06
Toluene (ug/kg)		Not PCOC		211.9	--	1.19E+07
SEMIVOCs						
Bis(2-ethylhexyl)phthalate (ug/kg)	8129.91	--	1.08E+05	220	--	1.50E+06
Di-n-butyl phthalate (ug/kg)	713.18	--	1.74E+06	220	--	4.25E+07
Fluoranthene (ug/kg)	374.58	--	6.35E+04		Not PCOC	
Pyrene (ug/kg)	386.04	--	3.57E+04		Not PCOC	
OTHER						
Aroclor-1254 (ug/kg)	3251.4	--	1.74E+03		Not PCOC	
Cyanide (mg/kg)		Not PCOC		15.93	--	4.95E+03

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TABLE III.2-2

RFI/RI CHARACTERIZATION, BACKGROUND, AND PRELIMINARY REMEDIATION GOAL INFORMATION
POTENTIAL CONTAMINANTS OF CONCERN
LISTED BY CARCINOGENS, NONCARCINOGENS, AND RADIONUCLIDES

Potential Contaminant of Concern (PCOC)	Surficial Soil (0-3" bgs(1))			Vadose Zone Soil (3" bgs to water table)		
	OU4 95% UCL (RFI/RI) (2)	95% UCL (Background) (4)	PRG (Future Resident) (7)	OU4 95% UCL (RFI/RI) (2)	95% UCL (Background) (4)	PRG (Construction Worker) (8)
RADIONUCLIDES						
Americium-241 (pCi/g)	26.24	0.027	2.65E-01	3.32	0.01	1.09E+00
Cesium-134 (pCi/g)	0.04	ND	8.90E-04	0.0098	ND	6.11E-02
Cesium-137 (pCi/g)		Not PCOC		0.05	0.166	1.51E-01
Gross alpha (pCi/g)	40.51	22.9	--		Not PCOC	
Gross beta (pCi/g)		Not PCOC		30.68	27.99	--
Plutonium-239 (pCi/g)	14.22	0.062	3.83E-01	6.74	0.02	1.16E+00
Plutonium-240 (pCi/g)	14.22	0.062	3.80E-01	6.74	0.02	1.16E+00
Radium-226 (pCi/g)		Not PCOC		1.44	0.65	5.22E-02
Strontium-89 (pCi/g)		Not PCOC		0.475	0.54	7.88E+01
Strontium-90 (pCi/g)		Not PCOC		0.475	0.54	7.42E+00
Tritium (pCi/g)	0.388	ND	1.63E+03	5.33	0.0316	4.95E+03
Uranium-233 (pCi/g)	14.29	1.22	5.25E+00	3.23	0.53	1.67E+01
Uranium-234 (pCi/g)	14.29	1.22	5.32E+00	3.23	0.53	1.67E+01
Uranium-235 (pCi/g)	0.163	0.09	1.68E-02	0.14	0.1	7.97E-01
Uranium-238 (pCi/g)	9.66	1.27	7.85E-04	6.66	0.63	5.41E-02

(1) bgs-below ground surface
(2)Calculated 95% upper confidence limit on the arithmetic mean using RFI/RI data; note that when the data could not be fit to a normal or lognormal distribution the reported maximum value was used as the 95% UCL value.
(3) Reported maximum value using RFI/RI data.
(4) Calculated 95% upper confidence limit on the arithmetic mean on background data (see text for details).
(5) Calculated value equal to the arithmetic mean plus two times the standard deviation on background data (see text for details).
(6) Reported maximum value for background data (see text for details).
(7) Calculated risk-based preliminary remediation goal for the future resident exposure scenario (see text for details).
(8) Calculated risk-based preliminary remediation goal for the construction worker exposure scenario (see text for details).

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III.2.3 Development of Contaminants of Concern

The final phase of the risk analysis process is to characterize the nature and extent of contamination at OU4 and refine the list of PCOCs to identify those COCs that are present in concentrations in excess of the calculated PRGs. Once these specific compounds were identified, the areas within OU4 and the volume of material that may have to be remediated could be defined.

COCs for which toxicity data were available were identified by comparing the representative PCOC concentration value (i.e., the 95 percent UCL, 95 percent UTL, or the maximum observation) to the most conservative risk-based PRG. Thus, for example, where a chemical had both carcinogenic and noncarcinogenic effects, the lower of the two resulting PRGs was used as the comparison criteria. For inorganics and radionuclides, the representative background level was also compared to the computed risk-based PRG. The greater of either the background level or the PRG was selected as the comparison criteria for representative PCOC concentration values. The rationale for this approach is that the target concentration level that defines contamination at the site should either be the level that is protective of human health at a cumulative risk level of 1.0×10^{-6} or a representative background level, whichever is higher. No target long-term concentration level would be lower than the representative background concentration (i.e., remediating below background concentrations will not be attempted).

The soil PRGs are presented in Table III.2-2. Only those chemicals for which PRGs could be calculated are shown in Table III.2-2. As described previously, essential human nutrients and naturally-occurring, ubiquitous anions were eliminated as PCOCs. As shown in Table III.2-2, the following PCOCs in surficial soils exceed their PRGs: beryllium; benzo(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; benzo(k)fluoranthene; bis(2-ethylhexyl)phthalate; chrysene; indeno(1,2,3-cd)pyrene; arochlor-1254; cadmium; americium-241; cesium-134; plutonium-239 and 240; and uranium-233, 234, 235, and 238. In vadose zone soils, far fewer PCOCs exceeded their PRGs. PCOCs in vadose zone soils which exceed their PRGs include cadmium, americium-241, plutonium 239 and 240, radium-226, and uranium 235 and 238.

The soil PRGs are developed to be protective of human receptors that may directly be exposed to the soils at OU4 through the upward pathways of exposure. The upward pathways include incidental ingestion, dermal contact, and inhalation of particulates of contaminants in soil. In addition to the risks from exposure to upward pathways are the risks from cross-media contamination to ground water. Estimating risks from contaminants in ground water is not the focus of this Phase I IM/IRA, but will be one of the primary objectives of the Phase II hydrogeologic studies. In order to determine what PCOCs may be contributors to contamination in the ground water at OU4, the previously described catastrophic dissolution and MYGRT models were used. Results of the modeling were compared to the previously described ground water comparison criteria. The results of the comparison are described in Appendix III.D.

III.2.3.1 Summary

Table III.2-3 presents the summary of the COCs based on the risk analysis. It also includes the COCs for which there is no toxicity information; these COCs will be retained as a conservative assumption. While at least one contaminant from each category of chemicals exceeded the soil PRG, all of the radionuclides, except cesium in vadose zone soils and strontium-89 and 90, exceeded soil PRGs. This indicates that the radionuclides are driving the need for remediation at the OU4 SEPs.

In addition to the risk posed by direct contact (upward pathways of exposure), the potential exists for contaminants in soil to impact ground water quality. An evaluation of this potential is provided in Appendix III.D. This appendix includes results of the catastrophic dissolution and MYGRT models. While these results are not designed to predict the risks from the ground water impacts, they are based upon the identified mechanism for potential contaminant transport from soils into ground water. The results can be used as a qualitative indication that some of the COCs may migrate in sufficient quantities to cause ground water criteria to be exceeded.

In addition to the risks from the chronic exposures, subchronic exposures during the remediation are evaluated in Part IV, Section 10.3. The calculations presented Section IV.10 have a level of uncertainty associated with the final result that is dependent on:

- The various input parameters (both the data used and the site-specific environmental values),
- The assumptions about environmental conditions that have been made, and
- Uncertainty associated with the modeling equations that have been used.

The largest sources for the uncertainty are the data that have been used in determining the constituent soil concentrations. The calculations used the 95% UCLs/UTLs for each soil constituent concentration. The use of a high confidence interval is an upper bound for the actual soil concentrations. The EPA states in RAGS that the 95% UCLs/UTLs are the accepted soil concentrations to use, and as such, will add conservatism to the estimate. The final results will also be uncertain because of the use of estimated site-specific input parameters (i.e., soil densities, moisture contents, excavation volume estimates, meteorological parameters, etc.). These parameters are averages of the conditions that are representative of the site. However, these conditions may not be homogeneous for the entire site. Therefore, the values of the parameters vary in reality and are uncertain. The assumptions used will also contribute to the uncertainty because an assumption is used when a well-defined number cannot be found and professional judgement must be used to determine the value (i.e., the use of a "typical" scraper weight of 40 tons when the actual weight is unknown). Typically, a value is used that overestimates the "real" value, and as such, makes the assessment conservative. The models

TABLE III.2-3
SUMMARY OF COCs BASED ON RISK ANALYSIS

POTENTIAL CONTAMINANTS OF CONCERN	SURFICIAL SOILS						VADOSE ZONE SOILS					
	RFI/RI 95% UCL/UTL	Background 95% UCL/UTL	PRG Resi-dential	TARGET LEVEL	COMMENTS	CONTAMINANT OF CONCERN	RFI/RI 95% UCL/UTL	Background 95% UCL/UTL	PRG Construction Worker	TARGET LEVEL	COMMENTS	CONTAMINANT OF CONCERN
METALS/INORGANICS												
Barium (mg/kg)						NO	108.4	93.87	6986.85	6986.85	Construction Worker PRG not exceeded	NO
Beryllium (mg/kg)	3.98	0.92	0.0019	0.92	Background target level exceeded	YES						NO
Cadmium (mg/kg)	172.1	0.64	0.60	0.64	Background target level exceeded	YES	163.06	2.3	18.80	18.80	Construction Worker PRG exceeded	YES
Cyanide (mg/kg)						NO	15.93	--	4945.80	4945.80	Construction Worker PRG not exceeded	NO
Manganese (mg/kg)						NO	238.92	190.5	346.51	346.51	Construction Worker PRG not exceeded	NO
Mercury (mg/kg)	0.17	0.03	0.18	0.18	Residential PRG not exceeded	NO						NO
Nitrate (mg/kg)	595.62	1.11	15815.84	15815.84	Residential PRG not exceeded	NO	1873.4	7.1	317637.92	317637.92	Construction Worker PRG not exceeded	NO
Nitrite (mg/kg)	595.62	1.11	988.49	988.49	Residential PRG not exceeded	NO	1873.4	7.1	19852.37	19852.37	Construction Worker PRG not exceeded	NO
Silver (mg/kg)	2.19	0.58	148.27	148.27	Residential PRG not exceeded	NO						NO
Strontium (mg/kg)						NO	0.275	--	119114.22	119114.22	Construction Worker PRG not exceeded	NO
Uranium (mg/kg)	29.0 a/	3.8	1.85	3.8	Background target level exceeded	YES	20.0 a/	1.9	61.66	61.66	Construction Worker PRG not exceeded	NO
Zinc (mg/kg)						NO	4.74	23.64	63747.50	63747.50	Construction Worker PRG not exceeded	NO
VOCs												
2-butanone (ug/kg)						NO	29	--	47697330.79	47697330.79	Construction Worker PRG not exceeded	NO
Acetone (ug/kg)						NO	69.92	--	5962196.64	5962196.64	Construction Worker PRG not exceeded	NO
Chloroform (ug/kg)						NO	12.5	--	98400.00	98400.00	Construction Worker PRG not exceeded	NO
Methylene chloride (ug/kg)						NO	30.56	--	78900.00	78900.00	Construction Worker PRG not exceeded	NO
Toluene (ug/kg)						NO	211.9	--	11924342.79	11924342.79	Construction Worker PRG not exceeded	NO
SEMIVOCs												
Benzo(a)anthracene (ug/kg)	830.29	--	7.40	7.40	Residential PRG exceeded	YES						NO
Benzo(a)pyrene (ug/kg)	881.44	--	0.74	0.74	Residential PRG exceeded	YES						NO
Benzo(b)fluoranthene (ug/kg)	371.31	--	7.40	7.40	Residential PRG exceeded	YES						NO
Benzo(k)fluoranthene (ug/kg)	422.5	--	74.02	74.02	Residential PRG exceeded	YES						NO
Bis(2-ethylhexyl)phthalate (ug/kg)	8129.91	--	2686.37	2686.37	Residential PRG exceeded	YES	220	--	49980.44	49980.44	Construction Worker PRG not exceeded	NO
Chrysene (ug/kg)	946.1	--	137.39	137.39	Residential PRG exceeded	YES						NO
Di-n-butyl phthalate (ug/kg)	713.18	--	1735035.21	1735035.21	Residential PRG not exceeded	NO	220	--	42488913.53	42488913.53	Construction Worker PRG not exceeded	NO
Fluoranthene (ug/kg)	374.58	--	63547.33	63547.33	Residential PRG not exceeded	NO						NO
Indeno(1,2,3-cd)pyrene (ug/kg)	712.54	--	7.40	7.40	Residential PRG exceeded	YES						NO
Pyrene (ug/kg)	386.04	--	35745.38	35745.38	Residential PRG not exceeded	NO						NO
OTHER												
Aroclor-1254 (ug/kg)	3251.4	--	11.87	11.87	Residential PRG exceeded	YES						NO

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TABLE III.2-3
SUMMARY OF COCs BASED ON RISK ANALYSIS

POTENTIAL CONTAMINANTS OF CONCERN	SURFICIAL SOILS						VADOSE ZONE SOILS					
	RFI/RI 95% UCL/UTL	Background 95% UCL/UTL	PRG Resi-dential	TARGET LEVEL	COMMENTS	CONTAMINANT OF CONCERN	RFI/RI 95% UCL/UTL	Background 95% UCL/UTL	PRG Construction Worker	TARGET LEVEL	COMMENTS	CONTAMINANT OF CONCERN
RADIONUCLIDES												
Americium-241 (pCi/g)	26.24	0.027	0.27	0.27	Residential PRG exceeded	YES	3.32	0.01	1.09	1.09	Construction Worker PRG exceeded	YES
Cesium-134 (pCi/g)	0.04	ND	0.001	0.001	Residential PRG exceeded	YES	0.0098	ND	0.06	0.06	Construction Worker PRG not exceeded	NO
Cesium-137 (pCi/g)						NO	0.05	0.166	0.16	0.166	Background target level not exceeded	NO
Plutonium-239 (pCi/g)	14.22	0.062	0.38	0.38	Residential PRG exceeded	YES	6.74	0.02	1.16	1.16	Construction Worker PRG exceeded	YES
Plutonium-240 (pCi/g)	14.22	0.062	0.38	0.38	Residential PRG exceeded	YES	6.74	0.02	1.16	1.16	Construction Worker PRG exceeded	YES
Radium-226 (pCi/g)						NO	1.44	0.65	0.05	0.65	Background target level exceeded	YES
Strontium-89 (pCi/g)						NO	0.475	0.54	78.80	78.80	Construction Worker PRG not exceeded	NO
Strontium-90 (pCi/g)						NO	0.475	0.54	7.42	7.42	Construction Worker PRG not exceeded	NO
Tritium (pCi/g)	0.388	ND	1630.00	1630.00	Residential PRG not exceeded	NO	5.33	212.2	4950	4950	Construction Worker PRG not exceeded	NO
Uranium-233 (pCi/g)	14.29	1.22	5.25	5.25	Residential PRG exceeded	YES	3.23	0.53	16.70	16.70	Construction Worker PRG not exceeded	NO
Uranium-234 (pCi/g)	14.29	1.22	5.32	5.32	Residential PRG exceeded	YES	3.23	0.53	16.70	16.70	Construction Worker PRG not exceeded	NO
Uranium-235 (pCi/g)	0.163	0.09	0.02	0.09	Background target level exceeded	YES	0.14	0.1	0.80	0.80	Construction Worker PRG exceeded	YES
Uranium-238 (pCi/g)	9.66	1.27	0.0008	1.27	Background target level exceeded	YES	6.66	0.63	0.05	0.63	Background target level exceeded	YES
COCs WITHOUT TARGET LEVELS												
Benzo(ghi)perylene	657.34	--	--	--	No available toxicity information	YES						NO
Lithium (mg/kg)						NO	14.26	83.2	--	--	No toxicity information	YES
Sodium	1274.36	165.4	--	--	No available toxicity information	YES	1863.7	2720	--	--	No toxicity information	YES
Phenanthrene (ug/kg)	381.55	--	--	--	No available toxicity information	YES						NO

a/ Values represent the highest of all the uranium isotopes and their background which have been converted from pCi/g to mg/kg.

used for the assessment calculations also introduce uncertainty into the results. The accuracy of the models is limited to several factors:

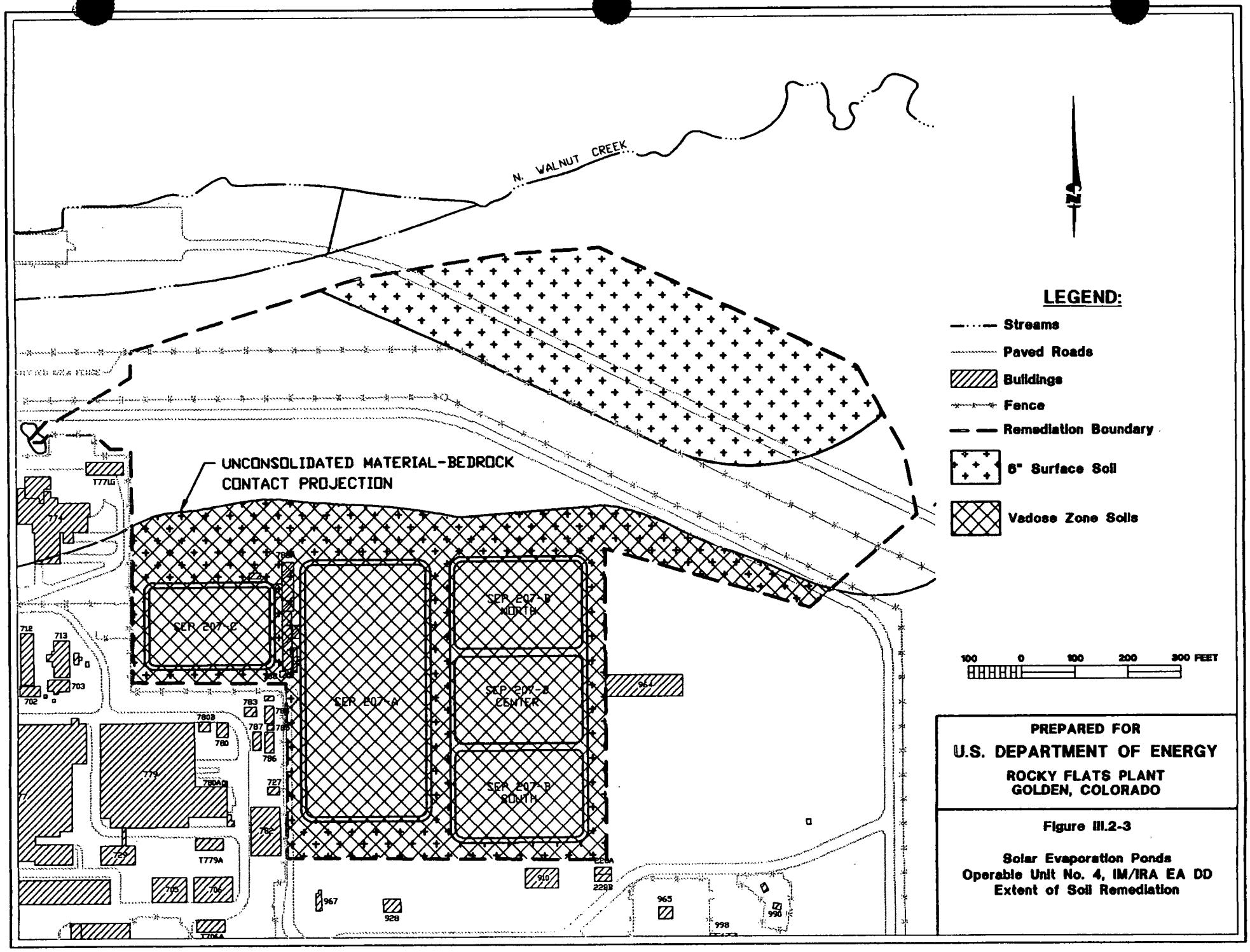
- Sophistication of the model's dispersion algorithms,
- The availability of site-specific data (i.e., meteorological data, geochemical parameters) to characterize conditions in the modeling domain.

The overall affect of these sources of uncertainty is that the final results can be accompanied by a conservative uncertainty of approximately one to two orders of magnitude.

The aerial extent of contamination is evaluated in the following section. It focuses on the COCs identified in Table III-2.3. The objective is to identify the locations and depths at which the COCs occur and the volume of soil that must be remediated.

III.2.4.4 Defining Areas of Concern

Based on the COCs presented in Table III.2-3, the areal extent of contamination within the OU4 boundary that may pose a risk to public health was established. Contaminated vadose soils (under and adjacent the SEPs) will be excavated to the depth of the mean historic high ground water elevation or until a level of contamination is reached that is below the vadose zone PRGs and below a concentration that is determined to be protective of ground water. Contaminated surficial soils within the OU4 boundary (north of the SEPs) will be excavated to 6-inches bgs. The objective of this mapping activity was to define those general areas, and their depths, that may have to be addressed during development and evaluation of an appropriate IM/IRA for OU4 since these areas exceed calculated PRGs, which are protective of human health. Historical data from OU4, which were not used to compute summary statistics, were incorporated into these maps to identify areas of concern. Maps for all of the specific COCs using only the RFI/RI data are presented in Section II.3 and Section II.4. Figure III.2-3 summarizes the areas of concern for all the COCs based on OU4 RFI/RI data. The areas of concern shown on the figure form the basis for the extent of potential contamination that will be the focus of the IM/IRA solution. This method of determining the areas of concern provides a very conservative estimate of the extent of contamination actually present. This will also provide a conservative estimate of the actual extent of contamination. The exact areas subject to the IM/IRA selected alternative will be determined during implementation of the OU4 IM/IRA. During implementation of the OU4 IM/IRA soil PRGs that are protective of ground water may be developed as necessary. Using the catastrophic dissolution and MYGRT models an iterative calculation can be performed to estimate the concentration of a COC in the soil that will result in a ground water concentration at or below the applicable ground water comparison criteria at the IHSS boundary. This tedious, time-consuming exercises will only be performed during detailed design if it is determined that it may streamline implementation and/or costs of the IM/IRA by reducing the volume of soils that need to be removed.


N. WALNUT CREEK
N
UNCONSOLIDATED MATERIAL-BEDROCK
CONTACT PROJECTION
SEP 207-C
SEP 207-A
SEP 207-B
NORTH
SEP 207-B
CENTER
SEP 207-B
SOUTH
LEGEND:
Streams
Paved Roads
Buildings
Fence
Remediation Boundary
6" Surface Soil
Vadose Zone Soils
100 0 100 200 300 FEET
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GOLDEN, COLORADO
Figure III.2-3
Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Extent of Soil Remediation

III.3 TECHNOLOGY IDENTIFICATION AND SCREENING

Process options, GRAs, and closure/remediation scenarios, are identified and screened in this section. Figure III.3-1 is a flow diagram that summarizes the activities that were performed to develop a closure/remediation general response action.

III.3.1 Technology Identification and Screening

A preliminary screening of possible treatment technologies to close and remediate the SEPs was conducted. The technologies that were considered are shown in Table III.3-1. Table III.3-1 is divided into three parts: technologies that could treat the liners/utilities, technologies that could treat the soils, and barrier methods that would be placed over the ponds to minimize infiltration or barrier methods to prevent the upward migration of ground water. In addition, technologies that could be applied *in situ* and *ex situ* were identified. *In situ* technologies are conducted with the waste/contaminated media left in place. *Ex situ* technologies require the physical removal of waste and contaminated media prior to their treatment.

Technologies were screened based on the following four criteria:

- Proven effectiveness;
- Applicability;
- Implementability; and
- Cost.

Each of the screening criteria is described below.

- **Proven Effectiveness** - A proven technology is one that has been used successfully at other sites (DOE or non-DOE) with similar wastes and/or characteristics. Since the IAG schedule does not allow a lengthy research and development period, technologies that have been proven only at the bench- or pilot-scale level without a demonstrated record of full-scale implementability were not considered to be proven technologies.

- **Applicability** - This criterion was used to screen a technology with respect to its applicability at the SEPs. If a demonstrated technology could not be utilized to effectively treat the identified contaminants or a class of contaminants (e.g., organics) within the IAG schedule, then it was eliminated from further evaluation. This criterion is discussed in terms of *in situ* and *ex situ* applicability.

- **Implementability** - Technologies were screened based on if the studies (e.g., feasibility) needed for their implementation could be performed within the treatability/engineering development time frame of the IAG schedule. Technologies requiring extensive testing and development that could not be implemented within the IAG schedule constraints were removed from the evaluation list. In addition, if

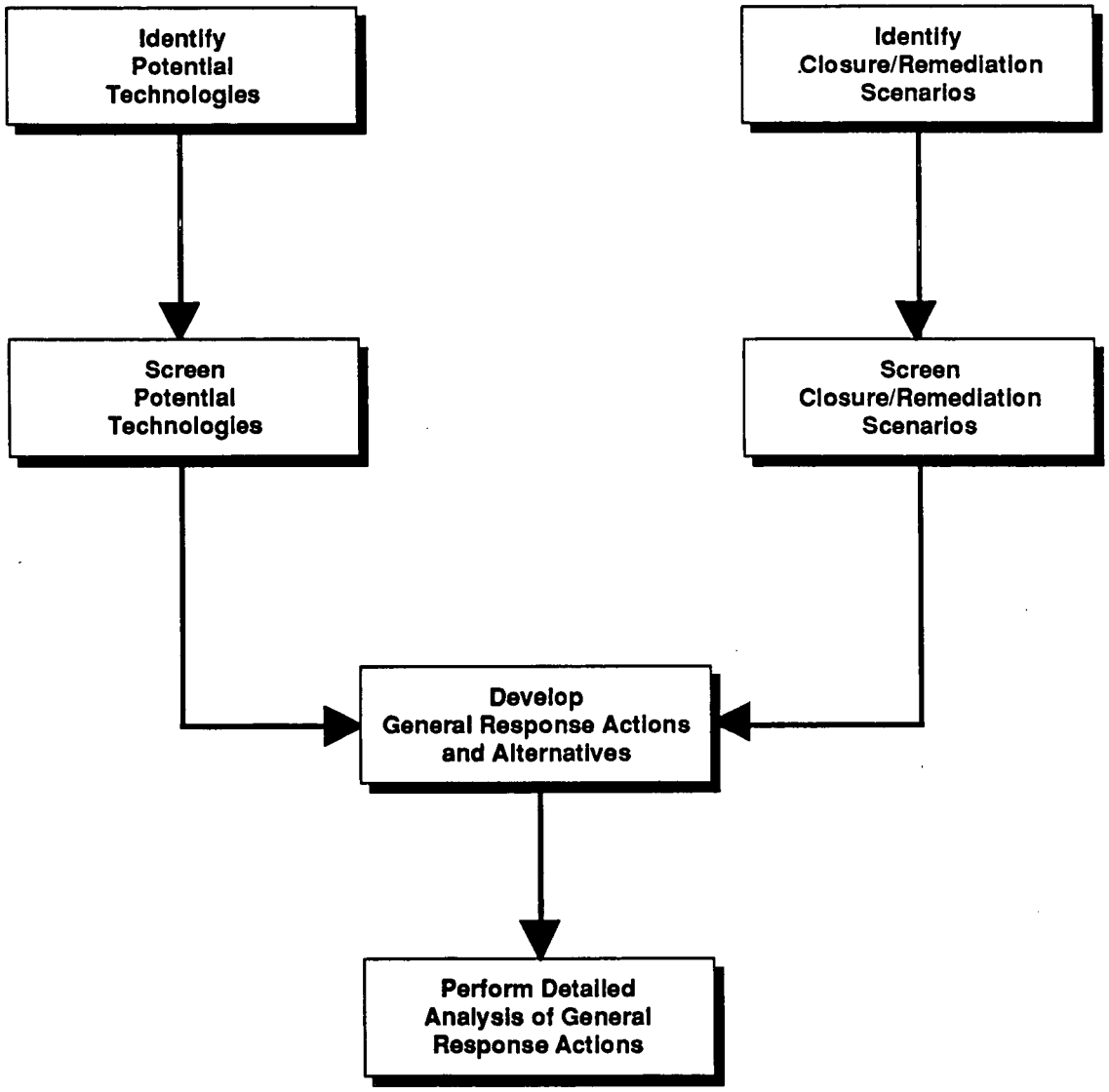

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Figure III.3-1

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Technology Screening and Alternative
Development Flow Diagram

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required resources were unavailable or could not be economically obtained, then the technology was eliminated from further evaluation.

- Cost - The cost of each technology was estimated and assigned a relative score of low, medium, or high. If the cost of one technology was much greater than the cost for other comparable technologies, then the technology with the greater cost was eliminated from further evaluation.

Technologies that failed to meet any one of the screening criteria were removed from the list for consideration. Figure III.3-2 is a summary of the technologies that were initially screened for the OU4 closure/remediation.

The results of the initial screening process are summarized in Table III.3-1 and illustrated on Figure III.3-2. Those process options which were eliminated based on application of the screening criteria are shaded on Figure III.3-2. The specific reasons these process options were eliminated are presented below.

III.3.1.1 Identification and Rationale for Technologies Failing the Screening Process

The technologies that failed the preliminary screening process are described in this section and the reasons for their elimination are discussed.

Vitrification

Vitrification is the process in which solid or semi-solid hazardous materials are transformed into a molten, vitreous mass which, upon cooling, will form a glass-like product which is typically highly inert, stable, and resistant to leaching. Vitrification can be used to treat a wide variety of waste types (contaminated with metals, radionuclides, and organics), and would be potentially suitable for treating the contaminated materials from the SEPs. Vitrification may be conducted either *in situ* or *ex situ* and typically requires off-gas treatment (high-efficiency particulate air filters and/or scrubbers). The development and procurement of the needed equipment will most likely require extension of the IAG schedule. Additionally, the cost of vitrification is and has historically been greater than the cost of comparable technologies for low-level waste. Vitrification was eliminated from the list of possible treatment technologies because of the time required to develop and implement the vitrification process, and cost.

Soil Flushing

Soil flushing is the *in situ* process of injecting fluid into contaminated soil and allowing the fluid to leach contaminants from the soil matrix. The fluid is then extracted from the subsurface via recovery trenches or wells for treatment. This technology could be utilized to wash the soils in place and transfer the contaminants to a more easily treated media (i.e., water). The extraction fluid could be either water or an aqueous chemical solution that would displace

TABLE III.3-1
IDENTIFICATION AND SCREENING OF POTENTIAL TECHNOLOGIES

Technology	Category		Preliminary Screening Criteria				Retained for Further Evaluation
	In Situ Applicability	*Ex Situ* Applicability	Proven Effectiveness	Applicability	IAG Schedule Implementability	Cost [a]	
BARRIERS							
Engineered Cover	N/A	N/A	Yes	Yes	Yes	Medium	Yes
Temporary Cover	N/A	N/A	Yes	Yes	Yes	Low	Yes
LINERS/UTILITIES							
Vitrification	Yes	Yes	Yes	Yes	No	High	No
Solidification/Stabilization	Yes	Yes	Yes	Yes	Yes	Medium	Yes
Containerization	No	Yes	Yes	Yes	Yes	High	Yes
Size Reduction	Yes	Yes	Yes	Yes	Yes	Low	Yes
SOILS							
Vitrification	Yes	Yes	Yes	Yes	No	High	No
Solidification/Stabilization	Yes	Yes	Yes	Yes	Yes	Medium	Yes
Soil Flushing	Yes	No	Yes	No	Yes	Medium	No
Soil Washing	No	Yes	Yes	Yes	Yes	Medium	Yes
Solvent Extraction	No	Yes	Yes	Yes	Yes	Medium	Yes
Precipitation	Yes	No	Yes	Yes	No	Low	No
Adsorption	Yes	No	No	Yes	Yes	High	No
Degradation	Yes	Yes	Yes	Yes	Yes	Medium	Yes
Incineration	No	Yes	Yes	Yes	Yes	High	No
Thermal Desorption	Yes	Yes	Yes	Yes	Yes	Medium	Yes
Electrokinetics	Yes	No	No	Yes	No	High	No
Containerization	No	Yes	Yes	Yes	Yes	High	Yes

[a] Cost range - Treatment methods: < $100/ton = Low; $100-500/ton = Medium; > $550/ton = High
- Barrier methods: < $5 million = Low; $5-20 million = Medium; > $20 million = High

OU4 Closure/ Remediation Scenarios	Remedial Types	Technologies	Descriptions	Screening Comments
No Action	None	Not Applicable	No action	Used as the baseline for detailed analysis
Containment	Monitoring	Ground Water Monitoring	Ongoing monitoring of wells	Potentially applicable
		Vadose Zone Monitoring	Ongoing monitoring of lysimeters	Potentially applicable
	Closure	Temporary Cover	Tarpaulin cover to minimize infiltration and erosion	Potentially applicable
		Engineered Cover	Clay and possibly synthetic-membrane-covered soil	Potentially applicable
Removal	Packaging	Containerization	Packaging of waste for storage/disposal	Potentially applicable
	Excavation	Mechanical	Contaminated media removal with standard earthmoving equipment	Potentially applicable
Ex Situ Treatment	Physical/Chemical Treatment	Degradation	Chemical or biological transformation of contaminants to be less toxic or less mobile	Potentially applicable
		Size Reduction	Mechanical operation to divide objects into smaller pieces	Potentially applicable
		Solidification/Stabilization	Contaminants encapsulated and/or chemically stabilized	Potentially applicable
		Soil Washing	Physical/chemical separation of contaminants from the soils	Potentially applicable
		Solvent Extraction	Dissolving of contaminants from the soils into the solvent fluid	Potentially applicable
	Thermal Treatment	Incineration	Combustion of contaminants in oxygen	Eliminated: High cost; only organics treated
		Thermal Desorption	Volatilize organics with secondary treatment	Potentially applicable
		Vitrification	Fusion of solid materials into a glass-like product	Eliminated: Schedule restrictions and high cost
In Situ Treatment	Physical/Chemical Treatment	Adsorption	Removal of contaminants from the liquid phase to the solid	Eliminated: Difficult to implement and high costs
		Degradation	Chemical or biological transformation of contaminants to be less toxic or less mobile	Eliminated: Difficult to implement
		Electrokinetics	Removal of ionic or charged species from soils	Eliminated: Low soil permeability
		Precipitation	Contaminants become insoluble with addition of chemicals	Eliminated: Low soil permeability
		Soil Flushing	Leaching of contaminants from the soils into the flushing fluids	Eliminated: Low soil permeability
		Solidification/Stabilization	Contaminants encapsulated and/or chemically stabilized	Potentially applicable
	Thermal Treatment	Thermal Desorption	Volatilize organics with secondary treatment	Eliminated: High cost
		Vitrification	Fusion of solids materials into a glass-like product	Eliminated: Proven effectiveness, schedule restrictions, and high cost
Storage Disposal	Onsite Storage	Existing	Onsite storage at existing permitted facility	Potentially applicable
		New	Agency-approved new onsite storage/facility	Potentially applicable
	Offsite Disposal	Waste Disposal Facility	Disposal at permitted offsite facility	Potentially applicable

LEGEND

xxxx Technology eliminated from futher evaluation

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Figure III.3-2

Solar Evaporation Ponds
Operable Unit No.4, IM/IRA EA DD
Initial Screening of Technologies

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the contaminants from the soil. Soil flushing is a proven technology that has been used successfully to treat many types of wastes, including radioactive wastes, at several DOE sites. However, soil flushing typically is effective only for soils that have hydraulic conductivities greater than 1.0×10^{-4} centimeters per day (cm/day). The OU4 soils have hydraulic conductivities that range from 1.0×10^{-3} cm/day to 1.0×10^{-9} cm/day. Therefore, soil flushing was eliminated from further consideration on the basis that it would not be effective for the existing conditions at OU4.

Precipitation

In situ precipitation techniques provide a means to immobilize heavy metals. This type of precipitation is performed by introducing aqueous chemical solutions (via infiltration galleries or sprinklers) into saturated soils to adjust the pH of the subsurface in order to form insoluble heavy metal complexes that remain in the soil. Metals will precipitate at varying pH levels (depending on the metal complex and valence structure). The formation of contaminant metal complexes is reversible at the proper pH conditions; therefore the treated soils would require continuous maintenance to maintain the proper soil conditions so that reversal of the process and destruction of the insoluble complexes do not occur. In addition, the reactant solution probably would not intimately contact the soil matrix due to low RFP soil permeabilities and the predominant interstitial flow regime. There are no known commercial or full-scale applications of this technology. Due to the significant clay content of RFP soils, it is unlikely that mechanical means, such as shallow soil mixing, would adequately loosen and disperse soil particles to allow intimate contact with the reactant solution. The potentials for incomplete reactions of available contaminants and disassociation of formed complexes give this technology's long-term effectiveness a great degree of uncertainty. Extensive testing would be required to validate the effectiveness of using *in situ* precipitation at the RFP. Therefore, *in situ* precipitation was eliminated from the list of possible treatment technologies because it was not considered to be implementable within the IAG schedule.

Adsorption

Adsorption is the operation of removing organic and metal contaminants from an aqueous phase with the use of activated carbon, resins, clays, zeolites, agricultural products (e.g., manure, peat), and chelants. Adsorption could be applied *in situ* at the SEPs by diverting ground water or vadose zone liquids to a trench filled with one or more of the adsorption materials listed above. Applicability of *in situ* adsorption will depend on the degree of flow control of ground water or vadose zone liquids. A flushing system might be required for the vadose zone. Determination of the required amount, location, and placement of adsorbent; and adsorbent efficacy and efficiency, which is influenced by the ground water flow regime through the adsorbent as well as soil contaminant desorption kinetics, all contribute to a great degree of uncertainty with respect to short-term effectiveness. The cost of adsorption has historically been higher than the cost of comparable technologies. Adsorption was eliminated from the list of possible treatment technologies because of the high costs associated with the volume of

adsorption materials required and system maintenance, and implementation difficulties associated with the low RFP soil permeabilities.

Degradation *(In Situ)*

Degradation is the process of using biological or chemical means to degrade primarily organic contaminants, although other types of contaminants have been demonstrated to be treated. *In situ* bioremediation can be carried out either by enhancing the soil conditions to increase the growth of the indigenous microorganism population, or by applying (with sprayers or injection wells) strains of microorganisms engineered to degrade specific contaminants. Many commercially available products and processes can be used to enhance *in situ* biodegradation. *In situ* bioremediation is limited to the subsoils. Oxidation and reduction reactions within the soil matrix may occur through management of the natural oxidation/ reduction processes in a soil or through addition of an oxidizing/reducing agent. Degradation processes are proven technologies that have been used successfully to treat many types of wastes. The *in situ* degradation process would not be applicable because of the implementation difficulties associated with low RFP soil permeabilities and was eliminated from the list of possible treatment technologies.

Thermal Desorption *(In Situ)*

Thermal desorption processes use heat to vaporize organic contaminants found in soils. *In situ* thermal desorption processes are proven technologies, and would be applicable for volatile organic contaminants at OU4. Thermal desorption would not destroy heavy metals or radionuclides, so it would be used in conjunction with other treatment/containment processes for these contaminants. However, *in situ* thermal desorption is more energy- and cost-intensive than *ex situ* thermal desorption processes, which is why it is not commonly used. *In situ* thermal desorption was eliminated from the list of possible treatment technologies because of the large costs and energy requirements, and limited applicability to OU4 contaminants.

Incineration

Incineration is primarily utilized to treat organic compounds by high-temperature oxidation and usually produces the byproducts; water vapor, carbon dioxide, sulfur dioxide, nitrogen oxides, and ash. It is a desirable *ex situ* treatment option when dealing with large quantities of combustible organic wastes. Incineration has been demonstrated and utilized successfully to treat organic wastes at many Superfund sites. Many types of mobile incineration units are available that could be transported and operated at the SEPs. Fuel could be delivered as required to supply the energy. Some tests would be required to determine the optimal incineration process, but this process could be implemented within the time constraints of the IAG schedule. Incineration would not destroy or immobilize heavy metals or radionuclides, so it would be used in conjunction with other treatment/containment processes for these contaminants. The ash waste would require stabilization. The current regulatory climate

indicates that incineration would not be easily accepted as a treatment remedy. The cost of soil incineration is generally higher than the cost of comparable thermal technologies because of the large, mostly inert soil mass requiring heating. Incineration therefore was eliminated from the list of possible treatment technologies because of its high cost and because it can only be used to treat organic contaminants.

Electrokinetics

Electrokinetic soil processing is an *in situ*, continuous process for the removal of ionic or charged species from soils, including heavy metals, radionuclides, and selected organic pollutants. Electrokinetics is the process of passing a low-intensity direct current through contaminated soil. This current creates localized acidic ground water conditions near the anode and basic ground water conditions near the cathode by electrolysis and ionic disassociation. Cations are desorbed from the soil near the anode and can be removed by pumping the ground water in the vicinity of the anodic region of influence, however the zone of treatment would have to be saturated in order to effect the migration of contaminants. No commercial or full-scale applications of this technology have been identified. Extensive testing would be required to validate the effectiveness of electrokinetics at the RFP, making it difficult to meet the IAG schedule. The cost of electrokinetics including the contribution from energy demands would most likely be higher than the cost of comparable technologies. Based on these discriminators electrokinetics was eliminated from the list of possible treatment technologies.

III.3.2 Description of Potentially Applicable Technologies

Technologies that passed all of the preliminary screening criteria are listed in Table III.3-2, along with the target contaminated media (e.g., soils, liners, and utilities/debris). The containment technologies are applicable to all of the above-mentioned contaminated media. Detailed descriptions of the applicable technologies are presented below.

The goals of the OU4 SEP closure address the media mentioned below. The design of the selected GRA will close/remediate the following media:

- **Pond Liners**

  The liners of SEPs 207-A, B, and C are considered hazardous waste by the CDH via the "derived from" rule in 6 CCR 261.3(c)(i). The COCs detected in the liners include metals and radionuclides. The results of the analytical analysis performed on the liner material have been presented earlier in Part II, Section 3.

- **Surface Soil Contamination**

  Surface soils with COC concentrations exceeding established PRGs are located in several areas within the OU4 boundaries. The various COCs include radionuclides,

TABLE III.3-2

POTENTIALLY APPLICABLE TREATMENT TECHNOLOGIES

In situ	*Ex situ*
Size Reduction (liners and utilities/debris)	Size Reduction (utilities/debris)
Solidification/Stabilization (soil and liners)	Solidification/Stabilization (liner, utilities/debris, and soils)
Backfill (containment)	Soil Washing (soils)
Engineered Cover (containment)	Degradation (soils)
Temporary Cover (containment)	Thermal Desorption (soils)
Abrasive Blasting/Scarification (utilities/debris)	Solvent Extraction (soils)
High-Pressure Wash/Chemical Extraction (utilities/debris)	Removal and Containerization for Storage or Disposal (liners, utilities/debris, and soils)
	Abrasive Blasting/Scarification (utilities/debris)
	High-Pressure Wash/Chemical Extraction (utilities/debris)
	Thermal Extraction (utilities/debris)

metals, volatile and semivolatile organic compounds, and pesticides. The COCs and PRGs identified for surface soils located within the OU4 boundaries (upward exposure pathways) have been presented earlier in Table III.2-3.

- **Vadose Zone Soil Contamination**

  Vadose zone soils with COC concentrations exceeding established PRGs are located primarily beneath the SEPs. The various COCs include radionuclides, metals, volatile and semivolatile organic compounds. The COCs and PRGs identified for vadose zone soils located within the OU4 boundaries (upward exposure pathways) have been presented earlier in Table III.2-3.

- **Remediation Debris**

  Debris materials will be generated during closure implementation. Debris will include utilities associated with the SEP operations and materials from the closure/removal of Building 788. The contaminants associated with these materials are the same contaminants found in the liners and soils because the utilities and Building 788 supported the SEPs operations.

Several methods may be pursued which address the above-noted media and meet remediation goals. These methods include the following:

- **Containment of Consolidated Media with Prevention of Contaminant Migration**

  The upward exposure pathways for the liners, surface soil, and vadose zone soil contamination include inhalation, ingestion, and dermal contact. Drinking water would be the primary exposure pathway for the ground water beneath the SEPs. Precipitation and run-on enable contamination to migrate from its current location in the form of runoff and infiltration. The engineered cover option would consolidate surface and vadose zone soils via excavation and placement of SEP liners and soil beneath the cover. The engineered cover would prevent precipitation and runon from infiltrating into the contaminated liner material, surface soils, and vadose zone soils. Historical information indicates that the ground water elevation beneath the SEPs has risen (seasonally) and contacted contaminated media and the SEP 207-B liners. The possibility therefore exists that the ground water may rise in the future and contact contaminated material. To address rising ground water concerns, engineered controls could be constructed to prevent rising ground water from contacting the contaminated liners and soils beneath the cover. These controls may include vertical walls/interception trenches, horizontal barriers, subsurface liners and leachate collection systems, grout curtains, and/or a subsurface drainage layer. A vertical wall/interceptor trench would divert ground water flowing towards the waste zone,

while the horizontal barrier and subsurface drainage layer would divert ground water rising from beneath the waste zone.

- **Removal of Contaminated Materials**

  Removal would include excavation and packaging of liners and contaminated soils for treatment or transportation to an approved offsite disposal facility. After removal of the liners and contaminated soils, the potential for the liners and soils releasing contaminants to the surface exposure pathways or contaminating the ground water would be eliminated.

- **Treatment of Materials to Extract Contaminants**

  Several *in situ* and *ex situ* treatment options are available to treat the liners and contaminated surface and vadose zone soils which should mitigate the possibility for contamination of the ground water beneath the SEPs. These treatment options may be utilized alone or in combination. Treatment options being considered include solidification/stabilization, soil washing, solvent extraction, bioremediation, oxidation/reduction, and thermal desorption.

The following subsections present detailed discussions with respect to the technologies that are considered to be potentially applicable for closure/remediation of the SEPs.

III.3.2.1 Engineered Cover

An engineered cover system for the SEPs would be designed to address site-specific conditions and concerns while meeting state and federal regulatory requirements. The covers would be designed to control infiltration of precipitation through the closed ponds and minimize leaching and migration that may occur from a rising water table via a subsurface drain component of the engineered cover, thereby reducing the quantity of leachate generated and inhibiting the movement of contaminants to the ground water. An engineered cover would also reduce the risk associated with direct exposure pathways for human and animal contact. An engineered cover system could be designed to contain and prevent the migration of the COCs at the OU4 SEPs.

The potential engineered cover technologies under consideration would, at a minimum, incorporate the requirements identified in Title 6 of the Colorado Code of Regulations (6 CCR) 1007-3, 265.228(a)(2)(iii), including:

- Provide long-term minimization of liquid migration through the SEPs;
- Function with minimal maintenance;
- Promote drainage and minimize erosion or abrasion of the cover;

- Accommodate settlement and subsidence to the maximum extent possible to maintain the integrity of the cover; and
- Have a permeability less than or equal to the permeability of the underlying natural soils present.

Surface water control measures would be integrated into the cover system. The engineered covers would divert surface water away from the cover areas in a controlled manner to avoid damage to the covers from erosion.

The engineered cover system would consist of layered components, drainage systems, and any other systems deemed necessary to close the SEPs. The selection and design of the final cover system components would be dependent on the nature and concentration of contaminants present; the level of performance required to ensure overall protection of human health and the environment; and the governing regulatory standards. Each of the potential engineered cover components, their function, and level of importance to long-term performance, are described below. In addition, six different cover design alternatives that have been applied at other facilities are presented. The identification of the components is intended to provide an understanding of the various layers that may comprise an engineered cover and how these engineered components may be combined to fulfill the above-mentioned performance objectives. Should containment be selected as the OU4 closure/remediation solution, the need for and the design of the cover components listed below will be addressed as part of the conceptual and detailed design efforts to optimize an engineered cover design for OU4 that will comply with the identified ARARs.

Stabilized Waste/Backfill

Depending on the structural stability of the underlying wastes and contaminated media, backfill material may be added to and mixed with them, and then compacted to form a stable base for the cover system. Additional backfill may also be placed over these compacted materials and compacted to establish the final grade before the placement of other cover components. Backfill is typically used to establish final grades and slopes because it is usually the least expensive of the available cover materials.

Hydraulic Barriers

Asphalt concrete, flexible membrane liners (FMLs), compacted clay soils, and geosynthetic clay liners (GCLs) may be used to serve as primary hydraulic barriers to infiltration. Asphalt concrete and clay soils provide a firm foundation for the overlying layers of the cover system. Clay soils can also serve as a consistent controlled bedding material for the protection of an overlying FML. GCLs may provide better bridging action than compacted clay soils when placed in tension (e.g., spanning a sink hole formed from the settlement of underlying material). GCLs, however, have not been proven over extended periods of time.

For this reason they would not be suitable for engineered covers requiring a long design life (i.e., greater than 75 years).

An FML would provide the initial low-permeability barrier to prevent infiltration migration where clay materials or GCLs were used as the primary hydraulic barrier. The clay layer must be placed below the frost depth to avoid shrinking and swelling. The FML would be placed directly above the clay to reduce the moisture fluctuations within the clay layer, since extreme saturation and desiccation of clay could cause severe cracks resulting in direct flow paths for moisture migration. The FML would be placed immediately following completion of the clay barrier to reduce surface drying and cracking. The FML would also roof-over the inconsistencies in the underlying compacted clay soil layer. FMLs are synthetic materials that are unproven over long periods of time. Therefore, FMLs are not typically used in engineered covers that have a design life requirement exceeding 75 years.

Hydraulic barrier materials may also be used beneath the consolidated contaminated materials as a subsurface liner. A subsurface liner would prevent leachate from migrating into the ground water and would prevent rising ground water from contacting contaminated materials.

Drainage Layer

A drainage layer typically consists of sand, gravel, or manufactured drainage fabrics. This layer would be designed to have larger void spaces than either the overlying cover soils or the underlying material and have proper pore distribution and adequate bottom slope. The drainage layer would provide a mechanism to laterally transport water moving downward through the cover, thereby minimizing the hydraulic head build-up over the underlying compacted material and reducing the volume of water infiltrating into the underlying material. Multiple drainage layers may be used for design redundancy and/or to provide the means to laterally transport water moving upward (i.e., from a rising ground water table), thereby minimizing hydraulic head build-up under buried wastes and preventing the ground water from contacting the wastes.

Biotic Barrier

A biotic barrier consisting of cobbles or riprap materials would prevent burrowing animals from tunneling into the waste zone. The biotic barrier also functions as a protective barrier in that plant roots would not penetrate the cobbles because soil moisture is greatly reduced in the void space of the cobbles.

Capillary Break

A capillary break consisting of coarse materials, such as sand, gravel, and cobble, could be used to reduce the amount of percolation through the engineered cover. The water pressure must be nearly equal to atmospheric pressure for significant quantities of water to flow into and

through the coarse material. The overlying fine-textured soils must become nearly saturated to allow water to flow into the coarse sublayers (Wing, 1993). This resistance to drainage increases the storage capacity of the overlying soils, and provides time for the processes of evaporation and transpiration to remove it.

Filters

A filter fabric (typically a nonwoven geotextile, either needle-punched or heat-bound), could be used between the topsoil/backfill material and the biotic barrier/drainage layer to prevent fines from sifting into the drainage layer voids, rendering the drainage layer nonfunctional. Filter fabrics are synthetic materials that are unproven over long periods of time. Therefore, filter fabrics would not be considered for engineered covers having a design life requirement exceeding 75 years. Sand and gravel can also be used as filter materials. These materials would serve the same function as filter fabric. These natural materials would be considered for engineered covers having a design life requirement exceeding 50 years.

Topsoil

The main function of the topsoil layer is to support adequate vegetation growth. This layer is designed to be of adequate depth to establish proper root growth for the selected vegetation. Topsoil typically has a medium texture to facilitate seed germination and plant root development. It is minimally compacted to facilitate root growth and to maintain sufficient infiltration to promote growth and root development through periods of drought. In the event that topsoil is scarce or costly, a general backfill material can be designated for the lower portion of the topsoil layer to establish final grades and slopes. Therefore, depth of the topsoil material can be minimized to serve the function of supporting vegetation establishment only.

Vegetation

The surface soils of the cover would be stabilized to decrease erosion due to wind and water. Vegetation is typically the aesthetically preferred final surface of a cover system, and proper vegetation establishment would reduce the damaging effects from erosion due to wind and surface water runoff. Plants also transmit water from the soil to the atmosphere through transpiration, providing a removal pathway for the water stored in the topsoil. When coordinated with surrounding native species, the plants also provide a pleasant blend with natural surroundings.

Erosion Protection

Pea gravel consisting of angular, 1/2-inch- to 3/4-inch-diameter pieces placed over a seeded cover aids in reducing surface erosion from wind and water. The pea gravel also encourages vegetation establishment by reducing evaporation in the uppermost portion of the topsoil to nourish vegetation in semiarid environments. The addition of the pea gravel may result in shorter and less frequent irrigation requirements for vegetation establishment and fewer repairs because of erosion rutting. In areas where steepened slopes are required due to space constraints or where erosion modeling deems it necessary, riprap materials may be used to stabilize these slopes.

The area immediately surrounding the cover areas would be regraded to drain runoff away from the covers. Where space or topographic constraints would not allow positive slopes away from the cover areas, berms and/or swales would be provided to keep surface water from entering the cover areas. The disturbed areas would be seeded with grasses indigenous to the site area.

Other Components

Design features will need to be incorporated to minimize leaching and migration that may occur from a potential rising ground water table. The application of these design features is contingent on the location/depth of consolidated waste, amount of leachate generated as predicted through computer modeling (see Section IV.10.4), and the assessment of the ground water conditions in the engineered cover area.

Vertical walls, or slurry walls, interceptor collection trenches, and horizontal barriers, are low-permeability subgrade walls that effectively control ground water when installed correctly. The use of slurry walls and horizontal barriers for containment is considered a proven, standard technique. Drains can be used in combination with the slurry walls or horizontal barriers to remove or divert ground water. A construction quality assurance/quality control program is critical to ensure that the walls or horizontal barriers function as designed. The disadvantages of slurry walls or horizontal barriers is that their integrity may be damaged by contaminants in the ground water. Their depths also are limited to 100 feet bgs. Long-term ground water monitoring is typically required with slurry walls and horizontal barriers.

Grout curtains are another type of low-permeability subgrade barrier that can control ground water flow. Construction of grout curtains is a well established, proven technique and its effectiveness is dependent on grout injection hole spacing and geologic conditions. A construction quality assurance/quality control program is critical to ensure that the grout curtain functions as designed. The grout curtain can be used in combination with a pump-and-treat scenario. The disadvantages of the grout curtain include its difficulty to be installed in heterogeneous soils and the lengthy ground water monitoring period required. Grout curtains are not usually considered a permanent solution.

A subsurface liner and leachate collection system could be used as an engineering control to reduce the possibility of leaching and migration of contaminants from a rising water table. The subsurface liner system will prevent ground water from contacting the waste zone, while the leachate collection system will treat any leachate produced from infiltration. The disadvantage of the subsurface liner and leachate collection system is that it is not a passive option; a treatment system will be operating to treat the leachate. This option is operationally intensive and more expensive in comparison with other engineering controls described above. This option may be required if the minimum technology requirements of a new hazardous waste disposal facility are determined to be relevant and appropriate.

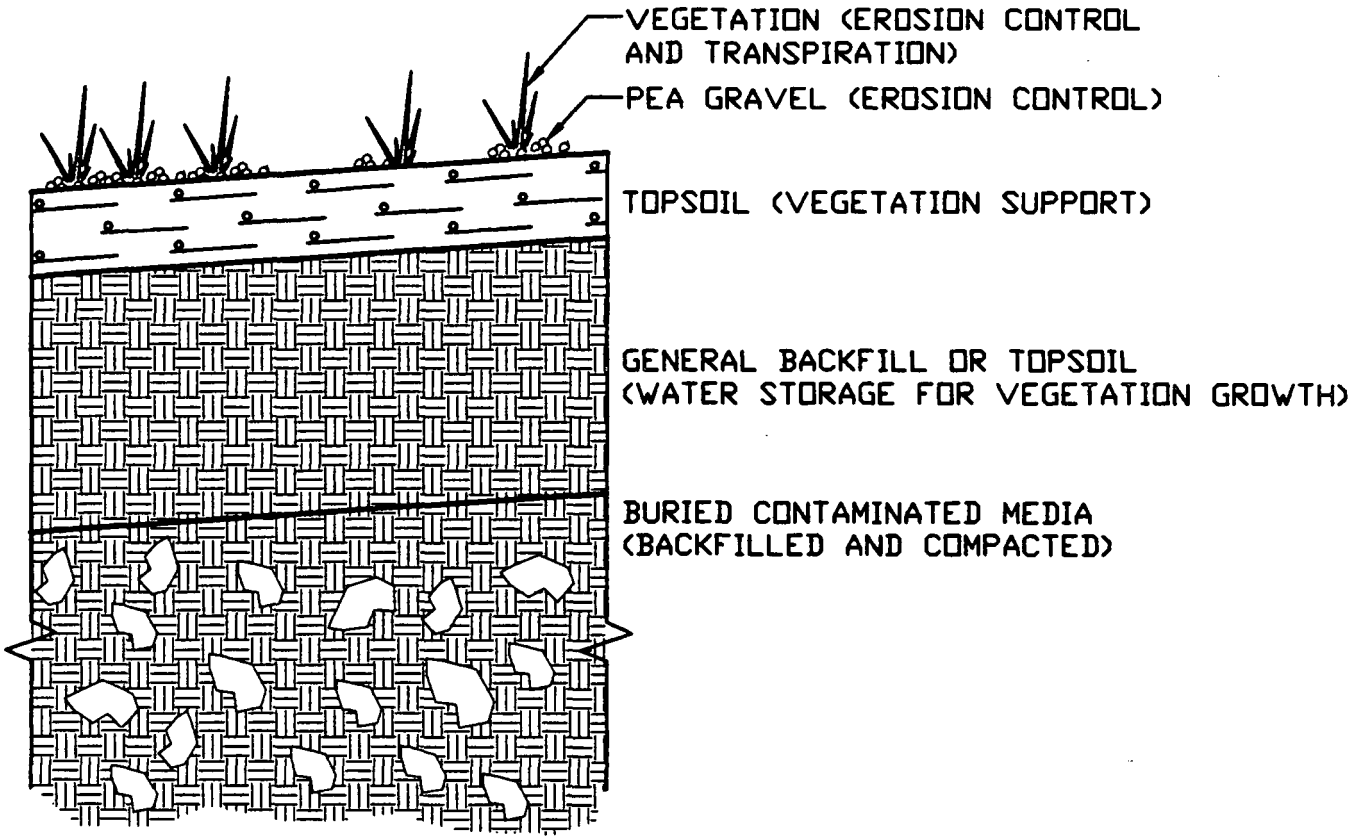
A subsurface drainage system consisting of layers of sand and gravel would divert ground water from the waste zone if the elevation of the ground water table rises in the future. This system would act passively to prevent contact of the wastes with a rising ground water table by allowing ground water to flow to the existing Interceptor Trench System (ITS).

Engineered Cover Alternatives

The alternatives that were considered for the engineered covers are discussed in detail below. The alternative engineered covers use different combinations of the components presented above. It should be noted that these cover alternatives are conceptual and that the final design of an engineered cover may be modified to comply with specific requirements. As previously stated, the need for an individual cover component would be finalized as a part of the conceptual and detailed design efforts. Geotechnical testing would be required for determination of hydraulic permeability, compaction, moisture content, dry density, moisture density, field density, particle size (gradation), liquid limit, plastic limit, and plasticity index to select the appropriate cover materials. It is assumed that in this analysis, local areas would be the source of backfill soils.

It is important to note that the analysis focusses on the engineered cover alternatives. The subsurface drain/control system will be selected and designed during conceptual and title design based upon the selected engineered cover design, hydraulic calculations, and performance modeling (if required).

Cover Alternative 1. This technology includes backfilling the area with general backfill/topsoil material and a final vegetative cover. Alternative 1 would reduce the potential of human and animal contact with the underlying material while providing an aesthetically pleasing final appearance that would blend with the natural surroundings. Backfilling and grading provide no hydraulic barriers to prevent infiltration of precipitation into the underlying material and ground water, so moisture removal would be dependent on evaporation and transpiration through the vegetative cover. Research at Los Alamos National Laboratory indicates that this method of reducing infiltration is effective in arid to semiarid environments. Figure III.3-3 shows the proposed design and components of this technology, which are as follows:



NOTES:

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Figure III.3-3

Solar Evaporation Ponds
Operable Unit No. 4
IM/IRA EA DD
Cover Alternative 1

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- Topsoil/backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

Cover Alternative 2. This cover system would exceed the performance level expected of backfilling and grading, in that it provides a biotic barrier/capillary break and a lateral drainage path for gravity-flow removal of moisture that has infiltrated through the overlying cover soils. The drainage layer would be designed to have a greater hydraulic conductivity than the underlying materials. The addition of this capillary break would discourage root growth into the underlying components, and the drainage layer would decrease the volume of moisture infiltrating into the underlying materials and ground water. Through proper balancing of evaporation, transpiration, and lateral migration through the drainage layer, much of the infiltration could be removed before reaching the underlying backfill and waste materials. Figure III.3-4 shows the proposed components of this alternative,

- Sand (drainage/cushion);
- Angular riprap (biotic barrier/capillary break);
- Gravel (filter);
- Sand (filter);
- Topsoil/Backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

Cover Alternative 3. This alternative is similar to Cover Alternative 2 in design objectives, but would utilize a manufactured drainage material (drainage nets, etc.) rather than a sand layer. Most commercial drainage nets are equivalent in performance to 1 foot of sand (approximate saturated hydraulic conductivity of 10^{-2} centimeters per second (cm/sec). The advantage of this option is that fewer haul loads would be required, compared to sand, to import the drainage net onto the site. The size of the area required for material stockpiling would also be reduced. The filter fabric layers above and below the drainage net function to capture soil fines. This will prevent clogging and allow the drainage net to perform as designed. The drawback to this cover design is that the long-term integrity (i.e., greater than 30 years) of the manufactured drainage net is unproven. Figure III.3-5 shows the proposed components of this alternative,

- Filter fabric (filter);
- Fabricated drainage net (drainage);
- Filter fabric (filter);
- Angular riprap (biotic barrier/capillary break);
- Filter fabric (filter);
- Topsoil/backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

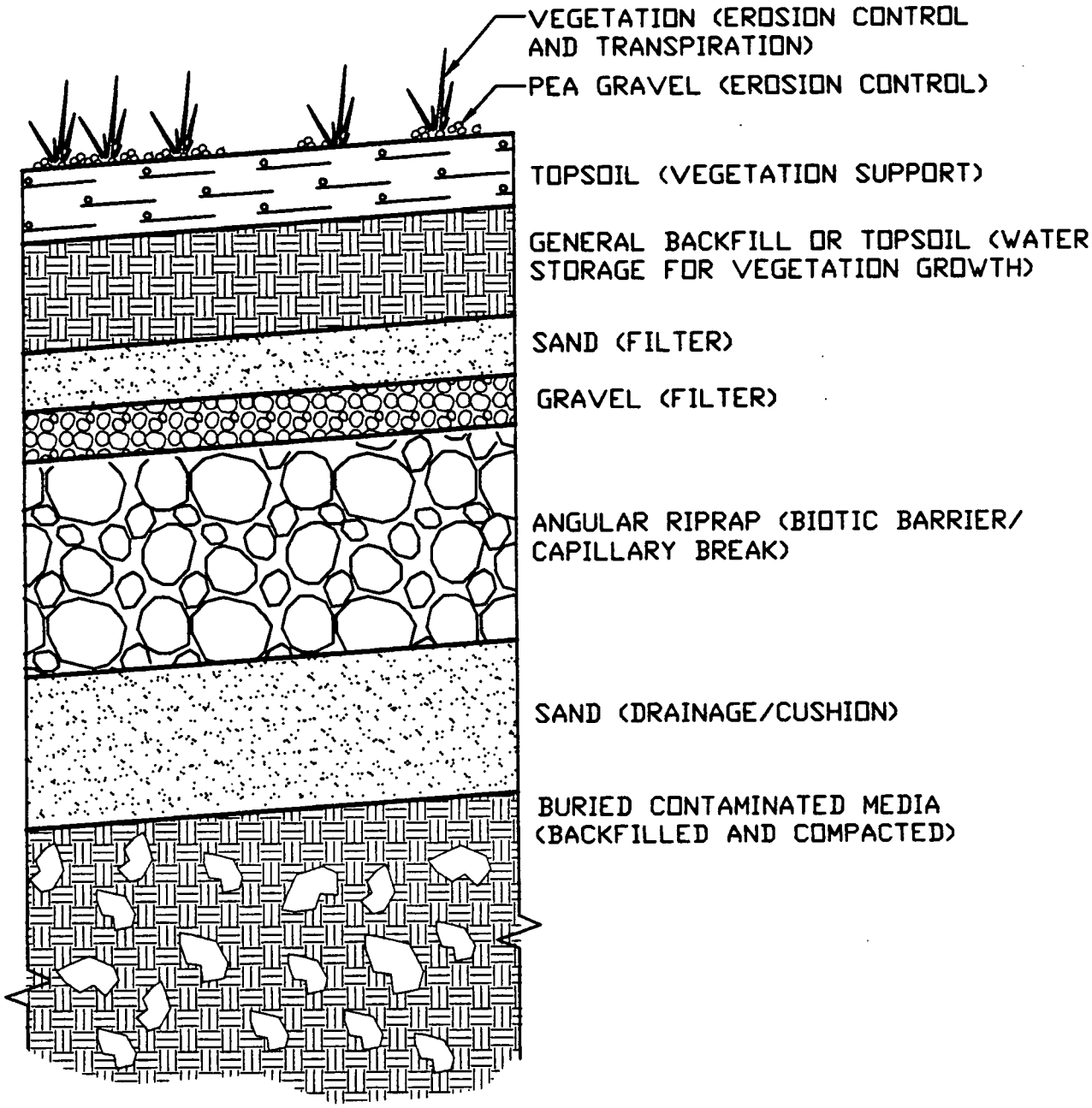

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Figure III.3-4

Solar Evaporation Ponds
Operable Unit No. 4
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Cover Alternative 2

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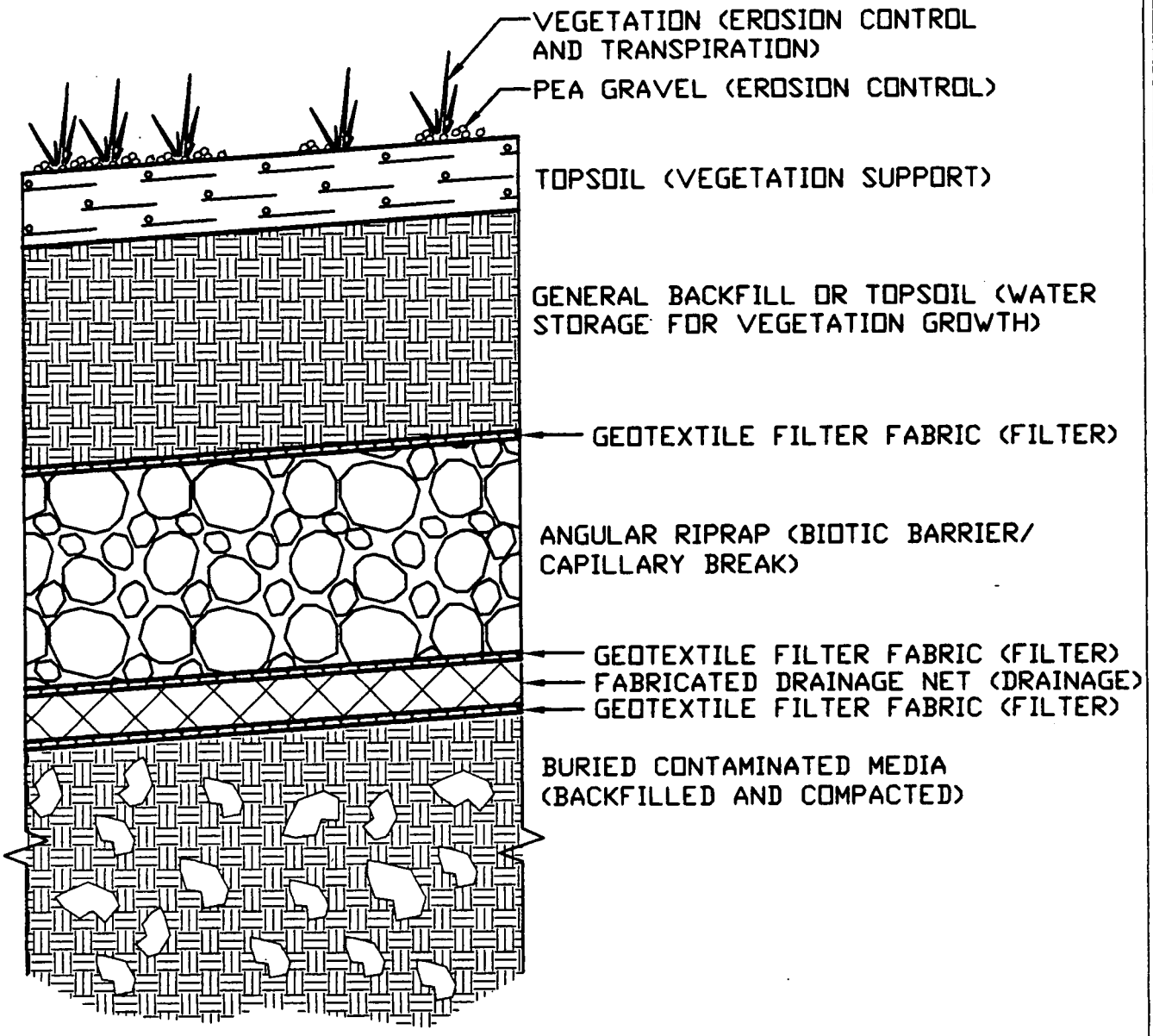

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Figure III.3-5

Solar Evaporation Ponds
Operable Unit No. 4
IM/IRA EA DD
Cover Alternative 3

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Cover Alternative 4. This cover system would perform the same evaporation, transpiration, and lateral drainage functions as the covers described above. However, this cover alternative would include the addition of a double-layered low permeability barrier under the drainage layer to prevent moisture infiltration into the underlying contaminated soil and wastes. This low permeability barrier would consist of a flexible membrane liner (FML) and a layer of compacted clay. FMLs are synthetic materials that are unproven over long periods of time. They are not typically used in engineered covers that have a design requirement exceeding 75 years. This engineered cover design is used to close hazardous waste sites in areas that receive high levels of annual precipitation. In the semiarid RFP environment, the clay may desiccate and crack, providing a direct channel for infiltration into the waste zone. Figure III.3-6 shows the proposed components of this alternative,

- Compacted clay (low permeability barrier);
- FML (low permeability barrier);
- Sand (drainage);
- Angular riprap (biotic barrier/capillary break);
- Geotextile filter fabric (filter);
- Topsoil/backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

Cover Alternative 5. This alternative is similar to Cover Alternative 4 in theory, but a GCL would replace the compacted clay soil barrier layer used in Cover Alternative 4. The installation of a GCL is less complicated than a compacted clay liner. The GCL is simply rolled out and overlapped, and moisture and compaction controls are instituted to ensure that the GCL meets design specifications. The GCL would also be thinner than a compacted clay liner; therefore, the transportation, handling, and storage requirements for the GCL would be less than the compacted clay liner. Although the material cost for the GCL is typically higher than for mined clay, this cover alternative may be more cost-effective overall when the lower construction, transportation, and storage costs are considered. GCLs are becoming more readily accepted as a design option for final cover applications. GCLs have not been proven over extended periods of time. Therefore, GCLs would not be suitable for engineered covers requiring a design life exceeding 75 years. Figure III.3-7 shows the proposed components of this alternative,

- Selected contaminated soils (cushion for GCL);
- GCL (low permeability barrier);
- FML (low permeability barrier);
- Sand (drainage/cushion);
- Angular riprap (biotic barrier/capillary break);
- Geotextile filter fabric (filter);
- Topsoil/backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

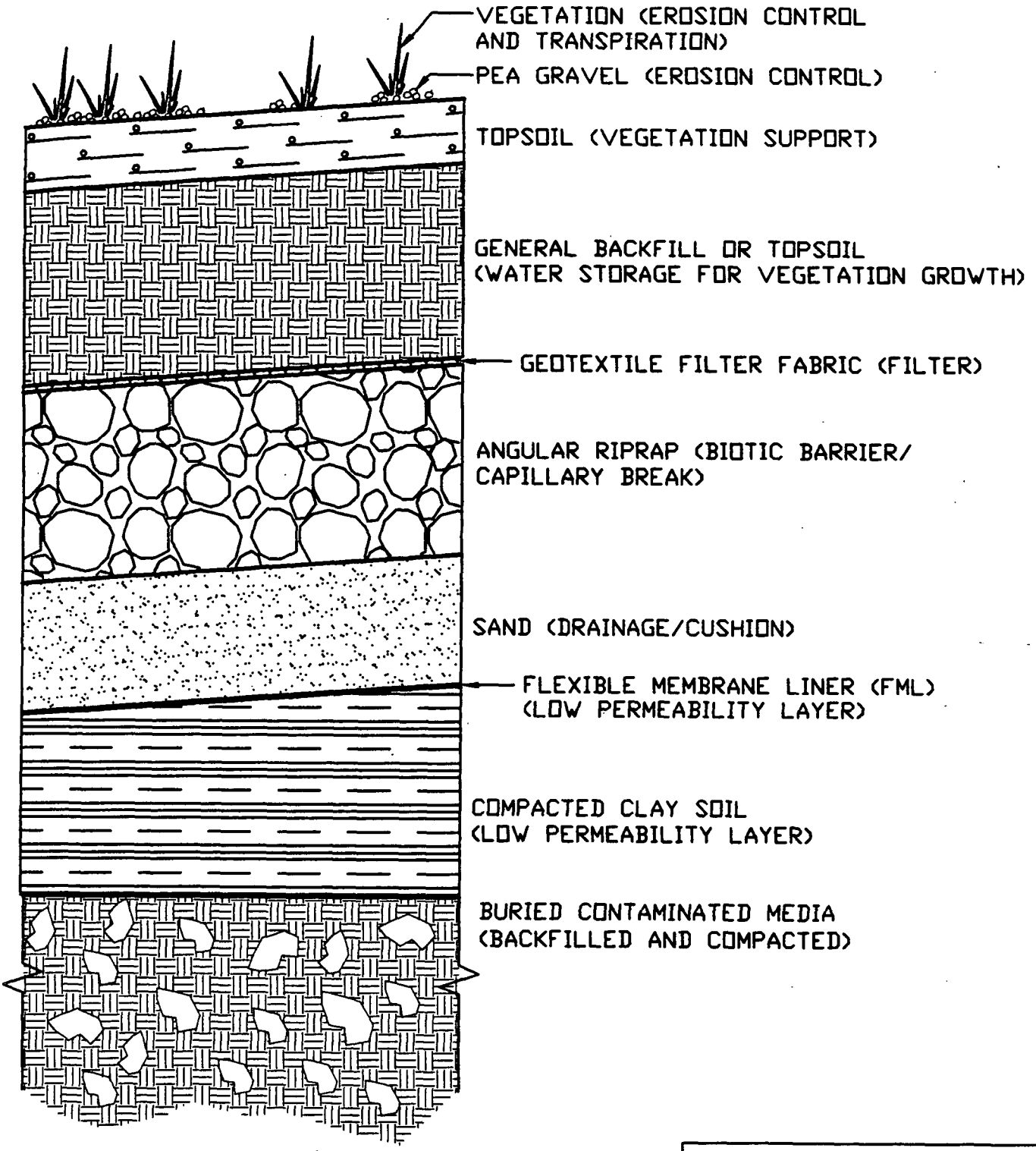

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Figure III.3-6

Solar Evaporation Ponds
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Cover Alternative 4

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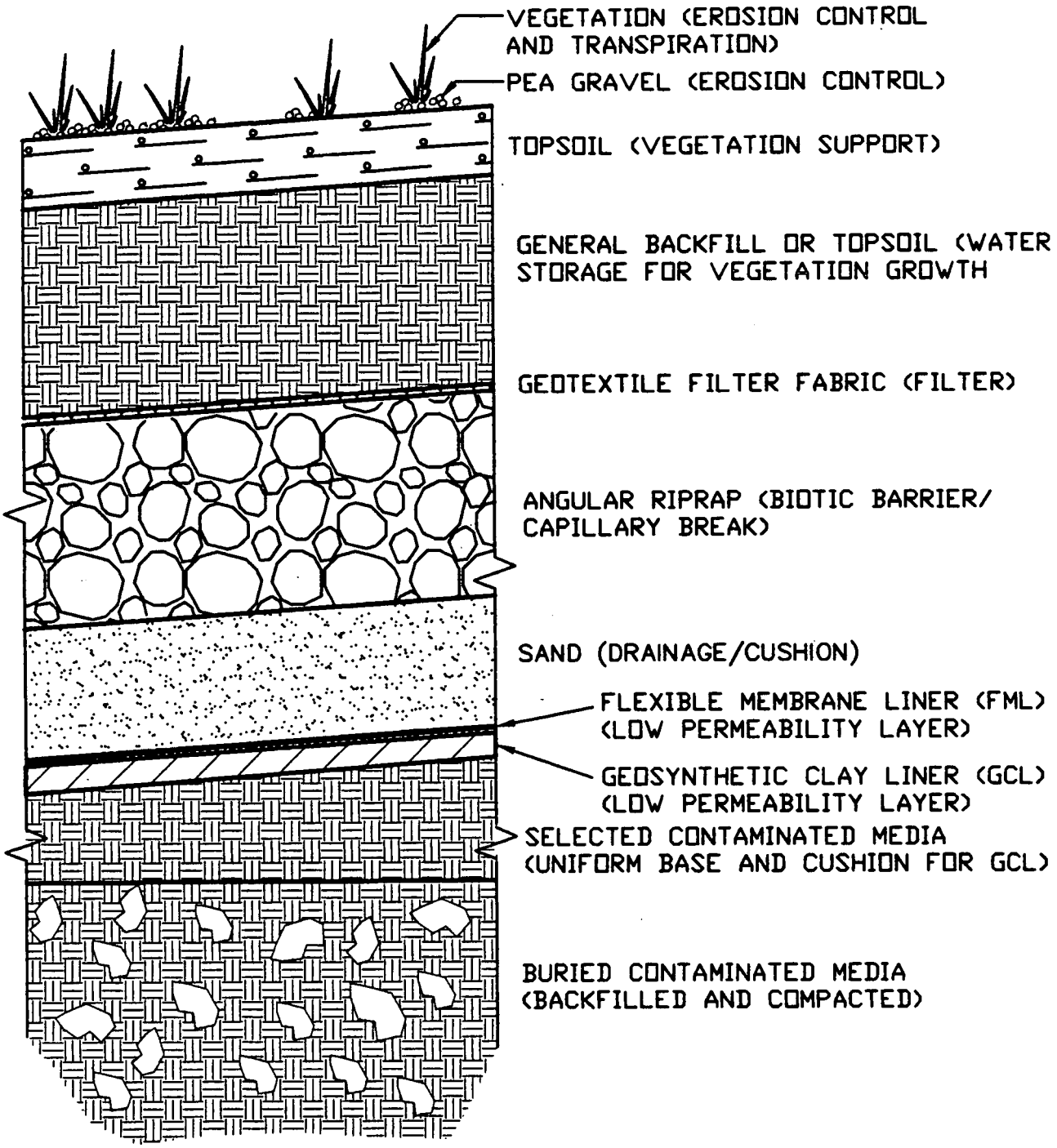

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Figure III.3-7

Solar Evaporation Ponds
Operable Unit No. 4
IM/IRA EA DD
Cover Alternative 5

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Cover Alternative 6. This alternative is developed using natural materials that are anticipated to provide sustained passive integrity over the long term. Geosynthetic materials would not be incorporated in this design alternative since their durability has not been proven for extended periods of time.

The design would include the addition of a low-permeability asphalt concrete layer and a poured polymeric asphalt coating. Asphaltic materials have long-term integrity if they are constructed below the frost line and are isolated from ultraviolet light and oxidizing materials. Figure III.3-8 shows the proposed components of this alternative

- Gravel base course (structural support);
- Asphalt concrete (low permeability barrier);
- Polymeric asphalt (low permeability barrier);
- Sand (drainage);
- Angular riprap (biotic barrier/capillary break);
- Gravel (filter);
- Sand (filter);
- Topsoil/backfill (support vegetative growth);
- Pea gravel (erosion control); and
- Vegetation (erosion control and transpiration).

This engineered cover system is similar to the design that has been proposed for the DOE Hanford Reservation in southeastern Washington. The Hanford engineered cover is designed for a passive lifespan of 1,000 years.

III.3.2.2 Temporary Cover

The temporary cover option would be implemented as an interim measure in the event that a significant amount of time is required to obtain additional information (i.e., hydrogeological data to assess the need for ground water remediation) to demonstrate the long-term effectiveness of a permanent IM/IRA solution. The temporary cover would be used to prevent short-term exposures by isolating the contaminants from the environment. Upon assessing the additional information, a final permanent solution would be selected and implemented.

The temporary cover would consist of a waterproof fabric (i.e., tarpaulin) that would be used to cover the SEPs to prevent the release of contaminants via surface water run-off and fugitive emissions. The edges of the tarpaulin would be overlapped and joined to prevent infiltration of precipitation. Concrete blocks or sand bags would be placed on the tarpaulin to anchor the cover system against high winds. The functional life of the tarpaulin is about 5 years due to degradation resulting from exposure to sunlight, oxidation, and wind. The SEPs may also be regraded to facilitate gravity drainage away from the covered areas. If gravity drainage cannot be provided by regrading the area, a pumping system may need to be installed. If

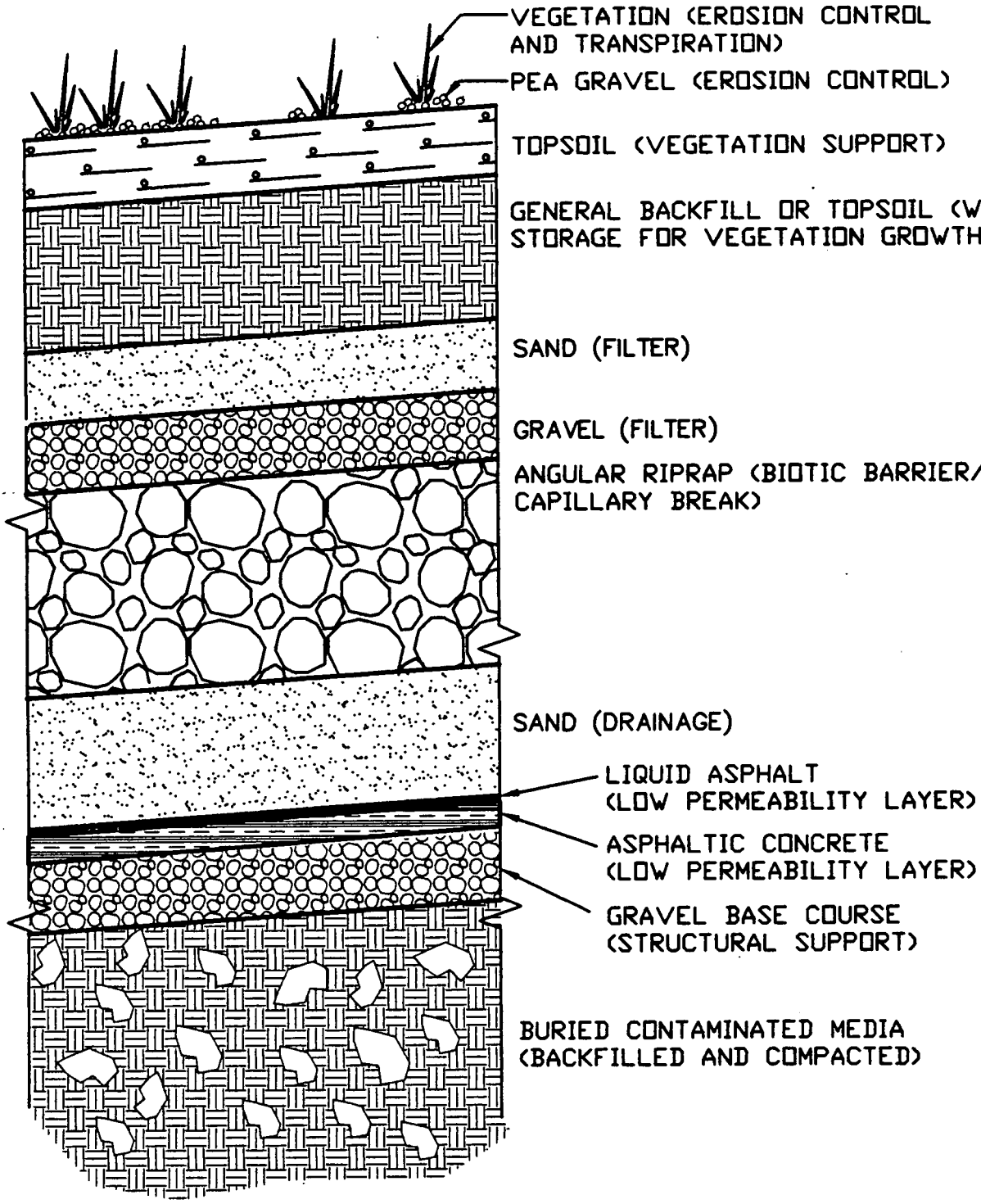

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Figure III.3-8

Solar Evaporation Ponds
Operable Unit No. 4
IM/IRA EA DD
Cover Alternative 6

93DN1105.DWG

pumping is required, ponding water, freezing weather conditions, and leakage through the tarpaulin may necessitate additional controls.

III.3.2.3 Solidification/Stabilization

Solidification/stabilization can be applied either *in situ* or *ex situ* depending on whether the contaminated media is to remain in place or must be excavated. *In situ* treatment of soils has been used in diverse applications to greatly reduce the mobility of the contaminants and decrease the potential for these contaminants to migrate to the ground water. An engineered cover over the treated soils may be required to provide long-term isolation. *Ex situ* treatment technologies also have been successfully used to treat radioactive, hazardous, and mixed waste to meet established waste acceptance criteria prior to disposal. In the commercial nuclear industry, radioactive wastes often are treated with a cementitious binder to mitigate the potential for release of radionuclides to the environment. The solidification/stabilization processes produce a treated medium that will not degrade appreciably either physically or chemically. The process is shown schematically on Figure III.3-9.

Solidification of a contaminated medium entails mixing the medium with a solidification agent and allowing it to harden into a leach-resistant, durable, monolithic solid. The operation may or may not incorporate the contaminants into the solidified matrix via chemical reactions, or both chemical and physical treatment may occur simultaneously. Solidification agents that have been used for contaminated media include:

- Cements (masonry, Portland, gypsum, polymeric);
- Lime/pozzalan mixtures (lime/fly ash, lime/blast furnace slag); and
- Encapsulation binders (bitumen, thermoplastic polymers, catalyzed polymers).

Additives often have been used with solidification agents to enhance or de-emphasize certain properties of the fluid or solidified matrix. These affected properties have included:

- Workability;
- Set-up (solidification) time;
- Contaminant leach-resistance;
- Environmental durability; and
- Strength development and ultimate strength.

Contaminants that have been successfully immobilized using solidification include:

- Most organic compounds;
- Metals; and
- Radionuclides.

Figure III.3-9

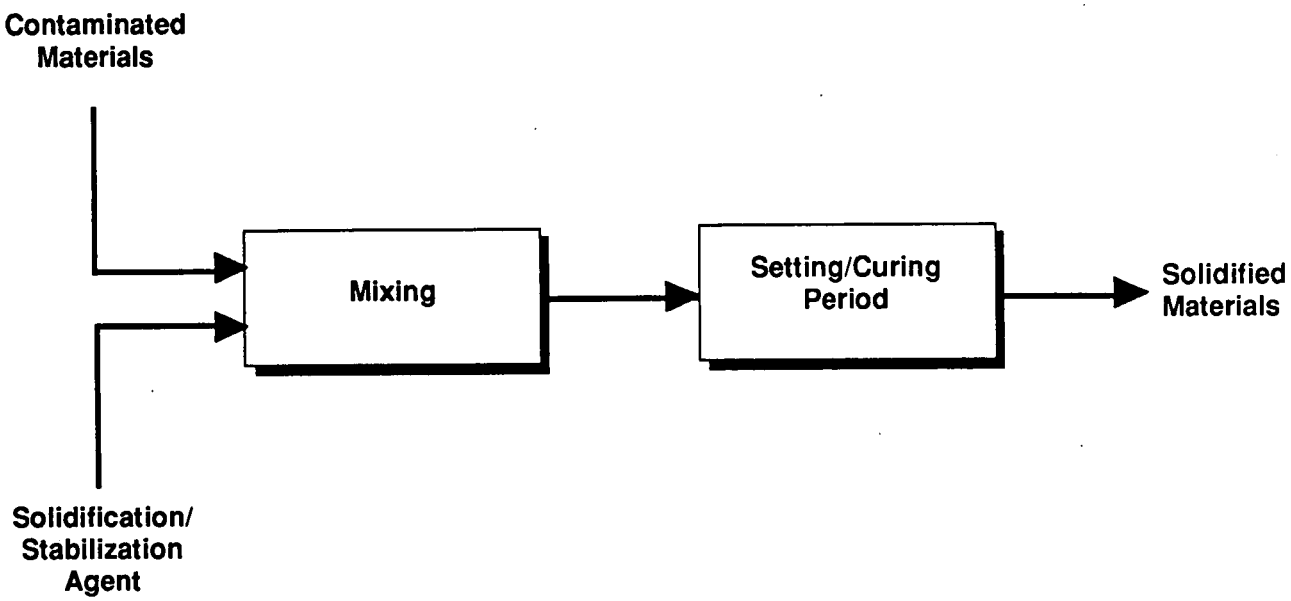

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Figure III.3-9

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Solidification/Stabilization
Process Flow

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Therefore, this technology is applicable for all of the various COCs at the OU4 SEPs. Cement and lime/pozzalan mixtures provide contaminant immobilization by chemical reactions with the binder and by encapsulation. Metal and radioactive ionic species typically are incorporated into the matrix through reactions with the cement or lime/pozzalan paste, although encapsulation of contaminant micelles (aggregates of usually large organic molecules acting as charged colloidal particles) may also occur. Organic contamination typically is bound by micelle encapsulation; and emulsifiers commonly are used to disperse the organic material throughout the paste. Some low molecular weight organics act as retarders by inhibiting the solidification reactions. As a result, these types of organics are difficult or impossible to solidify in a cementitious binder.

Encapsulation binders provide solidification of a contaminated medium by surrounding individual media particles or micelles with subsequent setting or hardening. Water accompanying the contaminated media may be consumed by binder solidification reactions (cements and catalyzed polymers), trapped as micelles within the binder, or evaporated (bitumen and thermoplastic polymers). Since the media are trapped in the binder, the media and contaminants are effectively immobilized. However, if a contaminant is relatively soluble in the binder, then this treatment may not provide effective contaminant leach resistance. Ineffective leaching resistance can occur when the contaminated medium contains low molecular weight organic compounds solidified with encapsulation binders, especially bitumen and thermoplastic polymers. In addition, when the solidification operation requires heating (as with bitumen and thermoplastic polymers), these volatile organics may require additional treatment through an off-gas collection and treatment system.

A contaminated medium may be solidified either *in situ* or *ex situ*, depending on the requirements for final disposition. These requirements include:

- Federal or state treatment regulations;
- Disposal site waste acceptance criteria;
- Solidification method effectiveness; and
- Waste disposal facility closure requirements.

The origin of *in situ* solidification of wastes and contaminated media is found in the construction industry when soils were stabilized with cementicious or pozzalanic formulations to provide increased structural load-bearing strength and resistance to slumping and settling. Typically, the required increase in strength was relatively small, and tolerances for solidification formulations and rates of application could be permissibly loose. With the advent of *in situ* waste and contaminated media solidification, the tolerances necessarily became more strict to ensure adequate and uniform treatment of contaminants. Additionally, contaminant sampling and survey protocols have to be adequately defined to ensure accurate characterization. Quality assurance and control requirements became more stringent to ensure that results can adequately be predicted and documented.

In situ solidification can be performed using a variety of common types of mixing equipment, and depends on the degree of mixing required and the depth of contaminated media to be solidified. Depending on the site requirements, dust suppression measures or dust collection equipment may be employed. Commonly used *in situ* mixing equipment includes:

- Backhoe or dragline,
- Backhoe-mounted mixing injectors, and
- Mixing augers.

In situ solidification would be applicable at OU4 if the levels of contamination present an unacceptable risk, and if removal followed by storage/treatment is impractical. Acceptance of this technology would be dependent upon verification that contaminants would be immobilized within the treated matrix.

In situ solidification of contaminated media offers the advantages of:

- Less material handling requirements (eliminates media excavation and packaging and reduced associated potential for worker exposure);
- No requirements for transportation to a storage or disposal facility; and
- No requirements for storage or disposal at another facility.

In situ solidification of contaminated media has the following disadvantages:

- Volume of solidified media is increased compared to the original contaminated media volume;
- Treatment effectiveness and solidified product homogeneity are uncertain because of variations of contaminant distribution in the media and media processing techniques;
- Reprocessing or packaging of unacceptable solidified media is difficult; and
- Significant research and development on bench-scale testing could be required to derive an adequate solidification recipe.

Ex situ solidification of wastes or contaminated media originated with the commercial nuclear industries. Wastes had to be disposed of offsite (because of lack of onsite disposal facilities) which required treatment and packaging in easily handled units. This solidification technique was adopted for wastes from hazardous waste sites when *in situ* methods were impractical or unfavorable. Since this technique treats contaminated media in small batches (approximately 300 cubic feet or less), contaminant characterization can be more decisive and solidified product properties are more easily ensured compared to the *in situ* technique. *Ex situ* solidification formulation development is similar to that for the *in situ* technique.

Ex situ solidification of contaminated media offers the following advantages:

- Contaminants are removed from the site; and

- Treatment effectiveness and solidified product homogeneity are relatively easily ensured.

Ex situ solidification of contaminated media has the following disadvantages:

- Volume of solidified media is increased compared to the original contaminated media volume (exceptions involve volume reduction of aqueous wastes treated in thermal encapsulation operations);
- Packaging inefficiency increases final disposal volume;
- Contaminated media and solidified product must be handled;
- Significant research and development could be required to derive an adequate solidification recipe;
- Transportation to a disposal facility is required; and
- Onsite storage or offsite disposal is required.

Solidification *in situ* may best be applied to the contaminated soils surrounding or beneath the SEPs. The soils are cobbly, sandy, and clayey loams which would be amenable to a variety of solidification reagents due to the particulate nature of these soils. Solidification of these soils would occur primarily by encapsulation, although metals and radionuclides adhering to the soil particles likely would react with cementicious or pozzalanic binders and become incorporated in those binders' matrices. Immobilization of contaminants should be effective since the majority of SEP soil contaminants are metals and radionuclides, with only minor amounts of organic compounds. The degree of immobilization would depend on the treated materials homogeneity, proper solidification technique (lack of cracks and voids), binder formulation, and ultimate strength. *Ex situ* solidification may be applied to secondary waste stream sludges, requiring solidification.

Treatability studies would be required in any case for solidification of SEP waste or contaminated media. Areas of study would include:

- Selection and application of the binder;
- Binder formulation development/degree of contaminant immobilization;
- Selection and performance of environmental durability tests; and
- Ratio of solidified to original media volume.

III.3.2.4 Soil Washing

In this process, the soils are excavated with contaminants sorbed onto soil particles, which typically are distributed according to ranges of particle sizes. After fractioning the excavated soils into clean and contaminated soil streams, the contaminants are separated from the contaminated soil in an aqueous-based system. The wash water may be augmented with a leaching agent, surfactant, pH adjustment, or chelating agent to increase the efficiency of removal of organics, metals, and radionuclides. The clean soil fractions usually are returned

to the site as backfill. Soil washing experiments at the DOE Hanford Reservation confirm that selective removal of fine sand, silt, and clay particles from the coarse fraction of sand, cobbles, and boulders is an effective method of selectively concentrating contamination. The residual waste streams (e.g., wash water/agent and concentrated soil contamination) may require further treatment depending on the process used. As part of the mechanical screening step, vegetative matter and detritus may also require separation for disposal or, if uncontaminated, may be recycled for use as mulch to help establish a vegetation cover on reclaimed areas. The soil washing process is shown schematically in Figure III.3-10.

Soil washing does not destroy wastes, but is a means of separating the contaminants, thereby reducing the volume of hazardous waste to be treated. Soil washing may be used in combination with bioremediation, incineration, and solidification.

This technology is designed for soils, sediments, and sludges. The contaminant groups for which soil washing may be applicable to are listed below:

- Halogenated semivolatile organic compounds (SVOCs);
- Nonhalogenated SVOCs;
- Halogenated volatile organic compounds (VOCs);
- Nonhalogenated VOCs;
- Pesticides;
- Metals; and
- Radionuclides.

The technology offers the potential for recovery of metals and can remove a wide range of organic and inorganic contaminants from coarse-grained soils. The following factors may limit the applicability and effectiveness of this process:

- Contaminants typically are found in fine soil fractions and in plant matter;
- Fine soil particles (silts, clays) are difficult to remove from washing fluid;
- Complex waste mixtures (e.g., metals with organics) make formulating the washing fluid difficult;
- High humic content in soil inhibits desorption of contaminants (i.e., contaminants become chelated); and
- Contaminant removal from wash fluids may be expensive.

Soil washing is a full-scale developed technology, but additional testing and treatability studies will need to be performed to demonstrate applicability to SEP media and contaminant types. These studies would include the selection of the appropriate additives to the soil washing water. [Note: The information used to prepare this section was derived from the following sources: (Air Force, 1986); (DOE, 1992); (EPA, 1989a); (EPA, 1989b); (EPA, 1990a); (EPA 1991b); (EPA, 1992a); (EPA, 1992b); (EPA, 1993a); (EPA, 1993b); (Smarkel, L.L., 1988); and (Trost, P.B. et al, 1987).]

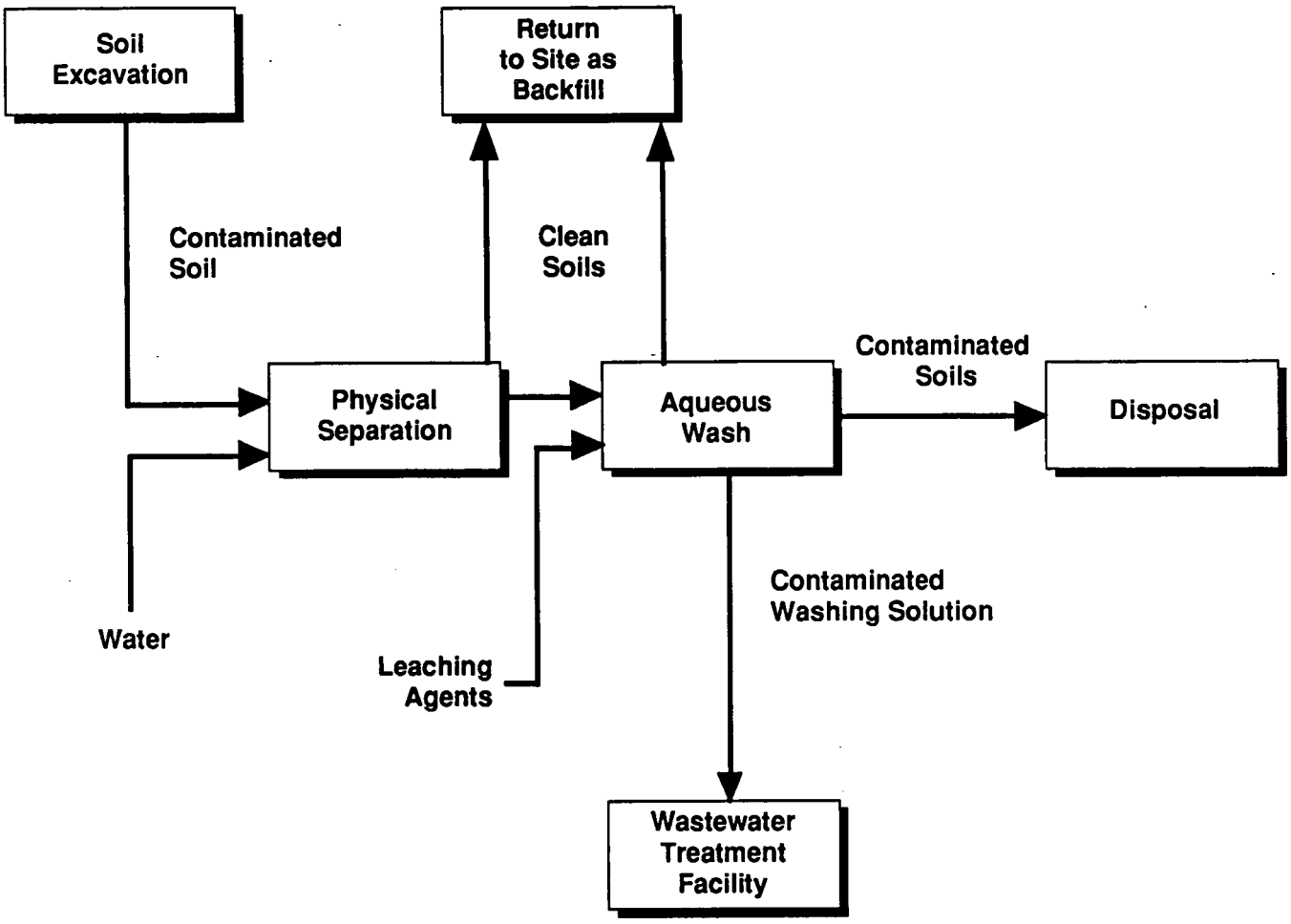

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Figure III.3-10

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Soil Washing Process Flow

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III.3.2.5 Solvent Extraction (Soils)

In this process, the contaminated soils are excavated, and then fed into an extraction unit where they are mixed with an appropriate solvent. The targeted contaminants (organics and possibly heavy metals) dissolve into the solvent. The extracted contaminants and solvent are then placed in a separator where the contaminants and solvent are separated for treatment and re-use, respectively. The treated soil may be returned to the site, disposed of, or routed for further treatment as appropriate. Organically-bound metals can be extracted along with the target organic contaminants, thereby creating residuals with special handling requirements. The solvent extraction process is shown schematically in Figure III.3-11.

Solvent extraction does not destroy wastes, but is a means of separating the contaminants, thereby reducing the volume of hazardous waste requiring treatment. Contaminants from large volumes of soil are concentrated into a smaller volume of liquids which is easier to treat. Solvent extraction may be used in combination with other technologies such as solidification, incineration, or soil washing, depending upon the nature of the soils and contaminants, and secondary waste streams.

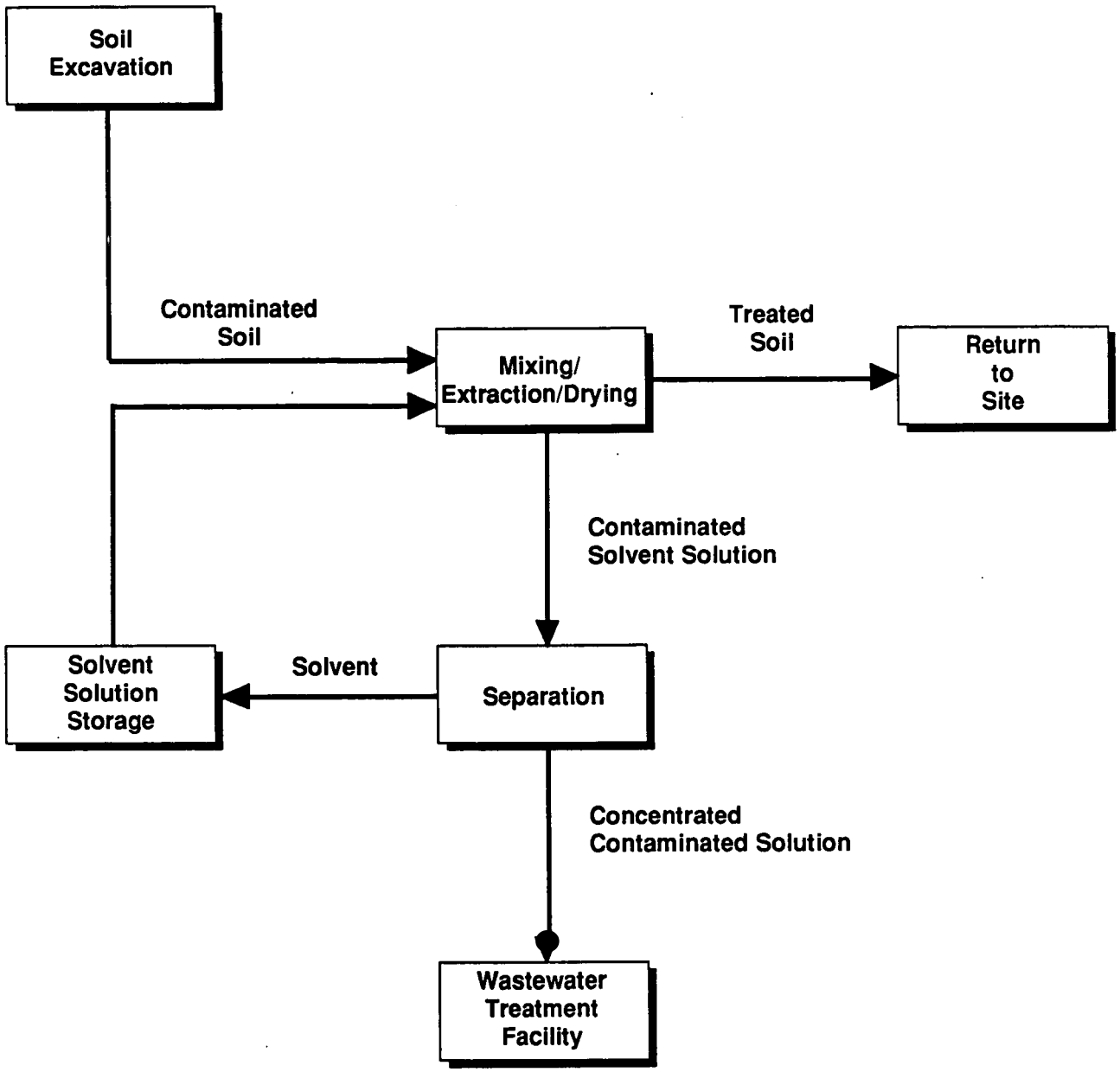
This technology is designed for soils, sediments, and sludges. The contaminant groups for which solvent extraction may be applicable to are listed below:

- Halogenated SVOCs;
- Nonhalogenated SVOCs;
- Halogenated VOCs;
- Nonhalogenated VOCs;
- Pesticides; and
- Heavy metals.

This technology may have to be combined with other technologies such as soil washing to treat all the COCs identified at the OU4 SEPs. The following factors may limit the applicability and effectiveness of this process:

- Traces of solvent may remain in the treated solids;
- The toxicity of the solvent may be prohibitive;
- Organically bound metals can be extracted along with the target organic contaminants, thereby creating residuals with special handling requirements;
- Solvent extraction is generally least effective on high-molecular-weight organic and hydrophilic substances; and
- Some soil types and moisture content levels will adversely impact process performance.

Solvent extraction is a fully developed technology, but treatability studies would be performed to demonstrate applicability to OU4 media and contaminant types. These studies



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ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure III.3-11

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Solvent Extraction Process Flow

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would include the selection of the appropriate solvents, and would address the amount of solvent that may remain in the treated solids. The toxicity of the solvent may become an important consideration. [Note: The information used to prepare this section was derived from the following sources: (DOE, 1992); (EPA, 1989c); (EPA, 1990b); (EPA, 1993a); (Hall, et al, 1990); (Rowe, R., 1987); (Reilly, T. R. et al, 1986); (Hazardous Waste Consultant, 1993); and (Weimer, 1989).]

III.3.2.6 *Ex Situ* Degradation

Degradation technologies can be divided into two main categories: biological processes and chemical processes. Each of these degradation technology types is discussed inmore detail in the following subsections.

III.3.2.6.1 Biological Processes (Bioremediation)

Bioremediation is a treatment technology which uses microorganisms (principally bacteria, fungi, and actinomycetes) to degrade and destroy organic and inorganic contaminants. These microorganisms use the organic and inorganic contaminants as substrate and oxygen sources, break the contaminants down into byproducts, and transform them into less toxic or nontoxic forms.

There are many options available for *ex situ* soil bioremediation. The most common *ex situ* bioremediation technologies for soils include bioreactors, composting, and landfarming. Landfarming would not be suitable for the subsoils at the SEPs because of the radioactive contamination that would be exposed to the environment. Treating soils with bioreactors would be carried out by mixing water and microbes with the contaminated soil to form a slurry mixture. Nutrients and pH adjustment chemicals would be added to ensure optimal conditions. Composting involves placing excavated soils either onto liners or pads, or into specially designed composting cells. Nutrients, pH adjustment chemicals, and water would be added to ensure optimal composting conditions. Depending on the types of contaminants being biodegraded, air can be circulated (if necessary) through the compost via perforated pipes in the compost bed, or through tilling the soil. Many commercially available products and processes can be used to enhance *ex situ* biodegradation.

Ex situ bioremediation can be used to treat soils and waste water. A wide variety of organic and some inorganic contaminants can be treated with bioremediation. The following contaminants and contaminant groups have been successfully treated with bioremediation processes:

- Halogenated VOCs;
- Halogenated SVOCs;
- Nonhalogenated VOCs;
- Nonhalogenated SVOCs;

- Solvents;
- Polynuclear aromatic (PNA) compounds;
- Benzene, toluene, ethylbenzene, and xylene (BTEX);
- Polychlorinated biphenyls (PCBs);
- Organic pesticides/herbicides; and
- Nitrate/nitrite (Cutter, 1992; EPA, 1993b).

Only bioremediation of organics will be discussed further, since bioremediation could not successfully treat any inorganic COCs found in the OU4 soils and liners. Therefore, this technology would need to be implemented in conjunction with other technologies to treat all of the COCs at the OU4 SEPs.

Microorganisms use organic material in the media as substrate, removing it by microbial respiration and synthesis. For most applications, aerobic (oxygen rich) processes are used for removal of organic hazardous wastes. However, anaerobic (oxygen deficient) processes have been shown to treat halogenated compounds more effectively than aerobic processes. For these reasons, it is important to know the components of the waste being treated. The simplified equation for the utilization of organic material as a substrate for respiration and cell synthesis is shown below:

Organics + O_2 + nutrients + cells -------->
new cells + CO_2 + H_2O + nonbiodegradable end products

III.3.2.6.2 Chemical Processes (Degradation)

Degradation of contaminants through chemical means involves changing the oxidation state (or number) of the contaminants and sometimes even the molecular structure of the contaminants through reactions with simple, usually inorganic oxidizing or reducing chemicals. Reducing or oxidizing the contaminants can decrease their toxicity, volume, or mobility by conversion to less toxic or nontoxic species, destruction of the original species, or conversion to insoluble species, respectively. Mixtures of contaminants, where some contaminants require oxidation and others require reduction (e.g., organics and metals), usually cannot be treated simultaneously. The contaminant mixtures require separation steps either before or during treatment, to segregate contaminants amenable to oxidation from those amenable to reduction. In all cases, however, when a contaminant is oxidized, its oxidizing agent is also reduced; and when a contaminant is reduced, its reducing agent is also oxidized.

<u>Oxidation</u>

Oxidation is a chemical reaction in which the oxidation state (or number) of an atom is increased. Oxidizing agents accept electrons, thereby increasing the oxidation state of donor atoms or contaminants. As a result, the toxicity (or mobility) of a contaminant can change. Oxidation can be an effective way of pre-treating wastes before biological treatment.

Compounds that are difficult to treat biologically can be partially oxidized to make them more amendable to biological treatment. Care must be taken to ensure that oxidation of the waste does not produce substances that are more toxic, soluble, or refractory to biological treatment than the parent compound.

Several technologies are available for *ex situ* soil oxidation. Reactors are most commonly used for *ex situ* oxidation. Treating soils in reactors is carried out by mixing water and oxidizing agents with the contaminated soil to form a slurry. The soil slurry pH would be adjusted to ensure optimal conditions. Many commercially available products and processes can be used to enhance *ex situ* oxidation processes.

Oxidation could be used to treat soil and waste water. In the past, oxidation has primarily been used to treat cyanide wastes and dilute solutions containing oxidizable organics. Some contaminants and contaminant groups which have been successfully treated with oxidation are listed below:

- Aldehydes;
- Unsaturated acids;
- Some pesticides;
- Alcohols; and
- Aromatic amines.

Typically, oxidation reactions are not used in the treatment of metals since some oxidizing agents may react violently with or may increase the solubility or toxicity of certain metals.

Types of equipment and materials needed for *ex situ* oxidation depend on the type of oxidizing agents being used. If ozone is used, an ozone generator would be required. Equipment and materials that may be required for *ex situ* oxidation include excavation equipment, oxidation reactors, oxidizing agents, pH adjustment chemicals, and if necessary, moisture and temperature control systems.

Treatability studies would be required to determine the potential for oxidation and reduction of waste constituents, oxidation products (particularly hazardous products), reduction products, soil moisture, soil type and profile, oxidation catalysts present in soil, selectivity of oxidizing agent(s) for specific wastes present at the site, and soil pH. Some of the factors affecting the oxidation process which would need to be considered in the treatability studies include soil moisture, soil and waste pH, soil type, characterization and concentrations of wastes, potential for oxidation of waste constituents, catalysts for oxidation present in soil, and naturally occurring oxidizable substances in the soil.

Reduction

Reduction is a chemical reaction in which the oxidation state (or number) of an atom is decreased by chemical reactions with electron donors. Reducing agents donate electrons to a contaminated atom, thereby reducing the oxidation state of the atom. In general, as a result of reduction, the toxicity or solubility of a contaminant can decrease, or it may be transformed to a more easily handled form.

Several technologies are available for *ex situ* soil reduction. Reactors are most commonly used for *ex situ* reduction. Treating soils in reactors is carried out by mixing water and reducing agents with the contaminated soil to form a slurry. The soil slurry pH would be adjusted to ensure optimal conditions.

Ex situ chemical reduction could be used to treat soils and waste water. A variety of metals and organics can be treated by reduction, including:

- Mercury;
- Chromium;
- Herbicides;
- Fungicides;
- Insecticides;
- Halogenated aromatics;
- PCBs;
- Di- and tri-nitrophenols;
- Hexachlorocyclopentadiene; and
- Trichloroethylene.

Equipment and materials that may be required for *ex situ* reduction include excavation equipment, reduction reactors, reducing agents, pH adjustment chemicals, and moisture and temperature control systems.

Some of the factors affecting the reduction process include soil and waste pH, soil moisture, characterization and concentrations of contaminants, and naturally occurring reducing substances in the soil. Treatability studies would be required to determine characterization and concentration of wastes, the potential for reduction of waste constituents, oxidation products, reduction products, soil moisture, soil type and profile, catalysts for reduction present in soil, selectivity of reducing agent(s) for specific wastes present at the site, soil organic matter, and soil and slurry pH.

III.3.2.7 Thermal Desorption *(Ex Situ)*

Thermal desorption processes use heat to vaporize VOC and SVOC contaminants found in soils. The temperatures required to vaporize contaminants are typically in the range of 150

degrees centigrade (°C) (300 °F) to 538 °C (1000 °F) (DOE, 1993c), but temperatures as high as 760 °C (1400 °F) are sometimes used depending on the contaminants (EPA, 1993b). As the contaminants vaporize, they are desorbed and separated from the soil. Contaminated soil is usually excavated before it is treated with thermal desorption.

Generally, thermal desorption technologies consist of at least two components: a primary chamber and a vapor recovery system. Some thermal desorption processes provide for complete treatment of the gases, vapors, and water produced. Others provide for only a vapor collection system and further treatment must be provided elsewhere. The *ex situ* thermal desorption process is shown schematically in Figure III.3-12. Skid-mounted units are commercially available.

Contaminated material is heated in the primary treatment chamber. Most thermal desorption systems allow for control of residence times and temperatures so that throughput can be maximized, and energy requirements can be minimized. Residence times may be controlled by on-line vapor emissions sampling systems. Dry solid product and soil vapors exit the chamber. Some systems provide processes that remoisturize the dry products to reduce the spread of contaminants remaining in the product.

Vapors are collected in the vapor recovery system where they are condensed or incinerated. Condensed vapors are collected and treated for disposal.

Thermal desorption can be used to treat soils contaminated by a wide variety of organic contaminants. The following list provides the general contaminant groups and specific organic compounds that could be treated by thermal desorption:

- Halogenated VOCs;
- Halogenated SVOCs;
- Nonhalogenated VOCs;
- Nonhalogenated SVOCs;
- Solvents;
- PNAs;
- BTEX;
- PCBs;
- Organic pesticides/herbicides;
- Organometallic pesticides/herbicides; and
- Volatile metals (arsenic and mercury) (EPA, 1993b).

This technology would need to be implemented in conjunction with another technology such as soil washing to treat the metal and radionuclide contaminants that have been identified at the OU4 SEPs.

Factors that have a significant effect on costs include:

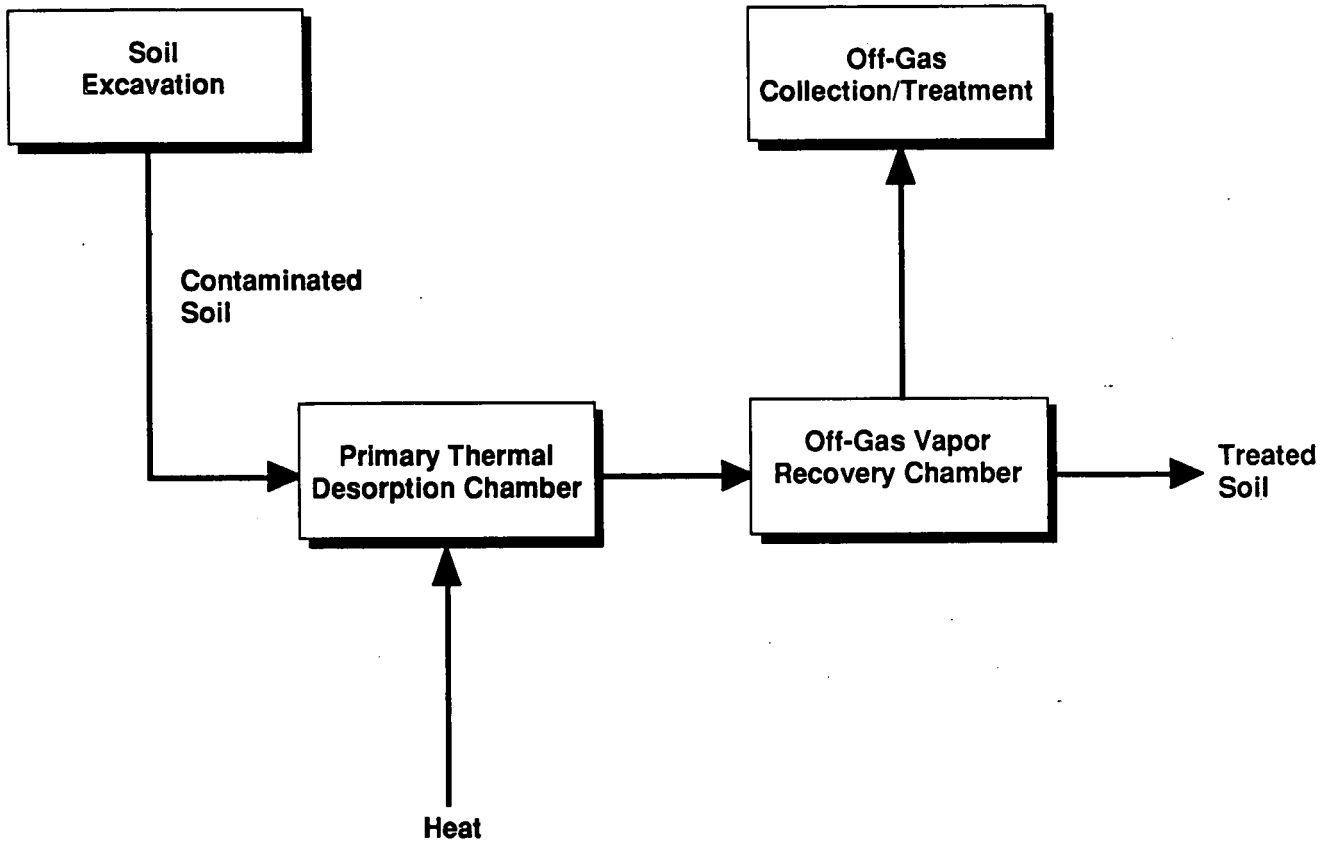

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Figure III.3-12

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
Ex Situ Thermal Desorption Process Flow

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- Moisture content of the media;
- Initial contaminant concentration;
- Target contaminant concentration;
- Waste quantity;
- Waste handling and preprocessing;
- Types of contaminants being treated; and
- Costs and availability of fuel (EPA, 1993b).

Treatability studies would be required to determine the efficiency and feasibility of thermal desorption in decontaminating soils to meet cleanup standards and regulatory requirements at the SEPs. Studies would also be required to determine the moisture content of the media and required temperatures and residence times to reach desired final contaminant levels.

III.3.2.8 Utilities/Equipment Treatment

Waste and equipment form the demolition of the utilities, Building 788, and RCRA Unit 48, will be decontaminated as required for handling, and where appropriate will be segregated and treated for reuse and or recycle. The primary considerations for treatment include minimizing worker and environmental exposure, waste minimization, natural resource conservation, and meeting waste acceptance criteria at a TSDF. The application of treatment will be balanced between the potential effectiveness and waste acceptance criteria versus the cost and secondary waste generated. In order to choose the most appropriate option, consideration will be given to characterization of the contamination, the tenacity of the contaminant adherence, chemical structure of the contaminants, final disposition of decontaminated equipment, generation of secondary wastes, treatment systems available, and waste acceptance criteria of targeted TSDFs. If the physical form of the contaminants is not amenable to the readily available selected BDAT, High Pressure Steam and Water, or requires excessive time and generates large volumes of waste-by-products, then decontamination is not deemed practical. The following Best Demonstrated and Available Technologies (BDATs), as discussed in the "Debris Rule" should be considered for the recoverable debris present at the OU4 SEPs.

III.3.2.8.1 Physical Extraction

Removal of surface contamination by high-pressure water/steam sprays, abrasive blasting, or scarification of facilities, equipment, debris, and utilities surfaces may be required to meet material/waste handling and reuse requirements, or to meet waste acceptance criteria if required. These technologies could be used in conjunction with size reduction (see Section III.3.2.9 Size Reduction). These technologies are applicable BDAT for contaminated debris, and can be applied both *in situ* and *ex situ*.

High-pressure water/steam sprays with regulated temperature and pressure can be effective in removing surface contamination and in removing contaminated surface layers. This

technology has been successfully applied at a decontamination facilities and at the RFP decontamination pad to remove both hazardous and low-level radioactive contamination. This technology has also been used to remove hazardous constituents. This technology generate significant volumes of secondary waste water requiring further storage, treatment or disposal.

Abrasive blasting utilizes water and/or air pressure and steel shot, grit, and other commercially available non-hazardous abrasive material to remove contamination or surface layers embedded with contaminants. Abrasive material must be packaged, treated, and disposed of as a hazardous, radiological, or mixed waste, requiring further storage, treatment, and/or disposal. Significant waste volume reduction can be achieved through transfer of contamination from large pieces of equipment/siding to abrasive media which can be compacted and packaged. This lower volume of waste, however, still requires final treatment and/or disposal. A relatively new technology that utilizes frozen carbon dioxide pellets has been shown to achieve good surface decontamination of certain materials while eliminating the volume of contaminated abrasive media since the solid carbon dioxide quickly sublimes after use leaving only the removed contaminants.

Scarification produces a smaller volume of secondary waste than high-pressure sprays or abrasives since no decontamination media is added to or mixed with the removed contaminants. Scarification utilizes grinding and cutting tools to remove contaminated surface layers. Dust and particle collection and tool decontamination are required with this process.

III.3.2.8.2 Chemical Extraction

Chemical extraction of hazardous wastes is BDAT for contaminated debris and utilities and can be applied both *in situ* and *ex situ*. There are three primary methods for chemical extraction: water washing and spraying, liquid-phase solvent extraction, and vapor-phase solvent extraction. Each of these methods is discussed below.

Water washing and spraying consists of water sprays or water baths of sufficient temperature, pressure, residence time, and agitation; containing surfactants, acids, bases, or detergents to remove hazardous contaminants from debris surfaces and surface pores, or to remove contaminated debris surface layers. Chemical extraction via water washing and spraying is similar to physical extraction techniques using high pressure, except that chemical extraction utilizes aqueous chemical solutions during decontamination.

Liquid-phase solvent extraction involves the use of a non-aqueous liquid or dissolves and/or suspends solution. The liquid solution is applied to debris surfaces and surface pores and hazardous contaminants in the liquid phase. The contaminants are removed from the debris along with the liquid or solution while using appropriate agitation, temperature, and residence time.

Vapor-phase solvent extraction involves application of an organic vapor, using sufficient agitation, residence time, and temperature, to dissolve hazardous contaminants on debris surfaces and in surface pores in the vapor phase. The dissolved contaminants are removed with the organic vapor.

All of the technologies categorized as chemical extraction have the potential to generate significant volumes of secondary waste requiring collection, storage, volume reduction (i.e., evaporation, neutralization), and final treatment (i.e., cementation, vitrification). Depending upon the chemical used in the extraction process, land disposal restrictions (LDRs) may be applicable to the secondary waste.

III.3.2.8.3 Thermal Extraction.

Metal melting is an acceptable *ex situ* treatment technology. This process requires metals to be segregated and packaged by composition and type of contaminant. Metals are loaded into the melter and are brought to a liquid state. The slag, containing impurities, is separated for further processing or disposal. Typically, the slag is further treated by incineration and packaged for disposal. The cost of this process is relatively high. DOE radiologically contaminated metallic debris have been melted and re-cast as shielding devices and waste containers to be re-used within the DOE complex. Several commercial facilities in the United States accept metallic low-level radioactive and low-level mixed wastes for melting and separation.

III.3.2.9 Size Reduction

Size reduction of the liners, utilities, and other contaminated debris may be required to facilitate consolidation and/or containerization of the materials for storage and disposal. This technology could be applied both *in situ* and *ex situ*. Some of the size reduction technologies being considered include circular diamond or carbide saws, diamond chain saw, diamond rope saw, flame cutting, shredders, crushers, gas torching, and an impact hammer. One or several of these technologies could be used to reduce the size of the liners, utilities, and debris prior to containment and disposal. High-force compaction may be used to volume-reduce containerized solid wastes.

The type of size reduction technology that is used would depend on the liners, utilities, and debris materials. The liner material includes at least asphalt concrete, asphalt planking, asphalt mastic, Petromat® lining, Hypalon® liner, and rubberized, crack-sealing material.

Many of these size reduction technologies could produce a substantial amount of dust. Water sprayers can be used to reduce airborne dust emissions, but will produce a secondary waste stream requiring collection and treatment.

III.3.2.10 Containerization

Containerization would involve excavating and placing the soils, liners, utilities, and debris (with size reduction, if necessary) into containers. The packaging process would require procurement of suitable containers. It is anticipated that either 55-gallon drums or wood crates (56 cu. ft. and 112 cu. ft.) would be used.

The minimum disposal requirements established by DOE Order 5820.2A would be followed when packaging the OU4 waste. The applicable disposal criteria are as follows:

- Waste must not be packaged for disposal in cardboard or fiberboard boxes, unless such boxes met DOT requirements and contain stabilized waste with a minimum of void space. For all types of containers, void spaces within the waste and between the waste and its packaging shall be reduced as much as practical;

- Liquid wastes, or wastes containing free liquid, must be converted into a form that contains as little freestanding and noncorrosive liquid as is reasonably achievable, but, in no case, shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container, or 0.5 percent of the volume of the waste processed to a stable form;

- Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

- Waste must not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste; and

- Waste must not be pyrophoric. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable.

It is also noted that,

- "Waste containing amounts of radionuclides below regulatory concern, as defined by Federal regulations, may be disposed without regard to radioactivity content."

Equipment and materials needed for placing the waste into containers include:

- Backhoes or similar excavation machinery to place waste into the containers;
- Lifting equipment;
- Hand tools;
- Fork truck and transport vehicles;
- Drums or crates; and
- Sprayers or similar equipment to control the generation of dust.

Traditional methods for remediation of radionuclide-contaminated soils, such as excavation, transportation, and permanent storage are costly (depending on the disposal site conditions) because of the typically large volumes of soil to be removed, and the protection requirements for the management of radioactive contamination.

Removal and disposal techniques potentially are applicable for all types of contamination. The following factors may limit the applicability and effectiveness of this process:

- Availability of disposal capacity for radioactive and mixed wastes nationally may be restricted or unavailable;
- Public concerns regarding land disposal may impact and delay the receiving facility in accepting RFP-generated waste;
- Offsite disposal cost may be prohibitive;
- Verification of nonmobility and stabilization of waste may be expensive; and
- Interim storage awaiting approval of additional DOE disposal sites may be costly and requires monitoring.

An applicable disposal site for the OU4 wastes must be selected, negotiated, and approved. Individual disposal sites will require tests and analyses that demonstrate adherence to waste acceptance criteria.

III.3.3 Identification and Description of General Response Actions

The technologies deemed to be potentially suitable for the closure and remediation of OU4 (see Table III.3-2) were combined into GRAs to allow comparison of the alternatives to select the most appropriate IM/IRA for OU4. The five GRAs are presented in Table III.3-3. In total, nine GRA alternatives were identified for consideration. Some of the common aspects of all the GRA alternatives are discussed below. The specific activities associated with each alternative are described in the following subsections.

An industrial hygiene and radiation assessment must be conducted prior to implementing the IM/IRA to identify worker safety requirements, including the need for personal protective equipment (PPE). A task-specific health and safety plan will be prepared to identify the worker protection requirements.

Depending on the GRA selected for the IM/IRA, structures in the vicinity of the SEPs could interfere with the implementation of the GRA. These potential interferences include aboveground/underground (AG/UG) utilities (including portions of OU9 - Original Process Waste Lines), Building 788, and the "pondcrete" production and processing equipment. Decontamination, removal, and/or other actions will be required to eliminate these interferences. The options being considered for the disposition of materials generated as a result of removing these structures include:

TABLE III.3-3
PRELIMINARY GENERAL RESPONSE ACTIONS AND ALTERNATIVES

General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
Alternatives A. Regrade and Seed	Alternatives A. Vegetative Cover (Cover Alternative 1) B. Temporary Cover (Tarpaulin) C. Engineered Cover (Cover Alternatives 2 to 6) Notes: 1. Consolidation or removal of contaminated media may be for all material or for zones where soils have COC concentrations exceeding the PRGs only. 2. Alternatives A and C will require post-closure care and monitoring. Alternative B does not include post-closure care and monitoring since this is a temporary measure which will be followed by a permanent solution. 3. Removal of Building 788 and pondcrete production equipment (RCRA units 21 and 48) will be required.	Alternatives A. Consolidation of Contaminated Debris and *In situ* Treatment of Contaminated Media/Waste with an Engineered Cover. B. Consolidation of Contaminated Debris, *In Situ* Soil Treatment with an Engineered Cover C. Removal of Contaminated Debris, *In Situ* Soil Treatment with an Engineered Cover Notes: 1. Consolidation or removal of contaminated media may be for all material or for zones where soils have COC concentrations exceeding the PRGs only. 2. *In situ* treatment will be solidification/stabilization. 3. Engineered cover alternatives 1 to 6 will be considered. 4. All alternatives will require post-closure care and monitoring. 5. Removal of Building 788 and pondcrete production equipment (RCRA units 21 and 48) will be required.	Alternatives A. Remove All Contaminated Media/Waste for Disposal and Backfill Notes: 1. Alternative will involve excavation and containerization of all contaminated media. [May require size reduction.] 2. Alternative may involve onsite storage, including the development of a new storage facility. 3. Alternative may include the offsite storage, treatment, and/or disposal of the contaminated media. 4. Alternative constitutes clean closure of the SEPs; post-closure care and monitoring would not be required. 5. Removal of Building 788 and pondcrete production equipment (RCRA units 21 and 48) will be required.	Alternatives A. Remove All Contaminated Media/Waste (*Ex Situ* Treatment) and Backfill Notes: 1. Alternative will involve excavation of all contaminated media/waste. 2. Alternative includes *Ex Situ* treatment to reduce the volume of contaminated media/waste requiring disposal. Clean soils will be returned to the site as backfill. *Ex situ* treatment includes: - decontamination - solidification/stabilization, - soil washing, - solvent extraction, - degradation, and - thermal desorption. 3. Alternative may involve onsite storage, including the development of a new storage facility for treatment residues. 4. Alternative may include the offsite storage, treatment, and/or disposal of the treatment residues. 5. Alternative constitutes clean closure of the SEPs; post-closure care and monitoring would not be required. 6. Removal of Building 788 and pondcrete production equipment (RCRA units 21 and 48) will be required.

- Decontamination/BDAT;
- Relocation;
- Onsite storage;
- Consolidation within the SEPs (if the chosen IM/IRA incorporates the use of an engineered cover); and
- Shipment of materials offsite.

Final disposition of the debris will be determined based on the GRA selected, the levels of contamination present in the debris, and the availability of storage/disposal sites. High COC contamination levels (exceeding the PRGs) confined to small, localized areas within soils in the vicinity of the SEPs are called zones. Zones where soils have COC concentrations exceeding the PRGs may need to be remediated on a case-by-case basis. The type, quantity, and concentration of contaminant(s) will determine the remediation strategy.

Potential remediation strategies for zones where soils have COC concentrations exceeding the PRGS include:

- Excavation and consolidation of contaminated soils within the SEPs prior to backfilling for construction of an engineered cover;
- Excavation and *ex situ* treatment; and
- Excavation and storage as waste for future treatment/disposal.

Some of the IM/IRA GRAs may require importation of equipment and materials from offsite locations. The need to import equipment and materials could impact the schedule and cost of the IM/IRA GRA since security procedures require inspection of any vehicle and equipment entering or exiting the Protected Area.

Sampling may be needed to monitor the performance of the IM/IRA during implementation and/or to verify that required standards have been achieved upon completion of the IM/IRA. A sampling and analysis plan will be prepared to specify the procedures that will be followed to meet the sampling objectives.

The above items were considered during the development and evaluation of the IM/IRA GRAs presented in the section. However, the need to address these items is contingent on the extent of the OU4 remedial activities. Section 4.3.1 describes how these items will be addressed to ensure effective implementation of the recommended IM/IRA GRA. The following nine GRA alternatives represent possible closure solutions for the SEPs.

III.3.3.1 General Response Action I - No Action

A. Regrade and Seed

The no action GRA is based on the assumption that the pond liners and adjacent soils would not cause an adverse impact to human health and the surrounding environment once the pond sludges have been removed. It is assumed that the IM/IRA objectives are achieved without any controls or other remedial actions. However, based on the information provided in Section III.2 existing surficial and vadose zone soil COC concentrations exceed the PRGs that were established to be protective of human health. As such, the no action GRA could only be selected if it can be demonstrated that the contaminants are immobile and confined within the soil matrix, or will degrade to acceptable levels, or be adequately addressed as part of a ground water remediation system. In this situation, there would not be a completed pathway by which human or ecological receptors could be exposed to unacceptable contaminant levels. To demonstrate that the no action risks to human health and the environment are minimal, the long-term (i.e., 1,000 years into the future) risk may need to be considered. If the no action GRA is demonstrated to be protective of human health and the environment, long-term monitoring would not be required either by regulation or to assess future risk, i.e., the no action GRA constitutes clean closure of the SEPs. However, if it is determined that additional actions are required to remediate the ground water, monitoring would need to be conducted to assess the effectiveness and progress of the ground water remediation activities. It should be noted that the no action GRA would not preclude remediation of ground water as part of the OU4 Record of Decision after the additional hydrogeological investigations and Risk Assessment activities.

Although no remedial actions are required, the no action GRA includes site alterations to facilitate proper drainage of the area. These drainage controls consist of regrading the SEPs area, using backfill, if necessary, and establishing a vegetative cover over the disturbed areas to minimize erosion. The regrading activities could require the removal or relocation of AG/UG utilities and other interferences. The resulting waste would be managed to achieve compliance with applicable regulations. Post-closure maintenance would be unnecessary.

Few raw materials or resources would be required to implement this GRA. The drainage control, and vegetative materials are standard and readily available. Items that would contribute to the overall cost of this GRA would include:

- Utilities removal/relocation;
- Site preparation;
- Topsoil; and
- Seed.

The benefits of this GRA would include:

- Post-closure monitoring would not be required;

- Elimination of potential closure structural interferences with future ground water characterization activities;
- Cost-effective remedy; and
- Protective of human health and the environment.

The disadvantage of this GRA is:

- The no action GRA can only be selected if it can be demonstrated that the contaminants are immobile and confined within the soil matrix, or will degrade to acceptable levels, or be addressed as part of a ground water remediation system.

III.3.3.2 General Response Action II - Containment (Closure in Place)

This GRA is based on constructing a cover system to isolate the contaminants from the environment. The required performance of the cover system is dependent on the nature of the contaminants and the degree to which contaminants are able to migrate from the media to the environment. That is, the larger the potential for contaminant migration to adversely impact human health, the more effective the cover must be.

Under this GRA, three GRA alternatives have been considered. The first alternative (A) involves excavating (and replacing) contaminated media to construct a subsurface drain, grading to provide positive drainage away from the contaminated areas, and establishing a vegetative cover to prevent erosion and to minimize infiltration by maximizing evaporation and transpiration. The second alternative (B) would be a temporary measure to preclude contaminant transport should additional information be required to select a final remedy for OU4. The third alternative (C) would be construction of a subsurface drain and an engineered barrier to provide long-term isolation of the contaminated media. Alternatives A and C are considered to be permanent final closure actions. Alternative B is designated as an interim closure action.

In addition to the construction of the cover system, a post-closure care and monitoring program would be established for alternatives A and C. To ensure that the integrity of the final cover system is maintained after closure, arrangements for restricting use of the property will be provided as part of a property deed filed with the local land use authority. A survey plat showing the boundaries of the engineered cover will be submitted along with the property deed. A description of each alternative is provided below.

A. Vegetative Cover

This GRA alternative would control the migration of contaminants via the air, surface water, and the ground water pathways. Under this GRA alternative, all contaminated soils, liners, utilities, and Building 788 (debris) from the SEPs would be excavated and temporarily stockpiled. Size reduction of the liners would be employed to consolidate them with the soils. A subsurface drainage system, that meets RCRA/CHWA standards for closing an interim status

surface impoundment, would be constructed above the mean historic high ground water elevation. The liners, soils, and debris would then be placed over the subsurface drainage system. Zones outside the pond limits, where soils have COC concentrations that exceed PRGs, would be excavated and consolidated with the liners and contaminated soils. The subsurface drainage system would be connected to the existing ITS so that potentially rising ground water would be precluded from contacting the liners or contaminated soils.

Backfill would be placed over the contaminated materials and grading would be performed to reshape the existing topography to manage infiltration, run-on, runoff, and erosion, and to prevent and minimize the contact between the surface water and contaminated materials. The backfill would be seeded to provide a vegetative cover. Pea gravel would be used to facilitate the growth of the vegetation and provide protection against erosion. A vegetative cover would provide a cost-effective, short- and long-term method for surface stabilization.

The transport of contaminants via air and surface water exposure pathways would be eliminated by ensuring that all contaminants are covered, to the proper depth, with clean backfill. Also by proper drainage and a hardy vegetative cover, infiltration into the contaminant areas can be minimized to reduce leaching of contaminants into the vadose zone.

Few raw materials or resources would be required to implement this GRA alternative. Drainage control backfill and vegetative materials are standard and readily available. It is assumed that offsite borrow areas would be the source of backfill material.

Items that would contribute to the overall cost of this GRA include:

- Facilities/utilities removal/relocation;
- Site preparation;
- Contaminated materials excavation and replacement;
- Subsurface drainage system;
- Backfill;
- Pea gravel;
- Topsoil;
- Seed; and
- Post-closure monitoring.

The primary operating costs would be derived from cover inspections, erosion control, and maintenance of the vegetation cover.

The advantages of this GRA include:

- Elimination of potential closure structural interferences with future hydrogeological characterization activities;
- Waste minimization; and

- Protective of human health and the environment.

The disadvantages of this GRA alternative would be:

- Contaminants would remain in place and have the potential to be a source of ground water contamination if precipitation infiltrates the vegetative cover;
- Possible adverse impacts to the objectives of the potential ground water remediation program; and
- Worker exposure to contaminants would be increased due to consolidation and size-reduction of the liners.

In summary, the objective of isolating the waste from air and surface water runoff contaminant exposure pathways would be achieved by the engineered cover. A resulting added benefit would be that waste treatment/storage/disposal facilities would not be required.

The drawback of this GRA is that the contaminants would remain after closure. If it is determined in the future that the contaminants left in place pose a significant risk via the ground water pathway, the entire source-control remedy may have to be replaced. This would result in a significant expenditure of additional funds.

B. Temporary Cover

This GRA alternative would consist of backfilling the empty SEPs with clean soil and/or grading the surrounding area to provide positive drainage away from the pond area. The ponds would then be covered with a temporary cover such as a tarpaulin or geotextile material to minimize erosion and infiltration of precipitation, and to minimize the contact between surface water and contaminated media. The cover would span the entire surface area of all of the ponds. Zones outside the pond limit where soils have COC concentrations exceeding the PRGs would be excavated and the removed materials would be placed under the temporary cover. All graded areas not covered by the tarpaulin/geotextile would be stabilized and/or vegetated to minimize erosion. This temporary measure would be implemented pending the results of the additional hydrogeological investigations, which may be used to select an appropriate ground water remedial solution (if necessary).

Few raw materials or resources would be required to implement this GRA alternative. Drainage control, backfill, and vegetative materials are standard and readily available. If the contaminant concentrations are below or near the PRGs, then little or no PPE would be required. It is assumed that onsite borrow areas will be the source for the backfill soils.

Items that would contribute to the overall cost of this GRA alternative include:

- Materials and installation of the temporary cover;
- Facilities/utilities removal/relocation;

- Site preparation; and
- Backfill.

The primary operating costs would be derived from:

- Cover inspections;
- Erosion control; and
- Maintenance of the temporary cover.

Advantages associated with this GRA are:

- Additional remedial actions could be easily implemented, if necessary; and
- Wastes are isolated from air, and surface water exposure pathways.

Disadvantages associated with this GRA alternative are:

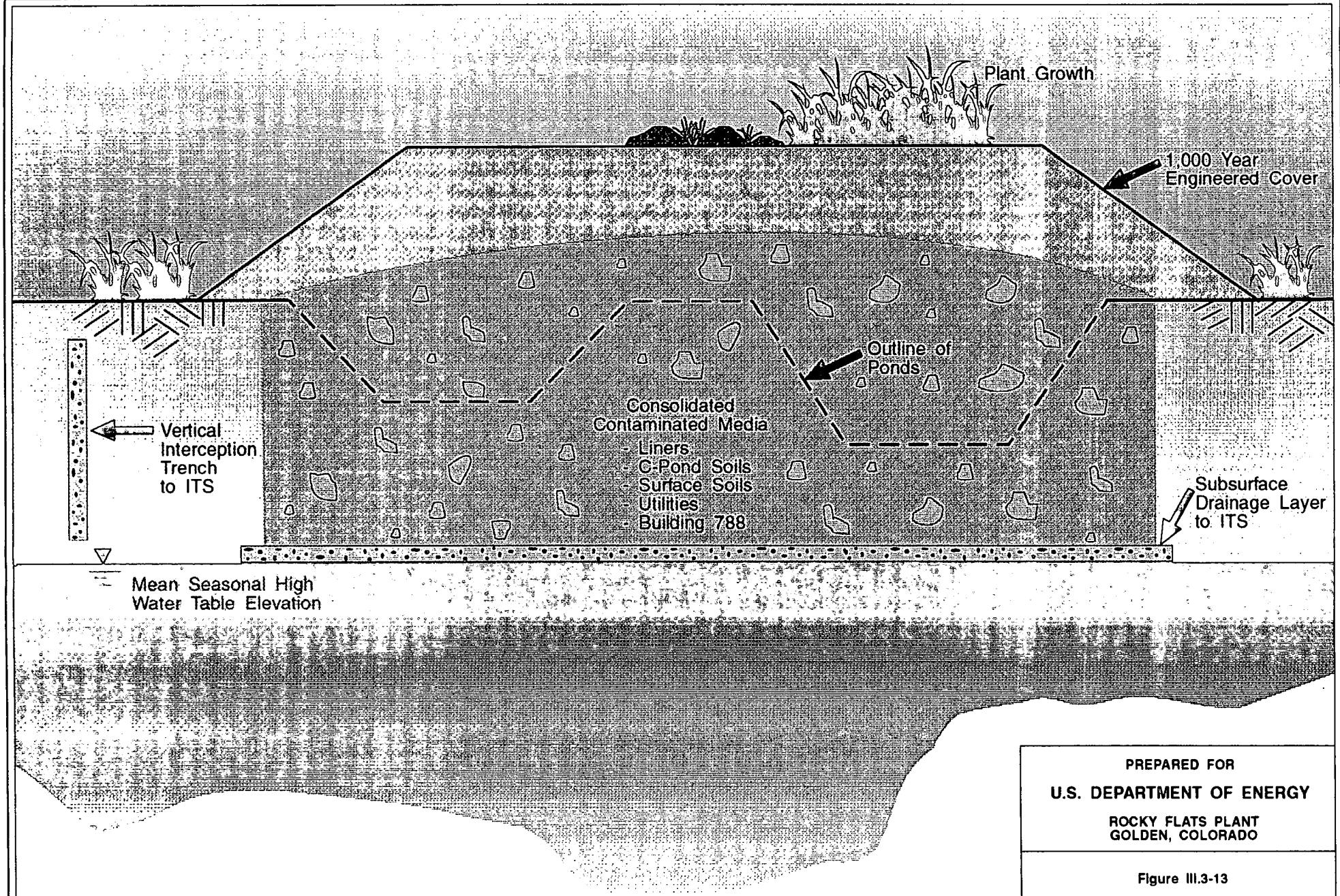
- Maintenance requirements could be significant due to degradation of the temporary cover from ultraviolet light, oxidation, wind, ponding of water and freeze/thaw cycles; and
- The potential exists for large volumes of clean soil used as backfill to be classified later as contaminated media.

In summary, benefits of the temporary protective cover GRA alternative would be the isolation of liners and subsurface soils from the atmosphere and surface runoff waters while additional hydrogeological investigations and the baseline risk assessment are being conducted to determine if additional action is required. If ground water characterization and risk assessment activities indicate that additional source controls are required, this temporary action would not preclude the implementation of additional actions.

C. Engineered Cover

This GRA alternative would be similar to the GRA alternative A and would consist of consolidating the liners, soils, debris, and zones outside the pond limits, and constructing an engineered cover with a subsurface drainage system that meets RCRA/CHWA standards for closing an interim-status surface impoundment. Size reduction would be required to consolidate the liners.

Figure III.3-13 presents a general schematic diagram of this alternative. This diagram is presented to generally depict the complexities of this alternative with respect to the other GRA II alternatives. The engineered cover would be installed as a physical barrier to eliminate air and surface water runoff exposure pathways. The cover would be designed to decrease mobility of contaminants in the soils and liners by reducing or eliminating precipitation infiltration into the contaminant zone and to reduce the leaching of contaminants into ground water. The cover



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ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure III.3-13

Solar Evaporation Ponds
Operable Unit No.4, IM/IRA EA DD
General Response Action II C
Schematic Diagram

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also would act as a barrier to prevent intrusion of animals into the contaminated materials. Engineered covers that have been considered are described in Subsection III.3.2.1. The disturbed areas would be vegetated to reduce erosion. The subsurface drainage system would divert ground water to the existing ITS and away from the consolidated waste zone if the elevation of the ground water rises.

To implement this GRA alternative, testing for hydraulic permeability, compaction, and moisture content would be required to select the appropriate cover materials. It is assumed that offsite borrow areas would be the source of backfill soils.

Items that would contribute to the overall capital cost of this alternative include:

- Facilities/utilities removal/relocation;
- Site preparation;
- Backfill;
- Pea gravel;
- Subsurface drainage system;
- Biotic barrier layer;
- Drainage and filter materials (if required);
- Topsoil;
- Seed; and
- Post-closure monitoring.

The primary operating costs would be derived from cover inspections, erosion control repairs, and cover maintenance.

The advantages of this GRA alternative would be:

- Waste minimization; and
- Isolation of wastes from air, surface water, and ground water exposure pathways.

The disadvantages of this GRA alternative would be:

- Contaminants would remain in place and have the potential to be a source of ground water contamination if precipitation infiltrates the engineered cover;
- Possible adverse impacts to the objectives of the potential ground water remediation program; and
- Worker exposure to contaminants would be increased due to consolidation and size-reduction of the liners.

In summary, a benefit of this GRA is waste minimization (or deferment of waste dispositioning in the case of GRA alternative B). A resulting added benefit would be that waste treatment/storage/disposal facilities would not be required. The objective of isolating the waste

from air, ground water, and surface water runoff contaminant exposure pathways would be achieved by the engineered cover.

The drawback of this GRA is that the contaminants would remain after closure. However, if it is determined in the future that the contaminants left in place pose a significant risk via the ground water pathway, the entire source-control remedy may have to be replaced. This would result in a significant expenditure of additional funds.

III.3.3.3 General Response Action III - *In Situ* Treatment (Closure in Place)

This GRA is similar to GRA II except that *in situ* treatment would be provided if it is determined that an engineered cover with a subsurface drainage system is not effective enough to adequately protect human health. The degree of treatment required and the required performance of the cover system is dependent on the contaminant concentrations and mobility, and the media (i.e., soils, liner, debris) to be treated. The cover aspects of GRA III, including post-closure care, and property use and deed restrictions, are identical to GRA II, alternative C.

Under this alternative, an engineered cover would be used to provide a physical barrier to eliminate air and surface water runoff exposure pathways by minimizing contact between contaminated media and the environment. The cover would be designed to decrease mobility of contaminants by reducing the amount of precipitation infiltrating the contaminated zone. The cover would preclude the release of contaminants to the surface environment and act as a barrier to prevent intrusion of animals into the treated material. Engineered covers that have been considered are described in Subsection III.3.2.1. The disturbed areas would be vegetated to reduce erosion. The subsurface drainage system would divert ground water away from the waste zone if the elevation of the ground water rises.

Treatability studies may be required to maximize the efficiency of *in situ* treatment. In addition, testing for hydraulic permeability, compaction, and moisture content would be required to select the appropriate materials for the engineered cover. It is assumed that onsite borrow areas would be the source of backfill soils. Zones where soils have COC concentrations exceeding the PRGs would be excavated, and the excavated materials would be placed within the SEPs prior to construction of the engineered cover. The disturbed areas would be vegetated to reduce erosion. Treatability studies would include, but not be limited to:

- Binding agent selection;
- Binder formulation development;
- Selection of environmental durability tests; and
- Ratio of solidified to original media volume.

Items that would contribute to the overall capital cost of this alternative include:

- Facilities/utilities removal/relocation;

- Site preparation;
- Backfill;
- Pea gravel;
- Biotic barrier layer;
- Hydraulic barrier layers;
- Drainage and filter materials (if required);
- Topsoil;
- Seed;
- Treatability studies;
- Post-closure monitoring; and
- *In situ* treatment equipment rental.

The primary operating costs would be derived from:

- Operation of *in situ* treatment equipment (temporary);
- Quality assurance/quality control testing;
- Inspections;
- Erosion control repairs; and
- Maintenance of the vegetation cover.

Three variations of this GRA exist:

A. Consolidation of contaminated debris (utilities and Building 788); and *in situ* treatment of contaminated media (soils and liners);
B. Consolidation of contaminated debris/waste (utilities, Building 788, and liners), and *in situ* soil treatment; and
C. Removal of contaminated debris/waste (utilities, Building 788, and liners), and *in situ* soil treatment.

These variations are discussed in more detail below.

A. Consolidation of Contaminated Debris (Utilities and Building 788), and *in Situ* Treatment of Contaminated Media/Waste (Soils and Liners) and an Engineered Cover

This alternative would involve *in situ* treatment of contaminated media and an engineered cover. The *in situ* soil treatment technology considered is solidification/stabilization. The debris may require size reduction for consolidation under the engineered cover. A description of these technologies has been presented in Subsections III.3.2.3 and III.3.2.9.

The advantages of this GRA alternative would be:

- Minimized worker exposure to contaminants;

- Waste minimization; and
- Immobilization of contaminants and elimination of them as a source of contamination to the ground water. (The engineered cover would isolate contaminants from surface runoff and air exposure pathways.)

The disadvantages of this GRA alternative would include:

- Less operational and quality control exist for many *in situ* treatment processes compared to *ex situ* treatment processes, which could result in nonuniform treatment of contaminated material;
- Contaminants remain in place and are a potential source of ground water contamination if the *in situ* treatment is not completely successful and precipitation infiltrates the engineered cover; and
- Potential for worker exposure to contaminants during media/waste handling operations.

In summary, this GRA alternative has the benefit of waste minimization. Contaminated materials would not be handled, thereby reducing the potential spread of contamination and the resulting increase in waste volume. The objective of isolating the waste from air and surface water runoff contaminant exposure pathways would be achieved. Worker exposure to contaminants would be minimized. The drawback of this GRA is that the *in situ* treated media would remain after closure. If it is determined in the future that the contaminants left in place pose a significant risk via the ground water pathway, the entire source-control remedy may have to be replaced. This would result in significant expenditure of additional funds.

B. Consolidation of Contaminated Debris/Waste (Utilities, Building 788, and Liners) and *In Situ* Soil Treatment with an Engineered Cover

This alternative consists of consolidating the liners and other contaminated debris, treating subsoils *in situ*, and constructing an engineered cover. A subsurface drainage layer would be installed above the treated soils to protect the untreated liners from potential contact with rising ground water. The *in situ* soil treatment technology considered is solidification/stabilization. The debris may require size reduction for consolidation under the engineered cover. A description of these technologies has been presented in Subsections III.3.2.3 and III.3.2.9. Figure III.3-14 presents a general schematic diagram of this alternative. This diagram is presented to generally depict the location of the subsurface drainage layer which would not be required by the other GRA III alternatives.

The advantages of this alternative would be:

- Minimization of worker exposure to contaminants;
- Waste minimization; and

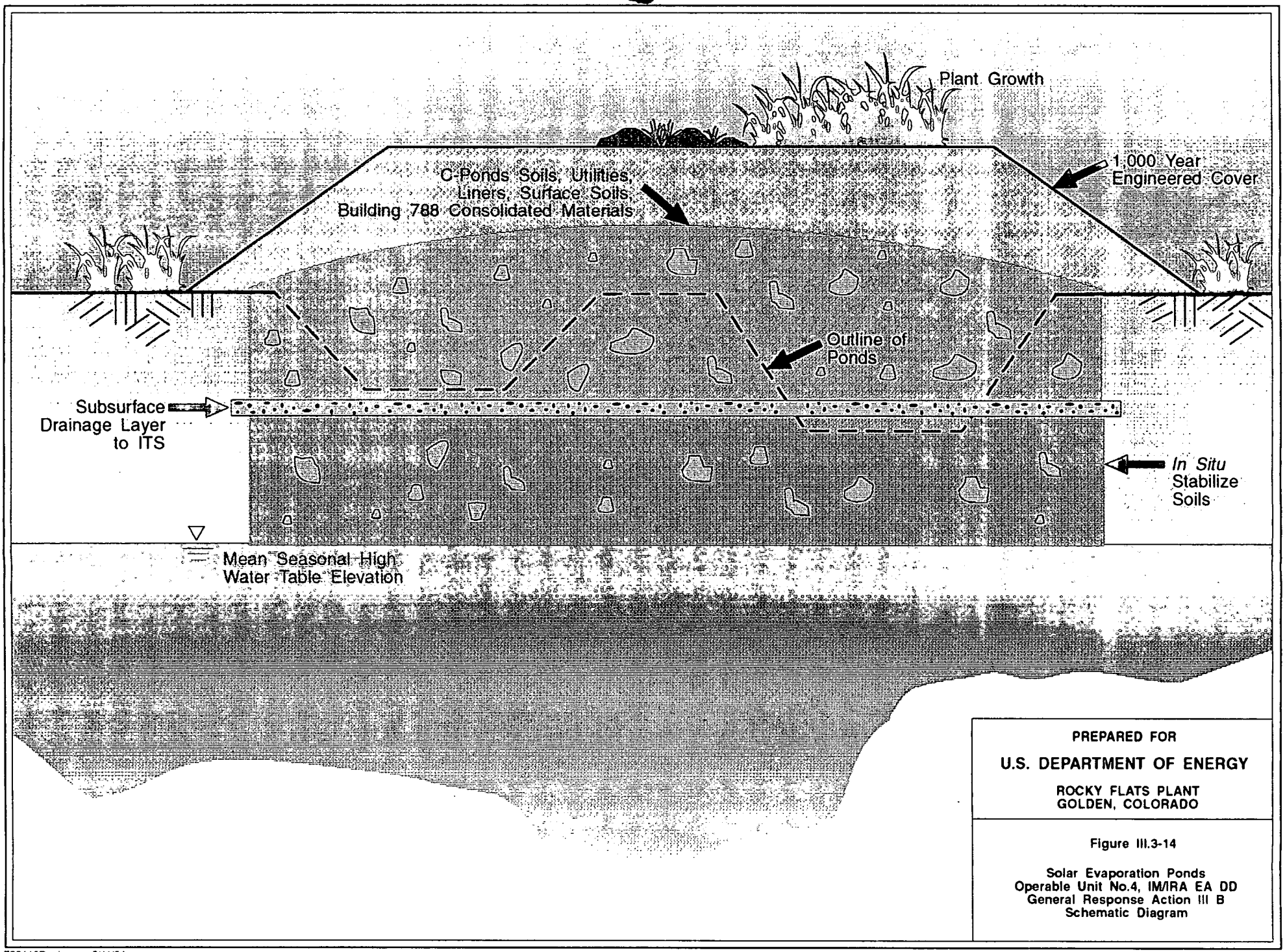

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Figure III.3-14

Solar Evaporation Ponds
Operable Unit No.4, IM/IRA EA DD
General Response Action III B
Schematic Diagram

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- Immobilization of contaminants and elimination of them as a source of contamination to the ground water. (The engineered cover would isolate contaminants from surface runoff and air exposure pathways.)

The disadvantages associated with this GRA are:

- Less operational control for many *in situ* treatment processes, compared to *ex situ* treatment processes, possibly resulting in nonuniform treatment of contaminated material; and
- Contaminants remain in place and are a potential source of ground water contamination if the *in situ* treatment is not completely successful and precipitation infiltrates the engineered cover; and
- Potential for worker exposure to contaminants during media/waste handling operations.

In summary, this GRA alternative offers the benefit of minimizing the amount of waste that would require treatment, storage, or disposal. Contaminated materials would not be handled, thereby reducing the potential spread of contamination and the resulting increase in waste volume. The objective of isolating the waste from air and surface water runoff exposure pathways would be achieved. Worker exposure to contaminants would be minimized since the subsurface soils would be treated *in situ*. Worker exposure could result from handling/size reducing the liners. The drawback of this GRA is that the *in situ* treated media would be a potential contaminant source to the ground water. If it is determined in the future that the contaminants left in place pose a significant risk via the ground water pathway, the entire source-control remedy may have to be replaced. This would result in significant expenditure of additional funds.

C. Removal of Contaminated Debris (Utilities, Building 788, and Liners), and *In Situ* Soil Treatment with an Engineered Cover

This GRA alternative is a variation of the preceding one and entails removing the liners and all contaminated debris for onsite storage or offsite treatment and/or disposal. This alternative is being considered to allow the cost of removal to be compared to the cost of consolidation. This cost comparison is intended to provide DOE with strategic planning, management, and budget information to assess potential impacts. The subsoils would be treated *in situ* via solidification/stabilization. The debris would require size-reduction for disposal. A description of these technologies has been presented in Subsections III.3.2.3 and III.3.2.9.

In addition to the cost items previously mentioned, removal and disposal of liners and debris would contribute significantly to the overall capital cost.

Advantages of this GRA alternative include:

- Contaminated debris would be removed and subsoils would be treated, eliminating the debris/waste contaminant sources and the leaching pathway into the ground water; and
- The engineered cover would isolate waste from the surface runoff and air exposure pathways.

Disadvantages of this GRA alternative include:

- Higher capital and operating costs;
- Less operational control exists for many *in situ* treatment processes; compared to *ex situ* treatment processes, possibly resulting in nonuniform treatment of contaminated material;
- Potential for worker exposure to contaminants during removal of the liners, utilities, and Building 788;
- Meeting offsite disposal requirements for the contaminated debris; and
- Soil contaminants remain in place and could be a source of ground water contamination if the *in situ* treatment is not completely successful and the engineered cover fails. However, the impact to the ground water was determined to be insignificant based on contaminant leaching model results (see Section IV.10.4).

In summary, the closure objective would be realized in that the engineered cover would isolate the remaining contaminants from airborne and surface water runoff exposure pathways. Ground water protection objectives would be met, as the liners and debris would be removed and the subsurface soils would be treated *in situ*. Primary drawbacks to this GRA alternative include increased potential for worker exposure to contaminants during removal of the contaminated liners/debris, more uncertainty of quality control of *in situ* treatment process, and the high costs of offsite disposal.

III.3.3.4 General Response Action IV - Contaminated Media Removal

A. Remove All Contaminated Media/Waste for Disposal and Backfill

This GRA involves the complete removal of all contaminated media/waste (i.e., liners, debris, Building 788, and soils) for either onsite storage or offsite treatment and/or disposal. This alternative constitutes "clean" closure of the SEPs; that is, the concentration of contaminants remaining in OU4 soils will be less than the established PRGs. Since this alternative involves clean closure, an engineered cover and post-closure care and monitoring would not be required. However, suitable backfill and grading would be required to replace the excavated material and to provide drainage and minimize erosion. The disturbed areas would be reseeded to provide a vegetative cover. It is assumed that offsite borrow areas would be the source of the backfill materials.

This alternative would involve containerization of the contaminated materials for storage, transport, and/or disposal. A size reduction would be used to facilitate waste handling and

compliance with disposal requirements. Also, an additional onsite storage facility may be needed should existing storage capacity not be adequate to handle the expected volume of waste.

Specific items that would contribute to the overall capital cost include:

- Facilities/utilities removal/location;
- Size reduction;
- Site preparation;
- Removal and containerization of contaminated media;
- Onsite storage facility, if required;
- Offsite disposal of contaminated materials;
- Backfill;
- Topsoil; and
- Seed.

Primary operating costs would be affected by:

- Amount of excavation required;
- Waste storage facility inspection and maintenance;
- Maintenance of closed site; and
- Transportation and disposal of contaminated materials.

Advantages of this alternative would include:

- Closure and ground water protection objectives would be met;
- Contaminated liners, utilities, Building 788, and subsoils would be removed, thus eliminating contaminant migration to the atmosphere, surface water, and ground water; and
- Post-closure monitoring would not be required.

Disadvantages associated with this alternative include:

- Liners, soils, and debris would eventually require shipment for offsite disposal;
- This alternative is likely to have high capital and operating costs; and
- Worker exposure to contaminants would not be minimized. Exposure would be increased during removal and storage of the liners, soils, and debris.

In summary, the benefit of this GRA would be that both the closure and ground water protection objectives would be met, as the sources of contaminants would be removed and would no longer present a threat to receptors via airborne, surface water, or ground water exposure pathways. Post-closure monitoring would not be required. Disadvantages of this GRA would be that workers would be exposed to contaminants during removal of the liners, debris, and subsurface soils, and a large volume of excavated materials would require costly offsite disposal.

It should be noted that the materials would be required to meet the waste acceptance criteria of the disposal site to be protective of human health and the environment.

III.3.3.5 General Response Action V - Contaminated Media/Waste Removal with *Ex Situ* Treatment

A. Remove All Contaminated Media (*Ex Situ* Treatment) and Backfill

As with the preceding alternative, all contaminated materials (soils, liners, utilities, and Building 788) would be removed. *Ex situ* treatment of the contaminated materials would be employed to reduce the volume of waste to be disposed and to meet waste acceptance criteria for the ultimate disposal facility. The segregation and/or concentration of contaminants from the contaminated materials could prove to be cost-effective since treated soils can be returned to OU4 as backfill. The establishment of treatment performance requirements to meet waste acceptance criteria is contingent on identification of the receiving facility.

Potential *ex situ* treatment technologies include:

- Decontamination;
- Solidification/stabilization;
- Soil washing;
- Solvent extraction;
- Degradation; and
- Thermal desorption.

These technologies may be combined to treat multiple contaminants. Engineering implementation and treatability studies would be performed to optimize the effectiveness of a chosen technology. Studies may also be required to determine how to most effectively manage treatment residues and secondary waste streams.

This GRA involves the complete removal of all contaminated media (i.e., liners, debris, and soils) for *ex situ* treatment and either onsite storage or offsite treatment and/or disposal. This alternative constitutes "clean" closure of the SEPs; that is, the concentration of contaminants remaining in OU4 soils will be less than the established PRGs. Since this alternative involves clean closure, an engineered cover and post-closure care and monitoring would not be required. However, suitable backfill and grading would be required to replace the excavated material and to provide drainage and minimize erosion. The disturbed areas would be reseeded to provide a vegetative cover. If additional backfill is required, it is assumed that offsite borrow areas would be the source of the backfill materials.

Items that would contribute to the overall capital cost of this GRA include:

- Facilities/utilities removal/relocation;

- Site preparation;
- Removal of contaminated soils, liners, utilities, and Building 788;
- Backfill;
- Decontamination;
- Offsite treatment facilities including secondary waste treatment;
- Seed;
- Topsoil;
- Treatability studies; and
- Liner disposal.

Primary operating costs would be influenced by:

- Amount of excavation required;
- Operation of *ex situ* treatment facilities;
- Maintenance of closed site; and
- Transportation and disposal of liners, soils, and debris.

Advantages of this alternative would be:

- The closure and ground water protection objectives would be met since the debris, liners, and subsoils would be removed and treated, eliminating contaminant migration into the atmosphere, surface water, and ground water;
- *Ex situ* treatment allows good operational control of the process to ensure regulatory compliance and quality control requirements; and
- Post-closure monitoring would not be required.

Disadvantages of this alternative would be:

- High costs would likely be incurred due to the operation of a treatment facility;
- Worker exposure to contaminants would not be minimized since exposure would be increased during removal, treatment, and packaging of contaminated materials; and
- High costs would be associated with the large amount of contaminated materials to be transported and disposed.

In summary, the benefits of this GRA would be that both the closure and ground water protection objectives would be met (sources of contaminants would be removed and would no longer pose a risk to receptors via air, surface runoff, or ground water exposure pathways), and soil would not have to be shipped for disposal offsite. Post-closure monitoring would not be required. Drawbacks of this GRA would be that workers potentially would be exposed to contaminants during removal, treatment, and packaging of contaminated materials. Costs for this GRA would be relatively high due to the shipment of contaminated materials for offsite treatment and disposal.

III.4 DETAILED ANALYSIS EVALUATION CRITERIA

After identifying the potential General Response Actions (GRAs), a detailed evaluation was conducted to select the preferred IM/IRA. This evaluation determined which GRA is most applicable to the site-specific conditions.

The provisions contained in Section IX.C of the IAG were followed to perform the detailed analysis of the GRAs. Although the criteria specified in Section IX.C of the IAG are to be followed as part of a Corrective Measures Study/Feasibility Study (CMS/FS) and do not specifically apply to the selection of an IM/IRA, these criteria were adopted for selecting the OU4 IM/IRA since the IM/IRA is considered to be the final closure and remediation for this operable unit. The IAG selection criteria are consistent with the statutory mandates of CERCLA Section 121 and the nine evaluation criteria presented in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). An explanation of the evaluation criteria used for the selection of the preferred IM/IRA is provided below.

The performance objectives identified in Section IX.C of the IAG required the IM/IRA to:

- Protect human health and the environment;
- Comply with ARARs unless a waiver is justified;
- Be cost-effective;
- Utilize permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable; and
- Address the preference for treatment as a principal element.

In assessing the GRAs under the last two mandates listed above, the following items were considered:

- Long-term uncertainties associated with land disposal;
- Goals, objectives, and requirements of the Solid Waste Disposal Act;
- Persistence, toxicity, mobility, and propensity to bioaccumulate of the hazardous substances and their constituents;
- Short- and long-term potential for adverse health effects from human exposure;
- Long-term maintenance costs;
- Potential for future remedial action costs if the GRA should fail; and
- Potential threat to human health and the environment associated with excavation, transportation, and redisposal or containment.

The nine evaluation criteria used to compare the various GRAs with respect to the above-mentioned performance objectives are listed in Figure III.4-1. Descriptions for each evaluation criterion are provided below.

THRESHOLD CRITERIA	• Overall Protection of Human Health and the Environment • Compliance with ARARs
PRIMARY BALANCING CRITERIA	• Long-Term Effectiveness and Permanence • Reduction of Toxicity, Mobility, or Volume through Treatment • Short-Term Effectiveness • Implementability • Cost
MODIFYING CRITERIA	• Regulatory Agency Acceptance • Community Acceptance

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Figure III.4-1

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
General Response Action
Evaluation Criteria

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Threshold Criteria

The following two threshold criteria are mandatory requirements that must be satisfied in order for the GRA to be selected.

(1) **Overall protection of human health and the environment** is the ability of the GRA to adequately eliminate, reduce, or control the chemical and radiological risks associated with each exposure pathway. The GRAs were assessed to determine both long- and short-term risks to human health and the environment. The PRGs were established as the action levels for protecting human health. Compliance with this evaluation criterion is based on the GRA's ability to isolate the contaminated media in excess of the PRGs so that human health and environmental exposures are eliminated.

(2) **Compliance with ARARs** is the ability of the GRA to satisfy the requirements specified in the list of ARARs. The GRAs were assessed to determine if the identified ARARs will be satisfied, or provide grounds for invoking a waiver.

Primary Balancing Criteria

Primary balancing criteria are used to identify and compare the major tradeoffs between the GRAs. The balancing criteria allow the GRAs to be ranked and to determine the preferred IM/IRA. Balancing criteria include the following:

(3) **Long-term effectiveness and permanence** is the anticipated ability of the GRA to maintain reliable protection of human health and the environment over time, once the IM/IRA objectives are met. GRAs were assessed to determine the long-term effectiveness and permanence they afford, along with the degree of certainty that the GRA will prove successful. Factors that may be considered in this assessment are the magnitude of residual risk remaining from untreated waste, or from treatment residuals of the remedial activities, and the adequacy and reliability of controls, such as containment systems and institutional controls, necessary to manage treatment residuals and untreated waste.

(4) **Reduction of toxicity, mobility, or volume through treatment** is the anticipated performance of the treatment technologies, if used. GRAs which employ treatment were assessed for the degree that the GRA reduces toxicity, mobility, or volume of waste or residuals.

(5) **Short-term effectiveness** is the time required to achieve the IM/IRA objectives and assess the adverse human health and environmental impacts resulting from implementation of the GRA. The GRAs were assessed to determine their short-term effectiveness by considering:

- Short-term risks that might be posed to the community during implementation of the GRA;
- Potential impacts on workers during implementation of the GRA;
- The effectiveness and reliability of protective measures;
- Potential environmental impacts of the GRA;
- The effectiveness and reliability of mitigative measures during implementation; and
- The time required to achieve protection.

In addition, the factors required to be assessed under NEPA were integrated into the selection of a GRA by incorporating these NEPA factors into this primary balancing criterion. The integration was necessary to ensure that NEPA concerns were included in the decision-making process to select the preferred alternative as required by DOE NEPA implementation regulations (10 CFR 1021). The NEPA assessment criteria are described in Section IV.10 and included consideration of direct and indirect impacts, unavoidable adverse impacts, irreversible or irretrievable commitment of resources, and cumulative impacts.

(6) **Implementability** is the technical and administrative feasibility, and availability of materials and services required to implement the GRA. The GRAs were assessed to determine the ease or difficulty of implementing the GRA by considering the following factors:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology;
- Reliability of the technology;
- Ease of undertaking additional remedial actions (if required); and
- Ability to monitor the effectiveness of the remedy.

(7) **Cost** is the amount of funds required to implement the GRA. The GRAs were assessed to determine capital costs including both direct and indirect costs. The operating costs associated with treatment would likely be realized over a period of less than one year. Therefore, these operating costs were included as capital costs. Long-term routine monitoring costs would be similar for most alternatives and were therefore addressed qualitatively.

Modifying Criteria

Modifying criteria will not be entirely known until the public comment period is over. These criteria will be considered, along with any new information, when preparing the Responsiveness Summary and may require modification of the preferred IM/IRA. Modifying criteria include:

(8) Regulatory agency acceptance is the ability of the preferred IM/IRA to address all of the concerns raised by the regulatory agencies including the agency's position and key concerns related to the preferred IM/IRA and other GRAs, and agency comments on compliance with the ARARs or the proposed use of waivers. These concerns are discussed, to the extent possible, in this Decision Document issued for public comment.

(9) Community acceptance refers to the public's general response to the preferred IM/IRA described in this Decision Document including community support or opposition to the preferred IM/IRA. These concerns will be considered, to the extent possible, when preparing the Responsiveness Summary.

III.5 DETAILED ANALYSIS OF GENERAL RESPONSE ACTIONS

The five GRAs presented in Section III.3.3 were compared to each other with respect to the criteria listed in Section III.4. The goals of the detailed analysis were to identify the GRAs which meet the threshold criteria and to select the GRA that best fulfills the primary balancing criteria. It is important to note that this evaluation is performed to determine if a GRA can be designed and implemented to achieve ARAR compliance and to be protective of human health and the environment. The final evaluation of protectiveness to human health and the environment will be conducted during the detailed design of the selected GRA.

For the threshold criteria, each GRA was assigned either a "yes" or "no" depending on whether the GRA would be protective of human health and environment and would comply with the identified ARARs. The GRA must meet these threshold criteria (i.e., "yes") in order to be retained for further consideration. For the balancing criteria, each GRA was awarded either "high," "medium," or "low" corresponding to a high, medium, or low level of agreement, respectively, with the objectives of each criterion. The evaluation results for each criterion were compared in order to rank the GRAs. The modifying criteria were not addressed in the detailed analysis and will be considered during the development of the Responsiveness Summary.

III.5.1 Overall Protection of Human Health and the Environment

As part of the detailed analysis, protection of human health and the environment was considered a threshold criteria. If a GRA was not protective of human health and the environment, then it could no longer be considered a viable IM/IRA. Each of the five GRAs were evaluated to determine if they would be protective of human health and the environment. The evaluation results are listed in Table III.5-1 and discussed below.

GRA I, No Action, was determined not to adequately protect human health and the environment because some contaminants in OU4 would remain at concentrations that exceed the PRGs. Although GRA I would not interfere with additional ground water characterization activities, risks to human health and the environment associated with this alternative would not be minimized or reduced in any way. The evaluation result indicates that GRA I should not be

TABLE III.5-1
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
MINIMIZE CURRENT RISK					
1. Does the GRA have the potential to lower the current risk?	No. However, the current risk was not quantified through a baseline risk assessment. Instead, PRGs have been calculated based upon a 10^{-6} health-based risk level. Some COCs concentrations exceed the calculated PRGs. Residual risk would only be reduced through natural attenuation and degradation. Current risk via the ground water pathway will be further quantified during an additional hydrogeological investigation.	Yes. Exposure resulting from the air, direct contact, ingestion, and surface water pathways are eliminated. Contaminant migration to ground water, if any, would be reduced. Modeling to determine the potential for leaching of contaminants from the untreated contaminated media demonstrates that the risk to human health or the environment is insignificant.	Yes. Same as GRA II. *In situ* treatment further reduces contaminant migration to ground water, if any, beyond that of GRA II.	Yes. The removal of contaminated media will eliminate all current and future risks at OU4, including any ground water concerns.	Same as GRA IV.
HUMAN HEALTH AND ENVIRONMENTAL PROTECTION					
2. Does GRA treat contamination?	No treatment provided.	No treatment provided; however, GRA reduces potential for migration of contaminants.	*In situ* solidification/stabilization would treat contamination; however, the extent of treatment may not be verifiable.	No treatment provided unless required to comply with the Waste Acceptance Criteria for the offsite disposal facility.	Contaminated soils would be removed and treated *ex situ*. Contaminated debris would be removed for offsite disposal.
3. Does GRA destroy or stabilize contaminants?	No contaminant destruction or stabilization.	No contaminant destruction or stabilization.	Contaminants may be stabilized by *in situ* treatment.	No contaminant destruction or stabilization unless required to comply with the Waste Acceptance Criteria for the offsite disposal facility.	*Ex situ* treatment will destroy or stabilize soil contaminants.
INSTITUTIONAL CONTROLS					
4. Is there a need to institutionally control risk?	By definition, "No Action" does not include any controls. However, institutional controls could be provided to prevent exposure.	Yes	Yes	No. PRGs are met.	No. PRGs are met.
5. What control measures need to be implemented?	Land use restrictions. The site would not be permitted for residential use.	Land use restrictions. No building, construction, or farming directly on the engineered cover. Ground water and vadose zone monitoring.	Land use restrictions. No building, construction, or farming directly on the engineered cover. Ground water and vadose zone monitoring.	None	None
EVALUATION RESULTS: **(Should the GRA be evaluated further?)**	**NO** **[However, "No Action" is retained as the baseline for comparison.]**	**YES**	**YES**	**YES**	**YES**

evaluated further; however, GRA I was retained for comparison purposes to allow the other GRAs to be ranked against a baseline.

GRA II includes an engineered cover and a subsurface drainage system to contain the OU4 contaminated materials. This GRA is considered protective of human health and the environment since it eliminates upward pathways of exposure (e.g. through air, surface soils, and surface water). The subsurface drain system would prevent potential rising ground water from contacting the consolidated contaminated materials. Some contaminants would continue to exceed PRGs (e.g., Plutonium 239/240, Uranium 235, and Americium 241) due to half-lives greater than 1000 years. This GRA only minimally interferes with additional ground water characterization activities. Because this alternative reduces risks to human health and the environment to an acceptable level (i.e., all contaminants exceeding PRGs are contained and isolated by the cover), the evaluation result is that GRA II was retained for further evaluation.

GRA III, *in situ* treatment (closure in place), is considered protective of human health and the environment. This alternative includes all the benefits of GRA II by providing an engineered cover plus the additional benefits of *in situ* treatment. Upward pathways of exposure would be eliminated and contaminants would be stabilized. The *in situ* treatment could provide a larger risk reduction than GRA II by immobilizing contaminants. As such, GRA III was retained for further evaluation.

GRA IV results in the removal of all OU4 contaminated media for offsite disposal. Under this GRA, residual risks to human health and the environment would be eliminated at OU4; however, ultimate protection of human health and the environment relies on the offsite disposal facility. This GRA is more protective of human health and the environment in the OU4 area than any of the three preceding GRAs. This GRA would have no impact on additional ground water characterization activities, once completed, and would eliminate the potential for contaminant migration from soils at OU4 into ground water. The evaluation result is that GRA IV was retained for further evaluation.

GRA V is identical to GRA IV in all respects except that the contaminated soil is to be treated onsite using *ex situ* technologies. The treated clean soil is to be returned to OU4 as backfill. Although contaminants may inadvertently be returned to OU4 if the treatment process is not effective, this is considered unlikely in light of the administrative and analytical controls that can be used. Since GRA V involves removal of all contaminated media in excess of the PRGs, it is considered protective of human health and the environment. Therefore, GRA V was retained for further evaluation.

III.5.2 Compliance with ARARs

As required by Paragraph 150 of the IAG, "[the] IM/IRA shall, to the greatest extent practicable, attain ARARs and be consistent with and contribute to the efficient performance of final response actions consistent with Section 121 of CERCLA." The IAG Statement of Work,

Section I.B.10, requires that, "[A]s a chapter of the draft Proposed IM/IRA Decision Document, DOE shall provide to EPA and the State a draft ARAR Analysis." This section is intended to fulfill the above-mentioned obligations, and identifies and analyzes the ARARs that must be met for the OU4 IM/IRA.

ARARs are substantive environmental requirements, cleanup standards, and standards of control that must be addressed as part of a GRA. ARARs must be identified on a site-specific basis. An ARAR may either be "applicable" or "relevant and appropriate", but not both. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

The three ARAR categories listed below were established by the EPA to identify and classify ARARs. The categories are used as guidance, because some ARARs may not neatly fall into this classification system.

Chemical-specific requirements are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in or discharged to the ambient environment.

Location-specific requirements are restrictions placed on the concentration of hazardous substances solely because they occur in special locations.

Action-specific requirements are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste.

In addition to ARARs, To-Be-Considered standards (TBCs) are to be factored into the GRA when appropriate. TBCs are nonpromulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status as potential ARARs. However, TBCs are used in determining the necessary level of cleanup for the protection of human health and the environment. The March 8, 1990 preamble to the final NCP rule (see 55 FR 8746) indicates that the use of TBCs is discretionary rather than mandatory; however, their incorporation is recommended.

The ARARs and TBCs identified for the OU4 IM/IRA are presented in Appendix III.E and are summarized in Table III.5-2. Input from both EPA and CDH was obtained in compiling

TABLE III.5-2
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

ARAR/TBC CITATION	REQUIREMENT DESCRIPTION	GENERAL RESPONSE ACTION [1]				
		I	II	III	IV	V
10 CFR 834 (Proposed)	DOE Radiation Protection Requirements for Public Health and the Environment [2]	TBC	TBC	TBC	TBC	TBC
33 USC § 1344 10 CFR 1022	Evaluate Federal Projects for Potential Floodplain and Wetland Impacts [3]	A	A	A	A	A
29 USC §§ 657 and 667 29 CFR 1910, Subpart Z	Worker Protection Requirements for Hazardous Waste/Remediation Operations [4]	---	A	A	A	A
29 USC § 668 DOE Order 5483.1A 29 CFR 1926	Occupational Health Standards for General Construction Activities [5]	A	A	A	A	A
16 USC §§ 469 and 470 36 CFR 65 and 800 CRS 20-80-401	Historic and Archeological Preservation[6]	A	A	A	A	A
5 CCR 1001- Regulation 1, III.D	Fugitive Particulate Emissions [7]	A	A	A	A	A
40 CFR 61, Subpart H 10 CFR 834 (Proposed)	NESHAP, Radionuclide Emissions [6]	---	A	A	A	A
40 CFR 122.26 5 CCR 1002-3	NPDES Stormwater Management Requirements	A	A	A	A	A
40 CFR 262.11 6 CCR 1007-3, 262.11	Hazardous Waste Determinations	A	A	A	A	A
40 CFR 262, Subparts B, C, and D 6 CCR 1007-3, 262, Subparts B, C, and D	Generator Requirements for the Offsite Transport of Hazardous Waste [8]	---	---	---	A	A
40 CFR 264, Subpart B 6 CCR 1007-3, 264, Subpart B	General Standards for Hazardous Waste Facilities [9]	---	---	---	A	A

TABLE III.5-2 (continued)
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

ARAR/TBC CITATION	REQUIREMENT DESCRIPTION	GENERAL RESPONSE ACTION [1/]				
		I	II	III	IV	V
40 CFR 264, Subpart C and D 6 CCR 1007-3, 264, Subpart C and D	Preparedness and Prevention and Emergency Procedures for Hazardous Waste Facilities [8/]	---	---	---	A	A
40 CFR 264, Subpart F 6 CCR 1007-3, 264, Subpart F	Ground Water Protection and Monitoring [10/]	---	A	A	---	---
40 CFR 264.117 to .120 6 CCR 1007-3, 264.117 to .120	Post-Closure and Use of Property	---	A	A	---	---
40 CFR 264, Subpart I 6 CCR 1007-3, 264, Subpart I	Requirements for Container Management and Storage	---	---	---	A	A
40 CFR 264, Subpart J 6 CCR 1007-3, 264, Subpart J	Requirements for the Treatment and/or Storage of Hazardous Waste in Tanks [11/]	---	---	---	---	A
6 CCR 1007-3. 264.552 (Proposed)	Establishment of Corrective Action Management Units to Facilitate Corrective Actions [12/]	---	TBC	TBC	---	TBC
40 CFR 265, Subpart B 6 CCR 1007-3, 265, Subpart B	General Standards for Interim Status Hazardous Waste Facilities [13/]	A	A	A	A	A
40 CFR 265.111 6 CCR 1007-3, 265.111	Interim Status Facility Closure Standards	A	A	A	A	A
40 CFR 265.113 6 CCR 1007-3, 265.113	Time Allowed for Closure	A	A	A	A	A
40 CFR 265.114 6 CCR 1007-3, 265.114	Disposal or Decontamination of Equipment Structures and Soils	---	A	A	A	A
40 CFR 265.115 6 CCR 1007-3, 265.115	Certification of Closure	A	A	A	A	A

TABLE III.5-2 (continued)
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

ARAR/TBC CITATION	REQUIREMENT DESCRIPTION	GENERAL RESPONSE ACTION [1/]				
		I	II	III	IV	V
40 CFR 265.116 6 CCR 1007-3, 265.116	Survey Plat	---	A	A	---	---
40 CFR 265.228 6 CCR 1007-3, 265.228	Closure and Post-Closure Care for an Interim Status Surface Impoundment	A	A	A	A	A
42 USC § 6924 40 CFR 268, Subpart A to D 6 CCR 1007-3, 268, Subpart A to D	Land Disposal Restrictions and Treatment Standards [14/]	---	A	A	A	A
40 CFR 268, Subpart E 6 CCR 1007-3, 268, Subpart E	Prohibition on Storage of Restricted Waste	---	---	---	A	A
40 CFR 300.440 CERCLA Section 121(d)(3)	Procedures for Planning and Implementing Offsite Response Actions [7/]	---	---	---	A	A
49 CFR 172, Parts B to F; 49 CFR 173, Parts B to O; 49 CFR 177	Offsite Transport of Hazardous Waste [7/]	---	---	---	A	A
16 USC § 1531 50 CFR 402 CRS 33-2-101	Evaluate Federal Projects for Potential Impact to Endangered or Threatened Species or Critical Habitats	A	A	A	A	A
6 CCR 1007-2, Part 2	Siting Requirements for Hazardous Waste Disposal Sites [15/]	---	A	A	---	---
10 CFR 835 DOE Order 5480.11, Section 9	Occupational Radiation Protection Standards [16/]	A	A	A	A	A
DOE Order 5400.5, Chapter IV	Residual Radioactive Material in Soil	TBC	TBC	TBC	TBC	TBC

TABLE III.5-2 (continued)
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

ARAR/TBC CITATION	REQUIREMENT DESCRIPTION	GENERAL RESPONSE ACTION [1/]				
		I	II	III	IV	V
DOE Order 5480.3	Packaging and Transportation Requirements for Radioactive Materials [7/]	---	---	---	TBC	TBC
DOE Order 5820.2A, Chapter III	Low-Level Radioactive Waste Management	---	TBC	TBC	TBC	TBC
Executive Order 11988	Floodplain Management - Federal Facilities	TBC	TBC	TBC	TBC	TBC
Executive Order 11990	Protection of Wetlands - Federal Facilities	TBC	TBC	TBC	TBC	TBC

NOTES:

A Requirement is identified as "Applicable" for this General Response Action.

R&A Requirement is identified as "Relevant and Appropriate" for this General Response Action.

TBC Requirement is identified as "To-Be-Considered" for this General Response Action.

--- Requirement is neither an ARAR nor a TBC for this General Response Action.

TABLE III.5-2 (continued)
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

1/ The IM/IRA General Response Actions are as follows:

- I - No Action
- II - Containment (Closure In Place)
- III - *In Situ* Treatment (Closure In Place)
- IV - Contaminated Media Removal
- V - Contaminated Media Removal with *Ex Situ* Treatment

2/ This regulation is proposed by the DOE to control radiation exposures for the protection of public health and the environment. Although NRC also has similar protection standards promulgated under 10 CFR 20.1301, the DOE regulation is the only ARAR identified for compliance purposes, since the DOE regulation is consistent with the NRC standards, will be applicable to RFP when promulgated, and is currently being implemented under existing DOE Orders.

3/ Although no wetlands are expected to be impacted, all federal actions are required to be assessed.

4/ Although OSHA standards are not considered ARARs (see 55 FR 8680), 40 CFR 300.150 specifically requires that all response actions under the NCP maintain worker safety and health as specified under 29 CFR 1910.120. This regulation is being listed for completeness and to ensure that these protection requirements are not overlooked when preparing the implementation plans for the selected IM/IRA alternative.

5/ Although OSHA standards are not considered ARARs (see 55 FR 8680), OSHA requirements would apply on their own merit. These OSHA standards apply to federal facilities as required by the Occupational Safety and Health Act [29 USC § 668] and Executive Order 12196; however, they are not independently enforced by OSHA. These occupational safety requirements are adopted and implemented under DOE Order 5483.1A. This regulation is being listed for completeness and to ensure that these protection requirements are not overlooked when preparing the implementation plans for the selected IM/IRA alternative.

6/ Although no historic or archeological sites are expected to be impacted, all federal actions are required to be assessed.

7/ This standard would involve the control of fugitive particulates during regrading and/or excavation activities.

8/ Record-keeping requirements are not normally considered to be ARARs since they are procedural/administrative requirements. However, offsite response actions must comply with all applicable regulations both substantive and procedural/administrative. The generator record keeping and reporting requirements would only be applicable in the case where hazardous waste is shipped offsite.

TABLE III.5-2 (continued)
PROPOSED LOCATION- AND ACTION-SPECIFIC ARARs/TBCs

9/ These requirements would only be applicable should a new hazardous waste storage or treatment facility be constructed as part of the IM/IRA alternative. These requirements would address the operation of the storage and treatment facility only. Should waste materials be stored or treated within existing onsite facilities, management of the waste will be the responsibility of the storage/treatment facility custodian.

10/ Post-closure ground water monitoring is required for the "dirty" closure of the surface impoundment unless the owner/operator can demonstrate that ground water monitoring is not necessary. The ground water monitoring requirements are addressed in Part V of this Decision Document.

11/ These requirements would only be applicable if hazardous waste is to be stored or treated in a tank.

12/ On February 16, 1993, the EPA promulgated final rules for Corrective Action Management Units (CAMUs) and Temporary Units (TUs) to promote more expeditious clean ups at many sites. The provisions for a CAMU/TU would be required for the consolidation of contaminated media (if designated as a hazardous waste) and/or the onsite treatment or storage of the remediation waste (if designated as a hazardous waste). Currently, the State of Colorado has not adopted the CAMU/TU rule. The implementation of these General Response Actions are based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate a CAMU/TU rule which will support the planned closure/remediation activities.

13/ Interim status operational requirements apply to hazardous waste facilities until they are certified as being closed. Security, training, and inspection programs will need to be maintained and revised, if necessary, to ensure that public health and the environment are adequately protected during the closure activities.

14/ In addition to complying with the required treatment standards for the land disposal of any designated hazardous waste, in the absence of a CAMU/TU designation, offsite shipments will need to be certified as required.

15/ CDH claims that a hazardous waste disposal site is developed in the event that hazardous waste remains in-place following the completion of closure activities. Pursuant to Part 18 of the IAG, the DOE does not have to comply with the procedural aspects of the siting regulations to obtain a Certificate of Designation for the onsite response action; however, these IM/IRA General Response Actions must comply with the substantive requirements of this regulation.

16/ Although occupational worker standards are not considered to be ARARs/TBCs, the citation to the DOE Radiation Protection Program is being provided for completeness and to ensure that these protection requirements are not overlooked when preparing the implementation plans for the selected IM/IRA alternative.

this ARAR/TBC list. The ARARs/TBCs are assembled based on the scope for each GRA. Appendix III.E provides the rationale as to why each ARAR/TBC was selected for the particular GRA. The primary requirements driving the closure of the SEPs for each ARAR category are briefly discussed below.

No chemical-specific ARARs have been identified for the surficial and vadose zone soils since federal and state cleanup standards for the soil COCs have not been established. In lieu of soil cleanup standards, PRGs have been determined to provide an effective substitute for the chemical-specific ARARs. The methodology used to determine the PRGs for these soils is presented in Section III.2. ARARs/TBCs associated with the remediation of the OU4 ground water will be addressed as part of the supplemental investigation specified in Part VI of this Decision Document. Chemical-specific ARARs have not been developed for ground water protection. Chemical-specific ground water ARARs will be developed during the follow-on hydrogeological investigations (Phase II).

The principal location-specific ARARs are the siting requirements for hazardous waste disposal sites promulgated as Part 2 of 6 CCR 1007.2. It has been determined that these siting and design requirements apply to GRAs II and III since they involve the development of a hazardous waste management site as an onsite response action. Pursuant to Part 18 of the IAG, the DOE does not have to comply with the procedural aspects of the siting regulations to obtain a Certificate of Designation; however, these GRAs must comply with the substantive requirements of this regulation.

The primary action-specific ARARs governing the closure of the SEPs are specified in the State of Colorado Hazardous Waste regulations. These regulations include the interim status closure requirements for surface impoundments in 6 CCR 1007-3, Part 265, Subpart G and K. These regulations are as *follows:*

Closure Performance Standard [6 CCR 1007-3, 265.111]: "The owner or operator must close his/her facility in a manner that: (a) Minimizes the need for further maintenance, (b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere, and (c) Complies with the closure requirements of this Subpart including, but not limited to, the requirements of Sections ... 265.228, ..."

Closure and Post-Closure Care [6 CCR 1007-3, 265.228(a)]: "At Closure, the owner or operator must: (1) Remove or decontaminate all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate, and manage them as hazardous waste unless Section 261.3(d) of these regulations applies; or (2) Close the impoundment and

provide post-closure care for a landfill under Subpart G and Section 265.310, including the following ...."

Compliance with the LDR standards (see 6 CCR 1007-3, Section 268) is another action-specific ARAR that was used to determine whether a particular GRA can be selected. Both characteristic (D006) and listed (F001, F002, F003, F005, F006, F007, and F009) wastes were placed into the SEPs (EG&G 1992a). Since listed hazardous waste was placed into the SEPs, contaminated liner and soils would need to be managed as hazardous waste based on application of the mixture rule [see 6 CCR 1007-3, 261.3(a)(2)(iii)] and EPA's "contained-in" policy [see OSWER Directive 944.1989(30)], respectively. The mixture rule states when listed hazardous waste is mixed with another solid waste the resulting mixture must be managed as a listed hazardous waste. Since the liners are considered to be a solid waste and to have been in contact with the listed hazardous waste placed into the SEPs, the liners are determined to be listed hazardous which would be classified by the above-mentioned F-series hazardous waste codes. Soils are not considered to be a solid waste, as such, they cannot be designated as a listed hazardous waste because of the mixture rule. However, if the contaminated soils contain a listed hazardous waste or constituent, the listed waste portion of the contaminated soil would need to be managed as a listed hazardous waste. If the listed hazardous waste portion cannot be removed from the contaminated soils, the entire soils would need to be managed as a hazardous waste unless the regulatory agencies determine that the contaminated soils no longer contains the listed hazardous waste. The management of contaminated soils as a hazardous waste is only required if the soils are excavated and contains a listed hazardous waste. The "contained-in" policy will be implemented in accordance with the June 18, 1991 letter from Martin Hestmark (EPA) and Gary Baughman (CDH) to Frazer Lockhart (DOE). For the purpose of the OU4 IM/IRA, contaminated soils will be managed as "contained-in" listed hazardous waste when hazardous waste constituents associated with the above F-series hazardous waste codes exceed their respective PRG. For those hazardous constituents where a risk analysis has shown that the contaminated soil does not pose an unacceptable risk and a PRG has not been established, then that listed hazardous waste is not considered to be "contained-in" the soil media.

The hazardous constituents and LDRs associated with these listed waste codes are presented in Table III.5-3. Based on the information provided in this table, LDR treatment standards may be applicable for the following constituents if placement of contaminated soil containing a listed waste occurs:

- Ethylbenzene;
- Cadmium;
- Chromium (Total);
- Lead;
- Nickel; and
- Silver.

TABLE III.5-3
POTENTIAL HAZARDOUS WASTE CONSTITUENTS AND LDRs

Hazardous Waste Constituent	LDR Standard (Non-Wastewater)		Maximum Contaminant Concentration (mg/kg)	
	CCWE [1/] (mg/L)	CCW [2/] (mg/kg)	Surficial (0 to 3")	Vadose Zone (3" to 12')
D006				
Cadmium	1.0		380	550
F001, F002, F003, and F005				
Acetone		160	ND	49
Benzene		3.7	ND	0.029
n-Butyl Alcohol		2.6	---	---
Carbon Disulfide	4.8		ND	0.029
Carbon Tetrachloride		5.6	ND	0.029
Chlorobenzene		5.7	ND	0.029
Cyclohexanone	0.75		ND	0.7
ortho-Dichlorobenzene		6.2	1.4 ND	0.44 ND
2-Ethoxyethanol	3/	3/	---	---
Ethyl Acetate		33	---	---
Ethylbenzene		6	ND	42
Ethyl Ether		160	---	---
Isobutyl Alcohol		170	---	---
Methanol	0.75		---	---
Methylene Chloride		33	ND	10
Methyl Ethyl Ketone		36	ND	0.088
Methyl Isobutyl Ketone		33	ND	0.058
2-Nitropropane	3/	3/	---	---
Pyridine		16	---	---
Tetrachloroethylene		5.6	ND	0.029
Toluene		28	ND	1.2

TABLE III.5-3 (continued)
POTENTIAL HAZARDOUS WASTE CONSTITUENTS AND LDRs

Hazardous Waste Constituent	LDR Standard (Non-Wastewater)		Maximum Contaminant Concentration (mg/kg)	
	CCWE 1/ (mg/L)	CCW 2/ (mg/kg)	Surficial (0 to 3")	Vadose Zone (3" to 12')
F001, F002, F003, and F005 (continued)				
1,1,1-Trichloroethane		5.6	ND	0.029
1,1,2-Trichloroethane		7.6	ND	0.029
1,1,2-Trichloro - 1,2,2-Trifluoroethane		28	---	---
Trichloroethylene		5.6	ND	0.029
Trichlorofluoromethane		33	---	---
Xylene (Total)		28	ND	0.029
F006, F007 and F009				
Cadmium	0.066		380	550
Chromium (Total)	5.2		48.5	780.5
Cyanide (Total)		590	---	43
Cyanide (Amenable)		30		
Lead	0.51		121	31.2
Nickel	0.32		180	474.5
Silver	0.072		3.7	5.7

NOTES:

1/ CCWE - Constituent Concentration in Waste Extract. LDR based on TCLP methodology, see 6 CCR 1007-3, 268.41.

2/ CCW - Constituent Concentration in Waste. LDR based on total analysis, see 6 CCR 1007-3, 268.43.

3/ Incineration is the specified non-wastewater technology-based treatment standard for this spent solvent.

--- Either analyte not analyzed, analytical results not reported, or maximum concentration not determined.

Of the above-listed constituents, the maximum OU4 contaminant concentration for ethylbenzene is based on pre-RFI/RI historical data and is considered suspect. For the remaining metals, the LDR standard is based on the TCLP test and all of the maximum contaminant concentrations are based on a total analysis. As such, direct comparison of the LDR standard with the characterization results to determine if the LDR standard would apply is not possible. Additional samples would need to be extracted using the TCLP procedure and analyzed to conclusively demonstrate that the LDR standards were met for contaminated soils containing listed wastes.

In order to facilitate the consolidation of contaminated media under GRAs II and III, a request for a Corrective Action Management Units (CAMU) designation would be prepared. On February 16, 1993, the EPA promulgated final rules for CAMUs and Temporary Units (TUs) to promote more expeditious cleanups at many sites. The State of Colorado is in the process of adopting a CAMU/TU rule similar to one proposed by the EPA. The implementability of GRAs II and III are based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate a CAMU/TU rule which will support the planned closure/remediation activities. Under GRA V, the contaminated materials will be treated to remove contaminants to levels below the established PRGs. Clean soils will be returned to OU4 as backfill and the concentrated treatment residues will be further stabilized, if required, for offsite disposal or temporary onsite storage. Since hazardous waste constituents will be removed from the soil, the clean backfill soils or other clean materials will no longer be managed as a "contained-in" listed waste. The concentrated treatment residues will be managed as a listed hazardous waste since they would be derived from the treatment of the listed hazardous waste originally contained-in the contaminated materials.

Compliance with ARARs is a threshold criterion; that is, each identified ARAR must be complied with or waived by EPA/CDH in order for the GRA to be selected. The ability of each GRA to comply with the identified ARARs/TBCs was assessed. The results of this assessment are provided in Table III.5-4.

With the exception of GRA I, No Action, each of the GRAs under consideration will comply with their respective ARARs/TBCs. GRA I does not comply with the closure requirements for an interim status surface impoundment (see 6 CCR 1007-3, 265.228) which requires that all contaminated soils be removed to achieve clean closure or that a final cover be installed. Since several hazardous waste constituents are above the calculated PRGs, some contaminated areas remain uncontrolled under the No Action GRA. Although the No Action GRA will not comply with the ARARs/TBCs, it is being retained for the detailed analysis to serve as the baseline for comparing the other GRAs. The strategy to achieve compliance with or justification to waive the ARARs for the preferred IM/IRA is presented in Section IV.11.

TABLE III.5-4
COMPLIANCE WITH ARARs/TBCs

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
CHEMICAL-SPECIFIC ARARS					
1. Can GRA achieve compliance with chemical-specific ARARs?	No chemical-specific ARARs have been identified for surficial and vadose zone soil COCs.	No chemical-specific ARARs have been identified for surficial and vadose zone soil COCs.	No chemical-specific ARARs have been identified for surficial and vadose zone soil COCs.	No chemical-specific ARARs have been identified for surficial and vadose zone soil COCs.	No chemical-specific ARARs have been identified for surficial and vadose zone soil COCs.
LOCATION-SPECIFIC ARARS					
2. Can GRA achieve compliance with location-specific ARARs?	Yes	Yes [1]	Yes [1]	Yes	Yes
ACTION-SPECIFIC ARARS					
3. Can GRA achieve compliance with action-specific ARARs?	No [2]	Yes	Yes	Yes	Yes
TO-BE-CONSIDERED STANDARDS					
4. Can GRA achieve compliance with other-defined criteria and guidance (TBCs)? [3]	Yes	Yes	Yes	Yes	Yes
WAIVERS AND VARIANCES					
5. Can non-compliant ARARs be waived or an alternate regulatory variance followed?	Receipt of a waiver from the non-compliant action-specific ARARs is unlikely.	Establishment of a CAMU may be required to facilitate consolidation of contaminated materials. [4]	Establishment of a CAMU may be required to facilitate consolidation of contaminated materials. [4]	No waivers would be anticipated.	No waivers would be anticipated.
EVALUATION RESULTS: (Should the GRA be evaluated further?)	**NO [However, "No Action" is retained as the baseline for comparison.]**	**YES**	**YES**	**YES**	**YES**

NOTES:

1 GRAs II and III involve development of a hazardous waste disposal site as an onsite response action. Pursuant to Part 18 of the IAG, the DOE does not have to comply with the procedural aspects of the siting regulations to obtain a Certificate of Designation; however, these GRAs must comply with the substantive requirements of this regulation.

2 GRA I does not comply with the interim status surface impoundment closure requirements; 6 CCR 1007-3, 265.228 requires that all contaminated soils be removed to achieve clean closure or that a final cover be installed. Since several hazardous waste constituents are above the calculated PRGs, some contaminated areas would be uncontrolled. GRA I is being retained for the detailed analysis to serve as the baseline for comparing with the other GRAs.

3 The adoption of and compliance with TBCs is discretionary. Although it is envisioned that all of the GRAs will comply with the identified TBCs, final acceptance will be based on the approval of the IM/IRA Decision Document.

4 GRAs II and III are based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate a CAMU rule which will support the GRA activities.

III.5.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence was evaluated for each of the five GRAs considered for the OU4 IM/IRA. The results of the evaluation are summarized in Table III.5-5. Eleven evaluation factors were considered in developing the evaluation result (i.e., high, medium, or low) for this criterion. The evaluation result for each GRA is provided in Table III.5-5 and are discussed below.

GRA I, No Action, would not reduce the magnitude of the residual risk beyond the reduction gained through natural attenuation and degradation. By definition, there would be no requirement for post-closure monitoring or long-term management to ensure that contaminant migration was not occurring. As such, institutional controls would need to be relied on to prevent potential exposure to contaminants. This GRA received a low evaluation result because the magnitude of the current risk would remain unchanged, and of the reliance on institutional controls.

GRA II includes closure in place with an engineered cover and a subsurface drainage system. The engineered cover would meet the IM/IRA performance objectives by effectively isolating the contained contaminants from the air, direct contact, ingestion, and surface water exposure pathways. The subsurface drainage system would prevent potential rising ground water from contacting the consolidated contaminated materials. In addition to routine inspections and maintenance, post-closure monitoring would be required by the Colorado Hazardous Waste Management regulations to evaluate the performance of the engineered cover over a post-closure care period. Although the IM/IRA performance objectives would be met, this GRA received a medium evaluation result because contaminants will remain in-place without treatment.

GRA III includes closure in place with *in situ* treatment and an engineered cover. The residual risks from contaminated media treated *in situ* would be lower than the risks from untreated media. Therefore, the potential for contaminant migration to the ground water is expected to be less than that of GRA II. The engineered cover would meet the IM/IRA performance objectives by effectively isolating the contaminated media from the air, direct contact, ingestion, and surface water exposure pathways. In addition to routine inspections and maintenance, post-closure monitoring would be required to evaluate the performance of the engineered cover. GRA received a high evaluation result because the combination of the engineered cover and the in-situ treated soils exceeds the performance objectives.

GRA IV includes the complete removal of contaminated media from OU4 which eliminates the residual risks. Interim storage of contaminated media is not viable due to limited onsite storage area. Therefore, no long-term management or post-closure monitoring would be required. An offsite disposal facility would have to be identified that could accept the contaminated media. The materials might have to be treated in order to meet the disposal

TABLE III.5-5
LONG-TERM EFFECTIVENESS AND PERMANENCE

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
5. What are the requirements for long-term monitoring?	By definition, long-term monitoring is not provided for "No Action".	This GRA would require monitoring to assess long-term performance of the engineered cover. Per 6 CCR 1007-3, 264.117, Ground water is required to be conducted for 30 years. The 30-year monitoring period can be extended or shortened based on CDH's review.	Same as GRA II.	Long-term monitoring would not be required for this GRA since all contaminated media would be removed from OU4.	Same as GRA IV.
6. What operations and maintenance functions must be performed?	No operations or maintenance would be performed for "No Action".	Long-term operation and maintenance (including inspections and repairs) of the following items would be performed: • Institutional controls, • Engineered and vegetative covers, • Erosion and drainage controls, and • Monitoring systems. The continued long-term operation of ground water remediation systems will be addressed as part of the additional hydrogeological investigation.	Same as GRA II.	This GRA constitutes removal of all contaminated media and does not require long-term operation or maintenance.	Same as GRA IV.
7. What difficulties and uncertainties may be associated with long-term operation and maintenance?	None, long-term operation and maintenance is not provided.	Few difficulties and uncertainties can be foreseen with long-term operation and maintenance because only conventional post-closure care is involved. The engineered cover may alter localized ground (water table elevation) and surface water flows. These alternations would not be significant enough to cause long-term impacts.	Same as GRA II.	None, long-term operation and maintenance is not provided.	None, long-term operation and maintenance is not provided.
8. What is the potential need for replacement of technical components?	None	The engineered cover will need to be repaired as required to maintain its integrity.	Same as GRA II.	None	None

TABLE III.5-5
LONG-TERM EFFECTIVENESS AND PERMANENCE

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
9. What is the magnitude of the threats or risks should the GRA need replacement?	The magnitude of the risk should this GRA need replacement will not increase from current levels.	The magnitude of the risk should this GRA need replacement will not increase from current levels.	The magnitude of the risk should this GRA need replacement will be less than current conditions since the contaminated soil would be treated *in situ*.	This GRA constitutes removal of all contaminated media and will not require replacement.	Same as GRA IV.
10. What is the degree of confidence that controls can adequately handle potential problems?	No controls are provided.	There is a high degree of confidence that controls can adequately handle most problems. Primarily controls will consist of maintaining the engineered cover and monitoring systems. Post-closure monitoring will provide early warning of potential contaminant migration. Failures due to catastrophic events (earthquake, flood, etc.), are unlikely.	Same as GRA II.	No controls are required under this GRA.	Same as GRA IV.
11. What are the uncertainties associated with land disposal of *residuals and untreated wastes*?	Land disposal will not be required for this GRA.	Modeling to determine the potential for leaching of contaminants from the untreated contaminated media demonstrates that the risk to human health or the environment is insignificant. The subsurface drainage/control system will prevent potential rising from contacting consolidated contaminated media.	Same as GRA II.	Under this GRA an offsite disposal facility would be for the contaminated materials. These materials would be treated, if required, the comply with applicable regulations and the waste acceptance criteria established for the permitted offsite facility. It should be noted that this GRA only alleviates the potential concerns at the existing location. The offsite disposal facility would be required to meet the regulations and requirements set forth in the permit(s).	Same as GRA IV. Concentrated residues from the soil treatment process would also be managed to meet disposal requirements.
EVALUATION RESULTS (How well does the GRA provide long-term protection?)	**LOW**	**MEDIUM**	**HIGH**	**HIGH**	**HIGH**

TABLE III.5-5
LONG-TERM EFFECTIVENESS AND PERMANENCE

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
MAGNITUDE OF RESIDUAL RISKS					
1. Will residual risks be reduced to acceptable levels?	No. Since contaminant reduction is not provided, residual risk would only be reduced through natural attenuation and degradation. The length of time required to reduce the residual risk to acceptable levels was not quantified. Residual risk associated with the ground water pathway will be quantified during the additional hydrogeological investigation.	Yes. Part IV.10 provides information that quantified the residual risks. Residual risks associated with air, direct contact, ingestion, and surface water pathways will be eliminated. Slight potential exists for contaminant migration to ground water; however, the leach modeling indicates that untreated waste with an engineered cover and subsurface drainage system is effective in reducing residual risks to acceptable levels.	Yes. This GRA reduces the potential for contaminant migration to the ground water beyond that provided by GRA II through the application of the *in situ* solidification/stabilization of the contaminated soils. However, the leach modeling indicates that untreated waste with an engineered cover and subsurface drainage system is effective in reducing residual risks to acceptable levels.	Yes. This GRA constitutes removal of all contaminated media; therefore, no residual risk should remain. Residual risk associated with the ground water pathway will be quantified during the additional hydrogeological investigation.	Same as GRA IV.
2. What is the magnitude of residual risks?					
ADEQUACY AND RELIABILITY OF CONTROLS					
3. What is the likelihood that the technologies will meet required process efficiencies or performance specifications?	This GRA does not include any technologies; therefore, this analysis factor is not applicable.	Based on the calculated PRGs and leach modeling results, the engineered cover would only need to preclude exposures associated with the air, direct contact, ingestion, and surface water pathways. Performance requirements to achieve this objective are expected to be minimal. Based on CDH regulations, the performance of the engineered cover is to last for 1,000 years. It is likely that an engineered cover in conjunction with a subsurface drainage/control system could be designed to ensure that the residual risks are maintained below acceptable levels for the 1,000 year period.	There is little operational control and quality control for many *in situ* treatment processes which could result in non-uniform treatment of contaminated material. The performance criteria for the engineered cover would be the same as GRA II.	This GRA does not include any technologies; therefore, this analysis factor is not applicable.	Excellent operational and quality control exists for many *ex situ* treatment processes and result in uniform treatment of contaminated material.
4. What type and degree of long-term management is required?	By definition, long-term management is not provided for "No Action".	Long-term management could include restricting access, managing surface water runoff, maintaining the engineered cover, and monitoring.	Same as GRA II.	Long-term management is not required since all contaminated materials will be removed.	Same as GRA IV.

facility's waste acceptance criteria. This GRA received a high evaluation result because the risks from contamination at OU4 would be eliminated; however, this GRA relies on the performance of the offsite disposal facility for the ultimate protection of human health and the environment.

GRA V includes the complete removal and treatment (ex situ) of contaminated media from OU4. Interim storage of contaminated media is not viable due to limited onsite storage area. Removal of the contaminated media would eliminate the residual risks; therefore, no long-term management or post-closure monitoring would be required. The treated soils would be returned as backfill. An offsite disposal facility would have to be identified that could accept the concentrated waste and contaminated debris. The contaminated waste and debris may need further treatment to meet the disposal facility's waste acceptance criteria or effluent discharge requirements. This GRA received a high evaluation result because the risks from contamination at OU4 would be eliminated; however, this GRA relies on the performance of the offsite disposal facility for the ultimate protection of human health and the environment.

In summary, GRAs IV and V are the most effective by eliminating residual risks and long-term management for OU4 if potential effects to offsite areas are not considered. The long-term offsite management and risks associated with using an offsite disposal facility for GRAs IV and V were not included in this analysis. The residual risks from the No Action GRA would remain unchanged and have the potential to impact human health and the environment. The residual risks from GRA II and III would be below IM/IRA performance objectives, but require long-term maintenance and monitoring to assess long-term effectiveness.

III.5.4 Reduction of Toxicity, Mobility, and Volume

The reduction of toxicity, mobility, and volume through treatment was evaluated for each of the five GRAs. Each GRA was evaluated using five analysis factors. As with the other primary balancing criteria, the evaluation result for each GRA is either high, medium, or low. The evaluation results for this criterion are summarized in Table III.5-6.

GRA I, No Action, does not reduce the toxicity, mobility, and volume of contaminated material in OU4. Contaminants could migrate into the ground water because immobilization of the contaminants is not provided. However, potential contaminant migration is not likely to significantly impact ground water quality because most of the COCs are relatively immobile in the unsaturated soils present due to their low hydraulic conductivity and high ion exchange capacity. The evaluation result for GRA I is low because no treatment is provided to reduce the toxicity or volume of contamination, and natural attenuation is the only method to reduce the toxicity of the contaminants.

GRA II includes closure in place using an engineered cover and a subsurface drainage system. Because no treatment is involved, contaminant toxicity and volume are not reduced. Mobility would be reduced because the engineered cover would minimize infiltration of precipitation and potential contaminant migration to the ground water. Contaminant mobility

TABLE III.5-6
REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME					
1. To what extent is the mass of toxic contaminants reduced?	No toxicity, mobility, or volume reduction provided. Contaminant toxicity would only be reduced through natural attenuation and degradation. Contaminant mobility is only reduced through sorption to the soil matrix.	No toxicity reduction provided. Contaminant toxicity would only be reduced through natural attenuation and degradation. Mobility of contaminants resulting from the air, direct contact, ingestion, and surface water pathways are eliminated. The engineered cover would reduce infiltration, thereby, reducing the mobility of contaminants to the ground water. Modeling to determine the potential for leaching of contaminants from the untreated contaminated media demonstrates that the risk to human health or the environment is insignificant. The subsurface drain/control system will prevent potential rising ground water from contacting consolidated contaminated materials. No volume reduction provided.	*In situ* treatment would not reduce the mass or volume of contaminants. Toxicity maybe reduced by immobilizing the contaminants. *In situ* treatment further reduces contaminant migration to ground water, if any, beyond that of GRA II.	All contaminated media would be removed from OU4; however, no treatment of the remediation waste is proposed unless required to meet the waste acceptance criteria of the offsite disposal facility. In this situation, the toxicity, mobility, and volume of the OU4 contaminated media is transferred to the offsite disposal facility. Contaminant toxicity would only be reduced through natural attenuation and degradation.	All contaminated media would be removed from OU4. *Ex situ* treatment would not destroy the contaminants but would concentrate them. Although the resulting waste volume would be smaller, it could also be more toxic. However, the treatment process could reduce toxicity by immobilizing the contaminants.
2. To what extent is the mobility of toxic contaminants reduced?					
3. To what extent is the volume of toxic contaminants reduced?					
4. What portion of contaminated material is treated?	None, no treatment provided.	None, no treatment provided.	*In situ* solidification/stabilization would be used to treated vadose zone soils above PRGs. Other contaminated media may also be treated.	No treatment of the remediation waste is proposed unless required to meet the waste acceptance criteria of the offsite disposal facility.	*Ex situ* treatment would be used to removed contaminants from the soils to allow the soils to be returned to OU4 as clean backfill.
ADVERSE IMPACTS					
5. What is the potential to generate other hazardous by-products during or after treatment?	None, no treatment provided.	None, no treatment provided.	*In situ* treatment should not produce hazardous by-products. Engineering controls would be used to ensure that fugitive particulate emissions do not occur during treatment.	None are expected if treatment is provided to meet the waste acceptance criteria of the offsite disposal facility.	Treatment of contaminated soils would produce a concentrated waste stream that would require additional treatment. Air pollution controls may need to be provided for point sources.

TABLE III.5-6
REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
EVALUATION RESULTS (How well does the GRA reduce toxicity, mobility, or volume through treatment?)	LOW	LOW	MEDIUM	LOW	HIGH

with respect to the upward exposure pathways (inhalation, ingestion, and dermal contact) will be greatly reduced by the engineered cover. VLEACH modeling results indicate that the resulting risk of potential contaminant migration to the ground water is insignificant. In addition, the subsurface drainage system will prevent potential rising ground water from contacting consolidated contaminated materials. Therefore, ground water would be protected. Since GRA II does not employ treatment, the evaluation result for this criterion is low.

GRA III includes an engineered cover similar to GRA II and *in situ* treatment of the contaminated soils. Under this GRA, contaminant mobility and toxicity may be reduced but no reduction in volume is achieved. Residual contamination might also remain as a potential source of ground water contamination. Because the GRA does not reduce contaminant volume and may only partially succeed in reducing contaminant mobility and toxicity, the evaluation result for GRA III is medium.

GRA IV includes complete removal of contaminated materials from OU4. Because all contaminated materials are removed, the mobility and toxicity of contaminants to the OU4 environment are eliminated. No hazardous byproducts would be produced and the potential for ground water contamination would be eliminated. It is important to note that while this GRA eliminates the risk from contamination at OU4, there is no reduction of toxicity, mobility, or volume through treatment. The potential risks from these materials would be transferred to another location where they could have an adverse impact during transportation or disposal. Therefore, the evaluation result for GRA IV is low.

GRA V is identical to GRA IV except that the contaminated soils would be treated onsite through *ex situ* technologies. *Ex situ* treatment would remove contaminants from the media and concentrate them within a secondary waste stream that can be more readily treated. The toxicity of the secondary waste stream would be increased in comparison to the untreated contaminated materials due to concentrating the contaminants. The toxicity, mobility, and volume of the contaminated materials would be greatly reduced and clean soil could be used as backfill at OU4. The evaluation result for GRA V is high since this GRA used treatment to reduce the toxicity, mobility, and volume of the OU4 contamination.

In summary, even though treatment is not required, GRA V was determined to be the most effective GRA in meeting the treatment goals established under this evaluation criterion since GRA V is the only GRA that reduces all three factors (i.e., toxicity, mobility, and volume). GRAs I and IV do not provide a reduction in any factor. GRA II would reduce contamination mobility by the construction of an engineered cover. GRA III would be more effective than GRA II at reducing mobility due to the *in situ* treatment of contaminated soil.

III.5.5 Short-Term Effectiveness

The results of the short-term effectiveness evaluation for the five GRAs are shown in Table III.5-7 and are discussed below. As with the other primary balancing criteria, the evaluation result could be either high, medium or low.

GRA I causes the least physical disturbances of all the GRAs but also reduces potential risks from exposure to contaminants the least. The potential for worker exposure to contaminants is least with this GRA. Completion of this GRA will require the least amount of time and is expected to minimize physical impacts to the OU4 environment. The transportation impacts will be the least under this GRA. This GRA will use the least amount of energy. GRA I offers the least amount of exposure and risk during implementation and was given an overall ranking of high.

GRA II causes more physical disturbances than GRA I but it also reduces exposure to contaminants through the upward pathways of exposure (e.g. through contaminants in air, surface soils, and surface water). Under this GRA, there is a greater potential for worker exposure to contaminants than GRA I. The transportation impacts, potential impacts to the OU4 environment, and the energy used will be greater than GRA I. The adverse impacts from this GRA are greater than GRA I and GRA III due to excavation, but they are less than those for GRAs IV and V because workers will be in closer contact to the contaminated materials during containerization or treatment. This GRA successfully reduces potential exposure to contaminants. For these reasons the evaluation result for GRA II is medium.

GRA III causes as many physical disturbances as GRA II but it is more effective in reducing worker exposure to contaminants through *in situ* soil treatment. The *in situ* treatment increases the amount of time for implementation of the GRA, increases the impacts to the OU4 environment, increases the transportation impacts, and increases the amount of energy required from that required for GRA II. For these reasons the evaluation result for GRA III is also medium.

GRA IV causes the most physical disturbances but no contamination remains onsite following completion. One disadvantage to this GRA would be the increased potential for worker exposure to contamination during excavation and handling activities. This GRA will take longer than any of the preceding GRAs to complete. It will result in the most adverse short-term physical impact to the OU4 environment, greater transportation impacts than the preceding GRAs, and use more energy than the preceding GRAs. For these reasons the evaluation result for GRA IV is low.

GRA V creates the most physical disturbances but no contamination remains onsite following completion of the GRA. This GRA creates the greatest potential for worker exposure to contaminants because all contaminated materials will be removed and may be treated onsite using *ex situ* technologies. The transportation impacts associated with this GRA would be less

TABLE III.5-7
SHORT-TERM EFFECTIVENESS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
PROTECTION OF THE COMMUNITY					
1. What are the risks to the community during implementation of the GRA that must be addressed?	The risks associated with this GRA are no different than what they presently are. Dust controls would be provided during regrading and seeding.	Atmospheric distribution calculations indicate that the risk to the community outside of the RFP boundary associated with contaminated media excavation and constructing the engineered cover is insignificant. Administrative (restricting excavation and construction activities during high winds) and engineering controls (use of dust suppressants) would be used to mitigated the potential for the release of contaminated fugitive dust. Air monitoring would be conducted to ensure that the controls are effective.	Same as GRA II. Additional controls may be required during *In situ* treatment operations.	Same as GRA II. The transportation of the contaminated media an offsite facility could increase risks to the community. Transportation risks would be minimized by covering bulk loads and selecting a transportation mode/route that minimizes the potential for accidents.	Same as GRA IV. However, transportation risks would be less of a concern than GRA IV since a small volume of remediation waste would need to be transported offsite. Contaminants may also be released into the atmosphere during *ex situ* soil treatment. Proper pollution controls would be provided to comply with air emission standards to ensure protection of the community.
2. How will these community risks be addressed and mitigated?					
3. What risks remain to the community that cannot be readily controlled?	The "No Action" GRA does not provide any controls. The remaining risks to the community would be similar to current conditions.	All risks can be mitigated or minimized.	All risks can be mitigated or minimized.	All risks can be mitigated or minimized.	All risks can be mitigated or minimized.

TABLE III.5-7
SHORT-TERM EFFECTIVENESS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
PROTECTION OF WORKERS					
4. What are the risks to the workers that must be addressed? 5. How will the risks to the workers be addressed and mitigated?	As discussed in Part IV.10.3, the risks to the workers are expected to be minimal. In addition, UG utilities and other construction activities could present a hazard. Mitigative measures include: • Dust Controls, • Personal Protective Equipment (PPE), • Limiting worker exposure times, • Rotating job positions, • Adhering to OHSA standards, • Locating UG utilities in the field prior to excavation, and • Deactivating AG/UG utilities, to the extent possible. A Health and Safety Plan will be prepared to identify the worker protection requirements (work practices and PPE).	As discussed in Part IV.10.3, the risks to be workers are expected to be minimal. The risk would be higher than GRA I due to the excavation of all contaminated surface soils and media beneath the IHSS 101 area for consolidation beneath the engineered cover. There would also be risks associated with engineered cover construction. The mitigative measures would be the same as GRA I.	As discussed in Part IV.10.3, the risks to the workers are expected to be minimal. The excavation risks should be less than GRA II since less contaminated media would be consolidated under this GRA. The engineered cover construction risks would be the same as GRA II. Additional risks associated with the *in situ* treatment process would need to be considered. The mitigative measures would be the same as GRA I.	As discussed in Part IV.10.3, the risks to the workers are expected to be minimal. Although the construction risk associated with the engineered cover would not need to be considered under this GRA, the excavation risks would be higher than those posed by GRA III, since this GRA involves excavation of all contaminated media within OU4. The additional handling, packing, and transport of waste for offsite disposal would cause the risk to be higher than GRA II. The mitigative measures would be the same as GRA I.	As discussed in Part IV.10.3, the risks to the workers are expected to be minimal. The excavation risks would be similar to GRA IV. Construction risks for the engineered cover would not be part of this GRA. *Ex situ* treatment of the contaminated soils would pose physical and chemical not encountered under any of the other GRAs. Chemical exposure could result from the handling of process chemicals and the concentrated waste residues. Although the resulting waste volume would be smaller, it could also be more toxic. The added toxicity of the concentrated waste would need to be considered when handling, packing, and transport for offsite disposal. In addition to the mitigative measures identified for GRA I, specific engineering and administrative controls may need to be provided for the *ex situ* treatment process.
6. What risks remain to the workers that cannot be readily controlled?	Encountering unknown utilities or uncharacterized zone of high contamination. Based on the locating the utilities prior to field work and the RFI/RI results, it is unlikely that unknown conditions will be encountered. A contingency plan will be developed for managing unexpected conditions.	Same as GRA I.	Same as GRA I.	Same as GRA I.	Same as GRA I.

TABLE III.5-7
SHORT-TERM EFFECTIVENESS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
ENVIRONMENTAL IMPACTS					
7. What adverse environmental impacts are expected with the construction and implementation of the GRA?	Adverse environmental impacts are not expected with implementing this GRA. However, remaining uncontrolled contaminants could potentially impact the wildlife, surface water, and ground water in the area.	Adverse environmental impacts are not expected with implementing this GRA. Vegetation, wildlife, and surface water could be temporarily disrupted in the borrow area due to traffic, dust, changing drainage patterns, and potential soil erosion.	Same as GRA II.	Same as GRA II.	Same as GRA II.
8. What are the available mitigation measures to be used and what is their reliability to minimize potential impacts?	Regrading the OU4 area and establishing vegetation would be improve environmental conditions by creating additional wildlife habitats and reducing potential for erosion.	Mitigative measures include: • Proper siting of the borrow area or purchasing materials for suppliers that maintain proper environmental controls, • Using dust suppressants, • Establishing erosion controls, and • Restoring the area upon completion of the IM/IRA.	Same as GRA II.	Same as GRA II.	Same as GRA II.
9. What are the impacts that cannot be avoided without additional mitigative measures should the GRA be implemented?	Special controls for protection of wetlands, floodplains, critical habitatives, endangered species are not required for this GRA.	Same as GRA I.	Same as GRA I.	Same as GRA I.	Same as GRA I.
ADDITIONAL NEPA CONSIDERATIONS					
10. What is the relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity?	The physical disruptions will temporarily limit the use of the OU4 and borrow areas. The long-term use of contaminated areas would need to be precluded by institutional controls.	The physical disruptions will temporarily limit the use of the OU4 and borrow areas. However, long-term benefits will be realized by eliminating potential exposure pathways. The long-term use of the engineered cover area would need to be precluded by institutional controls.	Same as GRA II.	The physical disruptions will temporarily limit the use of the OU4 and borrow areas. However, long-term benefits will be realized by eliminating potential exposure pathways. The long-term use of OU4 would not need to be restricted.	Same as GRA IV.
11. Will there be any irreversible and irretrievable commitment of resources?	Borrow soil used for grading would be irreversibly and irretrievably committed.	Borrow soil used for grading, the materials used for the engineered cover, and the zone behind the cover would be irreversibly and irretrievably committed.	Same as GRA II.	Same as GRA I.	Same as GRA I.

TABLE III.5-7
SHORT-TERM EFFECTIVENESS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
12. What are the direct and indirect effects of the GRA?	Direct impacts include: • Minimal physical disturbance, and • Unrestricted use of OU4 will be preclude. Indirect impacts include: • Minimal increase in local transportation, • Minimal (positive) impact to diversity and density of the plant and animal species within the OU4 environment, and • Minimal impact to local hydrogeology resulting from regrading and seeding, if potential recharge area.	Direct and indirect impacts are expected to be similar to GRA I. The diversity and density of the plant and animal species within the OU4 environment are expected to be impacted positively through the restoration of this area for wildlife and the elimination of exposure pathways to contaminants. Local hydrogeology impacts may be greater than GRA I due to further reduction of percolation by the engineered cover.	Same as GRA II. Local hydrogeology impacts may be greater than GRA II due to further reduction of percolation by the engineered cover and *in situ* solidification/stabilization of the contaminated soils.	Direct impacts include: • Physical disturbance during media removal. Indirect impacts include: • Minimal increase in local transportation to ship media offsite for disposal, • Minimal (positive) impact to diversity and density of OU4 environment, and • Minimal impact to local hydrogeology resulting from regrading and seeding, if potential recharge area.	Same as GRA IV.
13. What are the possible conflicts with the objectives of federal, regional, state, and local use plans and policies?	The RFP-wide land use plan is under development. Land use restrictions required as a part of this GRA will need to be incorporated into the RFP-wide plan.	Same as GRA I.	Same as GRA I.	Upon completion of this GRA land use restrictions are not required; therefore, other land use conflicts would not be encountered.	Same as GRA IV.
14. What are the energy requirements and conservation potential?	Energy is required to regrade and seed. Post-closure maintenance would not be provided. Conservation potential is minimal since the area is currently disturbed and there are no resource to conserve.	Energy is required to consolidate contaminated media, construct the engineered cover, and make repairs during post-closure. Energy conservation would be the same as GRA I.	In addition to the items identified for GRA II, energy would be required for the *in situ* treatment of the contaminated soils. Energy conservation would be the same as GRA I.	Energy is required for contaminated media excavation, packing, and transport; and backfill, regrading, and seeding. Energy conservation would be the same as GRA I.	In addition to the items identified for GRA IV, energy would be required for the *ex situ* treatment of the contaminated soils. Energy conservation would be the same as GRA I.
15. What are the requirements for natural or depletable resources?	None	None	None	None	None
16. What are the impacts to historical and cultural resources?	None	None	None	None	None
17. What are the impacts to urban quality?	The impacts are the same as those which currently exist.	Atmospheric distribution calculations indicate that the risk to the community outside of the RFP boundary associated with contaminated media excavation and constructing the engineered cover is insignificant.	Same as GRA II.	Same as GRA II.	Same as GRA II.

TABLE III.5-7
SHORT-TERM EFFECTIVENESS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
18. What are the cumulative impacts of the GRA?	Although this GRA would not interfere with other RFP activities, the long-term mission of remediating the RFP would not be achieved.	Although this GRA could interfere with other RFP activities, this GRA is consistent with the long-term mission of remediating the RFP.	Same as GRA II.	This GRA is consistent with the long-term mission of remediating the RFP and would not interfere with other RFP activities.	Same as GRA IV.
TIME UNTIL IM/IRA OBJECTIVES ARE ACHIEVED					
19. How long until IM/IRA objectives are achieved?	IM/IRA objectives would not be achieved by this GRA.	Approximately 7 to 12 months from start of construction. Additional investigation will be conducted to determine the need to supplement this GRA with ground water remediation.	Approximately 12 months from start of construction. Additional investigation will be conducted to determine the need to supplement this GRA with ground water remediation.	Approximately 12 months from start of construction. Additional investigation will be conducted to determine the need to supplement this GRA with ground water remediation.	Approximately 18 months from start of construction. Additional investigation will be conducted to determine the need to supplement this GRA with ground water remediation.
EVALUATION RESULTS **(How well does the GRA provide short-term protection?)**	**HIGH**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**

than GRAs II, III, and IV since the contaminated materials may be handled twice; once before the treatment process, and again following the treatment process. However, this GRA will take the longest to implement and will use the greatest amount of energy. For these reasons the evaluation result for GRA V is low.

In summary, GRAs II and III were determined to be the most effective in meeting the short-term effectiveness evaluation factors. These GRAs will have slightly greater impacts to the OU4 environment due to implementation than the No Action GRA, but unlike the No Action GRA, GRAs II and III would have a positive impact on the reduction of contaminant exposures. GRAs II and III would not impact the OU4 environment during implementation as much as GRAs IV and V. GRAs IV and V have the highest potential for worker exposure to contaminants because all the contamination will be excavated and workers will be in closer contact to the materials during containerization or treatment. GRA III has the advantage of reducing the potential for worker exposure to contaminants because much of the contaminated media would be left in-place.

III.5.6 Implementability

Implementability was evaluated for each of the five GRAs considered for the OU4 IM/IRA. The results of the evaluation are summarized in Table III.5-8. Twenty-two evaluation factors were considered in developing the evaluation result (i.e., high, medium, or low) for this criterion. The evaluation results for each GRA are provided in Table III.5-8 and are discussed below.

GRA I, No Action, would not be difficult to implement because there are:

- No technical difficulties associated with construction;
- No monitoring requirements during or after construction;
- No required coordination activities with other agencies;
- No special equipment requirements; and
- Construction can begin immediately.

This GRA received a high evaluation result.

GRA II includes closure in place with an engineered cover and subsurface drainage system. Engineered covers and subsurface drainage systems are proven technologies that have been implemented at many sites and are generally considered to be easy to construct. Storage/disposal facilities would not be required and materials to build the engineered cover are readily available. There would not be a requirement to coordinate implementing this GRA with other agencies. Monitoring would be required during construction. In addition, a post-closure monitoring program would be required. This GRA received a high evaluation result because it could be implemented relatively easily without special equipment and would not require storage or disposal facilities.

TABLE III.5-8
IMPLEMENTABILITY

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
ABILITY TO CONSTRUCT AND OPERATE TECHNOLOGY					
1. What difficulties may be associated with construction?	No difficulties expected.	Security requirements to ship and receive materials in/out of the Protected Area could cause construction delays. The implementation schedule will be structured to minimize this potential impact. The instability and seep slope of the north hillside could hamper construction of the engineered cover. Location of buildings on and adjacent to OU4 could cause interferes. The availability of areas could restrict the amount materials that can be stockpiled for the engineered cover.	Same as GRA II.	Security requirements to ship and receive materials in/out of the Protected Area could cause excavation delays. The implementation schedule will be structured to minimize this potential impact. Shoring of excavated areas, stockpiling of materials, and the sequencing of excavation and backfill soils.	Same as GRA IV.
2. What uncertainties are related to construction?	Not applicable	Poor weather may cause delays.	Same as GRA II. In addition, quality control is difficult and uncertain for *in situ* treatment processes.	Same as GRA II.	Same as GRA II.
RELIABILITY OF TECHNOLOGY					
3. What is the likelihood that technical problems will lead to schedule delays?	Not applicable	This GRA involves application of a proven technology, as such, no technical delays are expected.	Although *in situ* treatment has been applied at several sites, there is a potential to encounter technical delays as a result of site specific factors.	Same as GRA II.	Although *ex situ* treatment has been applied at several sites, there is a potential to encounter technical delays as a result of site specific factors. Less problems should arise with *ex situ* treatment than with *in situ* treatment. The likelihood of experiencing these difficulties is low.
STOPPED HERE EASE OF UNDERTAKING ADDITIONAL REMEDIAL ACTIONS					
4. What likely future remedial actions may be anticipated?	Ground water remediation is likely.	Ground water remediation is less than GRA I, but less likely than GRA III.	Ground water remediation is less under this GRA since contaminated material will be treated *in situ*.	Ground water remediation is less under this GRA since the liners will be removed, and the soil is treated *in situ*.	Ground water remediation is least under this GRA since contaminated media (soils and liners) will be removed.

TABLE III.5-8
IMPLEMENTABILITY

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
5. How difficult would it be to implement the additional remedial actions, if required?	There will not be an engineered cover to restrict access to media.	It may be difficult to implement additional remedial actions if they require excavation of the engineered cover to remove contaminated media.	If *in situ* treatment processes are not sufficient to remove or immobilize all the contaminants from the soils then there may be difficulty in removing contaminated soil if it requires excavation of the engineered cover.	It may be difficult to implement additional remedial actions if they require excavation of the engineered cover to remove contaminated media.	Further remediation of media should not be required since soils and liners are removed. However, if rework is necessary, it should be easy.
MONITORING CONSIDERATIONS					
6. Do migration or exposure pathways exist that cannot be monitored adequately during construction?	Not applicable	Ingestion, dermal, and inhalation pathways would require monitoring, but adequate controls and monitoring are available.	Ingestion, dermal, and inhalation pathways would require monitoring, but adequate controls and monitoring are available.	Ingestion, dermal, and inhalation pathways would require monitoring, but adequate controls and monitoring are available.	Ingestion, dermal, and inhalation pathways would require monitoring, but adequate controls and monitoring are available.
7. What risks of exposure exist should monitoring be insufficient to detect failure?	Not applicable	Worker exposure to contaminants and wind transport to nearby offsite receptors.	Workers exposure to contaminants and wind transport to nearby offsite receptors.	Workers might be exposed to contaminants. Wind transport to nearby offsite receptors.	Workers might be exposed to contaminants. Wind transport to nearby offsite receptors.
COORDINATION WITH OTHER AGENCIES					
8. What steps are required to coordinate with other agencies?	Not Applicable.	• Certificate of Designation is not required to be obtained per IAG Part 18. • Existing RCRA Part B Permit will need to be modified to reflect selected IM/IRA.	• Certificate of Designation is not required to be obtained per IAG Part 18. • Existing RCRA Part B Permit will need to be modified to reflect selected IM/IRA.	• Certificate of Designation is not required to be obtained per IAG Part 18. • Existing RCRA Part B Permit will need to be modified to reflect selected IM/IRA. • Waste shipped offsite shall be in accordance with Waste Acceptance Criteria (WAC). • Need to meet Department of Transportation (DOT) requirements for shipping waste.	• Certificate of Designation is not required to be obtained per IAG Part 18. • Existing RCRA Part B Permit will need to be modified to reflect selected IM/IRA. • Waste shipped offsite shall be in accordance with Waste Acceptance Criteria (WAC). • Need to meet DOT requirements for shipping waste. • Potential operating and disposal permits may be required for secondary waste produced during *ex situ* soil treatment.

TABLE III.5-8
IMPLEMENTABILITY

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
9. What steps are required to set up long-term or future coordination among agencies?	Not Applicable.	Post closure care provisions and maintenance. This would include a 5-year review as stated in the IAG Part 40. Under the IAG, the DOE would be required to conduct a review and submit the results to the EPA.	Post closure care provisions and maintenance. This would include a 5-year review as stated in the IAG Part 40. Under the IAG, the DOE would be required to conduct a review and submit the results to the EPA.	Post closure care provisions and maintenance. This would include a 5-year review as stated in the IAG Part 40. Under the IAG, the DOE would be required to conduct a review and submit the results to the EPA.	• Because contaminated media are removed, post closure care provisions and maintenance would not be required.
10. Can permits for offsite activities be obtained if required?	None required	None required	None required	Yes	Yes
AVAILABILITY OF TREATMENT, STORAGE CAPACITY, AND DISPOSAL SERVICES					
11. Are adequate treatment, storage capacity, and disposal services available?	None required	None required	• *In situ* treatment may be required for soils and the technology is available.	• Disposal will be required for liners and "hot spots" removed from the soils. The Envirocare facility is permitted to receive the materials.	• Disposal will be required for liners and possibly soils. The Envirocare facility is permitted to receive the materials. • *Ex situ* treatment may be required for soils. A treatment system would have to be constructed to treat the media.
12. How much disposal capacity is necessary?	None	None	None	Approximate volumes which may require storage: Liners ~ 317,000 cubic feet (cf) Hot spots ~ 100,000 cubic feet (cf)	Approximate volumes which may require storage: Liners ~ 317,000 cf Soils ~ 774,000 cf Hot spots in soils ~ 100,000 cf
13. Does the lack of capacity prevent implementation?	Not Applicable	Not Applicable	No	No	No
14. What additional provisions are required to ensure the needed additional capacity?	None	None	None	Approval to transport any removed "hot spots" to a disposal facility.	Approval to transport liners and contaminated media to a disposal facility.
AVAILABILITY OF NECESSARY EQUIPMENT AND SPECIALISTS					
15. Are the necessary equipment and specialists available?	Yes	Yes	Yes	Yes	Yes
16. What additional equipment and specialists are required?	None	None	*In situ* treatment equipment		*Ex situ* treatment equipment
17. Does the lack of equipment and specialists prevent implementation?	No	No	No	No	No

TABLE III.5-8
IMPLEMENTABILITY

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
18. What additional provisions are required to ensure the needed equipment and specialists?	None	None	None	None	None
AVAILABILITY OF PROSPECTIVE TECHNOLOGIES					
19. Are the technologies under consideration generally available and sufficiently demonstrated for the specific application?	Yes	Yes	Yes	Yes	Yes
20. Will technologies require site-specific design studies before they can be applied full scale to the type of waste at the site?	No	• Geotechnical testing would be required to implement the engineered cover.	• Engineering study requirements for potential *in situ* treatment and geotechnical testing.	• Geotechnical testing would be required to implement the engineered cover.	• Engineering study requirements for potential *ex situ* treatment and geotechnical testing.
21. When should the technology be available for full-scale use?	Immediately	The geotechnical study should be completed during design. Unless there are problems with the studies, the technologies should be available immediately.	The engineering requirements study should be completed during design. Unless there are problems with the studies, the technologies should be available immediately.	The geotechnical study should be completed during design. Unless there are problems with the studies, the technologies should be available immediately.	The engineering study requirements should be completed during design. Unless there are problems with the studies, the technologies should be available immediately.
22. Will more than one vendor be available to provide a competitive bid?	Yes, the closure of the ponds will be such that the specifications are not restricted to a single supplier.	Yes, the design of the engineered cover will be such that the specifications are not restricted to a single supplier.	Yes, the design of the engineered cover, and *in situ* treatment requirements will be such that the specifications are not restricted to a single supplier.	Yes, the design of the engineered cover will be such that the specifications are not restricted to a single supplier.	Yes, the design of the engineered cover, and *ex situ* treatment facilities will be such that the specifications are not restricted to a single supplier.
EVALUATION RESULTS (How well can the GRA be implemented?)	**HIGH**	**HIGH**	**LOW**	**MEDIUM**	**MEDIUM**

GRA III includes closure in place with *in situ* treatment, subsurface drainage system, and an engineered cover. Engineered covers and subsurface drainage systems are proven technologies that have been implemented at many sites and are generally considered to be easy to construct. *In situ* technologies are not considered to be difficult to implement, but quality control and verification of successful treatment is generally very difficult (it should be noted that quality control of some *in situ* technologies is more difficult than for others). Engineering implementation studies would be required to optimize the *in situ* treatment process. The uncertainties and quality control difficulties associated with *in situ* treatment could cause construction schedule delays. Storage/disposal facilities would not be required and materials to build the engineered cover are readily available. These would not be a requirement to coordinate implementing this GRA with other agencies. Monitoring would be required during construction. In addition, a post-closure monitoring program would be required. This GRA received a medium evaluation result because it could be implemented without requiring storage or disposal facilities, but it would be difficult to prove the *in situ* treatment effectiveness.

GRA IV includes the complete removal of contaminated media from OU4. Excavation of all the contaminated media for disposal at an offsite disposal facility would not be difficult with respect to construction. The largest drawback associated with this GRA is the identification and shipment of the contaminated media to an offsite disposal facility. The material would be required to meet the disposal facility's waste acceptance criteria which might require special packaging or treatment. Receiving approval and permits to transport contaminated media across state boundaries might be difficult and could cause schedule delays. GRA IV received a medium evaluation based primarily on the difficulties associated with offsite disposal.

GRA V includes the complete removal of contaminated media from OU4 with *ex situ* treatment. Excavation of all the contaminated media would not be difficult with respect to construction. *Ex situ* treatment of soils would provide effluent that could be easily demonstrated as being in compliance with treatment goals. Treated soils could be used as backfill within the SEPs. Engineering implementation studies would be required to optimize the *ex situ* treatment process. It is likely that permits would be required to operate the *ex situ* treatment facility and for discharging secondary waste streams. The largest drawback associated with this GRA is the identification and shipment of the liners to an offsite disposal facility. The material would be required to meet the disposal facility's waste acceptance criteria which might require special packaging or treatment. GRA V received a medium evaluation based primarily on the difficulties associated with offsite disposal.

In summary, GRAs I and II are the easiest to implement and would be expected to result in the lowest level of exposure to workers and the public during construction. GRA III would be slightly more difficult to implement than GRAs I and II because of *in situ* treatment. There is a high level of uncertainty associated with the disposal of liners and soils in an offsite disposal facility.

III.5.7 Cost

The results of the cost evaluation for the five GRAs at the SEPs are shown in Table III.5-9. Capital and operating costs were assessed. Capital costs were assessed quantitatively to a rough-order-of magnitude. Operating costs were assessed qualitatively because many of the GRAs would have minimal and similar operating costs. In addition, the operation period for the potential treatment systems would be short and were addressed as capital expenditures because the treatment would be an integral component of the overall closure. Each GRA was given a rating of high, medium, or low for an overall cost rating.

Professional engineering judgement and project experience relating to containment (i.e., engineered covers), treatment, and removal technologies were applied in developing the quantitative costing procedure. Additionally, industry-based assumptions were made, and current industry standards for both commercial and government work were applied. Construction and cost information were obtained from local contractors familiar with the RFP site conditions and DOE contracting requirements. Construction methodology and implementation were considered during cost development for the five GRAs. Technologies applied at similar projects in other parts of the country were researched, and relevant data were incorporated. Key information regarding management of contaminated waste (e.g., appropriate waste containers, monitoring procedures, and transportation of waste within the RFP and to offsite facilities) would also based on RFP information. A 40 percent contingency factor was applied to each cost estimate due to the uncertainties associated with the scope of work and the preliminary level of engineering detail. Additionally, the cost estimates did not include the following: future operating maintenance or monitoring costs, and costs associated with engineering implementation studies since these costs would be similar within each GRA. Cost spreadsheets and backup documentation are provided in Appendix III.F.

GRA I is the least expensive GRA with respect to both capital and operating costs. Therefore, this GRA received a high rating. This GRA is included in the detailed analysis to provide a baseline cost to allow comparison of the costs for the other GRAs.

GRA II would have higher costs than the No Action GRA due to the construction of an engineered cover and a subsurface drainage system, but would have lower costs than the other GRAs because there would not be any treatment or disposal costs. This GRA would have low operating costs that would consist of routine maintenance and post-closure monitoring. GRA II received a high rating since it has lower costs when compared to the other GRAs.

GRA III has higher capital and operating costs than GRA II, but lower costs than GRAs IV and V. The costs of *in situ* treatment are generally less than *ex situ* treatment or disposal. The operating cost would consist of routine maintenance and post-closure monitoring. Therefore, GRA III received a medium rating.

TABLE III.5-9
COSTS

Evaluation Factor	General Response Action I No Action	General Response Action II Containment (Closure in Place)	General Response Action III *In Situ* Treatment (Closure in Place)	General Response Action IV Contaminated Media Removal	General Response Action V Contaminated Media Removal with *Ex Situ* Treatment
CAPITAL COSTS					
1. What are the direct and indirect capital costs associated with the GRA? (Values provided in 1994 present worth dollars.)	1.5 Million	22 to 39 Million	65 to 178 Million	884 Million	428 to 453 Million
OPERATING COSTS					
2. What are the operational costs associated with the GRA?	There would not be any costs for post-closure.	Operating costs would include post closure care and engineered cover maintenance.	Operating costs would include post-closure care and maintenance of an engineered cover. [Note: Operating for *in situ* soil treatment included as capital cost.]	Since all contaminated media would be removed for offsite disposal, there would be no post-closure care costs.	Same as GRA IV. [Note: Operating costs associated with *ex situ* treatment included as capital cost.]
EVALUATION RESULTS (Is the GRA cost-effective and within available funding?)	**HIGH**	**HIGH**	**MEDIUM**	**LOW**	**LOW**

*/ Refer to Appendix III-G for details on the cost estimate.

GRA IV has the potential highest capital cost due to excavating contaminated media with offsite disposal. GRA IV would not include operating costs since all contaminants would be removed and post-closure care and monitoring would not be required. Based on the high capital cost, GRA IV received a low rating.

GRA V would have capital costs that could be higher than GRA III but lower than GRA IV. The cost of *ex situ* treatment are likely to exceed the costs of *in situ* treatment. However, the costs of *ex situ* treatment are less than the costs for the offsite disposal. GRA V would not include operating costs since all contaminants would be removed and post-closure care and monitoring would not be required. Based on the high capital cost, this GRA also received a low rating.

The results of the cost evaluation indicate that GRA II is the most cost-effective solution to achieve the IM/IRA performance objectives.

III.6 EVALUATION SUMMARY AND SELECTION OF THE PREFERRED IM/IRA

Table III.6-1 presents a summary of the detailed analysis of the GRAs. The evaluation results are as follows.

- GRA I cannot be selected since it failed both of the threshold criteria;

- GRA II received one low, two medium, and two high evaluation results. Comparatively, GRA II was ranked low with respect to reducing toxicity, mobility, and volume through treatment since this GRA does not treat the contaminated media. As previously stated, VLEACH modeling results indicate that treatment is not required to ensure the long-term protection of the underlying ground water if an engineered cover is constructed to minimize precipitation infiltration to the contaminated materials. In addition, the subsurface drainage/control system will prevent potential rising ground water from contacting consolidated contaminated materials. As such, this evaluation criteria was not considered to be vital for selection of the preferred IM/IRA. GRA II was determined to be the most effective for maximizing the factors associated with short-term effectiveness, implementability, and cost. Although this GRA was ranked lower than the other GRAs with respect to long-term effectiveness and permanence, GRA II meets all of the IM/IRA performance objectives. This GRA received a lower evaluation result that GRAs IV and V only because contaminants would remain at OU4 after completion of the IM/IRA;

- GRA III received four medium evaluation results and one high result. This GRA ranked near the middle-of-the-pack for all of the balancing criteria;

Table III.6-1
DETAILED EVALUATION SUMMARY

EVALUATION CRITERIA b/	GENERAL RESPONSE ACTION a/				
	I	II	III	IV	V
1) Overall Protection of Human Health and the Environment	No	Yes	Yes	Yes	Yes
2) Compliance with ARARs	No	Yes	Yes	Yes	Yes
3) Long-Term Effectiveness and Permanence	Low	Medium	High	High	High
4) Reduction of Toxicity, Mobility, and Volume Through Treatment	Low	Low	Medium	Low	High
5) Short-Term Effectiveness	High	Medium	Medium	Low	Low
6) Implementability	High	High	Medium	Medium	Medium
7) Cost	High	High	Medium	Low	Low
8) Regulatory Agency Acceptance c/					
9) Community Acceptance c/					
OVERALL EVALUATION RESULTS	d/	High	High	Low	Medium

Notes:

a/ Refer to Section III.3.3 for General Response Action Descriptions

I. No Action
II. Containment (Closure in Place)
III. *In Situ* Soil Treatment (Closure in Place)
IV. Contaminated Media Removal
V. Contaminated Media Removal with *Ex Situ* Treatment

b/ Refer to Section III.4 for Evaluation Criteria Descriptions:

1 & 2: Threshold Criteria
3 - 7: Primary Balancing Criteria
8 & 9: Modifying Criteria

c/ The 8th and 9th criteria are evaluated after the regulatory agency and public review periods.

d/ General Response Action I cannot be selected since the threshold criteria are not met.

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- GRA IV received three low scores, one medium score, and one high score. This GRA was the most costly. Although this GRA would eliminate the potential for contaminant exposure at OU4, it does not provide any treatment of the contaminated media and relies on the offsite disposal to ensure long-term protection of human health and the environment; and

- GRA V received two low scores, one medium score, and two high scores. This GRA was determined to be the best with respect to maximizing the long-term effectiveness and permanence and reduction of toxicity, mobility, or volume through treatment criteria. This GRA was also determined to be the worst with respect to the short-term effectiveness and implementability criteria.

Based on the results of the detailed analysis, DOE ranked the various GRAs and determined that GRA II, Containment (Closure in Place), should be the preferred IM/IRA for OU4. GRA II was chosen since it will achieve or maximize the following IM/IRA objectives.

- GRA II is a suitable long-term remedy for OU4 and complies with the State of Colorado requirements for the closure of an interim status surface impoundment. GRA II is also consistent with any additional actions that may be required to remediate ground water;

- GRA II's engineered cover will eliminate the potential for exposure via direct contact, inhalation, ingestion, and surface soil runoff;

- GRA II's subsurface drainage system will eliminate the potential for exposure via direct contact with the ground water;

- GRA II can be designed and implemented to comply with the identified ARARs;

- GRA II maximizes the objective to design and implement a closure/remediation system within the schedule milestones specified in the IAG;

- GRA II maximizes the objective to minimize the generation of new waste requiring treatment, storage, or disposal;

- GRA II can be implemented to minimize the spread of contaminants during construction;

- GRA II maximizes the objective to provide a cost-effective closure/remediation system; and

- The use of *in situ* or *ex situ* soil treatment is not necessary to ensure protection of human health and the environment. The engineered cover system and subsurface drainage system will provide protection of human health and the environment while limiting occupational exposure levels during construction activities.

It is recognized that GRA II has the potential to impact ground water since the contaminated media would remain under an engineered cover; however, the migration of contaminants that would adversely impact the ground water is unlikely due to the inclusion of a subsurface drainage control system. Appendix III.G contains an evaluation of the specific engineered cover alternatives. The engineered cover will limit the amount of infiltration through the contaminant zone and will be designed to be protective of human health and the environment for a period of 1,000 years. GRA II was selected over GRA III since the construction quality control and quality assurance of *in situ* treatment is difficult to ensure. In addition, the cost differential between GRA II and GRA III favors the selection of GRA II.

The wastes in the SEPs can remain in place as established under the 6 CCR 1007-3, 265.228(a)(2). At closure, the owner or operator must close the impoundment and provide post-closure care for a landfill under this section, Section 265 Subpart G and Section 265.310, including the following:

- Minimizes the need for further maintenance;

- Controls, minimizes, or eliminates post-closure escape of hazardous waste to the groundwater, surface water or atmosphere to the extent necessary to protect human health and the environment;

- Eliminate free liquids by removing liquid wastes or solidifying the remaining wastes and waste residues;

- Stabilize the remaining wastes to a bearing capacity sufficient to support the final cover; and

- Cover the surface impoundment with a final cover designed and constructed to:

  - Provide long-term minimization of the migration of liquids through the closed impoundment;

  - Function with minimum maintenance;

  - Promote drainage and minimize erosion or abrasion of the cover;

- Accommodate settling and subsidence so that the cover's integrity is maintained; and

- Have permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

In addition to the above-cited criteria, the owner/operator must maintain the integrity and effectiveness of the final cover including making repairs to the cover as necessary to correct the effects of settling, subsidence, erosion, or other events. Provisions shall be made for maintaining and monitoring the ground water monitoring system and for compliance with all other applicable requirements of this section. The final cover shall be constructed in a manner which prevents storm water run-on and run-off from eroding or otherwise damaging the final cover.

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APPENDIX III.A

DATA EVALUATION

APPENDIX III.A

DATA EVALUATION

The goal of the data evaluation conducted as part of the OU4 IM/IRA program was to determine concentration levels of various chemicals from the RFI/RI data set that may indicate contamination at the site. To achieve this goal, it was necessary to (1) develop an adequate data set from the RFI/RI data suitable to support risk analysis and remedial option evaluation, (2) compare representative background concentrations to RFI/RI concentrations to define potential contaminants of concern (PCOCs), and (3) define representative PCOC concentrations at the site. The following appendix contains detailed information on how the RFI/RI data set and available background data on inorganics and radionuclides was evaluated to determine whether statistically significant differences are discernable, and if so, compute representative concentrations to be compared to target remediation goals. The appendix also summarizes the results of a frequency of detection analysis (i.e., number of times an analyte was considered a detect per the total number of times for which the analyte was analyzed) completed on RFI/RI organic analytes, and identifies the representative organic PCOC concentrations to be used to compare to target remediation goals.

III.A.1 Data Management

Recent OU4 RFI/RI data from surficial soils and vadose zone soils were used to define the potential nature and extent of contamination at the site. Surficial soil were defined as soil from 0 to 3 inches in depth, and vadose zone soils were defined as soils from 3 inches to the mean historic high water table elevation. Data on inorganic and radionuclide analytes were statistically compared to appropriate populations from the Rock Creek background surficial soil data (DOE, 1993a) and the *1993 Background Geochemical Characterization Report for the Rocky Flats Plant* data for vadose zone soils (DOE, 1993b) to determine potential site-related contamination.

All surficial soil samples collected as part of the OU4 RFI/RI program were used to evaluate the potential presence of contamination at the site and develop representative chemical concentrations. Only OU4 RFI/RI vadose zone soil samples taken from above the mean historic high water table elevation were used in subsequent analysis. The sampling strategy followed as part of the OU4 RFI/RI program (limited to 2-foot and 6-foot composite samples) would not readily support further data aggregation of soil samples by depth. The vadose zone soils used in this analysis can be generically called unconsolidated material which includes all soil above the weathered bedrock. Not all soil data used in this analysis have been validated. An analysis of the completeness, accuracy, and representativeness of the OU4 RFI/RI data is contained within Part II of this document. A fully validated data set will be used to support the baseline risk assessment.

Background surficial soil data from Rock Creek were used as representative background populations for statistical analysis. Data from the following 20 background samples were included in this analysis (by unique sample number): SS03000WS, SS03001WS, SS03004WS, SS03006WS, SS03010WS, SS03011WS, SS03013WS, SS03014WS, SS03015WS, SS03018WS, SS03019WS, SS20040WC, SS20042WC, SS20043WC, SS20044WC, SS20045WC, SS20046WC, SS20047WC, and SS20047WC. Background vadose zone soil data from the Rocky Flats Alluvium (RFA), as reported in the *1993 Background Geochemical Characterization Report* (DOE, 1993b), were used as representative background populations for statistical analysis. RFA was selected as the representative background geologic unit suitable for comparison purposes because nearly all of the industrial area at the RFP, including the SEPs, is underlain by RFA and similar unconsolidated material. Data from eight different boreholes used to characterize background RFA were used in this analysis: B400089, B400289, B400389, B400489, B200589, B200689, B200789, and B200889. Only background vadose zone soil samples taken from above the mean historic high water table elevation were used.

III.A.2 Data Useability Analysis

Data from the OU4 RFI/RI program were carefully reviewed in a multi-step process to develop a final data set suitable to support statistical and risk analyses. Data were obtained from the Rocky Flats Environmental Database System (RFEDS), which has been validated in part by an independent subcontractor to DOE (QuantaLex) upon receipt from the analytical laboratory. Data obtained from RFEDS were subject to several additional quality checks in accordance with the guidance set forth in OSWER Directive 9285.7-09A *Guidance for Data Useability in Risk Assessment (Part A),* Final (EPA, 1992). All data that had been rejected during validation were discarded from the data set. Tentatively identified compounds (TICs), as defined by the analytical laboratory, were also eliminated from the data set. Data was then evaluated in terms of precision to determine how best to treat QC samples (duplicates, replicates) when compiling a final data set for statistical evaluation.

Validated data are classified within RFEDS in one of three ways: (1) V = valid and useable without qualification; (2) A = acceptable for use with qualification; and (3) R = rejected. Data that are marked as rejected were not used in any of the statistical computations or in the data-quality assessment. The precision of the data was examined to assess how best to use QC data such as duplicates and replicates. Precision is a measure of the reproducibility of analytical results. Precision is expressed quantitatively by the relative percent difference (RPD) between duplicate/replicate field samples. An initial screening was performed on the OU4 RFI/RI data to determine the precision of soil analytical results. An RPD for each analyte was calculated as follows:

$$RPD = \sum \frac{|R_1 - R_2|}{(R_1 + R_2)/2} x100$$

where R_1 and R_2 are the analytical results of the field sample and its QC partner. RPD values were not calculated for data that were flagged as with a U, UJ, or B (metals only) by the laboratory or during data validation, or which were reported as less than or equal to zero (anions and radionuclides only). The data flag "J" indicates an estimated analytical result. For most of the RFI/RI data, the flags "U" and "UJ" indicate the analyte was not detected above the contract-required detection limit (CRDL). The data flag "B" indicates the analytical result is greater than the instrument detection limit (IDL) but less than the method detection limit (MDL). More details on detection limits is presented later in this appendix.

The RPD used to delineate lack of precision was 20 percent. Although a high degree of variability is anticipated with soil analytical results due to the heterogeneity of the solid medium, a RPD value greater than 20 percent suggests a statistically significant difference that may insert bias into result interpretation. The only OU4 RFI/RI data sets to demonstrate an RPD value less than 20 percent were surficial soil metals, surficial soil water quality parameters, and vadose zone soil water quality parameters. Analytical results and QC partners could be averaged to create a single-point value without inserting significant bias into the data set. However, all other data sets exhibited RPD values greater than 20 percent. In these cases, only the reported analytical result was used in statistical computations. Table III.A-1 summarizes the results of the precision analysis.

Comparability between historic OU4 data (defined as data collected prior to the RFI/RI program) and the recent RFI/RI data was also examined. Comparability expresses the extent to which data collected over a period of years and analyzed with different methods can be considered equivalent. Comparability is assessed primarily by examining the precision of the data for possible correlations with sample date. However, rather than conduct a simple precision analysis on the historic and RFI/RI data, non-parametric analysis of variance (ANOVA) tests were employed to determine whether the two data sets were statistically different. The goal of this evaluation was to assess whether historic and RFI/RI represented statistically similar (comparable) data sets that could be combined and used in quantitative statistical computations. The Gehan Test (discussed later in this appendix) was used to determine whether historic data was statistically comparable to RFI/RI data. Results of this evaluation indicated that all metal, radionuclide, inorganic, water quality, and organic data sets were statistically significant. Thus the OU4 RFI/RI data set was used in quantitative statistical computations; historical data was used as a qualitative tool in support of statistical computations.

The RFI/RI data sets were not screened for outliers. An outlier is defined as an extreme result that does not conform to the pattern established by other results and is unlikely to be a valid member of the population of interest. An outlier may be the result of incorrectly read,

TABLE III.A-1
CALCULATED RELATIVE PERCENT DIFFERENCE
FOR PCOCs AT OU4

Potential Contaminant of Concern	Relative Percentage Difference (%)	
	Vadose	Surficial
Aluminum	1.6	13
Antimony	1.6	0.31
Arsenic	48	9.5
Barium	15	31
Beryllium	0	7.7
Cadmium	46	13
Calcium	50	0.9
Cesium	1.6	0.23
Chromium	5.8	5.4
Cobalt	27	3.8
Copper	10	7
Iron	17	8.4
Lead	69	14
Lithium	6.5	15
Magnesium	14	7.2
Manganese	58	6.8
Mercury	11	19
Molybdenum	2.1	0.57
Nickel	40	5.2
Potassium	12	12
Selenium	2	0.57
Silicon	11	0.35
Silver	8	13
Sodium	15	2.8
Strontium	29	12
Thallium	0.61	0.74
Tin	17	14
Vanadium	0.45	9.4
Zinc	20	1.6
Americium-241	25	0.78
Cesium-134	–	133
Gross Alpha	1.5	1.5
Gross Beta	22	16
Plutonium-239/240	39	17
Radium-226	16	13
Radium-228	9.8	–
Strontium-89/90	41	16
Tritium	8.6	146
Uranium-233/234	2.5	15
Uranium-235	23	0
Uranium-238	5.9	1.3

TABLE III.A–1
CALCULATED RELATIVE PERCENT DIFFERENCE
FOR PCOCs AT OU4

Potential Contaminant of Concern	Relative Percentage Difference (%)	
	Vadose	Surficial
Acetone	74	–
Benzo(a)anthracene	2.7	30
Benzo(a)pyrene	2.7	14
Benzo(b)fluoranthene	2.7	41
Benzo(g,h,i)perylene	2.7	21
Bis(2–ethylhexyl)phthalate	2.7	36
Chrysene	2.7	32
Di–n–butylphthalate	2.7	14
Fluoranthene	2.7	17
Indeno(1,2,3–cd)pyrene	2.7	5
Methylene Chloride	49	–
Phenanthrene	2.7	27
Pyrene	2.7	22
Toluene	7	–

recorded, or transcribed data; an incorrect calculation; an error in documentation; or an actual environmental condition. There are no universally applicable outlier tests, so data was not eliminated from the data set to be used in statistical computations on the basis of this type of screening step.

III.A.3 Exploratory Data Analysis

In July 1993, the Rocky Flats Office (RFO), Region VIII of the US Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) jointly sponsored the development of statistical procedures that could be used to compare specific OU characterization data to background data at the RFP. Dr. Richard O. Gilbert from the Statistical Design and Analysis Group at Battelle Pacific Northwest Laboratories developed a multi-phase process suitable for comparing specific OU data to background data. This process allowed evaluation of whether the OU site concentrations were statistically higher than those in background media. On October 8, 1993, this process (hereafter called the Gilbert process) was selected for use in the OU4 IM/IRA program to identify inorganic and radionuclide analytes that may be present in concentrations significantly higher than those in background media. The process was not applied to the organic analytes, however, because it was assumed that background organic analytes would not be present in significant amounts due to anthropogenic sources independent of RFP. For this data set, the techniques described in OSWER Directive 9285.7-01A *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (RAGS) (EPA, 1989) were used to identify potential organic analytes of interest. The techniques used do not include background analyses for organic analytes, but are based on frequency of detection data which may indicate an analyte is present at the site. Figure III.A-1 shows the flow shart for evaluating inorganic and radionuclide data. Figure III.A-2 shows the flow chart for evaluating organic data.

The first step in the Gilbert process is to visually examine the magnitude and variability of the RFI/RI data. Data for inorganic and radionuclide analytes for which there is background data were graphically compared to identify the degree of overlap between the two data sets, and to facilitate interpretation of distribution fitting tests and summary statistic results. Data for organic analytes for which there is no background data were graphically presented to facilitate interpretation of distribution fitting tests and summary statistic results. All data, even those below the detection limit, are included in the plots. Boxplots of all measured radionuclides were prepared and compared to background data. Histograms of all measured metals were prepared and compared to background data. Probability plots of organics and other analytes were prepared for only those analytes detected at the site with a frequency equal to or greater than 5 percent. To emphasize data pertaining to analytes that represent potential site contamination, only plots for analytes that were determined to be PCOCs are included in this appendix for review. The plots suggest that most analytes can reasonably be described by the lognormal distribution.

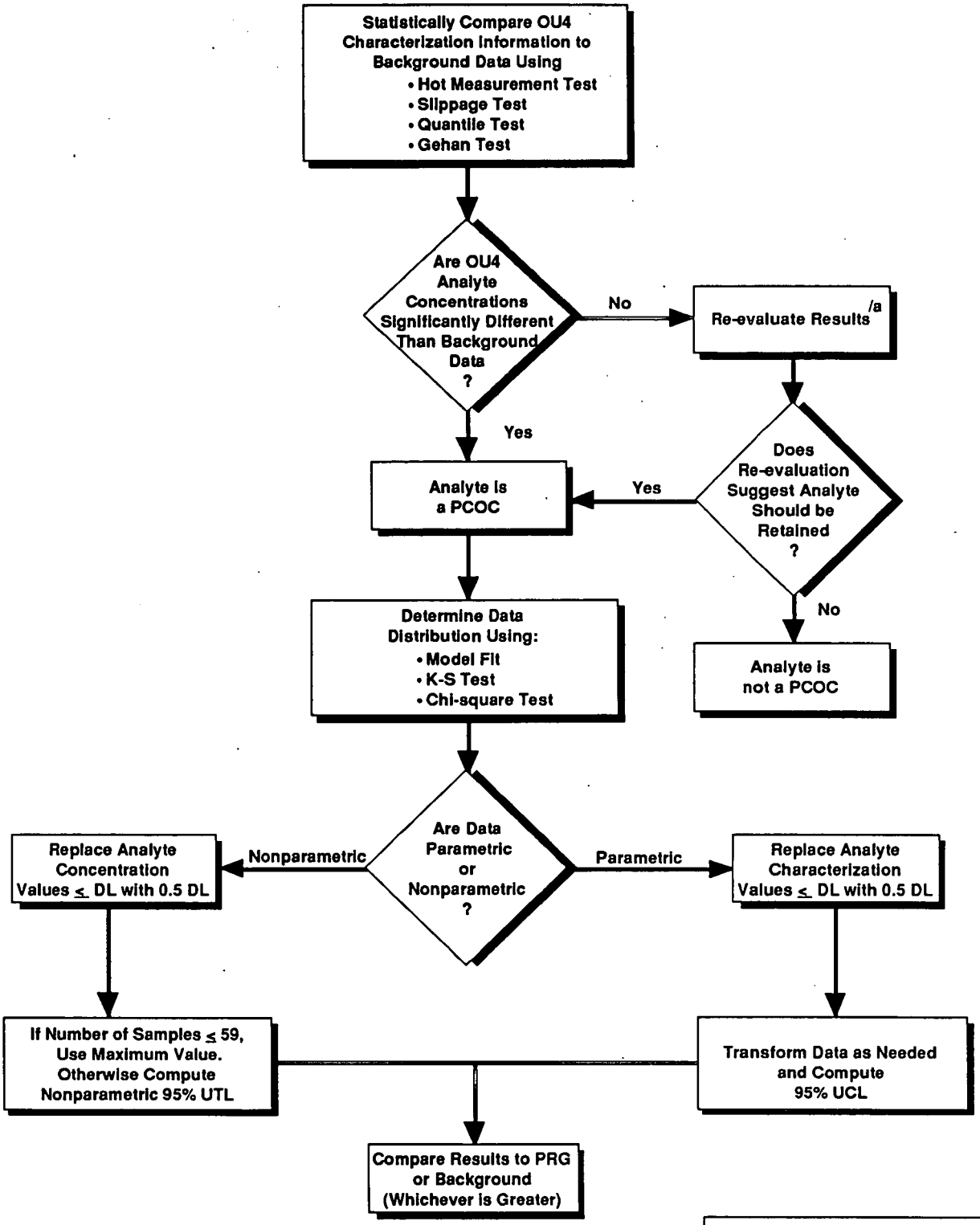

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Figure III.A-1

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
PCOC Identification/Quantification of Inorganics/Radionuclides

Notes:

a/ Refer to Appendix III-C and text for further details on other comparison and statistical "tools."

PCOC=Potential Contaminant of Concern

DL= Detection Limit

307IM14.pm4 PN nap 51394

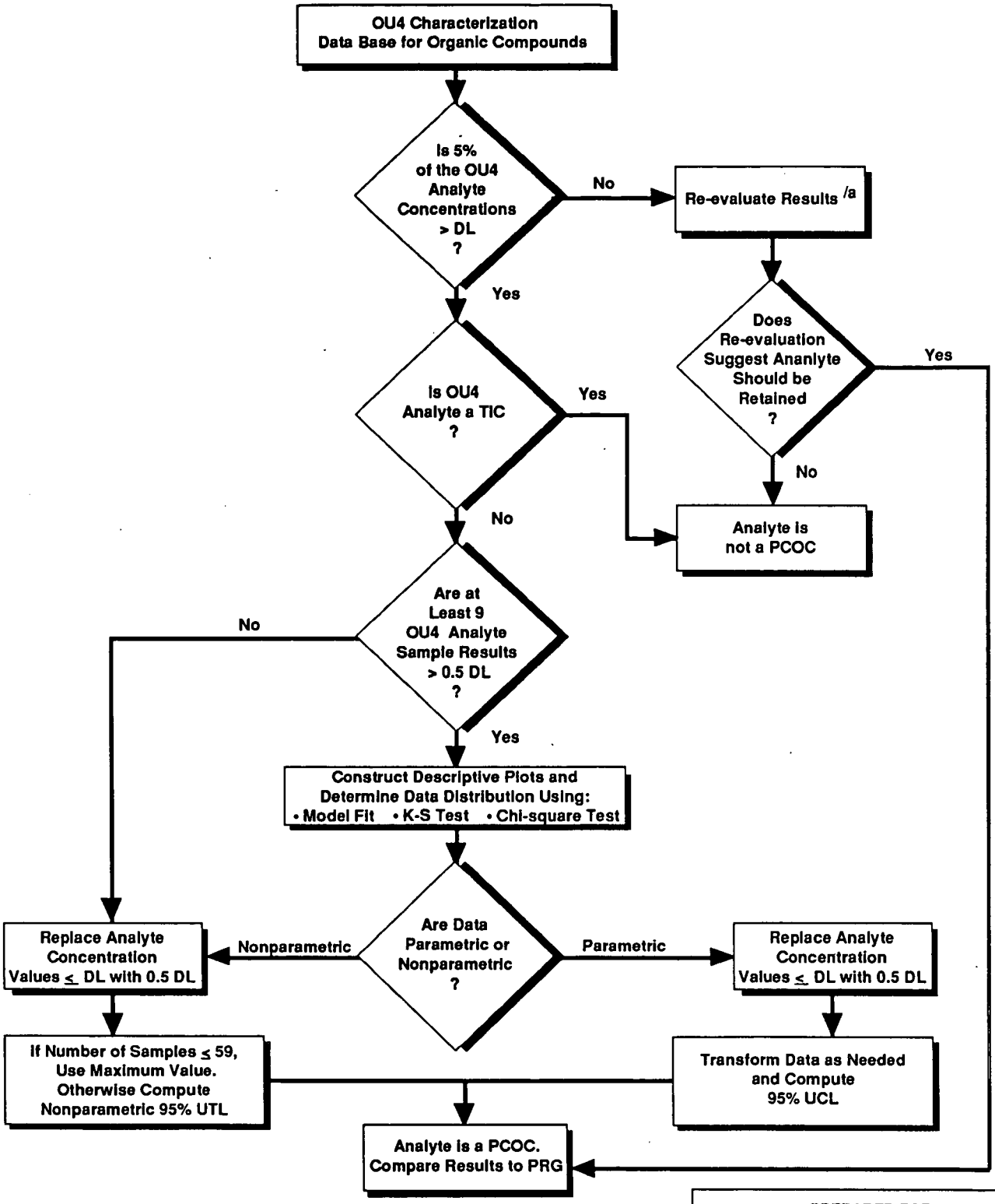

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Figure III.A-2

Solar Evaporation Ponds
Operable Unit No. 4, IM/IRA EA DD
PCOC Identification/Quantification of Organics

Notes:

a/ Refer to Appendix III-C and text for further details on other comparison and statistical "tools."

PCOC= Potential Contaminant of Concern
DL= Detection Limit
TIC= Tentatively Identified Compound

307IM15.pm4 PN nap 51394

Identifying analytical results which are below detection limits was complicated by the numerous reporting limits and result qualifiers in the RFI/RI data set. In some instances, the reported analytical result was the CRDL if the data were above the IDL but below the CRDL. Additionally, although the result qualifier field in the data set can be used to distinguish detects from non-detects, these values were not consistently available to support data analysis. To promote consistent treatment of the data and to maximize the amount of useful data available for analysis, the following approach was used:

(1) Analytical results for metals were defined as detects if the result qualifier field had a "B" code (indicating that the result was above the IDL but below the CRDL), or if the validation flag was a "JA" (indicating an acceptable, estimated value above the IDL but below the CRDL), or if the analytical result was greater than the reporting limit. If the data for metals did not meet at least one of these criteria, it was taken as a non-detect value.

(2) Result qualifier codes were used to define analytical results for radionuclides, organics, and water quality parameters as either non-detects ("U" value or variation on U codes) or detects.

Reported values for non-detect results were included in the data set when conducting non-parametric ANOVA tests and distribution fitting. Non-detect values were only replaced with one-half the reported result before computing summary statistics for each analyte suspected to represent site contamination. Other treatment of non-detects may yield somewhat different values, the use of a fixed replacement value for non-detects has the virtues of simplicity, widespread use, and consistency with RAGS guidance. This approach yields reasonably correct values for data sets with at least 80 percent detected results. The worst possible treatment of non-detect values is to eliminate them from statistical analyses (Gilbert, 1993).

Specific information on benchmark concentrations (e.g., minimum and maximum values), historical evidence, biomagnification properties, and other qualitative data on analytes included in the RFI/RI data set used in statistical computations are included in Tables III.A-2 through III.A-9. These tables also indicate the results of the frequency of detection analysis.

Table III.A-2. Summary of Additional Data Comparison and Evaluation Criteria: Identification of Potential Inorganic Contaminants of Concern (PCOCs) in Surficial Soil OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte – metals (mg/kg)	Analyzed in SS? (1)	>DL? (2)	<DL? (3)	Historical evidence? (4)	Analyzed in backgrnd? (5)	10x backgrnd? (6)	Biomag? (7)	Remarks (8)
Aluminum	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Antimony	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Arsenic	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Barium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Beryllium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Cadmium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Historical use evidence based on OU4-specific operations data
Calcium	Yes	Yes	No	Yes	Yes	Yes	No	Historical use evidence based on OU4-specific operations data
Cesium	Yes	No	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Chromium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Cobalt	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Copper	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Iron	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Lead	Yes	Yes	No	Yes?	Yes	No	No	Historical use evidence based on OU4-specific operations data
Lithium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Magnesium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Manganese	Yes	Yes	No	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Mercury	Yes	Yes	Yes	Yes?	Yes	Yes	Yes	Historical use evidence based on OU4-specific operations data
Molybdenum	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Nickel	Yes	Yes	Yes	Yes	Yes	Yes	No	Historical use evidence based on OU4-specific operations data
Nitrate	Yes	Yes	No	Yes	Yes	Yes	No	Historical use evidence based on OU4-specific operations data
Potassium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on OU4-specific operations data
Selenium	Yes	Yes	Yes	?	Yes	No	Yes	Historical use evidence based on RFP-wide operations data
Silicon	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Silver	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on OU4-specific operations data
Sodium	Yes	Yes	Yes	Yes	Yes	Yes	No	Historical use evidence based on OU4-specific operations data
Strontium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Thallium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Tin	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data
Vanadium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP-wide operations data
Zinc	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4-specific operations data

1. "Analyzed in SS?" indicates whether OU4 surficial soil samples were analytically screened for this analyte.
2. ">DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once above the reported detection limit.
3. "<DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Historical evidence" indicates whether the presence of the analyte in OU4 surficial soil samples is supported by process records and other historical information.
5. "Analyzed in backgrnd" indicates whether background surficial soil samples were analytically screened for this analyte.
6. "10x backgrnd" indicates whether the analyte was reported to be present in OU4 surficial soil samples at concentrations approximately equal to or greater than 10 times the maximum background concent measured in OU1 and/or OU2 background surficial soil data.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A–3. Summary of Additional Data Comparison and Evaluation Criteria: Identification of Potential Inorganic Contaminants of Concern (PCOCs) in Vadose Soil OU4, Solar Evaporation Ponds, IM/IRA–EA Rocky Flats Plant, Golden, Colorado

Analyte – metals (mg/kg)	Analyzed in BH? (1)	>DL? (2)	<DL? (3)	Historical evidence? (4)	Analyzed in backgrnd? (5)	10x backgrnd? (6)	Biomag? (7)	Remarks (8)
Aluminum	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Antimony	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Arsenic	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Barium	Yes	Yes	Yes	–	Yes	Yes	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Beryllium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Cadmium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Calcium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Cesium	Yes	Yes	Yes	–	Yes	Yes	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Chromium	Yes	Yes	Yes	Yes	Yes	Yes	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Cobalt	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Copper	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Iron	Yes	Yes	No	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Lead	Yes	Yes	No	Yes?	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Lithium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Magnesium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Manganese	Yes	Yes	No	–	Yes	Yes	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Mercury	Yes	Yes	Yes	Yes?	Yes	Yes	Yes	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Molybdenum	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Nickel	Yes	Yes	Yes	Yes	Yes	Yes	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Potassium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Selenium	Yes	Yes	Yes	?	Yes	No	Yes	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Silicon	Yes	Yes	No	Yes	No	– –	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Silver	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Sodium	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Strontium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Thallium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Tin	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.
Vanadium	Yes	Yes	Yes	–	Yes	No	No	Historical use evidence based on RFP–wide operations data; max. data in Pond 20??? area.
Zinc	Yes	Yes	Yes	Yes	Yes	No	No	Historical use evidence based on OU4–specific operations data; max. data in Pond 20??? area.

1. "Analyzed in BH?" indicates whether OU4 borehole soil samples were analytically screened for this analyte.
2. ">DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once above the reported detection limit.
3. "<DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Historical evidence" indicates whether the presence of the analyte in OU4 borehole soil samples is supported by process records and other historical information.
5. "Analyzed in backgrnd" indicates whether background borehole soil samples were analytically screened for this analyte.
6. "10x backgrnd" indicates whether the analyte was reported to be present in OU4 borehole soil samples at concentrations approximately equal to or greater than 10 times the mean background concentration as repo Background Geochemical Characterization Report.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A-4. Summary of Additional Data Comparison and Evaluation Criteria:
Identification of Potential Radionuclide Contaminants of Concern (PCOCs) in Surficial Soil
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Analyte – radionuclides (pCi/g)	Analyzed in SS? (1)	>DL? (2)	<DL? (3)	Historical evidence? (4)	Analyzed in background? (5)	10x backgrnd? (6)	Biomag? (7)	Remarks (8)
Americium-241	Yes	Yes	No	Yes	Yes	–	–	Historical use evidence based on OU4-specific operations data
Cesium-134	Yes	Yes	Yes	–	Yes	No	–	Historical use evidence based on RFP-wide operations data
Cesium-137	Yes	Yes	Yes	–	Yes	No	–	Historical use evidence based on RFP-wide operations data
Gross alpha	Yes	Yes	No	Yes	Yes	–	–	Historical use evidence based on OU4-specific operations data
Gross beta	Yes	Yes	No	Yes	Yes	–	–	Historical use evidence based on OU4-specific operations data
Plutonium 239/240	Yes	Yes	No	Yes	Yes	Yes	–	Historical use evidence based on OU4-specific operations data
Radium-226	Yes	Yes	No	–	Yes	–	–	Historical use evidence based on RFP-wide operations data
Radium-228	Yes	Yes	No	–	Yes	–	–	Historical use evidence based on RFP-wide operations data
Strontium-89/90	Yes	Yes	Yes	–	Yes	–	–	Historical use evidence based on RFP-wide operations data
Tritium (pCi/ml)	Yes	Yes	Yes	–	No	–	No	Historical use evidence based on OU4-specific operations data
Uranium-233/234	Yes	Yes	No	–	Yes	Yes	Yes?	Historical use evidence based on OU4-specific operations data
Uranium-235	Yes	Yes	Yes	–	Yes	Yes	–	Historical use evidence based on OU4-specific operations data
Uranium-238	Yes	Yes	No	–	Yes	Yes	–	Historical use evidence based on OU4-specific operations data

1. "Analyzed in SS?" indicates whether OU4 surficial soil samples were analytically screened for this analyte.
2. "> DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once above the reported detection limit.
3. "< DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Historical evidence" indicates whether the presence of the analyte in OU4 surficial soil samples is supported by process records and other historical information.
5. "Analyzed in backgrnd" indicates whether background surficial soil samples were analytically screened for this analyte.
6. "10x backgrnd" indicates whether the analyte was reported to be present in OU4 surficial soil samples at concentrations approximately equal to or greater than 10 times the mean background concentration as reported in OU1 and/or OU2 background surficial soil data.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A–5. Summary of Additional Data Comparison and [illegible]tion Criteria: Identification of Potential Radionuclide Contaminants of Concern (PCOCs) in Vadose Soil OU4, Solar Evaporation Ponds, IM/IRA–EA Rocky Flats Plant, Golden, Colorado

Analyte – radionuclides (pCi/g)	Analyzed in BH? (1)	>DL? (2)	<DL? (3)	Historical evidence? (4)	Analyzed in backgrnd? (5)	10x backgrnd? (6)	Biomag? (7)	Remarks (8)
Americium–241	Yes	Yes	Yes	Yes	Yes	–	–	Historical use evidence based on OU4–specific operations data
Cesium–134	Yes	No	Yes	–	No	–	–	Historical use evidence based on RFP–wide operations data
Cesium–137	Yes	Yes	Yes	–	Yes	No	–	Historical use evidence based on RFP–wide operations data
Gross alpha*	Yes	Yes	No	Yes	Yes	No	–	Historical use evidence based on OU4–specific operations data
Gross alpha – dissolved	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Gross alpha – susp.	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Gross alpha – particle activity/radioactivity	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Gross beta**	Yes	Yes	No	Yes	Yes	Yes	–	Historical use evidence based on OU4–specific operations data
Gross beta – dissolved	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Gross beta – susp.	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Gross beta – particle radioactivity	Yes	No	Yes	Yes	No	–	–	Historical use evidence based on OU4–specific operations data
Plutonium–238	Yes	No	Yes	–	No	–	–	Historical use evidence based on OU4–specific operations data
Plutonium 239/240	Yes	Yes	Yes	Yes	Yes	Yes	–	Historical use evidence based on OU4–specific operations data
Radium–226	Yes	Yes	No	–	Yes	No	–	Historical use evidence based on RFP–wide operations data
Radium–228	Yes	Yes	No	–	Yes	No	–	Historical use evidence based on RFP–wide operations data
Strontium–89/90	Yes	Yes	Yes	–	Yes	No	–	Historical use evidence based on RFP–wide operations data
Tritium (pCi/ml)	Yes	Yes	Yes	–	Yes	Yes	No	Historical use evidence based on OU4–specific operations data
Uranium–233/234	Yes	Yes	No	–	No	Yes	Yes?	Historical use evidence based on OU4–specific operations data
Uranium–235	Yes	Yes	Yes	–	Yes	No	–	Historical use evidence based on OU4–specific operations data
Uranium–238	Yes	Yes	No	–	Yes	Yes	–	Historical use evidence based on OU4–specific operations data

* Data also reported for dissolved, suspended, and particle activity/radioactivity; not included in statistical evaluations but considered here.

**Data also reported for dissolved, suspended, and particle activity/radioactivity; not included in statistical evaluations but considered here.

1. "Analyzed in BH?" indicates whether OU4 borehole soil samples were analytically screened for this analyte.
2. ">DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once above the reported detection limit.
3. "<DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Historical evidence" indicates whether the presence of the analyte in OU4 borehole soil samples is supported by process records and other historical information.
5. "Analyzed in backgrnd" indicates whether background borehole soil samples were analytically screened for this analyte.
6. "10x backgrnd" indicates whether the analyte was reported to be present in OU4 borehole soil samples at concentrations approximately equal to or greater than 10 times the mean background concentration a Background Geochemical Characterization Report.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A–6. Summary of Additional Data Comparison and Evaluation Criteria:
Identification of Possible Volatile and Semi–Volatile Organic Contaminants of Concern (PCOCs) in Surficial Soil
OU4, Solar Evaporation Ponds, IM/IRA–EA
Rocky Flats Plant, Golden, Colorado

Analyte – volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in SS? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (8)	Remarks (9)
Butyl benzyl phthalate		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available

Analyte – semi–volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in SS? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (8)	Remarks (9)
1,2–dichlorobenzene	DCB	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
1,2,4–trichlorobenzene		Yes	No	Yes	0/91		No	No	No specific operational use evidence available
1,3–dichlorobenzene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
1,4–dichlorobenzene	p–DCB	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4,5–trichlorophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4,6–trichlorophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4–dichlorophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4–dimethylphenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4–dinitrophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,4–dinitrotoluene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2,6–dinitrotoluene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2–chloronapthalene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2–chlorophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2–methylnapthalene		Yes	No	Yes	0/90	?	No	No	No specific operational use evidence available
2–methylphenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2–nitroaniline		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
2–nitrophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
3,3–dichlorobenzidine		Yes	No	Yes	0/80	?	No	No	No specific operational use evidence available
3–nitroaniline		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
3–penten–2–one		Yes	No	No	0/91	?	No	No	No specific operational use evidence available
4,6–dinitro–2–methylphenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available

Table III.A–6 (continued). Summary of Additional Data Comparison and Evaluation Criteria:
Identification of Possible Volatile and Semi–Volatile Organic Contaminants of Concern (PCOCs) in Surficial Soil
OU4, Solar Evaporation Ponds, IM/IRA–EA
Rocky Flats Plant, Golden, Colorado

Analyte – semi–volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in SS? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (8)	Remarks (9)
4–bromophenyl ether		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–chloroaniline		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–chloro–3–methyl phenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–chlorophenyl phenyl ether		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–methylphenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–nitroaniline		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
4–nitrophenol		Yes	No	Yes	0/89	?	No	No	No specific operational use evidence available
Acenaphthene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Acenaphthylene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Anthracene		Yes	Yes	Yes	3/91	?	No	No	No specific operational use evidence available
Benzoic acid	phenylformic acid	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Benzo(a)anthracene		Yes	Yes	Yes	7/91	?	No	No	No specific operational use evidence available
Benzo(a)pyrene		Yes	Yes	Yes	10/91	?	No	No	No specific operational use evidence available
Benzo(b)fluoranthene		Yes	Yes	Yes	18/91	?	No	No	No specific operational use evidence available
Benzo(ghi)perylene		Yes	Yes	Yes	5/91	?	No	No	No specific operational use evidence available
Benzo(k)fluoranthene		Yes	Yes	Yes	17/84	?	No	No	No specific operational use evidence available
Benzyl alcohol	phenylcarbinol	Yes	No	Yes	0/87	?	No	No	No specific operational use evidence available
Bis(2–chloroethoxy)methane		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Bis(2–chloroisopropyl)ether		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Bis(2–choroethyl)ether		Yes	Yes	Yes	16/91	?	No	No	No specific operational use evidence available
Bis(2–ethylhexyl)phthalate		Yes	Yes	Yes	23/24	?	No	No	No specific operational use evidence available
Chrysene	1,2–benzphenanthre	Yes	Yes	Yes	10/91	?	No	No	No specific operational use evidence available
Dibenzofuran	diphenylene oxide	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Dibenzo(a,h)anthracene	pentacene	Yes	Yes	Yes	1/91	?	No	No	No specific operational use evidence available
Diethyl phthalate	ethyl phthalate	Yes	Yes	Yes	2/86	?	No	No	No specific operational use evidence available
Dimethyl phthalate	DMP	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Di–n–butyl phthalate	DBP	Yes	Yes	Yes	5/91	?	No	No	No specific operational use evidence available
Di–n–octyl phthalate		Yes	Yes	Yes	3/91	?	No	No	No specific operational use evidence available
Fluoranthene	idryl	Yes	Yes	Yes	18/91	?	No	No	No specific operational use evidence available
Fluorene		Yes	Yes	Yes	1/91	?	No	No	No specific operational use evidence available
Hexachlorobenzene	perchlorobenzene	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Hexachlorobutadiene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Hexachlorocyclopentadiene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Hexachloroethane	carbon trichloride	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available

Table III.A-6 (concluded). Summary of [illegible]tional Data Comparison and Evaluation Criteria: Identification of Possible Volatile and Semi-Volatile Organic Contaminants of Concern (PCOCs) in Surficial Soil OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte – semi-volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in SS? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (8)	Remarks (9)
Indeno(1,2,3-cd)pyrene		Yes	Yes	Yes	5/91	?	No	No	No specific operational use evidence available
Isophorone		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Napthalene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Nitrobenzene		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
N-nitrosodiphenylamine		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
N-nitroso-di-propylamine		Yes	No	No	0/91	?	No	No	No specific operational use evidence available
Pentachlorophenol		Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Phenanthrene		Yes	Yes	Yes	15/91*	?	No	No	No specific operational use evidence available
Phenol	carbolic acid	Yes	No	Yes	0/91	?	No	No	No specific operational use evidence available
Pyrene		Yes	Yes	Yes	19/91	?	No	No	No specific operational use evidence available

*Presence suggested by historical data.

1. "Synomyns" identifies any other names the analyte/compound is commonly called.
2. "Analyzed in SS?" indicates whether OU4 surficial soil samples were analytically screened for this analyte.
3. ">DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once above the reported detection limit.
4. "<DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once at a concentration equal to or less than the reported detection limit.
5. "Freq. detect?" indicates the frequency with which the analyte was measured in OU4 surficial soil samples above the reported detection limit.
6. "Historical evidence" indicates whether the presence of the analyte in OU4 surficial soil samples is supported by process records and other historical information.
7. "Analyzed in backgrnd" indicates whether background surficial soil samples were analytically screened for this analyte.
8. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
9. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A-7. Summary of Additional D[illegible]Comparison and Evaluation Criteria:
Identification of Possible Volatile and Semi-Volatile Organic Contaminants of Concern (PCOCs) in Vadose Soil
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Analyte – volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in BH? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (8)	Remarks (9)
1,1,1-trichloroethane	methyl chloroform	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,1,2,2-tetrachloroethane		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,1,2-trichloroethane	vinyl trichloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,1-dichloroethane	ethylidene chloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,1-dichloroethene	vinylidiene chloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,2-dichloroethane	DCE(cis&trans isomers)	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,2-dichloropropane	Propylene dichloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,2-dichoroethane	(DCA)ethylene dichloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
1,3-dichlorobenzene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-butanone	methyl ethyl ketone	Yes	No	Yes	0/15*	?	No	No	No specific operational use evidence available
2-hexanone		Yes	No	Yes	0/90	?	No	No	No specific operational use evidence available
2-pentanone	methyl propyl ketone	Yes	No	No	0/90	?	No	No	No specific operational use evidence available
Acetone	2-propanone	Yes	Yes	Yes	13/80	?	No	No	No specific operational use evidence available
Benzene	benzol	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Bromodichloromethane		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Bromoform	methyl tribromide	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Bromomethane	methyl bromide	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Butyl benzyl phthalate		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Carbon disulfide		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Carbon tetrachloride	tetrachloromethane	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Chlorobenzene	phenyl chloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Chloroethane	ethyl chloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Chloroform	trichloromethane	Yes	Yes	Yes	0/92*	?	No	No	No specific operational use evidence available
Chloromethane	methyl chloride	Yes	No	Yes	0/90	?	No	No	No specific operational use evidence available
cis-1,3-dichloropropene		Yes	No	Yes	0/92*	?	No	No	No specific operational use evidence available
Dibromochloromethane	chlorodibromomethane	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Ethylbenzene	phenylethane	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Methylene chloride	dichloromethane	Yes	Yes	Yes	14/92	?	No	No	No specific operational use evidence available
Styrene		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Tetrachloroethene		Yes	No	Yes	1/92	?	No	No	No specific operational use evidence available

Table III.A-7 (continued). Summary of Additional Data Comparison and Evaluation Criteria: Identification of Possible Volatile and Semi-Volatile Organic Contaminants of Concern (PCOCs) in Vadose Soil OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte – volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in BH? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (9)	Remarks (10)
Toluene	methylbenzene	Yes	Yes	Yes	89/92	?	No	No	No specific operational use evidence available
Total xylene		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
trans-1,3-dichloropropene		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Tributyl phosphate	TBP	Yes	No	Yes	0/6	?	No	No	No specific operational use evidence available
Trichloroethene	ethylene trichloride	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Vinyl acetate		Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available
Vinyl chloride	chloroethene	Yes	No	Yes	0/92	?	No	No	No specific operational use evidence available

Analyte – semi-volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in BH? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (9)	Remarks (10)
1,2,4-trichlorobenzene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
1,2-dichlorobenzene	DCB	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
1,4-dichlorobenzene	p-DCB	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4,5-trichlorophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4,6-trichlorophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4-dichlorophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4-dimethylphenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4-dinitrophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,4-dinitrotoluene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2,6-dinitrotoluene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-chloronapthalene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-chlorophenol		Yes	No	Yes	0/21	?	No	No	No specific operational use evidence available
2-methylnapthalene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-methylphenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-nitroaniline		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
2-nitrophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
3,3-dichlorobenzidine		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
3-nitroaniline		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4,6-dinitro-2-methylphenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-bromophenyl ether		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-chloroaniline		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-chlorophenyl phenyl ether		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-chloro-3-methylphenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-methylphenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-nitroaniline		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
4-nitrophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Acenaphthene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Anthracene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Acenaphthylene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available

Table III.A-7 (continued). Summary of Additional Data Com[illegible]n and Evaluation Criteria: Identification of Possible Volatile and Semi-Volatile Organic Contaminants of Concern (PCOCs) in Vadose Soil OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte – semi-volatile organics (ug/kg)	Common Synomyns (1)	Analyzed in BH? (2)	>DL? (3)	<DL? (4)	Freq detect? (5)	Historical evidence? (6)	Analyzed in backgrnd? (7)	Biomag? (9)	Remarks (10)
Benzoic acid	phenylformic acid	Yes	No	Yes	0/18	?	No	No	No specific operational use evidence available
Benzo(a)anthracene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Benzo(a)pyrene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Benzo(b)fluoranthene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Benzo(ghi)perylene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Benzo(k)fluoranthene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Benzyl alcohol	phenylcarbinol	Yes	No	Yes	0/15	?	No	No	No specific operational use evidence available
Bis(2-chloroethoxy)methane		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Bis(2-chloroisopropyl)ether		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Bis(2-choroethyl)ether		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Bis(2-ethylhexyl)phthalate		Yes	Yes	Yes	1/24*	?	No	No	No specific operational use evidence available
Carbozole		Yes	No	Yes	0/6	?	No	No	No specific operational use evidence available
Chrysene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Dibenzofuran	diphenylene oxide	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Dibenzo(a,h)anthracene	pentacene	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Diethyl phthalate		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Dimethyl phthalate	DMP	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Di-n-butyl phthalate	DBP	Yes	Yes	Yes	0/24*	?	No	No	No specific operational use evidence available
Di-n-octyl phthalate		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Fluoranthene	idryl	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Fluorene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Hexachlorobenzene	perchlorobenzene	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Hexachlorobutadiene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Hexachlorocyclopentadiene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Hexachloroethane	carbon trichloride	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Indeno(1,2,3-cd)pyrene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Isophorone		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Napthalene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Nitrobenzene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
N-nitrosodiphenylamine		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
N-nitroso-di-propylamine		Yes	No	No	0/24	?	No	No	No specific operational use evidence available
Pentachlorophenol		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Phenanthrene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Phenol	carbolic acid	Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available
Pyrene		Yes	No	Yes	0/24	?	No	No	No specific operational use evidence available

* Presence suggested by historical data.

1. "Synomyns" identifies any other names the analyte/compound is commonly called.
2. "Analyzed in BH?" indicates whether OU4 borehole soil samples were analytically screened for this analyte.
3. ">DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once above the reported detection limit.
4. "<DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once at a concentration equal to or less than the reported detection limit.
5. "Freq. detect?" indicates the frequency with which the analyte was measured in OU4 borehole soil samples above the reported detection limit.
6. "Historical evidence" indicates whether the presence of the analyte in OU4 borehole soil samples is supported by process records and other historical information.
7. "Analyzed in backgrnd" indicates whether background borehole soil samples were analytically screened for this analyte.
8. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
9. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A-8. Summary of Additional Data Comparison and Evaluation Criteria: Identification of Potential Pesticides/PCBs Contaminants of Concern (PCOCs) in Surficial Soil OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte - pesticides/PCBs (ug/kg)	Analyzed in SS? (1)	>DL? (2)	<DL? (3)	Freq. detect? (4)	Historical evidence? (5)	Analyzed in backgrnd? (6)	Biomag? (7)	Remarks (8)
4,4-DDD	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
4,4-DDE	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
4,4-DDT	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Aldrin	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
alpha-BHC	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
alpha-Chlordane	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1016	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1221	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1232	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1242	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1248	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1254	Yes	Yes	Yes	5/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Arochlor-1260	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
beta-BHC	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
delta-BHC	Yes	No	Yes	0/72	No	No	No	No specific operational use evidence available; possible site-wide applications
Dieldrin	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Endosulfan I	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Endosulfan II	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Endosulfan sulfate	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Endrin	Yes	No	Yes	0/72	No	No	No	No specific operational use evidence available; possible site-wide applications
Endrin ketone	Yes	No	Yes	0/72	No	No	No	No specific operational use evidence available; possible site-wide applications
gamma-BHC (Lindane)	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
gamma-Chlordane	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Heptachlor	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Heptachlor epoxide	Yes	No	Yes	0/72	No	No	Yes	No specific operational use evidence available; possible site-wide applications
Methoxychlor	Yes	No	Yes	0/72	No	No	No	No specific operational use evidence available; possible site-wide applications
Toxaphene	Yes	No	Yes	0/72	No	No	No	No specific operational use evidence available; possible site-wide applications

1. "Analyzed in SS?" indicates whether OU4 surficial soil samples were analytically screened for this analyte.
2. "DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once above the reported detection limit.
3. "DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Freq. detect?" indicates the frequency with which the analyte was measured in OU4 surficial soil samples above the reported detection limit.
5. "Historical evidence" indicates whether the presence of the analyte in OU4 surficial soil samples is supported by process records and other historical information.
6. "Analyzed in backgrnd" indicates whether background surficial soil samples were analytically screened for this analyte.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

Table III.A–9. Summary of Additional Data Comparison and Evaluation Criteria: Identification of Potential Pesticides/PCBs Contaminants of Concern (PCOCs) in Vadose Soil OU4, Solar Evaporation Ponds, IM/IRA–EA Rocky Flats Plant, Golden, Colorado

Analyte – pesticides/PCBs (ug/kg)	Analyzed in BH? (1)	>DL? (2)	<DL? (3)	Freq. detect? (4)	Historical evidence? (5)	Analyzed in backgrnd? (6)	Biomag? (7)	Remarks (8)
4,4–DDD	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
4,4–DDE	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
4,4–DDT	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Aldrin	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
alpha–BHC	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
alpha–Chlordane	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1016	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1221	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1232	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1242	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1248	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1254	Yes	No	No	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Arochlor–1260	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
beta–BHC	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
[illegible]nide (mg/kg)	Yes	Yes	Yes	15/77	Yes	No	No	Historical use evidence based on OU4–specific operations data
delta–BHC	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Dieldrin	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Endosulfan I	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Endosulfan II	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Endosulfan sulfate	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Endrin	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Endrin ketone	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
gamma–BHC (Lindane)	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
gamma–Chlordane	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Heptachlor	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Heptachlor epoxide	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Methoxychlor	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications
Toxaphene	Yes	No	Yes	0/16	No	No	Yes	No specific operational use evidence available; possible site–wide applications

1. "Analyzed in BH?" indicates whether OU4 borehole soil samples were analytically screened for this analyte.
2. ">DL" indicates whether the analyte was measured in OU4 surficial soil samples at least once above the reported detection limit.
3. "<DL" indicates whether the analyte was measured in OU4 borehole soil samples at least once at a concentration equal to or less than the reported detection limit.
4. "Freq. detect?" indicates the frequency with which the analyte was measured in OU4 borehole soil samples above the reported detection limit.
5. "Historical evidence" indicates whether the presence of the analyte in OU4 borehole soil samples is supported by process records and other historical information.
6. "Analyzed in backgrnd" indicates whether background borehole soil samples were analytically screened for this analyte.
7. "Biomag" indicates whether the analyte exhibits any known biomagnification properties.
8. "Remarks" provide further details on source of information, location of samples with low rates of detection, etc.

III.A.4 Comparison to Background Data

The aforementioned procedures were completed to develop an RFI/RI data set to support statistical computations and risk analysis for the OU4 IM/IRA program. Data on inorganic and radionuclide analytes from this data set were statistically evaluated to determine whether RFI/RI concentrations were significantly different than background concentrations. The Gilbert process used four separate, non-parametric (i.e., distribution-free) ANOVA tests to determine if one population of data (i.e., the RFI/RI data) was statistically different than another population (i.e., the background data). Non-parametric tests were used so that inorganic and radionuclide analytes that may represent potential site contamination could be quickly identified without conducting distribution tests. These tests are appropriate for use on data that need not be characterized by a normal, lognormal, or other type of theoretical distribution.

The first non-parametric test was a straight comparison of the maximum RFI/RI observation for an analyte to either the calculated non-parametric 99 percent upper tolerance limit (UTL) or the maximum value of the background data. This test has been called the Hot Measurement (HM) comparison. The maximum RFI/RI concentration for vadose zone soil for each inorganic and radionuclide analyte was compared to the 99 percent UTL for that analyte as reported in the *1993 Background Geochemical Characterization Report* (DOE, 1993b). It was not possible to calculate a 99 percent UTL for background surficial soil analytes since fewer than 59 observations were available (Gilbert, 1993). Thus the maximum RFI/RI observation for surficial soil for each inorganic and radionuclide analyte was compared to the maximum background observation for that analyte. If the maximum RFI/RI observation exceeded the HM background value, the analyte was defined as a PCOC. Results of the HM test are presented in Tables III.A-10 through III.A-13.

The RFI/RI data was next tested using the non-parametric Slippage Test (Rosenbaum, 1954; Gilbert, 1993). This non-parametric ANOVA test is designed to determine if RFI/RI data and background data are from the same population (i.e., that there is no statistical difference between the two). The Slippage Test can be used even when all background measurements except the maximum observation are non-detects. The Slippage Test was conducted by simply counting the number of RFI/RI measurements which lie outside the maximum background measurement. The number of RFI/RI measurements which exceed the background measurement are compared to the number of measurements that would statistically be allowed to exceed this maximum value if the data came from the same population (i.e., there is no difference) given a specific probability level (i.e., 0.95). The probability (Q_s) that s measurements from the RFI/RI data set for each inorganic and radionuclide analyte will be greater than the largest value from the background population is given by:

Table III.A-10. Summary of Statistical Evalu[illegible]
Identification of Potential Inorganic Contaminants of Concern (P[illegible]n Surficial Soil
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Analyte – metals (mg/kg)	Background 95% UCL	> 99% UTL backgrnd? (1)	Slippage test Exceeded? (2)	Slippage test Allowed (5%)? (3)	Quantile test? (4)	Gehan test? (5)	Preliminary Conclusions (6)
Aluminum		32500 > 21800	4	14	0.564	-2.46957	Not a potential COC
Antimony		24.8 > 14.6	2	14	0.0055	0.24226	Not a potential COC; all nondetects
Arsenic		8.3 > 8.0	0	14	1.0	-3.39143	Not a potential COC
Barium		393 < 470	1	14	0.874	-3.92542	Not a potential COC
Beryllium	0.92	9.6 > 1.5	12	14	0.00003	4.40185	Potential COC
Cadmium	0.64	382 > 1.8	40	16	0.00000	3.96768	Potential COC
Calcium	8282.95	248000 > 13600	30	14	0.00766	2.63276	Potential COC
Cesium		247 > 150	0	14	--	0.00000	Not a potential COC
Chromium		48.4 > 22.0	14	14	0.0761	-1.21812	Not a potential COC
Cobalt		31 > 24	1	14	0.839	-6.37687	Not a potential COC
Copper		77.5 > 22.2	8	14	0.246	-1.45668	Not a potential COC
Iron		27900 > 24900	1	14	0.878	-3.01414	Not a potential COC
Lead		121 > 51	4	14	0.537	-4.49701	Not a potential COC
Lithium		34.9 > 17.7	2	14	0.447	-4.20658	Not a potential COC
Magnesium		6500 > 6380	1	14	0.864	-2.73393	Not a potential COC
Manganese		7650 > 2220	1	14	0.857	-4.33366	Not a potential COC
Mercury	0.03	1.8 > 0.15	18	16	0.00862	1.38944	Potential COC
Molybdenum		9.9 > 5.8	0	14	--	0.00000	Not a potential COC
Nickel		176 > 19.1	4	14	0.255	-3.01958	Not a potential COC
Nitrate/Nitrite	1.11	1500 > 0.0048	37	16	0.00551	2.46759	Potential COC
Potassium		6620 > 5310	2	14	0.617	-4.08405	Not a potential COC
Selenium		0.99 > 0.76	0	14	0.364	-4.02583	Not a potential COC
Silicon	202.7	11300 > 2250	76	14	5E-14	5.31315	Potential COC
Silver	0.58	3.3 > 2.9	4	14	0.0173	4.87988	Potential COC
Sodium	165.4	2440 > 290	14	14	0.00013	0.40754	Potential COC
Strontium		510 > 109	7	14	0.379	0.01498	Not a potential COC
Sulfide		--	--	--	--	--	Not a potential COC
Thallium		0.99 > 0.58	4	14	0.00035	-4.90974	Not a potential COC; majority of samples collected nondetects
Tin		61.5 > 58.5	2	14	0.708	-8.81987	Not a potential COC
Vanadium		67.6 > 46.2	6	14	0.436	-1.46951	Not a potential COC
Zinc		460 > 90.2	9	14	0.273	-0.30614	Not a potential COC

1. '99% UTL backgrnd?' indicates whether the maximum measured OU4 concentration exceeded the maximum reported concentration from OU1 and/or OU2 background surficial soil data.
2. 'Slippage test exceeded?' indicates the number of unique OU4 measurements of this analyte which exceeded the maximum reported concentration from OU1 and/or OU2 background surficial soil data.
3. 'Slippage test allowed (5%)?' indicates how many OU4 measurements can lie outside the maximum reported background surficial soil concentration using the nonparametric Slippage Test statistic and a probability of < 5%.
4. 'Quantile test?' provides the calculated p-value using the nonparametric Quantile Test statistic; all values < 0.05 suggest that the analyte is a potential COC.
5. 'Gehan test?' provides the calculated test statistic using the nonparametric Gehan Test; all values > 1.645 suggest that the analyte is a potential COC.
6. 'Preliminary conclusions' identifies whether an analyte is a potential COC based on the nonparametric statistical evaluations; all potential COCs have been placed in bold face.

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Table III.A–11. Summary of Statistical Evaluations:
Identification of Potential Inorganic Contaminants of Concern (PCOCs) in Vadose Soil
OU4, Solar Evaporation Ponds, IM/IRA–EA
Rocky Flats Plant, Golden, Colorado

Analyte – metals (mg/kg)	Background 95% UCL	> 99% UTL backgrnd? (1)	Slippage test Exceeded? (2)	Slippage test Allowed (5%)? (3)	Quantile test? (4)	Gehan test? (5)	Preliminary Conclusions (6)
Aluminum		42400 < 55097	4	7	0.349	−1.75071	Not a potential COC
Antimony		28.5 > 15.7	2	7	0.667	--	Not a potential COC
Arsenic		41.8 > 21.48	0	7	1.0	−1.97573	Not a potential COC
Barium	93.87	364 < 388.97	7	7	0.211	1.77681	Potential COC
Beryllium		19 > 18.83	0	7	1.0	−7.99569	Not a potential COC
Cadmium	2.3	547 > 2.36	30	7	2.30E−03	2.80675	Potential COC
Calcium	7781.79	328000 > 67402.6	54	7	0.213	2.85213	Potential COC
Cesium		261 < 1267.3	0	7	1	−10.34507	Not a potential COC
Chromium		120 > 113.77	0	7	1	−2.82030	Not a potential COC
Cobalt		36.2 < 48.79	3	7	0.565	−2.16078	Not a potential COC
Copper		79.7 > 59.1	4	7	0.417	0.54611	Not a potential COC
Iron		31800 < 63388.7	5	7	0.366	−1.17120	Not a potential COC
Lead		278 > 30.54	10	7	0.237	0.01793	Not a potential COC
Lithium	83.2	79.9 > 53.41	10	7	0.0593	−2.08903	Not a potential COC
Magnesium		5860 < 14931.58	2	7	0.597	0.95415	Not a potential COC
Manganese	190.5	3140 > 1505.36	15	7	0.0713	2.44983	Potential COC
Mercury		1.2 < 2.81	1	7	0.374	−2.91713	Not a potential COC
Molybdenum		41.0 = 41.0	0	7	1.0	−2.96875	Not a potential COC
Nickel		82.1 < 103.63	2	7	0.426	−3.58136	Not a potential COC
Nitrate/Nitrite	7.1	6100 > 0.007	49	5	0.000000629	6.73508	Potential COC
Potassium	1562.86	21100 > 10780.6	18	7	0.011	3.16096	Potential COC
Selenium		2.9 = 2.9	0	7	1	−5.50938	Not a potential COC
Silicon		--	--	--	--	–	Not a potential COC
Silver		40.9 > 19.99	0	7	1.0	0.22283	Not a potential COC
Sodium	2720	10200 > 1310	33	7	0.0000596	3.34255	Potential COC
Strontium		398 > 342.6	4	7	0.505	0.65068	Not a potential COC
Sulfide	43000	43000 > 30082.97	0	5	1	0.48285	Potential COC; possible hot spot
Thallium		4.2 > 2.6	0	7	5.64E−01	0.50990	Not a potential COC
Tin		312 = 312	0	7	1.0	−2.56372	Not a potential COC
Vanadium		82.2 < 138.33	4	7	0.351	−1.81597	Not a potential COC
Zinc	23.64	168 < 216.23	9	7	0.283	2.89262	Potential COC

1. "99% UTL backgrnd?" indicates whether the maximum measured OU4 concentration exceeded the maximum concentration in soil from 0–12' from RFA as reported in the 1993 Background Geochemical Characterization Report.
2. "Slippage test: exceeded?" indicates the number of unique OU4 measurements of this analyte which exceeded the maximum concentration in soil from 0–12' in RFA as reported in the 1993 Background Geochemical Characterization Report.
3. "Slippage test: allowed (5%)?" indicates how many OU4 measurements can lie outside the maximum reported background vadose soil concentration using the nonparametric Slippage Test statistic and a probability of < 5%.
4. "Quantile test?" provides the calculated p–value using the nonparametric Quantile Test statistic; all values < 0.05 suggest that the analyte is a potential COC.
5. "Gehan test?" provides the calculated test statistic using the nonparametric Gehan Test; all values > 1.645 suggest that the analyte is a potential COC.
6. "Preliminary conclusions" identifies whether an analyte is a potential COC based on the nonparametric statistical evaluations; all potential COCs have been placed in bold face.

Table III.A–12. Summary of Statistical Evaluations:
Identification of Potential Radionuclide Contaminants of Concern (COCs) in Surficial Soil
OU4, Solar Evaporation Ponds, IM/IRA–EA
Rocky Flats Plant, Golden, Colorado

Analyte – radionuclides (pCi/g)	Background 95% UCL	> 99% UTL backgrnd? (1)	Slippage test Exceeded? (2)	Slippage test Allowed (5%)? (3)	Quantile test? (4)	Gehan test? (5)	Preliminary Conclusions (6)
Americium–241	0.027	220 > 0.0405	69	10	1.50E–14	6.26242	Potential COC
Cesium–134	--	0.09 > 0	--	--	--	--	Potential COC; no background data available
Cesium–137	1.693	0.79 < 2.5	0	14	1	–5.53538	Not a potential COC
Gross alpha	22.934	440 > 28	71	49	0.016	1.70585	Potential COC
Gross beta	34.646	110 > 40	16	13	0.05	–1.28217	Not a potential COC
Plutonium 239/240	0.062	56 > 0.1	53	9	1.36E–10	5.19215	Potential COC
Radium–226	1.026	2.9 > 1.1	6	15	0.426	–2.39761	Not a potential COC
Radium–228	2.512	16 > 2.9	2	15	0.755	–2.05263	Not a potential COC
Strontium–89/90	0.817	1.5 > 1.0	5	16	0.532	–2.38529	Not a potential COC
Tritium (pCi/L)	--	--	--	--	--	--	Potential COC; no background data available
Uranium–233/234	1.223	41 > 1.20	35	10	0.000669	1.4138	Potential COC
Uranium–235	0.09	2. 3 > 0.1393	17	10	0.0398	2.52486	Potential COC
Uranium–238	1.27	27 > 1.521	24	10	0.00729	0.75627	Potential COC

1. "99% UTL backgrnd?" indicates whether the maximum measured OU4 concentration exceeded the maximum reported concentration from OU1 and/or OU2 background surficial soil data.
2. "Slippage test: exceeded?" indicates the number of unique OU4 measurements of this analyte which exceeded the maximum reported concentration from OU1 and/or OU2 background surficial soil data.
3. "Slippage test: allowed (5%)?" indicates how many OU4 measurements can lie outside the maximum reported background surficial soil concentration using the nonparametric Slippage Test statistic and a probability of < 5%.
4. "Quantile test?" provides the calculated p–value using the nonparametric Quantile Test statistic; all values < 0.05 suggest that the analyte is a potential COC.
5. "Gehan test?" provides the calculated test statistic using the nonparametric Gehan Test; all values > 1.645 suggest that the analyte is a potential COC.
6. "Preliminary conclusions" identifies whether an analyte is a potential COC based on the nonparametric statistical evaluations; all potential COCs have been placed in bold face.

Table III.A-13. Summary of Statistical Evaluations:
Identification of Potential Radionuclide Contaminants of Concern (PCOCs) in Vadose Soil
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Analyte – radionuclides (pCi/g)	Background 95% UCL	> 99% UTL backgrnd? (1)	Slippage test Exceeded? (2)	Slippage test Allowed (5%)? (3)	Quantile test? (4)	Gehan test? (5)	Preliminary Conclusions (6)
Americium-241	0.01	6.1 > 0.02	39	10	0.0204	5.01308	Potential COC
Cesium-134	--	--	--	--	--	--	Potential COC; No background data available
Cesium-137	0.166	0.42 > 0.14	3	7	0.776	3.42414	Potential COC
Gross alpha		116 > 47.21	7	7	0.26	-2.44828	Not a potential COC
Gross beta	27.99	55 > 44.62	12	7	0.107	2.34865	Potential COC
Plutonium 239/240	0.02	25 > 0.02	62	7	1.55E-07	5.24538	Potential COC
Radium-226	0.65	5.89 > 0.96	24	7	0.06	4.01448	Potential COC
Radium-228		3.5 > 2.32	13	7	0.164	0.91394	Not a potential COC
Strontium-89/90	0.54	0.8 < 1.09	0	7	1	3.43906	Potential COC
Tritium (pCi/L)	0.212	57.98 < 545.96	87	7	2.53E-20	6.7912	Potential COC
Uranium-233/234	0.53	21 > 2.04	49	7	0.005	6.43524	Potential COC
Uranium-235	0.1	0.87> 0.11	24	7	0.578	6.56477	Potential COC
Uranium-238	0.63	11.46 > 1.79	65	7	5.66E-07	6.52405	Potential COC

1. "99% UTL backgrnd?" indicates whether the maximum measured OU4 concentration exceeded the maximum reported concentration in soil from 0-12' from RFA as reported in the 1993 Background Geochemical Characterization Report.
2. "Slippage test: exceeded?" indicates the number of unique OU4 measurements of this analyte which exceeded the maximum reported concentration in soil from 0-12' in RFA as reported in the 1993 Background Geochemical Characterization Report.
3. "Slippage test: allowed (5%)?" indicates how many OU4 measurements can lie outside the maximum reported background vadose soil concentration using the nonparametric Slippage Test statistic and a probability of < 5%.
4. "Quantile test?" provides the calculated p-value using the nonparametric Quantile Test statistic; all values < 0.05 suggest that the analyte is a potential COC.
5. "Gehan test?" provides the calculated test statistic using the nonparametric Gehan Test; all values > 1.645 suggest that the analyte is a potential COC.
6. "Preliminary conclusions" identifies whether an analyte is a potential COC based on the nonparametric statistical evaluations; all potential COCs have been placed in bold face.

$$Q_s = n\binom{m}{s} B(n+m-s, s+1)$$

where n = the number of background observations available for comparison;
m = the number of RFI/RI observations available for comparison;
s = the number of RFI/RI observations that exceed the maximum background value; and
B = the complete Beta function:

$$B(m,n) = \int t^{m-1}(1-t)^{m-1}\,dt$$

where n = the number of background observations greater than zero;
m = the number of RFI/RI observations greater than zero; and
t = the probability of an event occurrence, $0 < t < 1$.

Thus the probability level can be fixed so that a value of s can be determined (Slippage Test statistic):

$$\sum_{s=0}^{s_0-1} \le \epsilon < \sum_{s=0}^{s_0} Q_s$$

where epsilon represents the fixed probability level and all other variables are as defined previously. Critical values for s given a probability level (or level of significance) of 0.95 have been compiled by Rosenbaum (1954). If the number of RFI/RI observations exceeding the maximum background value is greater than that predicted using the selected probability level, the analyte may be a PCOC. All identical observations for both RFI/RI and background were treated as ties, and only counted once. Critical values were not extrapolated beyond those provided by Rosenbaum (1954); this conservative approach to statistically limiting the degree of difference between large RFI/RI and background data sets increases the level of confidence with which one could conclude whether or not site concentrations are significantly different than background. Results from the Slippage Test are presented in Tables III.A-10 through III.A-14.

The third non-parametric ANOVA test used to compare RFI/RI data to background data was a modified version of the Quantile Test (Johnson et al., 1987; Gilbert, 1993). The non-parametric Quantile Test is a powerful rank test designed to compute the probability at which a certain count of observations from the RFI/RI data set would be above the maximum background measurement. Thus the Quantile Test may have more power than the Slippage Test when the magnitude of difference between the two populations of data being tested is not large.

The Quantile Test statistic used in this evaluation is given by:

$$p = \frac{\binom{m+n-c}{n-s}\binom{c}{s}}{\binom{m+n}{n}}$$

where $c = m + n - [(m + n + 1)b_1]$, which represents the number of ranks receiving a weight of one under a specific quantile condition (i.e., $b_1 = 0.8$ for upper 20th quantile). All variables are defined as previously.

If the computed p-value is less than the critical value of 0.05 (i.e., using a level of significance of 0.95), then the analyte may be a PCOC. Computing the p-value using this test statistic provides detailed information in addition to merely assessing if an analyte is a PCOC or not a PCOC. The computed p-value provides quantitative information on the degree of significance of the conclusion. For example, if the computed p-value for analyte A is 0.009, the value is well below the critical value selected to define PCOCs (i.e., the test suggests with a level of certainty that analyte A is a PCOC). Conversely, if the computed p-value for analyte B is 0.049, which is still below the critical value selected for this application, analyte B could be classified as a PCOC although with less significance than for analyte A. In this case, information from other tests and sources may be important in determining whether analyte B should be classified as a PCOC. Identical observations were treated as ties and were only counted as one unique measurement.

It is important to note that this form of the Quantile Test statistic could not be applied to data on several analytes. The differences in the size of the two populations resulted in a p-value greater than 1 (which has no statistical meaning). In these cases, the Quantile Test was modified to a form similar to the Slippage Test statistic. Results from the Quantile Test are presented in Tables III.A-10 through III.A-13.

The fourth non-parametric ANOVA test used to compare RFI/RI data to background data was the Gehan Test (Gehan, 1965; Palachek et al., 1993; Gilbert, 1993). The Gehan Test is most appropriate for use on data sets which include multiple detection limits and/or non-detects. This test is equivalent to the Mann-Whitney/Wilcoxon Rank Sum Test if neither data set contains no non-detects. The Gehan Test was easily computed within a database to derive ranks and the test statistic. The Gehan ranking procedure used is as follows:

(1) Combine and order the RFI/RI data and background data sets from smallest observation to largest observation;
(2) Assign an index (I) value of 0 if the observation is a detect and an I value of 1 if the observation is a non-detect;
(3a) If the smallest observation has an I value of 0, assign a d value of 1 and an e value of

0; or

(3b) If the smallest observation has an I value of 1, assign a d value of 0 and an e value of 1;

(4) Increase the total value of d by 1 whenever an observation has an I value of 0, and increase the total value of e by 1 whenever an observation has an I value of 1;

(5) Count the number of I values set equal to 1 for the combined data set;

(6) Compute the Rank of each observation as:

Rank = d + [(total of I values set equal to 1 + e)/2] for I values = 0 and
Rank = (total of I values set equal to 1 + 1 + d)/2 for I values = 1; and

(7) Average computed ranks for all identical observations.

The Gehan Test statistic is then computed:

$$Z = \frac{\sum_{i=1}^{N} d_i(aR_i)}{\left[\frac{mn}{N(N-1)} \sum_{i=1}^{N} (aR_i)^2\right]^{0.5}}$$

where N = the total number of observations in the combined data set;
d_i = 1 if the ith observation is from the RFI/RI data set or
= 0 if the ith observation is from the background data set; and
aR_i = 2(Rank) - (N+1).

All other variables are as defined previously. If the computed Gehan Test statistic is greater than 1.645, the analyte may be a PCOC. Results of the Gehan Test are presented in Tables III.A-10 through III.A-13.

Conclusions about whether a specific inorganic or radionuclide analyte is a PCOC to be considered as part of the OU4 IM/IRA program were based on the results of these statistical tests. An analyte was identified as a PCOC if it failed any of the ANOVA statistical tests described herein. In general, there was little disagreement between tests. A final list of potential inorganic and radionuclide PCOCs, based on the results of the background analyses discussed above, is presented in Table III.2-1 within the text of Part III.

III.A.5 Frequency of Detection Evaluation

As previously discussed, background statistical analyses could not be completed for organic analytes. Instead, information on the frequency of detection of a particular organic analyte was collected and evaluated. All organic analytes that reported as detects with a frequency greater than 5 percent were retained as organic PCOCs. Tables III.A-6 through III.A-

9 presents the results of the frequency of detection analysis for analytes for which there is no corresponding background data. These organic PCOCs are included on Table III.2-1 within the text of Part III.

III.A.6 Development of Representative PCOC Concentrations

Data distributions of the full data set were evaluated for each of the PCOCs. Both non-detects and detects were included in this statistical computation. The data set on the analyte was evaluated to determine whether the data could be described by a parametric, theoretical distribution using both the Chi-Square Test and the Kolmogorov-Smirnov One-Sample Test. The Chi-Square Test computes the probability that RFI/RI data can reasonably be described by a certain theoretical distribution (such as normal or lognormal) by comparing observed and expected frequencies. The Chi-Square Test statistic (X^2) is given by:

$$X^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

where O_i = the observed frequency of class i;
E_i = the expected frequency of class i from fitted distribution; and
k = number of classes after aggregation.

A computed Chi-Square value less than 0.05 (using a significance level of 0.95) suggests that the test distribution is not a good model for the data. Most PCOC data can be adequately described by the lognormal distribution. Results of the Chi-Square Test for each PCOC are summarized in Table III.A-14.

A second distribution fitting test also was conducted on all RFI/RI data sets for PCOCs. The Kolmogorov-Smirnov One-Sample (KS) Test was used in addition to the Chi-Square Test. This approach was adopted because the KS Test may provide further information about the data distribution than the Chi-Square Test because it uses individual data values to determine an empirical distribution function rather than merely grouping observations. The KS Test focuses on the entire distribution, not just its central tendency. Thus the KS Test is considered more powerful than the Chi-Square Test. Details on the KS Test can be found in Conover (1980) and Gilbert (1987). A computed significance level greater than 0.05 indicates the model distribution may be a good fit for the data. Again, most PCOC data can be adequately described by the lognormal distribution. Results of the KS Test for each PCOC are summarized in Table III.A-14.

Table III.A-14 Distribution Fitting Test Results and Statistics
for Potential Contaminants of Concern (PCOCS)
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Potential Contaminants of Concern	Size of Data Set	Chi-Square Test Normal	Chi-Square Test Lognormal	K-S Test Normal	K-S Test Lognormal	Estimated Distribution	Mean*	Standard Deviation*	95% UCL
Surficial Soils									
Beryllium (mg/kg)	71	2.22E-14	-	4.99E-07	1.64E-04	nonparametric	1.030	1.284	3.980
Cadmium (mg/kg)	71	0.000	-	0.000	5.40E-05	nonparametric	19.315	66.468	172.100
Calcium (mg/kg)	71	0.000	0.129	9.2E-05	0.417	lognormal	9.396	1.076	28733.230
Mercury (mg/kg)	64	0.000	4.08E-04	6.28E-08	0.150	lognormal	-2.566	0.993	0.170
Nitrate/Nitrite (mg/kg)	100	0.000	-	0.000	0.012	nonparametric	80.590	230.645	595.620
Silicon (mg/kg)	71	2.01E-04	0.344	0.037	0.865	lognormal	7.820	0.715	3811.000
Silver (mg/kg)	71	6.41E-04	3.60E-05	0.024	1.06E-03	nonparametric	1.272	0.400	2.190
Sodium (mg/kg)	71	0.000	9.01E-13	0.000	7.29E-06	nonparametric	282.704	431.343	1274.360
Americium-241 (pCi/g)	69	0.000	-	0.000	0.791	lognormal	-0.307	2.244	26.240
Cesium-134 (pci/g)	15	-	-	0.149	0.601	lognormal	-4.451	1.037	0.040
Gross alpha (pCi/g)	64	0.000	-	5.41E-07	0.337	lognormal	3.186	0.784	40.510
Plutonium-239,240 (pCi/g)	58	1.11E-15	-	3.75E-06	0.871	lognormal	-0.371	2.036	14.220
Tritium (pCi/L)	61	0.000	-	0.000	0.258	lognormal	5.218	1.890	2604.940
Uranium-233,234 (pCi/g)	71	0.000	-	2.45E-07	0.036	nonparametric	2.622	5.074	14.290
Uranium-235 (pCi/g)	70	0.000	-	4.24E-07	0.752	lognormal	-2.651	1.045	0.163
Uranium-238 (pCi/g)	71	0.000	0.002	7.62E-07	0.011	nonparametric	2.041	3.314	9.660
Vadose Zone Soil									
Barium (mg/kg)	101	2.64E-04	0.856	0.085	0.997	lognormal	4.421	0.563	108.400
Cadmium (mg/kg)	101	0.000	-	0.000	0.000	nonparametric	14.591	66.488	163.060
Calcium (mg/kg)	101	0.000	0.110	1.56E-07	0.627	lognoramal	9.225	1.668	67187.440
Lithium (mg/kg)	101	0.000	0.029	1.02E-05	0.207	lognormal	2.276	0.699	14.260
Manganese (mg/kg)	101	0.000	-	0.000	0.125	lognormal	5.081	0.715	238.920
Nitrate/Nitrate (mg/kg)	86	0.000	-	0.000	0.114	lognormal	3.341	2.491	1873.400
Potassium (mg/kg)	101	0.000	0.019	1.05E-05	0.079	lognormal	7.567	0.721	2884.430
Sodium (mg/kg)	101	0.000	2.07E-04	3.48E-06	1.49E-07	nonparametric	6.039	1.478	1863.700
Sulfide (mg/kg)	71	0.000	-	0.000	5.50E-09	nonparametric	9.155	13.924	41.170
Zinc (mg/kg)	101	1.23E-05	0.794	0.022	0.985	lognormal	3.324	0.637	4.740
Americium-241 (pCi/g)	66	0.000	0.012	3.65E-07	0.533	lognormal	-2.845	2.368	3.320
Cesium-134 (pci/g)	23	0.051	-	0.417	0.473	lognormal	-5.347	0.808	0.010
Cesium-137 (pCi/g)	58	0.000	9.90E-04	9.39E-08	0.067	lognormal	-4.650	1.479	0.050
Gross beta (pCi/g)	99	0.004	0.400	0.114	0.799	lognormal	3.290	0.369	30.680
Plutonium-239,240 (pCi/g)	62	0.000	-	2.09E-08	0.952	lognormal	-2.523	2.485	6.740
Radium-226 (pCi/g)	52	9.29E-12	3.10E-03	2.42E-04	0.203	lognormal	-0.026	0.653	1.440
Strontium-89,90 (pCi/g)	67	0.012	0.015	0.159	0.462	lognormal	-1.581	1.041	0.475
Tritium (pCi/L)	94	0.000	0.035	6.72E-06	0.322	lognormal	7.520	2.118	35778.380
Uranium-233,234 (pCi/g)	94	0.000	0.004	8.85E-09	0.515	lognormal	0.487	0.964	3.230
Uranium-235 (pCi/g)	94	0.000	0.383	1.24E-05	0.755	lognormal	-2.707	1.015	0.140
Uranium-238 (pCi/g)	98	0.000	5.77E-04	2.79E-07	5.83E-03	nonparametric	1.954	2.106	6.660

* NOTE: Statistical approximations of the mean and standard deviation of lognormal data are given as the mean and standard deviation of ln(x), respectively.

Table III.A-14 (continued). Distribution Fitting Test Results and Statistics
for Potential Contaminants of Concern (PCOCS) at OU4
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Potential Contaminants of Concern	Size of Data Set	Chi-Square Test		K-S Test		Estimated Distribution	Mean*	Standard Deviation*	95% UCL
		Normal	Lognormal	Normal	Lognormal				
Surficial Soils									
Benzo(a)anthracene (ug/kg)	98	0.000	4.12E-08	4.05E-04	1.28E-03	nonparametric	232.847	267.551	830.290
Benzo(a)pyrene(ug/kg)	98	5.00E-12	3.83E-05	3.76E-04	1.16E-04	nonparametric	256.765	279.749	881.440
Benzo(b)fluoranthene (ug/kg)	98	0.000	0.560	1.94E-06	0.109	lognormal	5.322	0.890	371.310
Benzo(ghi)perylene (ug/kg)	98	5.73E-10	8.82E-10	1.16E-03	1.84E-05	nonparametric	230.020	191.364	657.340
Benzo(k)fluoranthene (ug/kg)	91	0.000	2.21E-05	3.37E-08	0.136	lognormal	5.415	0.923	422.500
Bis(2-ethylhexyl)phthalate (ug/kg)	98	0.000	-	0.000	0.037	nonparametric	876.592	3248.238	8129.910
Chrysene (ug/kg)	98	2.22E-16	8.27E-04	4.06E-04	3.70E-03	nonparametric	260.398	307.071	946.100
Di-n-butyl phthalate (ug/kg)	98	0.000	0.000	9.18E-05	5.45E-09	nonparametric	204.561	227.773	713.180
Fluoranthene (ug/kg)	98	0.000	0.303	1.11E-08	0.267	lognormal	5.441	0.986	374.580
Indeno(1,2,3-cd)pyrene (ug/kg)	98	8.75E-12	9.57E-08	5.06E-03	4.00E-05	nonparametric	231.286	215.520	712.540
Phenanthrene (ug/kg)	98	0.000	1.00E-04	3.36E-08	0.209	lognormal	5.325	0.911	381.550
Pyrene (ug/kg)	98	0.000	0.284	6.43E-08	0.280	lognormal	5.505	0.950	386.040
Aroclor (ug/kg)	85	0.000	-	0.000	0.000	nonparametric	305.653	1319.187	3251.400
Vadose Zone Soils									
2-butanone (ug/kg)	15	-	-	4.18E-02	0.014	nonparametric	8.233	6.242	29.000
Acetone (ug/kg)	80	0.000	9.24E-05	5.48E-05	2.24E-03	nonparametric	19.750	22.081	69.920
Bis(2-ethylhexyl)phthalate (ug/kg)	17	-	-	7.78E-03	1.06E-03	nonparametric	174.706	48.941	220.000
Chloroform (ug/kg)	92	0.000	0.000	0.000	0.000	nonparametric	4.299	3.656	12.500
Di-n-butyl phthalate (ug/kg)	17	-	-	9.99E-03	1.55E-03	nonparametric	177.588	42.024	220.000
Methylene chloride (ug/kg)	92	0.000	6.29E-05	2.16E-07	1.34E-03	nonparametric	7.685	10.163	30.560
Toluene (ug/kg)	92	1.67E-15	0.020	1.66E-05	0.318	lognormal	4.370	1.172	211.900
Cyanide (mg/kg)	77	0.000	0.000	0.000	0.000	nonparametric	1.745	6.242	15.930

* NOTE: Statistical approximations of the mean and standard deviation of lognormal data are given as the mean and standard deviation of ln(x), respectively.

If the distribution fitting tests and the graphic plots suggested that the data were normally distributed, a representative concentration for that PCOC was developed by first replacing all non-detect values with one-half the reported detection limit and then applying normal approximations. If the distribution fitting tests and the graphic plots suggested that the data were lognormally distributed, all non-detects were replaced with one-half the reported detection limit, and the data was then transformed by computing the natural logarithm of the raw data before a representative concentration for that PCOC was developed using lognormal approximations. If the distribution fitting tests and graphic plots indicated that the data could not reasonably be described by parametric approximations, the representative concentration for that PCOC was developed using non-parametric statistics.

III.A.6.1 Parametric PCOC Data

The 95 percent upper confidence limit (UCL) of the arithmetic mean was defined as the representative contaminant concentration value. This value was identified as a conservative estimate of the representative concentration at the site because of the uncertainty associated with estimating the true average concentration at the site. The 95 percent UCL is used to represent the highest exposure concentration by medium that a receptor could reasonably be expected to contact (EPA, 1992). The 95 percent UCL of the arithmetic mean were developed to compare to target long-term concentration goals for the site. Details on target concentration goals by medium are presented in Part III.

The 95 percent UCL for data that are normally distributed was calculated as:

$$UCL=\bar{x}+t\left(\frac{s}{\sqrt{n}}\right)$$

where UCL = upper confidence limit;
x = mean of data;
s = standard deviation of data;
t = student t-statistic (Gilbert, 1987); and
n = number of observations in PCOC data set.

The mean used in the UCL calculations for normally distributed data was based on the following approximation:

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i$$

where x_i = the value of the ith observation and all other variables are as defined previously. The standard deviation used in the UCL calculations for normally distributed data was based on the following approximation:

$$s=\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}$$

where all variables are as defined previously.

The 95 percent UCL for lognormal data was calculated as:

$$UCL=e^{\bar{y}+0.5s_y^2+\frac{s_yH}{\sqrt{n-1}}}$$

where e = the base of the natural log;
y = mean of the transformed data;
s_y = standard deviation of the transformed data;
H = H-statistic (Gilbert, 1987); and
n = the number of observations in the PCOC data set.

For lognormal data, the mean of the transformed data was based on the following approximation:

$$\bar{y}=\frac{1}{n}\sum_{i=1}^{n}lnx_i$$

where all variables are as defined previously. The standard deviation for lognormal data was estimated from the following approximation:

$$s_y = \sqrt{\frac{\sum_{i=1}^{n} (\ln x_i - \bar{y})^2}{n-1}}$$

where all variables are as defined previously. Table III.A-15 presents the computed representative concentrations for each parametric PCOC.

III.A.6.2 Nonparametric PCOC Data

For PCOC data that could not reasonably be described as parametric, the 95 percent UTL was computed as the representative concentration for the site. The 95 percent UTL was defined as the value most representative of a contaminant concentration for large, non-parametric data sets (i.e., the number of observations in the PCOC data set must be equal to or exceed 59). The method of estimating the 95 percent UTL for large data sets is described in Hahn and Meeker (1991). However, most of the non-parametric PCOC data sets derived from RFI/RI data had less than 59 observations. It was not possible to determine the 95 percent UTL for these smaller data sets. In these cases, the maximum detected value was used as the most representative PCOC concentration for the site. Table III.A-15 identifies the representative concentration for each non-parametric PCOC.

III.A.7 Development of Representative Background Concentrations

A similar procedure as described above was applied to background data for inorganic and radionuclide PCOCs. Background data was evaluated to determine whether analyte concentrations were parametric or nonparametric using the distribution fitting tests described in section III.A.6. Once data distribution had been determined based on the results of the tests and graphical plots, all non-detects were replaced with one-half the reported detection limit. The representative background concentration for each PCOC was computed using the same methods described in section III.A.6. Table III.A-16 identifies the representative background concentration for each PCOC. These values may serve as target long-term concentration goals in the event that risk-based concentration goals are more stringent than representative background concentrations. These computed representative concentrations were in agreement with those for background surficial soil as reported in the *Draft Final Phase III RFI/RI Report for OU1* (DOE, 1993a) and for those for vadose zone soil as reported in the *1993 Background Geochemical Characterization Report* (DOE, 1993b) considering that background data set developed to support the IM/IRA program was limited to those samples above the mean historic high water table elevation.

Table III.A-15. Summary of Computed Representative Concentrations Potential Contaminants of Concern (PCOCs) OU4, Solar Evaporation Ponds, IM/IRA-EA Rocky Flats Plant, Golden, Colorado

Analyte	Representative Background Concentration	Representative PCOC Concentration
Surficial Soil		
Americium-241 (pCi/g)	0.027	26.24
Cesium-134 (pCi/g)	ND	0.04
Gross alpha (pCi/g)	22.9	40.51
Plutonium-239,240 (pCi/g)	0.062	14.22
Tritium (pCi/L)	ND	2604.94
Uranium-233,234 (pCi/g)	1.22	14.29
Uranium-235 (pCi/g)	0.09	0.163
Uranium-238 (pCi/g)	1.27	9.66
Beryllium (mg/kg)	0.92	3.98
Cadmium (mg/kg)	0.64	172.1
Calcium (mg/kg)	8282.95	28733.23
Mercury (mg/kg)	0.03	0.17
Nitrate/Nitrite (mg/kg)	1.11	595.62
Silicon (mg/kg)	202.7	3811
Silver (mg/kg)	0.58	2.19
Sodium (mg/kg)	165.4	1274.36
Benzo(a)anthracene (ug/kg)	--	830.29
Benzo(a)pyrene (ug/kg)	--	881.44
Benzo(b)fluoranthene (ug/kg)	--	371.31
Benzo(ghi)perylene (ug/kg)	--	657.34
Benzo(k)fluoranthene (ug/kg)	--	422.5
Bis(2-ethylhexyl)phthalate (ug/kg)	--	8129.91
Chrysene (ug/kg)	--	946.1
Di-n-butyl phthalate (ug/kg)	--	713.18
Fluoranthene (ug/kg)	--	374.58
Indeno(1,2,3-cd)pyrene (ug/kg)	--	712.54
Phenanthrene (ug/kg)	--	381.55
Pyrene (ug/kg)	--	386.04
Aroclor-1254 (ug/kg)	--	3251.4
Vadose Zone Soil		
Americium-241 (pCi/g)	0.01	3.32
Cesium-134 (pCi/g)	ND	0.0098
Cesium-137 (pCi/g)	0.166	0.05
Gross beta (pCi/g)	27.99	30.68
Plutonium-239,240 (pCi/g)	0.02	6.74
Radium-226 (pCi/g)	0.65	1.44
Strontium-89,90 (pCi/g)	0.54	0.475
Tritium (pCi/L)	212.2	35778.38
Uranium-233,234 (pCi/g)	0.53	3.23
Uranium-235 (pCi/g)	0.1	0.14
Uranium-238 (pCi/g)	0.63	6.66
Barium (mg/kg)	93.87	108.4
Cadmium (mg/kg)	2.3	163.06
Calcium (mg/kg)	7781.79	67187.44
Lithium (mg/kg)	83.2	14.26
Manganese (mg/kg)	190.5	238.92
Nitrate/Nitrite (mg/kg)	7.1	1873.4
Potassium (mg/kg)	1562.86	2884.43
Sodium (mg/kg)	2720	1863.7
Sulfide (mg/kg)	43000	41.17
Zinc (mg/kg)	23.64	4.74
2-butanone (ug/kg)	--	29
Acetone (ug/kg)	--	69.92
Bis(2-ethylhexyl)phthalate (ug/kg)	--	220
Chloroform (ug/kg)	--	12.5
Di-n-butyl phthalate (ug/kg)	--	220
Methylene chloride (ug/kg)	--	30.56
Toluene (ug/kg)	--	211.9
Cyanide (mg/kg)	--	15.93

Table III.A-16. Distribution Fitting Test Results and Statistics
for Background Concentrations of Potential Contaminants of Concern (PCOCS)
OU4, Solar Evaporation Ponds, IM/IRA-EA
Rocky Flats Plant, Golden, Colorado

Background Analytes	Size of Data Set	Chi-Square Test Normal	Chi-Square Test Lognormal	K-S Test Normal	K-S Test Lognormal	Estimated Distribution	Mean*	Standard Deviation*	95% UCL
Surficial Soils									
Beryllium (mg/kg)	11	-	-	0.958	0.999	lognormal	-0.297	0.277	0.920
Cadmium (mg/kg)	8	-	-	0.575	0.608	lognormal	-0.886	0.410	0.640
Calcium (mg/kg)	11	-	-	0.306	0.459	lognormal	8.636	0.444	8282.950
Mercury (mg/kg)	9	-	-	0.118	0.113	normal	0.032	3.632E-03	0.030
Nitrate/Nitrite (mg/kg)	9	-	-	0.507	0.956	lognormal	0.577	0.653	1.110
Silicon (mg/kg)	11	-	-	0.496	0.918	lognormal	4.882	0.467	202.700
Silver (mg/kg)	11	-	-	0.087	0.122	lognormal	-0.611	0.096	0.580
Sodium (mg/kg)	11	-	-	0.277	0.476	lognormal	4.695	0.452	165.400
Americium-241 (pCi/g)	15	-	-	0.826	0.958	lognormal	-4.002	0.489	0.027
Cesium-134 (pci/g)	-	-	-	-	-	-	-	-	**
Gross alpha (pCi/g)	-	-	-	-	-	-	-	-	22.900
Plutonium-239,240 (pCi/g)	19	-	-	0.605	0.898	lognormal	-3.015	0.381	0.062
Tritium (pCi/L)	-	-	-	-	-	-	-	-	***
Uranium-233,234 (pCi/g)	15	-	-	0.746	0.640	normal	1.154	0.153	1.220
Uranium-235 (pCi/g)	15	-	-	0.756	0.862	lognormal	-3.348	0.861	0.090
Uranium-238 (pCi/g)	15	-	-	0.996	0.981	normal	1.192	0.193	1.270
Vadose Zone Soil									
Barium (mg/kg)	34	6.05E-05	0.015	0.049	0.472	lognormal	4.022	0.718	93.870
Cadmium (mg/kg)	26	2.30E-04	3.00E-12	6.20E-03	2.26E-04	nonparametric	0.673	0.398	2.300
Calcium (mg/kg)	34	0.000	-	3.32E-05	0.172	lognormal	8.175	0.914	7781.790
Lithium (mg/kg)	34	2.75E-07	5.29E-13	4.45E-03	1.30E-03	nonparametric	9.096	3.751	83.200
Manganese (mg/kg)	34	1.20E-03	0.068	0.288	0.892	lognormal	4.749	0.700	190.500
Nitrate/Nitrate (mg/kg)	24	-	-	7.47E-04	0.017	nonparametric	1.056	0.902	7.100
Potassium (mg/kg)	33	1.71E-03	0.037	0.294	0.903	lognormal	6.738	0.787	1562.860
Sodium (mg/kg)	34	2.64E-09	3.66E-05	2.02E-05	5.76E-03	nonparametric	194.074	185.589	2720.000
Sulfide (mg/kg)	25	-	-	1.01E-06	6.89E-03	nonparametric	1722.550	8599.469	43000.000
Zinc (mg/kg)	33	0.341	2.26E-03	0.884	0.080	normal	19.062	16.007	23.640
Americium-241 (pCi/g)	2	-	-	-	-	-	-	-	0.010
Cesium-134	-	-	-	-	-	-	-	-	**
Cesium-137 (pCi/g)	4	-	-	0.417	0.417	normal	0.125	0.050	0.166
Gross alpha (pCi/g)	-	-	-	-	-	-		-	
Gross beta (pCi/g)	26	0.194	0.444	0.657	0.887	lognormal	3.075	0.404	27.990
Plutonium-239,240 (pCi/g)	9	-	-	0.016	0.016	nonparametric	0.011	3.33E-03	0.020
Radium-226 (pCi/g)	26	2.08E-03	3.32E-03	0.160	0.261	lognormal	-0.513	0.177	0.650
Strontium-89,90 (pCi/g)	11	-	-	0.621	0.678	lognormal	-1.485	0.778	0.540
Tritium (pCi/L)	25	0.058	0.119	0.444	0.337	normal	0.168	0.980	212.200
Uranium-233,234 (pCi/g)	26	-	-	0.178	0.127	normal	0.546	0.182	0.530
Uranium-235 (pCi/g)	<2	-	-	-	-	-	-	-	0.100
Uranium-238 (pCi/g)	26	-	0.443	0.678	0.275	normal	0.562	0.029	0.630

* NOTE: Statistical approximations of the mean and standard deviation of lognormal data are given as the mean and standard deviation of ln(x), respectively.

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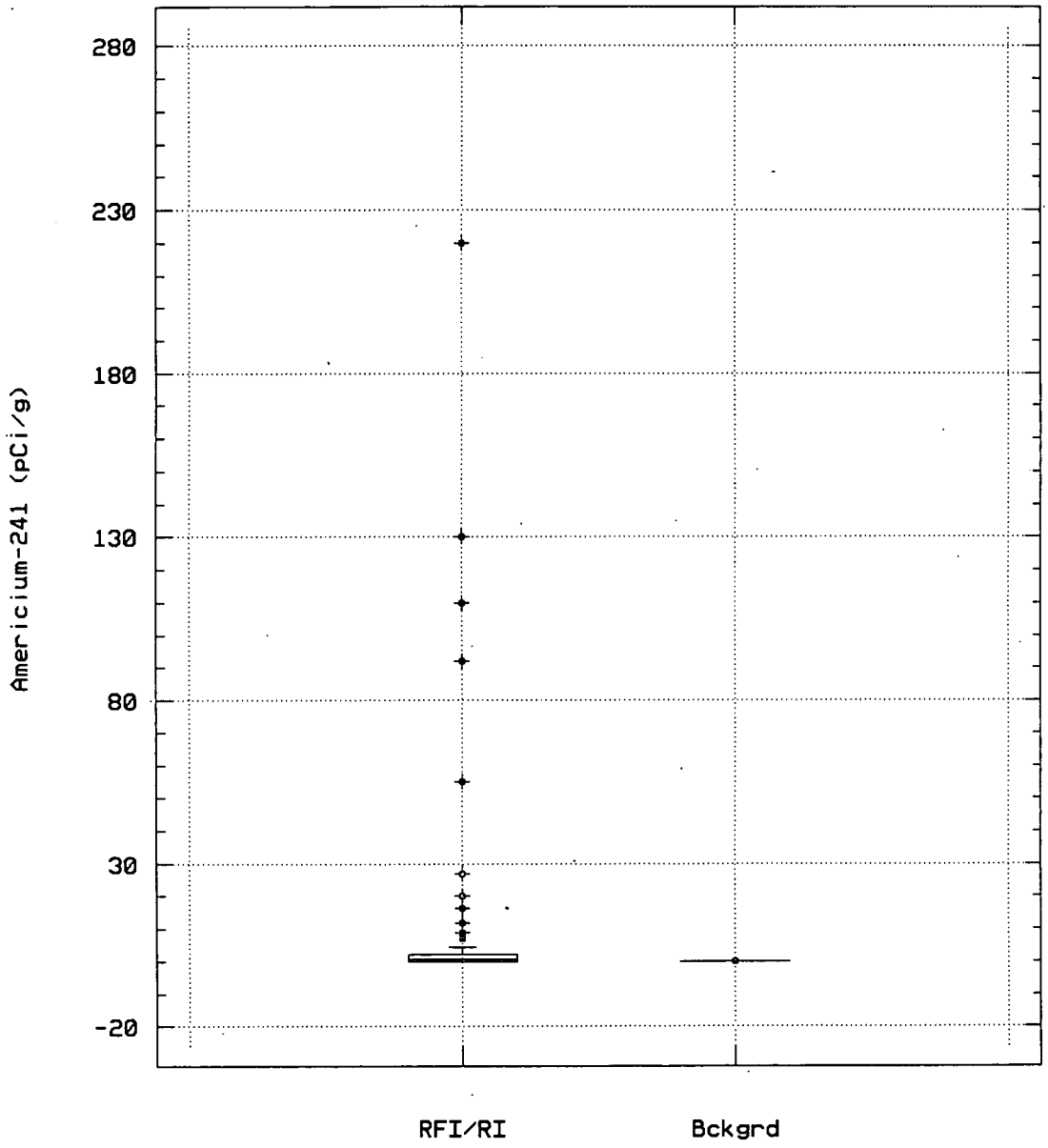
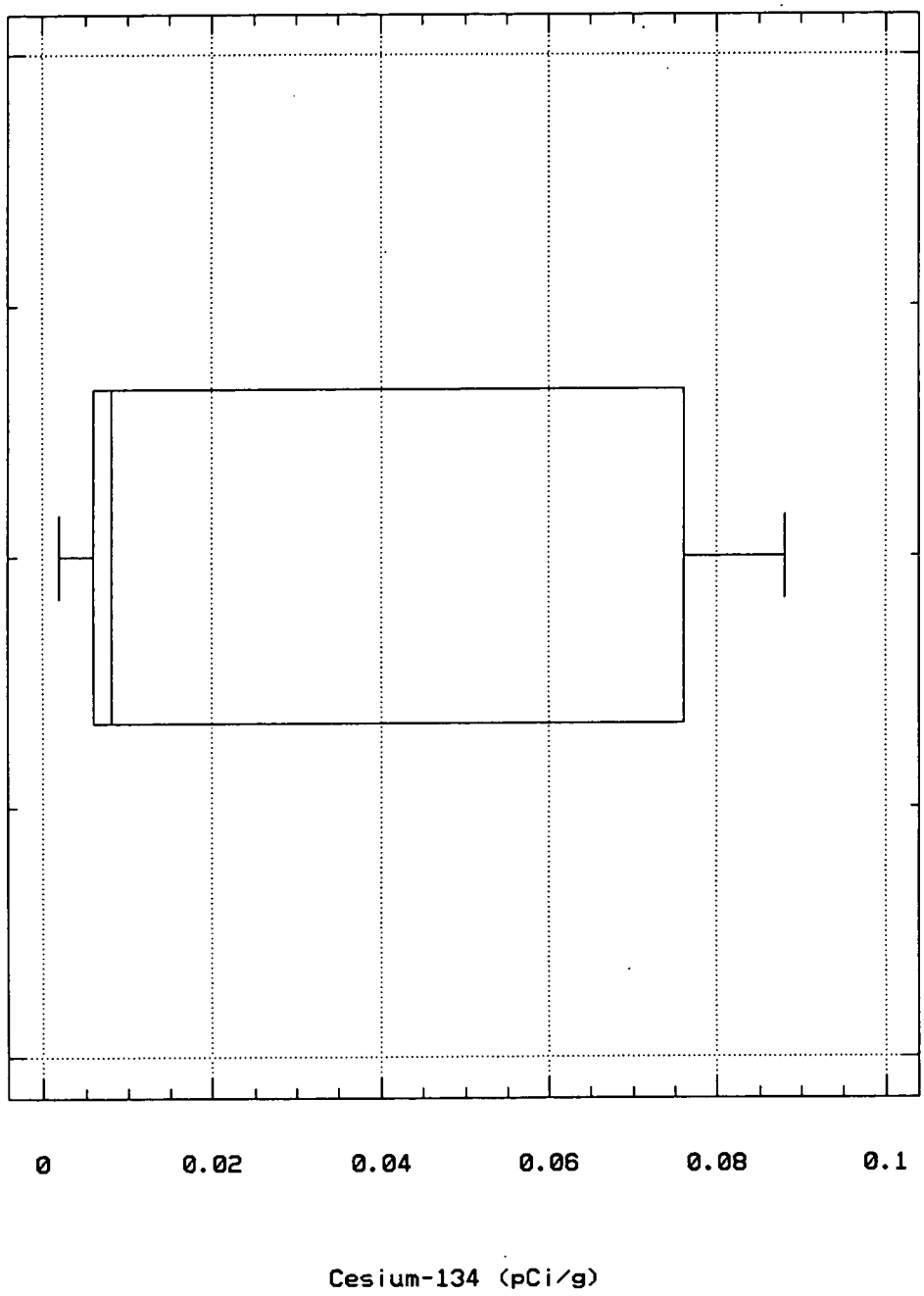
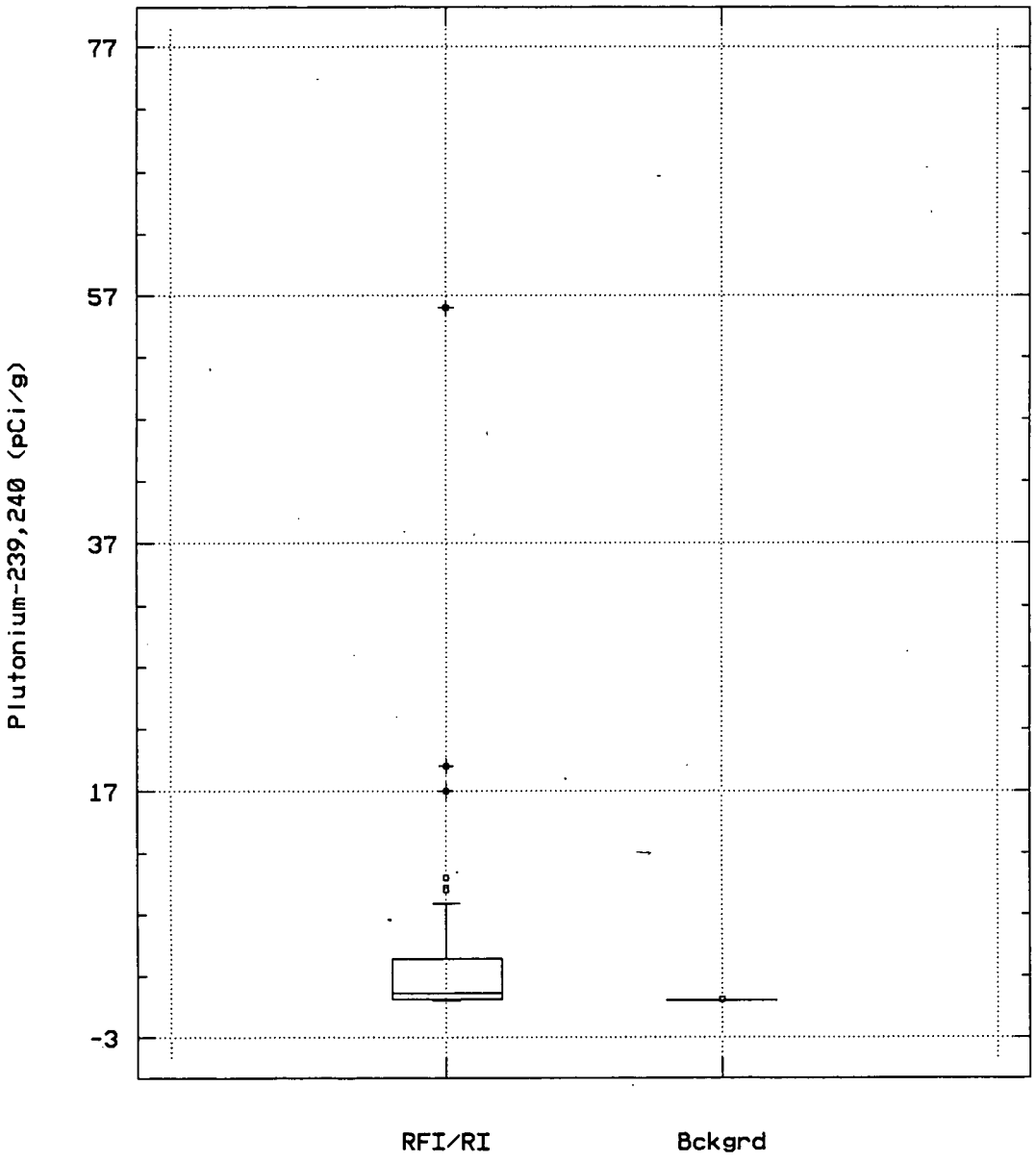
Comparison of RFI/RI and Background Data
Americium-241 in Surficial Soil



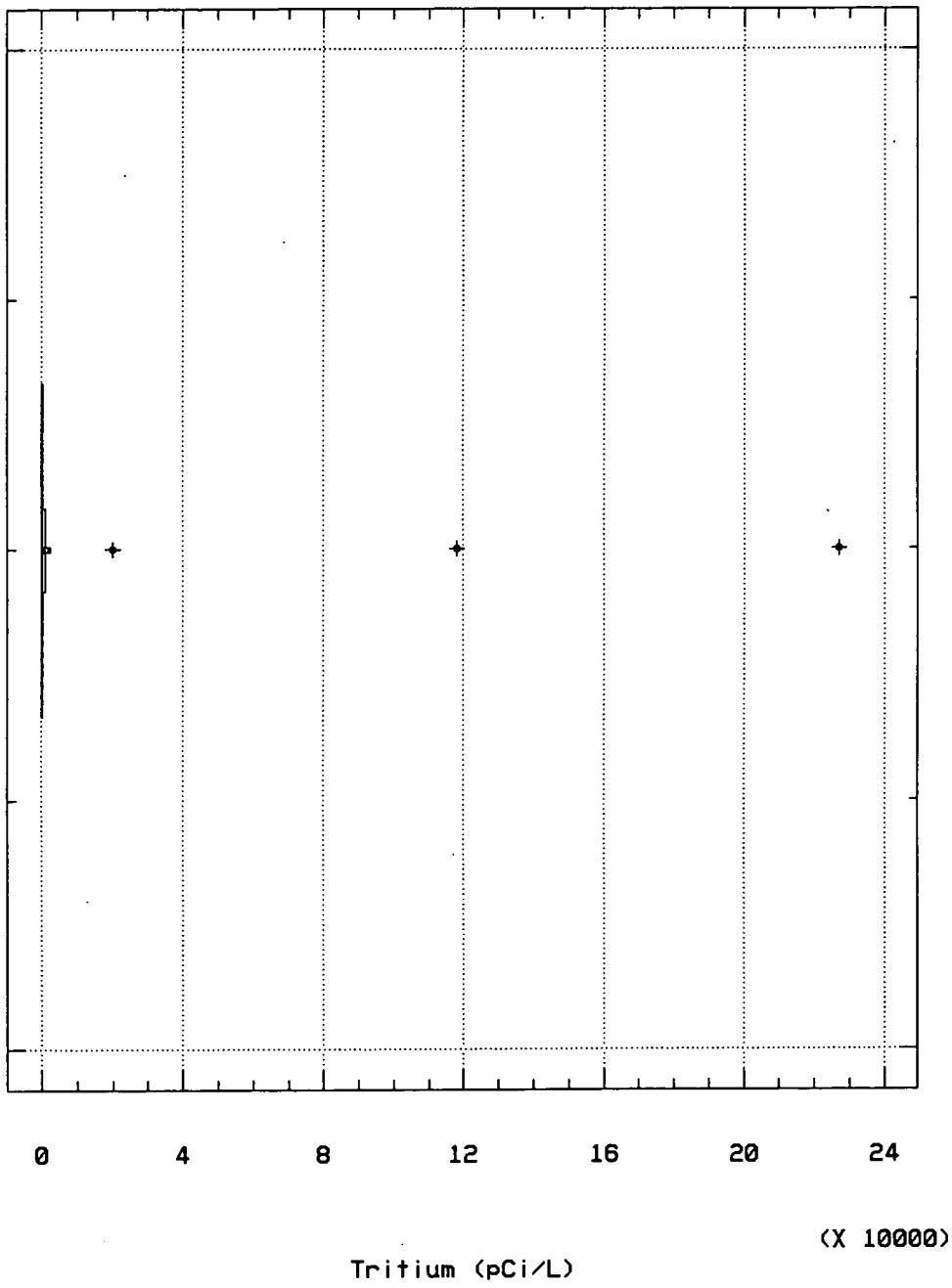
RFI/RI Cesium-134 in Surficial Soil



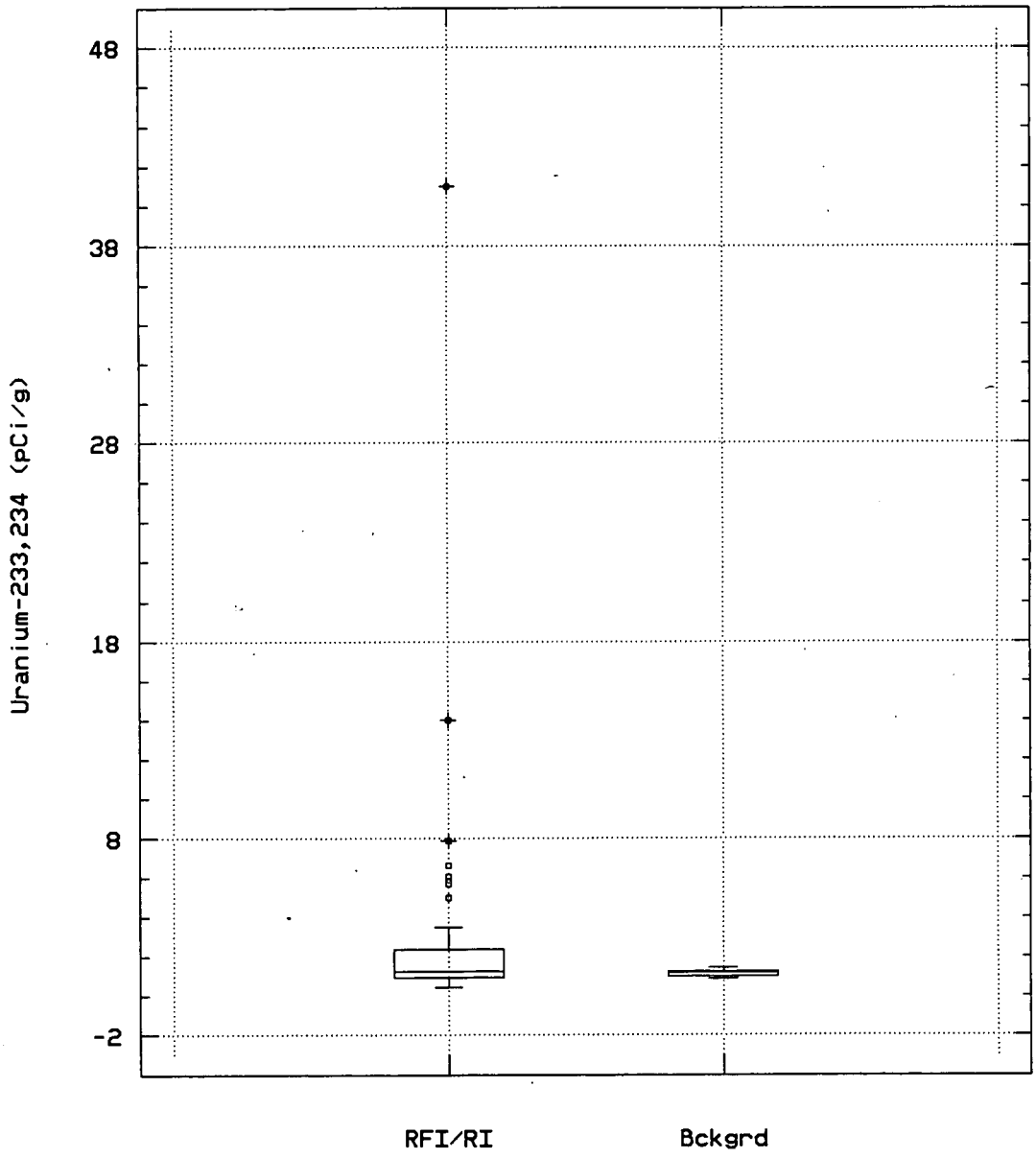
Comparison of RFI/RI and Background Data
Plutonium-239,240 in Surficial Soil



RFI/RI Tritium in Surficial Soil



Comparison of RFI/RI and Background Data
Uranium-233,234 in Surficial Soil



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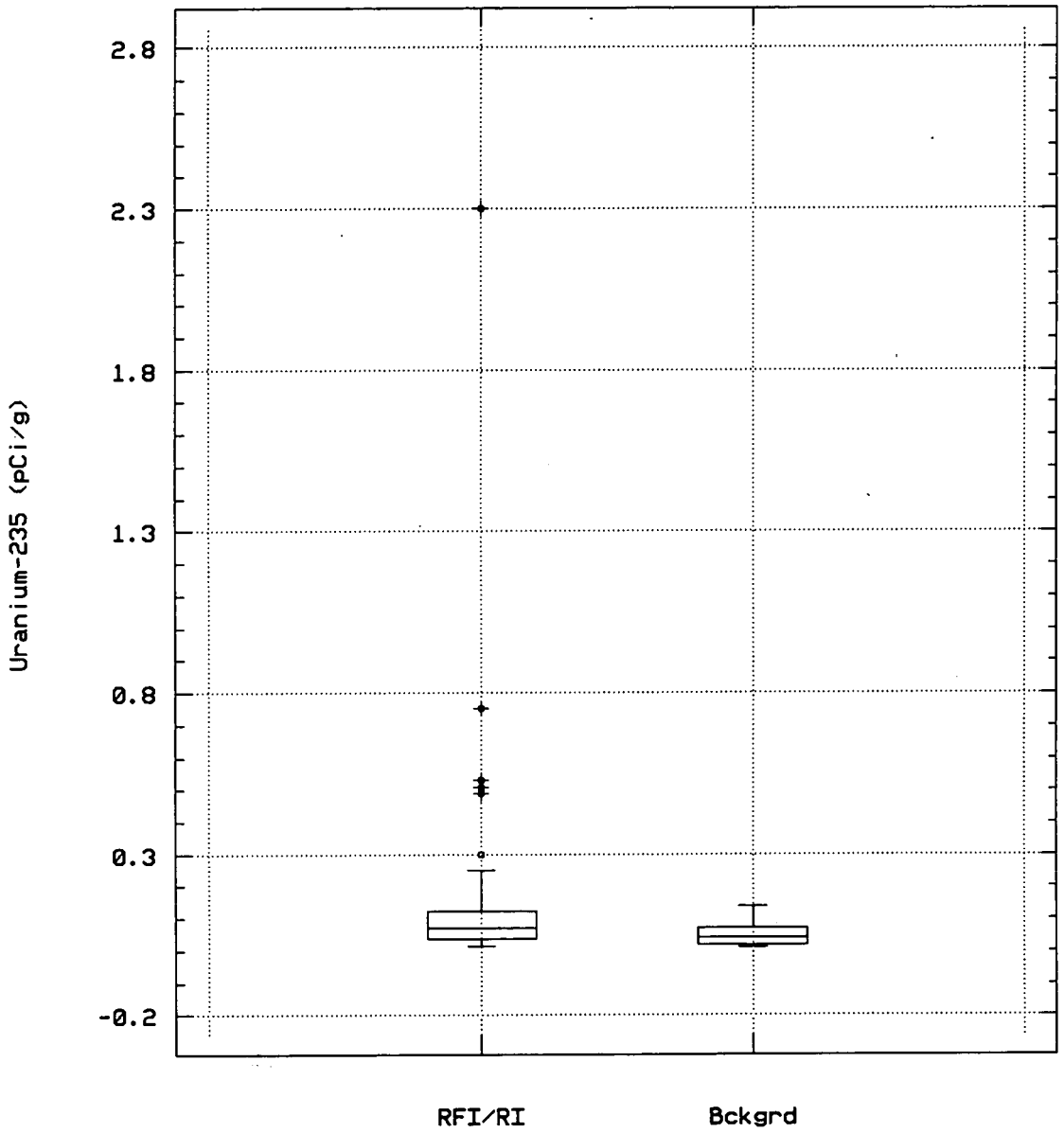

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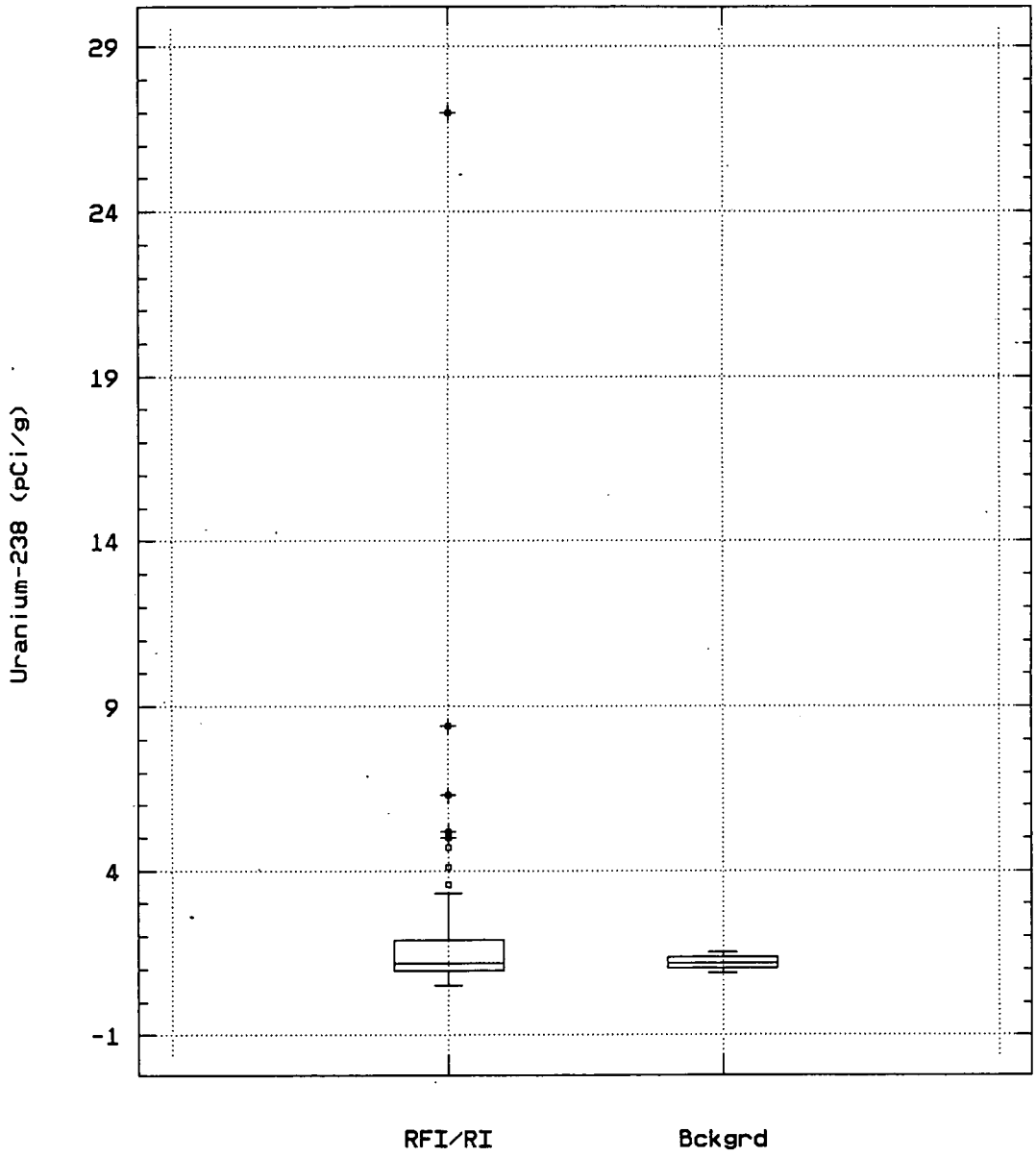
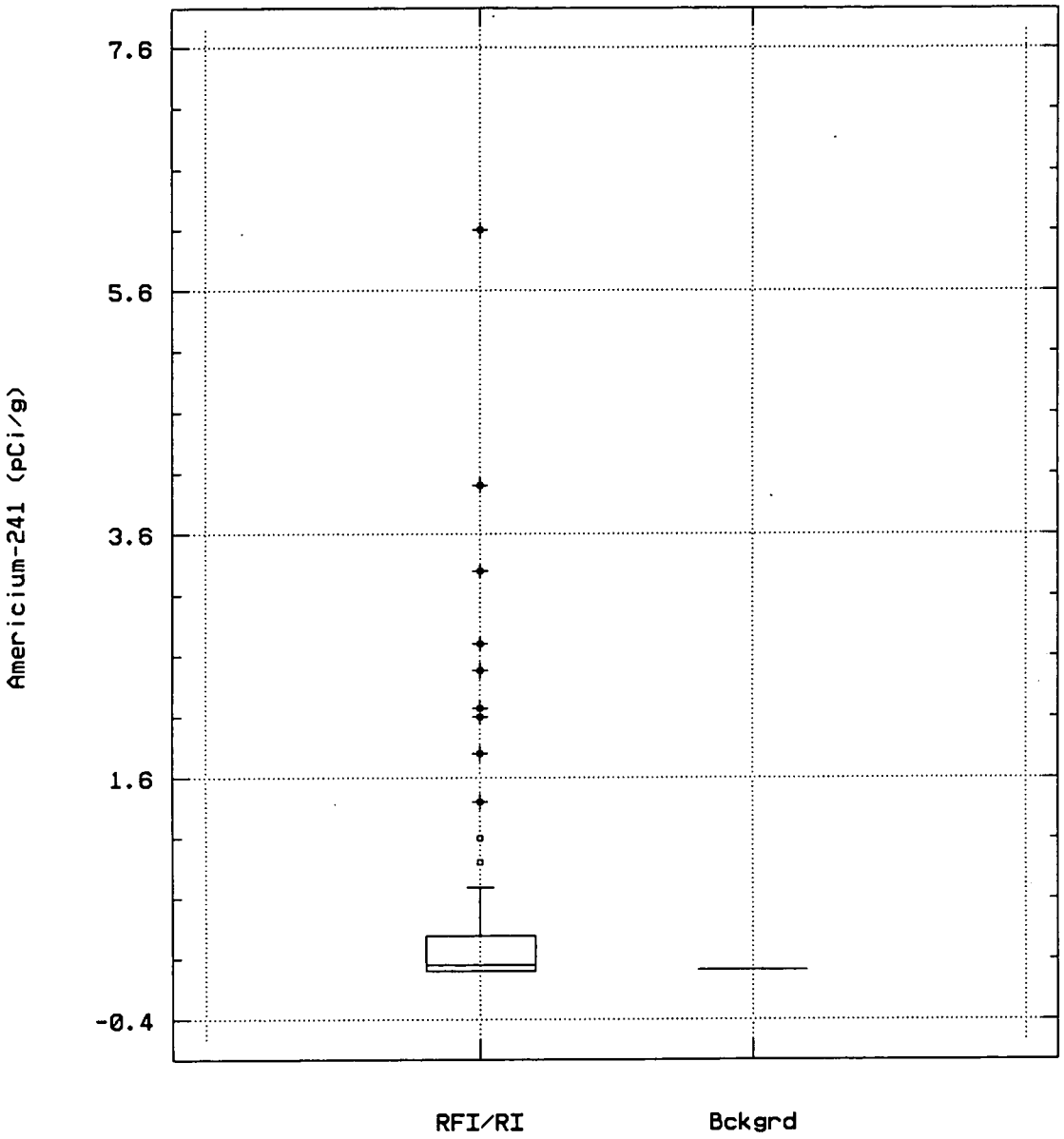
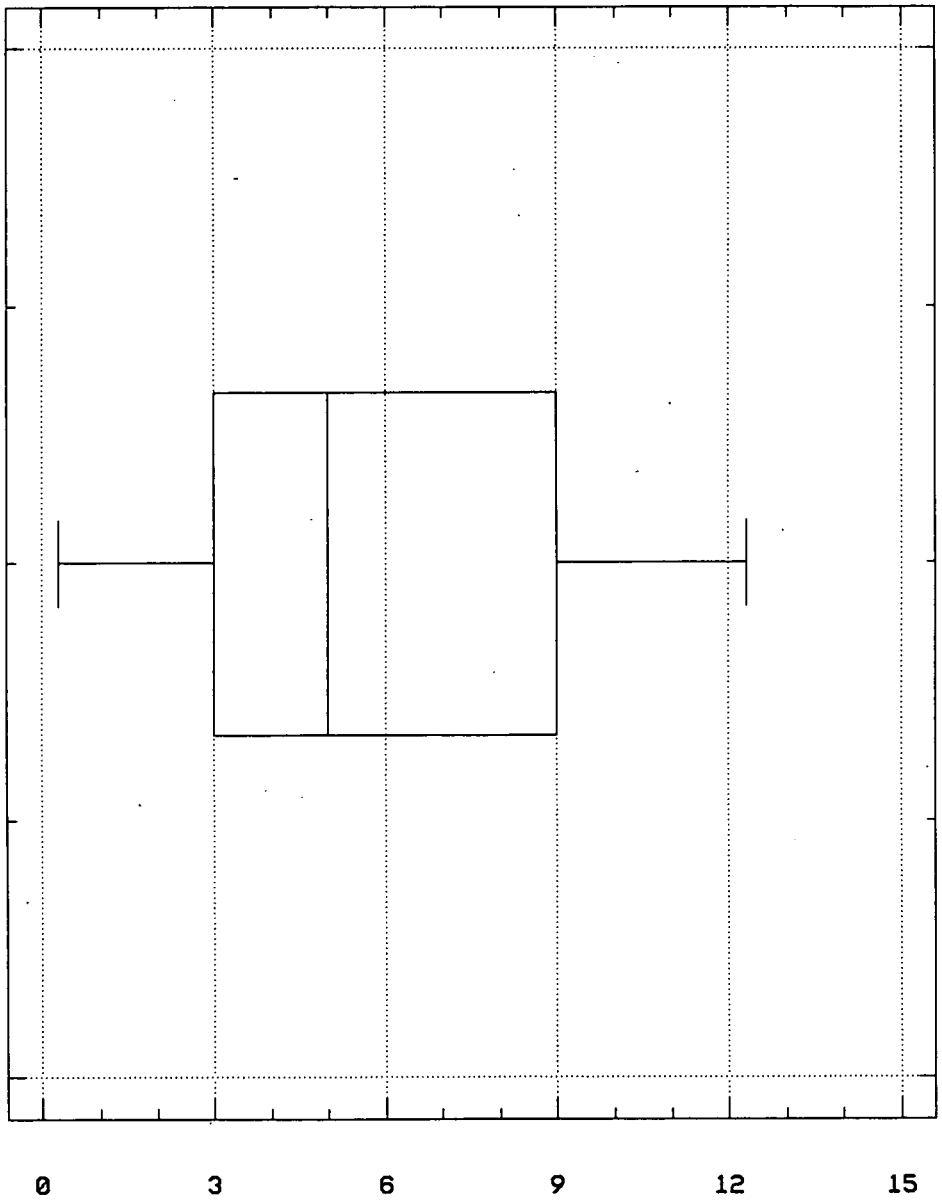


Comparison of RFI/RI and Background Data
Americium-241 in Vadose Zone Soil



RFI/RI Cesium-134 in Vadose Zone Soil



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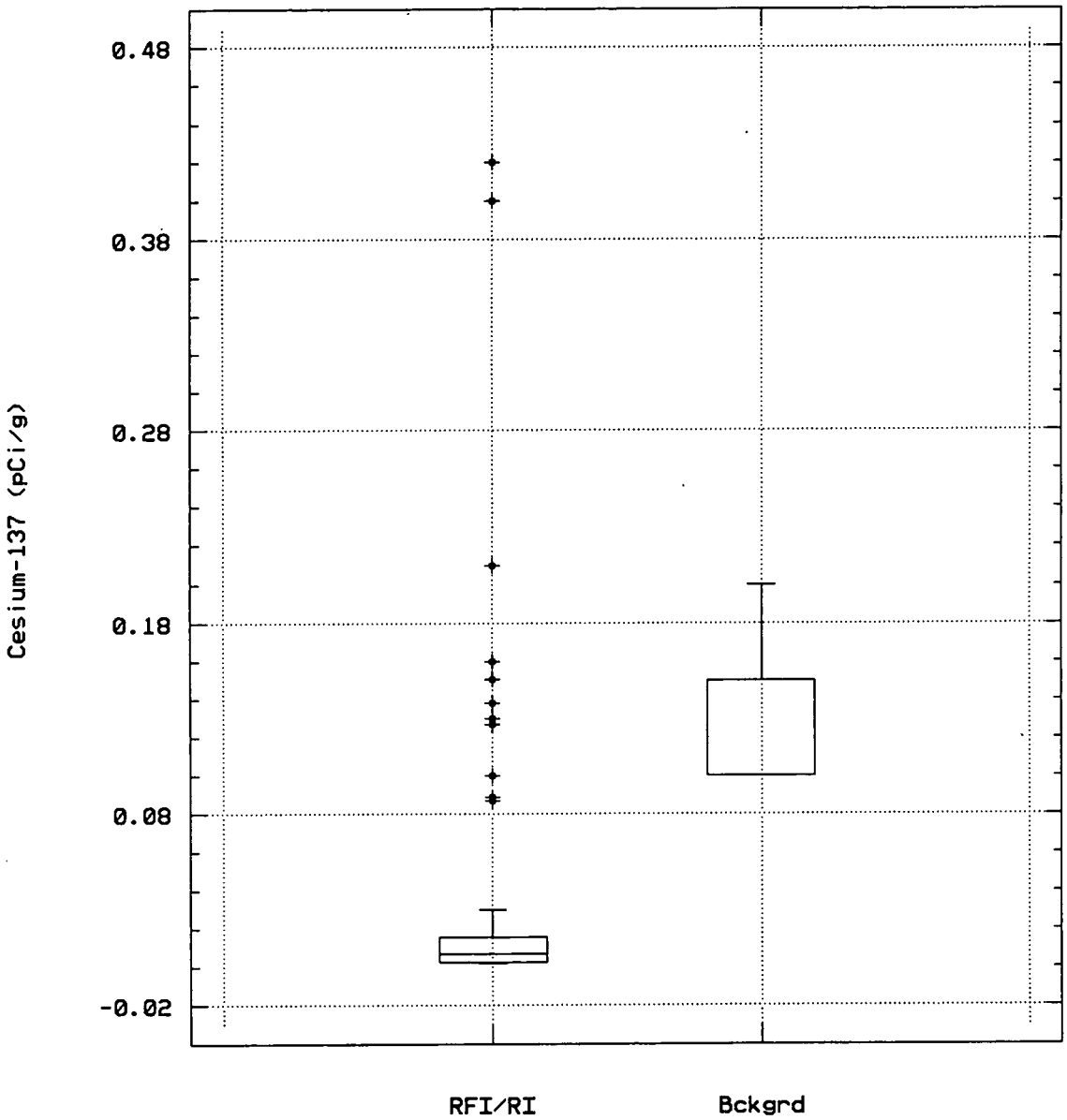
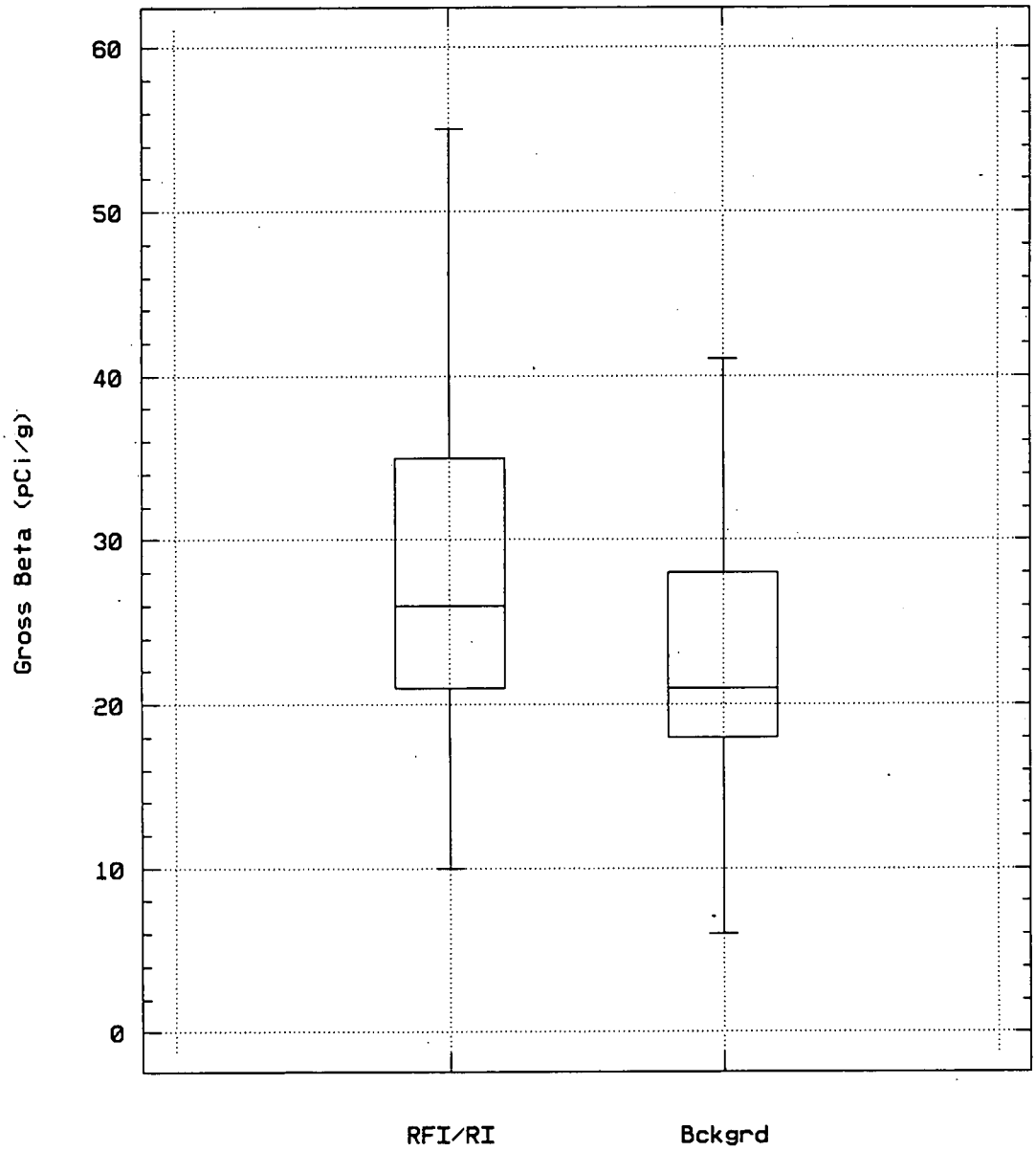
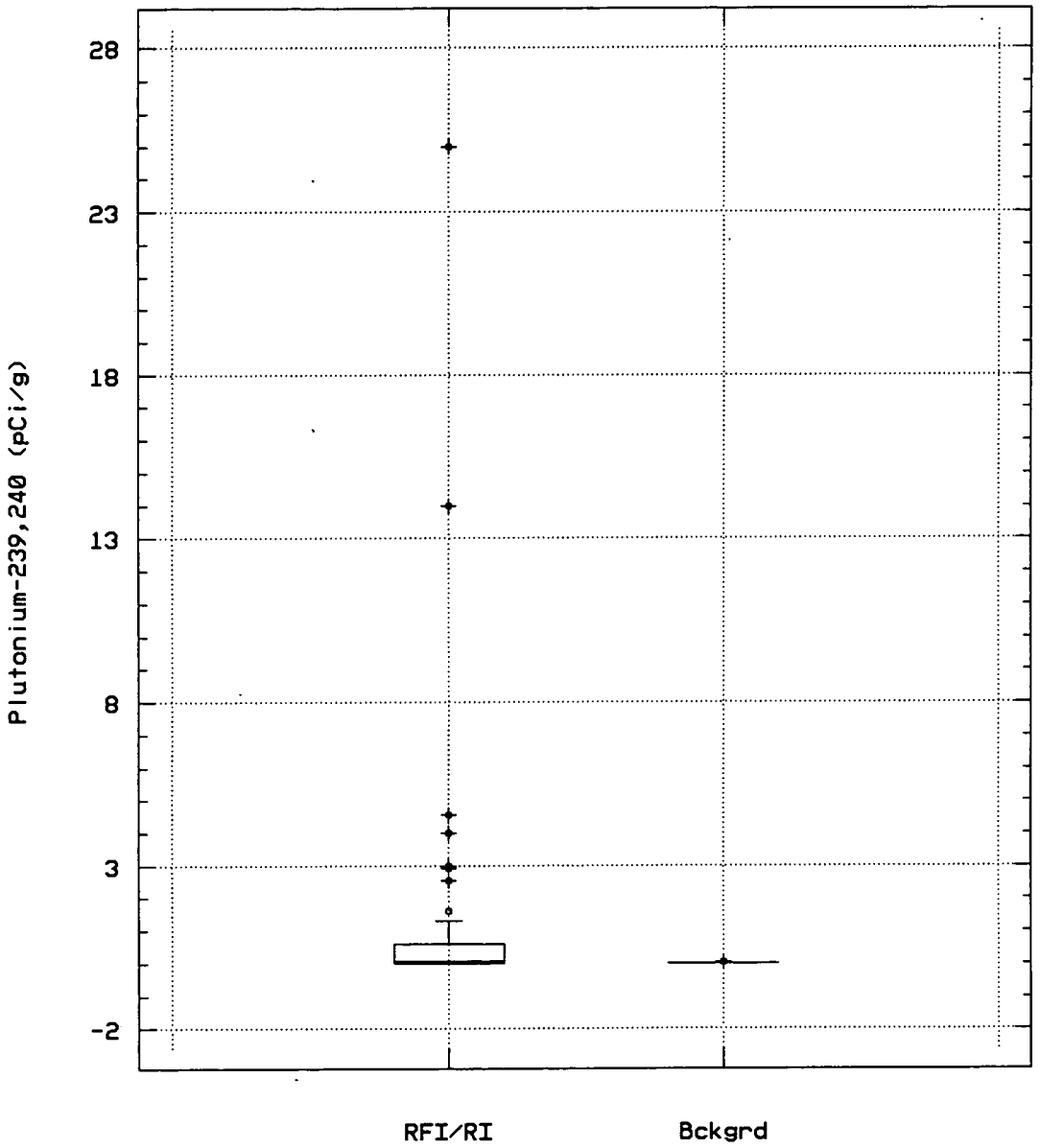


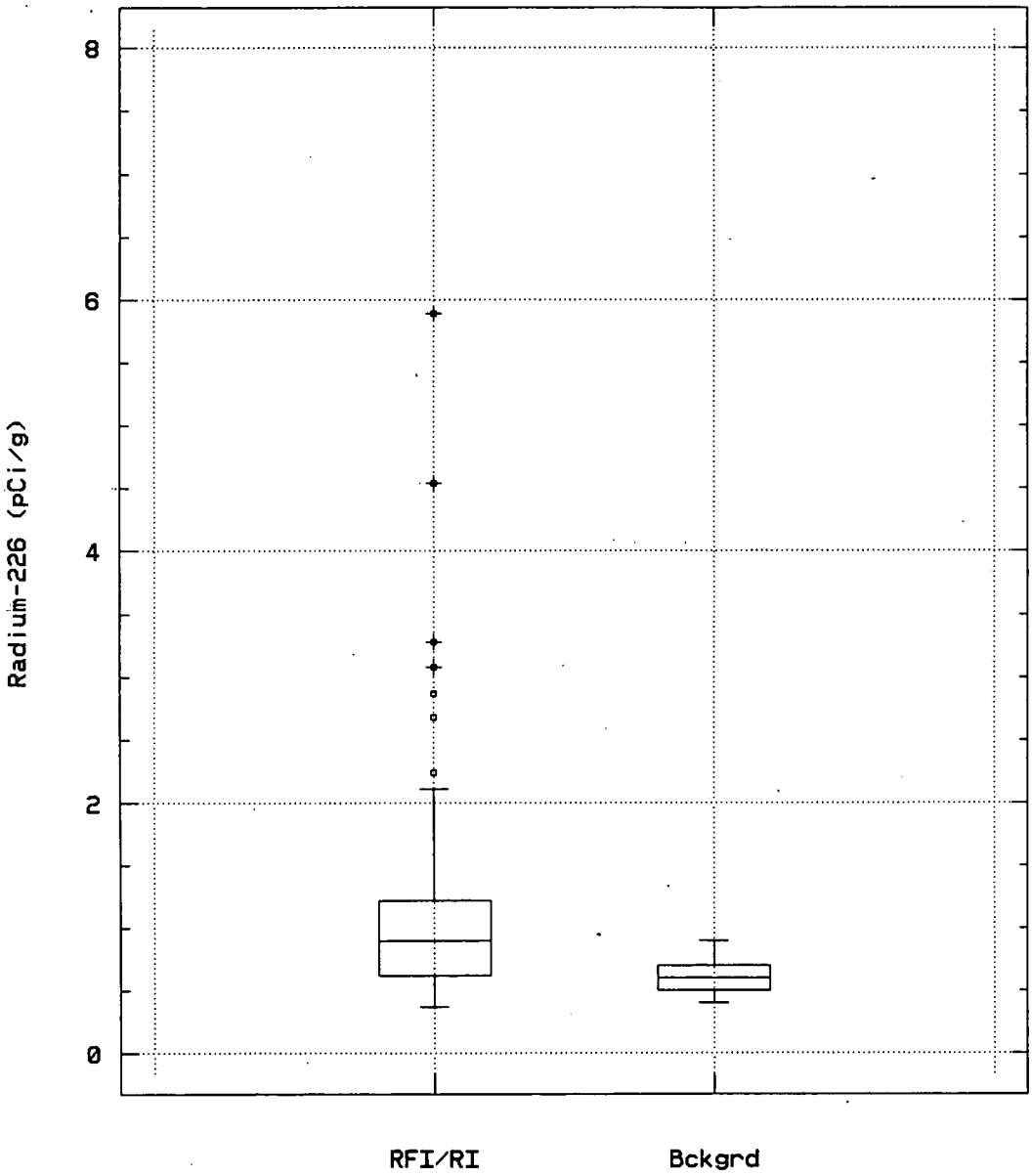
Comparison of RFI/RI and Background Data
Gross Beta in Vadose Zone Soil



Comparison of RFI/RI and Background Data
Plutonium-239,240 in Vadose Zone Soil



Comparison of RFI/RI and Background Data
Radium-226 in Vadose Zone Soil



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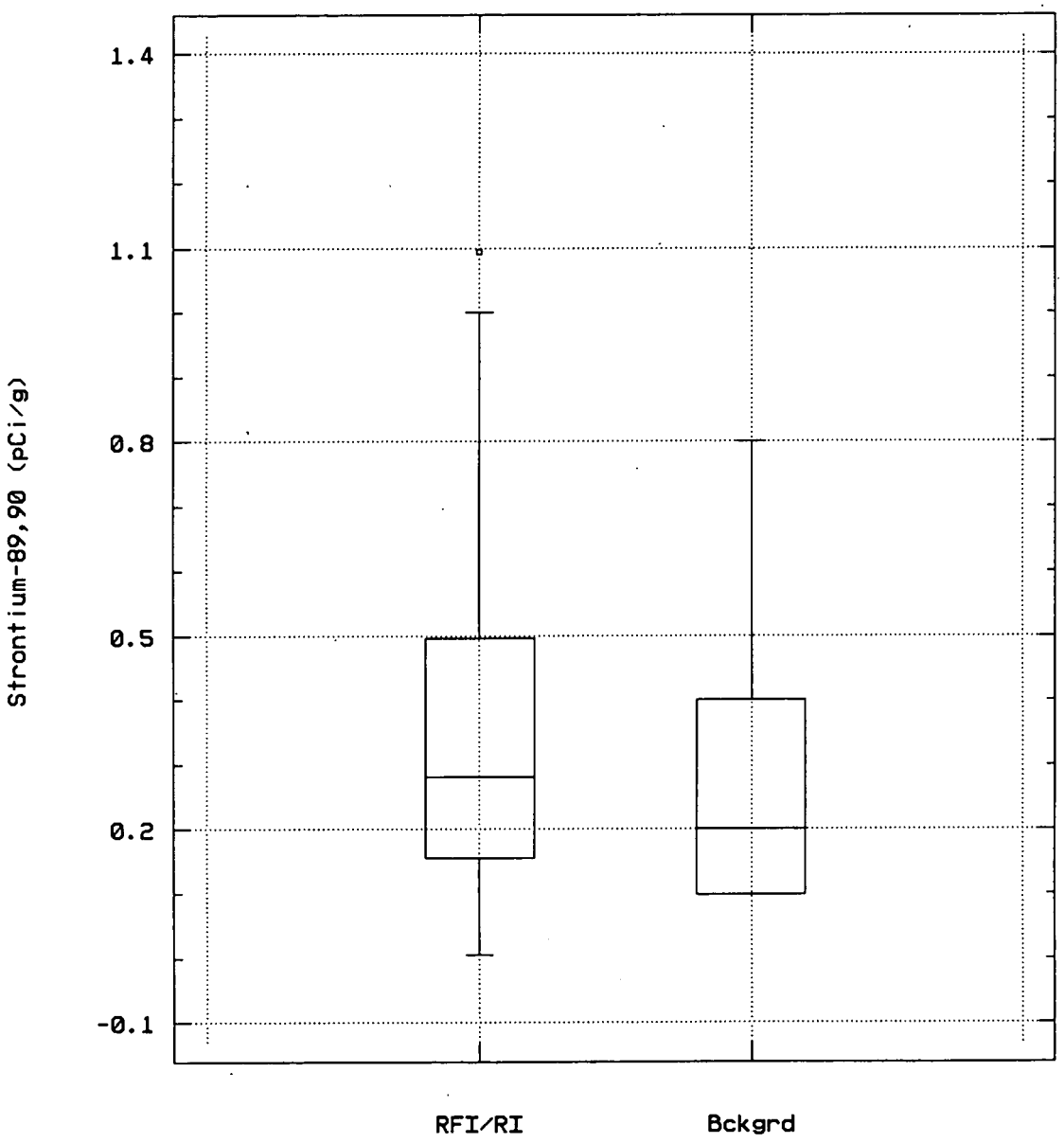
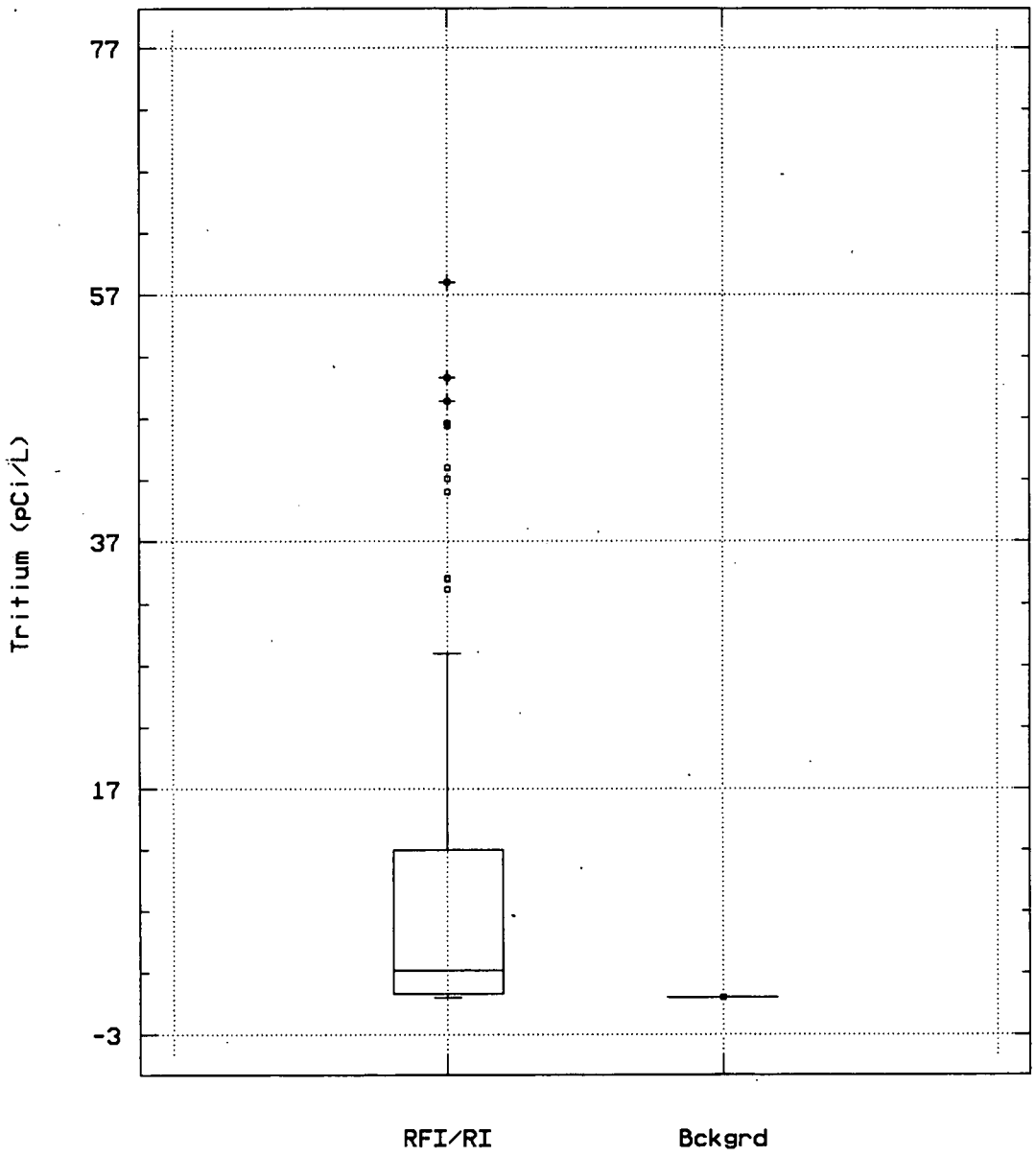
Strontium-89,90 in Vadose Zone Soil



Comparison of RFI/RI and Background Data
Tritium in Vadose Zone Soil



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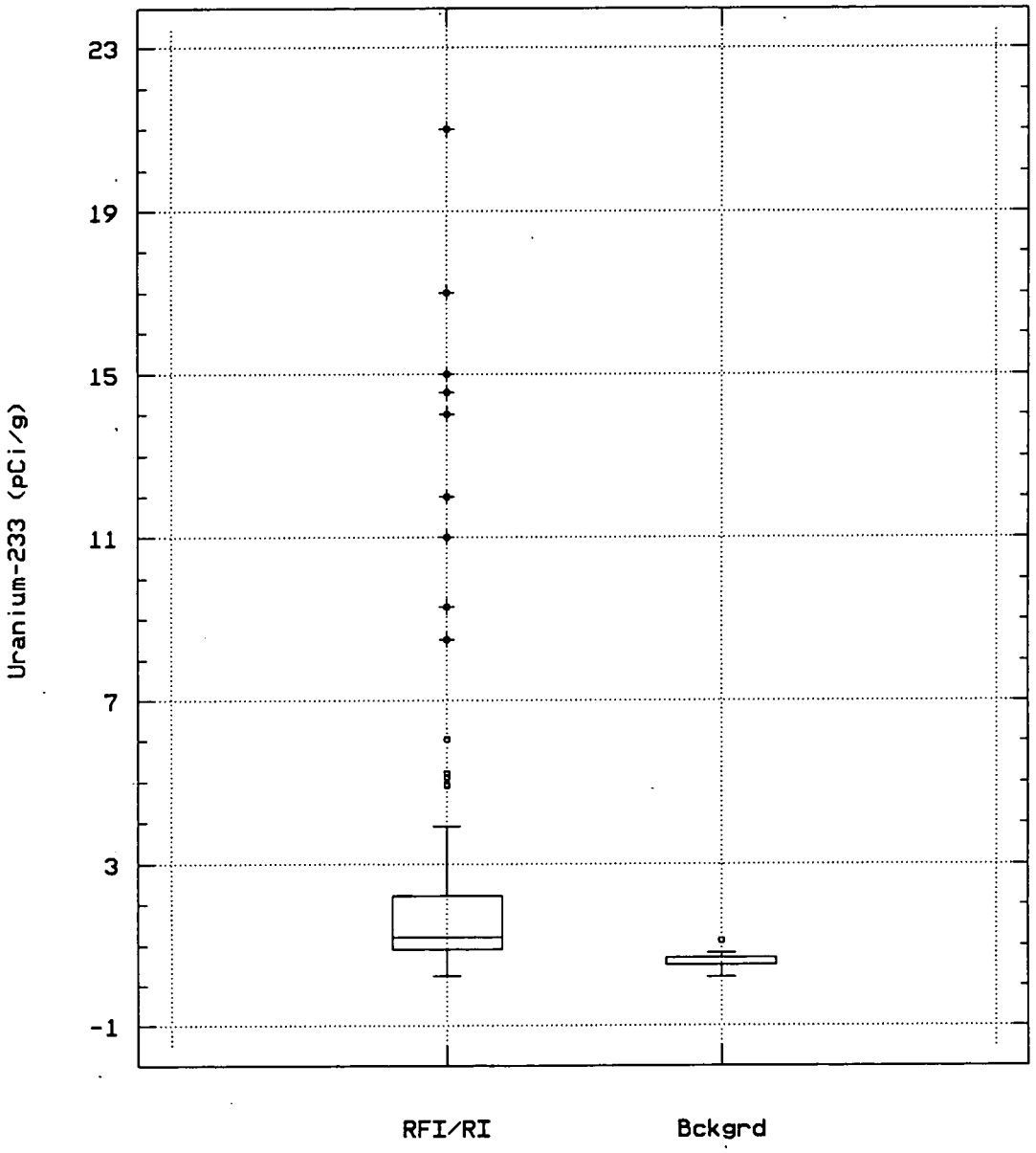
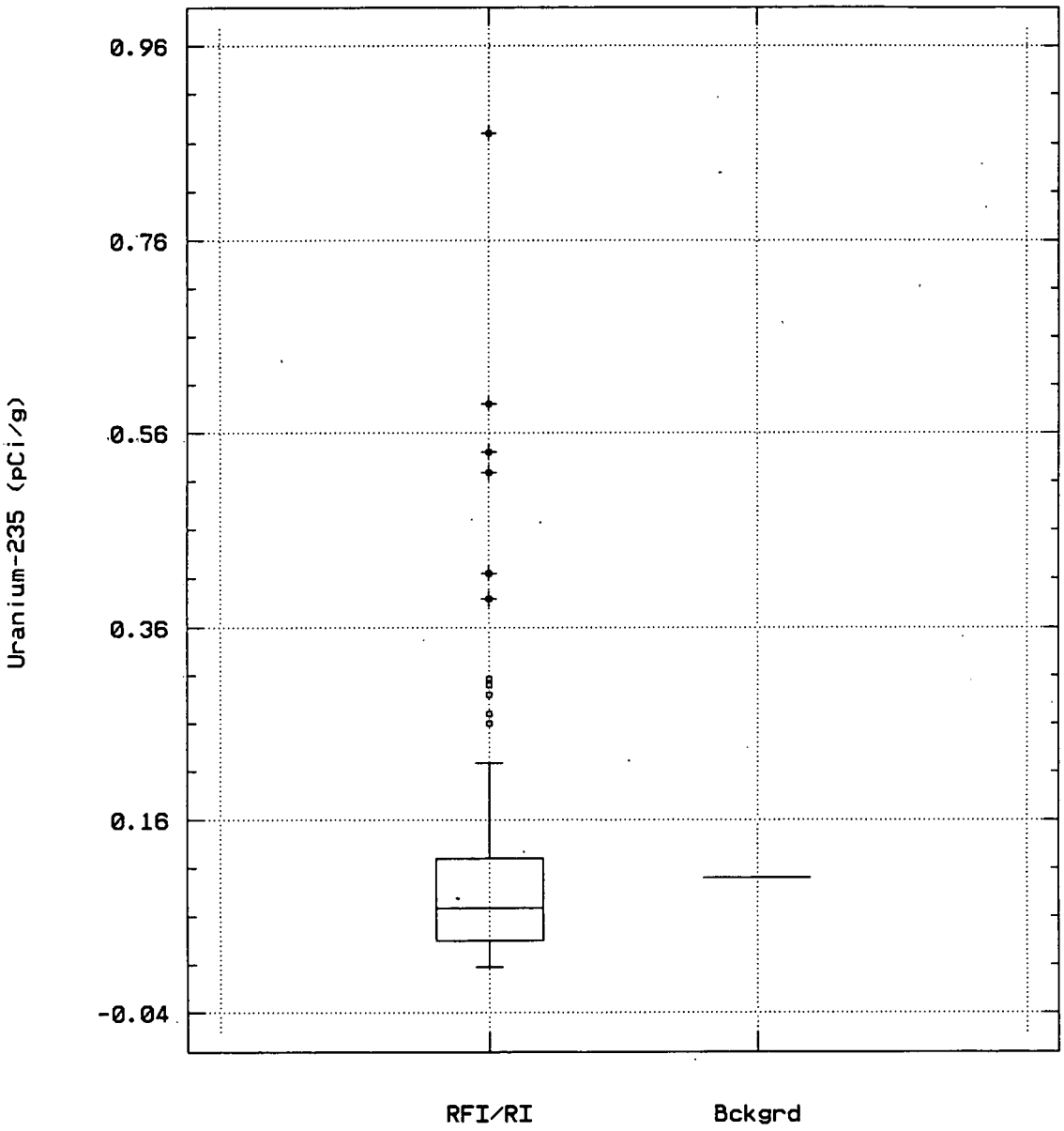
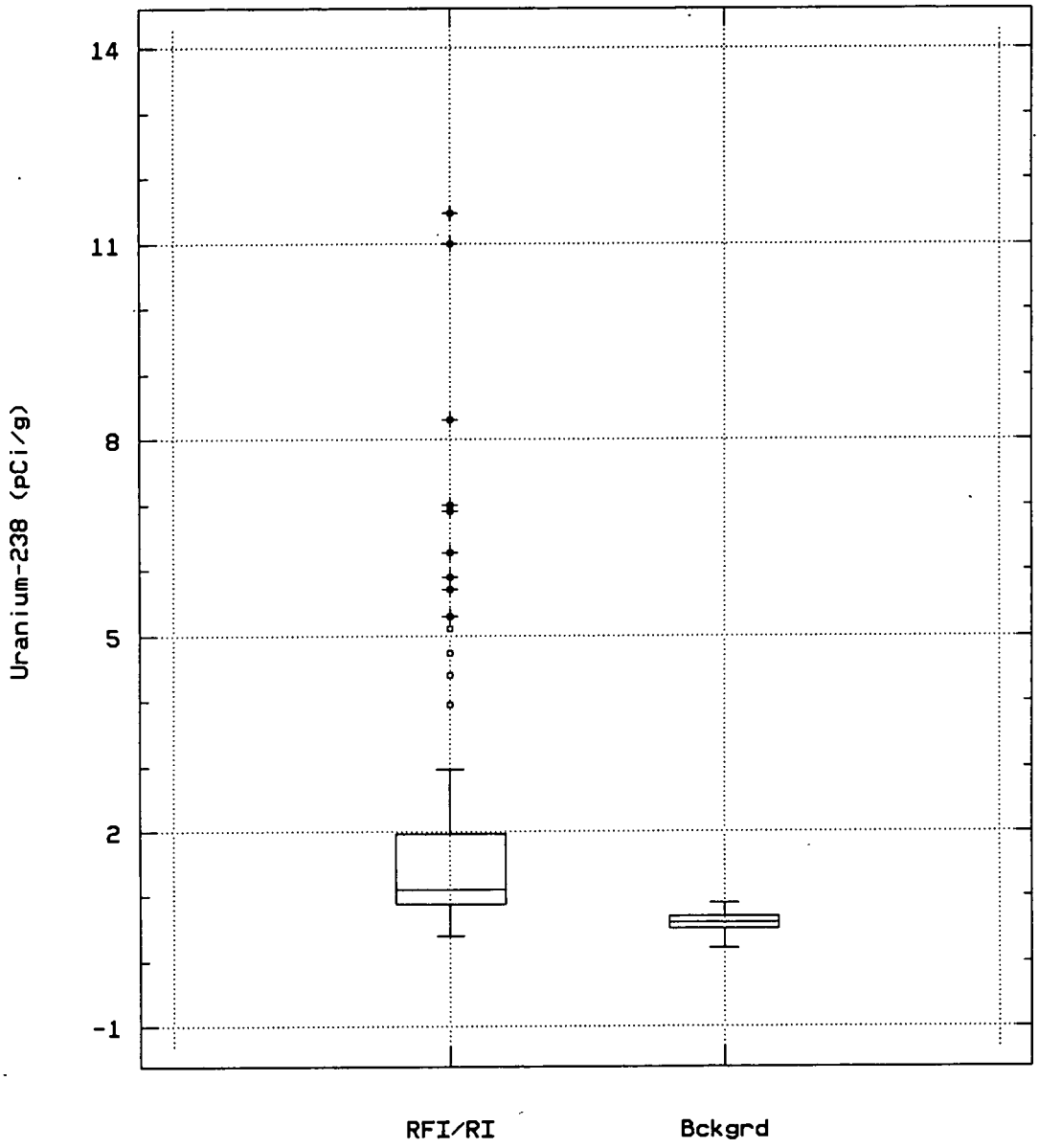
Uranium-233 in Vadose Zone Soil



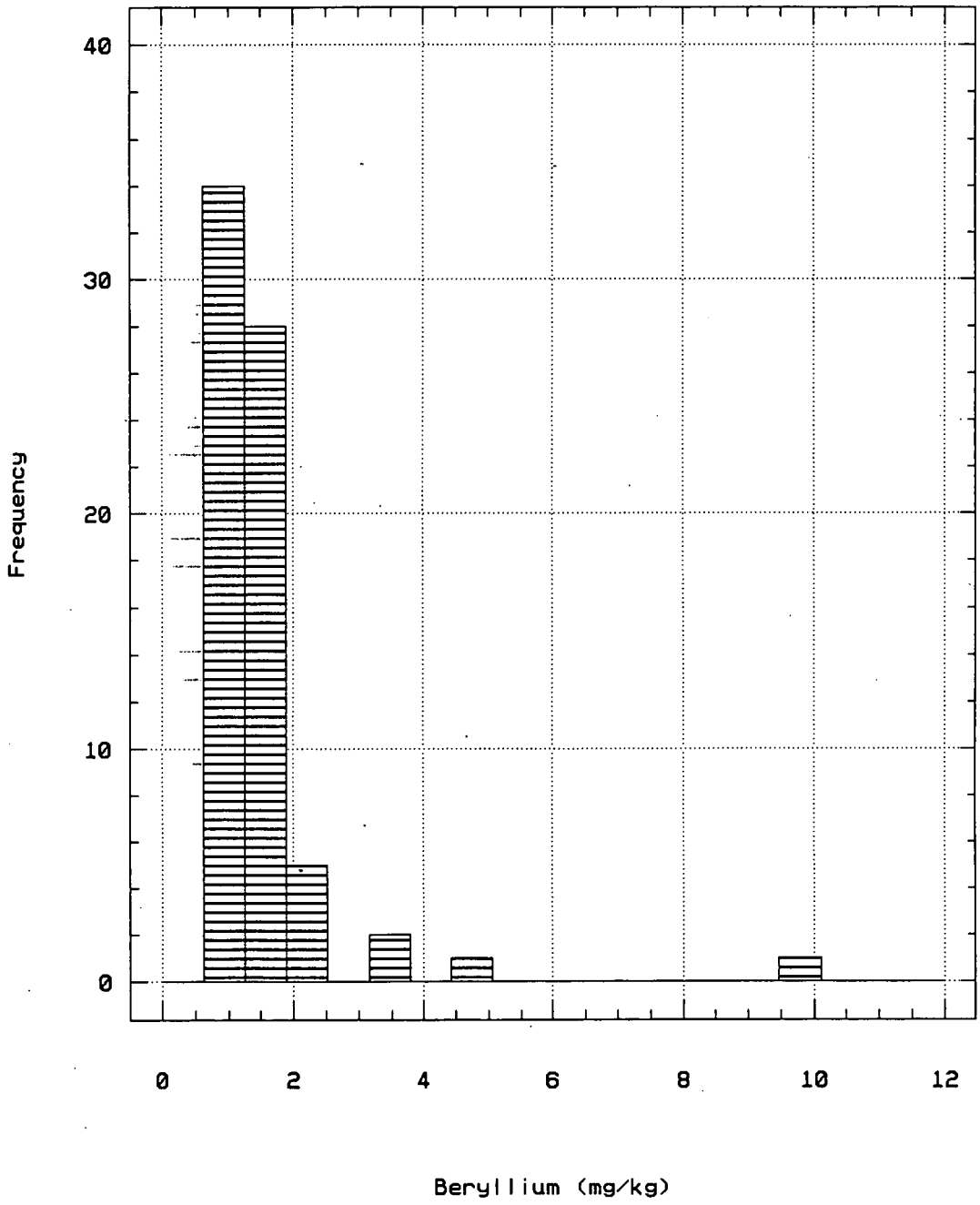
Comparison of RFI/RI and Background Data
Uranium-235 in Vadose Zone Soil



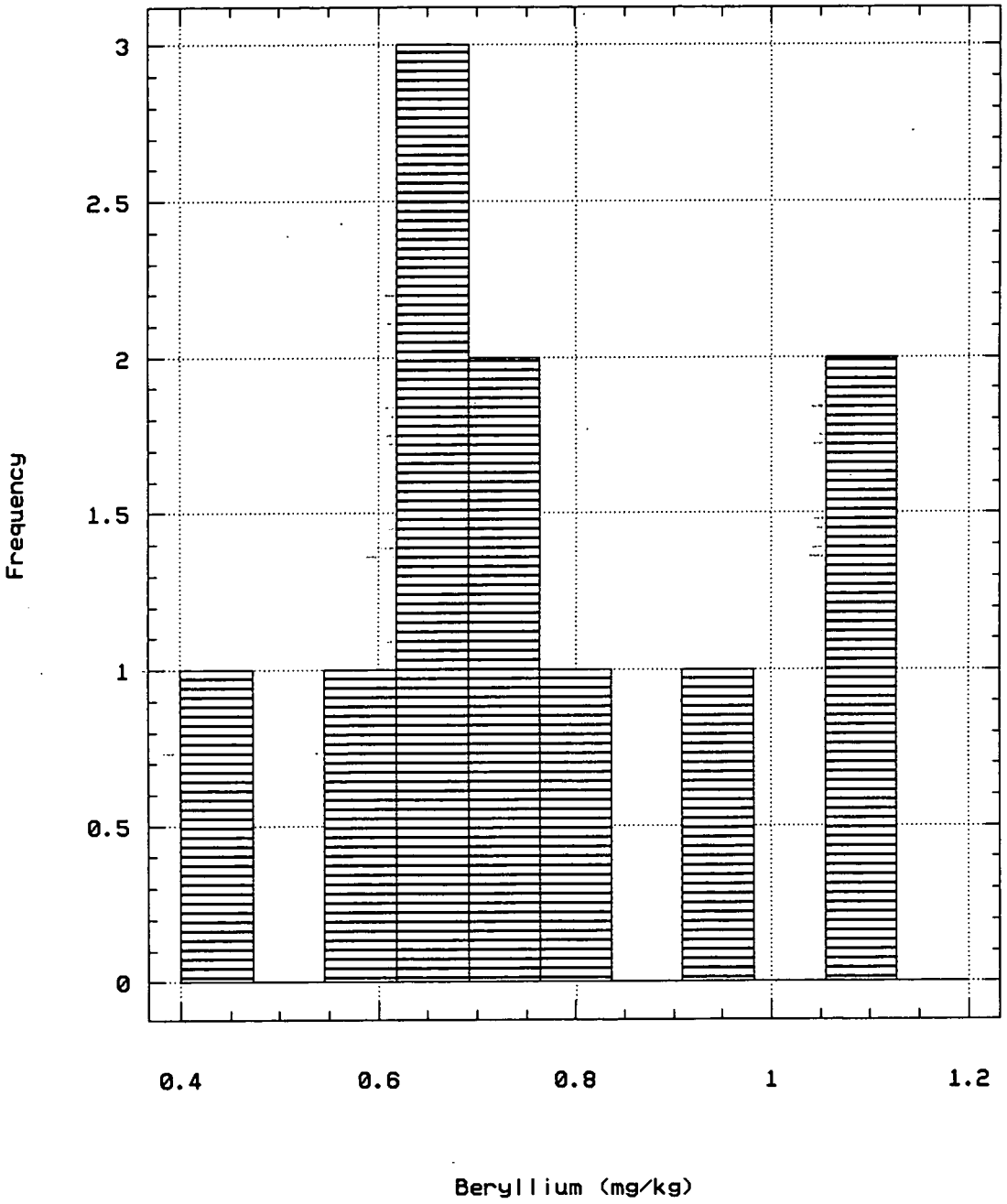
Comparison of RFI/RI and Background Data
Uranium-238 in Vadose Zone Soil



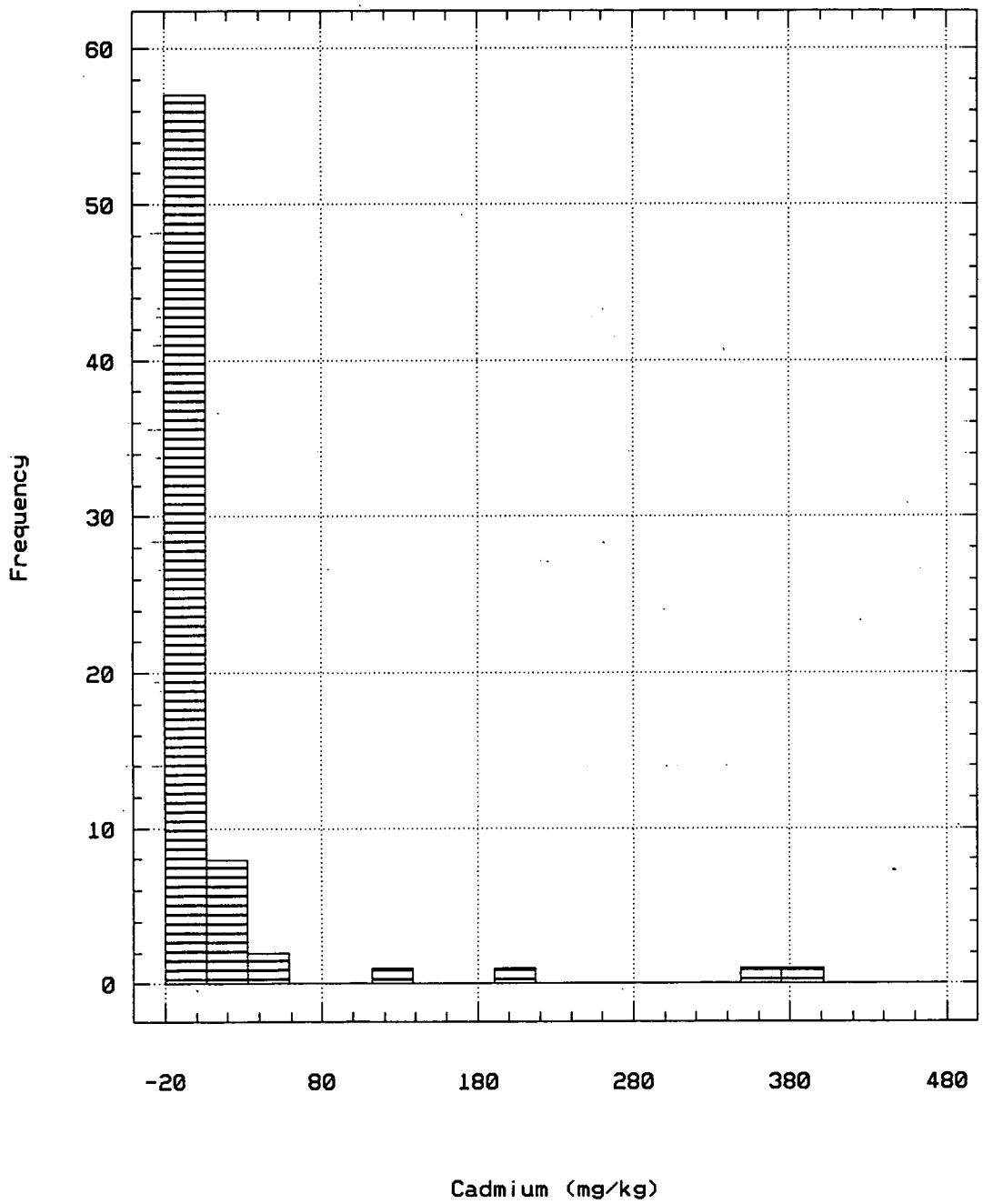
Frequency Histogram
RFI/RI Beryllium in Surficial Soil



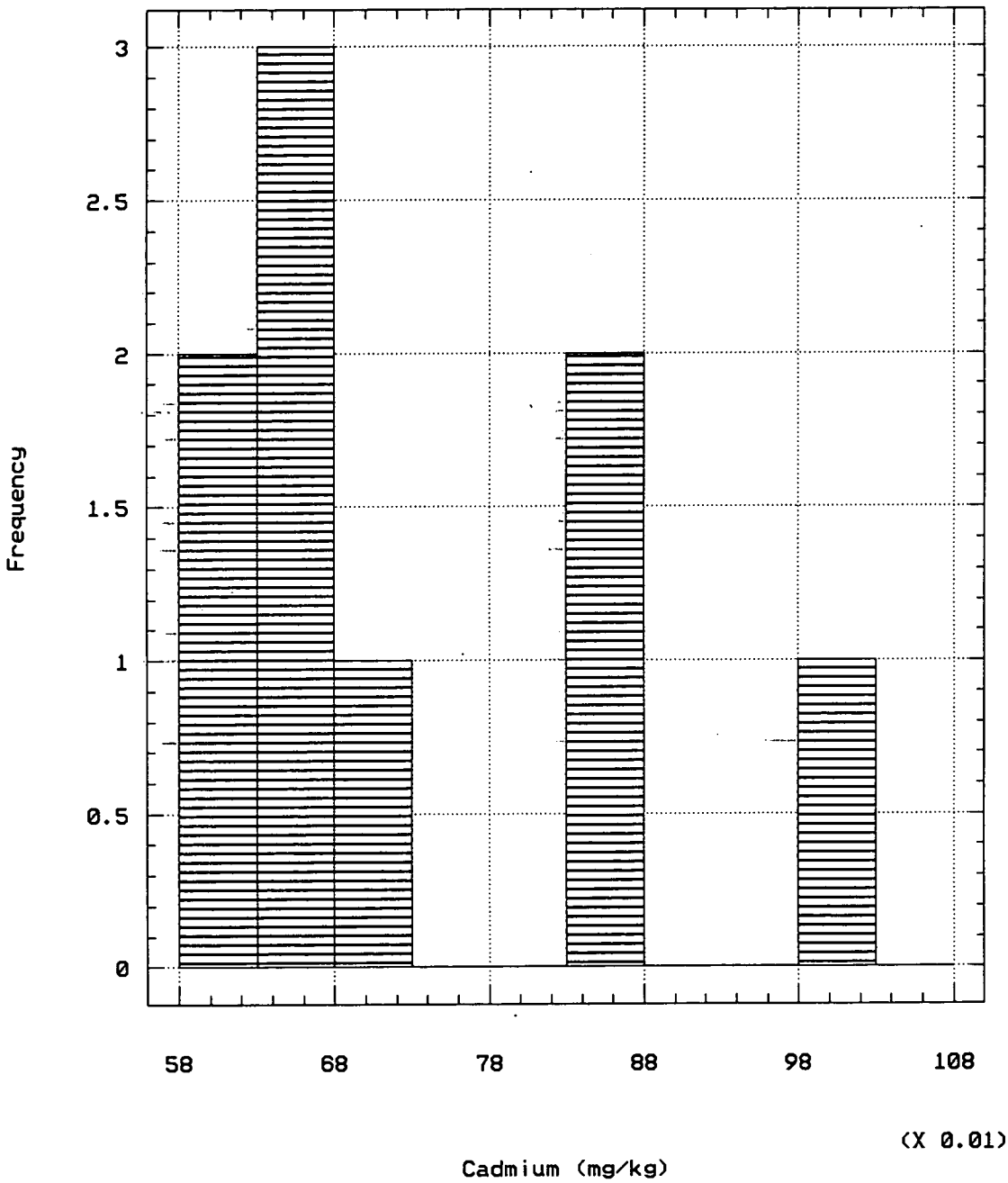
Frequency Histogram
Background Beryllium in Surficial Soil



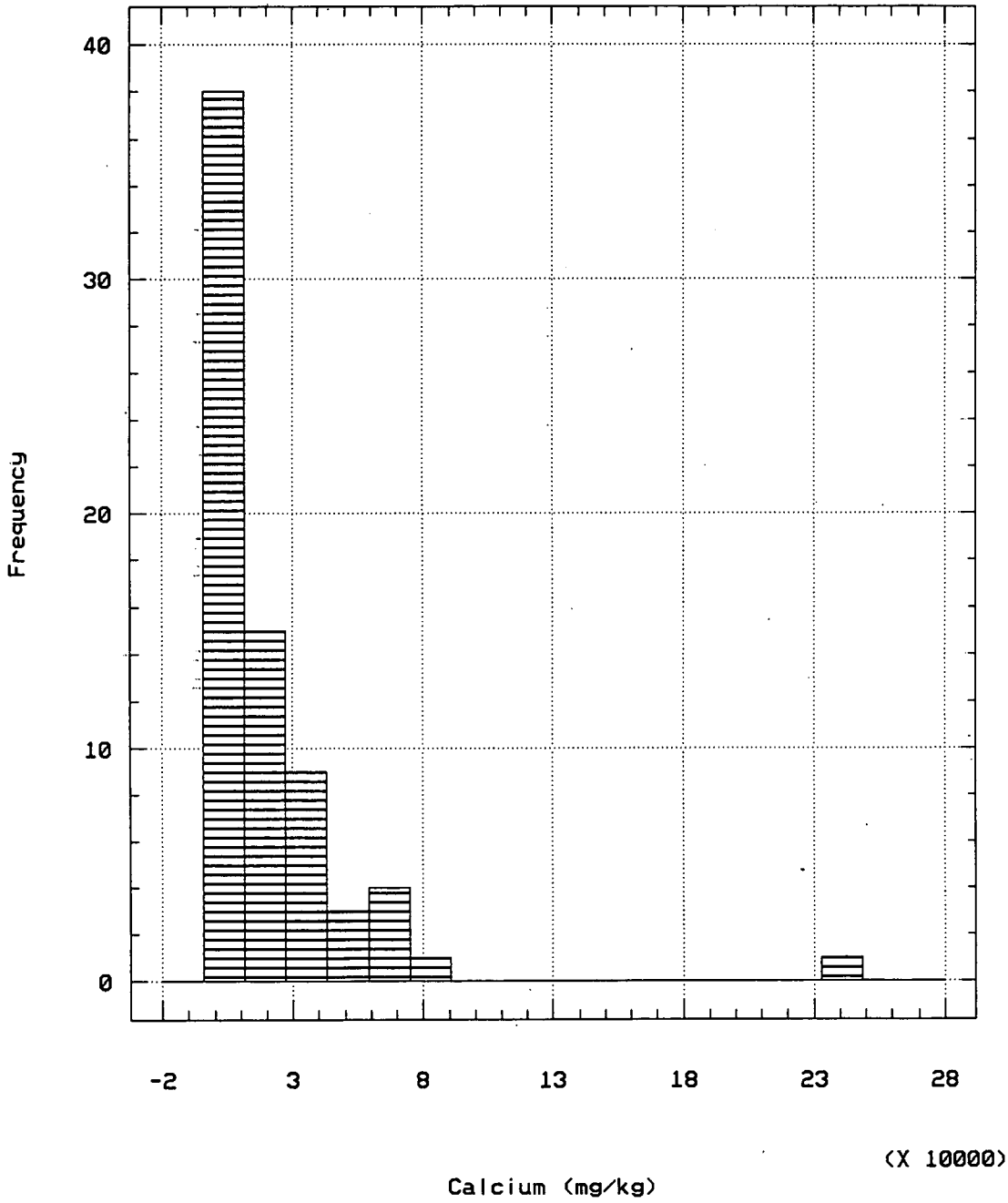
Frequency Histogram
RFI/RI Cadmium Surficial Soil



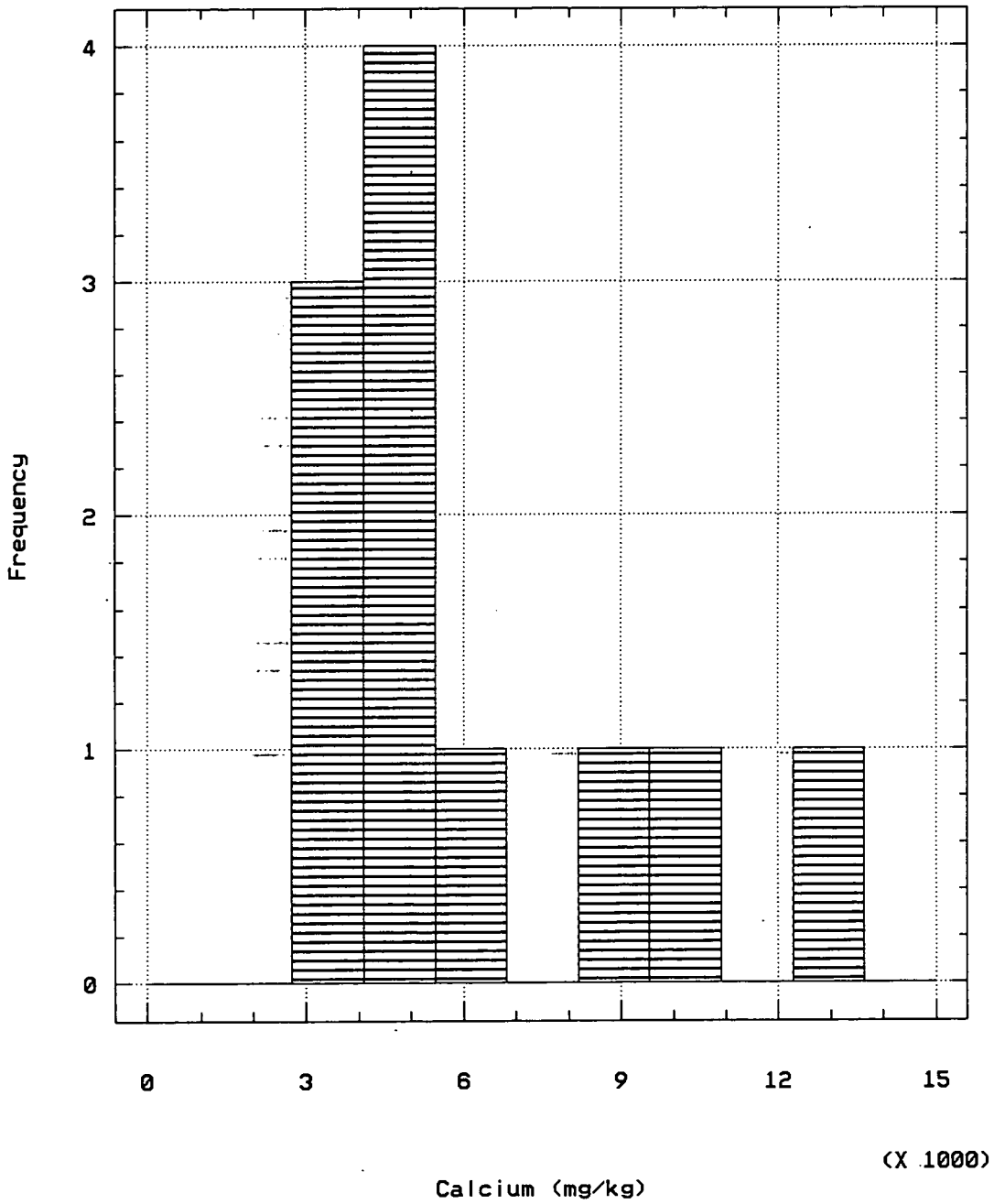
Frequency Histogram
Background Cadmium in Surficial Soil



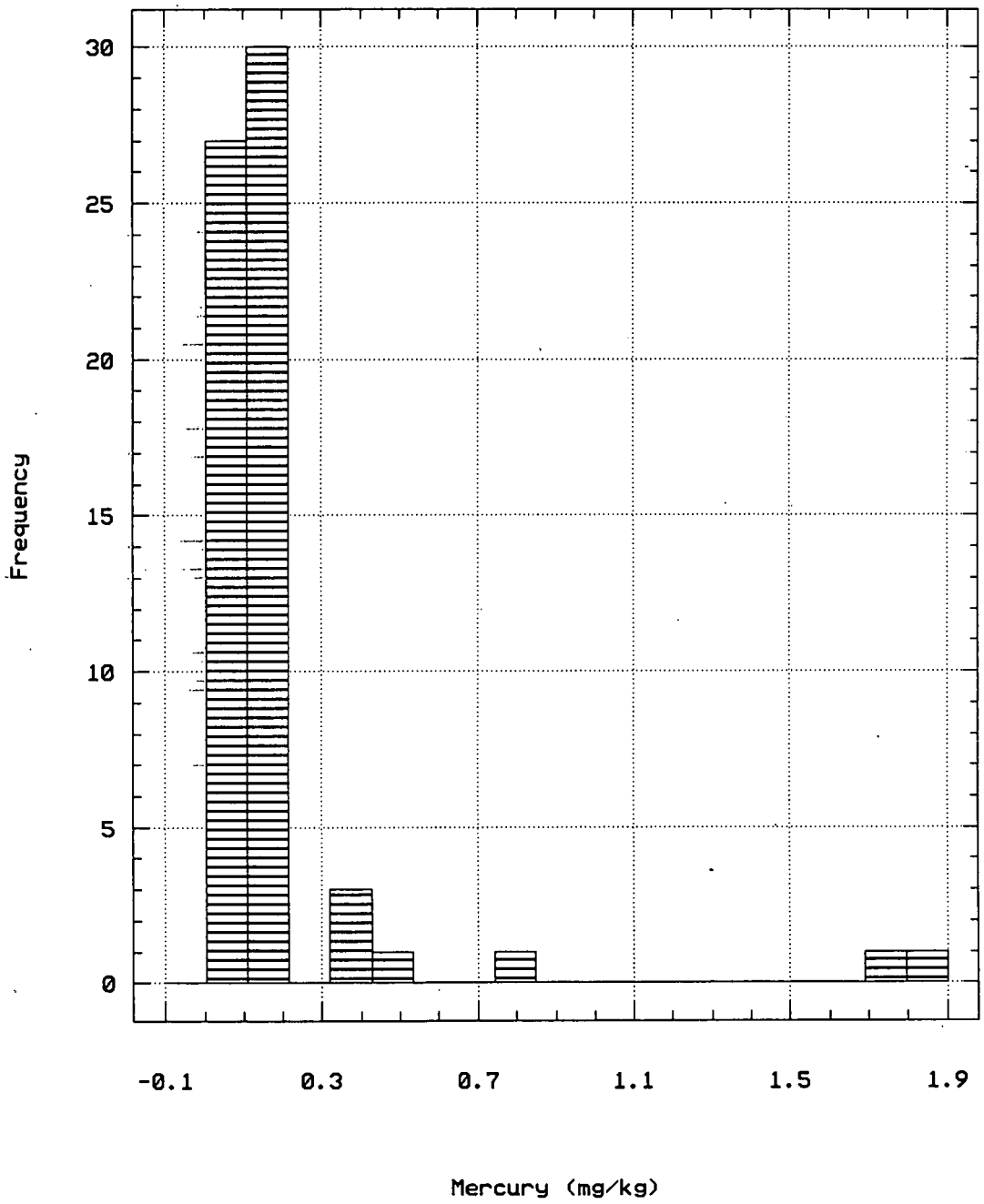
Frequency Histogram
RFI/RI Calcium in Surficial Soil



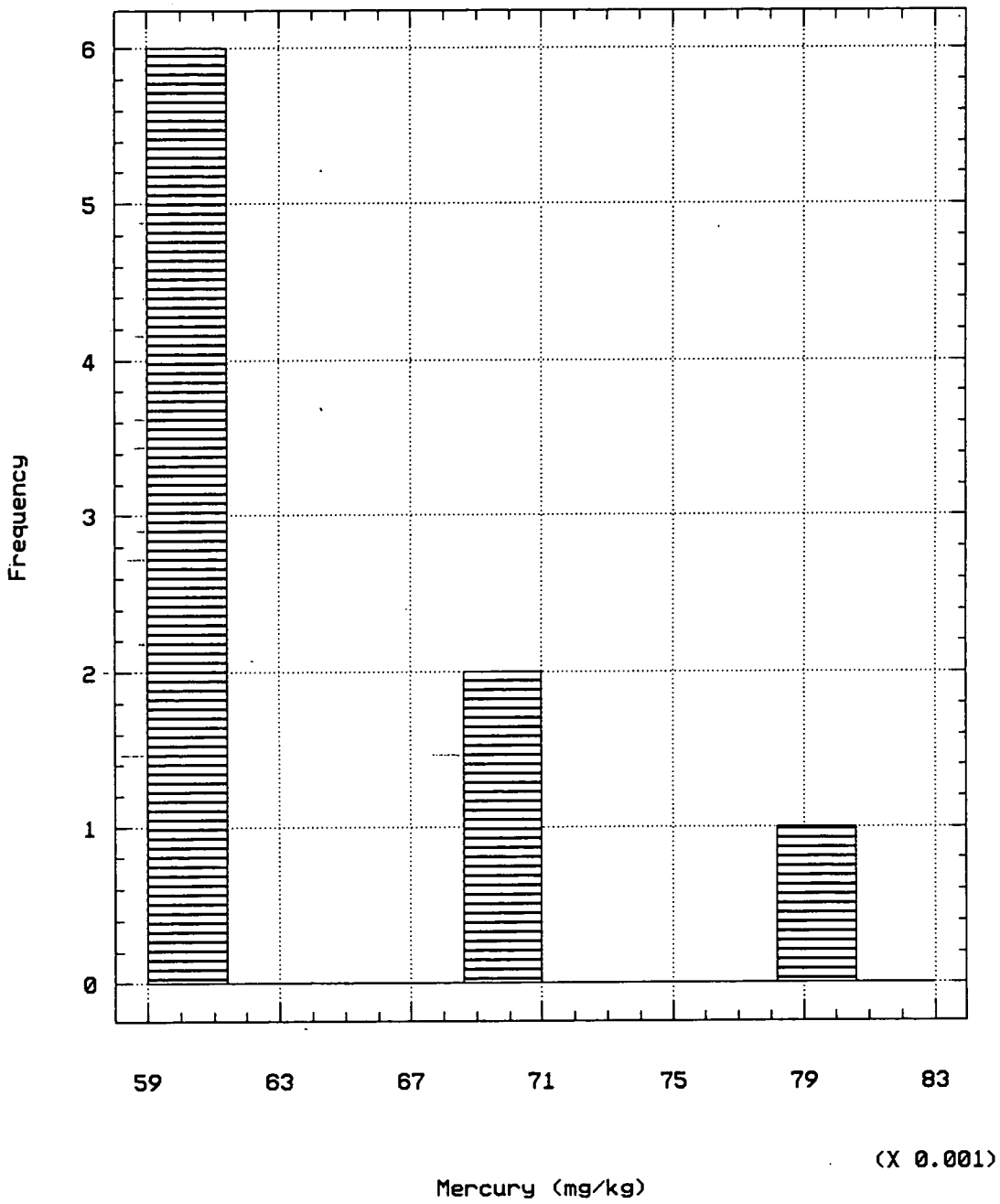
Frequency Histogram
Background Calcium in Surficial Soil



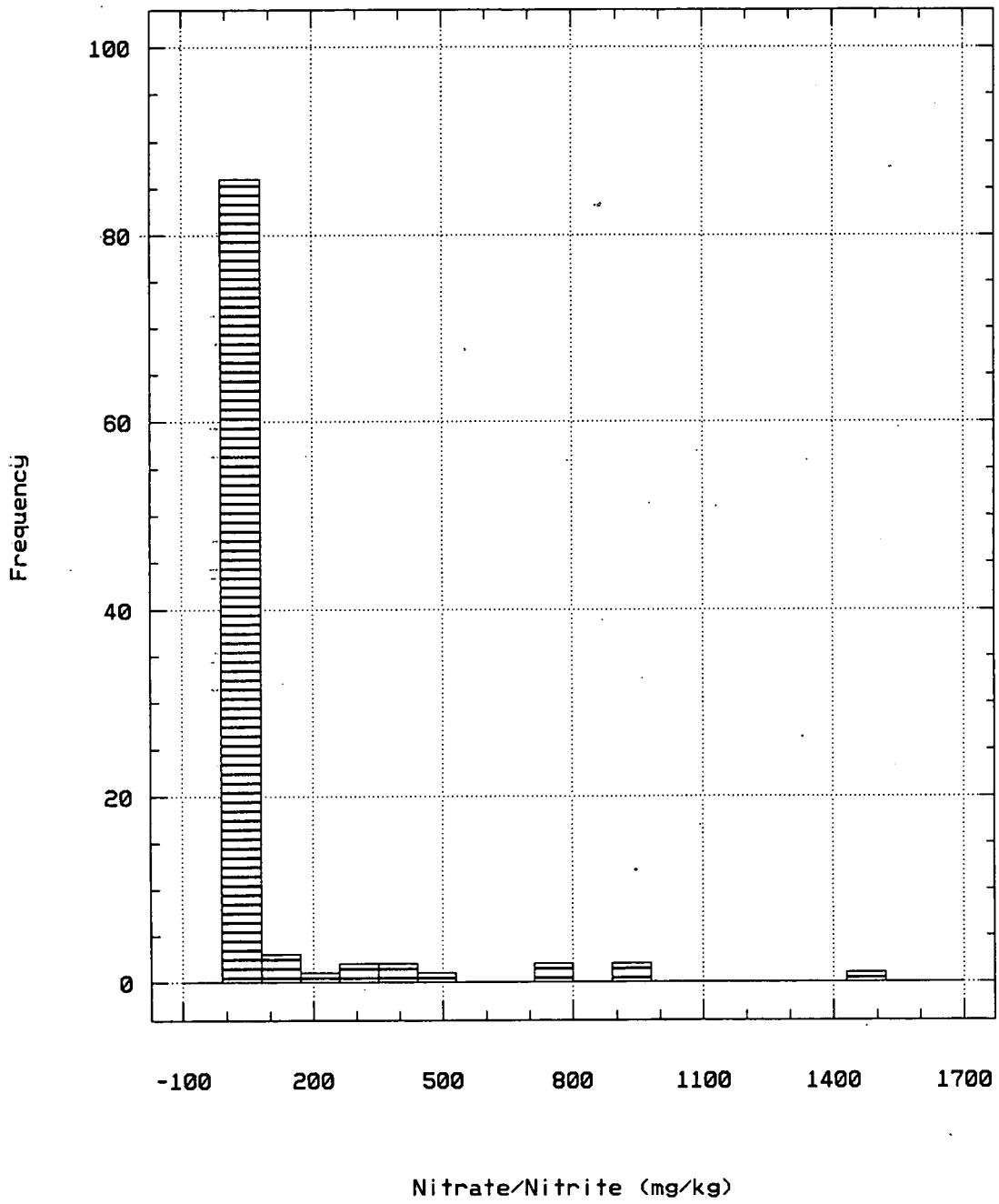
Frequency Histogram
RFI/RI Mercury in Surficial Soil



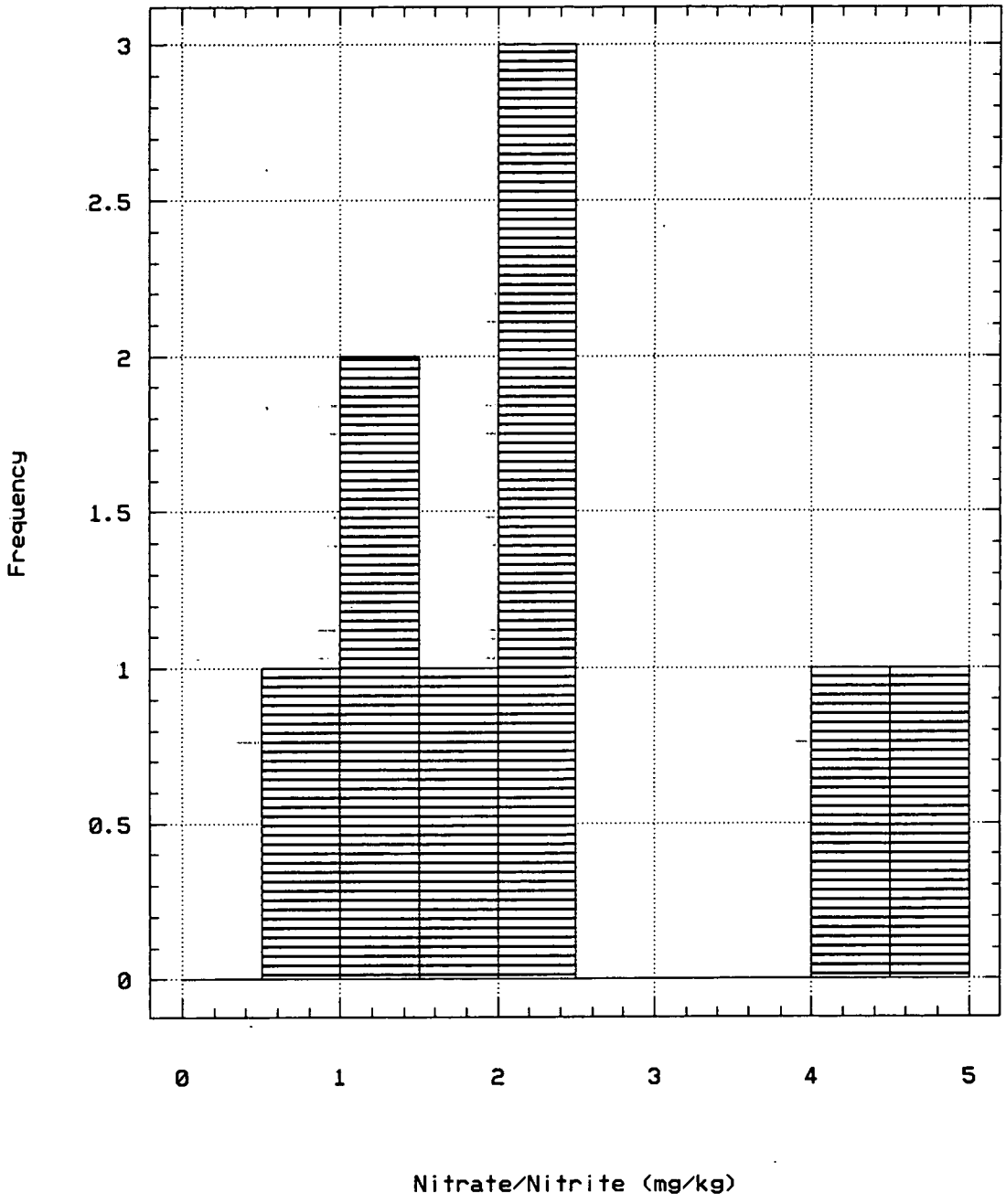
Frequency Histogram
Background Mercury in Surficial Soil



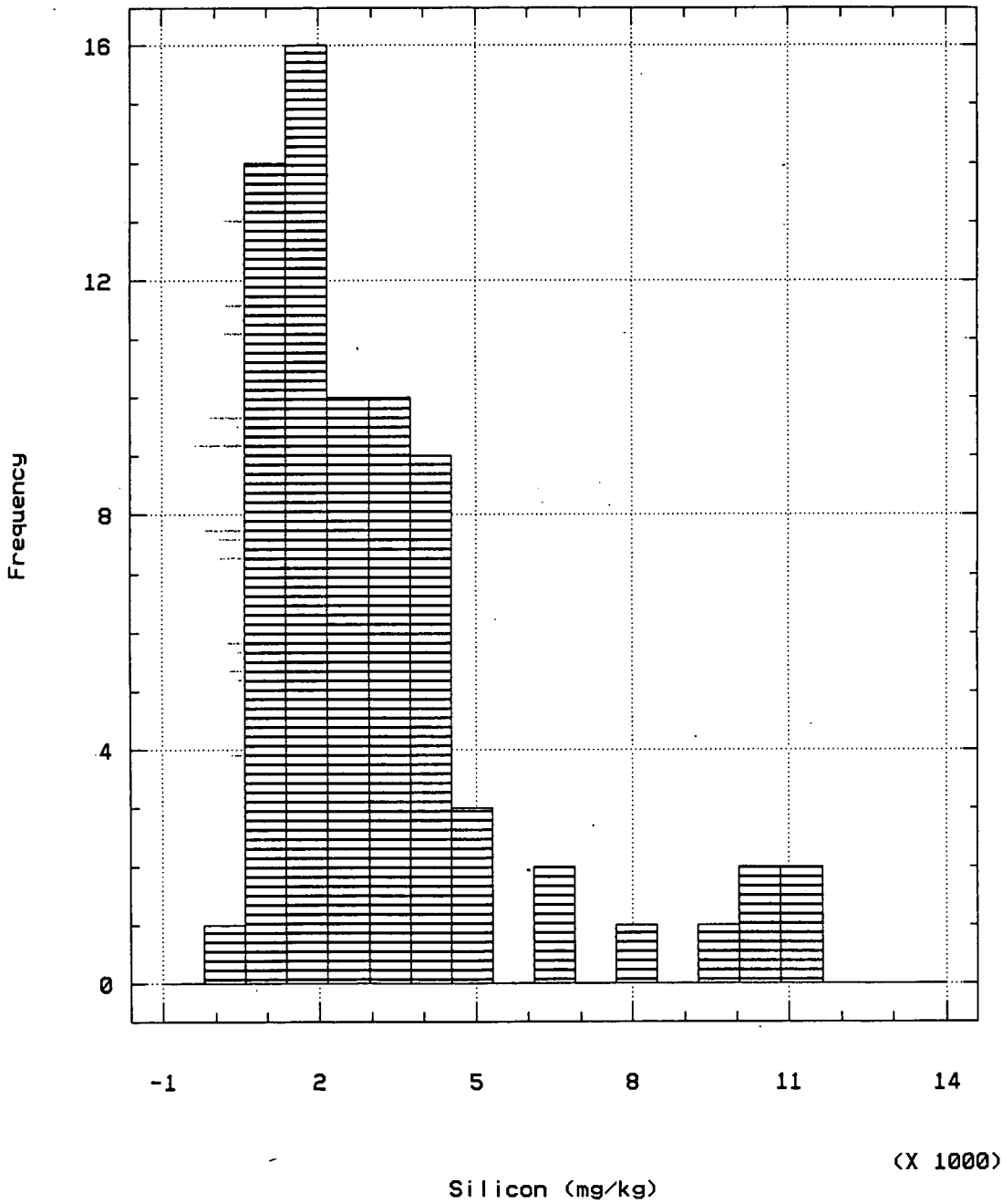
Frequency Histogram
RFI/RI Nitrate/Nitrite in Surficial Soil



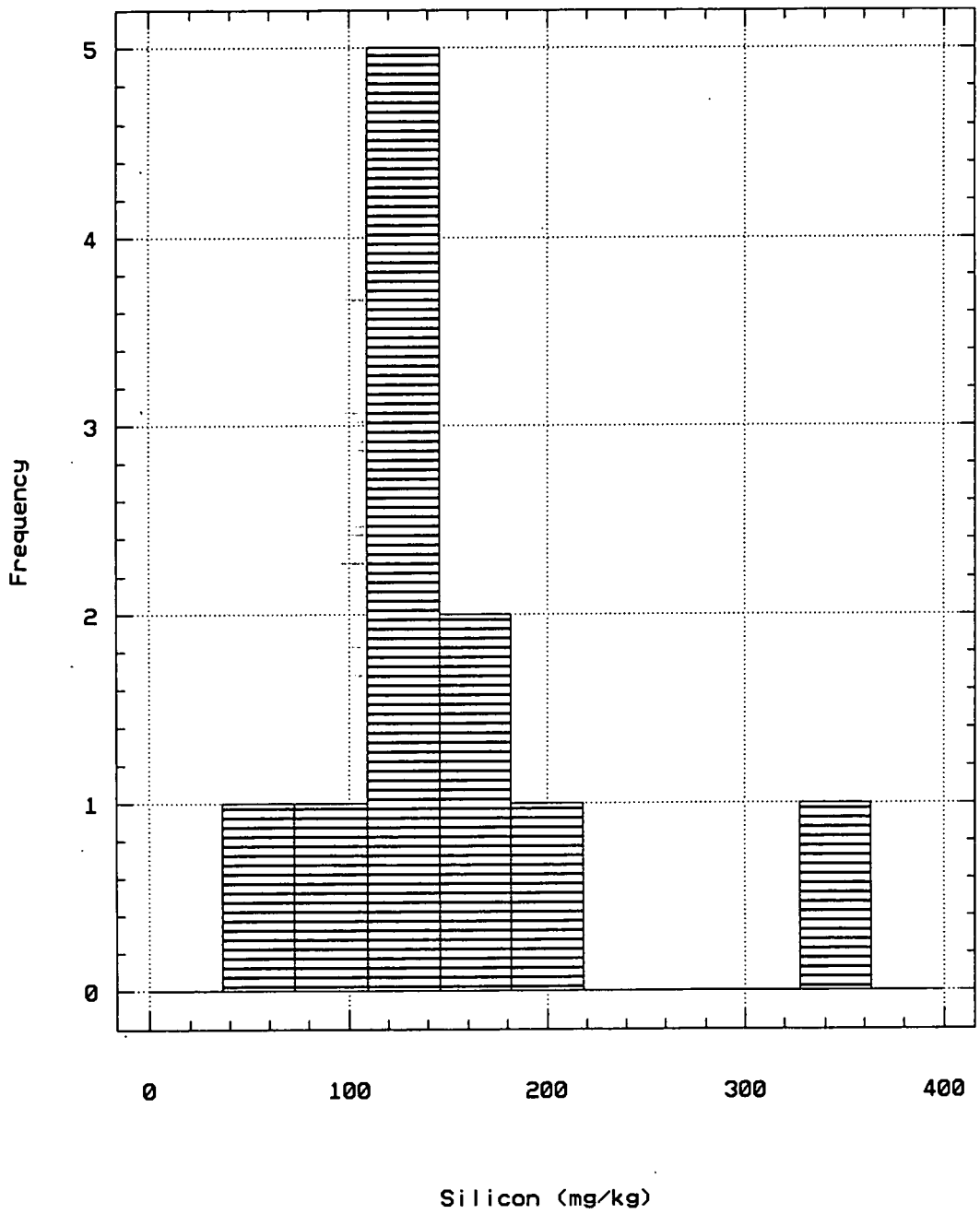
Frequency Histogram
Bkground Nitrate/Nitrite in Surface Soil



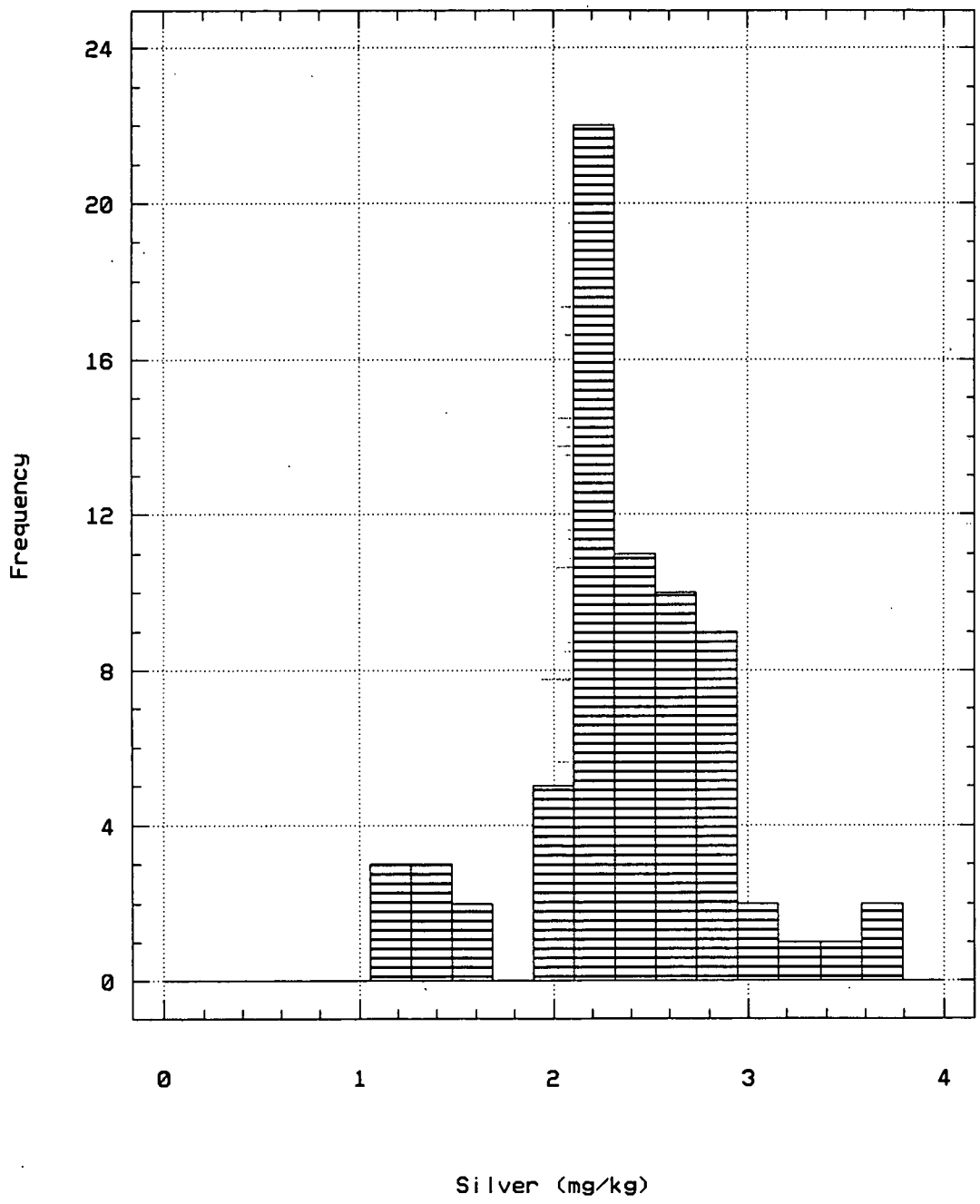
Frequency Histogram
RFI/RI Silicon in Surficial Soil



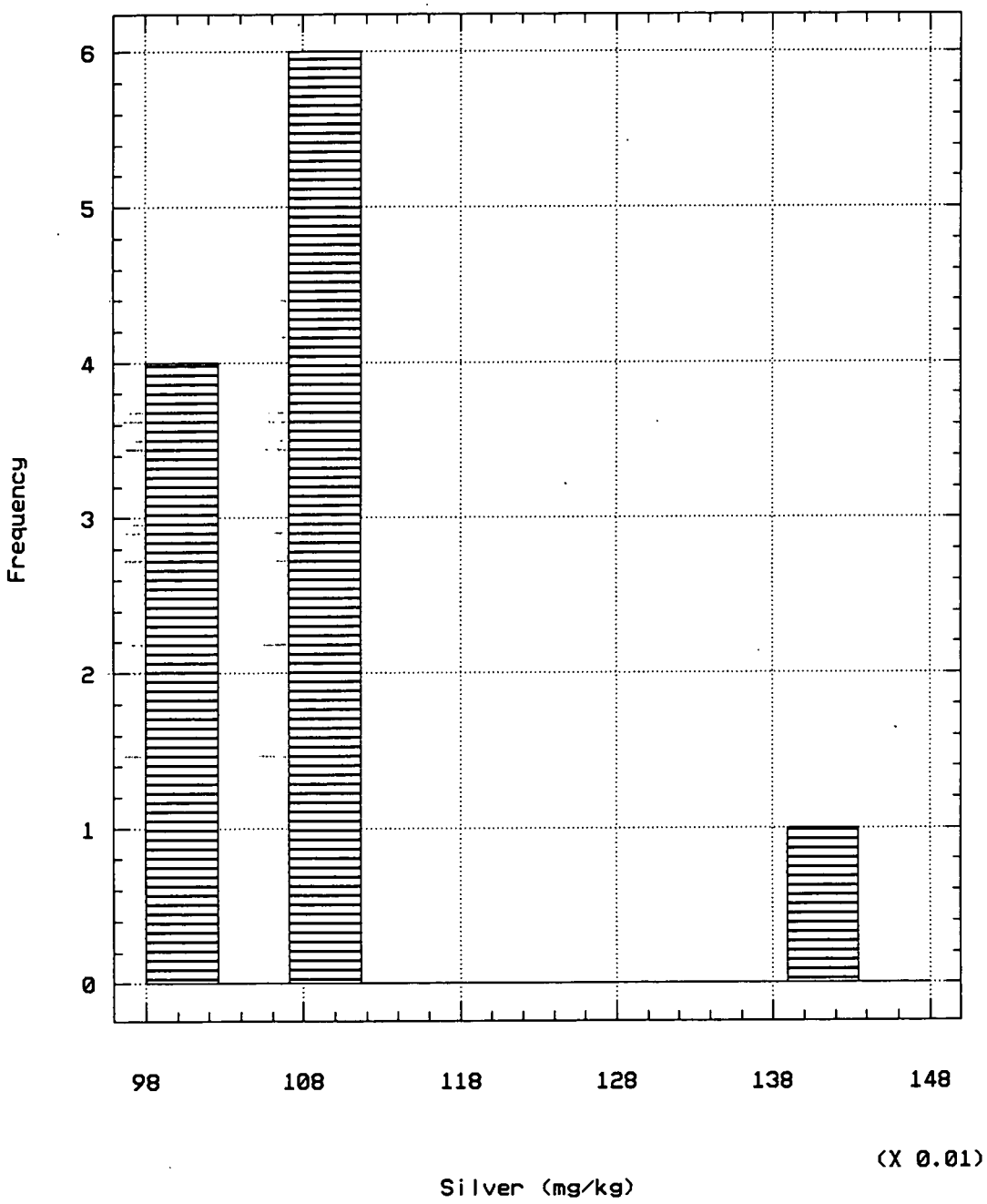
Frequency Histogram
Background Silicon in Surficial Soil



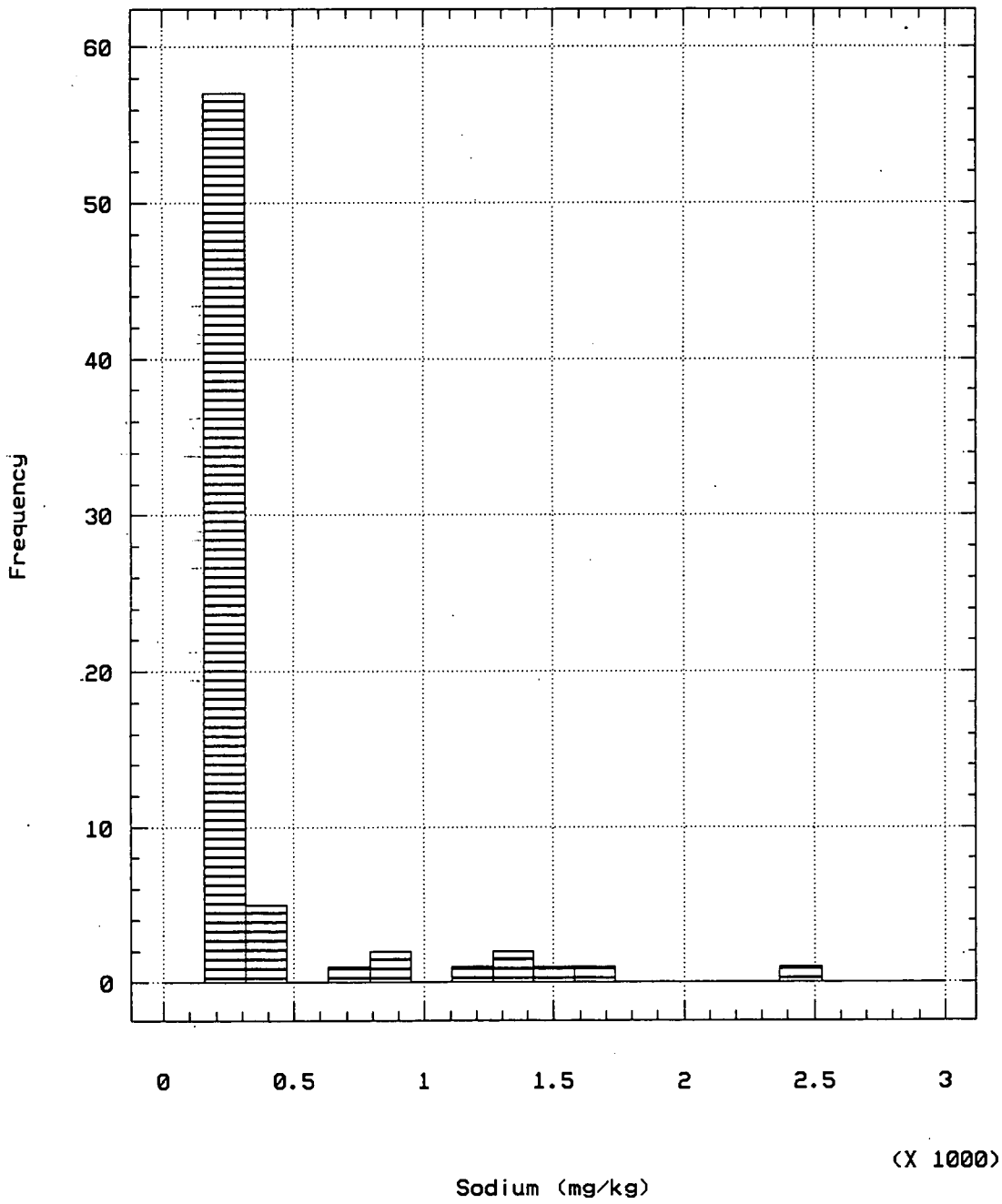
Frequency Histogram
RFI/RI Silver in Surficial Soil



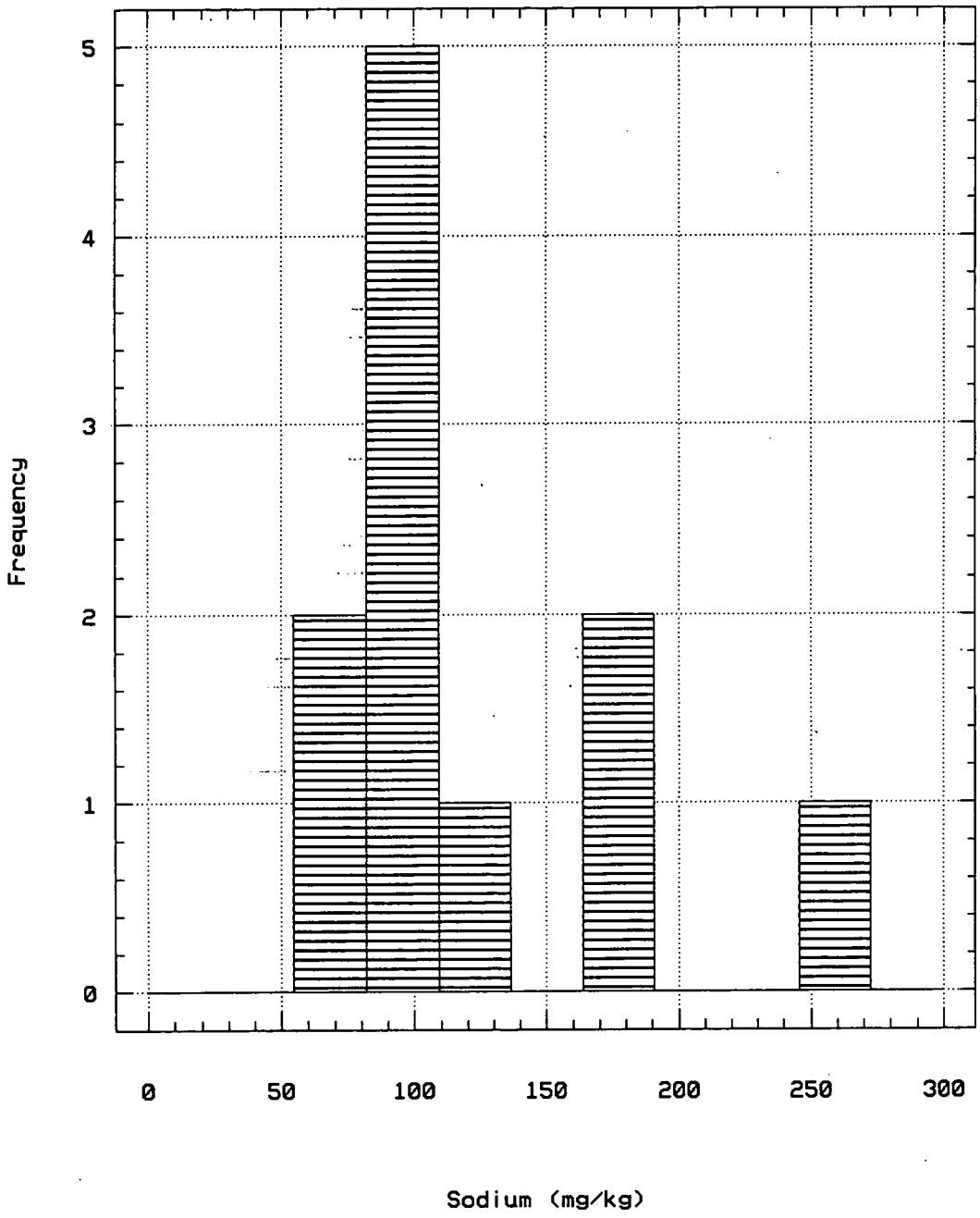
Frequency Histogram
Background Silver in Surficial Soil



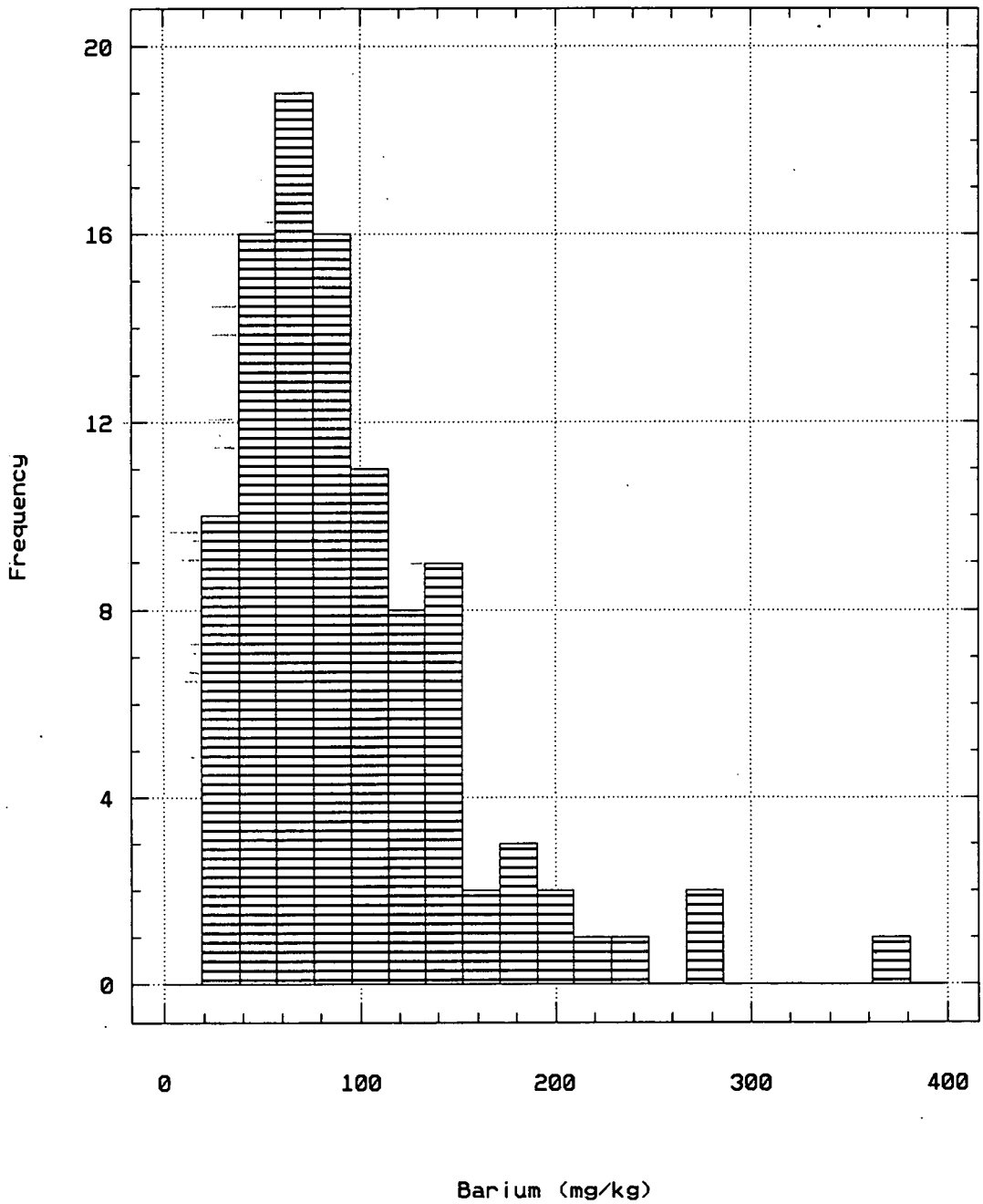
Frequency Histogram
RFI/RI Sodium in Surficial Soil



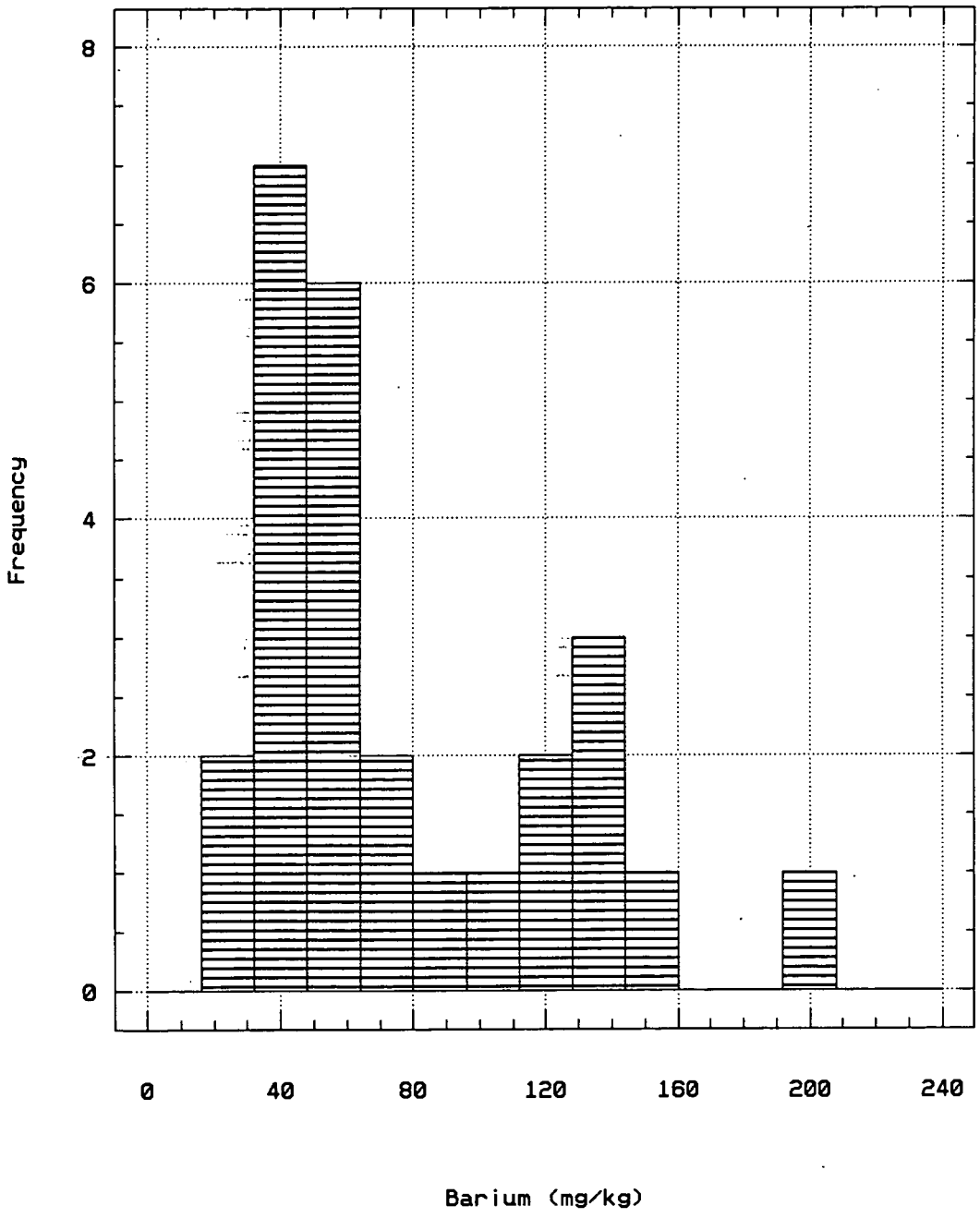
Frequency Histogram
Background Sodium in Surficial Soil



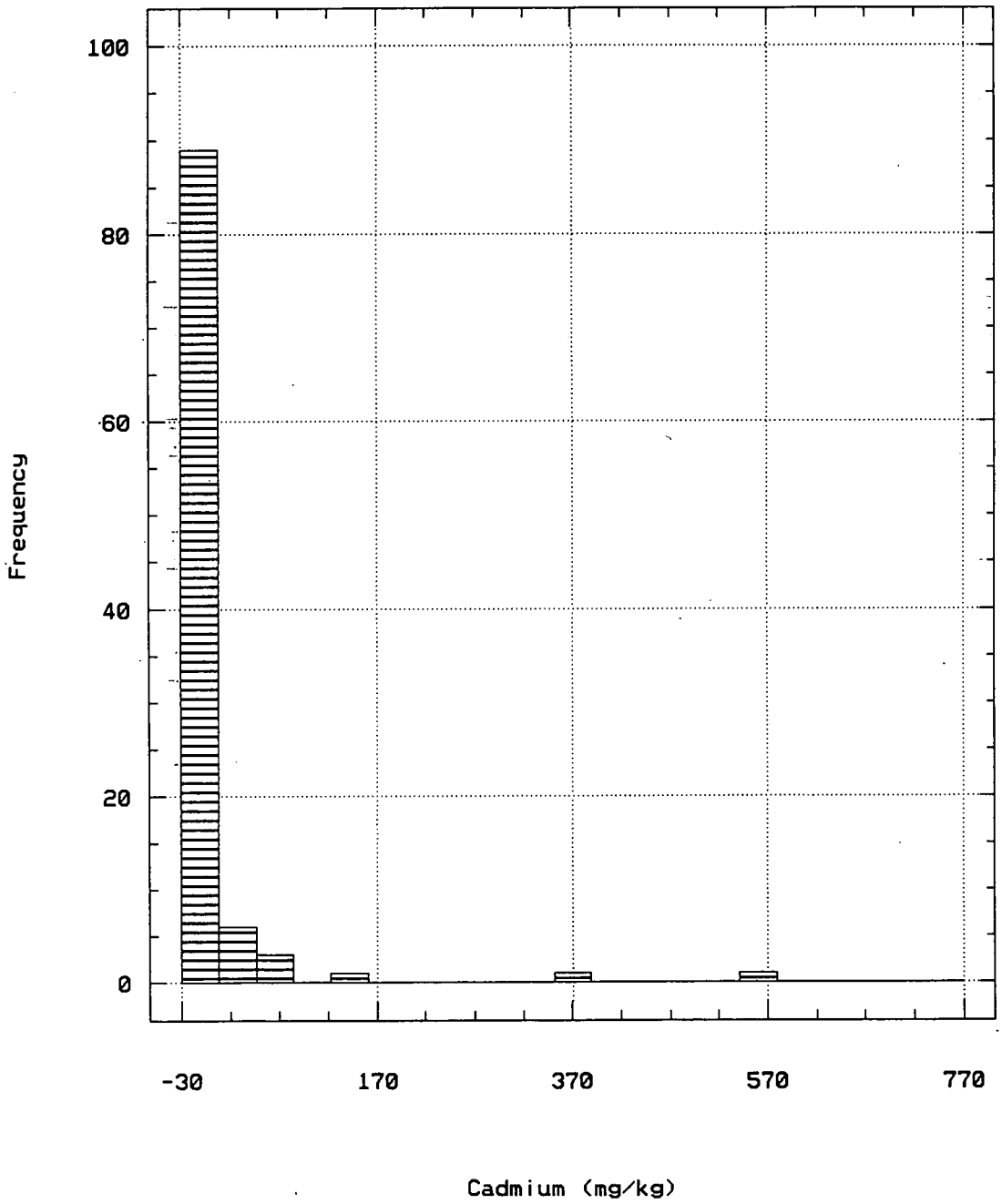
Frequency Histogram
RFI/RI Barium in Vadose Zone Soil



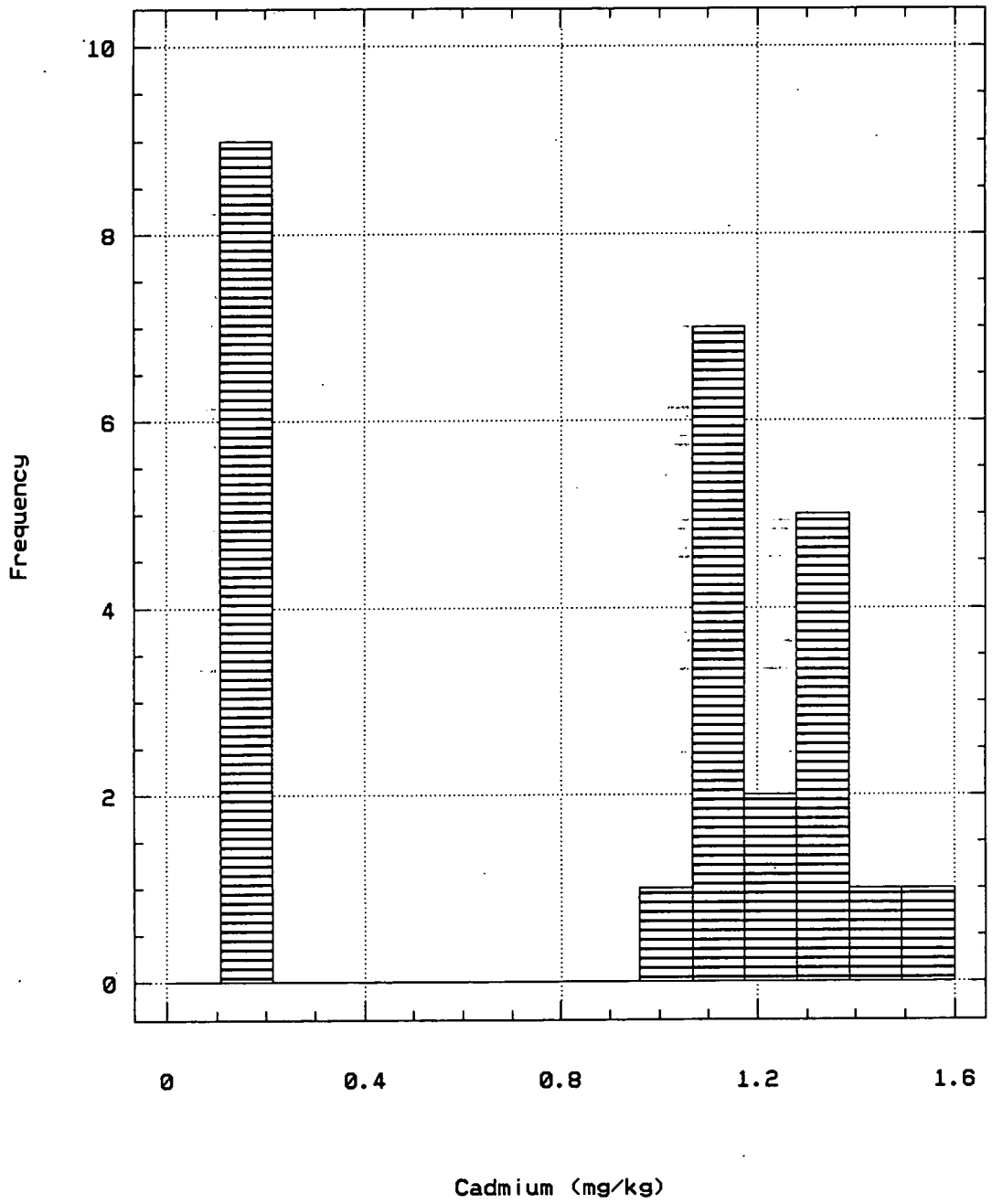
Frequency Histogram
Background Barium in Vadose Zone Soil



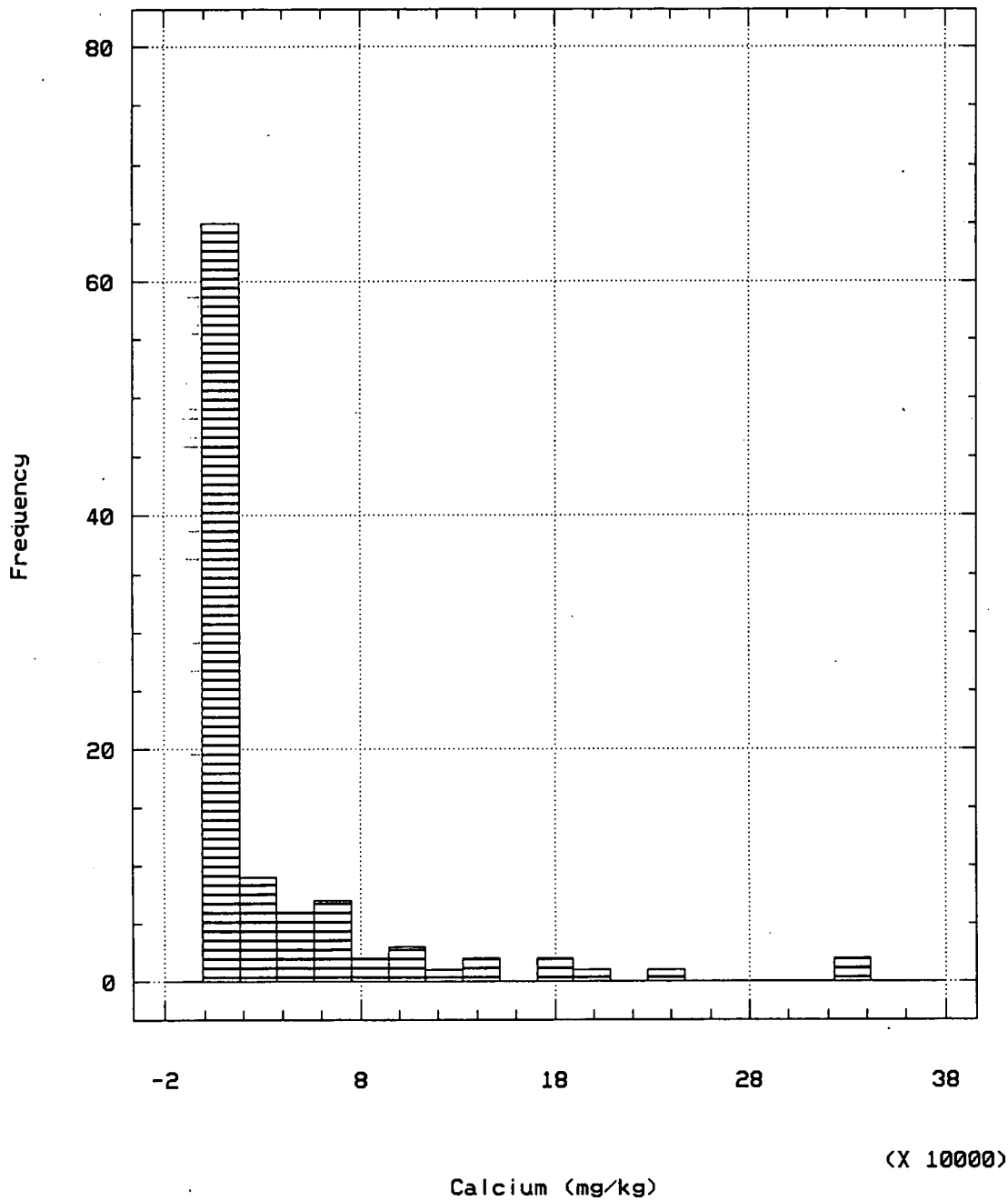
Frequency Histogram
RFI/RI Cadmium in Vadose Zone Soil



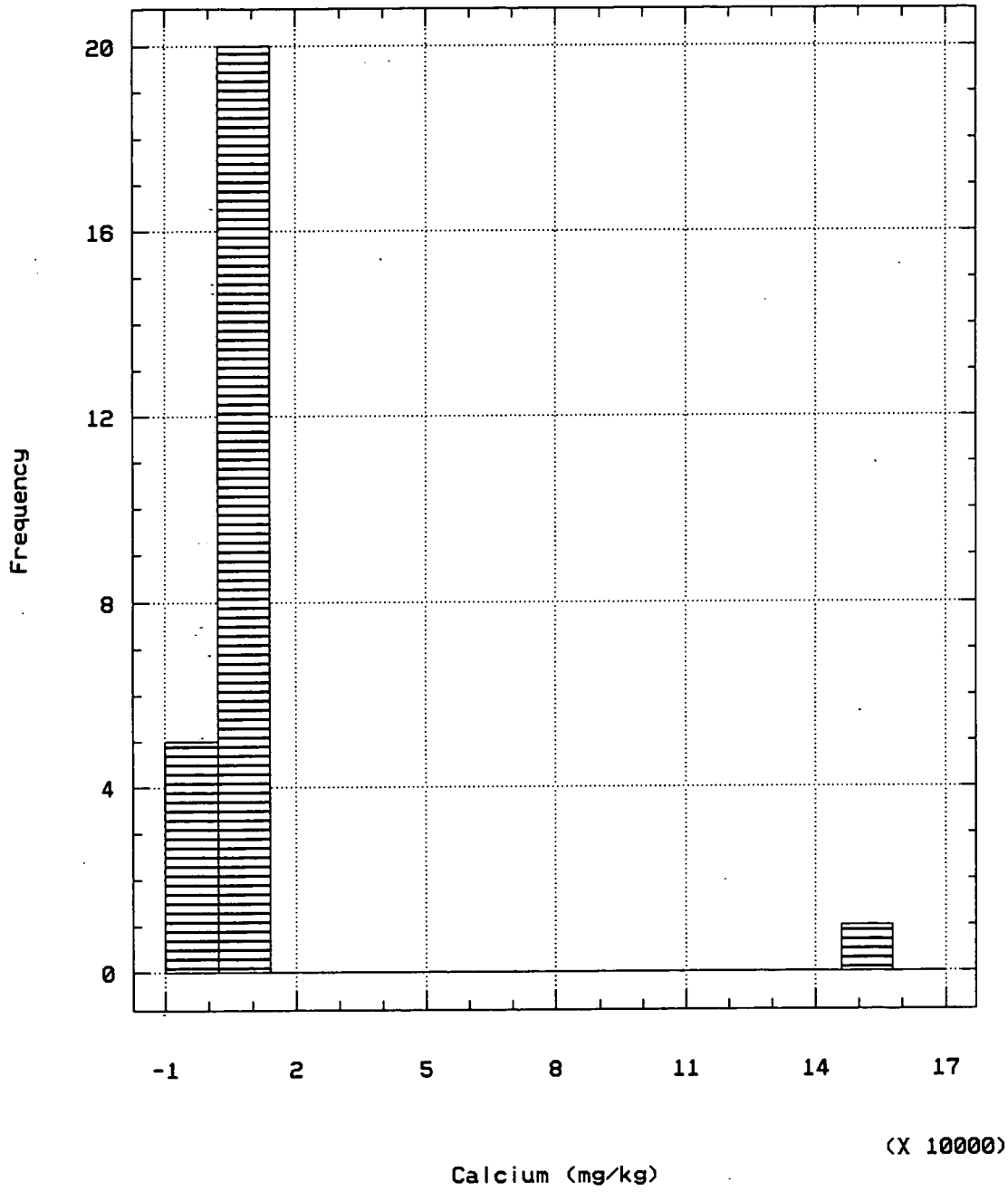
Frequency Histogram
Background Cadmium in Vadose Zone Soil



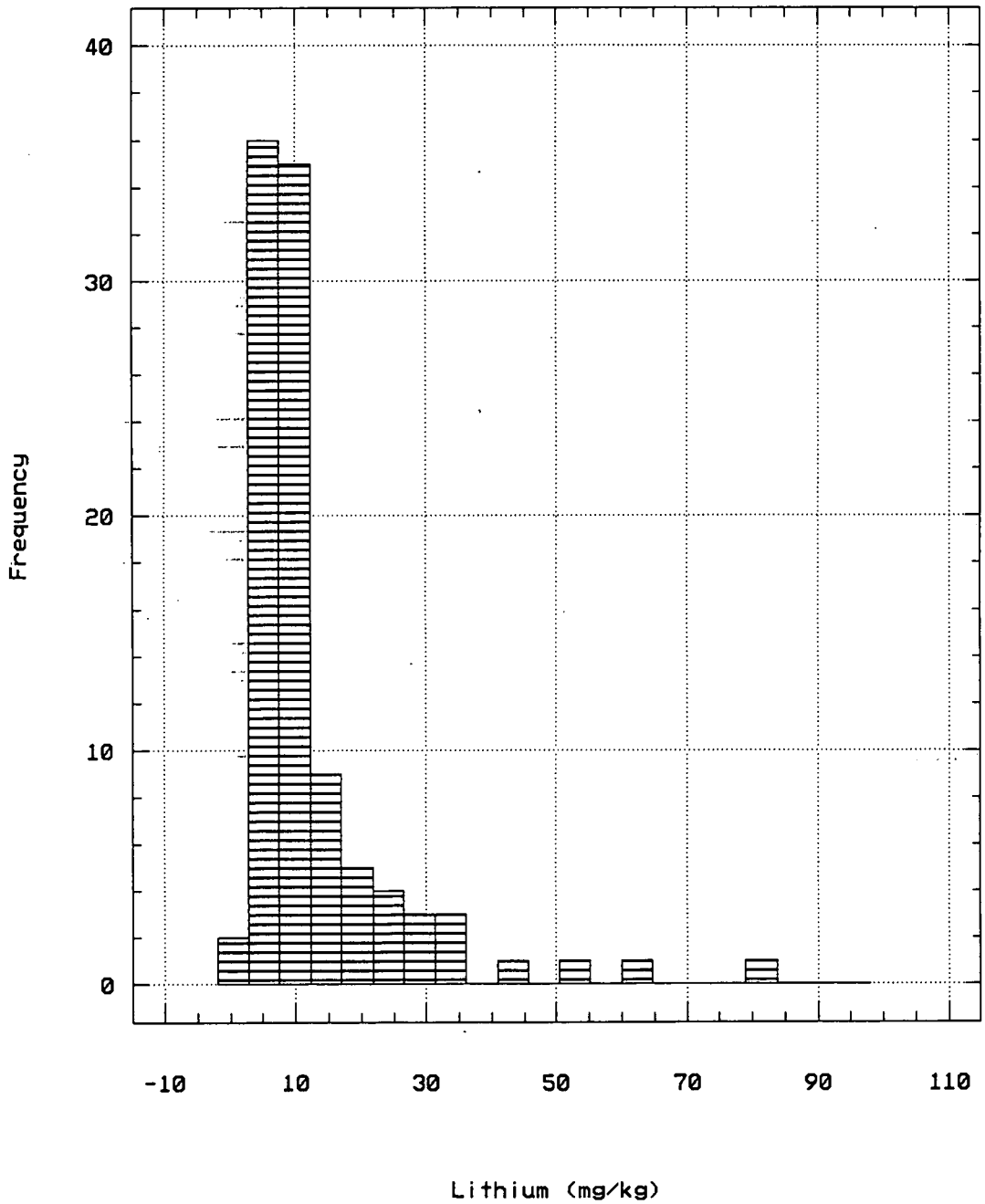
Frequency Histogram
RFI/RI Calcium in Vadose Zone Soil



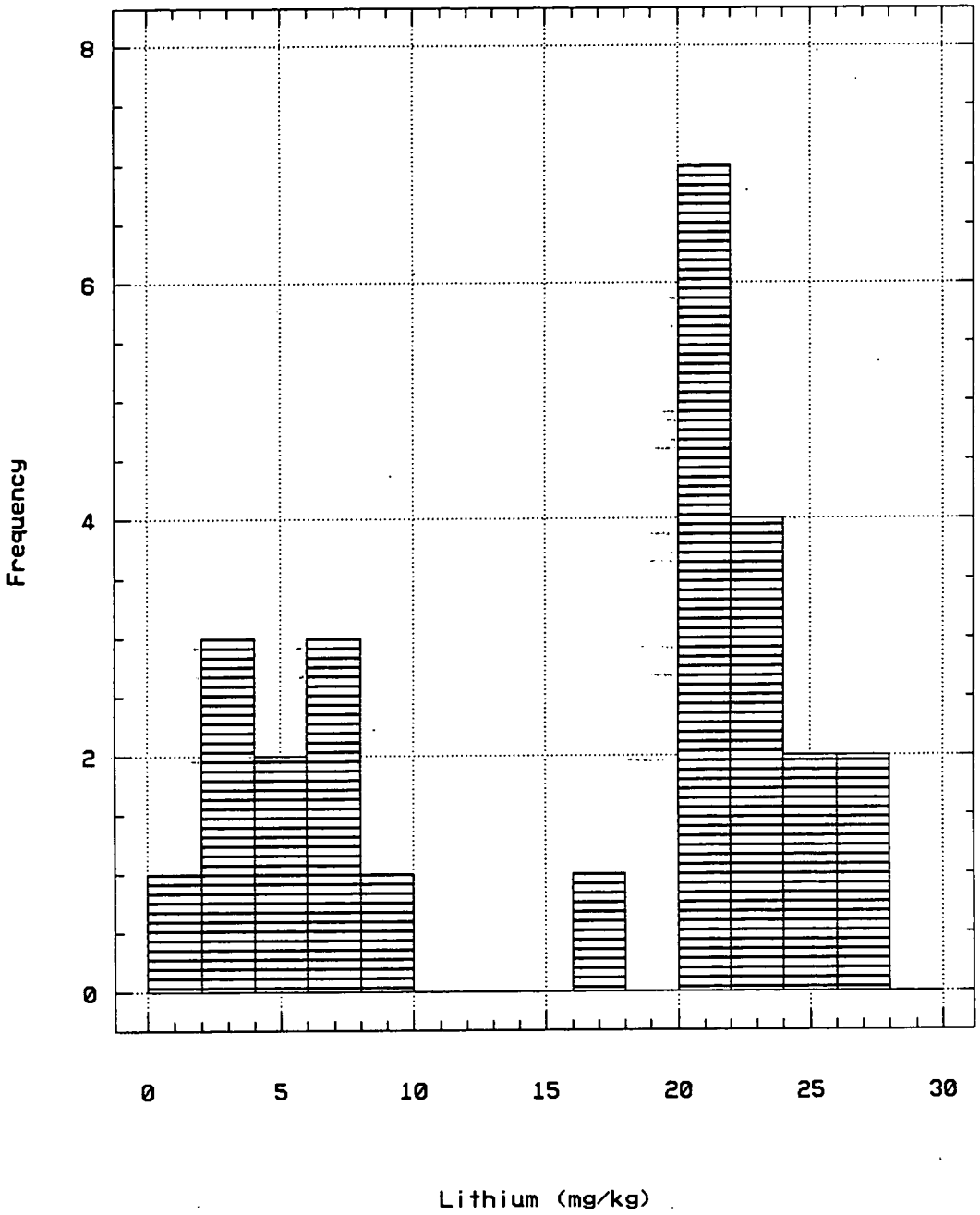
Frequency Histogram
Background Calcium in Vadose Zone Soil



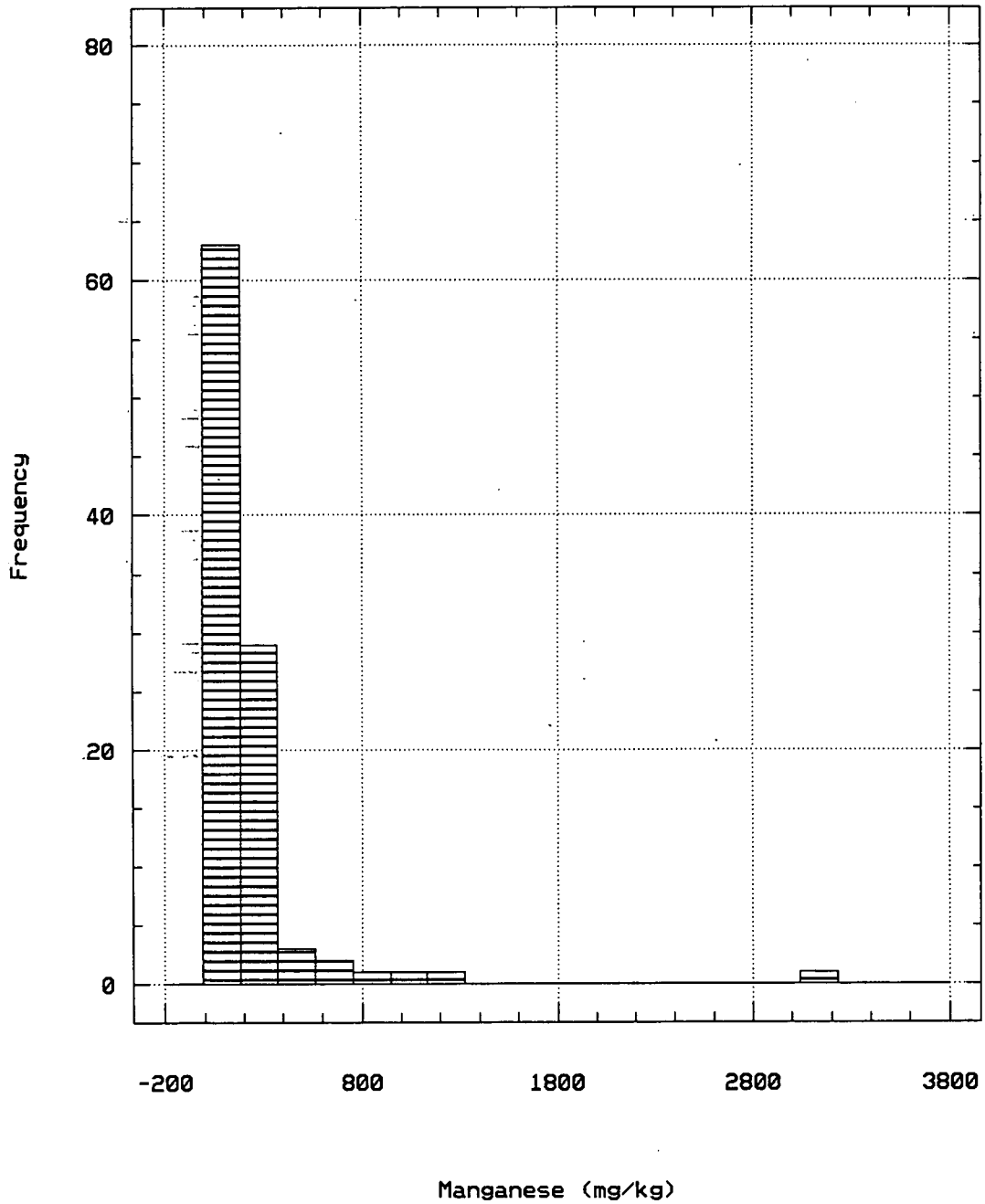
Frequency Histogram
RFI/RI Lithium in Vadose Zone Soil



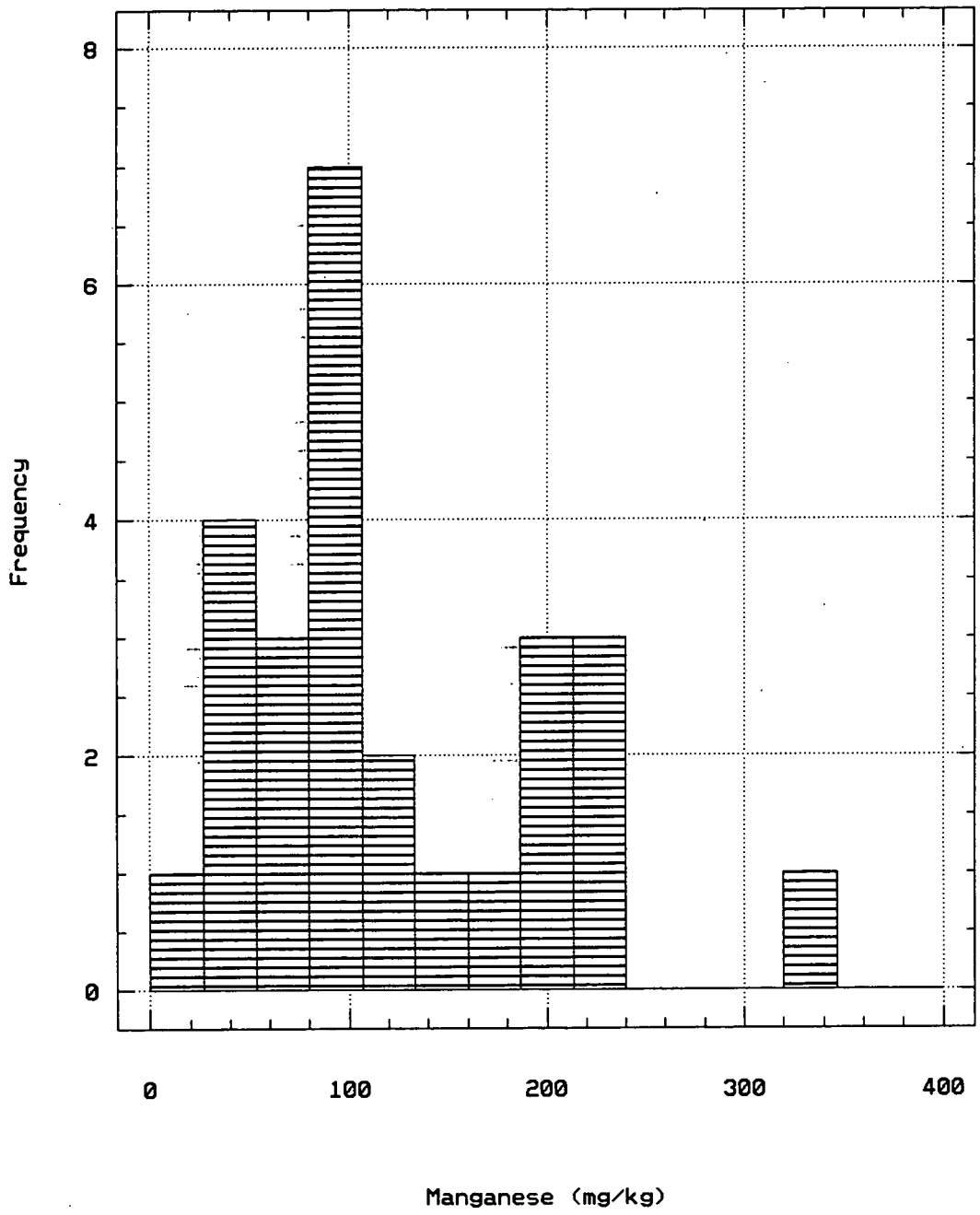
Frequency Histogram
Background Lithium in Vadose Zone Soil



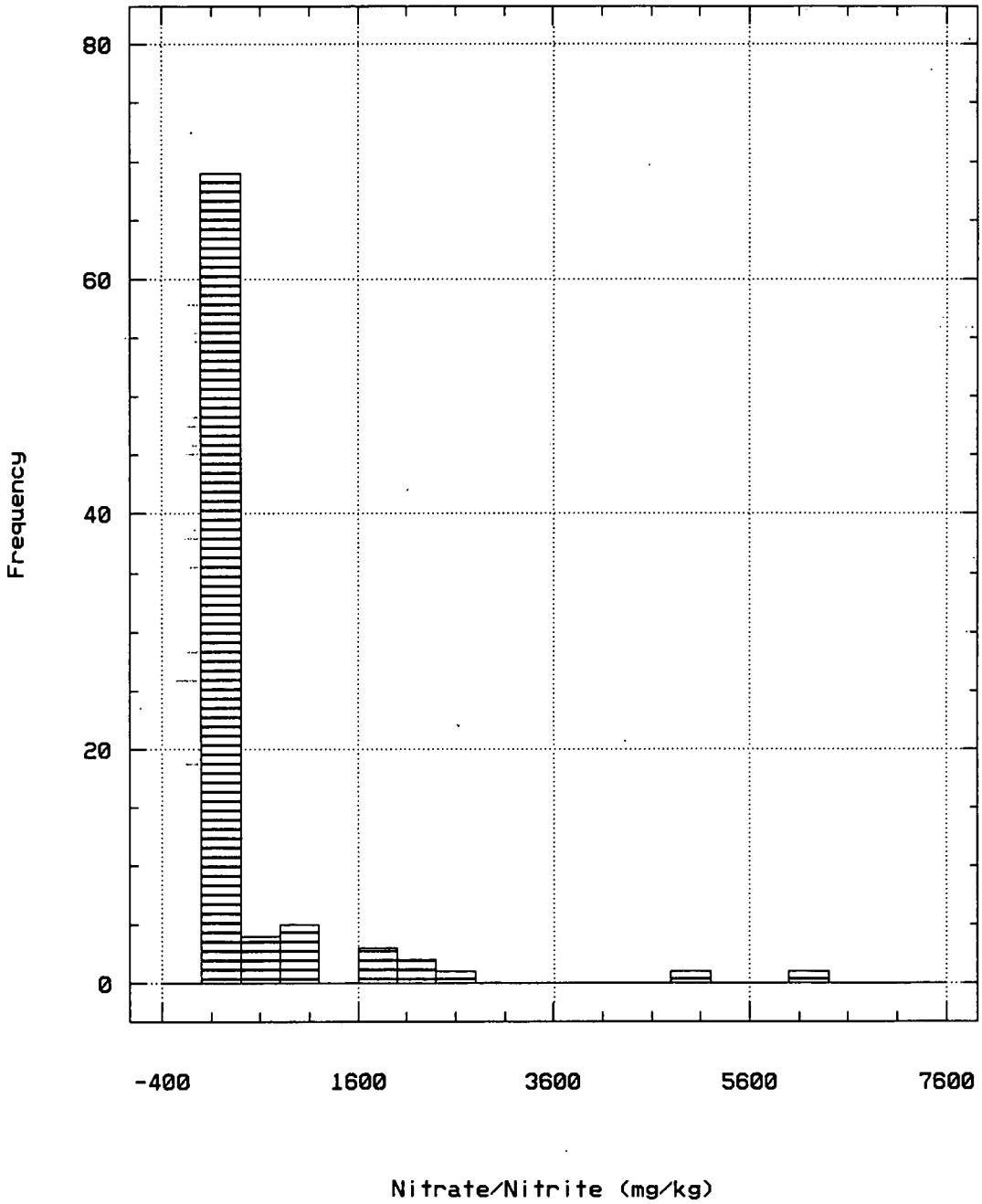
Frequency Histogram
RFI/RI Manganese in Vadose Zone Soil



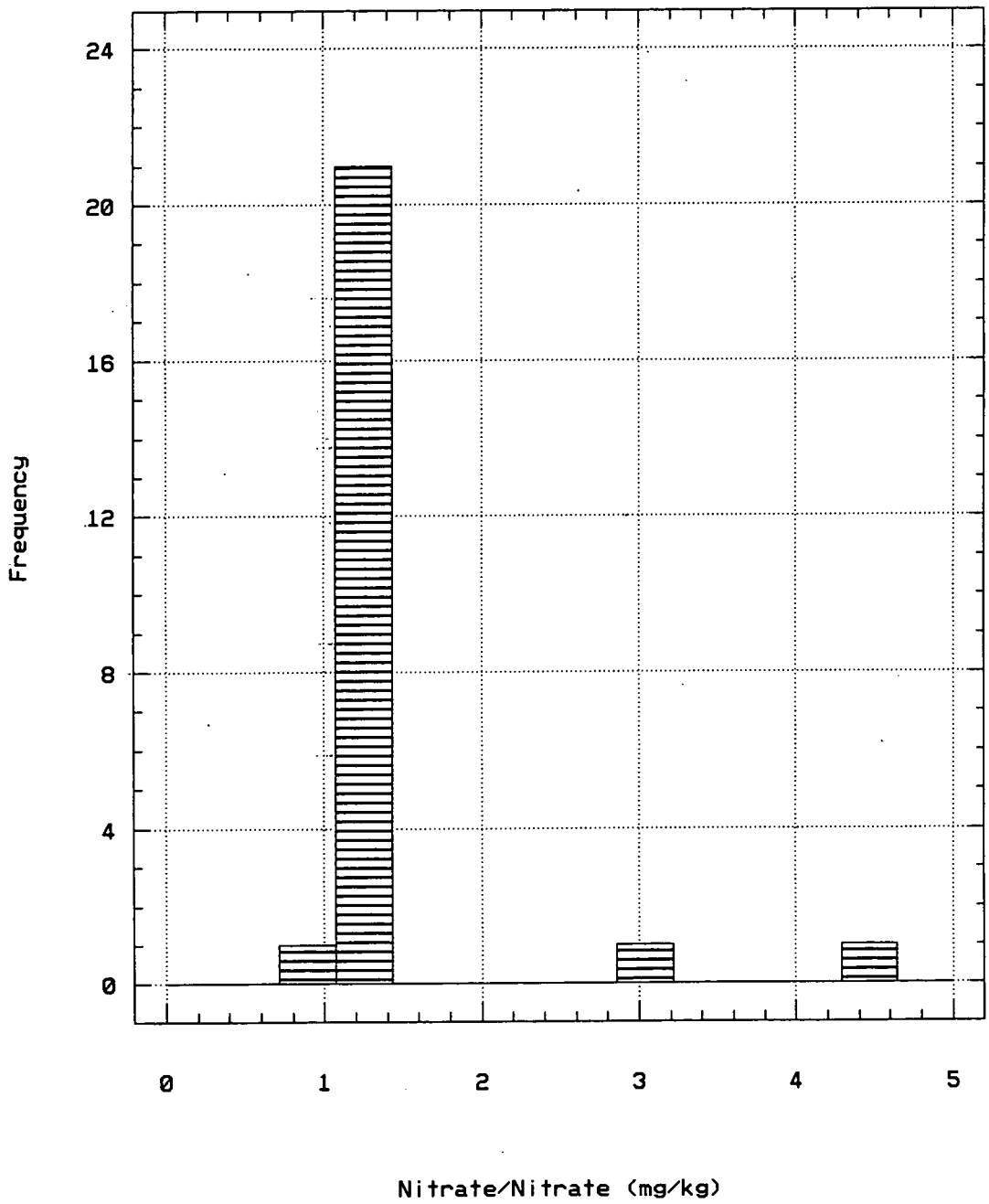
Frequency Histogram
Background Manganese in Vadose Zone Soil



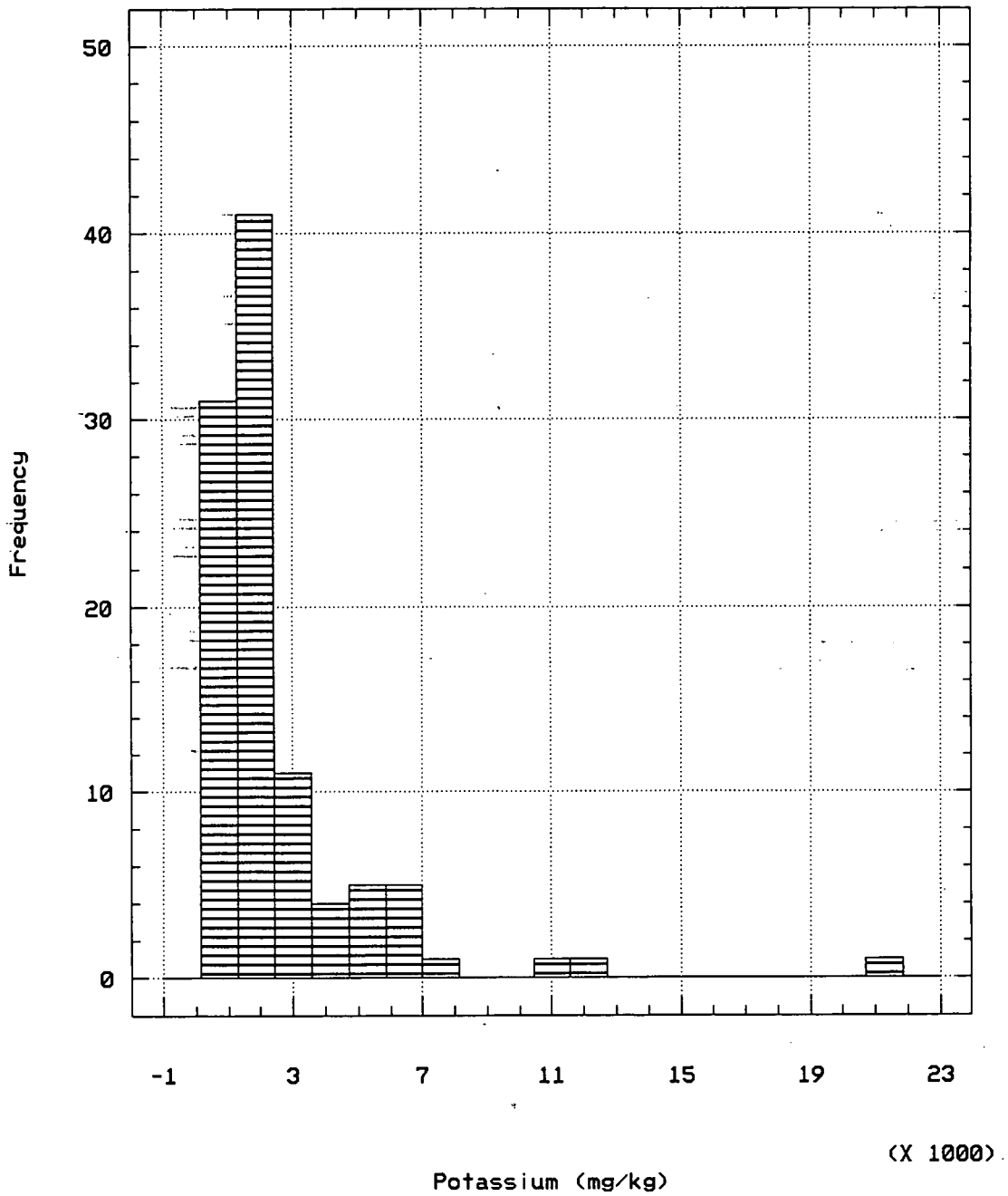
Frequency Histogram
RFI/RI Nitrate/Nitrite in Vadose Soil



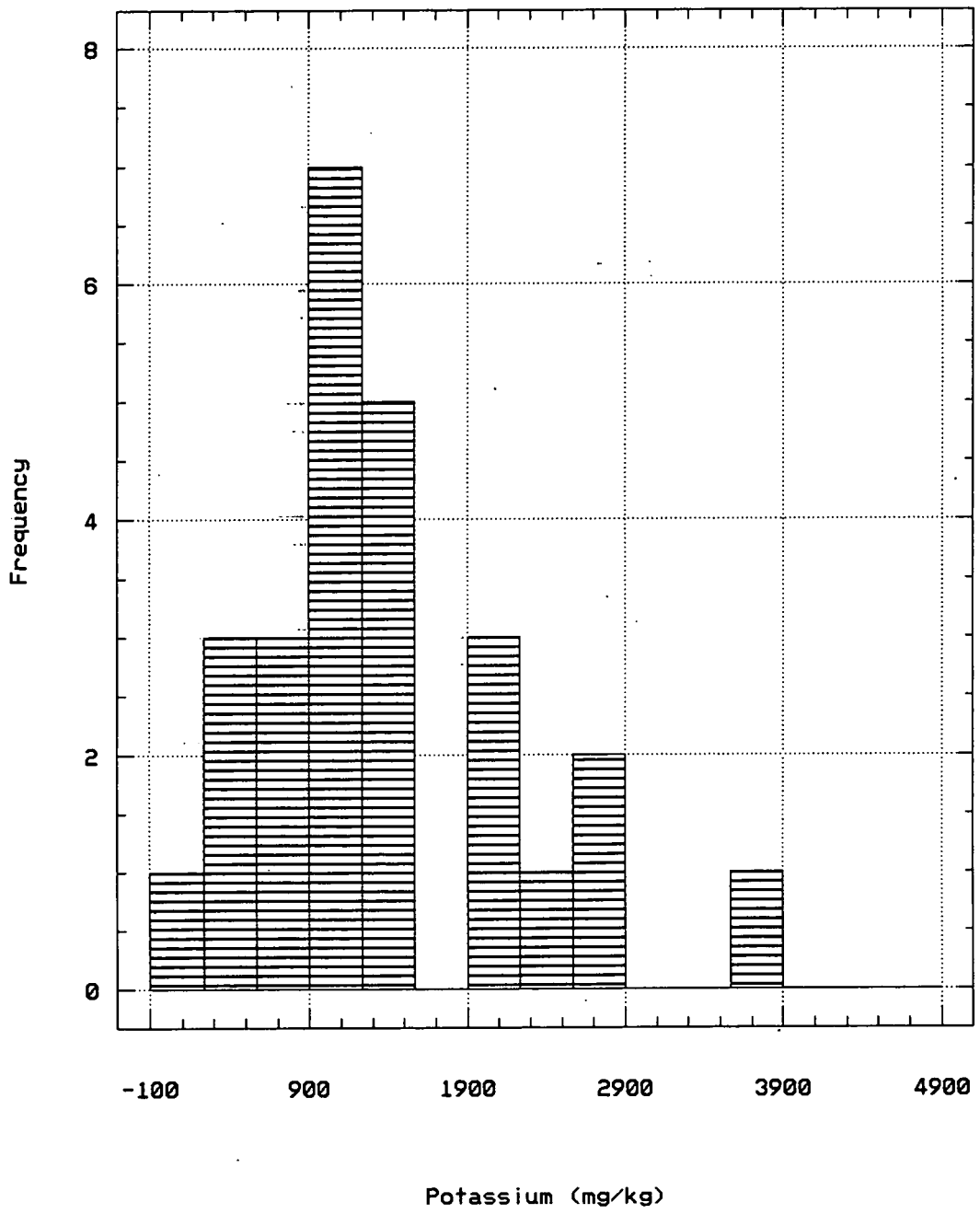
Frequency Histogram
Background Nitrate/Nitrite in Vadose Soi



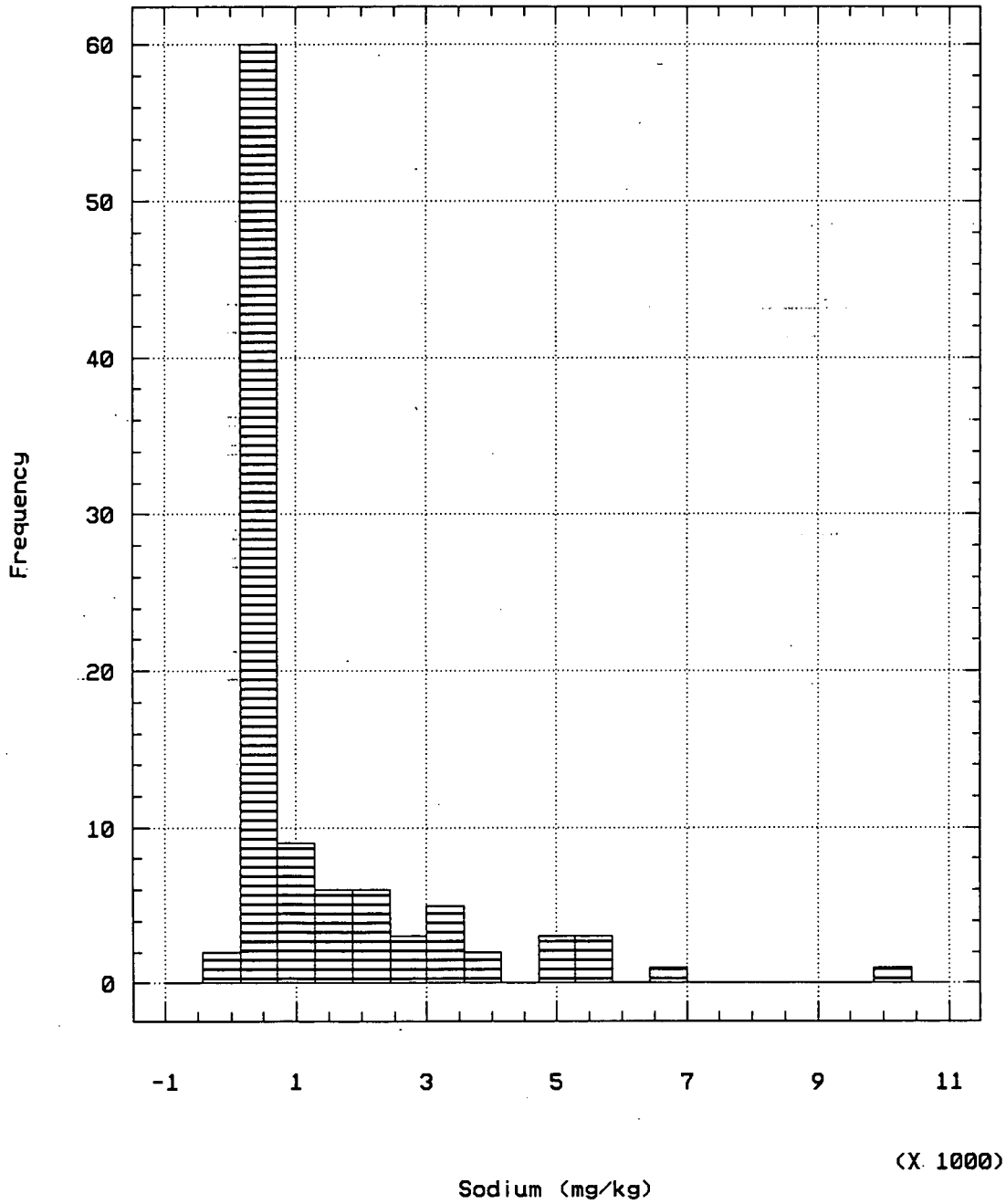
Frequency Histogram
RFI/RI Potassium in Vadose Zone Soil



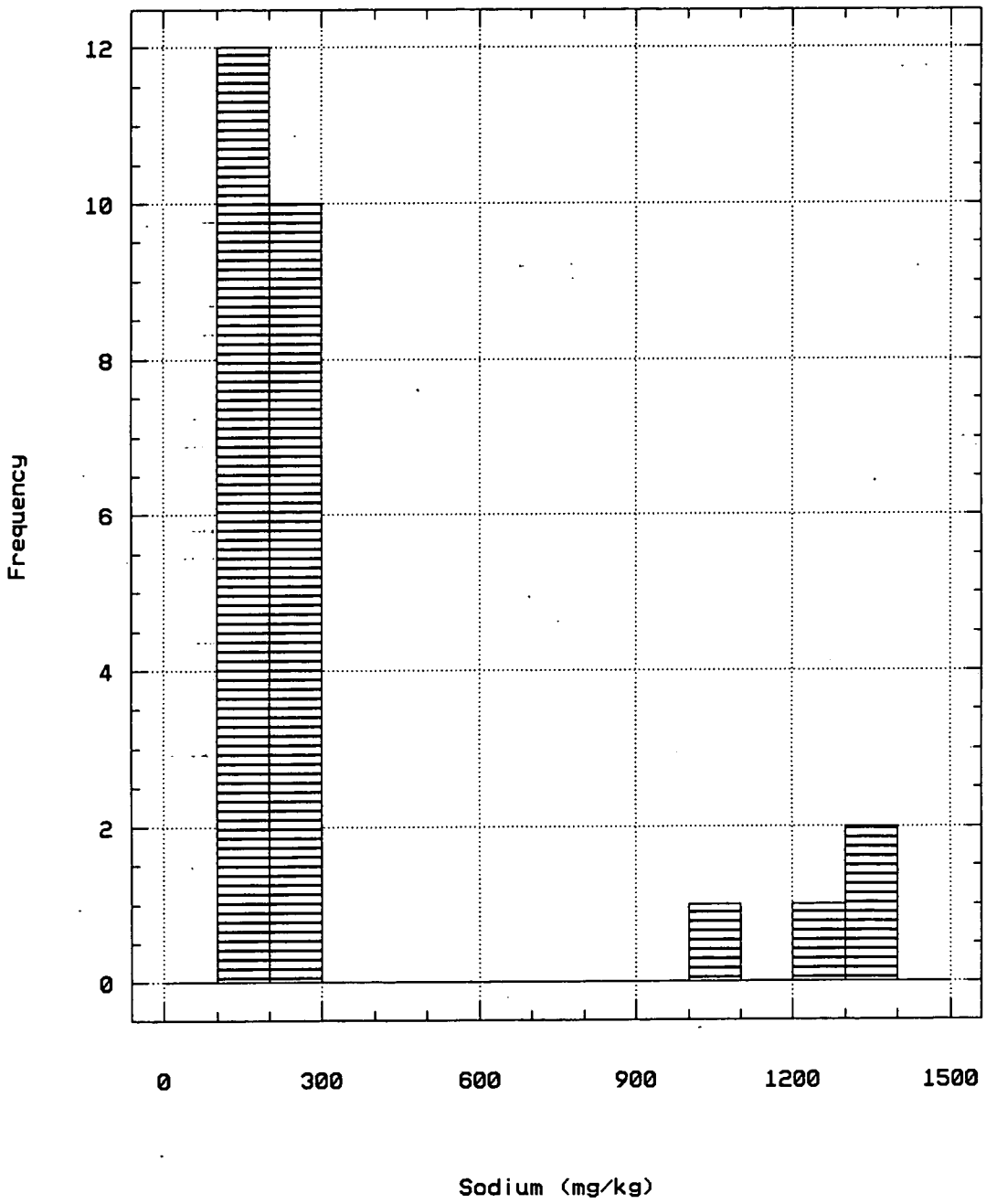
Frequency Histogram
Background Potassium in Vadose Zone Soil



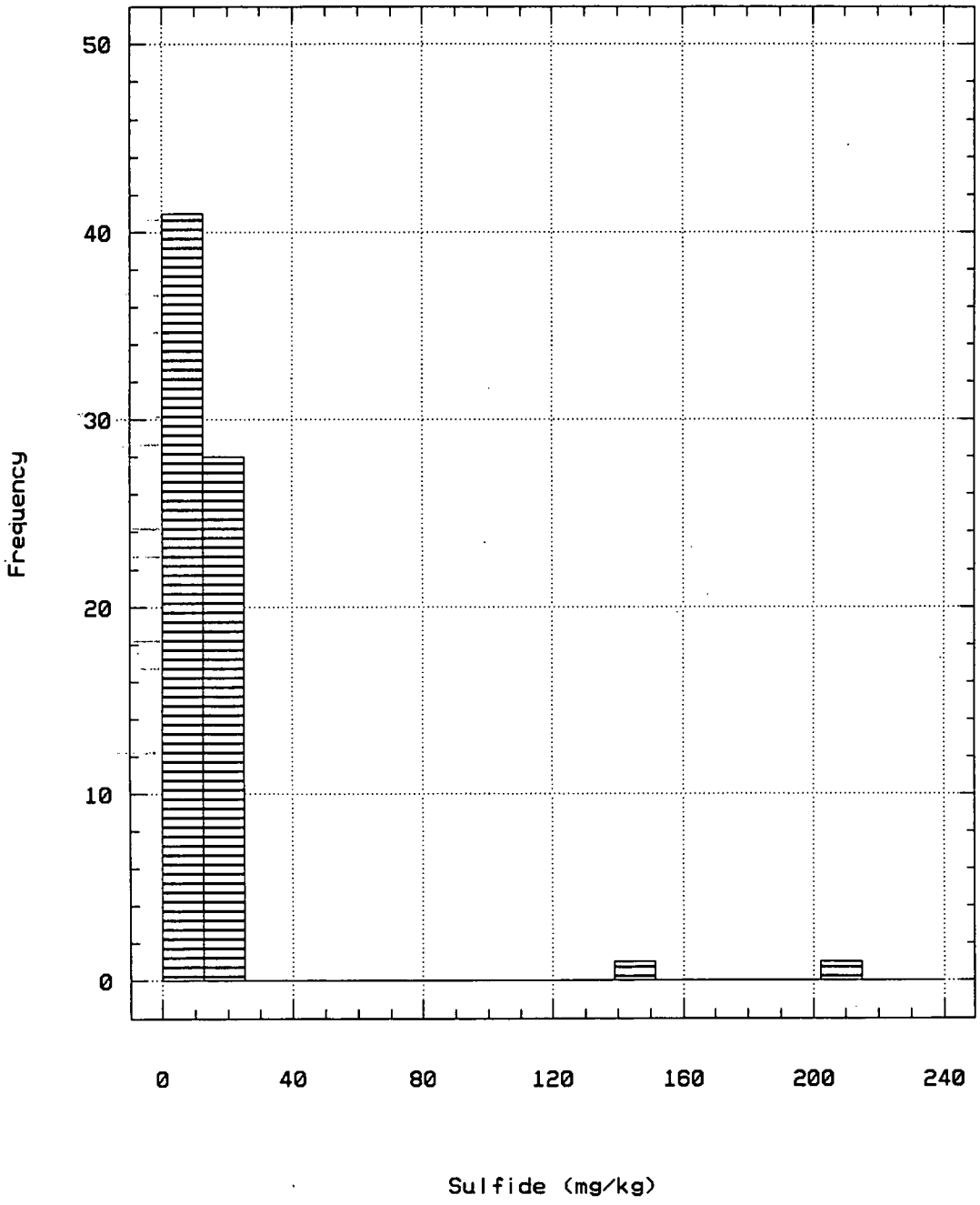
Frequency Histogram
RFI/RI Sodium in Vadose Zone Soil



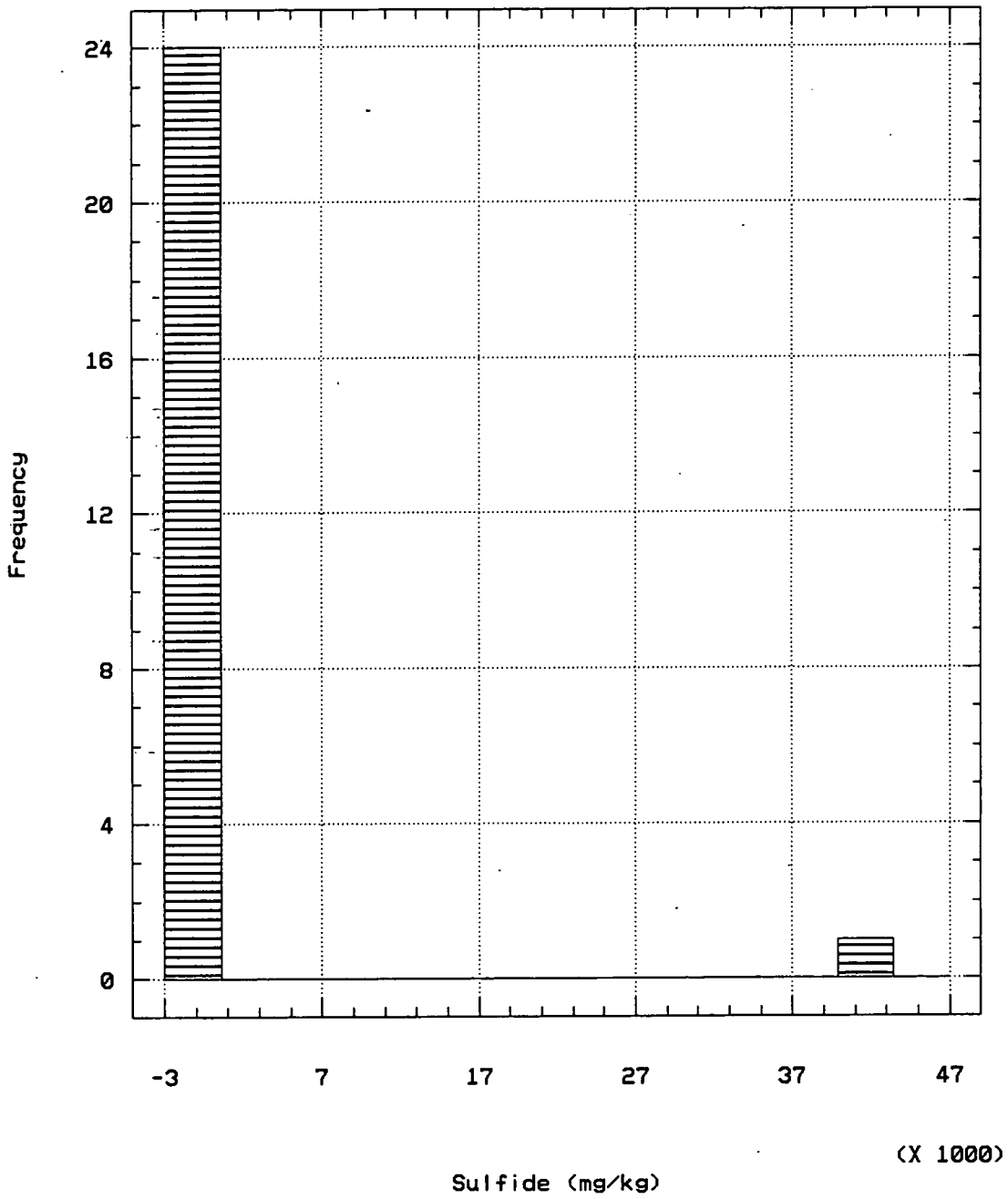
Frequency Histogram
Background Sodium in Vadose Zone Soil



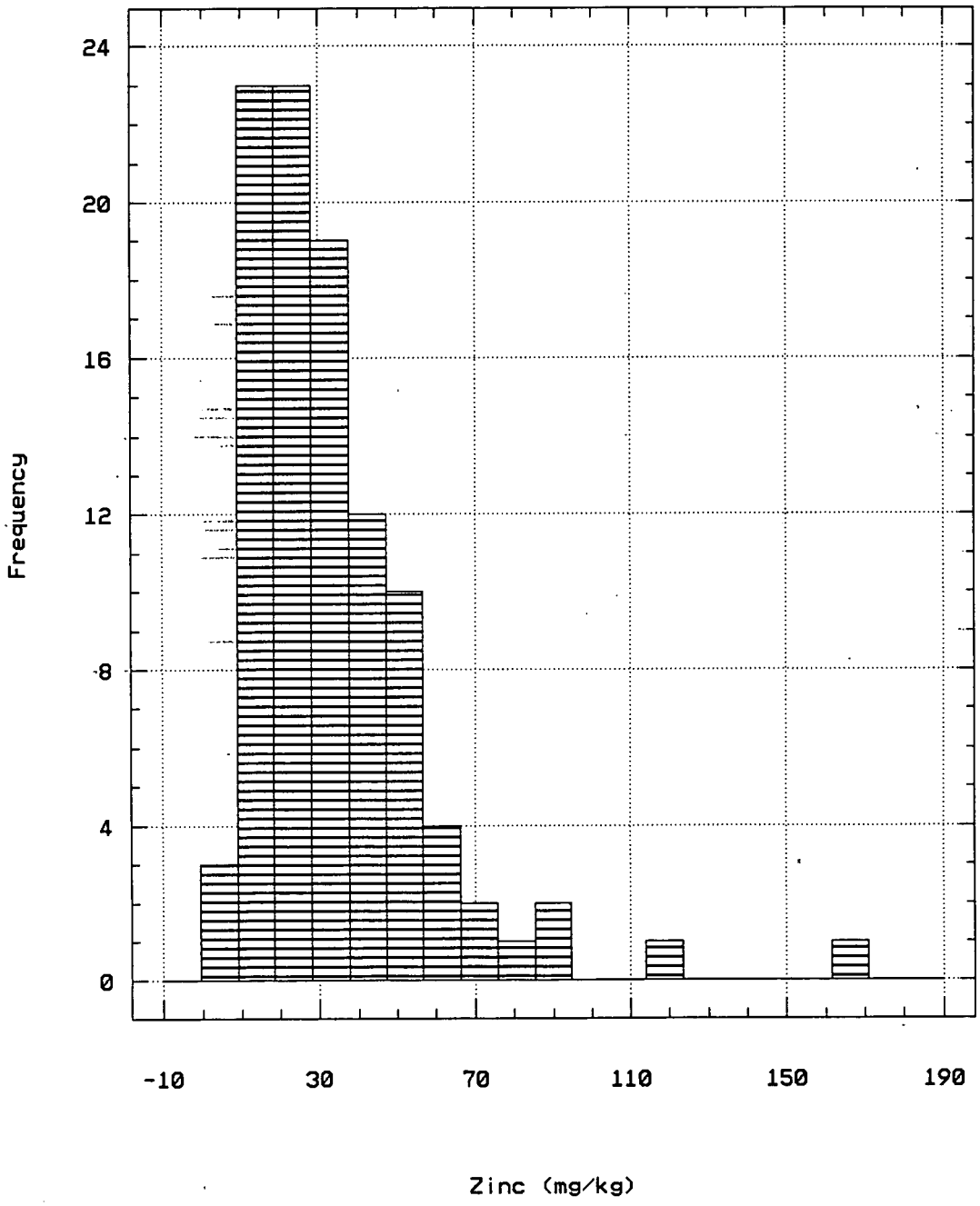
Frequency Histogram
RFI/RI Sulfide in Vadose Zone Soil



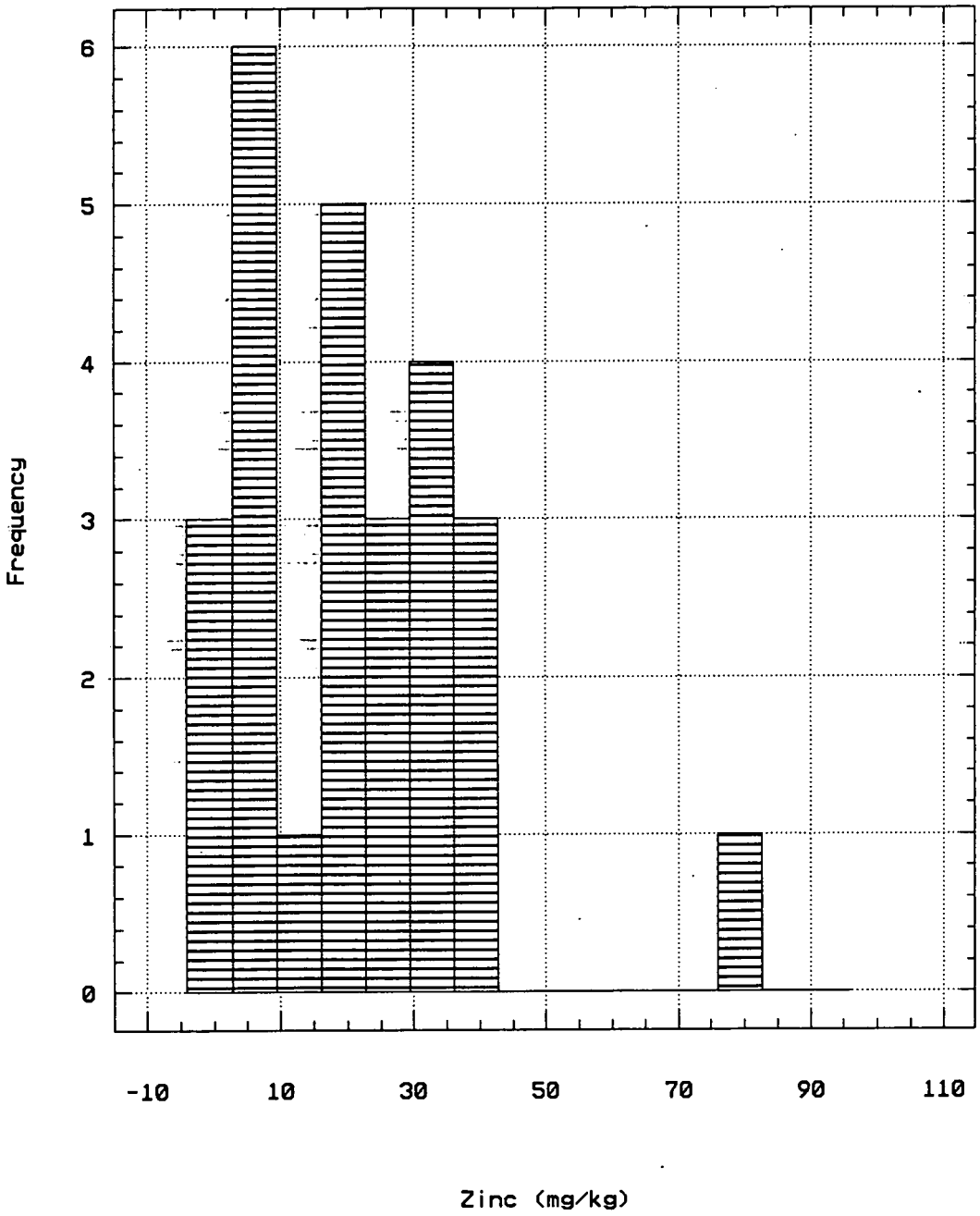
Frequency Histogram
Background Sulfide in Vadose Zone Soil



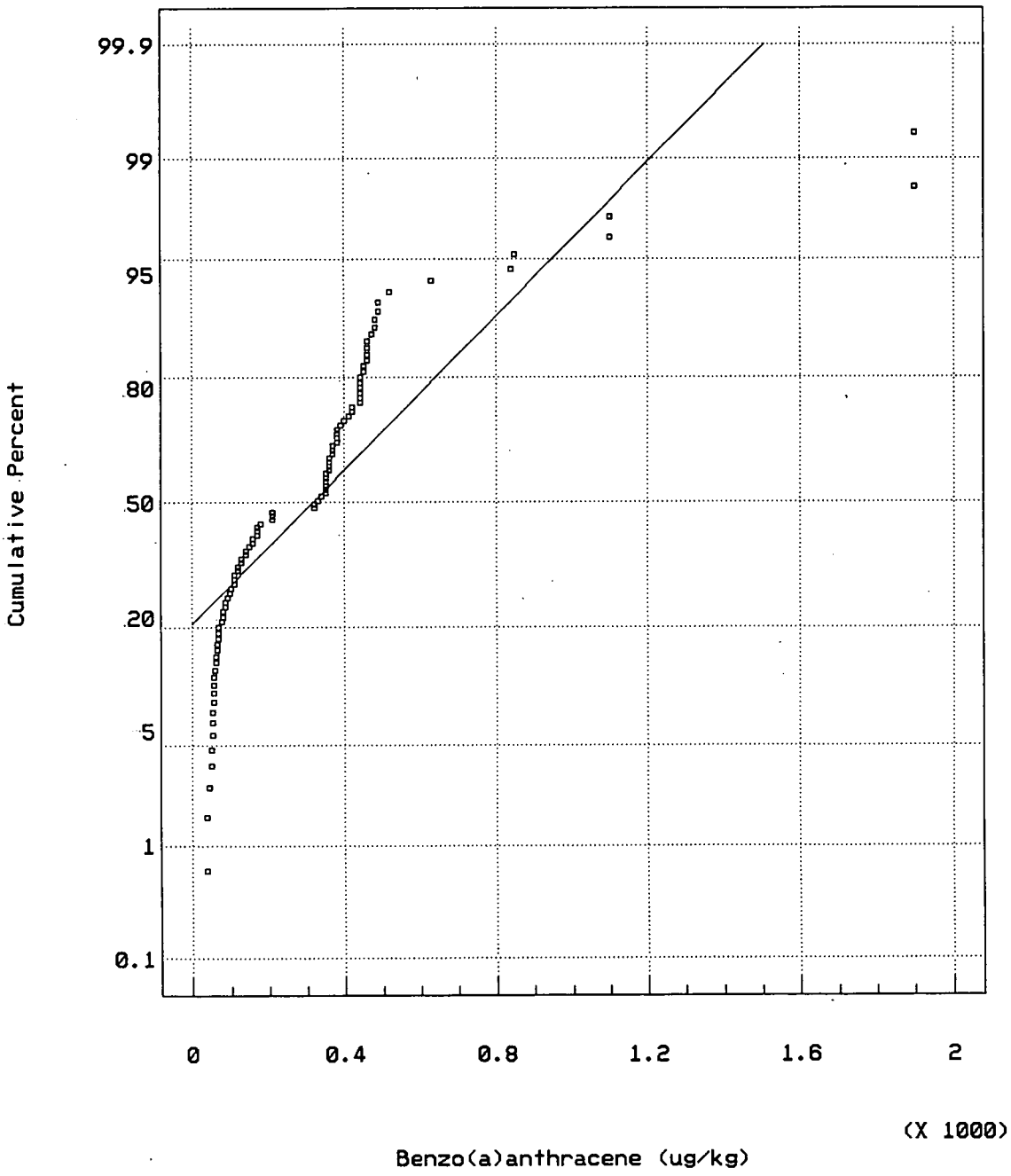
Frequency Histogram
RFI/RI Zinc in Vadose Zone Soil



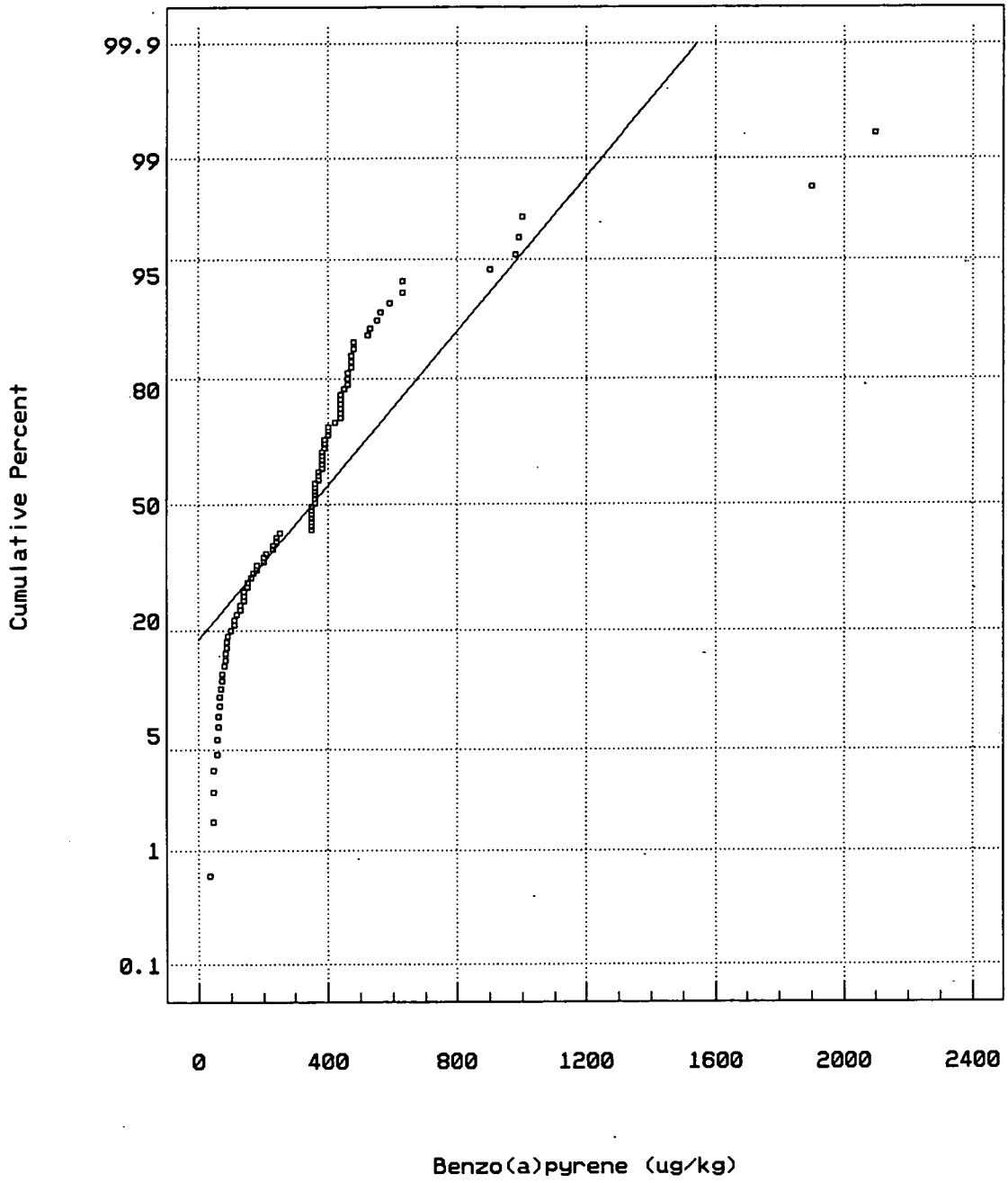
Frequency Histogram
Background Zinc in Vadose Zone Soil



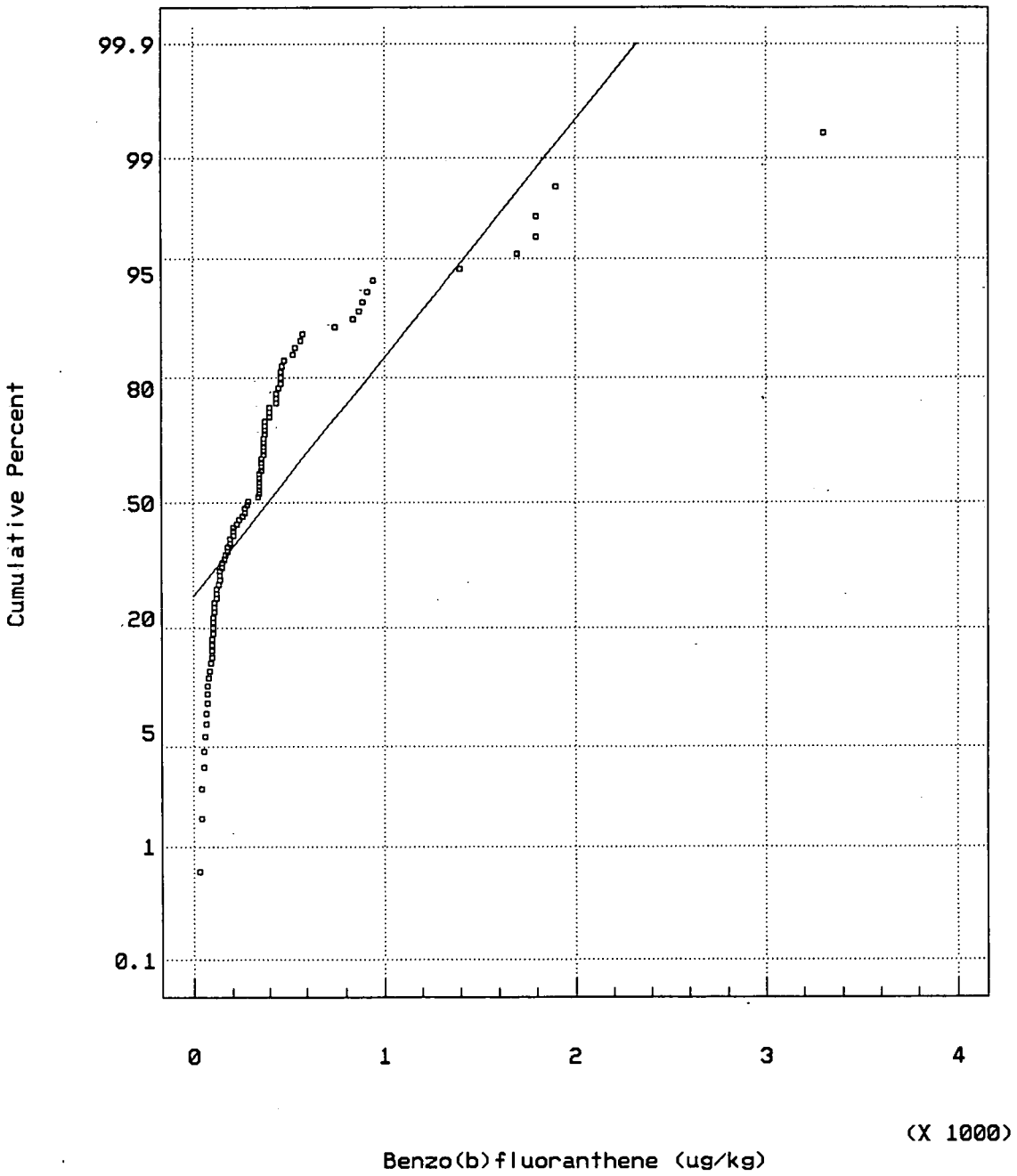
Normal Probability Plot
Benzo(a)anthracene in Surficial Soil



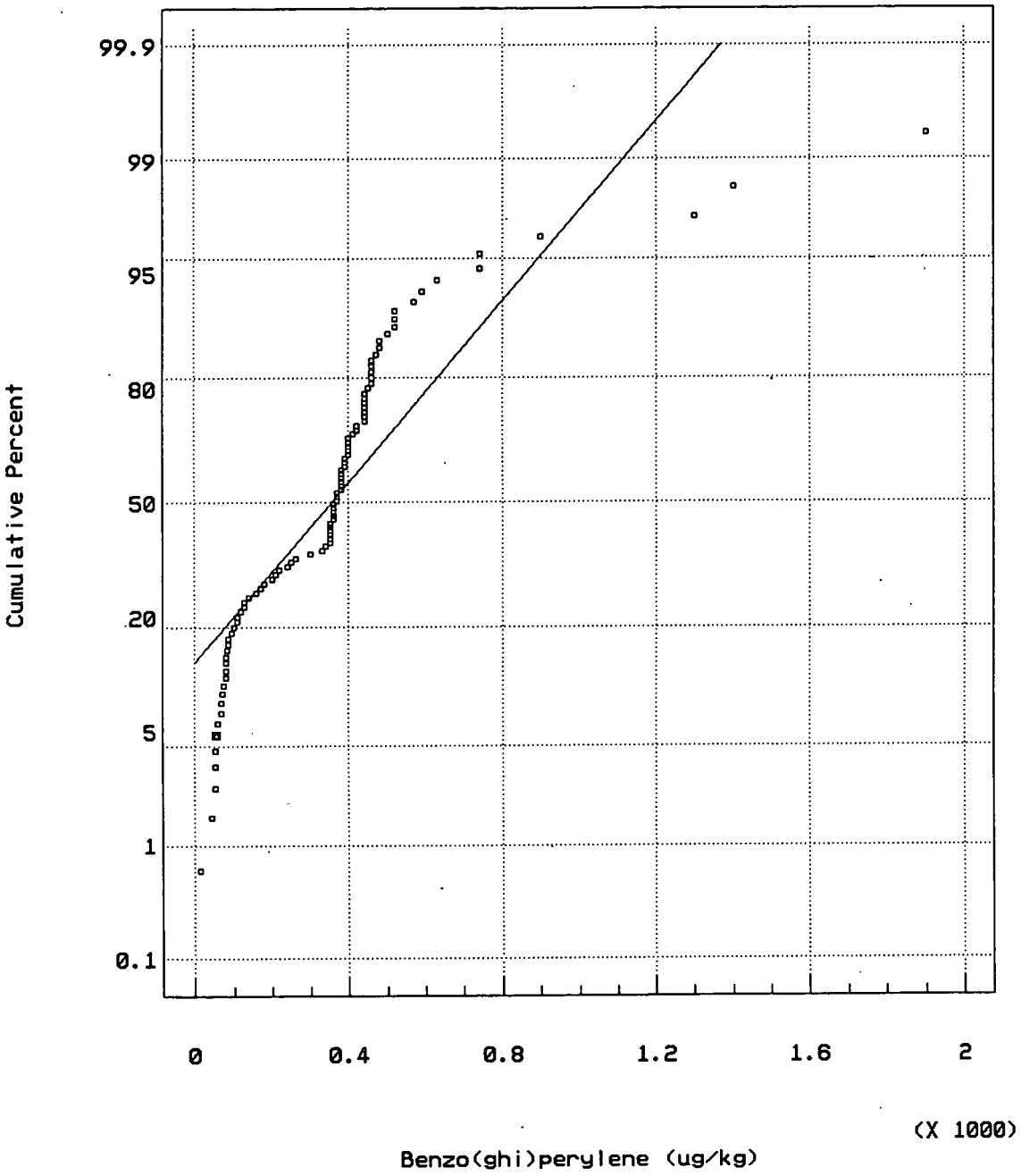
Normal Probability Plot
Benzo(a)pyrene in Surficial Soil



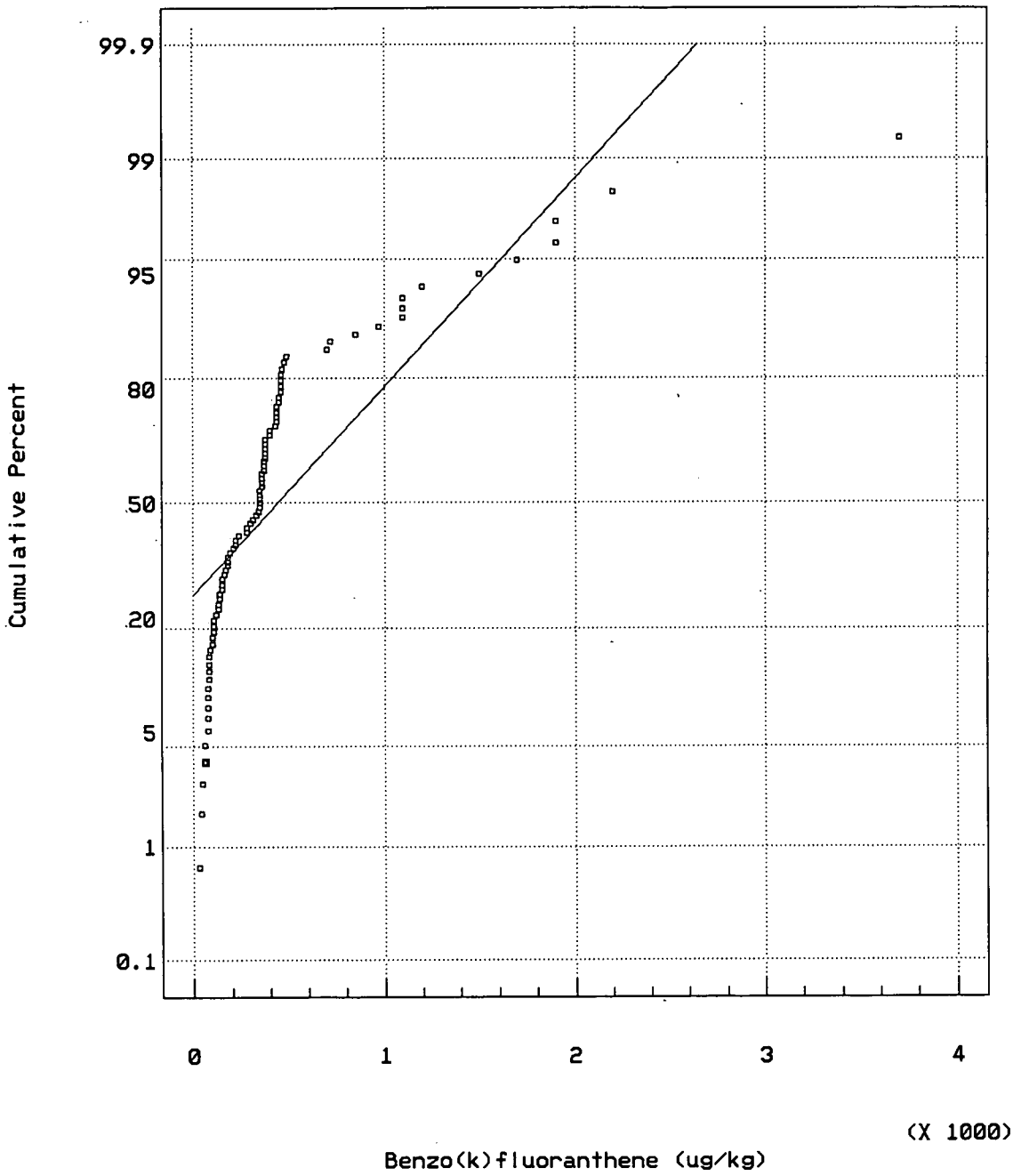
Normal Probability Plot
Benzo(b)fluoranthene in Surficial Soil



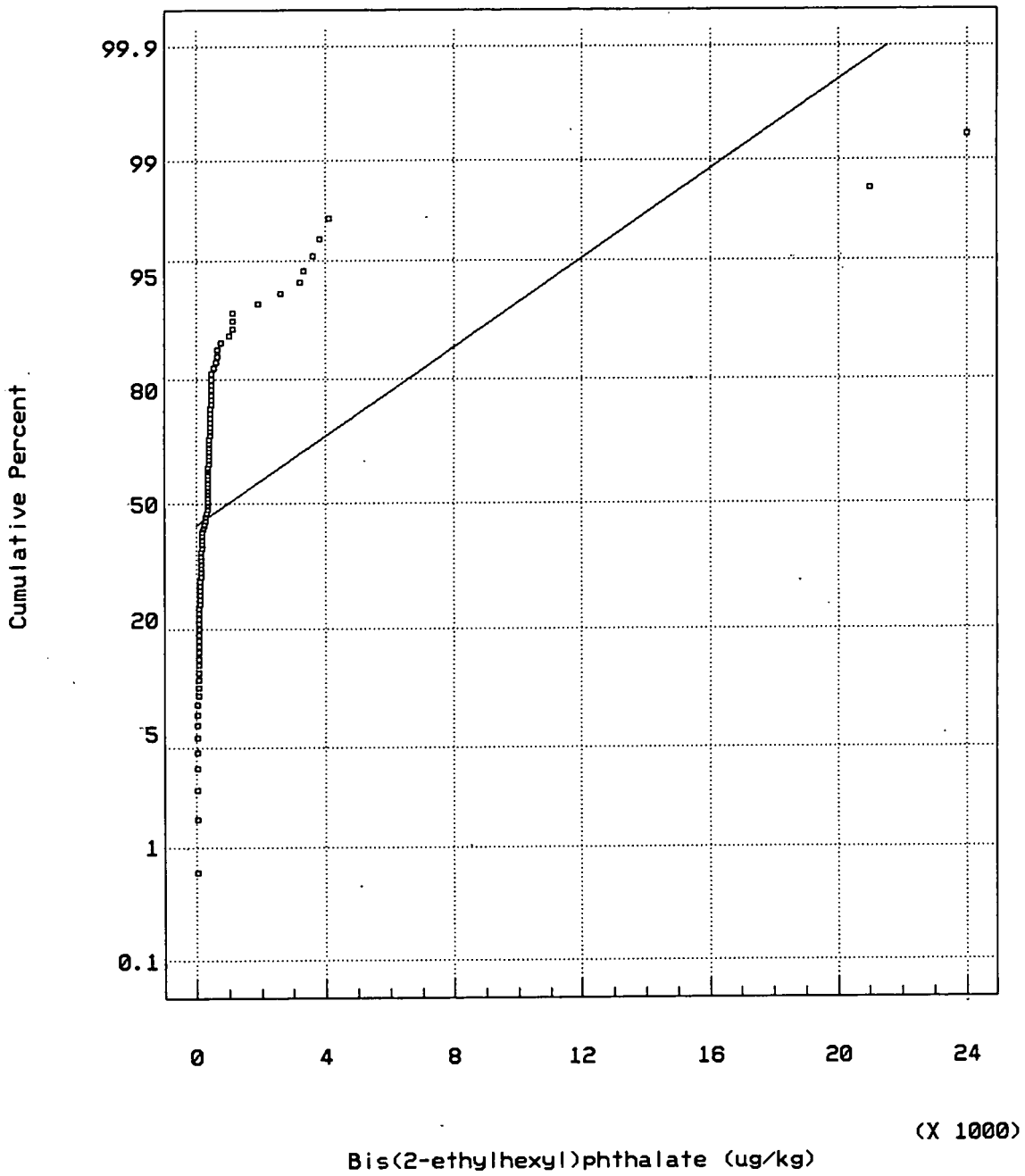
Normal Probability Plot
Benzo(ghi)perylene in Surficial Soil



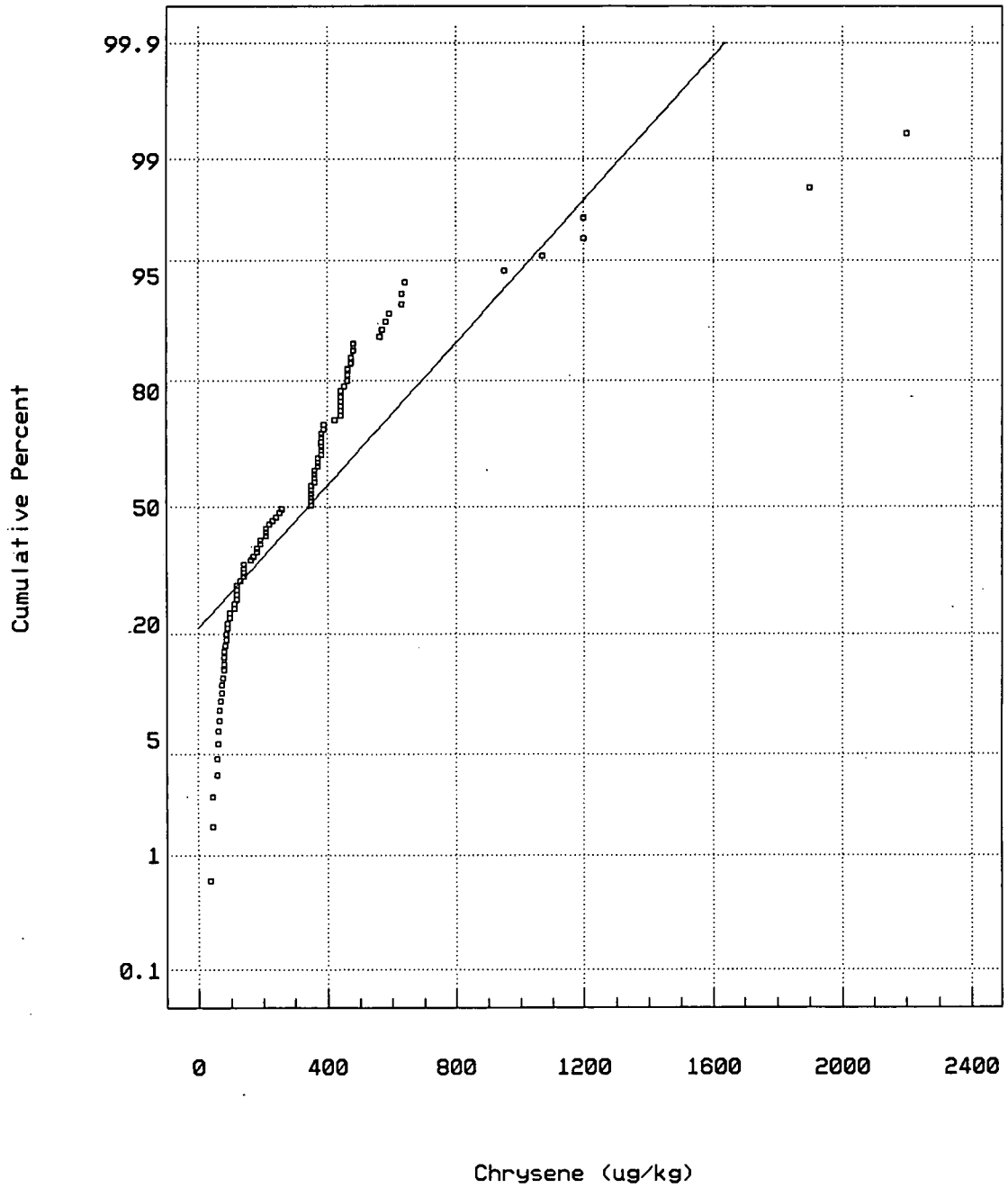
Normal Probability Plot
Benzo(k)fluoranthene in Surficial Soil



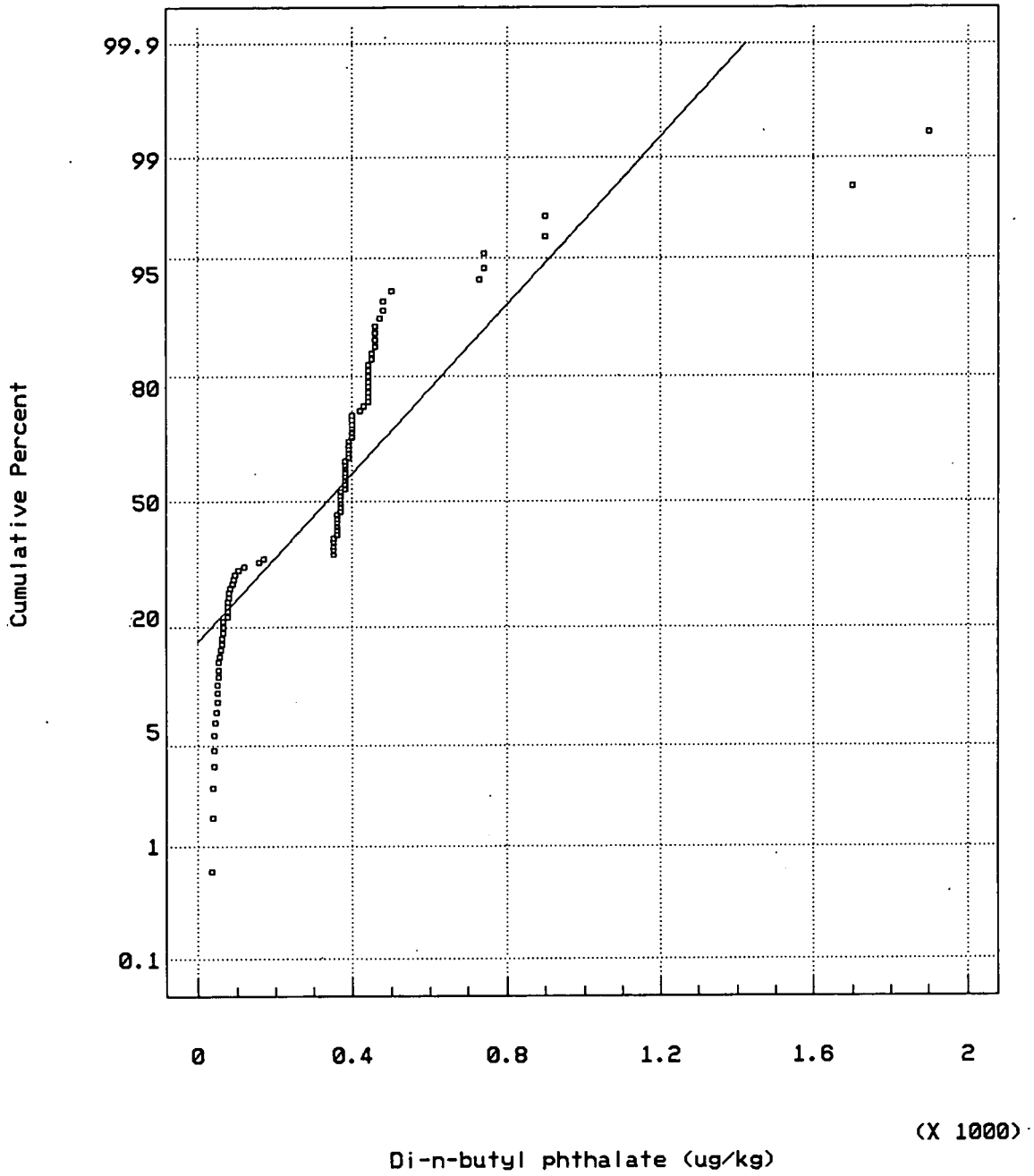
Normal Probability Plot
Bis(2-ethylhexyl)phthalate in Surficial



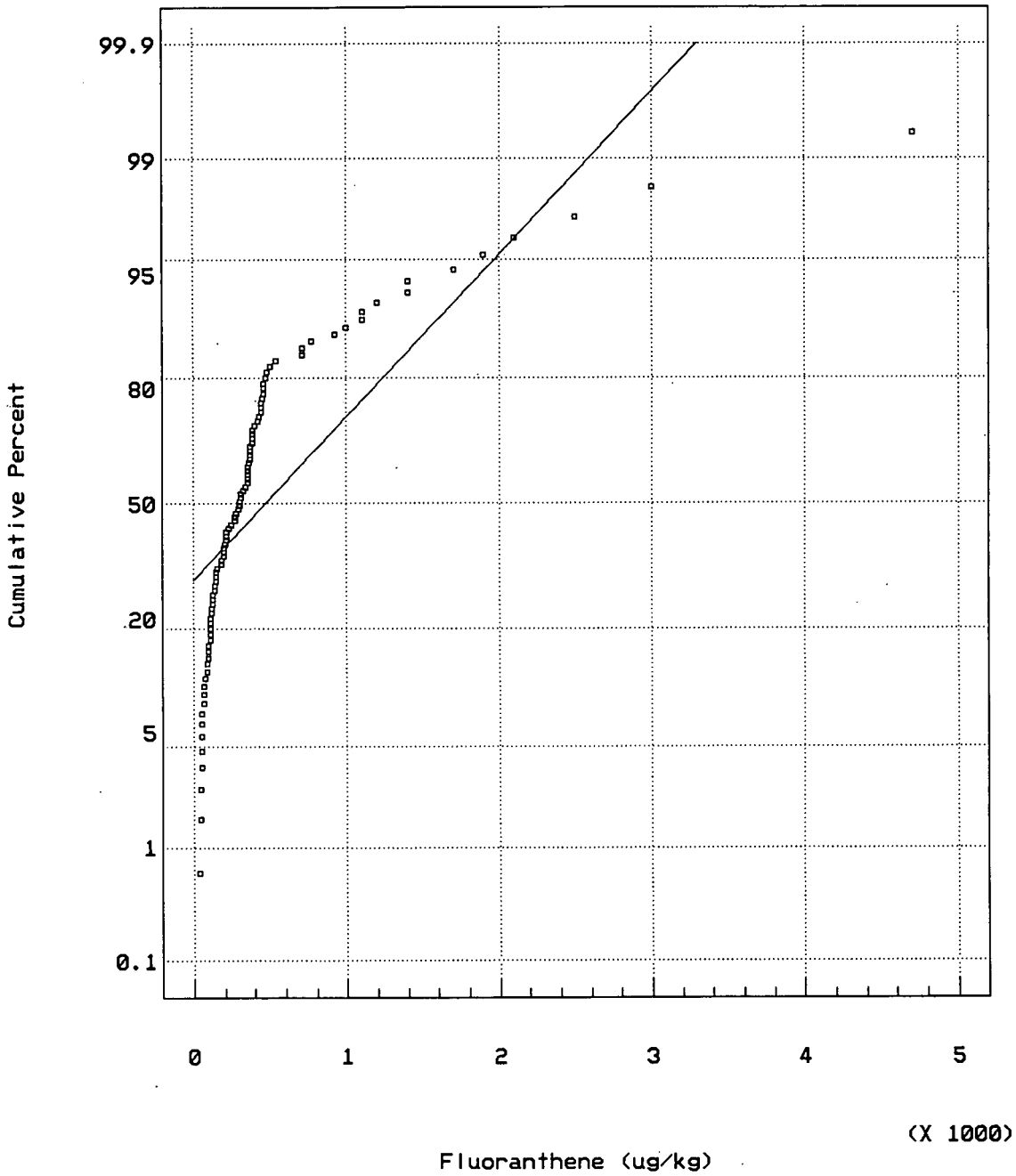
Normal Probability Plot
Chrysene in Surficial Soil



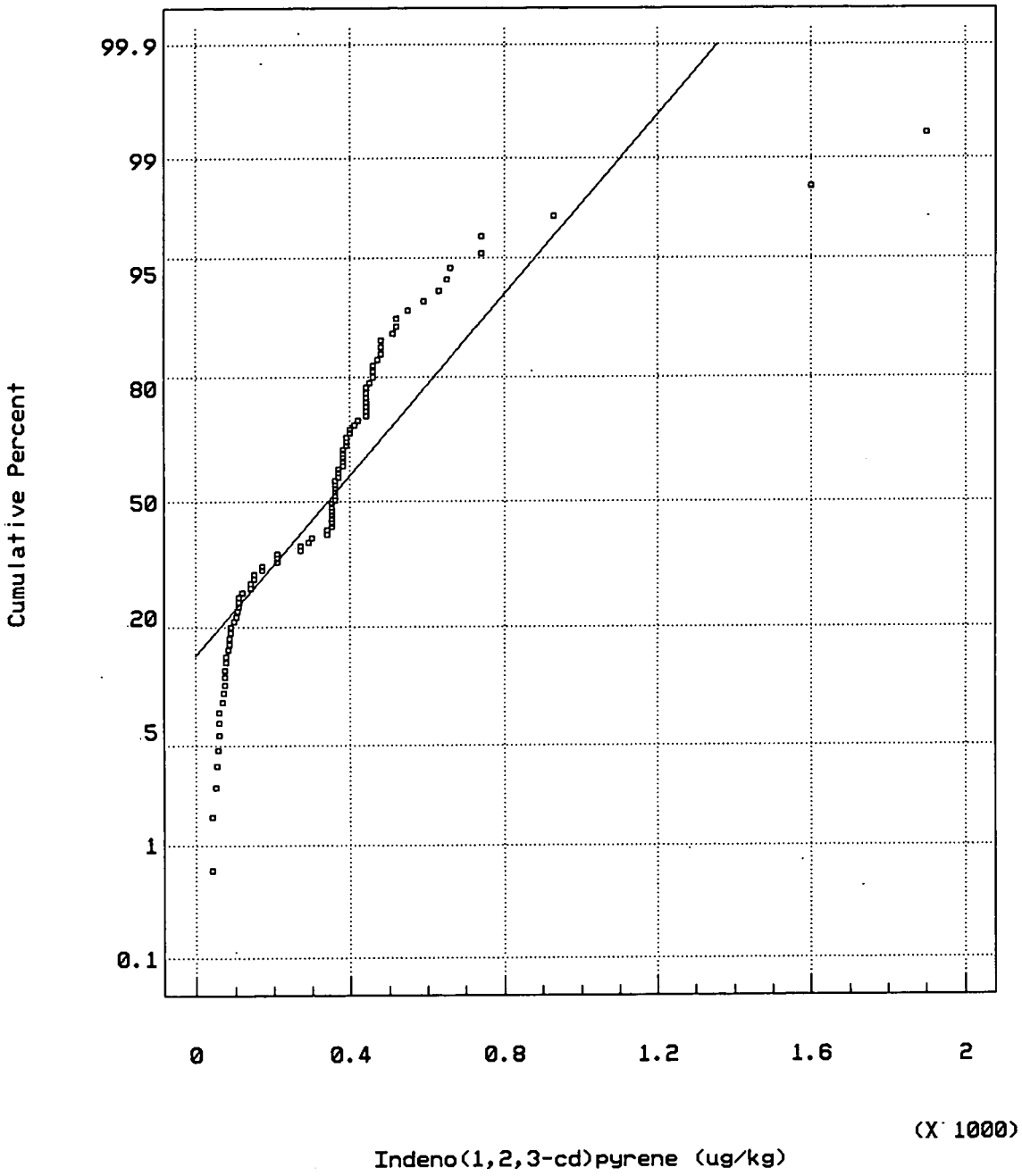
Normal Probability Plot
Di-n-butyl phthalate in Surficial Soil



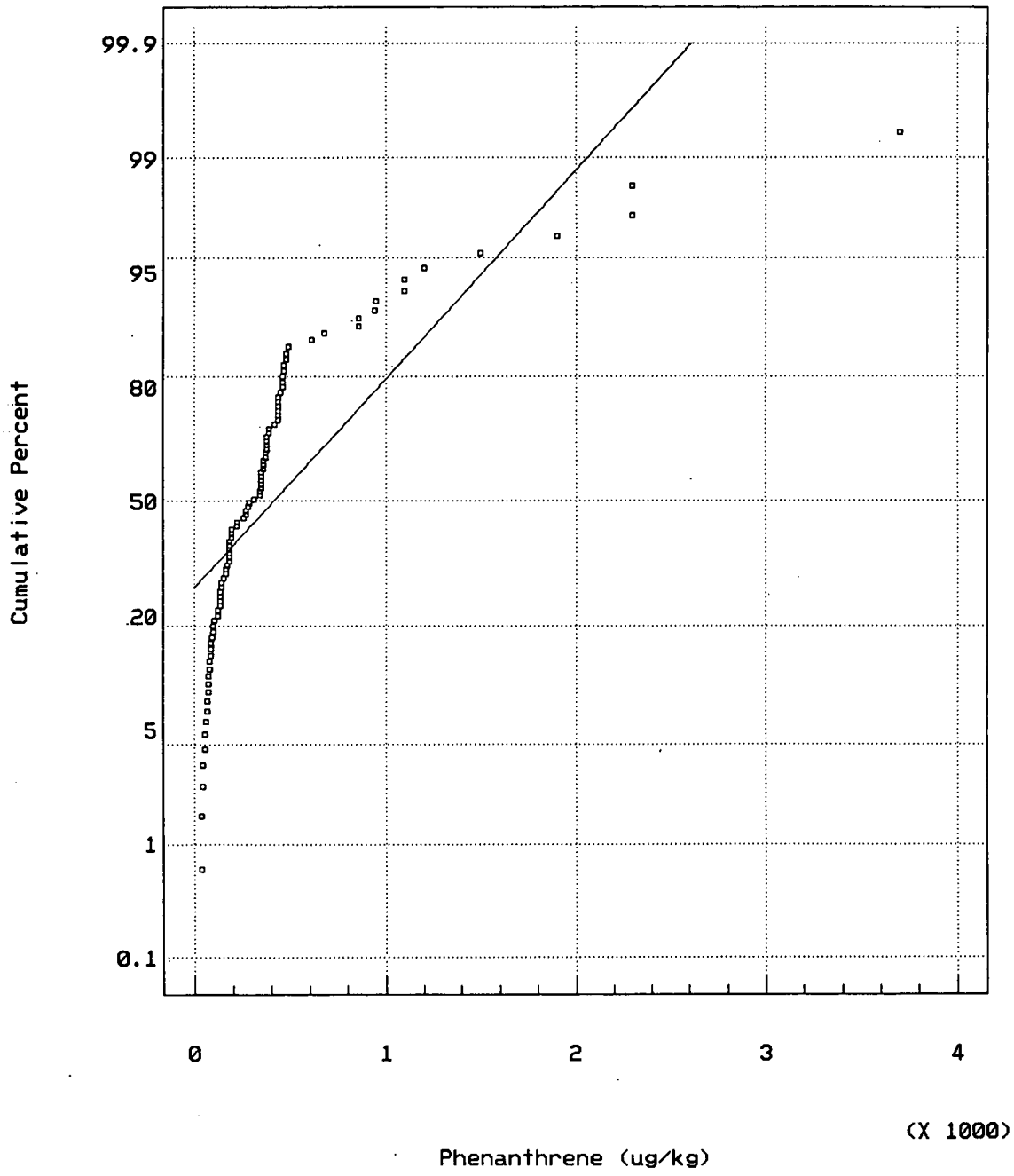
Normal Probability Plot
Fluoranthene in Surficial Soil



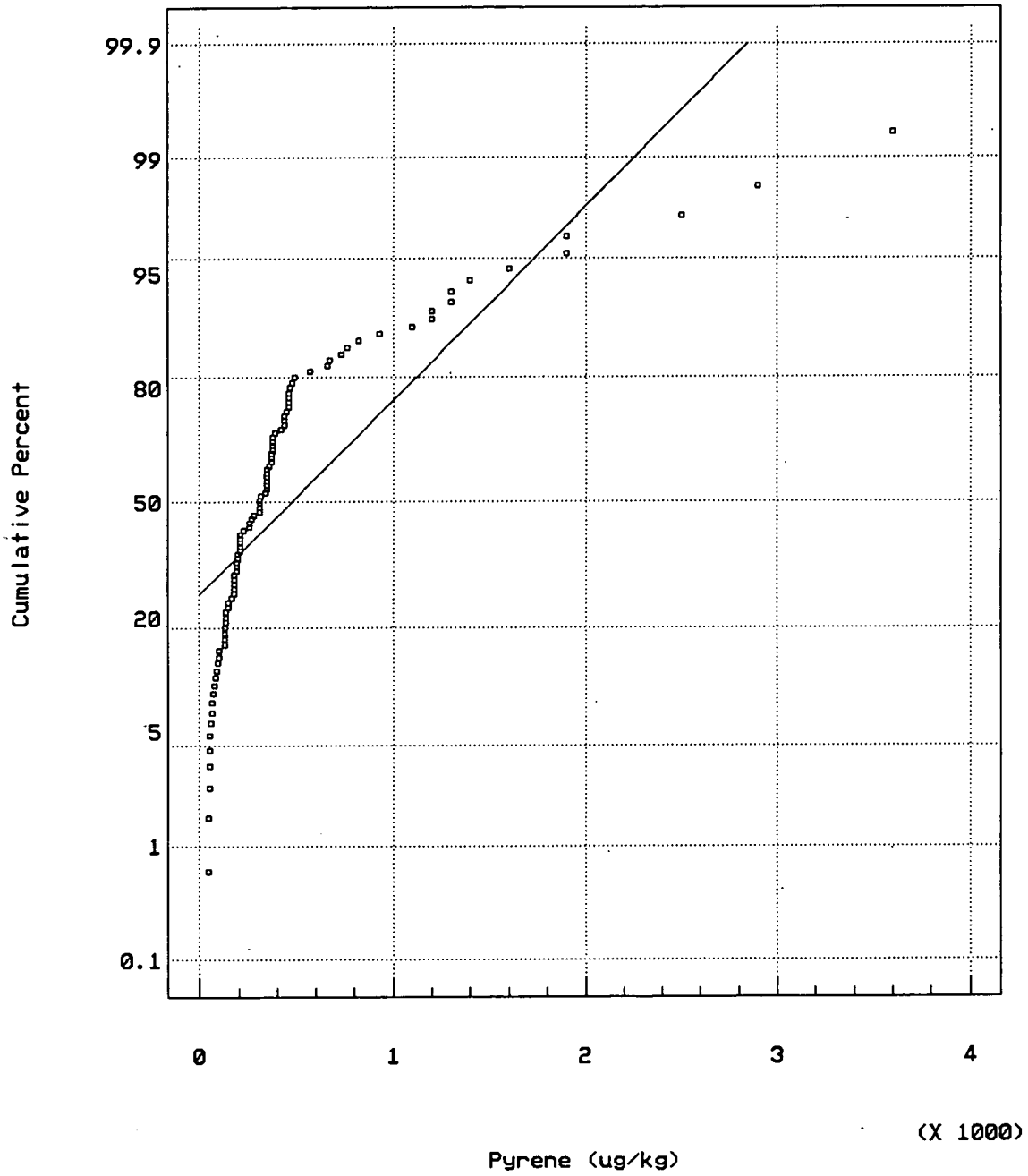
Normal Probability Plot
Indeno(1,2,3-cd)pyrene in Surficial Soil



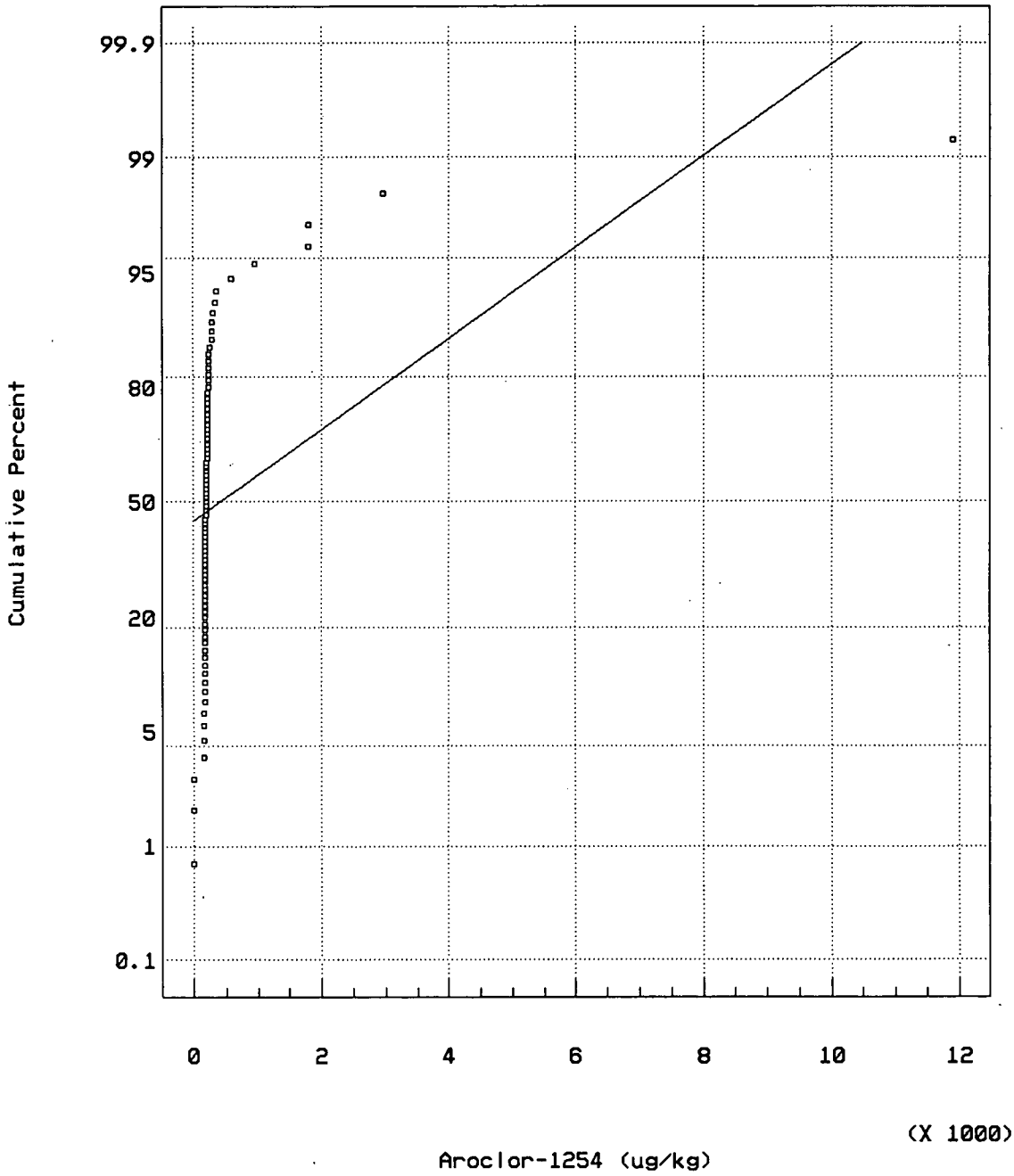
Normal Probability Plot
Phenanthrene in Surficial Soil



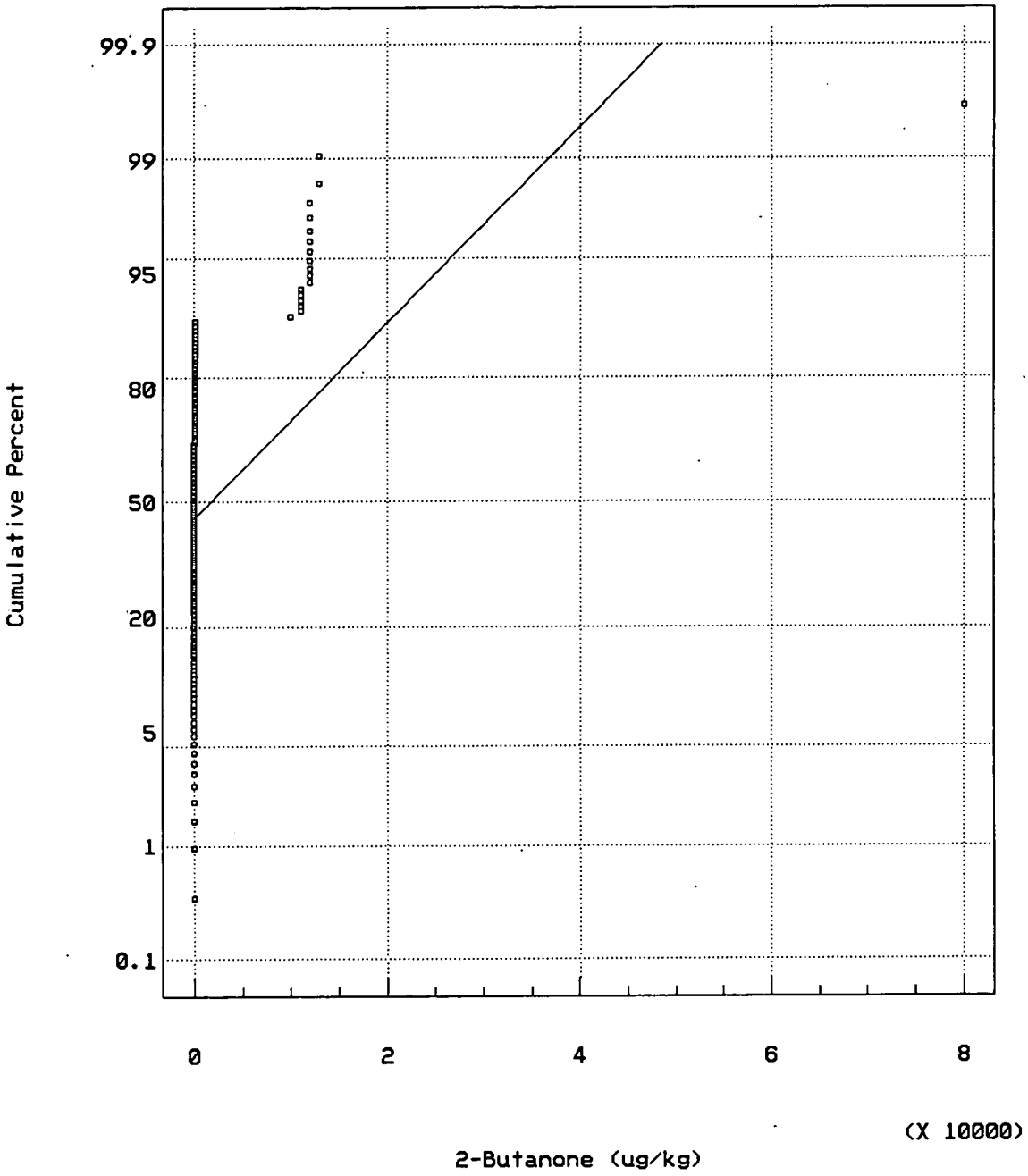
Normal Probability Plot
Pyrene in Surficial Soil



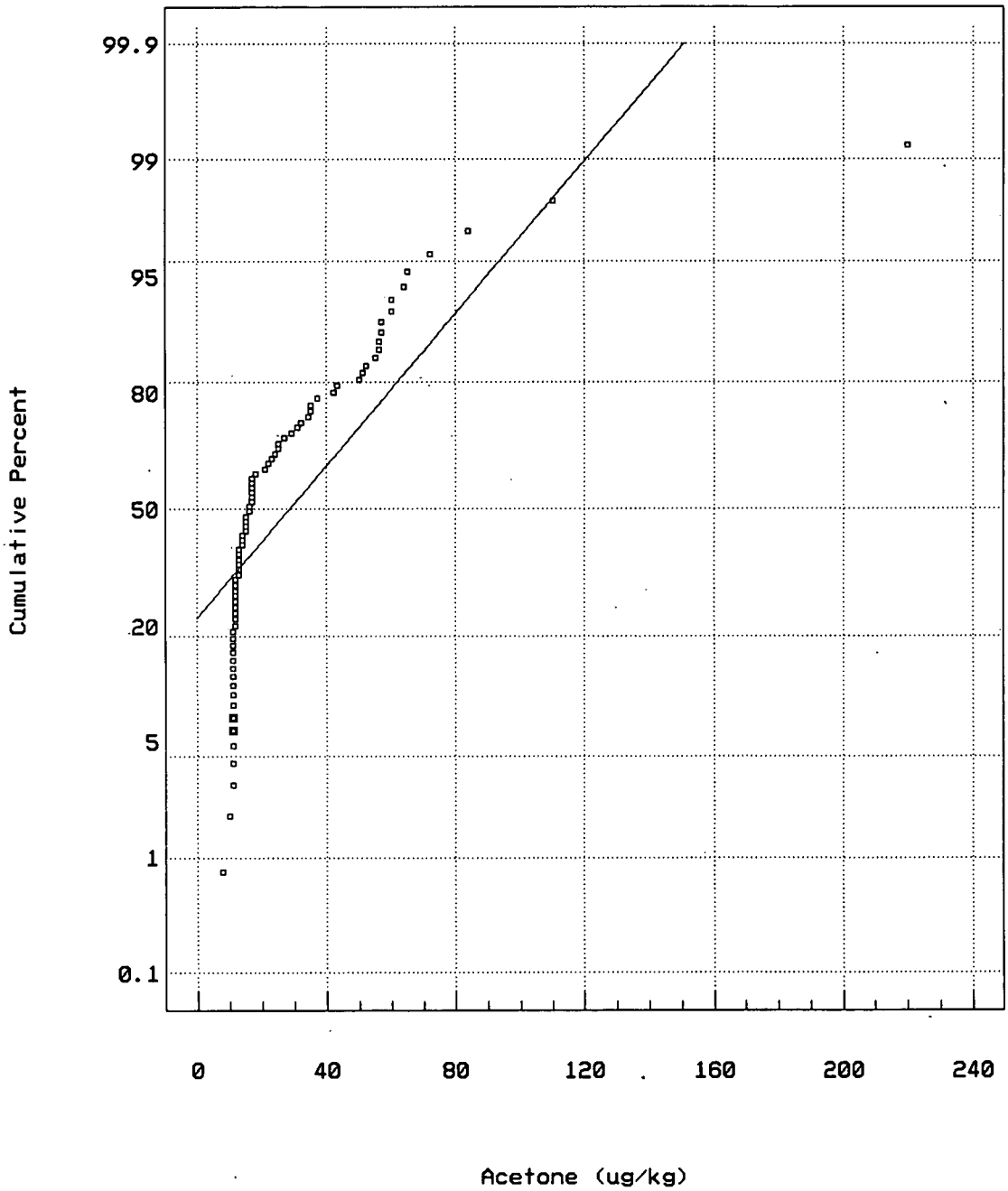
Normal Probability Plot
Aroclor-1254 in Surficial Soil



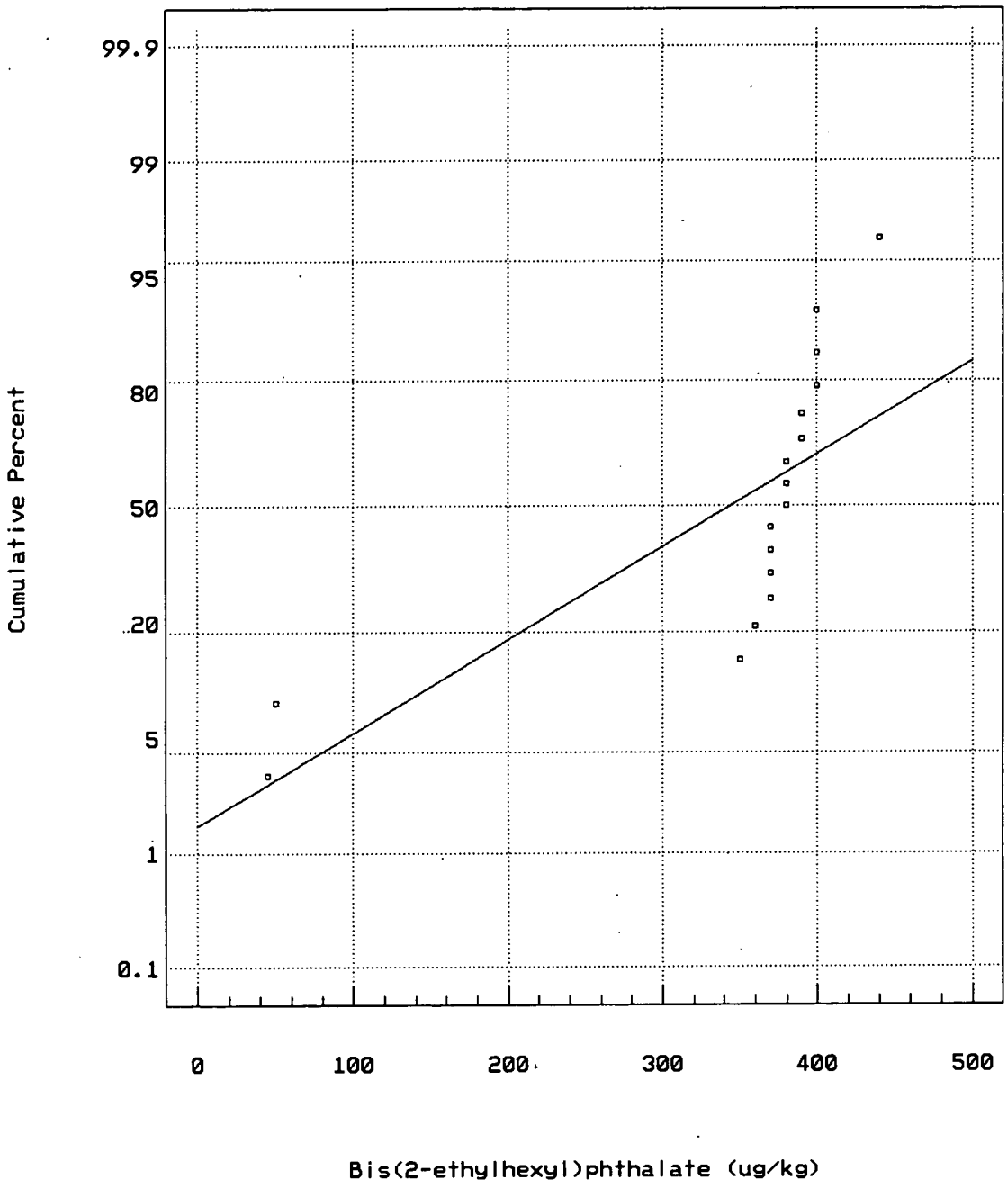
Normal Probability Plot
2-Butanone in Vadose Zone Soil



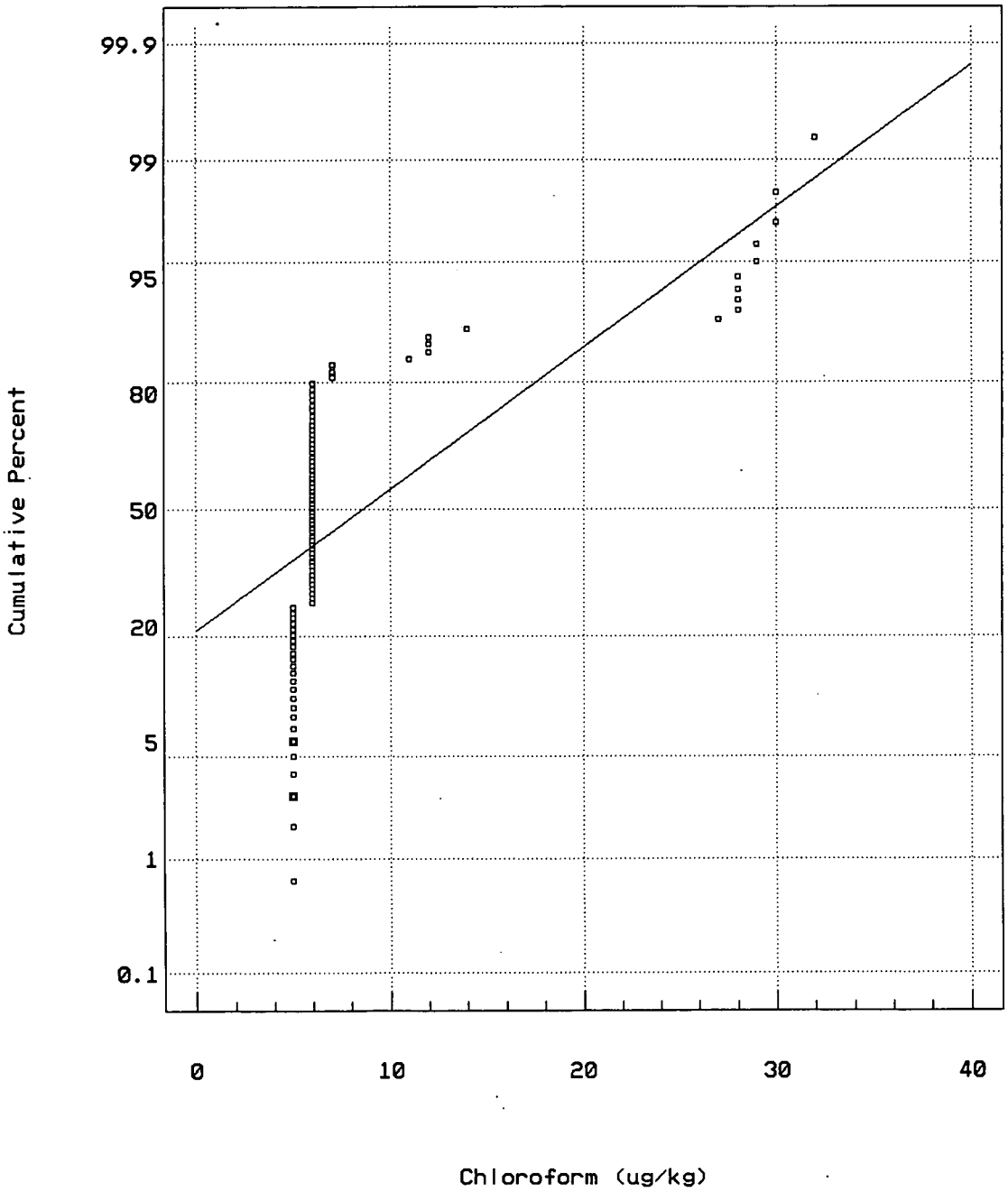
Normal Probability Plot
Acetone in Vadose Zone Soil



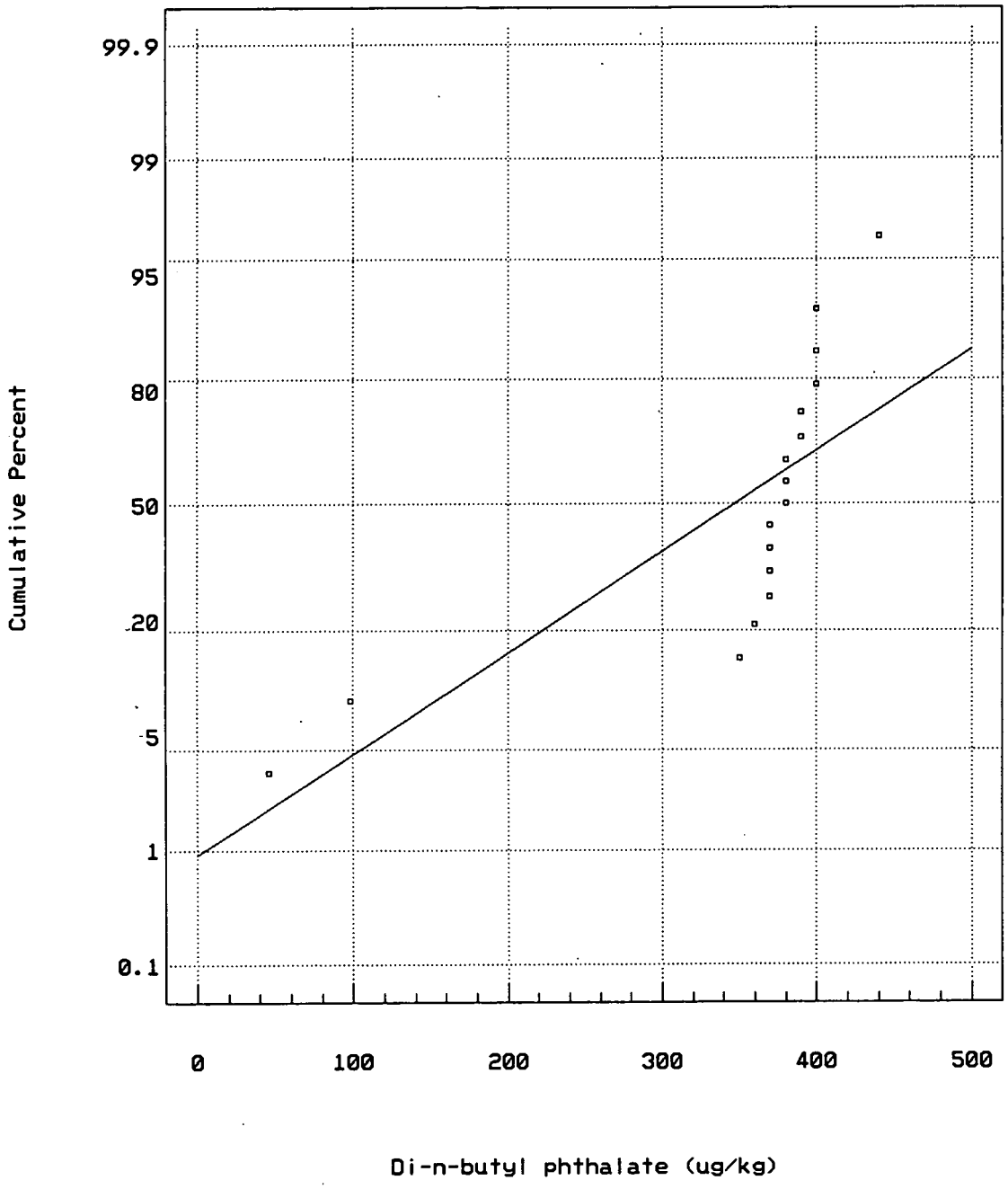
Normal Probability Plot
Bis(2-ethylhexyl)phthalate in Vadose Zon



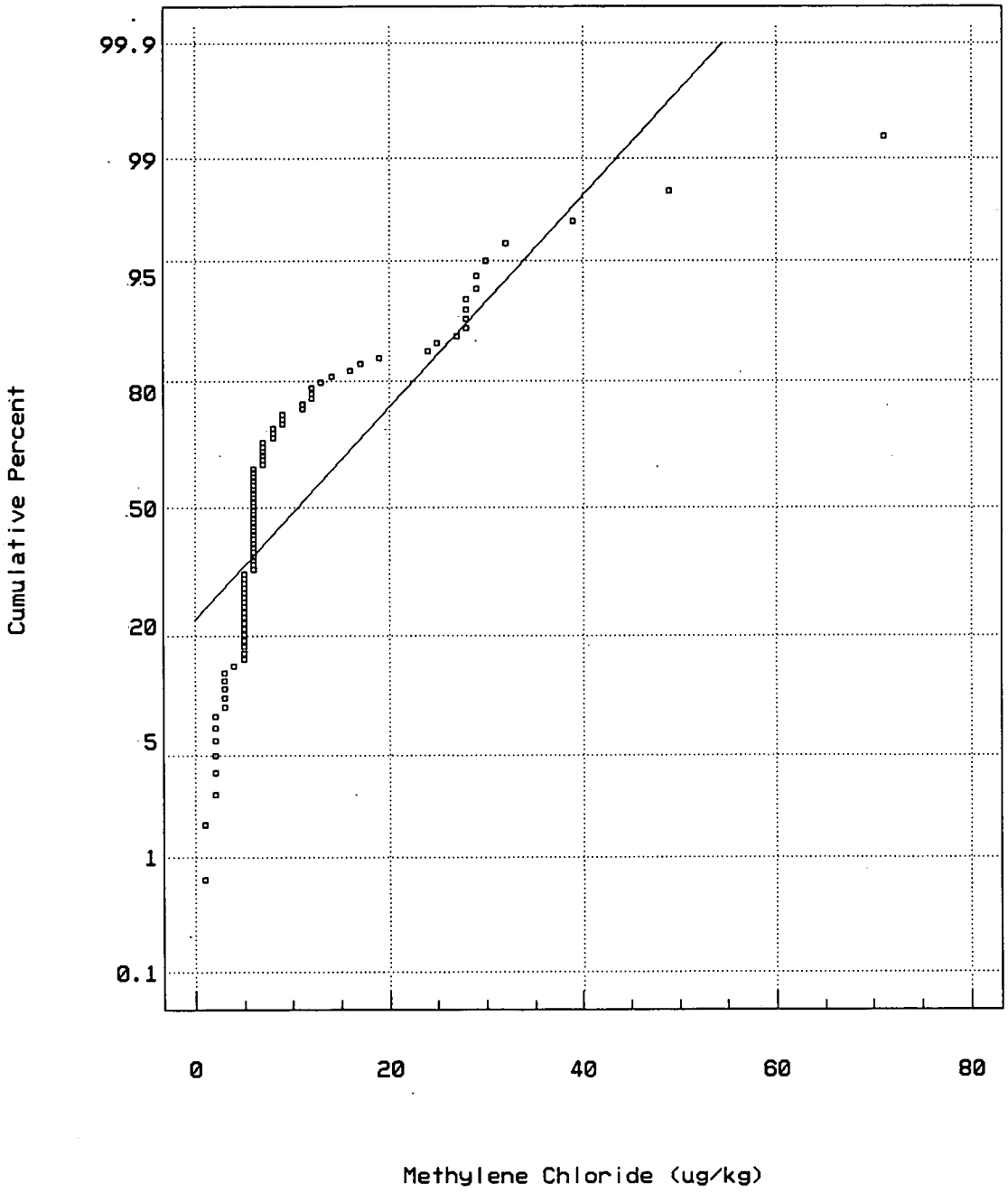
Normal Probability Plot
Chloroform in Vadose Zone Soil



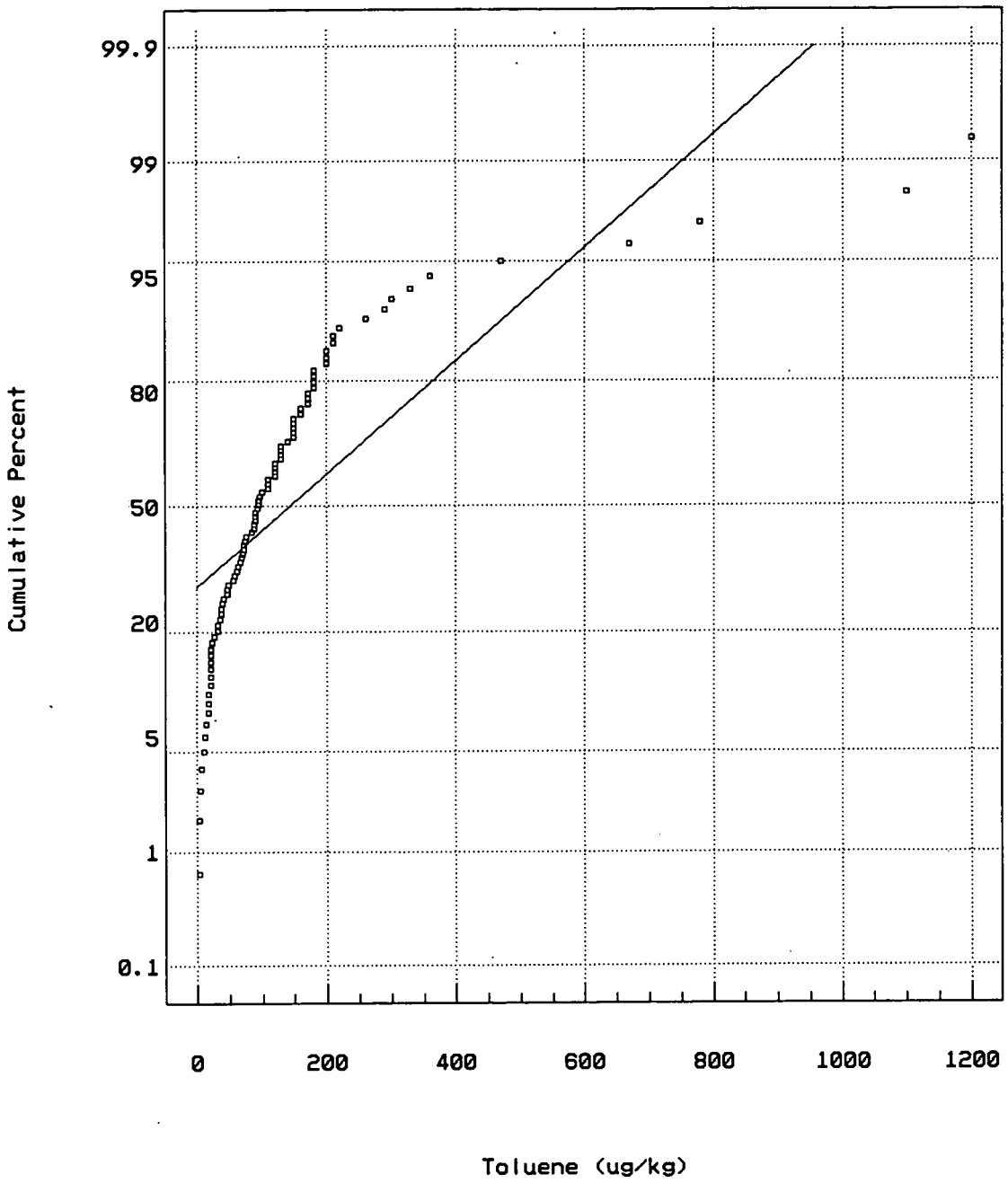
Normal Probability Plot
Di-n-butyl phthalate in Vadose Zone Soil



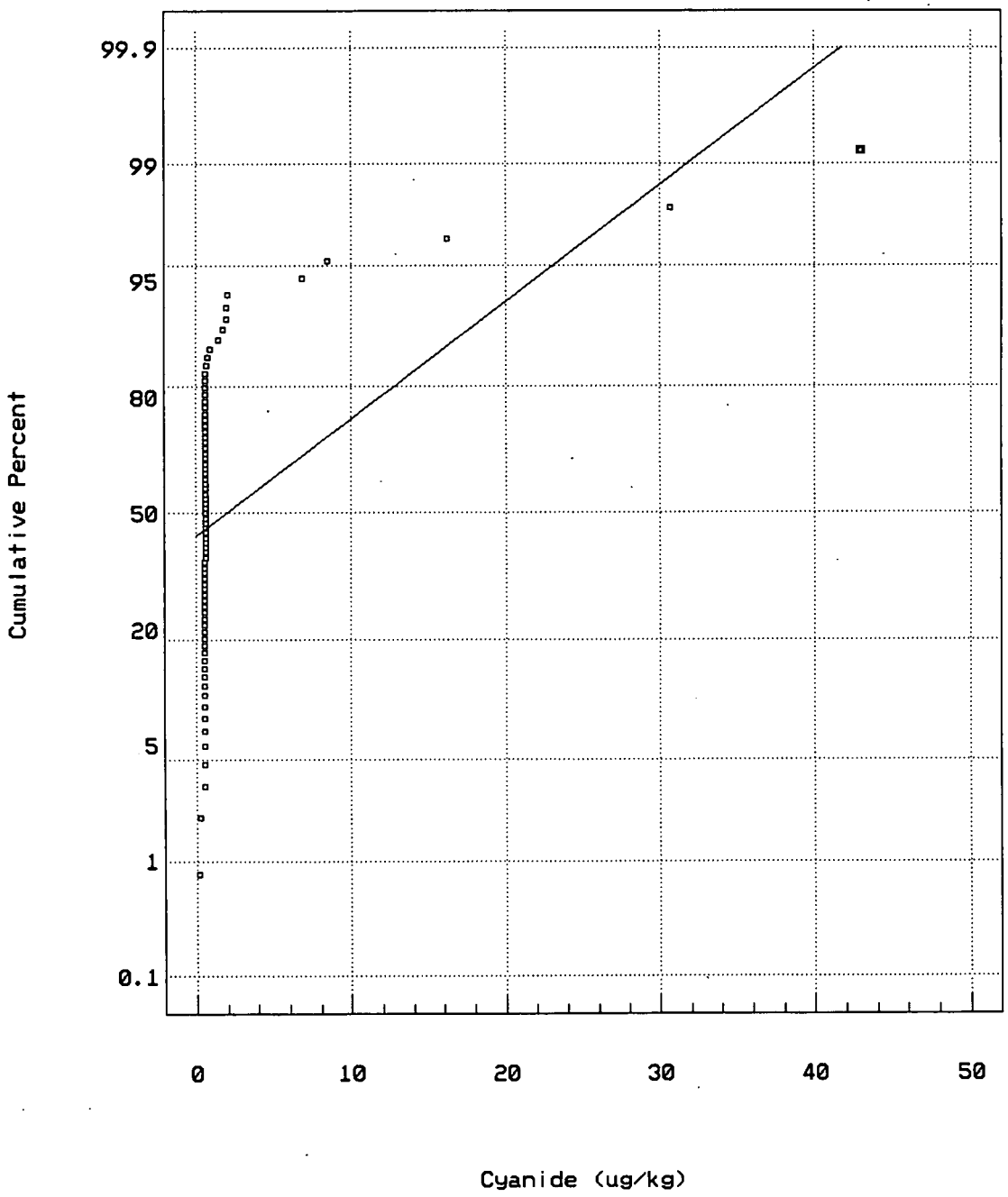
Normal Probability Plot
Methylene Chloride in Vadose Zone Soil



Normal Probability Plot
Toluene in Vadose Zone Soil



Normal Probability Plot
Cyanide in Vadose Zone Soil



APPENDIX III.B

PRELIMINARY REMEDIATION GOAL

CALCULATIONS AND TOXICITY TABLES

Table III.B-1
Residential Exposure Parameters for Noncarcinogens in Soil
OU4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, Colorado

Contaminant of Concern	RfD oral[a] (mg/kg-day)	RfC Inhal (mg/cu m)[b]	RfC Inhal[b] (mg/kg-day)	RfD derm[a] (mg/kg-day)	adult (days)	child (days)	adult (kg)	child (kg)	EF (days/yr)	adult (yr)	child (yr)	CF (kg/mg)	soil adult (mg/day)	soil child (mg/day)	air adult (m^3/day)	air child (m^3/day)	adult (cm^2)	child (cm^2)	AB	AF (mg/cm^2/event)	PEF (m^3/kg)	THI	PRG (mg/kg)
Aroclor 1254	7.00E-05			6.30E-05	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.06	1	4.63E+09	1.00E+00	1.74E+00
Benzo(a)anthracene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Benzo(a)pyrene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Benzo(b)fluoranthene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Benzo(ghi)perylene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Benzo(k)fluoranthene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Beryllium	5.00E-03			5.00E-05	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	1.00E+00	1.23E+01
Bis(2-ethylhexyl)phthalate	2.00E-02			1.00E-02	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	5.00E-01	1.08E+02
Cadmium	5.00E-04			1.00E-05	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	2.50E-01	5.96E-01
Cesium					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Chrysene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Di-n-butylphthalate	1.00E-01			9.00E-02	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.00E+00	1.74E+03
Fluoranthene	4.00E-02			8.00E-03	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	3.33E-01	6.35E+01
Indeno(1,2,3-cd)pyrene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Mercury	3.00E-04	3.00E-04	8.57E-05	3.00E-06	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	2.50E-01	1.85E-01
Nitrate	1.60E+00			3.20E-01	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	3.33E-01	1.58E+04
Nitrite	1.00E-01			2.00E-02	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	3.33E-01	9.88E+02
Phenanthrene					8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Pyrene	3.00E-02			6.00E-03	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	2.50E-01	3.57E+01
Silver	5.00E-03			1.00E-03	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	1.00E+00	1.48E+02
Uranium	3.00E-03			3.00E-05	8760	2190	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	2.50E-01	1.85E+00

*NOTE -
AT = Average Time (days)
BW = Body Weight (kg)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
CF = Conversion Factor (kg/mg)
IR soil = Soil Ingestion Rate (mg/day)
IR air = Air Inhalation Rate (m^3/day)
SA = Exposed Surface Area of Body (cm^2)
AB = Absorption Factor (unitless)
AF = Adherence Factor (mg/cm^2/event)
PEF = Particulate Emission Factor (m^3/kg)
THI = Target Hazard Index (unitless)
PRG = Preliminary Remediation Goals (mg/kg)

Table III.B-2
Residential Exposure Parameters of Carcinogens in Soil
OU4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, Colorado

Contaminant of Concern	SF (oral)[a] 1/(mg/kg-d)	SF (inhl) 1/(ug/cu m)	SF (inhl)[b] 1/(mg/kg-d)	SF (derm)[c] 1/(mg/kg-day)	AT (days)	BW Adult (kg)	BW Child (kg)	EF (days/yr)	ED adult (yr)	ED child (yr)	CF (kg/mg)	IR soil adult (mg/day)	IR soil child (mg/day)	IR air adult (m^3/day)	IR air child (m^3/day)	SA adult (cm^2)	SA child (cm^2)	AB	AF (mg/cm^2/event)	PEF (m^3/kg)	Risk	PRG (mg/kg)
Aroclor 1254	7.70E+00			8.56E+00	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.06	1	4.63E+09	5.00E-07	1.19E-02
Benzo(a)anthracene	7.30E-01			3.65E+00	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	7.40E-03
Benzo(a)pyrene	7.30E+00			3.65E+01	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	7.40E-04
Benzo(b)fluoranthene	7.30E-01			3.65E+00	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	7.40E-03
Benzo(ghi)perylene					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Benzo(k)fluoranthene	7.30E-02			3.65E-01	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	7.40E-02
Beryllium	4.30E+00	2.40E-03	8.40E+00	4.30E+02	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	5.00E-07	1.93E-03
Bis(2-ethylhexyl)phthalate	1.40E-02			2.80E-02	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	5.00E-07	2.69E+00
Cadmium		1.80E-03	6.30E+00		25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	5.00E-07	1.91E+03
Cesium					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Chrysene	7.30E-01			1.20E-02	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	1.37E-01
Di-n-butylphthalate					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Fluoranthene					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Indeno(1,2,3-cd)pyrene	7.30E-01			3.65E+00	25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	1.67E-07	7.40E-03
Mercury					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Nitrate					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Nitrite					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Phenanthrene					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Pyrene					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.1	1	4.63E+09	NA	--
Silver					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--
Uranium					25550	70	15	350	24	6	1.00E-06	100	200	20	18	7100	4600	0.01	1	4.63E+09	NA	--

*NOTE -
AT = Average Time (days)
BW = Body Weight (kg)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
CF = Conversion Factor (kg/mg)
IR soil = Soil Ingestion Rate (mg/day)
IR air = Air Inhalation Rate (m^3/day)
SA = Exposed Surface Area of Body (cm^2)
AB = Absorption Factor (unitless)
AF = Adherence Factor (mg/cm^2/event)
PRG = Preliminary Remediation Goals (mg/kg)

Table III.B-3
Construction/Maintenance Worker Exposure Parameters for Noncarcinogens in Soil
OU-4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, CO

Contaminants of Concern	RfD oral (mg/kg-day)	RfC Inhal (mg/cu m)	RfC Inhal (mg/kg-day)	RfD derm (mg/kg-day)	AT (days)	BW (kg)	EF (days/yr)	ED (yr)	CF (kg/mg)	IR soil (mg/day)	IR air (m^3/day)	SA (cm^2)	AB	AF (mg/cm^2/event)	PEF (m^3/kg)	THI	PRG (mg/kg)
Acetone	1.00E-01			9.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	2.50E-01	5.96E+03
Barium	7.00E-02	5.00E-04	1.43E-04	3.50E-03	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	6.99E+03
Bis(2-ethylhexyl)phthalate	2.00E-02			1.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.1	1	4.63E+09	2.50E-01	1.50E+03
2-Butanone	6.00E-01	1.00E+00	2.86E-01	5.40E-01	3650	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	3.33E-01	4.77E+04
Cadmium	5.00E-04			1.00E-05	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	2.50E-01	1.88E+01
Chloroform	1.00E-02			1.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	2.50E-01	6.43E+02
Cyanide	2.00E-02			1.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	4.95E+03
Di-n-butyl phthalate	1.00E-01			9.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.1	1	4.63E+09	1.00E+00	4.25E+04
Lithium					3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	--
Manganese	5.00E-03	5.00E-05	1.43E-05	1.50E-04	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	3.47E+02
Methylene chloride	6.00E-02	3.00E+00	8.57E-01	5.88E-02	3650	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	2.50E-01	3.80E+03
Nitrate	1.60E+00			3.20E-01	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	3.18E+05
Nitrite	1.00E-01			2.00E-02	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	1.99E+04
Strontium	6.00E-01			1.20E-01	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	1.19E+05
Toluene	2.00E-01	4.00E-01	1.14E-01	1.80E-01	3650	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	2.50E-01	1.19E+04
Uranium	3.00E-03			3.00E-05	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	2.50E-01	6.17E+01
Zinc	3.00E-01			7.50E-02	3650	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	3.33E-01	6.37E+04

*NOTE –
AT = Average Time (days)
BW = Body Weight (kg)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
CF = Conversion Factor (kg/mg)
IR soil = Soil Ingestion Rate (mg/day)
IR air = Air Inhalation Rate (m^3/day)
SA = Exposed Surface Area of Body (cm^2)
AB = Absorption Factor (unitless)
AF = Adherence Factor (mg/cm^2/event)
PEF = Particulate emission Factor (m^3/kg)
THI = Target hazard index (unitless)
PRG = Preliminary Remediation Goals (mg/kg)

Table III.B-4
Construction/Maintenance Worker Exposure Parameters for Carcinogens in Soil
OU-4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, CO

Contaminant of Concern	SF (oral) 1/(mg/kg-d)	SF (inhl) 1/(ug/cu m)	SF (inhl) 1/(mg/kg-d)	SF (derm) 1/(mg/kg-d)	AT (days)	BW (kg)	EF (days/yr)	ED (yr)	CF (kg/mg)	IR soil (mg/day)	IR air (mg/day)	SA (cm^2)	AB	AF (mg/cm^2/event)	PEF (m^3/kg)	Risk	PRG (mg/kg)
Acetone					25550	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	NA	
Barium					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Bis(2-ethylhexyl)phthalate	1.40E-02			2.80E-02	25550	70	60	10	1.00E-06	480	20	4700	0.1	1	4.63E+09	3.33E-07	5.00E+01
2-Butanone					25550	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	NA	*
Cadmium		1.80E-03	6.30E+00		25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	1.00E-06	1.10E+05
Chloroform	6.10E-03	2.30E-05	8.05E-02	6.10E-03	25550	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	3.33E-07	9.84E+01
Cyanide					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Di-n-butyl phthalate					25550	70	60	10	1.00E-06	480	20	4700	0.1	1	4.63E+09	NA	
Lithium					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Manganese					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Methylene chloride	7.50E-03	4.70E-07	1.65E-03	7.65E-03	25550	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	3.33E-07	7.89E+01
Nitrate					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Nitrite					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Strontium					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Toluene					25550	70	60	10	1.00E-06	480	20	4700	0.25	1	4.63E+09	NA	
Uranium					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	
Zinc					25550	70	60	10	1.00E-06	480	20	4700	0.01	1	4.63E+09	NA	

*NOTE -
AT = Average Time (days)
BW = Body Weight (kg)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
CF = Conversion Factor (kg/mg)
IR soil = Soil Ingestion Rate (mg/day)
IR air = Air Inhalation Rate (m^3/day)
SA = Exposed Surface Area of Body (cm^2)
AB = Absorption Factor (unitless)
AF = Adherence Factor (mg/cm^2/event)
PEF = Particulate Emission Factor (m^3/kg)
PRG = Preliminary Remediation Goals (mg/kg)

TABLE III.B-5
RESIDENTIAL EXPOSURE PARAMETERS FOR RADIONUCLIDES IN SOIL
OU-4, SOLAR EVAPORATION PONDS, IM/IRA
ROCKY FLATS PLANT, GOLDEN, CO

Chemical	SF(ingest) (Risk/pCi)	SF(inh) (Risk/pCi)	Ext Exp Risk/yr/pCi/g	EF (days/yr)	ED (yr)	IFsoil (mg-yr-day)	TR	Se (unitless)	Te (unitless)	PRG (pCi/g)
Americium 241	2.40E-10	3.20E-08	4.90E-09	350	30	3600	1.11E-07	0.2	1.0	2.65E-01
Cesium 134	4.10E-11	2.80E-11	5.20E-06	350	30	3600	1.11E-07	0.2	1.0	8.90E-04
Gross alpha				350	30	3600	NA	0.2	1.0	--
Plutonium 239	2.30E-10	3.80E-08	1.70E-11	350	30	3600	1.11E-07	0.2	1.0	3.83E-01
Plutonium 240	2.30E-10	3.80E-08	2.70E-11	350	30	3600	1.11E-07	0.2	1.0	3.83E-01
Tritium	5.40E-14	7.80E-14	nr	350	30	3600	1.11E-07	0.2	1.0	1.63E+03
Uranium 233	1.60E-11	2.70E-08	4.20E-11	350	30	3600	1.11E-07	0.2	1.0	5.25E+00
Uranium 234	1.60E-11	2.60E-08	3.00E-11	350	30	3600	1.11E-07	0.2	1.0	5.32E+00
Uranium 235	1.10E-10	6.10E-08	2.70E-07	350	30	3600	1.11E-07	0.2	1.0	1.68E-02
Uranium 238	2.10E-11	2.40E-08	5.90E-06	350	30	3600	1.11E-07	0.2	1.0	7.85E-04

03:29 PM

TABLE III.B-6
CONSTRUCTION/MAINTENANCE WORKER EXPOSURE PARAMETERS FOR RADIONUCLIDES IN SOIL
OU-4, SOLAR EVAPORATION PONDS, IM/IRA
ROCKY FLATS PLANT, GOLDEN, COLORADO

Chemical	SF(ingest) (Risk/pCi)	SF(inh) (Risk/pCi)	Ext Exp Risk/yr/pCi/g	EF (days/yr)	ED (yr)	IRair (cu m/day)	IRsoil (cu m/day)	PEF (cu m/kg)	TR	Se (unitless)	Te (unitless)	PRG (pCi/g)
Americium 241	2.40E-10	3.20E-08	4.90E-09	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.09E+00
Cesium 134	4.10E-11	2.80E-11	5.20E-06	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	6.11E-02
Cesium 137	2.80E-11	1.90E-11	2.00E-06	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.58E-01
Gross beta				60	10	20	480	4.63E+09	NA	0.2	0.3	--
Plutonium 239	2.30E-10	3.80E-08	1.70E-11	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.16E+00
Plutonium 240	2.30E-10	3.80E-08	2.70E-11	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.16E+00
Radium 226	1.20E-10	3.00E-09	6.00E-06	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	5.22E-02
Strontium 89	3.00E-12	2.90E-12	4.70E-10	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	7.88E+01
Strontium 90	3.60E-11	6.20E-11	nr	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	7.42E+00
Tritium	5.40E-14	7.80E-14	nr	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	4.95E+03
Uranium 233	1.60E-11	2.70E-08	4.20E-11	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.67E+01
Uranium 234	1.60E-11	2.60E-08	3.00E-11	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	1.67E+01
Uranium 235	1.10E-10	6.10E-08	2.70E-07	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	7.97E-01
Uranium 238	2.10E-11	2.40E-08	5.90E-06	60	10	20	480	4.63E+09	7.69E-08	0.2	0.3	5.41E-02

Table III.B-7
Toxicity Information for Organic and Inorganic Contaminants of Concern
OU-4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, CO

Material Name	CAS Number		Chem Class (1)	Tox Class (2)	CAG Group (3)	Administered RfD (4) (mg/kg-d)		SF (4) (kg-d/mg)		Absorpt Efficiency (5)		Absorbed Derm RfD (6) (mg/kg-d)	Derm SF (6) (kg-d/mg)		Inhalation RfC (4) (mg/cu m)		IUR (4) (cu m/ug)		Target Organ (noncarcinogen)	Target Organ (carcinogen)
Acetone	67641		v	nc	d	1.00E-01		-		9.00E-01	~	9.00E-02	--		nr		-		kidney	-
Arochlor-1254	11097691	(7)	f	c	b2	7.00E-05		7.70E+00		9.00E-01		6.30E-05	8.56E+00		nr		ur		reduced birth rates	liver
Barium	7440393		m	nc	nr	7.00E-02		-		5.00E-02		3.50E-03	--		5.00E-04	*	-		fetotoxicity, blood pressure	-
Benzo(a)anthracene	56553		s	c	b2	nr		7.30E-01	(8)	2.00E-01	~	--	3.65E+00	(8)	nr		ur		-	forestomach
Benzo(a)pyrene	50328		s	c	b2	nr		7.30E+00		2.00E-01		--	3.65E+01		nr		ur	*	-	forestomach
Benzo(b)fluoranthene	205992		s	c	b2	nr		7.30E-01	(8)	2.00E-01	~	--	3.65E+00	(8)	nr		ur		-	forestomach
Benzo(ghi)perylene	191242		s	nc	d	nr		-		2.00E-01	~	--	--		nr		-		-	-
Benzo(k)fluoranthene	207089		s	c	b2	nr		7.30E-02	(8)	2.00E-01	~	--	3.65E-01	(8)	nr		ur		-	forestomach
Beryllium	7440417		m	c	b2	5.00E-03		4.30E+00		1.00E-02		5.00E-05	4.30E+02		nr		2.40E-03		none reported	lung, all sites
Bis(2-ethylhexyl)phthalate	117817		s	c	b2	2.00E-02		1.40E-02		5.00E-01		1.00E-02	2.80E-02		nr		nr		liver	liver
2-Butanone	78933		v	nc	d	6.00E-01		-		9.00E-01	~	5.40E-01	--		1.00E+00		-		fetotoxicity	-
Cadmium	7440439		m	c	b1	5.00E-04		nr		2.00E-02		1.00E-05	--		ur		1.80E-03		kidney	lung
Chloroform	67663		v	c	b2	1.00E-02		6.10E-03		1.00E+00		1.00E-02	6.10E-03		ur		2.30E-05		liver	kidney, liver
Chrysene	218019		s	c	b2	nr		7.30E-03	(8)	6.00E-01		--	1.22E-02	(8)	nr		ur		-	forestomach
Cyanide	57145		m	nc	d	2.00E-02		-		5.00E-01		1.00E-02	--		nr		-		nerve, thyroid, weight loss	-
Di-n-butyl phthalate	84742		s	nc	d	1.00E-01		-		9.00E-01		9.00E-02	--		nr		-		increased mortality	-
Fluoranthene	206440		s	nc	d	4.00E-02		-		2.00E-01	~	8.00E-03	--		nr		-		liver, blood	-
Indeno(1,2,3-cd)pyrene	193395		s	c	b2	nr		7.30E-01	(8)	2.00E-01	~	--	3.65E+00	(8)	nr		ur		-	forestomach
Lithium			m	nc	nr	nr		-		1.00E-02	~	--	--		nr		-		-	
Manganese	7439965		m	nc	d	5.00E-03		-		3.00E-02		1.50E-04	--		5.00E-05		-		nerve	-
Mercury	7439976		m	nc	d	3.00E-04	*	-		1.00E-02		3.00E-06	--		3.00E-04	*	-		kidney, nerve	-
Methylene Chloride	75092		v	c	b2	6.00E-02		7.50E-03		9.80E-01		5.88E-02	7.65E-03		3.00E+00	*	4.70E-07		liver	liver
Nitrate	14797558		w	nc	nr	1.60E+00		-		2.00E-01	~	3.20E-01	--		nr		-		blood	-
Nitrite	14797650		w	nc	nr	1.00E-01		-		2.00E-01	~	2.00E-02	--		nr		-		blood	-
Phenanthrene	85018		s	nc	d	nr		-		2.00E-01	~	--	--		nr		-		-	-
Pyrene	149000		s	nc	d	3.00E-02		-		2.00E-01	~	6.00E-03	--		nr		-		kidney	-
Silver	7440224		m	nc	d	5.00E-03		-		2.00E-01		1.00E-03	--		nr		-		skin	-
Strontium	7440246		m	nc	d	6.00E-01		-		2.00E-01	~	1.20E-01	--		nr		-		fetotoxicity	
Toluene	108883		v	nc	d	2.00E-01		-		9.00E-01	~	1.80E-01	--		4.00E-01		-		kidney, liver, nerve	-
Uranium	744611		m	nc	d	3.00E-03		-		1.00E-02		3.00E-05	--		nr		-		kidney	-
Zinc	7440666		m	nc	d	3.00E-01		-		2.50E-01		7.50E-02	--		nr		-		blood	-

(1) f = polychlorinated biphenyls, m = metals, s = semi-volatiles, v = volatiles, w = inorganics
(2) nc = noncarcinogen, c = carcinogen.
(3) CAG = USEPA Carcinogen Assessment Group. Group A = Human Carcinogen; Group B1 = Probable Human Carcinogen (with some human data);
Group B2 = Probable Human Carcinogen (with no human data); Group C = Possible Human Carcinogen; Group D = Not Classified; nr = unable to assess carcinogenic potential.
(4) From IRIS (Micromedix, Inc., 1993). When IRIS values were unavailable, HEAST (USEPA, 1993a) was used. An asterick (*) indicates that values were taken from HEAST. A double asterisk (**) indicates a value was obtained from HEAST 1991. RfD = reference dose; SF = slope factor; RfC = reference concentration, IUR = inhalation unit risk; NR = not reported; UR = under review; NV = non-verifiable. A blank space indicates that this item is not applicable, or that there is no entry in either IRIS or HEAST. A pound sign (#) indicates that two RfD values are available and the one for food is presented.
(5) The absorption factors were cited in the appropriate ATSDR Profiles. The tilde sign (~) indicates that ATSDR Profiles were not available and default values were used (use of default values are explained in the text).
(6) Administered Dose RfD x Oral Absorption Factor = Absorbed Dose RfD; Administered Dose SF/Oral Absorption Factor = Absorbed Dose SF.
(7) The toxicity values are for PCBs (CAS No. 1336-36-3).
(8) The slope factor (or unit risk) for this chemical was derived by multiplying the slope factor (or unit risk) for benzo(a)pyrene by a relative potency factor, as follows: benzo(a)anthracene, 0.1; chrysene, 0.001; benzo(b)fluoranthene, 0.1; benzo(k)fluoranthene, 0.01; and indeno(1,2,3-cd)pyrene, 0.1(USEPA, 1993b).

Table III.B-8
Toxicity Information for Radionuclides
OU-4, Solar Evaporation Ponds, IM/IRA
Rocky Flats Plant, Golden, CO

Material Name		CAS Number	Slope Factor (1) Ingestion (Risk/pCi)	Inhalation (Risk/pCi)	External Exposure (Risk/yr/pCi/g)	Target Organ (2)
Americium-241		14596-10-2	2.40E-10	3.20E-08	4.90E-09	lung, bone, liver, gonads
Cesium-134		013967-70-9	4.10E-11	2.80E-11	5.20E-06	lung, liver, spleen, muscle, GI
Cesium-137	(3)	010045-97-3	2.80E-11	1.90E-11	2.00E-06	lung, liver, spleen, muscle, GI
Plutonium-239		15117-48-3	2.30E-10	3.80E-08	1.70E-11	lung, bone, liver, gonads
Plutonium-240		14119-33-6	2.30E-10	3.80E-08	2.70E-11	lung, bone, liver, gonads
Radium-226	(3)	013982-63-3	1.20E-10	3.00E-09	6.00E-06	lung, bone, GI
Strontium-89		14158-27-1	3.00E-12	2.90E-12	4.70E-10	lung, bone, GI
Strontium-90	(3)	10098-97-2	3.60E-11	6.20E-11	nr	lung, bone, GI
Tritium		10028-17-8	5.40E-14	7.80E-14	nr	all soft tissue
Uranium-233		13968-55-3	1.60E-11	2.70E-08	4.20E-11	lung, bone, liver, kidney
Uranium-234		13966-29-5	1.60E-11	2.60E-08	3.00E-11	lung, bone, liver, kidney
Uranium-235	(4)	15117-96-1	1.10E-10	6.10E-08	2.70E-07	lung, bone, liver, kidney
Uranium-238	(4)	07440-61-1	2.10E-11	2.40E-08	5.90E-06	lung, bone, liver, kidney

(1) USEPA classifies all radionuclides as Group A (known human) carcinogens.
All toxicity factors were obtained from HEAST (USEPA, 1993a).
(2) Sources: The Health Physics and Radiological Health Handbook (Scinta, Inc., 1992).
(3) Cesium-137, radium-226, and strontium-90 slope factors include progeny because they are in equilibrium with their progeny.
(4) Uranium-235 and uranium-238 slope factors include the progeny that would be in equilibrium within 1000 years of generation.
The uranium-238 slope factor does not include uranium-234 because it is addressed as a separate isotope.

APPENDIX III.C

CHEMICAL PROFILES FOR

POTENTIAL CONTAMINANTS OF CONCERN

ACETONE

CAS NUMBER

67-64-1

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: Miscible [1]
Vapor Pressure: 231 mm Hg at 25°C [1]
Henry's Law Constant: 3.67 x 10^{-5} atm-m^3/mole [1]
Specific Gravity: 0.788 at 25/25°C [2]
Organic Carbon Partition Coefficient: 0.28 [3]

FATE DATA: HALF-LIVES

Soil: 1 - 7 days [4]
Air: 11.6 - 116 days [4]
Surface Water: 1 - 7 days [4]
Groundwater: 2 - 14 days [4]

NATURAL SOURCES

Plants, animals, automobile exhaust, volcanoes, forest fires [1].

ARTIFICIAL SOURCES

Chemical industry, wood pulping, air pollution breakdown product, wood-burning fireplaces, tobacco smoke [1].

FATE AND TRANSPORT

Acetone evaporates rapidly from solid surfaces, but the miscibility of it retards losses from water. It is highly mobile in the soil/groundwater system, and that which does not volatilize from soil, will be readily dispersed in groundwater and carried to any downgradient discharge zones. Biodegradation occurs in soil, surface water, and groundwater. Adsorption to sediment and bioconcentration should not be significant. Acetone will be washed out of the atmosphere with rain [1,3,4].

HUMAN TOXICITY

General. Acetone acts primarily as an irritant and as a central nervous system depressant. Acetone is not considered to be mutagenic. The USEPA has placed acetone in weight-of-evidence cancer Group D,indicating that it is not classifiable as to human carcinogenicity [5].

Oral Exposure. A chronic chronic oral RfD of 0.1 mg/kg/day is based on a NOEL of 100 mg/kg/day for increased liver and kidney weights and nephrotoxicity in a subchronic oral study in rats [5]. Acetone is readily absorbed following oral exposure. Oral LD_{50} values in animals ranged from 3000 to 9750 mg/kg [3]. Fatal oral doses in humans have not been reported, but oral exposure to 200 ml (2860 mg/kg/day) acetone has resulted in gastroenteritis, narcosis and possible renal injury [3]. Information regarding the effects of acetone on human development are not available, but limited data in animals indicate that acetone is not a developmental toxicant [3]. There is no information regarding the carcinogenicity of acetone in humans or animals following oral exposure, therefore, an oral Slope Factor is not available [5,6].

Inhalation Exposure. A chronic inhalation RfC is not available for acetone [5,6]. Acetone is readily absorbed following inhalation exposure. Reported acute inhalation LC_{50} values are 110,000 mg/m^3 for 62 minutes in mice, and 50,100 mg/m^3 for 8 hours in rats [3]. Inhaled acetone has not been reported to be fatal to humans. Human exposure to concentrations of 250 to 1000 ppm acetone has resulted in irritation of the eyes, nose and throat. Exposure to higher levels may result in depression of the central nervous system and narcosis [3]. Long-term inhalation of acetone by humans has resulted in hyperemia (increase in blood) in the conjunctiva and pharynx), lung irritation, rough breathing, dizziness, headaches, insomnia and stomach pain [3]. Information regarding the effects of acetone on human development are not available, but limited data in animals indicate that acetone is not a developmental toxicant [3]. There is no information regarding the carcinogenicity of acetone in humans or animals following inhalation exposure, therefore, an inhalation Unit Risk factor is not available [5,6].

Dermal Exposure. An acute dermal LD_{50} value of 20,000 mg/kg has been reported in rabbits [3]. Dermal exposure to acetone has not been reported to be fatal to humans. Short-term (90 minutes) application of acetone to the skin of humans has resulted in mild edema and hyperemia of the skin [3]. Animal studies indicate that chronic dermal application of acetone may result in reversible cataracts in guinea pigs, but not rabbits [3].

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AMERICIUM-241

CAS NUMBER

14596-10-2

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Metal [1]

PHYSICAL AND CHEMICAL DATA

Water Solubility: Trivalent americium is most common in aqueous solution [1]
Vapor Pressure: Not Applicable
Specific Gravity: ND [3]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Americium is a silvery metal that does not occur naturally in soils and rocks [1]. Americium has four oxidation states: Am (III), Am (IV), Am (V) and AM (VI) with the most stable being Am (III).

NATURAL SOURCES

Americium is a completely man-made element [1]. However, americium is a transplutonium radionuclide that is produced by the decay of Pu-241 [1,2].

ARTIFICIAL SOURCES

The first isotope was prepared in 1944 by bombardment of Pu-234 with alpha particles. It is also formed spontaneously by the beta-decay of Pu-241 [1].

FATE DATA: HALF-LIVES

Am-241: 4.32×10^2 years [3]

FATE AND TRANSPORT

Americium is a transplutonium radionuclide that has become of intensified interest along with plutonium. This interest is related to the increased use of Pu-238 as a fuel and in breeder reactor systems. Americium as well as other transplutonium radionuclides (i.e., curium) are believed to have fate and toxicities similar to

plutonium [2]. Americium, however, tends to be more mobile than plutonium in soils. Am-241 is generally used as a diagnostic aid in bone mineral analysis and as a radiation source [4].

TOXICITY

General. Toxicity data for americium (as well as other transplutonium radionuclides, such as curium) are limited. The available data, however, suggest a qualitative similarity to the toxicity of plutonium [2]. Routes of exposure to americium are ingestion of contaminated foods and water and the inhalation of contaminated particulate matter. Health effects of plutonium that may be related to the health effects from americium exposure may include, but are not limited to, radiation pneumonitis, pulmonary fibrosis, pulmonary neoplasia, bronchioloalveolar carcinomas, osteosarcomas, and liver cancer [2]. Additonal signs and symptoms include loss of appetite, nausea and vomiting, diarrhea, fever, with possible suppression or failure of critical body functions. Nonstochastic effects may also apply. USEPA classifies all radionuclides as Group A carcinogens. This classification is based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiation-induced cancers in humans [3].

Oral Exposure. USEPA derived a cancer slope factor of 2.4×10^{-10} (risk/pCi) for the ingestion of Am-241 [3].

Inhalation Exposure. Am-241 will be cleared from the lungs in a matter of weeks [3]. Research has shown that inhaled americium, however, appears more soluble than inhaled plutonium and is rapidly translocated to the target organs of the liver, kidneys, and skeleton. Other critical body organs affected include the GI tract and lower large intestine [1,2]. Americium, following inhalation exposure, will be solubilized and translocated to the liver and skeleton where it will be strongly retained, similar to plutonium [2]. A slope factor of 3.2×10^{-8} (risk/pCi) was derived for inhalation exposure to Am-241 [3].

Dermal Exposure. Information was not available regarding the effects of americium following dermal contact.

External Exposure. A slope factor of 4.9×10^{-9} (risk/yr per pCi/g soil) was derived for external exposure to Am-241 [3].

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BARIUM

CAS NUMBER

7440-39-3

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: decomposes [1]
Vapor Pressure: insignificant at 25°C [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 3.51 at 20/20°C [1]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Barium is a naturally-occurring element. The concentration of barium in minimally disturbed soils varies tremendously. A collection of 1,319 soil samples from across the conterminous U.S. determined that 86 percent were less than or equal to 700 ppm, with a geometric mean of 440 ppm, but with a maximum value as high as 3,000 ppm. Of fifteen samples collected around Ohio, 80 percent were found to contain barium at concentrations less than or equal to 500 ppm, with a maximum value between 500 and 700 ppm [2].

FATE AND TRANSPORT

Barium is a highly reactive metal that occurs naturally only in the combined state. Most barium released to the environment from industrial sources is in forms that do not become widely dispersed. In the atmosphere, barium is likely to be present in the particulate form. Environmental fate processes may transform one barium compound to another; however, barium itself is not degraded. It is removed from the atmosphere primarily by wet or dry deposition [1].

In aquatic media, barium is likely to precipitate out of solution as an insoluble salt, or adsorb to suspended particulate matter. Sedimentation of suspended solids removes a large portion of the barium from surface waters. Barium in sediments is

found largely in the form of barium sulfate. Bioconcentration in freshwater aquatic organisms is minimal [1].

Barium in soil may either be taken up to a small extent by vegetation, or transported through soil with precipitation. Barium is not very mobile in most soil systems. The higher the level of organic matter, the greater the adsorption. The presence of calcium carbonate will also limit mobility. Mobility is increased in the presence of high chloride concentrations. Barium complexes with fatty acids, for example, in acidic landfill leachate, will be much more mobile [1].

HUMAN TOXICITY

General. The primary target of barium toxicity is the cardiovascular system [1]. Information regarding the genotoxicity of barium are equivocal. Barium has not been place in a weight-of-evidence cancer group by the USEPA [3].

Oral Exposure. A chronic oral RfD of 0.07 mg Ba/kg/day is based on a NOAEL of 0.21 mg Ba/kg/day for increased blood pressure in a long-term drinking water study in humans [3]. Barium is poorly absorbed following oral exposure (about 5%) [1]. In rats, acute oral LD_{50} values range from 132 to 277 mg/kg [1]. In humans, ingestion of very large amounts of barium (doses not reported) over a short period may cause paralysis or death. Ingestion of lower doses of barium over a short period may result in difficulties in breathing, increased blood pressure, changes in heart rhythm, stomach irritation, minor changes in blood, muscle weakness, changes in nerve reflexes, swelling of the brain, and damage to the liver, kidney, heart, and spleen [1]. Studies in animals report effects similar to those found in humans. Barium sulfate is sometimes given orally or rectally for the purpose of making X rays. This has not been shown to be harmful [1]. There is no evidence that oral exposure to barium affects human reproduction or development and developmental and reproduction studies in animals are inconclusive [1]. Barium has not been shown to cause cancer in humans or animals following oral exposure, therefore, an oral slope factor is not available [1,3].

Inhalation Exposure. A chronic inhalation RfC of 0.0005 mg/m^3 is based on a NOEL of 0.8 mg/m^3 for fetotoxicity in rats [4]. Approximately 65% of an inhaled concentration of barium is absorbed following inhalation exposure [1]. Barium has not been reported to be fatal to humans or animals following inhalation exposure [1]. Studies examining the toxicity of inhaled barium in humans and animals are extremely limited but suggest that exposure results in effects on the respiratory, cardiovascular, and gastrointestinal systems [1]. There is no evidence that inhaled barium affects human reproduction or development, but studies in animals suggest

that barium may have adverse effects on these processes [1]. Barium is not known to cause cancer in humans or animals following inhalation exposure, therefore, an inhalation unit risk is not available [1,3].

Dermal Exposure. Dermal exposure to barium has not been reported to be fatal in humans or animals. Limited animal studies indicate that barium is a dermal and ocular irritant, but the results of this study are inconclusive [1].

ECOLOGICAL TOXICITY

General. Barium compounds are generally insoluble making them relatively unavailable for biological uptake [5]. All water- or acid-soluble barium compounds are poisonous. Barium is considered a nonessential element for plants and animals.

Vegetation. There are very few reports of barium toxicity to plants, except under conditions of acidic soils or with highly concentrated soil solutions where the bioavailable fractions are excessive (e.g., 2 mg/L soluble barium). Some authors report that concentrations of barium need to be extreme before toxicity occurs. Barium accumulation in plants is unusual except when the barium concentration exceeds calcium and magnesium concentrations in the soil, a condition which may occur when sulfate is depleted [6].

Aquatic Life. Barium ions in general are rapidly precipitated or removed from solution by chemical bonding, adsorption, and sedimentation. In most natural water, there is sufficient sulfate or carbonate to precipitate soluble barium present in the water, converting it to an insoluble nontoxic compound [6]. Experimental data indicate that soluble barium concentrations would have to exceed 50,000 μg/L before toxic effects to aquatic life might be observed [5]. Other data show the concentrations of barium lethal to half the test population of fish range from 150 to 10,000 mg/L [7]. Because barium represents little hazard under natural conditions, there are no federal or Ohio aquatic life water quality standards [8,9].

Wildlife. Soluble barium compounds such as barium chloride, barium carbonate, barium sulfide, and barium oxide are highly toxic to animals when ingested [10], although it is unlikely that suitable conditions would exist under natural conditions to accommodate exposure to these compounds. No reports of barium toxicity to wildlife under natural conditions were identified.

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BERYLLIUM

CAS NUMBER

7440-41-7

COMMON SYNONYMS

Glucinium.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: Insignificant at 25°C [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 1.848 20/4°C [2]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATION

Beryllium is a naturally-occurring elemtn. The concentration of beryllium in minimally disturbed soils varies tremendously. A collection of 1303 soil samples from across the counterminous U.S. determined that 86 percent were less than 2 ppm, with a geometric mean of 0.63 ppm and a maximum value of 15 ppm. Sixteen soils samples were gathered in (or on a shared border of) Ohio; ten of these samples showed concentrations <1 ppm, four showed concentrations from 1.0 ppm to <2.0 ppm, and two showed concentrations exceeding 2.0 ppm (no data on maximum value within Ohio) [3].

FATE AND TRANSPORT

Pure beryllium is a gray metal, resistant to attack by acids (due to formation of a thin oxide film). In nature, beryllium is present in much greater concentrations in soils and sediments than in water. Beryllium is tightly adsorbed to most types of soils because it displaces divalent cations that share common sorption sites. Consequently, beryllium has limited mobility in soil and is not likely to leach to groundwater. Beryllium will not volatilize from water or soil. In water, beryllium compounds may hydrolyze to form other beryllium compounds. In air, beryllium will probably be in the form of beryllium oxide. It is not known if beryllium will be transformed to more soluble compounds,

which will be removed via precipitation. Bioconcentration of beryllium in aquatic organisms will not be significant [1].

HUMAN TOXICITY

General. The major target of beryllium toxicity is the respiratory system [1]. Information regarding the mutagenicity of beryllium are mixed. Beryllium has been placed in weight-of-evidence Group B2, indicating that it is a probable human carcinogen [4].

Oral Exposure. A chronic oral RfD of 0.005 mg Be/kg/day is based on a NOAEL of 0.54 mg Be/kg/day for no adverse effects in a chronic oral study in rats [4]. Beryllium is poorly absorbed following oral exposure. Information regarding the effects of oral exposure in humans are not available and animal studies are limited. Acute oral LD_{50} values in rodents ranged from 18 to 200 mg Be/kg/day [1]. Rats fed a diet containing high levels of beryllium (>10 mg Be/kg/day) developed rickets. When the diet is deficient in calcium, beryllium will substitute for calcium in the bone, resulting in rickets; it is not known if this effect will occur in humans [1]. Information regarding the potential effects of ingested beryllium on reproduction and development in humans and animals are not available. There is no evidence that ingested beryllium causes cancer in humans, but animal studies suggest that beryllium may be carcinogenic following oral exposure [1]. An oral Slope Factor of 4.3 $(mg/kg/day)^{-1}$ has been derived based on an increase in the incidence of gross tumors at various sites in rats [4].

Inhalation Exposure. An inhalation RfC for beryllium is not available [4,5]. Beryllium is absorbed following inhalation exposure, but the extent of absorption is not known. Acute, 4-hour inhalation LC_{50} values in animals were 0.15 to 0.86 mg/m^3 in rats and 4.02 mg/m^3 in guinea pigs [1]. Occupational exposure of humans to beryllium dusts, including both inhalation and dermal exposure, is the primary route of beryllium exposure. The respiratory system is the target of beryllium toxicity following both acute and chronic exposure. Short-term exposure results a condition called chemical pneumonitis, which is characterized by cough, a burning in the chest, shortness of breath, anorexia and increasing fatigue. These effects are associated with concentrations > 0.1 mg Be/m^3 [1]. Chronic exposure to beryllium results in a condition known as berylliosis, or chronic beryllium disease, which is characterized by the presence of granulomas, fibrosis and emphysema in the lungs. Berylliosis has been found to occur at concentrations > 0.001 mg/m^3 [1]. The chemical pneumonitis occurs primarily with exposure to soluble beryllium compounds, while the berylliosis results primarily from exposure to insoluble beryllium compounds. Both conditions may be fatal. Effects on the heart, liver and kidney may also occur, but are probably secondary

to the respiratory effects. There is no evidence that inhaled beryllium will cause developmental effects in humans, but studies in animals indicate that intratracheal exposure to beryllium may result in developmental effects [1]. Lung cancer has also been found in occupationally exposed workers [1]. An inhalation Unit Risk of 0.0024 $(ug/m^3)^{-1}$ has been derived based on an increase in the incidence of lung tumors in humans [4].

Dermal Exposure. Dermal exposure to beryllium has not been reported to be fatal to humans or animals. Dermal exposure to beryllium may result in allergic reactions in both humans and animals [1]. Skin granulomas (non-cancerous growths) may form on the skin of sensitized individuals [1].

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BIS(2-ETHYLHEXYL)PHTHALATE

CAS NUMBER

117-81-7

COMMON SYNONYMS

1,2-Benzenedicarboxylic acid bis(2-ethylhexyl)ester; di(2-ethylhexyl) phthalate; dioctylphthalate.

ANALYTICAL CLASSIFICATION

Semi-volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 0.3 mg/L at 25°C [1]
Vapor Pressure: 6.45 x 10^{-6} mm Hg at 25°C [1]
Henry's Law Constant: 1.1 x 10^{-5} atm-m^3/mole [1]
Specific Gravity: 0.99 at 20/20°C [2]
Organic Carbon Partition Coefficient: 10,000 - 100,000 [1]

FATE DATA: HALF-LIVES

Soil: 5 - 23 days [3]
Air: 2.9 - 29 hours [3]
Surface Water: 5 - 23 days [3]
Groundwater: 10 - 389 days [3]

NATURAL SOURCES

Possible product of animal and/or plant life.

ARTIFICIAL SOURCES

Plasticizer for polyvinylchloride and other polymers; disposal/incineration of plastic(s)/polymer(s) [1].

FATE AND TRANSPORT

Bis(2-ethylhexyl)phthalate (hereafter, BEHP) has a strong tendency to adsorb to soils and sediments, suggesting low likelihood of leaching to groundwaters. Given the very low vapor pressure and Henry's Law constant of BEHP, volatilization from soils and waters is very unlikely. This compound does show a tendency to bioconcentrate in aquatic organisms. Hydrolysis (from aquatic systems), photolysis (in the water and atmosphere), and photo-oxidation (in atmospheric systems) are not predicted to be

important removal processes. In aquatic environments, aerobic biodegradation occurs rapidly following acclimation; no anaerobic biodegradation occurs. Some slight biodegradation in soils is expected. In the atmosphere, the primary removal mechanism is via rainfall washout [1].

HUMAN TOXICITY

General. There is currently no evidence that BEHP causes adverse effects in humans, but animal studies indicate that the liver, kidneys and testes are targets of oral exposure [4]. Information regarding the genotoxicity of BEHP are equivocal but indicate that BEHP may act as a co-carcinogen in rodents [4]. The USEPA has placed BEHP in weight-of-evidence cancer Group B2, indicating that it is a probable human carcinogen [5].

Oral Exposure. A chronic oral RfD of 0.02 mg/kg/day is based on a LOAEL of 19 mg/kg/day for increased relative liver weight in a chronic oral study in guinea pigs [5]. BEHP is readily absorbed following oral exposure. Acute oral LD_{50} values of 30,600 mg/kg and 33,900 mg/kg have been defined for rats and rabbits, respectively [4]. BEHP has not been found to be fatal to humans at doses up to 143 mg/kg; mild abdominal pain and diarrhea were the only effects reported at this dose [4]. Oral studies in animals reported effects on the liver (morphological changes, nodules, tumors), kidneys (effects on kidney cells), thyroid and pancreas (changes in the acinar cells of both organs), and testes (atrophy and degeneration). Animal studies indicated that monkeys are less susceptible to the toxic effects of BEHP than are mice and rats [4]. The relative susceptibility of humans is not known. Effects on fetal development (reduced survival, malformations) were reported in rodents following oral exposure [4]. There is no evidence that BEHP causes cancer in humans, but studies in animals suggest that oral exposure results in liver cancer [4]. An oral slope factor of 0.014 $(mg/kg/day)^{-1}$ is based on the incidence of liver tumors in mice [5].

Inhalation Exposure. An inhalation RfC is not available for BEHP [5]. Information regarding the toxicity of inhaled BEHP in humans are not available and data in animals are limited to one developmental study [4]. In the developmental study, no adverse effects were reported in rats following exposure to up to 300 mg/m^3 during gestation [4]. There is no evidence that inhaled BEHP causes cancer in humans or animals, therefore, an inhalation unit risk for cancer is not available for BEHP [5].

Dermal Exposure. An acute dermal LD_{50} value of 24,750 mg/kg was reported for rabbits [4]. Dermal exposure of both humans and animals indicate that BEHP is neither an irritant nor a sensitizer [4].

ECOLOGICAL TOXICITY

General. Bis(2-ethylhexyl)phthalate (BEHP) is the most well studied of the phthalate esters. Most information reported in the technical literature dealt with phthalate esters as a group. Autian [6] suggests there is evidence phthalate esters are degraded by microbiota and metabolized by fish and animals. As a result, phthalate esters are not likely to biomagnify. According to Arthur D. Little, Inc. [7], phthalate esters readily complex with natural organic substances (e.g., fulvic acid) to form complexes which are very soluble in water. BEHP is nonvolatile, strongly adsorbed, and has a high potential for bioaccumulation.

Vegetation. Review of the technical literature did not produce information regarding the phytotoxic effects of BEHP.

Aquatic Life. Bioconcentration factors (BCFs) for fish and aquatic invertebrates range from 54 to 2,680. Fathead minnows accumulated levels of BEHP 1,380 times the water concentration of 2.5 μg/L after 28 days. Residue half-life was 7 days. Invertebrates accumulated BEHP up to 13,400 times when exposed to water concentrations ranging from 0.08 to 0.3 μg/L. Over 90 percent of the residues were lost within 10 days [8]. The 96-hour LC_{50} of bluegill is more than 770,000 μg/L [9]. The LC_{50} of *Daphnia magna* exposed to BEHP was 11,000 μg/L. There are no USEPA acute or chronic aquatic life criteria for BEHP [10]. The Ohio aquatic life chronic water quality criterion is 8.4 μg/L in warmwater and modified warmwater habitats [11].

Wildlife. The only information available on wildlife toxicity to BEHP concerns laboratory animals. The oral LD_{50} values for rats is 31,000 mg/kg, 30,000 mg/kg, for mice, and 34,000 mg/kg for rabbit [12].

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2-BUTANONE

CAS NUMBER

78-93-3

COMMON SYNONYMS

Methyl ethyl ketone, MEK.

ANALYTICAL CLASSIFICATION

Volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 239,000 mg/L [1]
Vapor Pressure: 90.6 mm Hg at 25°C [1]
Henry's Law Constant: 1.05×10^{-5} atm-m^3/mole [1]
Specific Gravity: 0.805 at 20/4°C [2]
Organic Carbon Partition Coefficient: 34 [1]

FATE DATA: HALF-LIVES

Soil: 1 to 7 days [3]
Air: 2.7 to 26.7 days [3]
Surface Water: 1 to 7 days [3]
Groundwater: 2 to 14 days [3]

NATURAL SOURCES

Volcanoes, forest fires, products of biological degradation, food [1].

ARTIFICIAL SOURCES

Chemical industry, coatings industry, manufacturing, combustion of gasoline, cigarette smoke. Present in smog as the result of natural photooxidation of olefinic hydrocarbons from automobiles and other sources [1].

FATE AND TRANSPORT

Some of the MEK released to soil will partially evaporate into the atmosphere, while some may leach to groundwater, where it may slowly biodegrade. It does not strongly adsorb to soils and sediments. If released to surface water, it will be lost slowly to evaporation or slowly biodegraded. It does not significantly

bioconcentrate in aquatic organisms. It photodegrades in the atmosphere at a moderate rate, but may be removed by rainfall first [1].

HUMAN TOXICITY

General. MEK is considered to be of low toxicity. Moderate air concentrations of MEK may cause mild irritation of the nose, throat, eyes, and skin in humans. Serious health effects in animals have been observed only at very high concentrations [4]. The USEPA has placed MEK in weight-of-evidence Group D; that is, it is not classifiable as to human carcinogenicity [5].

Oral Exposure. The chronic RfD of 0.6 mg/kg/day is based on a NOAEL of 1771 mg/kg/day for decreased fetal birth weight in a multigeneration/developmental study in rats [5]. MEK is rapidly absorbed following oral exposure. The oral LD_{50} reported for rats was 2,737 mg/kg. Exposure of rats to 1,080 mg/kg caused minor kidney damage. A clinical report of human ingestion of an unknown quantity of MEK indicated some cardiopulmonary distress, but resulted in full recovery within less than a week [4].

Inhalation Exposure. The chronic RfC of 1 mg/m^3 is based on a NOAEL of 2978 mg/m^3 for decreased fetal birth weight in a developmental study in mice [5]. MEK is well absorbed during inhalation exposure. Uptake by humans ranged from 41% to 53% of the inspired quantity. The 4-hour LC_{50} in rats was 11,700 ppm. No rats died within 14 days of exposure to 92,239 ppm for 0.5 hours. Guinea pigs exposed to 10,000 ppm became unconscious within 5 hours. No information was found regarding human deaths following exposure to MEK. Humans exposed to 100 ppm MEK complained of slight nose and throat irritation which became objectionable at 300 ppm. Exposure of pregnant rats to 3,000 ppm during gestation resulted in only a slight increase in the number of malformed fetuses [4].

Dermal Exposure. No information was located regarding the rate or extent of absorption following dermal exposure in humans or animals. The dermal LD_{50} for MEK in rabbits was reported to be 10 mL/kg. Application of 0.1 ml MEK to the forearms of humans once daily for 18 days produced no adverse effects. Application of MEK to rabbits and guinea pigs caused minimal skin irritation, erythema, and/or increase in skin-fold thickness. MEK was found to be moderately irritating to the eyes of rabbits [4].

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CADMIUM

CAS NUMBER

7440-43-9

COMMON SYNONYMS

None noted.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: Neglibible [2]
Henry's Law Constant: ND
Specific Gravity: 8.65 at 25/4°C [1]
Organic Carbon Partition Coefficient: ND

BACKGROUND CONCENTRATIONS

Pure cadmium is a silver-white, blue-tinged, lustrous metal with a distorted hexagonal close-packed structure; cadmium is easily cut with a knife. Cadmium can be found in zinc ores, as greenockite (CdS), and as otavite ($CdCO_3$). The estimated occurrence of cadmium in the earth's crust is from 0.1 to 0.2 ppm [1]. No data on cadmium was gathered as part of the 1984 Department of the Interior survey of conterminous United States soils [3].

FATE AND TRANSPORT

Elemental cadmium is insoluble in water [1], while cadmium compounds show varying degrees of solubility depending on the nature of the compounds and the aquatic environment [2]. Cadmium in the environment may be found as cadmium salts, hydrated cations, or organic/inorganic cadmium complexes. As hydrated cations or complexes, cadmium may be considered fairly mobile in water (relative to other heavy metals). Cadmium in soils may leach into water, especially under acidic conditions. It does not volatilize from either waters or soils, but does exhibit a tendency to adsorb strongly to clays, muds, and humic/organic materials in soils and waters. Complexation and sorbing with organic materials are the most important factors in aquatic fate and transport. The evidence indicates that cadmium bioconcentrates in all levels of the food chain. Cadmium accumulation has been reported in many animal and plant

species. Reported BCFs range from 113 to 18,000 for invertebrates, and from 3 to 2,213 for fish. The pH and humus content of the water affect bioconcentration [2].

HUMAN TOXICITY

General. Breathing air with very high levels of cadmium severely damages the lungs and can cause death. High cadmium levels in the diet severely irritate the digestive tract, while lower levels consumed over a long period of time may cause kidney damage [2]. The USEPA has placed cadmium in weight-of-evidence Group B1, indicating that it is a probable human carcinogen [4].

Oral Exposure. A chronic oral RfD of 0.0005 mg/kg/day for water is based on a NOAEL of 0.005 mg/kg/day for proteinuria following chronic exposures in humans. A chronic oral RfD of 0.001 mg/kg/day for food is based on a NOAEL of 0.01 mg/kg/day for proteinuria following chronic exposures in humans [4]. It is estimated that humans absorb about 5 percent of ingested cadmium [2]. In rats and mice the acute oral LD_{50} values range from about 100 to 300 mg/kg. Two human deaths due to intentional ingestion of cadmium resulted from doses of 25 and 1,500 mg/kg [4]. Symptoms of acute toxic reaction to ingestion may include gastroenteritis, vomiting, diarrhea, abdominal pain, increased salivation, choking, anemia, hypotension, respiratory arrest, pulmonary edema, renal dysfunction, and death. Chronic oral overexposure symptoms may include renal dysfunction and/or failure, as well as anemia [1,2,5]. Cadmium has been implicated as a fetotoxin by the oral route in animal studies [2].

Inhalation Exposure. The USEPA does not currently provide an inhalation RfC for cadmium [4,6]. It is estimated that humans rapidly absorb about 25 percent of inhaled cadmium. The 15-minute LC_{50} for rats exposed to cadmium oxide fumes is approximately 33 mg/m^3. It has been estimated that exposure to 1 mg/m^3 for 8 hours might be sufficient to cause death in humans [2]. Symptoms associated with acute cadmium poisoning via inhalation may include fever, headache, dyspnea, pleuritic chest pain, conjuctivitis, rhinitis, sore throat, cough, pulmonary edema, extreme restlessness, respiratory failure, and death. Chronic inhalation overexposure symptoms may include renal dysfunction and/or failure, dyspnea, emphysema, bronchitis, and anemia [1,2,5]. Cadmium has been implicated as a developmental toxin by the inhalation route in animal studies [2]. An inhalation unit risk of 0.0018 $(ug/m^3)^{-1}$ is based on excess lung cancers observed in humans [4].

Dermal Exposure. Cadmium is poorly absorbed through the skin [2]. No other useful information regarding dermal exposure to cadmium was located.

ECOLOGICAL TOXICITY

General. Cadmium is considered nonessential for plants and animals. It is relatively mobile in the environment compared to most other heavy metals. Cadmium occurs naturally in close association with zinc, usually in concentrations directly related to zinc levels [7]. Its cumulative nature in organisms and its high toxicity makes it an extremely dangerous poison for most animals. Cadmium is accumulated through the food chain in sufficient quantities to be harmful to higher trophic levels. However, no evidence was found of biomagnification of this element through trophic levels [8].

Vegetation. The soil chemistry of bioavailable cadmium is controlled by pH. Brooks [9] reported that the general toxicity of cadmium to plants was moderate. Cadmium is usually more available in acidic, sandy soils than in neutral or alkaline soils with large amounts of clay and organic matter [7]. Absorption is strongly pH-dependent, increasing as conditions become more alkaline. It has been suggested that there is a 100-fold increase in cadmium absorption for each unit increase in pH [10]. Plants tissues normally contain <0.5 ppm cadmium, but many species may accumulate much higher concentrations (up to several hundred ppm) when they grow in soil with elevated cadmium concentrations. Cadmium levels in plant tissues may subsequently affect the balance of essential elements in the plant [7]. It has been noted that 3 mg/kg of cadmium in the tissues of plants depressed growth [11]. Tall fescue (*Festuca arundinacea*) had a reduced yield of 50 percent with a soil concentration of 320 mg/kg [10].

Aquatic Life. In aquatic systems, water hardness affects the biological toxicity of cadmium. The uptake of cadmium is faster in hard water than in soft water, but the total concentration of cadmium is greater in soft water [12]. Cadmium uptakes also increase with increasing water temperature and decreasing salinity [8]. The environmental mobility of cadmium is influenced by the pH levels in the water. Cadmium is less mobile in alkaline waters than in acid waters because it becomes chemically bound in alkaline waters [13]. Cadmium can be quite toxic to aquatic organisms, even in concentrations of less than 1 ppm [10]. Fish are quite susceptible to acute toxicity, with reported 4-day LC_{50} values ranging from 0.002 to 2.9 mg/L [8]. Cadmium has been reported to accumulate in the tissues of aquatic organisms at concentrations hundreds to thousands of times higher than in the water [12]. The federal chronic freshwater quality criterion for cadmium is 3.37 μg/L based on water hardness of 400 mg/L $CaCo_3$ [14].

Wildlife. Cadmium has been shown to have a toxic effect on a variety of mammals and birds. Mammals have no effective mechanism for the elimination of ingested cadmium; therefore, the cadmium tends to accumulate in the liver and kidneys. Its relative

toxicity to mammals has been rated from moderate to high [15]. Toxic effects include decreased growth rates, anemia, infertility, fetus abnormalities, abortion, kidney disease, intestinal disease, and hypertension [11]. The known effects for mallards are all sublethal, primarily affecting the kidneys, testes, and egg production [8]. In mallards chronically dosed with cadmium contaminated food, significant effects on energy metabolism were found at 450 mg/kg, but not at 150 mg/kg [11]. In general, cadmium levels in excess of 20 ppm may reduce reproductive output of nesting waterfowl. More direct effects on individual mallards may occur as cadmium levels approach 200 ppm [8].

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CESIUM

CAS NUMBER

Cs-134: 13967-70-9
Cs-137: 10045-97-3

COMMON SYNONYMS

None

ANALYTICAL CLASSIFICATION

Radionuclide/Alkali metal [1,3]

PHYSICAL AND CHEMICAL DATA

Water Solubility: reacts with water to form hydroxide with evolution of hydrogen, which ignites spontaneously [1]
Vapor Pressure: 1 mm Hg @ 279°C [2]
Specific Gravity: 1.873 @ 20°C [2]
Organic Carbon Partition Coefficient: ND

BACKGROUND CONCENTRATIONS

Cesium is a naturally occurring, silvery-white radioactive alkali metal that is found in the earth's crust at a concentration of one ppm [1]. Cs-133 is the only natural isotope of cesium. Artificial isotopes of cesium include Cs-123, 125-132 and 134-144 [1].

NATURAL SOURCES

Cesium occurs in nature in the aluminosilicates, pollucite (a hydrated silicate of aluminium and cesium) and lepidolite, and in the borate, rhodizite [1].

ARTIFICIAL SOURCES

Cesium is generally used in photoelectric cells and as a "getter" in vacuum tubes [1]. Cesium-137 is an important constituent of radioactive fallout. Cs-137 is also used as an encapsulated energy source [1].

FATE DATA: HALF-LIVES

Cs-134: 2.06 years [3]
Cs-137: 30.2 years [3]

FATE AND TRANSPORT

Cesium is an analog of potassium, indicating that it is widespread in all environmental media. Cs-137 is an important part of radioactive fallout. Cs-137 decays to and reaches the radioactive equilibrium with its daughter product, barium-137 [1].

TOXICITY

General. Cesium can be harmful because it acts as an analog of potassium. After exposure, cesium is distributed throughout the body, resulting in body-wide energy deposition. Cesium, acting similarly to potassium, will be rapidly absorbed into the bloodstream and distributed throughout the tissues of the body [1,4]. Health effects resulting from cesium-134 exposure include acute radiation poisoning and cancer. Acute radiation syndrome, characterized by effects on the nervous system, gastrointestinal system and hematopoietic system, occurs following whole body irradiation with high doses of radiation. At very high doses (over 5000 rads), effects on the nervous system include vomiting and drowsiness, tremors, ataxia, convulsions and death within 24 to 72 hours. Effects on the gastrointestinal system, including ulceration and hemorrhage, occur maximally 3 to 5 days after exposure to doses in the range of 600 to 2000 rads. Effects on the hematopoietic system, primarily leukopenia, occur within 48 hours of exposure to 200 to 1000 rads [5].

USEPA classifies all radionuclides as Group A carcinogens. This classification is based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiation-induced cancers in humans [3].

Exposure to cesium may occur following radioactive fallout: individuals may be exposed to cesium deposited on the ground, taken up by vegetation and directly deposited on vegetation [4]. Because cesium is a metabolic analog of potassium, it is rapidly distributed throughout the entire body [1].

Oral Exposure. Cesium should be is fairly rapidly absorbed through the gastrointestinal tract, given that it is an analog of potassium. The following oral slope factors were derived by USEPA for cesium isotopes: 4.1×10^{-11} (risk/pCi) for Cs-134 and 2.8×10^{-11} (risk/pCi) for Cs-137 [3].

Inhalation Exposure. Cesium isotopes will be cleared from the lungs in a matter of days [3]. The following inhalation slope factors were derived by USEPA for cesium isotopes: 2.8×10^{-11} (risk/pCi) for Cs-134 and 1.9×10^{-11} (risk/pCi) for Cs-137 [3].

Dermal Exposure. Information regarding potential effects following dermal contact with cesium were not located.

External Exposure. The following slope factors were derived by USEPA for external exposure to cesium isotopes: 5.2×10^{-6} (risk/yr per pCi/gm soil) for Cs-134 and 0.0 (risk/yr per pCi/gm) for Cs-137 [3].

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CHLOROFORM

CAS NUMBER

67-66-3

COMMON SYNONYMS

Trichloromethane

ANALYTICAL CLASSIFICATION

Volatile (organic).

PHYSICAL AND CHEMICAL DATA

Water Solubility: 7,950 mg/L [1]
Vapor Pressure: 246 mm Hg at 25°C [1]
Henry's Law Constant: 4.35×10^{-3} atm-m^3/mole [1]
Specific Gravity: 1.484 at 20/20°C [2]
Organic Carbon Partition Coefficient: < 34 [1]

FATE DATA: HALF-LIVES

Soil: 1 to 6 months [3]
Air: 26 to 260 days [3]
Surface Water: 1 to 6 months [3]
Groundwater: 2 months to 5 years [3]

NATURAL SOURCES

Plants [1].

ARTIFICIAL SOURCES

Chemical industry, chlorination of drinking water, municipal sewage, power plants, auto exhaust, dry cleaning industry, fumigation, manufacturing [1].

FATE AND TRANSPORT

The majority of chloroform released to the environment ends up in the atmosphere, where it may be transported long distances. It is not adsorbed significantly on soils or sediment. Chloroform in soils will leach to groundwater, where it may remain for long periods of time or until discharged. Since it is substantially denser than water, when it occurs as a separate phase it tends to sink to the bottom of the aquifer. Releases to surface soils and water will be dissipated primarily by evaporation. It is

subject to significant biodegradation. It is not expected to bioconcentrate in aquatic organisms [1].

HUMAN TOXICITY

General. Chloroform exerts adverse effects on the central nervous system, liver, and kidneys. It was used as a surgical anesthetic for many years before its harmful effects on the liver and kidney were recognized. High doses of chloroform have also been found to cause liver and kidney cancer in experimental animals [4]. The USEPA has placed chloroform in weight-of-evidence Group B2, indicating that it is a probable human carcinogen [5].

Oral Exposure. A chronic oral RfD of 0.01 mg/kg/day is based on a LOAEL of 12.9 mg/kg/day determined for fatty cyst formation following chronic administration to dogs [5]. Chloroform is readily absorbed following oral exposure, with up to 100% of an administered dose being absorbed by humans. Acute oral LD_{50} values in rats range from 446 to 2,180 mg/kg. Reported fatal oral doses for humans ranged from 212 to 3,755 mg/kg. Long-term exposure by ingestion can adversely affect liver and kidney function. Toxic effects may include jaundice and burning urination. Decreased fetal weight was observed in the offspring of pregnant rats receiving 400 mg/kg/day by gavage. Gonadal atrophy was observed in both sexes of rats treated by gavage at a rate of 410 mg/kg/day [4]. An oral slope factor of 6.1×10^{-3} $(mg/kg/day)^{-1}$ is based on kidney tumors observed in rats following exposure to treated drinking water [5].

Inhalation Exposure. An inhalation RfC for chloroform is currently under review by the USEPA RfD/RfC Work Group [6]. Chloroform is readily absorbed following inhalation exposure. An LC_{50} of 9,770 ppm was reported for female rats exposed for 4 hours. Breathing air concentrations of 10,000 to 22,500 ppm for less than 30 minutes did not result in increased mortality in human surgical patients. A concentration of about 40,000 ppm for a few minutes may be sufficient to cause death in humans. Deaths resulting from the use of chloroform as a surgical anesthetic were due to acute hepatotoxicity. Short-term inhalation of high concentrations causes tiredness, dizziness, and headache. Long-term exposure by inhalation can adversely affect liver and kidney function. Toxic effects may include jaundice and burning urination. Chloroform has been shown to be fetotoxic and teratogenic in experimental animals. Adverse reproductive effects in male and female rodents have also been reported [4]. An inhalation unit risk of 2.3×10^{-5} $(\mu g/m^3)^{-1}$ is based on hepatocellular carcinomas observed in female mice following gavage administration [5].

Dermal Exposure. Chloroform is readily absorbed following dermal exposure. No deaths or hepatic effects were observed in rabbits when 3,980 mg/kg was applied to the belly for 24 hours. However, adverse effects to the skin and kidney in rabbits were noted following 24-hour exposure to 1,000 mg/kg [4].

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CYANIDE

CAS NUMBER

57-12-5

COMMON SYNONYMS

None noted.

ANALYTICAL CLASSIFICATION

Inorganic (wet chemistry).

PHYSICAL AND CHEMICAL DATA

Note: Data is for hydrogen cyanide (HCN).

Water Solubility: miscible [1]
Vapor Pressure: 264.3 mm Hg at)°C [1]
Henry's Law Constant: 5.1 x 10^{-2} atm-m^3/mole [1]
Specific Gravity: 0.6884 at 20°C (liquid) [1]
Organic Carbon Partition Coefficient: ND

FATE DATA: HALF-LIVES

Soil: ND
Air: ND
Surface Water: ND
Groundwater: ND

NATURAL SOURCES

Fruits, roots, and leaves of numerous plants [1].

ARTIFICIAL SOURCES

Vermicidal fumigants; insecticides; rodenticides; metal polishes; electroplating solutions; metallurgical processes [1,2].

FATE AND TRANSPORT

Cyanides may be found in the environment bound with organic and/or inorganic cations. The fate and transport of cyanide, therefore, is dependent upon the properties of the cyanide-bound material. Any discussion attempting to encompass all properties of cyanide-bound materials is beyond the scope of this assessment.

Cyanides may occur in soils as hydrogen cyanide, alkali metal salts, or immobile metallocyanide complexes. The fate of cyanides in soil will be largely dependent upon pH conditions of that soil. Volatilization of hydrogen cyanide from surface soils is expected to be a primary removal mechanism for soils having a pH of 9.2 or less. Though cyanide typically does not sorb strongly to soils (or organic matter therein), leaching to unprotected groundwaters is not expected to be significant due to the probability of cyanide fixation by trace metals found in soils, or transformation of cyanide via microbial action. However, if the initial cyanide loading proves toxic to soil-based microorganisms, leaching to groundwater may be expected. In water, cyanide occurs most commonly in the form of hydrogen cyanide. Hydrogen cyanide is removed from water primarily by volatilization. The rate of volatilization is also pH-dependent, with more rapid volatilization occurring at lower pH values [1].

Although simple metal cyanides and hydrogen cyanide are not expected to bioconcentrate in aquatic organisms, concentrations of simple metal cyanides have been detected in the tissues of fish exposed to waters containing silver and copper metal complexes. There is, as well, no evidence of biomagnification through trophic levels. Adsorption to suspended solids and sediments in waters will occur, but is expected to be a minor pathway in comparison to volatilization and biodegradation. [1]

Atmospheric concentrations of cyanide will exist almost exclusively as hydrogen cyanide, though small amounts of metal cyanides may exist associated with particulate matter. Given the relatively slow degradation rate of hydrogen cyanide in the atmosphere, this material has the potential to be transported for long distances. The most important removal mechanism for hydrogen cyanide in the atmosphere is via reaction with photochemically-produced hydroxyl radicals. Removal of hydrogen cyanide via either dry or wet deposition is expected to be a negligible mechanism. Metal cyanides (as particulates) will, however, be subject to deposition via gravitational settling and/or rainfall washout. [1]

HUMAN TOXICITY

General. Cyanide is highly toxic to humans following all routes of exposure. Cyanide acts by inhibiting enzymes that are needed to use oxygen efficiently, resulting in respiratory arrest. The major targets of cyanide toxicity are the central nervous system, the lungs and the heart [1]. Cyanide is not mutagenic and has been placed in weight-of-evidence cancer Group D, indicating that it is not classifiable as to human carcinogenicity [3].

Oral Exposure. A chronic oral RfD of 0.02 mg/kg/day is based on the NOAEL of 10.8 mg/kg/day for weight loss, thyroid effects and nervous system effects in a chronic study in rats [3]. Cyanide is readily absorbed following oral exposure. Acute oral LD_{50} values ranged from 2.7 to 11 mg/kg in rats, 2.34 to 2.70 mg/kg in rabbits and 4.3 mg/kg in mice [1,2]. In humans, an average fatal dose of 1.52 mg/kg has been calculated based on case reports of intentional or accidental poisonings. The lowest reported fatal dose in humans was 0.56 mg/kg [1]. Acute oral poisoning results in effects on the gastrointestinal system (vomiting), the heart (atrial fibrillation, shallow pulse, inaudible heart sounds), kidneys (increased protein output) and nervous system (tremors, stupor, coma). These effects have occurred at doses above 15 mg/kg [1]. Similar effects have been found in animals. Information regarding potential effects of cyanide on reproduction and development in humans are not available, but studies in animals indicate that effects on development may result following oral exposure [1]. Cyanide is not known to cause cancer in humans or animals following any route of exposure, therefore, an oral slope factor is not available [3].

Inhalation Exposure. A chronic inhalation RfC is not available for cyanide [3]. Cyanide is readily absorbed following inhalation exposure. Acute inhalation LC_{50} values vary according to duration of exposure: in rats, values ranged from 3,417 ppm (10 seconds) to 142 ppm (60 minutes), and in rabbits, values ranged from 2,200 ppm (45 seconds) to 208 ppm (35 minutes) [1]. In humans, an average fatal concentration is estimated to be 546 ppm for a 10-minute exposure. Exposure to 110 to 135 ppm for greater than an hour can be life-threatening, while exposure to 18-36 ppm for the same time period may not cause any effects [1]. Acute exposures to approximately 6 ppm and above may result in effects on the respiratory system (dyspnea, nasal irritation), cardiovascular system (chest pain, heart palpitations), gastrointestinal system (abdominal pain, nausea, vomiting), and nervous system (lightheadedness, breathlessness, numbness, headaches, and, at higher concentrations, coma). Chronic inhalation exposure of workers to comparable concentrations results in effects similar to those reported following acute exposure. Information regarding the potential effects of cyanide on reproduction and development are not available in humans or animals [1]. Cyanide is not known to cause cancer in humans or animals following any route of exposure, therefore, an inhalation unit risk is not available [3].

Dermal Exposure. The average fatal dose of cyanide in humans following dermal exposure was estimated to be 100 mg/kg [1]. Acute dermal LD_{50} values in rabbits

ranged from 1.0 to 8.93 mg/kg [1]. Toxic effects observed following dermal exposure are similar to those following other routes of exposure [1].

ECOLOGICAL TOXICITY

General. Cyanide is a highly lethal, but short-lived noncumulative poison. No evidence was found of either cyanide bioaccumulation or biomagnification [4]. Hydrogen cyanide is the most common and the most toxic of the cyanides. The environmental chemistry of cyanide is complex, with cyanide gas (HCN) and ionic cyanide (CN^-) representing the toxic chemical forms.

Vegetation. Cyanide seldom remains biologically available in soils because it is either complexed by trace metals, metabolized by various microorganisms, or lost through volatilization. In plants, elevated cyanide concentrations inhibit respiration [5]. Some plant species, such as arrowgrass (*Triglochin* sp.) wind wild cherry (*Prunus*), are natural producers of cyano compounds and will have inherent high concentrations of these compounds in their tissues.

Aquatic. Cyanide in aquatic systems exists as simple hydrocyanic acid; as water-soluble alkali metal salts, such as potassium cyanide and sodium cyanide; and as metallocyanide complexes of variable stability [4]. Cyanide toxicity increases with decreasing pH and dissolved oxygen. Cyanide concentrations in the range from 50 to 100 μg/L have proven to eventually fatal to many sensitive fishes and levels above 200 μg/L probably are rapidly fatal to most fish species [6].

The 96-hour LC_{50} of cyanide for bluegill was 56.0 to 227.0 μg/L and the maximum toxicant concentration was 9.3 to 19.8 μg/L [5]. The 96-hour LC_{50} of cyanide for juvenile and adult fathead minnows was 117.0 to 157.0 μg/L and 121.0 to 129.0 μg/L, respectively [7]. During chronic exposure, cyanide inhibited spawning in bluegill at 5.0 μg/L and reduced growth rate in fathead minnows at 35.0 μg/L [5]. The federal chronic freshwater quality criterion for cyanide is 5.2 μg/L [8]. The Ohio aquatic life habitat and water supply standard for cyanide is 12.0 μg/L for warmwater and modified warmwater habitats [9].

Wildlife. Cyanide is acutely toxic to birds and mammals in very small concentrations. Cyanide biomagnification in the food chain has not been reported, possibly due to rapid detoxification of sublethal doses by most species, and death at higher doses [5]. In mallards, a single oral dose of cyanide of 0.53 mg/kg body weight produced no deaths, but an LC_{50} result was produced at 1.43 mg/kg body weight [5]). In rabbits, a single oral dose of 10.0 to 15.0 mg/kg body wight produced a 100 percent kill in 14 to 30 minutes [5].

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LITHIUM

CAS NUMBER

7439-93-2

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Metal

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble
Vapor Pressure: 1 mm Hg at 723°C [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 0.534 g/cm^3 at 20°C [1]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Lithium is a naturally-occurring earth metal. The total amount of strontium in the earth's crust is estimated to be 0.005% by weight [1]. The concentration of lithium in minimally disturbed soils varies tremendously. A collection of 1258 soil samples from across the conterminous U.S. determined that 85 percent were less than or equal to 30 ppm, with a geometric mean of 20 ppm and a maximum value of 150 ppm [2].

NATURAL SOURCES

Lithium is a silvery-white metal with a body-centered cubic structure. Lithium tarnishes to grayish-white on exposure to air and becomes yellowish when exposed to moist air [1]. The following minerals contain 3-10% Li_2O: spodumene, lepidolite, petalite, amblygonite and triphylite [1].

ARTIFICIAL SOURCES

Lithium is used in the manufacture of alloys, especially lithium-hardened bearing metals, as a "getter" in vacuum tubes, in making catalysts for the polyolefin plastics industry, and in fuels for aircrafts and missiles. Lithium salts are used in porcelain enamels, in air conditioning and for making multi-purpose greases [3].

FATE AND TRANSPORT

In the environment, lithium is primarily found in the following minerals: spodumene, lepidolite, petalite, amblygonite and triphylite [1]. Lithium has been reported to occur in low concentrations in the hydrosphere (11 ppm in sea water) and in certain mineral waters. Information regarding the fate and transport of lithium compounds in the environment were not located.

HUMAN TOXICITY

General. Lithium becomes caustic when in contact with moisture. Consequently, skin and eye burns may result from direct contact and skin, eye and mucous membrane irritation may result from fumes [1]. The primary targets of lithium toxicity are the respiratory system skin and eyes, although significant neurological effects (muscular twitches, mental confusion, blurred vision, EKG changes, hypotension, lethargy, slurred speech, coma) [1,4]. Therapeutic levels are considered to be blood concentrations of 0.6 to 1.2 mEq/L. Mild to moderate toxic effects may occur at 1.5 to 2.5 mEq/L while severe toxic effects may occur at 2.5 to 3 mEq/L [1]. Levels greater than 3 or 4 mEq/L are considered to be fatal, especially in patients on chronic lithium therapy [1]. The USEPA has not placed lithium in a weight-of-evidence cancer group [5,6].

Oral Exposure. A chronic oral RfD is not available for lithium [5,6]. Ingestion of lithium causes burns in the gastrointestinal tract as well as nausea, vomiting and diarrhea [1].

Inhalation Exposure. A chronic inhalation RfC is not available for lithium [5,6]. Inhalation of lithium results in irritation and burning of the mucous membranes of the respiratory system [1].

Dermal Exposure. Direct contact with lithium results in burns to the eyes and skin [1].

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MANGANESE

CAS NUMBER

7439-96-5

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: decomposes [1]
Vapor Pressure: insignificant at 25°C [1]
Henry's Law Constant: Not Applicable [1]
Specific Gravity: 7.20 at 20/4°C [1]
Organic Carbon Partition Coefficient: Not Applicable [1]

BACKGROUND CONCENTRATIONS

Manganese is a naturally-occurring element. The concentration of manganese in minimally disturbed soils varies tremendously. A collection of 1,317 soil samples from across the conterminous U.S. determined that 89 percent were less than or equal to 700 ppm, with a geometric mean of 330 ppm, but with a maximum value as high as 7,000 ppm. Of fifteen samples collected around Ohio, 80 percent were found to contain manganese at concentrations less than or equal to 700 ppm, with a maximum value between 1,000 and 7,000 ppm [2].

FATE AND TRANSPORT

Environmental fate processes may transform one manganese compound to another; however, manganese itself is not degraded. Elemental manganese and inorganic manganese compounds may exist in air as suspended particulate matter. Such particles are removed from the atmosphere primarily by dry deposition, and, to a lesser extent, by washout. In water, the metal may exist in any of four oxidation states (2+, 3+, 4+, or 7+). Mn(+2) predominates in most waters, and usually combines with carbonate to form a compound of low solubility. In extremely reduced water, poorly soluble sulfides are formed. Manganese is often transported in rivers as suspended sediments. Manganese in water may be significantly

bioconcentrated at lower trophic levels. Bioconcentration may not be significant in predatory fish; thus biomagnification may not be significant [1].

Adsorption of manganese to soils may be highly variable, increasing with higher organic content and anion-exchange capacity. At low concentrations, manganese may be "fixed" by clays, and will not be readily released into solution. At higher concentrations, it may be desorbed by ion exchange. For example, the discharge of waste water into estuarine environments resulted in the mobilization of manganese from the bottom sediments. Also, microorganisms may increase the mobility of manganese under some circumstances [1].

HUMAN TOXICITY

General. The only adverse health effect identified following exposure to high levels of manganese is a condition known as "manganism," which results in psychomotor disturbances. Manganese in small amounts is believed to be an essential nutrient for humans [1]. The USEPA has placed manganese in weight-of-evidence Group D; that is, it is not classifiable as to human carcinogenicity [3].

Oral Exposure. The chronic RfD for the manganese ranges from 0.005 mg/kg/day for the ingestion of manganese in water to 0.14 mg/kg/day for the ingestion of manganese in food [3]. Both RfDs are based on a NOAEL for central nervous system effects determined from human chronic ingestion data [3]. The amount of manganese absorbed from the gastrointestinal tract typically averages 3 to 5%. Most animal studies indicate that manganese compounds have low acute oral toxicity. A NOAEL of 2,300 mg/kg/day in food for 6 months was determined for mice. On the other hand, single doses of highly concentrated solutions of various manganese compounds delivered to rats by gavage produced LD_{50} values ranging from 410 to 820 mg manganese/kg/day. Thus it was concluded that high doses delivered by gavage did not yield a model relevant for normal environmental exposure. Evidence for the onset of manganism in humans following oral exposure is inconclusive. In animals, changes in the brain have been observed following very high oral exposure [1].

Inhalation Exposure. An RfC of 0.00005 $\mu g/m^3$ is based on a LOAEL of 0.15 mg/m^3 for impairment of neurobehavioral function in occupationally exposed workers [3]. The rate and extent of absorption of manganese following inhalation is unknown. A significant fraction of inhaled manganese-containing particles are carried via mucociliary transport to the gastrointestinal tract. Exposure of humans to high levels of manganese dust in air for a prolonged period of time (1 month to several years) may cause mental and emotional disturbances, and the impairment of

locomotion and dexterity, a condition known as manganism. However, this condition has only been documented for workers in mines and foundries. Manganism occurs because excessive manganese injures a part of the brain that helps control body movements. Some of the symptoms of manganism can be reduced by medical treatment, but the brain injury is permanent [1].

Dermal Exposure. No information was located on the dermal absorption of manganese or adverse health effects resulting therefrom. It is reasonable to assume that intake via this pathway under normal circumstances is minimal.

ECOLOGICAL TOXICITY

General. Manganese is an essential trace element or micronutrient for plants and animals. Manganese does not occur naturally as a metal, but is found in various salts and minerals, frequently in association with iron compounds [4]. Manganese readily bioaccumulates in plants and animals, but does not biomagnify in food chains.

Vegetation. At pH values of 5.0 or less, manganese is rendered very soluble and excessive accumulation in plants can result. At pH values of 8.0 or above, precipitation results in the removal of bioavailable manganese from the soil [5].

Wetland plants, such as cattails, tend to maintain higher tissue concentrations of manganese than upland plants, probably because of greater availability of soluble manganese in wet soils or sediments [6]. Cattails can take up 779 mg/kg dry weight without injury [4]. Plants having more than 400 to 3,000 mg/kg of manganese (dry weight) in their tissues may exhibit toxic symptoms depending on the plant species [6]. Manganese toxicity in young plants is indicated by brown spotting on leaves [5]. Vegetation phytotoxic concentrations in soils and sediments are species specific and range widely.

Aquatic Life. Manganese ions are rarely found at concentrations above 1 mg/L, so manganese is not considered to be a problem in freshwater [7]. Manganese is toxic to fish in concentrations ranging from 1.5 to 1000 mg/L. Most toxic thresholds for fish are probably less than 50 mg/L [4]. Toxicity of manganese increases with decreasing pH [8]. Manganese has been shown to bioaccumulate in freshwater invertebrates [4]. There are no USEPA or OEPA aquatic life water quality standards [9,10].

Wildlife. The divalent form of manganese has a low order of toxicity to biota, especially to vertebrate animals. The hexavalent form is highly toxic, but does not occur in nature. Toxic concentrations of divalent manganese is reported in the diets

of the following species: birds, 4,800 ppm; rats greater than 2,000 ppm; and rabbits 1,250 to 6,000 ppm. Toxic levels of manganese in mammals can cause decreased feed intake, decrease growth, reduced hemoglobin, and even death [11]. Growing rats have had dietary intake as high as 1,000 to 2,000 mg/kg with no apparent ill effects [6]. Maximum tolerable levels of manganese recommended by the National Academy of Sciences was 15 mg/kg body weight for sheep and cattle, 16 mg/kg body weight for swine, and 250 mg/kg body weight for poultry [11].

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MERCURY

CAS NUMBER

7439-97-6

COMMON SYNONYMS

Hydragyrum; quicksilver

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 0.56 mg/L [1]
Vapor Pressure: 2 x 10^{-3} mm Hg at 25°C [2]
Henry's Law Constant: ND
Specific Gravity: 13.534 at 25/4°C [2]
Organic Carbon Partition Coefficient: ND

BACKGROUND CONCENTRATIONS

Mercury is a naturally-occurring element. Elemental mercury is a silver-white, heavy, mobile, liquid metal exhibiting slight volatility at room temperature [2]. Concentrations of mercury at sampling points across the contiguous United States exhibit a limited, but varied range. A total of 1,267 soils samples were gathered by the United States Geological Survey for mercury concentration analysis. Of this total, 1,263 samples exhibited some concentration of mercury across a range of <0.01 ppm to a maximum of 4.6 ppm. Fourteen percent of the total samples gathered showed a mercury concentration of from less than 0.01 ppm up to 0.002 ppm; 16 percent showed concentrations between 0.002 ppm and 0.032 ppm, 33 percent between 0.032 and 0.051, 24 percent between 0.051 and 0.13, and 13 percent showed concentrations of mercury to be from 0.13 ppm up to a maximum value of 4.6 ppm; geometric mean concentration of mercury was 0.058 ppm. Fifteen soils samples were gathered in (or on a shared border of) Ohio. Of these samples, one showed a mercury concentration of between 0.02 and 0.032 ppm, two showed concentrations between 0.032 and 0.051, eight between 0.051 and 0.13, and four had mercury concentrations at values between 0.13 ppm up to 4.6 ppm (no data on Ohio maximum concentration) [3].

FATE AND TRANSPORT

Mercury may exist as one of three forms: elemental mercury, inorganic mercury, and organic mercury. Elemental mercury will combine with sulfur at ordinary temperatures, and react with nitric acid and/or ammonia solutions in air (to form Hg_2NOH); it does not react with hydrochloric acid, sulfuric acid (when cold), or alkalies. Mercurous salt will be slowly degraded by sunlight [2]. Inorganic mercury compounds generally dissociate into the mercuric form (Hg^{2+}) rather than the mercurous form (Hg^{+}). Organic mercury compounds are generally divided into two broad classes: alkyl mercury (e.g., monomethyl mercury) and phenyl mercury (e.g., phenylmercury acetate). Organic mercury compounds are more easily absorbed than elemental and/or inorganic forms, but will readily undergo biodegradation with the ultimate release of inorganic mercury. Organomercury compounds, especially alkyl mercury compounds, are viewed as posing the greatest toxicological danger [4]. Given their high specific gravity/density values, elemental and inorganic mercury compounds are generally susceptible to gravitational deposition in sediments of aqueous environments. Given the relative values of water solubility and vapor pressure, mercury should be expected to be a fairly mobile material. Mercury entering surface waters can be microbially converted to methylmercuric ion given favorable conditions. Methylmercury accumulates in carnivorous fish to levels 10,000 times those concentrations found in the ambient water [1].

HUMAN TOXICITY

General. Long-term exposure to either organic or inorganic mercury can permanently damage the brain, kidneys, and developing fetuses. Short-term exposure can also have adverse health effects, but full recovery is more likely. Methylmercury is a potent neurotoxin [1]. The USEPA has placed inorganic mercury in weight-of-evidence Group D, indicating that it is not classifiable as to human carcinogenicity [5].

Oral Exposure. The chronic RfD of 0.0003 mg/kg/day is based on kidney effects observed following oral administration in the rat [6]. Oral absorption of metallic mercury by humans has been estimated to be approximately 0.10%. Organic forms of mercury are readily absorbed by humans and animals via the oral route. For example, in one study approximately 95% of methylmercuric nitrate was absorbed. The oral LD_{50} for $HgCl_2$ ranged from 35 to 105 mg/kg in rats. The lethal dose of $HgCl_2$ in adult humans has been estimated to range from 10 to 42 mg/kg. Signs of acute mercury toxicity in humans and animals include gastrointestinal lesions and renal involvement. Death is usually caused by shock, cardiovascular collapse, acute renal failure, and severe gastrointestinal damage. A number of human deaths have resulted from organic mercury ingestion; the lethal dose is estimated to range between 10 and 60 mg/kg. A

neurological syndrome in humans following the consumption of methylmercury-contaminated fish has been characterized by many symptoms including tingling in the extremities, impaired vision, hearing, taste, and smell, incoordination, weakness, slurred speech, irritability, memory loss, depression, and insomnia. Pregnant women who have ingested organic mercury have given birth to infants with severe brain damage. The evidence that the brain damage was caused by organic mercury is very strong [1].

Inhalation Exposure. The RfC of 0.0003 mg/m^3 is based on a NOAEL of 0.009 mg/m^3 determined for humans exposed by inhalation [6]. Metallic mercury diffuses rapidly across lung membranes into the blood. Studies have shown that about 74 to 80% of inhaled elemental mercury vapor is retained in human tissues. Exposure to a metallic mercury vapor concentration of 28.8 mg/m^3 for 1 to 30 hours reportedly caused death in rabbits. In humans, death reportedly occurred following exposure to about 1.1 mg/m^3 diethylmercury vapor for 4 to 5 months. Symptoms of exposure to metallic mercury vapor in humans include chest pains, dyspnea, cough, hemoptysis, impairment of pulmonary function, tremors, insomnia, decreased motor function, headaches, decreased libido, and irritability. Some kidney damage in humans may occur at vapor concentrations of elemental mercury of 0.1 mg/m^3. Inorganic mercury vapor has been reported to cause menstrual disturbances and spontaneous abortions in women, and congenital malformations and resorptions in the offspring of exposed female rats [1].

Dermal Exposure. Both inorganic and organic forms of mercury are absorbed by the skin, although the extent of absorption was not reported. Children exposed to inorganic mercury salts dermally, exhibited the following symptoms: tremor of face or extremities, sudden jerky movements, a lack of muscle tone, impaired reflexes, seizures, light sensitivity, deafness, insomnia, and irritability. Symptoms in an adult human exposed dermally to metallic mercury were reported to include headache, tinnitus, and vertigo [1].

ECOLOGICAL TOXICITY

General. Biologically, mercury is considered nonessential and nonbeneficial for plants and animals. It is a highly toxic element that can both bioaccumulate in biota and readily biomagnify through biological food chains, increasing by a factor of three to five at each higher trophic level [7]. Organic forms of mercury such as methylmercury and dimethylmercury are readily bioavailable; are produced by anaerobic bacteria in aquatic sediments; and are more toxic than inorganic mercury. Substantial environmental research has been conducted for this metal.

Vegetation. Mercury is not readily taken up by plants. Most higher vascular plants are resistant to mercury poisoning, although they may accumulate it to a limited degree [8].

Symptoms of toxicity include stunting of seedling growth and root development, and an inhibition of photosynthesis causing yield reduction [9]. Mercury concentrations in plant leaves range from 0.001 to 0.01 ppm [10]. The phytotoxic concentration of mercury in the soil was reported to be greater than 10 ppm [10]. Phytotoxic levels reported from four studies range from 0.3 to 5 mg/kg (soil dry weight) [9].

Aquatic Life. The most serious mercury contamination in the aquatic food chain occurs with methyl mercury. Methylmercury is very soluble in water, which means it is readily accumulated by aquatic organisms. Freshwater plants appear to be less sensitive than freshwater fish or invertebrates to methyl mercury. Bioaccumulation of mercury was markedly enhanced at elevated water temperatures, reduced water salinity or hardness, reduced water pH, increased age of the organism, and reduced organic matter content of the medium; in the presence of zinc, cadmium, or selenium in the solution; and after increased duration of exposure [11]. Mercury toxicity varies among species, with concentrations in water of 0.1 to 2.0 μg/L fatal to sensitive aquatic species and concentrations of 0.03 to 0.1 μg/L associated with significant sublethal effects [11]. Spawning in fathead minnows was inhibited by 0.00012 mg/L mercury, and the entire test population was killed by 0.0008 mg/L in 3 months [7]. Other studies with the same species, however, found only detrimental effects at 0.12 mg/L and no toxic effects at 0.07 mg/L [7]. Fish toxicity from mercury ranges from 30 μg/L (guppy) to 1,000 μg/L (*Mozambique tilapia*) [9]. In fish, the biological half-life of mercury is between 1 and 3 years [7]. Bioconcentration factors range from 5,000 for mercury to 4,000 to 85,000 for methylmercury [9]. For aquatic life protection, mercury water levels should not exceed 0.012 μg/L (4-day average) or 2.4 μg/L on an hourly average [11]. The federal chronic freshwater quality criterion for mercury is 0.012 μg/L [12]. The Ohio chronic aquatic life habitat and water supply standard for mercury is 0.2 μg/L for warmwater and modified warm water habitat [13].

Wildlife. Mercury in birds and mammals can adversely affect reproduction, growth and development, behavior, blood chemistry, coordination, vision, hearing, and metabolism [9]. Environmental concentrations of 0.1 ppm or greater would have significant detrimental effects on waterfowl population dynamics [7]. Intensive studies have been conducted on mallards. Studies of over three generations of mallards have shown that methylmercury fed in concentrations as low as 0.5 ppm resulted in reduced reproductive output and altered behavior in young ducklings. This concentration is calculated to be equivalent to 0.1 ppm in a wild diet [7]. Acute oral LD_{50} based on tests with five other bird species ranged from 2.2 to 37.8 mg/kg for methylmercury and 11.5 to 75.5 mg/kg for ethylmercury. The LD_{50} in mule deer for organomercury is 17.88 mg/kg [9]. Bowen [14] reported that a dietary intake of 800 ppm mercury (as HG^{+2}) was lethal to

rats (study duration not provided). The biological half-life for mercury is 20 to 70 days in most species. The biological half-life of methylmercury in mammals is 70 to 80 days [7].

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METHYLENE CHLORIDE

CAS NUMBER

75-09-2

COMMON SYNONYMS

Dichloromethane [1]

ANALYTICAL CLASSIFICATION

Volatile Organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 13,000 mg/L at 25°C [1]
Vapor Pressure: 434.9 mm Hg at 25°C [1]
Henry's Law Constant: 2.68 x 10^{-3} atm-m^3/mole [1]
Specific Gravity: 1.3255 at 20/4°C [2]
Organic Carbon Partition Coefficient: 47.86 [1]

FATE DATA: HALF-LIVES

Soil: 1 - 4 weeks [3]
Air: 19.1 - 191 days [3]
Surface Water: 1 - 4 weeks [3]
Groundwater: 2 - 8 weeks [3]

NATURAL SOURCES

None noted [1].

ARTIFICIAL SOURCES

Aerosol propellant; paint remover; metal degreaser; urethane foam blowing agent; paint/ink industries; aluminum forming; coal mining; photographic equipment; pharmaceutical, organic chemicals/plastics, and rubber processing industries; foundries; and laundries [1,2].

FATE AND TRANSPORT

Methylene chloride released to soil will evaporate quickly from near-surface soils, given its high vapor pressure. That which does not volatilize can be expected to leach through soils to groundwater not protected by a confining layer. Under normal environmental conditions, hydrolysis in soils and/or groundwaters is not predicted. Aerobic biodegredation of methylene chloride is reported to be complete (within 6 hours to 7

days), and anaerobic biodegradation will proceed after a variable-length acclimation period. The primary removal process of methylene chloride from surface waters is volatilization. Biodegredation of methylene chloride is possible in natural waters, but will be a slow process relative to volatilization. Hydrolysis in surface waters, under normal environmental conditions, is not to be expected. The greater portion of atmospheric methylene chloride will degrade by reaction with hydroxyl radicals; photolysis is not expected. A small portion of the methylene chloride will diffuse to the stratosphere and will subsequently undergo rapid photolytic degradation and reaction with chlorine radicals. The moderate solubility of methylene chloride suggests the probability of atmospheric washout via rainfall.

Given its low, estimated bioconcentration factor of 5 (calculated from the octanol/water partition coefficient [1]), methylene chloride is not expected to bioconcentrate in aquatic biota.

HUMAN TOXICITY

General. The major targets of methylene chloride toxicity are the central nervous system, the liver and the kidneys [4]. Information regarding the mutagenicity of methylene chloride are equivocal. The USEPA has placed methylene chloride in weight-of-evidence cancer Class B2, indicating that it is a probable human carcinogen [5].

Oral Exposure. The chronic oral RfD of 0.06 mg/kg/day is based on a NOAEL of 6 mg/kg/day for liver toxicity in a chronic oral study in rats [5]. Methylene chloride is readily absorbed following oral exposure. An acute oral LD_{50} of 2100 mg/kg was reported for rats [4]. Human fatalities resulting from oral exposure to methylene chloride have not been reported. Limited animal data indicates that effects on the liver and kidneys occur at doses above 55 mg/kg/day [4]. There is no evidence to suggest that methylene chloride affects reproduction or development. There is no evidence that methylene chloride causes cancer in humans, but studies in animals suggest that oral exposure results in liver cancer [4]. An oral slope factor of 7.5×10^{-3} $(mg/kg/day)^{-1}$ was derived based on the incidence of liver cancer in mice [5].

Inhalation Exposure. A chronic inhalation RfC of 3 mg/m^3 is based on a NOAEL of 694.8 mg/m^3 for liver toxicity in a chronic study in rats [6]. Methylene chloride is readily absorbed following inhalation exposure. An acute LC_{50} of 16,189 ppm was reported for mice [4]. The odor threshold is approximately 200 ppm. Case studies have demonstrated that inhaled methylene chloride can be fatal to humans, but exposure levels were not reported [4]. Acute (3-4 hours) exposure to concentrations of 300 ppm or greater results in adverse effects on vision and hearing, while exposure to 800 ppm or

greater results in impairment of psychomotor performance (reaction time, hand precision, steadiness) [4]. In most cases, effects will disappear when exposure ceases. Animal studies indicate that exposure to higher concentrations (1000 ppm) results in unconsciousness or death [4]. Animal studies indicate that methylene chloride is not likely to produce adverse effects on reproduction or development in humans [4]. There is no evidence that methylene chloride causes cancer in humans, but studies in animals suggest that inhalation exposure results in liver cancer [4]. An inhalation unit risk of 4.7 x 10^{-7} $(\mu g/m^3)^{-1}$ was derived based on the incidence of liver cancer in mice [5].

Dermal Exposure. No information is available regarding the effects of dermal exposure to methylene chloride in humans. Limited animal studies report adverse effects on the eye of rabbits following exposure. The effects were reversed within a few days [4].

ECOLOGICAL TOXICITY

General. Methylene chloride is highly volatile, is weakly absorbed to soil, and has no significant potential for bioaccumulation. It is highly mobile in the soil/ground water system [7]. No information was found regarding biomagnification of methylene chloride.

Vegetation. The sorption of methylene chloride is not well documented. Transformation processes such as hydrolysis and biodegradation are not expected to be important in natural soil systems [7]. Review of the technical literature did not produce information regarding the phytotoxic effects of methylene chloride.

Aquatic Life. CH2M Hill, Inc. [8] states that acute values for fathead minnows and bluegill are 193,000 μg/L and 224,000 μg/L, respectively. The 96-hour LC_{50} of green sunfish is 550 ppm [9]. According to Arthur D. Little, Inc. [7], there is no criterion for acute toxicity in freshwater species, but the LOEL occurs at 11,000 μg/L halomethanes. There are no USEPA aquatic life water quality standards for methylene chloride [10]. The Ohio chronic water quality standard for methylene chloride is 430 μg/L in warmwater and modified warmwater habitats [11].

Wildlife. Methylene chloride is slightly toxic to mammals. CH2M Hill, Inc. [8] states the oral LD_{50} for rats is 2,136 mg/kg and for mice is 1,987 mg/kg. The lowest lethal dose for rabbits is 1,900 mg/kg. Methylene chloride has a low to moderate acute oral toxicity in lab animals. The LD_{50} value for rats and rabbits fed undiluted methylene chloride is about 2,000 mg/kg [7].

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NITRATE

CAS NUMBER

14797-55-8

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Inorganic

PHYSICAL AND CHEMICAL DATA

The following data is for sodium nitrate:

Water Solubility: 921,000 mg/L at 25°C [1]
Vapor Pressure: ND
Henry's Law Constant: ND
Specific Gravity: 2.26 [2]
Organic Carbon Partition Coefficient: ND

FATE DATA: HALF-LIVES

Soil: ND
Air: ND
Surface Water: ND
Groundwater: ND

NATURAL SOURCES

Vegetables such as beets, celery, lettuce, and spinach; mineralization of soil organic matter [3,4]

ARTIFICIAL SOURCES

Diffuse sources of nitrogen include farm fertilizer and animal wastes, lawn fertilizer, leachate from waste disposal in sanitary landfills and dumps, atmospheric sources, nitric oxide and nitrite discharges from automobile exhausts [3]

FATE AND TRANSPORT

Nitrates may be found in the environment bound with organic and/or inorganic matter. The fate and transport of nitrates, therefore, is dependent upon those

properties associated with the nitrate-bound material. Any discussion attempting to encompass all properties of nitrate-bound materials is beyond the scope of this assessment.

HUMAN TOXICITY

General: Nitrate is a normal component of the diet, with a typical daily intake of 75 mg/day (0.2-0.3 mg nitrate-nitrogen/kg/day) reported for U.S. adults [4]. Over 85% of the intake comes from the natural nitrate content of vegetables, such as beets, celery, lettuce and spinach. The primary target of nitrate toxicity is the blood, with methemoglobinemia occurring, especially in infants [4]. Nitrate is converted to nitrite, and nitrite oxidizes the Fe^{+2} form of iron in hemoglobin to the Fe^{+3} form, which renders the hemoglobin unable to transport oxygen. This condition results in reduced oxygen transport to tissues. Levels of 10% methemoglobin (MetHb) are not associated with adverse effects, but concentrations above 10% may cause cyanosis (bluish color to skin and lips). MetHb levels above 25% lead to weakness, rapid pulse and tachypnea, and levels exceeding 50-60% may be fatal [4]. Infants aged 0-3 months are most sensitive to this condition because the infant gastrointestinal system has a normally high pH which favors the growth of nitrate-reducing bacteria, and because infants have hemoglobin F, which is more susceptible to oxidation [4]. Information regarding the genotoxic potential of nitrate was not located. The USEPA has not placed nitrate in a weight-of-evidence cancer group [4].

Oral Exposure. A chronic oral RfD of 1.6 mg/kg/day is based on a NOAEL of 1.6 mg/kg/day for methemoglobinemia in infants (dose based upon the amount of nitrogen within the nitrate molecule) [4]. Nitrate is absorbed following oral exposure, but the extent of absorption is not known. The NOAEL for the methemoglobin response in infants appears to be 10 mg/L in drinking water (1.6 mg/kg/day) [4]. Information regarding other systemic effects resulting from nitrate exposure was not located. There is no evidence that ingested nitrate results in effects on reproduction or development in humans or animals. There is no information regarding the carcinogenicity of nitrate, therefore, an oral Slope Factor is not available [4,5].

Inhalation Exposure. There is no information regarding the effects of inhaled nitrate in humans or animals. Consequently, a chronic inhalation RfC and an inhalation Unit Risk for cancer are not available for nitrate [4,5].

Dermal Exposure. There is no information regarding the effects of dermal exposure to nitrate in humans or animals.

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NITRITE

CAS NUMBER

14797-65-0

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

The following information is for sodium nitrite:

Water Solubility: ND
Vapor Pressure: ND
Henry's Law Constant: ND
Specific Gravity: 2.17 [1]
Organic Carbon Partition Coefficient: ND

FATE DATA: HALF-LIVES

Soil: ND
Air: ND
Surface Water: ND
Groundwater: ND

NATURAL SOURCES

Bound to organic and/or inorganic matter in the environment

ARTIFICIAL SOURCES

Sodium nitrite used in the manufacture of diazo dyes, and in numerous processes involving the manufacture of organic chemicals; textile fabric dyeing and printing; bleaching processes of silk, flax, and linen; photography. Also used in meat curing, coloring and preserving [1]

FATE AND TRANSPORT

Nitrites may be found in the environment bound with organic and/or inorganic matter. The fate and transport of nitrites, therefore, is dependent upon those properties associated with the nitrite-bound material. Any discussion attempting to

encompass all properties of nitrite-bound materials is beyond the scope of this assessment.

HUMAN TOXICITY

General. In the gastrointestinal tract, nitrate is converted to nitrite. Nitrite oxidizes the Fe^{+2} form of iron in hemoglobin to the Fe^{+3} form, which renders the hemoglobin unable to transport oxygen. This condition results in reduced oxygen transport to tissues. Levels of 10% methemoglobin (MetHb) are not associated with adverse effects, but concentrations above 10% may cause cyanosis (bluish color to skin and lips). MetHb levels above 25% lead to weakness, rapid pulse and tachypnea, and levels exceeding 50-60% may be fatal [2]. Infants aged 0-3 months are most sensitive to this condition because the infant gastrointestinal system has a normally high pH which favors the growth of nitrate-reducing bacteria, and because infants have Hemoglobin F, which is more susceptible to oxidation [2]. Information regarding the genotoxic potential of nitrite was not located. The USEPA has not placed nitrite in a weight-of-evidence cancer group [2].

Oral Exposure. A chronic oral RfD of 0.1 mg/kg/day is based on a NOEL of 1.0 mg/kg/day for methemoglobinemia in infants [2]. Nitrite is absorbed following oral exposure, but the extent of exposure is not known. The NOAEL for the methemoglobin response in infants appears to be 10 mg/L in drinking water (1.0 mg/kg/day) [2]. Information regarding other systemic effects resulting from nitrite exposure was not located. There is no evidence that ingested nitrite results in effects on reproduction or development in humans or animals. There is no information regarding the carcinogenicity of nitrite, therefore, an oral Slope Factor is not available [2,3].

Inhalation Exposure. Information was not located regarding the toxicity of inhaled nitrite in humans or animals. Consequently, a chronic inhalation RfC and an inhalation Unit Risk are not available [2,3].

Dermal Exposure. Information was not located regarding the toxicity of dermal exposure to nitrite in humans or animals.

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POLYCYCLIC AROMATIC HYDROCARBONS

GENERAL

Polycyclic aromatic hydrocarbons (PAHs) are a large group of chemicals formed during the incomplete combustion of organic materials. There are over one hundred PAHs, and they are found throughout the environment in air, water, and soil. Seven of the 15 PAHs addressed in this profile are classified as probable human carcinogens [1,2].

CAS NUMBERS

Acenaphthene	83-32-9	Chrysene	218-01-9
Acenaphthylene	208-96-8	Dibenzo(a,h)anthracene	53-70-3
Anthracene	120-12-7	Fluoranthene	206-44-0
Benzo(a)anthracene	56-55-3	Fluorene	86-73-7
Benzo(a)pyrene	50-32-8	Indeno(1,2,3-cd)pyrene	193-39-5
Benzo(b)fluoranthene	205-99-2	Phenanthrene	85-01-8
Benzo(g,h,i)perylene	191-24-2	Pyrene	129-00-00
Benzo(k)fluoranthene	207-08-9		

COMMON SYNONYMS

Polynuclear aromatic hydrocarbons, PNAs, PAHs.

ANALYTICAL CLASSIFICATION

Semivolatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: insoluble to 3.93 mg/L [1]
Vapor Pressure: negligible to very low at 25°C [1]
Henry's Law Constant: 6.95×10^{-8} to 1.45×10^{-3} atm-m^3/mole [1]
Specific Gravity: approximately 0.9 to 1.4 at 0 to 27°C [1]
Organic Carbon Partition Coefficient (K_{oc}): 2.5×10^3 to 5.5×10^6 [1]

FATE DATA: HALF-LIVES

Soil: 12.3 days to 5.86 years [3]
Air: 0.191 hours to 2.8 days [3]
Surface Water: 0.37 hours to 1.78 years [3]
Groundwater: 24.6 days to 10.4 years [3]

NATURAL SOURCES

Volcanoes, forest fires, crude oil, and oil shale [1].

ARTIFICIAL SOURCES

Motor vehicles and other petroleum fuel engines, wood-burning stoves and fireplaces, furnaces, cigarette smoke, industrial smoke or soot, and charcoal-broiled foods [1].

FATE AND TRANSPORT

Because the physical and chemical properties of PAHs vary substantially depending on the specific compounds in question, the fate and transport characteristics vary. Thus, the following discussion is presented in very general terms. Some fate characteristics are roughly correlated with molecular weight; so the compounds are grouped as follows [1]:

- Low molecular weight: acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene;
- Medium molecular weight: fluoranthene and pyrene; and
- High molecular weight: benzo(a)anthracene, benzo(b)fluoranthene, benzo-(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo-(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

PAHs are present in the atmosphere in the gaseous phase and sorbed to particulates. They may be transported great distances, and are subject to photodegradation as well as wet or dry deposition [1].

PAHs in surface water are removed by volatilization, binding to particulates and sediments, bioaccumulation, and sorption onto aquatic biota. The low molecular weight PAHs have Henry's Law constants in the range of 10^{-3} to 10^{-5} atm-m^3/mole, and would therefore be expected to undergo significant volatilization; medium molecular weight PAHs have constants in the 10^{-6} range; and high molecular weight PAHs have constants in the range of 10^{-5} to 10^{-8}. Half-lives for volatilization of benzo(a)anthracene and benzo(a)pyrene from water have been estimated to be greater than 100 hours. It has been reported that lower molecular weight PAHs could be substantially removed by volatilization under conditions of high temperature, shallow depth, and high wind. For example, anthracene was found to have a half-life for volatilization of 18 hours in a stream with moderate current and wind. In an estuary, volatilization and adsorption are the primary removal mechanisms for medium and high molecular weight PAHs, whereas volatilization and biodegradation are the major mechanisms for low molecular weight compounds. PAHs can bioaccumulate in plants and animals, but are subject to extensive metabolism by high-trophic-level consumers, indicating that biomagnification is not significant [1].

Potential mobility in soil is related to the organic carbon partition coefficient (K_{oc}). The low molecular weight PAHs have K_{oc} values in the range of 10^3 to 10^4, which indicates a moderate potential to be adsorbed to organic material. Medium molecular weight compounds have values on the order of 10^4, while high molecular weight compounds have values in the 10^5 to 10^6 range. The latter compounds, then, have a much greater tendency to adsorb and resist movement through soil. Volatilization of the lower molecular weight compounds from soil may be substantial. However, some portion of PAHs in soil may be transported to groundwater, and then move laterally in the aquifer, depending on soil/water conditions [1].

HUMAN TOXICITY

General. Ingestion of, inhalation of, or dermal contact with PAHs by laboratory animals has been shown to produce tumors. Reports in humans show that individuals exposed by inhalation or dermal contact for long periods of time to mixtures of PAHs and other compounds can also develop cancer. However, the relationship of exposure to any individual PAH with the onset of cancer in humans is not clear [1]. The available RfDs and weight-of-evidence groups for the PAHs addressed in this profile are presented in Table 1. The available slope factors are presented below. No other toxicity values were available [2,4].

Oral Exposure. Indirect evidence suggests that benzo(a)pyrene may not be readily absorbed following oral exposure in humans. On the other hand, absorption in rats appears to be rapid and efficient. Whether or not there is actually a significant difference between humans and rats in the capacity to absorb benzo(a)pyrene is questionable. It should be noted that the degree of uptake is highly dependent on the vehicle of administration. A NOAEL of 150 mg/kg/day was determined for gastrointestinal, hepatic, and renal effects in rats following acute oral exposure to benzo(a)pyrene or benzo(a)anthracene. LOAELs in the range of 40 to 160 mg/kg/day were determined for developmental and reproductive effects in mice following acute oral exposure to benzo(a)pyrene [1]. An oral slope factor of 7.3 $(mg/kg/day)^{-1}$ for benzo(a)pyrene is based on tumors detected in the forestomachs of rats and mice in various diet studies [2].

Inhalation Exposure. The USEPA does not currently provide inhalation RfCs for any of the PAHs [2,4]. Pure PAH aerosols appear to be well absorbed from the lungs of animals. However, PAHs adsorbed to various particles appear to be poorly absorbed, if at all. The latter are most likely to be removed from the lungs by mucociliary clearance and subsequent ingestion. Lung cancer in humans has been strongly associated with long-term inhalation of coke-oven emissions, roofing-tar emissions, and cigarette smoke, all of which contain mixtures of carcinogenic PAHs. It has been estimated that

TABLE 1
SELECTED TOXICITY DATA FOR PAHS[a]

Compound	CAG Group[b]	Oral RfD (mg/kg/d)	Species	Critical Effect	Experimental Doses (mg/kg/day)	Study Type[c]
Acenaphthene	NR	0.06	Mouse	Hepatotoxicity	NOAEL: 175 LOAEL: 350	SC
Acenaphthylene	D	UR				
Anthracene	D	0.3	Mouse	None observed	NOEL: 1,000	SC
Benzo(a)anthracene	B2	NR				
Benzo(a)pyrene	B2	NR				
Benzo(b)fluoranthene	B2	NR				
Benzo(g,h,i)perylene	D	NR				
Benzo(k)fluoranthene	B2	NR				
Chrysene	B2	NR				
Dibenzo(a,h)anthracene	B2	NR				
Fluoranthene	D	0.04	Mouse	Nephropathy, increased liver wt, hematol alter	NOAEL: 125 LOAEL: 250	SC
Fluorene	D	0.04	Mouse	Decreased RBC, packed cell vol, and hemoglobin	NOAEL: 125 LOAEL: 250	SC
Indeno(1,2,3-cd)pyrene	B2	NR				
Phenanthrene	D	NR				
Pyrene	D	0.03	Mouse	Renal tubular pathology, decreased kidney weights	NOAEL: 75 LOAEL: 125	SC

a. From IRIS [2]. When IRIS values were unavailable, HEAST [4] values were used. RfD = reference dose, NR = not reported
b. CAG = USEPA Carcinogen Assessment Group. B2 = probable human carcinogen; D = not classifiable as to human carcinogenicity.
c. SC = subchronic.

the 8-hour time-weighted average exposure to PAHs in older coke plants was approximately 22 to 33 $\mu g/m^3$ [1]. An inhalation slope factor is not available for any of the PAHs [2,4].

Dermal Exposure. Limited *in vivo* evidence exists that PAHs are at least partially absorbed by human skin. An *in vitro* study with human skin indicated that 3% of an applied dose of benzo(a)pyrene was absorbed after 24 hours. Studies in mice indicated that at least 40% of an applied dose of benzo(a)pyrene was absorbed after 24 hours. The carcinogenic PAHs as a group cause various noncancerous skin disorders in humans and animals. Substances containing mixtures of PAHs have been linked to skin cancers in humans. Studies in laboratory animals have demonstrated the ability of benz(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene to induce skin tumors [1].

ECOLOGICAL TOXICITY

General. The molecular weight of the individual PAHs affects their mobility and solubility in the environment, with lower weight compounds generally being more volatile and soluble than higher weight compounds, which have strong sorption properties. In aquatic environments, PAH partitioning in sediments occurs in an equilibrium process, with a potential for localized occurrences of high levels of dissolved PAHs [5,6]. PAHs can bioaccumulate in plants and animals, but do not biomagnify in food chains. Inter- and intraspecies responses to carcinogenic PAHs are variable, and some PAHs tend to inhibit the carcinogenicity of other compounds in mammals [7]. A variety of adverse effects on aquatic and terrestrial animals has been observed.

Vegetation. Plants absorb PAHs from soils through their root systems, and can translocate them to above ground parts. Lower weight PAHs are absorbed more readily than other PAHs [7]. Airborne deposition of particulate PAHs, and the subsequent adsorption to the skins of fruits and vegetables, accounts for reported higher PAH concentrations in aboveground versus underground plant parts. Soil concentrations of benzo(a)pyrene typically may reach 1,000 mg/kg; concentrations for total PAHs typically exceed benzo(a)pyrene concentrations by at least one order of magnitude. PAH concentrations in vegetation typically range from 20 to 1,000 $\mu g/kg$ [6]. Some plants biocentrate PAHs in their oily parts (e.g., seeds) above levels in surrounding soils, but this does not appear to be typical [6]. In limited studies on PAHs in plants, phytotoxic effects were rare; photosynthetic inhibition in algae has been documented [7,6]. Some vascular plants catabolize benzo(a)pyrene [6], and PAHs synthesized by plants may act as growth hormones [7,8]. Plants may serve as a pathway for exposure of higher-order consumers to toxic levels of PAHs.

Aquatic Life. Most PAHs in aquatic environments tend to sorb to sediments, and sediment-associated PAHs have accounted for up to 77 percent of the steady-state body burden in benthic amphipods [7]. Absorption and assimilation of PAHs vary widely among species and according to the specific compound. Crustaceans and fish appear better able to assimilate, metabolize, and eliminate PAHs than do molluscs and polychaetes [7,8]. Fish appeared to detoxify benzo(a)pyrene as quickly as it was absorbed in water-only exposures [9]. Little potential for biomagnification through aquatic food chains exists, and bioconcentration factors range widely. A 2- to 3-day exposure BCF of 485 was reported for anthracene in fathead minnows, and a 24-hour BCF of 12 was reported for benzo(a)pyrene in bluegill [7].

Toxic effects of PAHs in fish include liver, thyroid, gonad, and skin tumors. Phenanthene has an LC_{50} of 370 μg/L in grass shrimp, and benz(a)anthracene has an LC_{87} of 1,000 μg/L in bluegill [7]. In the Black River, Ohio, where sediment PAH levels were 10,000 times those in a control location, brown bullheads showed elevated concentrations of lower molecular weight PAHs in their livers and a higher incidence of liver tumors [5,7,8]. Dissolved fluorene introduced into pond waters resulted in reduced growth in bluegill at 0.12 mg/L, and in increased vulnerability to predation at 1.0 mg/L [7].

There are no promulgated federal or state aquatic life water quality criteria for any of the PAHs, though the USEPA has proposed a chronic criterion of 6.3 μg/L and an acute criterion of 30 μg/L for phenanthrene in fresh waters [10,11].

Wildlife. PAH toxicity studies in animals are mostly confined to laboratory experiments. Many PAHs can produce tumors in skin and epithelia tissues in all animal species tested, with malignancies induced by microgram acute exposures. Some carcinogenic PAHs can pass across skin, lungs, intestines, and placenta in mammals. Target organs are diverse, and the tissue affected is dependent on the compound and method of exposure. For example, dietary benzo(a)pyrene caused leukemia, lung adenoma, and stomach tumors in mice. Ancillary tissue damage may accompany carcinomas [7]. Selective effects based on age and gender of the receptor have also been observed [8,12,9,13]. Mammals do not tend to accumulate PAHs, which is likely due to the rapid metabolism of these compounds. For example, the biological half-life of benzo(a)pyrene in rat blood and liver was 5 to 10 minutes [7].

There is a scarcity of data on PAHs that are not carcinogenic [14]. Many chemicals, including other PAHs, modify the carcinogenic actions of PAHs in laboratory animals. Inhibitors of PAH-induced tumors include selenium, vitamins A and E, flavones, and ascorbic acid [7]. LD_{50} values also range widely: acute oral LD_{50} values for rodents range from 50 mg/kg body weight for benzo(a)pyrene to 700 mg/kg for phenanthrene,

to 2,000 mg/kg for fluoranthene. Chronic oral carcinogenicity values for rodents include 40 mg/kg for benzo(b)fluoranthene, 72 mg/kg for benzo(k)fluoranthene, and 99 mg/kg for chrysene [7].

In a study on mallards, no mortality or visible toxic effects were observed over 7 months during which birds were fed diets containing 4,000 mg/kg PAHs, though heptatic changes were observed. Sax [9] reports that single oral doses of 250 ppm benzo(a)pyrene were not acutely toxic to ducks or chickens.

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PLUTONIUM

CAS NUMBER

Pu-239: 15117-48-3
Pu-240: 14119-33-6
Metallic: 7440-07-5

COMMON SYNONYMS

None

ANALYTICAL CLASSIFICATION

Radionuclide/Metal

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: Insignificant [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 19.84 g/cm^3 at 25°C [1]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Plutonium is a silvery-white, highly reactive, compound that exists in trace quantities of naturally occurring uranium ores.

NATURAL SOURCES

Plutonium occurs in trace quantities in naturally occurring uranium ores. It is formed by irradiation of natural uranium with the neutrons which are present [2]. Plutonium is composed of various isotopes or forms with Pu-238 and Pu-239 being the most technologically important [2].

ARTIFICIAL SOURCES

Plutonium may be released as a result of its use as a heat source and in atomic weapons and power reactors [1].

FATE DATA: HALF-LIVES

Pu-239: 2.41 x 10^4 years [2]
Pu-240: 6.57 x 10^3 years [2]

FATE AND TRANSPORT

Fifteen isotopes of plutonium are known. Half-lives for these isotopes range from 4.96 hours for Pu-243 to 82,600,000 years for Pu-244 [2]. Plutonium exists in five oxidation states in aqueous solutions: Pu (III), Pu (IV), Pu (V), Pu (VI) and Pu (VII). The most stable of these in aqueous solutions is Pu (IV).

Plutonium can form complexes with most ions commonly encountered in soils, indicating that ion exchange aids in the adsorption of plutonium to soils [3]. Adsorption of plutonium to soils is also dependent upon pH: low adsorption of plutonium was found in soils with a pH <2 and 8-13 [4].

HUMAN TOXICITY

General. Plutonium exposure results primarily in radiological effects. The radiological effects include bone necrosis, bone and lung cancer, effects on the reproductive system and effects on the developing fetus. The USEPA has not placed natural plutonium in a weight-of-evidence cancer group [5], but all radioactive chemicals are considered Group A, human carcinogens [6]. This classification is based on the fact that all radionuclides emit ionizing radiation, which has been shown to result in radiation-induced cancers in humans [6].

Oral Exposure. A chronic oral RfD is not available for plutonium [5,6]. Ingested natural plutonium has not been reported to cause cancer in humans or animals, therefore, an oral slope factor is not available [5]. An oral slope factor of 2.3×10^{-10} (risk/pCi) has been derived by USEPA for both Pu-239 and Pu-240 [6].

Inhalation Exposure. A chronic inhalation RfC is not available for plutonium [5,6]. Inhaled plutonium is expected to clear the lungs over a period of years [6]. Exposure to high concentrations of plutonium via inhalation produces effects ranging from radiation pneumonitis and fibrosis to lung tumors [2]. An inhalation Unit Risk is not available for natural plutonium [5]. An inhalation slope factor of 3.8×10^{-8} (risk/pCi) was derived by USEPA for both Pu-239 and Pu-240 [6].

Dermal Exposure. Plutonium can enter the body through the skin [2]. Information was not available regarding the toxicity of plutonium following dermal contact.

External Exposure. Cancer slope factor for external exposure to plutonium of 1.7×10^{-11} and 2.7×10^{-11} (risk/yr per pCi/gm soil) were derived for Pu-239 and Pu-240, respectively [6].

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POLYCHLORINATED BIPHENYLS (PCBS)

GENERAL

Polychlorinated biphenyls (PCBs) represent a class of chlorinated aromatic compounds which, until they were banned in 1979, had widespread industrial application because of their stability, inertness, excellent dielectric properties, and excellent solvent characteristics [1]. There are 209 possible PCB congeners when biphenyl is chlorinated. Monsanto Corporation marketed mixtures of PCBs under the trade name Aroclor. The Aroclors are identified by a four-digit numbering code in which the first two digits indicate biphenyl (12 carbon atoms), and the last two digits indicate the average chlorine content by weight percent. For example, Aroclor 1260 has an average chlorine content of 60%. An exception to this system is Aroclor 1016, with an average chlorine content of 41% [2]. Given their extensive past usage history, PCBs may be expected to be found throughout the environment. This profile addresses four Aroclors and PCBs collectively, as listed below.

CAS NUMBERS

Aroclor 1242	53469-21-9
Aroclor 1248	12672-29-6
Aroclor 1254	11097-69-1
Aroclor 1260	11096-82-5
PCBs	1336-36-3

COMMON SYNONYMS

PCBs, Aroclors

ANALYTICAL CLASSIFICATION

Semivolatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 6.00×10^{-3} to 2.40×10^{-1} mg/L at 24 to 25°C [3]
Vapor Pressure: 7.71×10^{-5} to 4.06×10^{-4} mm Hg at 25°C [3]
Henry's Law Constant: 5.60×10^{-4} to 2.70×10^{-3} atm-m^3/mole [3]
Specific Gravity: 1.38 to 1.62 at 25°C [2]
Organic Carbon Partition Coefficient: 5.13×10^{3} to 2.63×10^{6} [3]

FATE DATA: HALF-LIVES

Soil: 6 to > 365 days [1]
Air: 2 days to 4.7 years [1]
Surface Water: 9.5 hours to > 365 days [1]
Groundwater: persistent

NATURAL SOURCES

None noted.

ARTIFICIAL SOURCES

Electrical transformers; dielectric fluids; solvents.

FATE AND TRANSPORT

As a class of compounds, polychlorinated biphenyls exhibit a tendency to sorb strongly to soils and suspended solids/sediments in waters. PCB releases to the environment, then, will be expected to show very limited mobility and present only a slight danger of leaching to unprotected groundwaters. There is a wide distribution of a variety of microorganisms capable of degrading PCBs, mainly through dechlorination actions. The degradation rate/action of these microorganisms is lowered, however, as the number of chlorine ion substitutions on the biphenyl parent compound increases. In addition, biodegradation rates are slowed by the tight sorptive ability of PCBs, low ambient temperatures, low moisture content, extremes in pH, and available oxygen content (with no biodegradation evidenced under anaerobic conditions). The number of chlorine ion substitutions also affects volatilization and photoionization rates; as chlorine ion substitutions increase, so do these rates. PCBs volatilized to the atmosphere undergo two major modes of degradation: reaction with hydroxyl radicals and/or reaction with ozone. Reaction with hydroxyl radicals (resulting in substitution of OH^- for Cl^- on the biphenyl parent compounds) is the more important of these two processes. Hydrolysis and/or oxidative reactions are not considered to be important fate processes for PCBs. Generally, PCBs having a higher chlorine content exhibit greater persistency in the environment than do PCBs with lower chlorine content. Bioconcentration of PCBs in aquatic organisms is expected to be an important process for all PCBs, and shows an increase as the chlorine content increases [1].

HUMAN TOXICITY

General. PCBs are known to cause skin irritations, such as acne and rashes, in humans. Young children of women who ate foods containing high levels of PCBs, such as fish, before and during their pregnancies may experience learning difficulties. Consumption of contaminated food is presumed to be the major route of exposure for the general

population [2]. The USEPA has placed PCBs in weight-of-evidence Group B2, indicating that they are probable human carcinogens [4].

Oral Exposure. A chronic RfD of 0.00007 mg/kg/day is based on a reduction in birth rates in exposed monkeys [4]. PCBs are readily absorbed by humans via the oral route. Absorption in rats reportedly ranges from 75% to 90% of the administered dose. Single-dose LD_{50} values determined for rats ranged from 1,010 mg/kg for Aroclor 1254 to 4,250 mg/kg for Aroclor 1242 [2].

Numerous studies have been done on human children born to mothers who consumed large quantities of PCB-contaminated fish while pregnant. In one such study, the concentrations in the fish consumed ranged from 168 ppb to 3,012 ppb. Overall consumption of fish and levels of total PCBs in cord serum were positively correlated with lower birth weight, smaller head circumference, and shorter gestational age. By 7 months of age the infants with the highest levels of PCBs in cord serum scored significantly lower on neurobehavioral tests. By 4 years of age the children with the highest levels of PCBs in cord serum exhibited poorer performance on tests involving short-term memory [2].

Occupational studies have indicated possible PCB-related cancers of the liver, gastrointestinal tract, hematopoietic system, and skin [2]. An oral slope factor of 7.7 $(mg/kg/day)^{-1}$ is based on hepatocellular carcinomas observed in rodents [4].

Inhalation Exposure. The USEPA does not currently provide an inhalation RfC for PCBs [4,5]. Qualitative evidence exists that PCBs are absorbed via inhalation in humans and rats. NOAELs in rats, rabbits, guinea pigs, and mice exposed for up to 121 days ranged from 5.4 to 8.6 mg/m^3. A LOAEL of 1.5 mg/m^3 for liver and kidney degeneration was determined for rats exposed for 213 days. Upper respiratory tract and eye irritation, cough, and tightness of the chest were symptoms noted in humans exposed to 0.007 to 11 mg/m^3. Low birth weight and shortened gestational age has been correlated with occupational exposure of pregnant women to PCBs; however, confounding factors make these studies suspect [2]. The USEPA does not currently provide an inhalation slope factor or unit risk for PCBs [4,5].

Dermal Exposure. Hard data on dermal absorption of PCBs by humans and animals are lacking. Absorption efficiency in rhesus monkeys and guinea pigs ranged from about 15% to 34%. Median lethal doses for single dermal applications of PCBs to rabbits were as follows (mg/kg): <1,269 for Aroclors 1242 and 1248, <3,169 for Aroclors 1221 and 1262, and <2,000 for Aroclors 1232 and 1260. Liver and kidney damage were noted in rabbits treated dermally 5 days/week for up to 38 days with up to 44 mg/kg/day Aroclor 1260 [2].

ECOLOGICAL TOXICITY

General. This discussion is limited to Aroclors 1254 and 1260. Environmental persistence of PCBs is determined by the degree of chlorination. Higher chlorobiphenyls, i.e., those with five or more chlorine atoms, are more persistent in the environment than those with three or fewer chlorine atoms. Aroclor 1254 has five chlorine atoms per moleclue, and Aroclor 1260 has six or more, making them among the most stable compounds in this chemical class [6].

Since 1979, the manufacture, processing, distribution, and use of PCB's has been banned in the United States [6]. However, because these chemicals are so stable, the major source of Aroclor 1254 and Aroclor 1260 release to the environment is an enviromental cycling process of these compounds previously introduced into the environment. The cycle involves volatilization from water and soil into the atmosphere with subsequent removal from the atmosphere via wet or dry deposition, followed by revolatilization [7]. Although biodegradation of Aroclor 1254 and Arolclor 1260 may occur very slowly in the environment, no other degradation mechanisms have been shown to be important in natural systems. Therefore, biodegradation may be the ultimate fate process [7].

PCBs have a significant environmental toxicity to invertebrates, fish, birds, and mammals. PCB toxicity is further enhanced by their ability to bioaccumulate and biomagnify in the food chain [6]. Their persistence in the environment, their ability to bioconcentrate in almost all classes of biota, and their ability to bioconcentrate and biomagnify through the food chain make PCBs a potentially significant hazard to fish, wildlife, and invertebrate resources [6].

Vegetation. CH2M Hill [8] summarized data that show that PCBs are not very toxic to terrestrial plants. Beets grown in soils with PCBs at a concentration of 100 mg/kg (dry weight) had no significant reduction in growth, while a significant reduction in growth of corn was noted at this concentration. Ostrich ferns growing on sediments with PCB residues of 26 mg/kg (mostly Aroclor 1254) showed five-fold increases in somatic mutations (genetic damage), but other plants in the contaminated area were not genetically damaged. While one source states that PCBs in the soil at concentrations of 100 mg/kg (dry weight) had no significant effect on growth of soybeans, another source identifies a 27 percent reduction in growth of soybean plants at this soil concentration and states that the NOEL is 2 to 3 mg/kg. Regardless, all of these values show low phytotoxicities for this class of compounds.

PCBs have been shown to bioconcentrate in both terrestrial and aquatic plants. Studies summarized in Eisler [6] showed dry-weight concentrations in foliage, grasses, aspen leaves, and goldenrod leaves of up to 0.29 ppm, 0.14 ppm, 0.12 ppm, and 0.32 ppm dry

weight, respectively. Some of these values exceed the FDA limit of 0.2 ppm for PCBs in feeds for livestock [6]. Crop leaves (soybeans, string beans, and corn) grown on a contaminated site had PCB levels of 30 ppb to 50 ppb [7] BCFs of 10^4 to 10^5 were reported in various species of algae [6]. Although in-tissue concentrations of PCBs may not be toxic to the plants, they could be important as sources of PCBs in higher trophic levels.

Aquatic Life. The federal aquatic life criterion for PCBs for the chronic protection of freshwater aquatic life is 0.014 μg/L [9]. The corresponding criterion from the state of Ohio for PCBs is 0.001 μg/L. In addition, the state of Ohio requires that "Any whole sample of any representative aquatic organism shall not exceed 0.64 mg/kg (wet weight)" [10]. This latter requirement is to protect higher trophic levels from the ingestion of natural foods containing toxic concentrations of PCBs.

The chronic aquatic life standards derive in part from the toxicity of PCBs to aquatic invertebrates and fish. Studies show 96-hour LC_{50}s (acute toxicities) for freshwater invertebrates are usually between 50 μg/L and 800 μg/L. Most 96-hour LC_{50}s for warm water fish are between 100 μg/L and 600 μg/L [11,12,6,7]. Generally, an application factor of 0.01 is used to convert acute toxicities to criteria that provide for the chronic protection of aquatic life [11]. However, because of the extent to which PCBs bioaccumulate, more stringent criteria are appropriate [11].

A major concern to aquatic life is the bioconcentration of PCBs. Studies cited in virtually every summary article on PCBs showed concentration factors ranging from 10^3 to 10^5 in freshwater invertebrates and fish [11,12,6,13,7]. PCBs with the highest chlorination (which would include Aroclor 1254 and Aroclor 1260) were accumulated most readily [6]. This ability to bioaccumulate further enhances the toxicity of these compounds [6]. Diet contributes most of the total PCB body burdens of upper-level aquatic carnivores, with diet accounting for 90 percent of the total PCB body burden in brown trout and 51 to 83 percent in striped bass [6]. Elimination of accumulated PCBs is slow, with no elimination by codfish larvae after 12 days and 97.8 percent retention by chironomid (an invertebrate) larvae after 7 days [6].

Wildlife. Because of their ability to bioaccumulate, PCBs have been studied more extensively in wildlife than have most other chemicals. Studies summarized by Eisler [6] show that effects vary among PCB compounds. For example, tissues from cattle that had been dosed with Aroclor 1254 and fed to mink at levels as low as 0.64 ppm fresh weight of diet caused severe reproductive effects. However, Aroclors 1016 and 1221 at dietary concentrations of 2 ppm produced no adverse reproductive effects in mink over a 9-month period, nor did Aroclor 1242 at 5 ppm during a similar period.

Aroclor 1260 has relatively low oral toxicity, at least to rats. Micromedex, Inc. [7] cites several studies in which laboratory rats were fed Aroclor 1260 at concentrations of 100 ppm to 1,250 ppm in the diet for periods ranging from 2 months to 21 months. Although sublethal effects such as reduced reproductive success, liver tumors, and retarded growth were noted, these concentrations did not cause large-scale mortality.

Aroclor 1254 has been tested in a number of species of wildlife. LD_{50} data for dietary intake of Aroclor 1254 that were summarized in Eisler [6] and Micromedex, Inc. [7] are presented below.

Raccoon	>50 mg/kg, 8 days
Cottontail rabbit	>10 mg/kg, 12 weeks
Mink	4 mg/kg, no time given
Mink	6.7 mg/kg, 9 months
White-footed mouse	>100 mg/kg, 3 weeks
Norway rat	>75 mg/kg, 6 days
Mouse, PCB-resistant	>250 mg/kg, 18 weeks

Aroclor 1254 apparently is more toxic to rats than is Aroclor 1260. Rats fed Aroclor 1254 at the rate of 1,000 mg/kg in the diet all died in 53 days; mortality started at day 28 [6]. These and other feeding studies suggest that a total intake of about 500 to 2,000 mg of Aroclor 1254 per kg body weight is the lethal level in rats for dietary exposures of 1 to 7 weeks [6].

In the body, PCBs are accumulated primarily in the adipose tissue, skin, and liver [6,13,]. More highly chlorinated congeners have longer half-lives, with a half-life of Aroclor 1260 in humans of 33 to 34 months [7].

Birds are generally more resistant to acutely toxic effects of PCBs than mammals [6]. Studies summarized in Eisler [6] and Micromedex Inc. [7] showed that mallards, ring-necked pheasants, bobwhite quail, and Japanese quail had 5-day LD_{50}s for ingestion of Aroclor 1254 and Aroclor 1260 ranging from 600 ppm to more than 2,000 ppm in the diet. Acute LD_{50}s for European starlings, red-winged blackbirds, and brown-headed cowbirds were all 1,500 mg/kg in the diet [6]. However, sublethal effects can occur at much lower concentrations. For example, 20 ppm in the diet of chickens caused a significant decrease both in the hatchability of eggs and in the viability of the surviving chicks [11]. Delayed reproduction and decreased numbers of eggs occurred in mourning doves fed 10 ppm Aroclor 1254 for 28 days [8].

Bioaccumulation also occurs in birds. Diet is an important route of PCB accumulation, with highest liver concentrations of PCBs in birds that fed on fish, followed by species that feed on small birds and mammals; and on worms and insects. Concentrations were lowest in herbivorous bird species [6]. In general, PCB accumulation is rapid and elimination is slow. For example, in common grackles, the biological half-life of Aroclor 1254 was calculated to be 89 days [6].

The Red Book [11] states, "Evidence is accumulating that PCBs do not contribute to shell thinning of bird eggs." However, this statement was contradicted by Prager [13] and Micromedex, Inc. [7], who indicate that PCBs cause eggshell thinning and reduced reproductive ability. Although Eisler [6] cited several PCB-related instances of eggshell thinning and associated reproductive failure in cormorants, peregrine falcons, bald eagles, and black-crowned night herons, he states, "At present, the evidence implicating PCBs as a major source of eggshell thinning is inconclusive."

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RADIUM

CAS NUMBER

Ra-223: 15623-45-7
Ra-224: 13233-32-4
Ra-226: 13982-63-3
Ra-228: 15262-20-1

COMMON SYNONYMS

Radium

ANALYTICAL CLASSIFICATION

Radionuclide/Metal

PHYSICAL AND CHEMICAL DATA

Water Solubility: decomposes, with the evolution of H_2 [1]
Vapor Pressure: ND [1]
Specific Gravity: 5.5 [1]
Organic Carbon Partition Coefficient: ND [1]

BACKGROUND CONCENTRATIONS

Radium is a naturally occurring, silvery-white radioactive metal that can exist in several forms or isotopes, including Ra-223, Ra-224, Ra-226 and Ra-228. The earth's crust contains about 7×10^{-12}% radium [1].

NATURAL SOURCES

Radium is a disintegration product of uranium and occurs in uranium ores, such as pitchblende and uranite [1].

ARTIFICIAL SOURCES

The combustion of coal may be the most important mechanism for releasing radium into the environment. When combusted, radium may volatilize and then condense onto coal fly ash particles, which in turn may be released from power plants as fugitive emissions. The concentrations of Ra-226 in fly ash have ranged from 1 to 10 pCi/g. The leaching of uranium mine tailings and the release of ore-processing effluents generated by leaching, decantation, and filtration processes in uranium mining are believed to be the most significant water-related release of radium [2].

FATE DATA: HALF-LIFE

Ra-223: 11.4 days
Ra-224: 3.62 days
Ra-226: 1,600 years [3]
Ra-228: 5.75 years [3]

FATE AND TRANSPORT

Radium is highly mobile in coarsely textured soils, resulting in the potential for groundwater contamination. Liming of the soil increases radium retention by the formation of an insoluble calcium-beryllium complex with radium. The concentration of radium in seawater is about 4 to 5 orders of magnitude lower than that in soil, with ocean sediments containing large stocks of Ra-226.

TOXICITY

General. The primary effects of radium exposure are acute radiation poisoning and cancer of the lung and bone. Acute radiation syndrome, characterized by effects on the nervous system, gastrointestinal system and hematopoietic system, occurs following whole body irradiation with high doses of radiation. At very high doses (over 5000 rads), effects on the nervous system include vomiting and drowsiness, tremors, ataxia, convulsions and death within 24 to 72 hours. Effects on the gastrointestinal system, including ulceration and hemorrhage, occur maximally 3 to 5 days after exposure to doses in the range of 600 to 2000 rads. Effects on the hematopoietic system, primarily leukopenia, occur within 48 hours of exposure to 200 to 1000 rads [1]. It is important to note that effects observed after the ingestion of radium may be attributed to the presence of any daughter products produced in vivo and their radioactive emissions in addition to the toxic effects of radium [1].

USEPA classifies all radionuclides as Group A carcinogens. This classification is based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiation-induced cancers in humans [3].

The intake of radium in food and fluids appears to be the main source of exposure to radium. Pulmonary exposure may also occur if radium is associated with inhaled particulate matter. Because radium is a metabolic analog of calcium, it is rapidly bioconcentrated and deposited in the skeleton [1].

Oral Exposure. Radium is fairly rapidly absorbed through the gastrointestinal tract following oral exposure (10-35%) [1]. The following oral slope factors were derived

by USEPA for radium isotopes: 6.4×10^{-11} (risk/pCi) for Ra-223, 3.8×10^{-11} (risk/pCi) for Ra-224, 1.2×10^{-10} (risk/pCi) for Ra-226 and 1.0×10^{-10} (risk/pCi) for Ra-228 [3].

Inhalation Exposure. Radium isotopes will be cleared from the lungs in a matter of weeks [3]. The following inhalation slope factors were derived by USEPA for radium isotopes: 3.1×10^{-9} (risk/pCi) for Ra-223, 1.2×10^{-9} (risk/pCi) for Ra-224, 3.0×10^{-9} (risk/pCi) for Ra-226 and 6.6×10^{-10} (risk/pCi) for Ra-228 [3].

Dermal Exposure. Information regarding potential effects following dermal contact with radium were not located.

External Exposure. The following slope factors were derived by USEPA for external exposure to radium isotopes: 2.3×10^{-7} (risk/yr per pCi/gm soil) for Ra-223, 2.3×10^{-8} (risk/yr per pCi/gm) for Ra-224, 1.2×10^{-8} (risk/yr per pCi/gm) for Ra-226 and 0.0 (risk/yr per pCi/gm) for Ra-228 [3].

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SILVER

CAS NUMBER

7440-22-4

COMMON SYNONYMS

Argentum; Argentum crede; CI77820; shell silver; silver atom; silver colloidal; silflake; silber. [1]

ANALYTICAL CLASSIFICATION

Metal.

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: Insignificant at 25°C [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 10.49 at 15/4°C [2]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Silver is a naturally-occurring element whose average abundance is 0.1 ppm in the earth's crust and 0.3 ppm in soil [1].

FATE AND TRANSPORT

Silver is a white metal with a face-centered cubic structure. With the exception of gold, no other metal is more malleable or ductile. Silver is not appreciably attacked by water, atmospheric oxygen, or most acids (with the exception of dilute nitric acid and hot concentrated sulfuric acid). It is insoluble in water, but solubilizes in fused alkali hydroxides (in the presence of air), in alkali cyanides (in the presence of air), and in fused alkali peroxides. Additionally, most salts of silver are photosensitive [2].

Silver released to soils under oxidizing conditions will be found primarily in compounds with bromide, chloride, and/or iodide; silver released to soils under reducing conditions will be primarily in the form of free silver metal and/or silver sulfide. The fate and transport, then, of silver released to soils is a function of the form of silver-containing material/compound released (i.e., elemental silver versus silver nitrate). In addition, the mobility of silver through soils is influenced by: the

drainage rate of the soil (silver is readily removed from well-draining soils); the reduction-oxidation (redox) potential and pH of the soil, which affects the ability of manganese and iron (among others) to immobilize silver; and organic matter, which tends to form complexes with silver. Plants account for another mechanism of silver removal from soils since plants will take silver from soils into the root system. Biodegradation and/or biotransformation of silver is expected to be very restricted since silver proves toxic to most microorganisms [1].

Silver released to waters will be found primarily as sulfates, bicarbonates, sulfate salts, chlorides, and particulate-associated matter. Sorption appears to be the primary process affecting partitioning of silver through sediment layers in waters, with silver being sorbed readily by compounds such as manganese dioxide. The redox potential and pH of waters will affect the ability of silver to sorb to organic matter therein. Bioconcentration of silver in aquatic organisms represents another fate/transport process of significant concern, given the bioconcentration factor ($\log_{BCF}$ = 4.82) for silver. In addition, silver is slowly bioaccumulated by aquatic organisms ($\log_{BAF}$ = 1.41). Biomagnification through the trophic levels is expected to be minimal, however. As with silver released to soils, silver released to waters is not expected to undergo significant biodegradation/biotransformation given its inherent toxicity [1].

Atmospheric concentrations of silver will primarily be found as particulate-associated matter and/or fine particles of metallic silver. The major forms of atmospheric silver include: metallic silver, silver sulfide, silver sulfate, silver carbonate, and silver halides. Silver found in any of these forms may be subject to long-range transport, and will eventually be removed from the atmosphere via dry or wet deposition; up to 50% of silver released to the atmosphere from industrial operations has been demonstrated to travel up to 100 km prior to deposition [1].

HUMAN TOXICITY

General. The major targets of silver toxicity are the respiratory system following inhalation exposure and the skin following inhalation, oral and dermal exposure [1]. Data suggest that silver is a mutagen. The USEPA has placed silver in weight-of-evidence cancer Group D, indicating that it is not classifiable as to human carcinogenicity [3].

Oral Exposure. A chronic oral RfD of 0.005 mg/kg/day is based on a LOAEL of 0.014 mg/kg/day for argyria in a long-term study in humans [3]. Approximately 20% of an oral dose of silver is absorbed through the gastrointestinal tract [1]. Ingested silver has not been reported to be fatal to humans, and LD_{50} values are not

available for animals. Short- and long-term ingestion of silver results in argyria (grey or blue-grey discoloration of the skin) in humans. The dose associated with argyria is not known. Argyria is considered to be more of a cosmetic problem rather than a health problem. Information is not available regarding the potential effects of silver on reproduction or development in humans. There is no evidence that silver causes cancer in humans or animals and, therefore, an oral Slope Factor is not available [3].

Inhalation Exposure. A chronic inhalation RfC is not available for silver [3]. Silver is absorbed through the respiratory tract, but the extent of absorption is not known. Inhaled silver has not been reported to be fatal to humans, and LC_{50} values are not available for animals. Occupational exposure to 0.039 to 0.378 mg/m^3 has resulted in effects on the respiratory system (sneezing, stuffiness, runny nose, sore throat, cough, wheezing, chest tightness) and on the gastrointestinal system (abdominal pain) [1]. Occupational exposure also results in argyria. Information is not available regarding the potential effects of silver on reproduction or development in humans. There is no evidence that silver causes cancer in humans or animals, and therefore, an inhalation Unit Risk is not available [3].

Dermal Exposure. Silver has not been reported to be fatal in humans or animals following dermal exposure. Argyria and mild allergic responses are the only known effects of dermal exposure to silver [1]. The doses that elicit these effects are not known.

ECOLOGICAL TOXICITY

General. Silver is not an essential element for plants or animals. Silver toxicity ranks second only to mercury among the heavy metals [4]. Many of its salts, such as silver chloride, sulfide and arsenate, are insoluble [5].

Vegetation. No reports of silver toxicity in plants growing under natural conditions were found. Under man-induced conditions, silver toxicity to corn was reported at 0.0098 μg/ml and 0.0049 μg/ml was fatal to lupines [6]. Silver tends to be retained in surface soil at a pH greater than 4, especially in soils with a high concentration of organic matter. In plants, silver has a tendency to accumulate in the root [7]. The ratio of silver content in plants to soil has been given as 1:1.5. Such a ratio must be used with caution because the silver content of plants has a very wide range [7].

Aquatic Life. Silver nitrate and sulfate are relatively soluble compounds of silver and are considered toxic to aquatic life. Silver is not present in aquatic animals at very high concentrations because most of its compounds are virtually insoluble in

water and because silver has a very short biological half-life [5]. Extremely low concentrations of silver, as low as 0.0000001 mg/L, have been found to be harmful to sensitive fish species. LC_{50} values for fish range from 0.003 mg/L for silver nitrate to 250 mg/L for silver thiosulfate. However, most reported LC_{50}s were between 0.003 and 0.1 mg/L [5]. Fish are capable of accumulating silver from water, however, the food chain is not an important route of silver accumulation for animals at higher trophic levels [4]. The federal chronic freshwater quality criterion for silver is 0.12 μg/L based on water hardness of 400 mg/L $CaCO_3$ [8]. The state aquatic life habitat and water supply standard for silver is 17.0 μg/L based on water hardness of 400 mg/L $CaCO_3$ [9].

Wildlife. No references have been found which discuss or report toxic effects of silver on wildlife under natural conditions. Silver is a general microconstituent of many animals. Although the presence of silver in most animals suggests that it might serve some purpose, its role in animal metabolism is still unknown [7]. Long-term experiments with rats and rabbits concluded that ingestion of silver in drinking water at a dose of 0.0025 mg/kg body weight did not produce any detrimental effects. Doses of 0.025 mg/kg body weight affected the rats' reflexes and rabbits' immunological activity [7]. Field studies exposing sheep ewes to as much as 10 mg/kg/day failed to produce clinical signs of toxicity [10].

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STRONTIUM

CAS NUMBER

Metallic: 7440-24-6
Sr-89: 14158-27-1
Sr-90: 10098-97-2

COMMON SYNONYMS

None.

ANALYTICAL CLASSIFICATION

Metal/Radionuclide

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: 10 mm Hg at 898°C [2]
Henry's Law Constant: Not Applicable
Specific Gravity: 2.6 g/cm^3 [1]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Strontium is a naturally-occurring alkaline earth metal. The total amount of strontium in the earth's crust is estimated to be 430 gm/ton [1]. The concentration of strontium in minimally disturbed soils varies tremendously. A collection of 1318 soil samples from across the conterminous U.S. determined that 88 percent were less than or equal to 300 ppm, with a geometric mean of 120 ppm and a maximum value of 3000 ppm [3].

NATURAL SOURCES

Strontium is a silvery-white alkaline earth metal. It is primarily found in the sulfate (celestine) or carbonate (strontianite) forms. Strontium is found in small quantities associated with calcium or barium minerals [4]. Strontium has four naturally-occurring isotopes: Sr-84, Sr-86, Sr-87 and Sr-88 [1].

ARTIFICIAL SOURCES

The most economically useful isotope of strontium is the artificial isotope Sr-90. Sr-90 has a half-life of 28 years and is used in fireworks, red signal flares and on tracer

bullets [4]. Sr-90 is also being considered as a source of electric power [4]. Sr-90 may be released during its production or use.

FATE DATA: HALF-LIVES

Sr-89: 50.6 days [5]
Sr-90: 28.6 years [5]

FATE AND TRANSPORT

Strontium (II) is the only oxidation state that is encountered in soil-contacted solutions, and there is little tendency for strontium to form complexes with inorganic ligands [6]. Strontium is likely to be 100% cationic with the principal reaction with soils and rocks being ion exchange [7].

Many strontium compounds appear to be very soluble, especially when in an acidic environment. Low pH results in a relatively high migration velocity of strontium compounds to groundwater [8,9].

Strontium is an unstable compound that breaks down or decays. Sr-90 is a high energy beta emitter that produces effects resulting from internal irradiation following oral or inhalation exposure [1].

HUMAN TOXICITY

General. Strontium exposure results in both chemical and radiological effects. The bones are the major target of toxicity of strontium. Excessive strontium results in an inhibition of calcification of epiphyseal cartilage and deformities of long bones. Strontium acts by substituting for calcium during bone formation or by displacing calcium from existing calcified matrix [10]. When strontium accumulates in the body and undergoes radioactive decay, cancer is the primary effect of concern. The USEPA has not placed natural strontium in a weight-of-evidence cancer group [10], but all radioactive chemicals are considered Group A, human carcinogens [5]. This classification is based on the fact that all radionuclides emit ionizing radiation, which has been shown to result in radiation-induced cancers in humans [5]. Strontium tends to deposit in the bones, resulting in beta-ray induced hematopoietic tissue lesions and malignant bone growth [1].

Oral Exposure. A chronic oral RfD of 0.6 mg/kg/day is based on a NOAEL of 190 mg Sr/kg/day for rachitic bones in an acute, subchronic and chronic oral study in rats [10]. Absorption of strontium from the gastrointestinal tract varies greatly (9-63%) [10]. Strontium behaves similarly to calcium, therefore, a deficiency of dietary calcium leads to an increased absorption of strontium [10]. There is no information

regarding the effects of ingested strontium on human reproduction or development, but studies in animals suggest that strontium may be a developmental toxicant [10]. Ingested natural strontium has not been reported to cause cancer in humans or animals, therefore, an oral Slope Factor is not available [9]. Oral slope factors of 3.0×10^{-12} and 3.3×10^{-11} (risk/pCi) have been derived for Sr-89 and Sr-90, respectively [5].

Inhalation Exposure. A chronic inhalation RfC is not available for strontium [8]. Once inhaled, strontium is cleared from the lungs over a period of days [5].. An inhalation Unit Risk is not available for natural strontium [10]. Inhalation slope factors of 2.9×10^{-12} and 5.6×10^{-11} (risk/pCi) have been derived for Sr-89 and Sr-90, respectively [5].

Dermal Exposure. Information regarding the effects of strontium following dermal contact were not located.

External Exposure. A cancer slope factor for external exposure of 4.7×10^{-10} (risk/yr per pCi/gm soil) was derived for Sr-89 [5]. A cancer slope factor for external exposure was not derived for Sr-90 because Sr-90 does not emit gamma radiation [5].

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TOLUENE

CAS NUMBER

108-43-2

COMMON SYNONYMS

Methylbenzene.

ANALYTICAL CLASSIFICATION

Volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 534.8 mg/L at 25°C [1]
Vapor Pressure: 28.4 mm Hg at 25°C [1]
Henry's Law Constant: 5.94 x 10^{-3} atm-m^3/mole (temperature not given) [1]
Specific Gravity: 0.866 at 20/4°C [2]
Organic Carbon Partition Coefficient: 37 to 178 [1]

FATE DATA: HALF-LIVES

Soil: 4 to 22 days [3]
Air: 10 hours to 4.3 days [3]
Surface Water: 4 to 22 days [3]
Groundwater: 1 to 4 weeks [3]

NATURAL SOURCES

Volcanoes, forest fires, and crude oil [1].

ARTIFICIAL SOURCES

Gasoline, fuel oils, automobile exhaust, chemical industry, paints and lacquers [1].

FATE AND TRANSPORT

Much of the toluene released to surface soil will be lost to volatilization. It is mobile in soils and will leach to groundwater. Biodegradation occurs slowly in soil and groundwater, but is inhibited by high concentrations. Under ideal conditions of low concentration and acclimated microbial populations, rapid biodegradation may occur. Losses from surface water occur due to volatilization and biodegradation. It will not significantly adsorb to sediment or bioconcentrate in aquatic organisms. In the atmosphere it will degrade or be washed out with rain [1].

HUMAN TOXICITY

General. Toluene acts primarily on the central nervous system [4]. The USEPA has placed toluene in weight-of-evidence Group D; that is, it is not classifiable as to human carcinogenicity [5].

Oral Exposure. A chronic RfD of 0.2 mg/kg/day is based on a NOAEL of 223 mg/kg/day for changes in liver and kidney weights in a subchronic oral study in rats. The LOAEL in this study was a dose of 446 mg/kg/day [5]. Toluene is absorbed more slowly from the gastrointestinal tract than from the lungs [6]. The acute oral LD_{50} for adult rats is in the range of 5,000 to 7,300 mg/kg [4,6]. Brain damage was noted in mice receiving 1,250 mg/kg/day by gavage for 13 weeks [6].

Inhalation Exposure. The RfC of 0.4 mg/m^3 is based on a LOAEL of 88 ppm for central nervous system effects observed in humans following inhalation exposure [5]. Toluene is rapidly absorbed following inhalation by humans and animals [6]. The inhalation LC_{50} in mice is 5,300 ppm for an 8-hour exposure. Exposure of humans by inhalation to 200 ppm for 8 hours produced mild fatigue, weakness, confusion, lacrimation, and tingling of the skin. At 600 ppm, additional effects included euphoria, headache, dizziness, dilated pupils, convulsions, and nausea. After 8 hours at 800 ppm, symptoms were more pronounced; effects included nervousness, muscular fatigue, and insomnia persisting for several days. Exposure to concentrations of 10,000 to 30,000 ppm could lead to narcosis and death. Chronic abusive inhalation of toluene vapors by humans produces central nervous system impairment and emotional and intellectual disturbances. Uptake in the various brain regions is widespread due to the high lipid solubility of toluene and the high lipid content of the brain. Effects on animals following high levels of exposure include hearing loss, kidney effects, and lung lesions. High level oral intake by animals has resulted in weight increases in the liver and kidney, and brain tissue damage [4].

Dermal Exposure. The absorption of toluene through human skin is slow, falling within the range of 14 to 23 mg/cm^2/hour. Dermal contact with toluene by humans may cause skin damage. Application of toluene to the eyes of rabbits reportedly resulted in moderately severe injury [6].

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TRITIUM

CAS NUMBER

10028-17-8

COMMON SYNONYMS

Triterium [1]
Hydrogen-3 [1]

ANALYTICAL CLASSIFICATION

Gas [2]

PHYSICAL AND CHEMICAL DATA

Water Solubility: ND [1]
Vapor Pressure: ND [1]
Specific Gravity: ND [1]
Organic Carbon Partition Coefficient: ND [1]

BACKGROUND CONCENTRATIONS

Tritium is a radioactive compound that naturally occurs in the environment; the principal source of natural tritium is cosmic radiation.

Natural tritium concentrations vary geographically from about 10 T.U. (tritium units) for northern and southern midlatitude precipitation to 1 T.U. for equatorial precipitation [3]. The background tritium content of deep ocean and groundwater is essentially zero [4]. therefore, the tritium content of rocks, minerals and deeper sediments is also nearly zero unless contacted by tritium-contaminated groundwater [3].

NATURAL SOURCES

Tritium is the naturally occurring radioactive isotope of hydrogen [2]. The principle source of tritium is nuclear reactions induced by cosmic radiation in the upper atmosphere, where fast neutrons, protons, and deuterons collide with components of the stratosphere. A significant amount of tritium from the sun's surface is believed to be brought to the earth by solar wind and flare emissions. This tritium is believed to be rapidly incorporated into water molecules and mixed into the water present in the atmosphere and biosphere. Tritium is also present in meteorites [1].

ARTIFICIAL SOURCES

Tritium is formed in large quantities in both fission and fusion reactions and is present in the effluents from nuclear reactors and thermonuclear weapon explosions [5]. The two major forms of tritium released to the environment from artificial sources are tritiated water vapor and tritium-hydrogen gas [6]. Tritium produced in fusion-based nuclear explosions exceeds the natural background of tritium in the environment [1]. Tritium is also widely used as a radioactive tracer in chemical, biochemical, and biological research [2].

FATE DATA: HALF-LIFE

Tritium: 12.26 years [2].

FATE AND TRANSPORT

Tritium is a radioactive isotope of hydrogen, therefore, its behavior in the environment is expected to be similar to that of hydrogen. Tritiated water should behave similarly to ordinary water and, therefore, should enter the hydrological cycle.

TOXICITY

General. Tritium is not believed to constitute an external radiation hazard [1]. However, tritium, as tritiated water (^3HOH), is readily absorbed into the blood stream from the GI tract, skin, and lungs and is distributed as body water, thereby presenting a serious hazard by exposing vital body tissue to internal radiation. Also, any of its radiation effects are comparable to whole-body irradiation. Concern has been expressed over tritium's concentration into vital structures such as DNA when it enters the body in organic form [5]. Routes of exposure to tritium are ingestion of contaminated foods and water and the inhalation of contaminated particulate matter.

Health effects resulting from exposure may include, but are not limited to, fatal and nonfatal cancers, hereditary effects, as well as nonstochastic effects (e.g., cataracts) [6]. The median lethal dose (LD_{50}) of tritium is estimated to be 10 Curies [1]. USEPA classifies all radionuclides as Group A carcinogens. This classification is based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiation-induced cancers in humans [7].

Oral Exposure USEPA derived a cancer slope factor of 5.4×10^{-14} (risk/pCi) for the ingestion of tritium [7].

Inhalation Exposure USEPA derived a cancer slope factor of 7.8E-14 for inhalation exposure to tritium [7].

External Exposure A slope factor has not bee derived for external exposure to tritium [7].

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URANIUM

CAS NUMBER

U-233: 13968-55-3 [1]
U-234: 13966-29-5 [1]
U-235: 15117-96-1 [1]
U-238 (metallic): 7440-61-1 [1]

COMMON SYNONYMS

Uranium I (238U); Uranium-238; U [2]

ANALYTICAL CLASSIFICATION

Metal/Radionuclide

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [2]
Vapor Pressure: Insignificant at 25°C [2]
Henry's Law Constant: Not Applicable [2]
Specific Gravity: 19.05 g/cm^3 [2]
Organic Carbon Partition Coefficient: NA [2]

BACKGROUND CONCENTRATIONS

Uranium is a naturally-occurring element which is present in the earth's crust at approximately 2 ppm [2]. The concentration of uranium in minimally disturbed soils varies tremendously. A collection of 354 soil samples from across the conterminous U.S. determined that 76 percent were less than or equal to 2.8 ppm, with a geometric mean of 2.3 ppm and a maximum value of 11 ppm [3].

NATURAL SOURCES

Uranium is a silver-white, lustrous, radioactive metal which is composed primarily of three isotopes or forms: uranium-234, uranium-235, and uranium-238 [2,4]. The main raw material of uranium is pitchblende or carnotite ore, but it is widely distributed in nature and is present in a variety of minerals as well as rocks, soil, water, and plants [2,5,6]. Uranium is believed to be an important constituent of approximately 155 minerals and occurs frequently in minerals such as uranite, autunite, and uranophane, as well as phosphate rock and monazite sands. Acidic rocks with a high silicate content such as granite may have a uranium content above average [5].

ARTIFICIAL SOURCES

Depleted uranium is a by-product of the uranium enrichment process during which natural uranium is enriched by increasing the percentage of the uranium-235 isotope [5].

FATE DATA: HALF-LIVES

U-233: 1.59×10^5 years [1]
U-234: 2.45×10^5 years [1]
U-235: 7.04×10^8 years [1]
U-238: 4.46×10^9 years [1]

FATE AND TRANSPORT

Uranium in the atmosphere may be transported to surface water, plants, and soil through wet and dry deposition. Atmospheric transport of particulate uranium is dependent upon particle size, distribution and particle density. Deposition on surface water and transport to sediments is likely to be the ultimate fate of atmospheric uranium. The mobility of uranium in soil and water is primarily controlled by the following two reactions: complexation with anions and ligands, and reduction of U^{+6} to U^{+4}. Other factors that control the mobility of uranium in soil and water are oxidation-reduction potential, pH, and sorbing characteristics of the soils and sediments. Conditions that increase the rate of formation of soluble complexes and decrease the rate of sorption to soil and sediment should increase the mobility of uranium. Uranium is not expected to leach readily to groundwater, particularly in soils containing clay and iron oxide. Bioconcentration of uranium in aquatic organisms is not expected to be significant [2].

Uranium is an unstable compound that breaks down or decays. It has a complex radioactive decay scheme resulting in the emission of different decay products (e.g., thorium) and radiations (e.g., alpha) [2,5]. The decay product of uranium is thorium, which is not stable. The decay of uranium and thorium continues until stable lead is formed [2]. Data from the Hanford Site indicates that uranium, as well as other radionuclides, are highly absorbed in groundwater sediment systems [2].

HUMAN TOXICITY

General. Uranium exposure results in both chemical and radiological effects. Following high dose exposure to uranium, the kidney is the major target of toxicity. When uranium accumulates in the body and undergoes radioactive decay, cancer is the primary effect of concern. The USEPA has not placed natural uranium in a

weight-of-evidence cancer group [7], but all radioactive chemicals are considered Group A, human carcinogens [1]. This classification is based on the fact that all radionuclides emit ionizing radiation, which has been shown to result in radiation-induced cancers in humans [1].

Oral Exposure. A chronic oral RfD of 0.003 mg/kg/day is based on a LOAEL of 2.8 mg/kg/day for initial body weight loss and moderate nephrotoxicity in a subchronic study in rabbits [7]. Uranium is poorly absorbed following oral exposure (1%) [2]. Uranium has not been reported to be fatal to humans, and lethal doses in animals are dependent upon the chemical compound administered. The lowest reported LD_{50} values in rodents were 115 to 136 mg uranium/kg for uranyl acetate dihydrate [2]. Generally, the soluble uranium compounds are more toxic than the insoluble compounds. There is no information regarding the toxicity of ingested uranium in humans, but studies in animals indicate that the kidney is the target of uranium toxicity. Oral treatment resulted in renal lesions which were characterized by atrophic effects on the tubules, at doses of approximately 5 mg uranium/kg/day and above [2]. There is no information regarding the effects of ingested uranium on human reproduction or development, but studies in animals suggest that uranium is a developmental (e.g., stunted fetuses, increase in skeletal malformations, embryolethality) and reproductive toxicant (fetal resorptions, degenerative changes in testes) [2]. Ingested natural uranium has not been reported to cause cancer in humans or animals, therefore, an oral Slope Factor is not available [7]. The following oral slope factors have been derived for by USEPA for uranium isotopes: 1.6×10^{-11} (risk/pCi) for U-233, and 1.6×10^{-11} (risk/pCi) for U-234, U-235 and U-238 [1].

Inhalation Exposure. A chronic inhalation RfC is not available for uranium [7]. Uranium is rather poorly absorbed following inhalation exposure (approximately 20%) [2] and is cleared from the lungs over a period of years [1].. In animals, acute inhalation LC_{50} values in rats ranged from 120,000 mg uranium/m^3 for 2 minutes to 12,000 mg/m^3 for 10 minutes [2]. The majority of the information regarding uranium exposure in humans is from epidemiological studies of uranium workers. These studies reported effects on the respiratory tract (obstructive pulmonary disease, emphysema, fibrosis, silicosis), and on the kidneys (nephritis, renal disease) [2]. Exposure concentrations resulting in these effects were not reported. Inhaled uranium has not been shown to cause effects on reproduction or development in humans or animals. An increase in deaths due to lung cancer has been reported in uranium miners, but the deaths are considered to result from the radiological effects of radon and its decay products, and not from natural uranium. Long-term animal

carcinogenicity studies using natural uranium have not been performed, therefore, it is difficult to ascertain whether inhalation of natural uranium will cause cancer. An inhalation Unit Risk is not available for natural uranium [7]. The following inhalation slope factors have been derived by USEPA for uranium isotopes: 2.7 x 10^{-8} (risk/pCi) for U-233, 2.6 x 10^{-8} (risk/pCi) for U-234, 2.5 x 10^{-8} (risk/pCi) for U-235 and 2.4 x 10^{-8} (risk/pCi) for U-238 [1].

Dermal Exposure. The lowest reported LD_{50} value for uranium in animals was 59 mg uranium/kg for uranyl nitrate in rabbits [2]. Effects on the kidneys (excess protein in the urine) and skin (irritation and tissue damage) were reported in animals following dermal application of various uranium compounds [2].

External Exposure. The following slope factors for external exposure have been derived by USEPA for uranium isotopes: 4.2 x 10^{-11} (risk/yr per pCi/gm soil) for U-233, 3.0 x 10^{-11} (risk/yr per pCi/gm) for U-234, 2.4 x 10^{-7} (risk/yr per pCi/gm) for U-235 and 2.1 x 10^{-11} (risk/yr per pCi/gm) for U-238 [1].

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ZINC

CAS NUMBER

7440-66-6

COMMON SYNONYMS

None noted.

ANALYTICAL CLASSIFICATION

Inorganic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: Insoluble [1]
Vapor Pressure: Insignificant at 25°C [1]
Henry's Law Constant: Not Applicable
Specific Gravity: 7.14 at 25/4°C [2]
Organic Carbon Partition Coefficient: NA

BACKGROUND CONCENTRATIONS

Zinc is a naturally occurring element essential to many life forms [1]. It is widespread in nature and may be found in many known compounds. The estimated occurrence of zinc in the earth's crust is 0.02 percent by weight [2]. The concentration of zinc in minimally disturbed soils varies tremendously. A collection of 1,248 soils samples from across the conterminous U.S. determined that 87 percent were less than or equal to 74 ppm, with a geometric mean of 48 ppm, but with a maximum as high as 3500 ppm [3]. Zinc concentrations in Ohio farm soils were found to range from 47 to 138 ppm, with a mean value of 75 ppm [4].

FATE AND TRANSPORT

Elemental zinc is a bluish-white, lustrous metal having a distorted hexagonal close-packed structure [2]. It is stable in dry air, but upon exposure to moist air will form a white coating composed of basic carbonate. Zinc loses electrons (oxidizes) in aqueous environments [2]. In the environment, zinc is found primarily in the 2+ oxidation state. Elemental zinc is insoluble; most zinc compounds show negligible solubility as well, with the exception of elements (other than fluoride) from Group VIIa of the Periodic Table compounded with zinc (i.e., $Zn\ Cl_2$, ZnI_2) showing a general 4:1 compound to water solubility level. In polluted waters, zinc often complexes with a variety of organic and inorganic ligands. Therefore, the overall mobility of zinc in an aqueous

environment, or through moist-to-wet soils, may be accelerated by compounding/complexing reactions [1].

Zinc has a tendency to adsorb to soils and sediment/suspended solids in waters. Adsorption to sediments/suspended solids is the primary fate for zinc in aqueous environments, and will greatly limit the amount of solubilized zinc. Zinc is an essential element and, therefore, is accumulated by all organisms. Zinc concentrations in air are relatively low except near industrial sources. Volatilization is not an important process from soil or water [1].

HUMAN TOXICITY

General. Zinc is an essential trace element, therefore, toxic effects can result if too much or too little is taken into the body. The Recommended Dietary Allowances (RDAs) for zinc are 15 mg/day for men and 12 mg/day for women [1]. The major targets of zinc toxicity are the gastrointestinal tract following oral exposure and the lungs following inhalation exposure [1]. Zinc is not mutagenic and has been placed in weight-of-evidence Group D, indicating that it is not classifiable as to human carcinogenicity, by the USEPA [5].

Oral Exposure. A chronic oral RfD of 0.3 mg/kg/day is based on a LOAEL of 1 mg/kg/day for effects on red blood cells in human females [5]. Approximately 20-30% of an oral dose of zinc is absorbed by the gastrointestinal tract [1]. Zinc has not been reported to be fatal to humans and oral LD_{50} values in animals are not available [1]. In humans, gastrointestinal effects (vomiting, abdominal cramps, diarrhea) and hematological effects (anemia) have resulted from oral exposure to doses greater than 2 mg zinc/kg/day. Long-term administration of zinc can result in copper deficiency [1]. In animals, effects on the liver and kidneys, as well as the gastrointestinal and hematological systems, have been reported [1]. Studies in animals indicate that exposure to high doses of zinc (200 to 500 mg/kg/day) results in reduced fetal growth and altered concentrations of zinc and copper in both the mother and fetus [1]. There is no evidence that exposure to zinc affects development or reproduction in humans. There is no evidence that zinc causes cancer in humans or animals following oral exposure, therefore, an oral Slope Factor is not available [5].

Inhalation Exposure. A chronic inhalation RfC is not available for zinc [5]. Zinc is absorbed through the respiratory tract, but the extent of absorption is not known. In humans, death has resulted from exposure to high concentrations (estimated at 97,635 mg/m^3) of zinc-containing smoke [1]. In mice, the reported LCT_{50} (product of lethal concentration and time to kill 50% of the animals) of zinc chloride was 11,800 mg-min/m^3 [1]. Short-term exposure to zinc dust and zinc fumes results in "metal fume

fever". This condition is characterized by an acute impairment of pulmonary function. Acute (10-12 minutes) inhalation of 600 mg zinc/m^3 as zinc oxide has resulted in nasal passage irritation, cough, chest pain, lung rales, and decreased vital capacity. No symptoms of metal fume fever were reported following exposure to zinc oxide at 14 mg/m^3 for 8 hours, 45 mg/m^3 for 20 minutes, or occupational exposure to 8-12 mg/m^3 [1]. Information is not available regarding effects on reproduction or development in human or animals following inhalation exposure. There is no evidence that inhaled zinc causes cancer in humans or animals, therfore, an inhalation Unit Risk is not available [5].

Dermal Exposure. Zinc has not been reported to be fatal in humans or animals following dermal exposure. Topical application of zinc (in the form of zinc oxide or calamine lotion), however, is used to promote healing of burns and wounds [1].

ECOLOGICAL TOXICITY

General. Zinc is an essential trace element for plants and animals. It is the most mobile of the metals in surface water systems, but only moderately mobile in soil/water systems [7]. Zinc is bioaccumulated by all organisms, but it does not biomagnify in terrestrial or aquatic food chains.

Vegetation. Studies of bulrush, sedge, cattail, and reeds indicate relatively high zinc absorption ability [8]. Bioavailable zinc is readily accumulated in the leaves of many plants; however, it is of low availability to animals, probably due to the formation of insoluble complexes of zinc with calcium and phytic acid in the plants [9]. The phytotoxic level of zinc in the soil ranges from 500 to 2000 ppm, with toxicity being enhanced under acidic soil conditions. The normal range of zinc in leaves of various plants is 15 to 150 ppm, and the maximum suggested concentration in plants to avoid phytotoxicity is 300 ppm [10]. Plant species exhibit a wide range of tolerances to zinc concentrations in soils.

Aquatic Life. Extensive test data are available for zinc effects on aquatic life. The acute lethal toxicity of zinc is greatly affected by water hardness, with soft water being more toxic than hard water. Both an increase in temperature and a reduction in dissolved oxygen also increase zinc toxicity [8]. Zinc is most toxic in aquatic biota at a pH of 8.0, and least toxic at a pH of 6.0 [7]. Fish growth was inhibited by zinc at a concentration of 0.05 to 0.08 mg/L, swimming was impaired at 0.06 to 0.3 mg/L, and reproduction was reduced at 0.05 to 0.88 mg/L [8]. The 96-hour LC_{50} for fathead minnows was 33,000 μg/L at a water hardness of 360 mg/L $CaCO_3$ [11]. The federal chronic freshwater quality criterion for zinc is 343 μg/L based on a water hardness of

400 mg/L $CaCO_3$ [12]. The Ohio aquatic life habitat standard is 340 μg/L based on a water hardness of 400 mg/l $CaCO_3$ [13].

Wildlife. Animals are generally protected from zinc poisoning through plant consumption because high concentrations of zinc are phytotoxic before they accumulate in toxic concentrations in plant tissues eaten by animals [10]. Zinc compounds are relatively nontoxic to animals, particularly mammals, because animals can physiologically regulate the absorption and excretion of this metal. For example, a dietary intake of 2,500 ppm zinc produced no discernable effects in rats, while 10,000 ppm is required to induce high mortality. A zinc concentration of 2.2 g/kg in rats and 1.9 to 2.2 g/kg in rabbits was lethal [9].

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APPENDIX III.D

EVALUATION OF POTENTIAL GROUND WATER ELEVATION RISE

APPENDIX III.D

EVALUATION OF POTENTIAL GROUNDWATER ELEVATION RISE

The Phase I RFI/RI has identified that ground water levels vary widely throughout OU4, and that ground water levels are subject to substantial seasonal fluctuations. The IM/IRA is required to address contamination that may be present from the surface down to the mean seasonal high ground water level within the boundary of the IHSS. Future investigations and evaluations (defined as Phase II by the IAG) will address potential risks and recommend remediation as necessary for contamination that may be present below the mean seasonal ground water level. Historical evidence suggests, however, that ground water does occasionally rise above the mean seasonal high ground water level. Analytical data suggest that there is a correlation between rising seasonal ground water levels and the release of contaminants identified in the vadose zone beneath the SEPs (including nitrate and radionuclides). Consequently, there may be a potential for future ground water levels to rise above the mean high seasonal level, such that ground water quality may be impacted and/or additional human health or environmental risks may result. The purpose of this analysis is to consider the impacts that a rising ground water table would have on these risks.

III.D.1 Estimation of the Potential Rise in Ground Water

The purpose of this analysis was to quantify the potential for the piezometric surface in the area of the Solar Evaporation Ponds to rise above an average "maximum" water table elevation. Specifically, the analysis is to be used to estimate the volume of contaminated, or potentially contaminated, vadose zone material that might be contacted by ground water, and thus be a contaminant source to ground water.

Figure III.D-1 is an average "maximum" upper hydrostratigraphic unit (UHSU) ground water table map. This map was constructed using historical UHSU and 1993 hydrograph data. For historical hydrograph data, four of the highest water level values were selected and averaged for each monitoring well. In the selection process, the criterion for choosing a high water table value was that the high-water-table value be separated by at least five months from a previous value. For the 1993 water level measurements the maximum water level was chosen and three analogous high water table values were chosen to represent other potential high-water-table levels. These values were also averaged and used in the construction of the averaged "maximum" water table map.

To estimate the potential rise above an average "maximum" ground water surface, precipitation data and hydrogeological data were reviewed. Data from automatic water level monitoring equipment and neutron probes at OU4 (as well as infiltration tests conducted at OU2) suggest that infiltration does not occur on a uniform basis. Precipitation data was gathered to compare to the hydrographs.

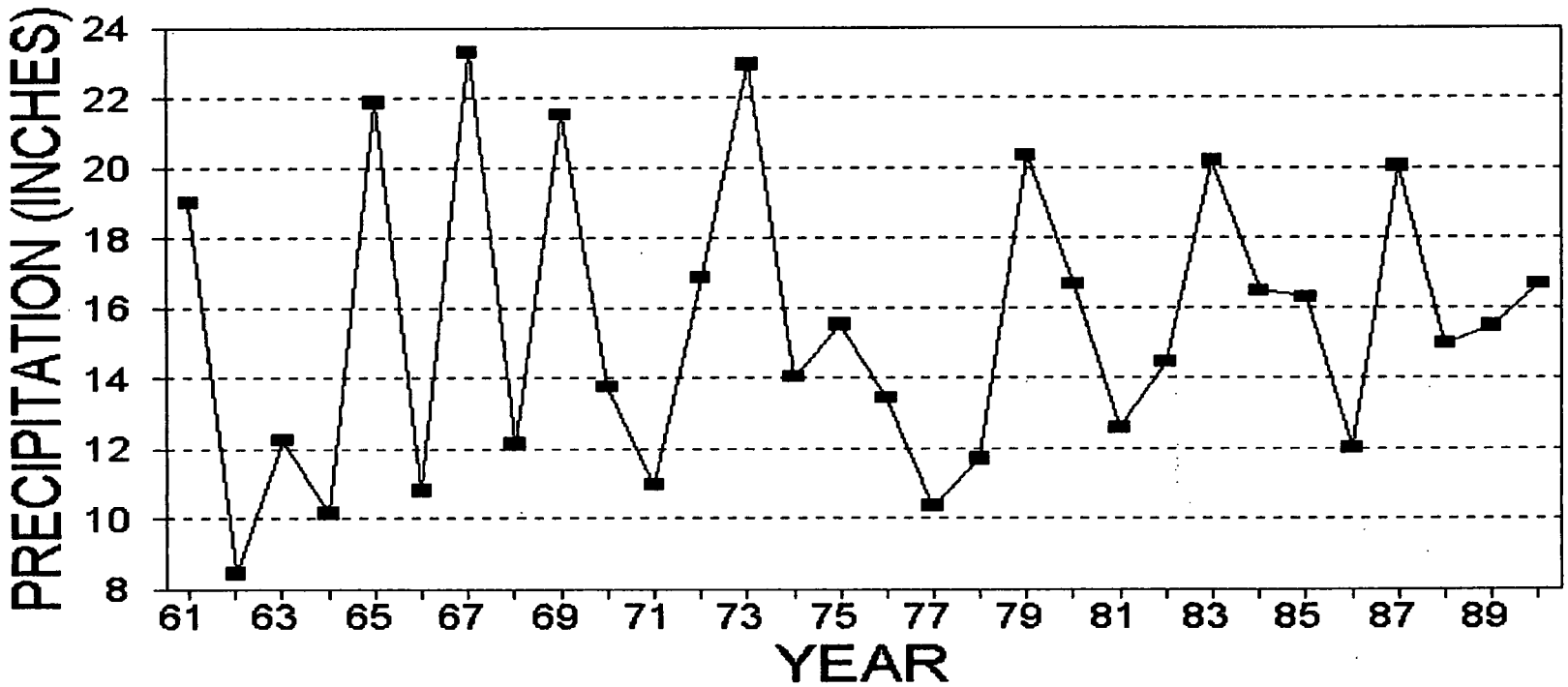
Figure III.D-2 shows yearly precipitation data for the Denver area (Bair, 1992). Even though the average annual precipitation is approximately 15 inches per year, it is not uncommon to receive nearly 24 inches of precipitation. These precipitation values are small compared to the evapotranspiration losses that dominate infiltration. Evapotranspiration of approximately 60 inches occurs each year at the RFP (Viessman et al, 1989).

Figure III.D-3 is a compilation of the UHSU hydrographs at OU4. Plotted about their mean value, these graphs indicate that no one period is dominantly drier or wetter than any other period. If there were distinct periods of dryness or wetness then these periods should be correlated to the drier and wetter years in Figure III.D-2. Thus, it appears that precipitation does not directly interact with the ground water table.

Figure III.D-4 presents monthly average, extreme, and the difference between the average and the extreme precipitation data. Based upon this data for the months between March and October an additional 3 to 5 inches of precipitation could occur. Based on the resources from which this data was taken (Bair, 1992), one-half to nearly all of this additional precipitation most likely would occur during one event. The result would be increased runoff with little infiltration. Thus, precipitation data can not be conclusively linked to water table rises and any increased precipitation may not cause the water table to rise above the historical levels that have been so far recorded at OU4.

Table III.D-1 indicates the recorded UHSU water table extremes. These values are time-independent. An average height for the water table to rise above the average "maximum" water table surface is 0.73 feet. Based upon the OU4 hydrographs, local areas behave differently with water level rises and at different times. The greatest variance is at monitoring well P210289 (east of SEP 207—B South) where 2.2 feet of additional water table rise was encountered.

Associated with a water table rise, it is possible that an additional 0.73 feet of rise may be observed above the averaged "maximum" water table surface. This value represents a "typical" extreme that would be associated with pore water flushing on an areal basis. It is also possible that an additional 2.2 feet of rise above the averaged "maximum" water table surface may be observed. Although this 2.2 foot value is a local variance in the UHSU water table fluctuations, it is plausible that it could occur on an averaged areal basis. Therefore, 2.2 feet is used as the assumed rise in the water table elevation for the modeling evaluation.



PREPARED FOR

U.S. DEPARTMENT OF ENERGY

ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure III.D-2

Solar Evaporation Ponds
Operable Unit No.4, IM/IRA EA DD
Yearly Precipitation Data
for the Denver Area

ou4IVb.cdr nap 51194

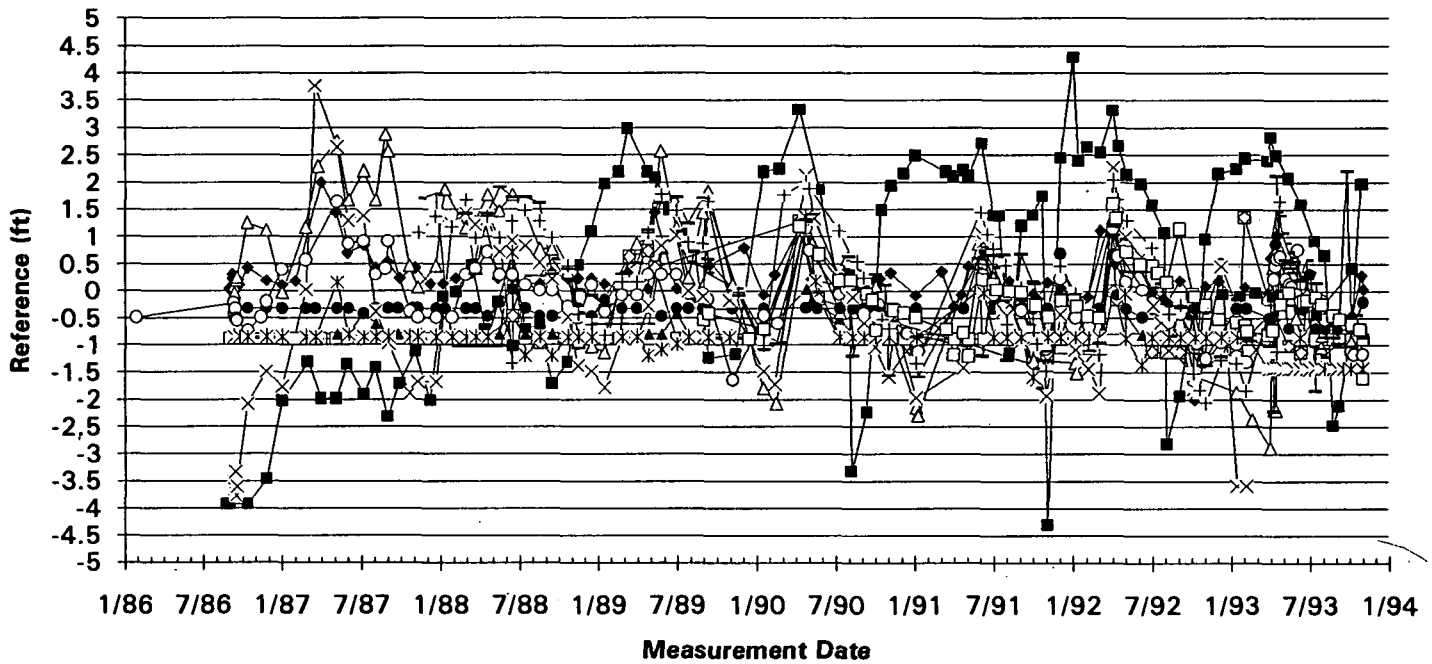


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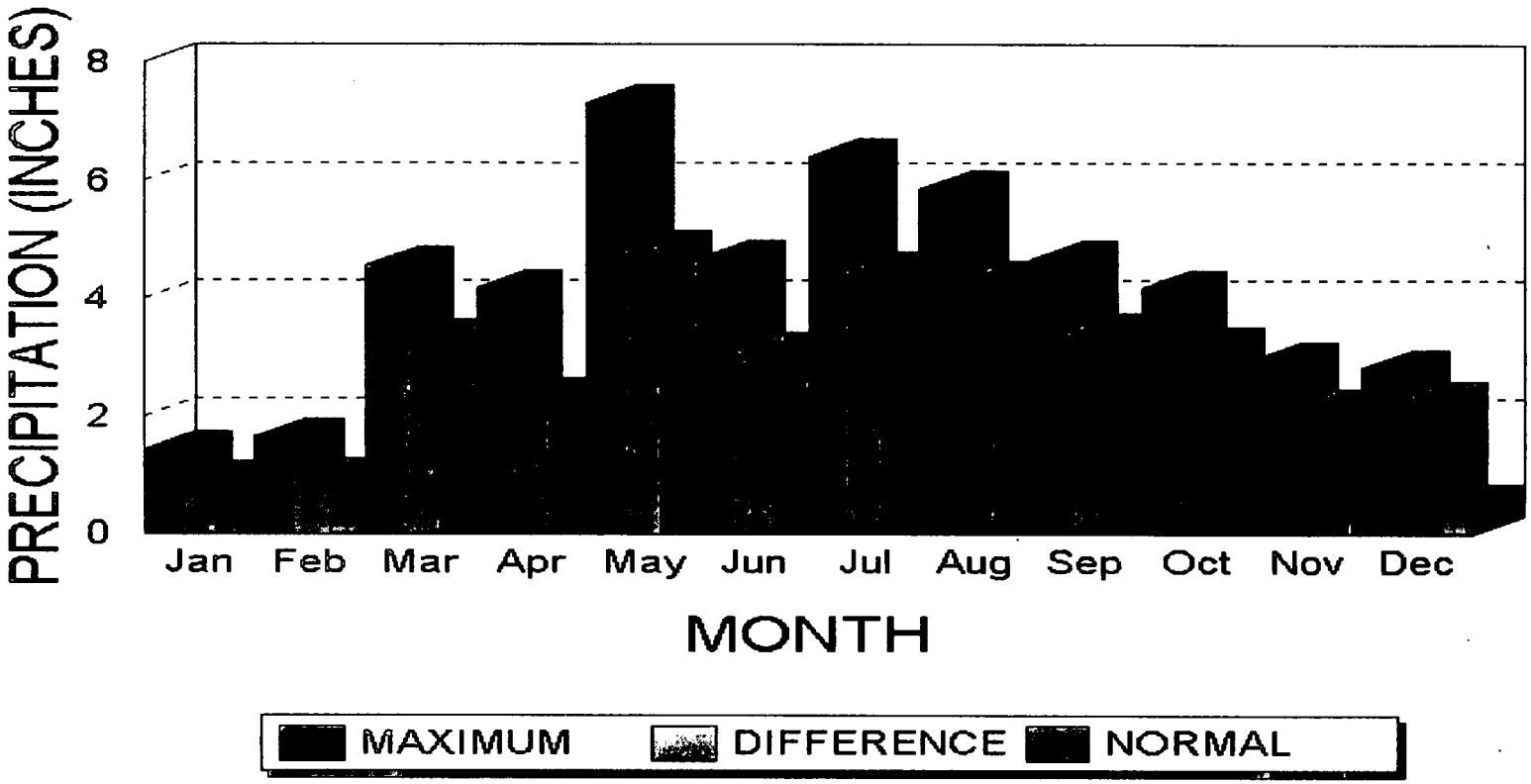
Figure III.D-3

Solar Evaporation Ponds
Operable Unit N.4, IM/IRA EA DD
Composite UHSU Hydrograph

rf85x11h



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GOLDEN, COLORADO

Figure III.D-4

Solar Evaporation Ponds
Operable Unit No.4, IM/RA EA DD
Monthly Precipitation Data
for the Denver Area

ou4IVa.cdr nap 51194

TABLE III.D-1
UHSU WATER TABLE FLUCTUATIONS

Borehole	HIGH 1	HIGH 2	HIGH 3	HIGH 4	AVE HIGH	MAX HIGH	MIN HIGH	DIFF(MAX-AVE)
B208089	5925.5	5925.1	5924.1	5923.9	5924.65	5925.5	5923.9	0.85
B208589	5854.95	5854.75	5854.65	5853.9	5854.563	5854.95	5853.9	0.3875
B208789	5905.25	5905.2	5903.75	5903.1	5904.325	5905.25	5903.1	0.925
B210489	5855.4	5855.1	5854.9	5854.6	5855	5855.4	5854.6	0.4
P207489	5976.7	5976.5	5976.4	5975.9	5976.375	5976.7	5975.9	0.325
P207689	5961.95	5961.1	5961.1	5960.75	5961.225	5961.95	5960.75	0.725
P207889	5960.95	5960.7	5960.2	5959.95	5960.45	5960.95	5959.95	0.5
P209289	5969.75	5969.7	5969.35	5969.25	5969.513	5969.75	5969.25	0.2375
P209789	5961.6	5960.4	5960.25	5959.8	5960.513	5961.6	5959.8	1.0875
P209989	<5889.92	<5889.92	<5889.92	<5889.92	<5889.92	0	0	0
P213989	<5947.38	<5947.38	<5947.38	<5947.38	<5947.38	0	0	0
P218389	5949.6	5948.95	5947.9	5946	5948.113	5949.6	5946	1.4875
P219089	5939.9	5937	5936	5935.6	5937.125	5939.9	5935.6	2.775
P219189	5933.6	5933.6	5931.25	5931.1	5932.388	5933.6	5931.1	1.2125
P219489	5947.6	5947.5	5946.6	5945.9	5946.9	5947.6	5945.9	0.7
1386	5839	5838.25	5838.25	5837.9	5838.35	5839	5837.9	0.65
1586	5845.7	5845.2	5845	5844.55	5845.113	5845.7	5844.55	0.5875

TABLE III.D-1 (Continued)
UHSU WATER TABLE FLUCTUATIONS

1786	5865	5864.5	5864.45	5864.25	5864.55	5865	5864.25	0.45
1886	5880.5	5880.4	5879.8	5879.2	5879.975	5880.5	5879.2	0.525
2086	5951.5	5950.75	5950.4	5950.3	5950.738	5951.5	5950.3	0.7625
2286	5973.95	5973.8	5973.65	5972.9	5973.575	5973.95	5972.9	0.375
2486	5976.25	5976.25	5976	5975.8	5976.075	5976.25	5975.8	0.175
2686	5967.7	5967.25	5967.25	5966.8	5967.25	5967.7	5966.8	0.45
2886	5961.2	5959.6	5959.5	5959	5959.825	5961.2	5959	1.375
2986	5953.3	5953.05	5952.4	5951.8	5952.638	5953.3	5951.8	0.6625
3787	5963.1	5963.05	5962.8	5962.7	5962.913	5963.1	5962.7	0.1875
3887	5965.7	5965.45	5965.4	5965.2	5965.438	5965.7	5965.2	0.2625
5687	5973.85	5973.55	5973.4	5973.05	5973.463	5973.85	5973.05	0.3875
40193	<5880.7	<5880.7	<5880.7	<5880.7	<5880.7	0	0	0
41193	5957.6	5957.4	5957	5956.95	5957.238	5957.6	5956.95	0.3625
41693	5962.2	5962.2	5962.2	5962.15	5962.188	5962.2	5962.15	0.0125
42993	5970.3	5970.05	5969.95	5969.8	5970.025	5970.3	5969.8	0.275
43893	5968.6	5968.55	5968.1	5967.95	5968.3	5968.6	5967.95	0.3
43993	5964.2	5963.8	5963.5	5963	5963.625	5964.2	5963	0.575
44893	5913.9	5913.5	5913.4	5913.3	5913.525	5913.9	5913.3	0.375

TABLE III.D-1 (Continued)
UHSU WATER TABLE FLUCTUATIONS

44993	<5914.2	<5914.2	<5914.2	<5914.2	<5914.2	0	0	0
45093	<5916.3	<5916.3	<5916.3	<5916.3	<5916.3	0	0	0
45293	<5912.3	<5912.3	<5912.3	<5912.3	<5912.3	0	0	0
45393	<5907	<5907	<5907	<5907	<5907	0	0	0
45593	<5928	<5928	<5928	<5928	<5928	0	0	0
45793	5948.55	5946.65	5946.65	5946.55	5947.1	5948.55	5946.55	1.45
45993	5948.5	5946.6	5945.75	5945.7	5946.638	5948.5	5945.7	1.8625
46093	<5925.6	<5925.6	<5925.6	<5925.6	5925.6	0	0	0
46293	5941.25	5940.9	5940.6	5940.45	5940.8	5941.25	5940.45	0.45
46393	5881.9	5881.05	5880.75	5880.3	5881	5881.9	5880.3	0.9
46493	<5887.3	<5887.3	<5887.3	<5887.3	5887.3	0	0	0
76192	<5954	<5954	<5954	<5954	5954	0	0	0
B208189	5919.7	5916.7	5916.6	5916.4	5917.35	5919.7	5916.4	2.35
B208289	5836.3	5836.1	5835.9	5835.8	5836.025	5836.3	5835.8	0.275
B208389	<5869	<5869	<5869	<5869	<5869	0	0	0
B208489	<5847.1	<5847.1	<5847.1	<5847.1	5847.1	0	0	0
B208689	5860.25	5857.1	5856.6	5856.4	5857.588	5860.25	5856.4	2.6625
B210389	5854.9	5852.8	5852.4	5852.2	5853.075	5854.9	5852.2	1.825

TABLE III.D-1 (Continued)
UHSU WATER TABLE FLUCTUATIONS

P207589	5952.55	5951.25	5950.6	5950.55	5951.238	5952.55	5950.55	1.3125
P207789	5939.25	5939.2	5939.05	5938.75	5939.063	5939.25	5938.75	0.1875
P207989	5950	5949.6	5948.7	5947.9	5949.05	5950	5947.9	0.95
P208989	5952.4	5951.1	5950.25	5949.8	5950.888	5952.4	5949.8	1.5125
P209089	5951.75	5951.25	5951.1	5949.5	5950.9	5951.75	5949.5	0.85
P209189	5974.5	5972	5972	5971.9	5972.6	5974.5	5971.9	1.9
P209389	5967.2	5966.5	5966.25	5966.1	5966.513	5967.2	5966.1	0.6875
P209489	5953.6	5952.9	5952.4	5952.25	5952.788	5953.6	5952.25	0.8125
P209589	5933.5	5932.45	5932	5931.9	5932.463	5933.5	5931.9	1.0375
P209689	5937.9	5937.25	5936.5	5936.4	5937.013	5937.9	5936.4	0.8875
P209889	5938.4	5937.9	5937.9	5937.75	5937.988	5938.4	5937.75	0.4125
P210089	5882.6	5882.25	5881.75	5881.7	5882.075	5882.6	5881.7	0.525
P210189	5970.9	5970.5	5970.4	5970.2	5970.5	5970.9	5970.2	0.4
P210289	5955.9	5953.45	5953	5952.45	5953.7	5955.9	5952.45	2.2
P213889	<5942.8	<5942.8	<5942.8	<5942.8	5942.8	0	0	0
P219589	5946.25	5946.25	5945	5944	5945.375	5946.25	5944	0.875
o2691	5931	5929.1	5929	5927.4	5929.125	5931	5927.4	1.875
3086	5954.45	5954.45	5954.3	5953.8	5954.25	5954.45	5953.8	0.2

TABLE III.D-1 (Continued)
UHSU WATER TABLE FLUCTUATIONS

3186	<5955.3	<5955.3	<5955.3	<5955.3	5955.3	0	0	0
41993	5970.55	5968.9	5967.95	5967	5968.6	5970.55	5967	1.95
42393	5971.7	5971.7	5971.7	5971.65	5971.688	5971.7	5971.65	0.0125
43293	5943.25	5942.45	5942.35	5942	5942.513	5943.25	5942	0.7375
43593	5973.45	5973.2	5972.75	5972.7	5973.025	5973.45	5972.7	0.425
45693	5937.25	5936.25	5932.9	5931.6	5934.5	5937.25	5931.6	2.75
45893	5949.2	5945.45	5945.25	5945.25	5946.288	5949.2	5945.25	2.9125
46193	5929.8	5929.6	5929.6	5929	5929.5	5929.8	5929	0.3
								0.73227848101

III.D.2 Modeling of Potential Groundwater Rise

A simulation of the potential impacts of a rising ground water table was performed to predict the effect of the contaminated vadose zone soils on ground water quality in the vicinity of the boreholes, and at the downgradient IHSS boundary. Only the contaminated media contained within Individual Hazardous Substance Site (IHSS) 101, (which includes only the vadose zone soils in the vicinity of the SEPs), was the focus of the simulation to predict ground water quality at the downgradient IHSS boundary. The IHSS boundary is essentially the Point of Compliance (POC) for ground water quality with respect to the SEP closure. A vadose zone flushing model, and a groundwater contaminant migration model (MYGRT) were utilized to simulate vadose zone material/ground water physical interactions and evaluate contaminant leaching and migration from the vadose zone soils to ground water. This model assumes a relatively rapid and simplistic removal mechanism. The vadose zone flushing model is discussed in detail in the next section. The products of these models are considered to be conservative estimates of ground water contaminant concentrations at the IHSS boundary due to the vadose zone soils from varying boring locations. Figure III.D-5, Analysis of Ground water Quality Impacts: Potential Effects of a Rising Phreatic Surface, illustrates the concepts used in the modeling simulation.

This simulation was used to estimate the concentration of each contaminant at the IHSS boundary by using the leachate output from the flushing model as the initial source concentration for MYGRT. Conservative values and assumptions were used to model a potential leachate release from vadose zone soils and transport via groundwater to the IHSS boundary.

Modeled Contaminants

A staged approach to investigating potential ground water impacts was adopted. This approach was designed to identify whether contaminated vadose zone soils that could become saturated by a rising ground water table over time could significantly impact ground water quality at the site. The first stage in this process focussed on those PCOCs most likely to potentially impact ground water quality because they are: 1) very mobile (mobility) or; 2) present in large quantities (mass); or 3) governed by stringent ground water comparison criteria (the IM/IRA cleanup goals for cross-media contamination). Three general classes of chemical (i.e., metals/inorganics, radionuclides, and organics) are represented in the PCOC list. Thus ten of the approximately 44 PCOCs were selected and modeled using a vadose zone flushing and MYGRT models to determine potential ground water impacts. The ten selected PCOCs were: cadmium; cyanide; nitrate/nitrite; zinc; Aroclor-1254; indeno(1,2,3-cd)pyrene; methylene chloride; americium-241; tritium; and uranium-235. These ten contaminants were selected as part of the first stage as they would most likely drive the volume and extent of the media warranting remediation.

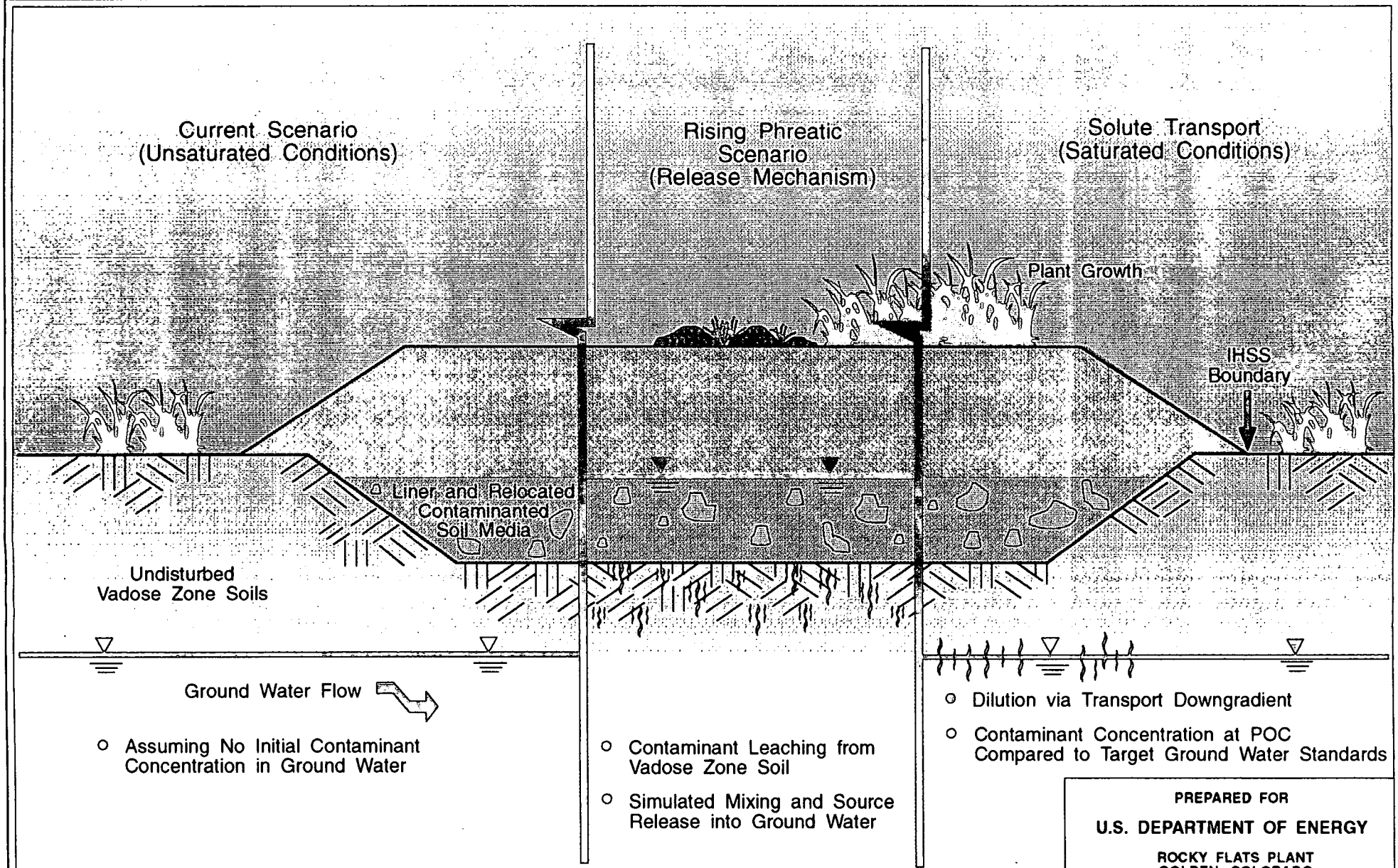

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Figure III.D-5

Solar Evaporation Ponds
Operable Unit No.4, IM/IRA EA DD
Analysis of Ground Water Quality Impacts:
Potential Effects of Rising Phreatic Surface

722446C.cdr nap 5/1194

Cadmium was selected because it is ubiquitous of the site, is relative toxic, and persistent. Cyanide was selected because it is relatively mobile. Nitrate/nitrite was modeled because it has historically had a significant impact on ground water. Nitrate/nitrite is also very mobile and has a relatively stringent ground water comparison criteria. Zinc was selected for completeness. Although zinc is not toxic, nor is it very mobile, it was selected because of its persistence and to be used for a baseline to compare against the other results.

The three selected organics, Aroclor-1254, indeno(1,2,3-cd)pyrene, and methylene chloride, were chosen primarily for their mobility. While Aroclor-1254 and methylene chloride are relatively toxic, there is no toxicity information specifically for indeno(1,2,3-cd)pyrene. Toxicity data for benzo(a)pyrene was used to develop ground water criteria for indeno(1,2,3-cd)pyrene following EPA guidance (EPA, 1993d). Indeno(1,2,3-cd)pyrene was selected to represent the general mobility of the PAHs. The modeling results indicate that the mobility of all the PAHs would likely cause PAH concentrations in ground water to exceed comparison criteria.

The radionuclides, americium-241, tritium, and uranium-235 were modeled as representative radionuclide contaminants. Americium-241 was shown to be relatively mobile (see part IV of this document). Tritium was selected because it is not retarded in saturated systems. Uranium-235 was selected because it has the most stringent ground water comparison criteria of all the uranium species identified as PCOCs for the site and is a suspected site related contaminant.

Comparison Criteria

Because ground water remediation is a Phase II activity, ground water cleanup standards have not yet been established. For the purposes of this evaluation, ground water protection criteria were developed to be protective of ground water with respect to the onsite resident (described in Section III.2.2.1.1) and for the downgradient IHSS boundary. During Phase II, alternative ground water comparison criteria may be developed. The comparison criteria developed for Phase I in this section are developed to be protective of human health and the environment. The ground water protection criteria are not intended to be final cleanup standards for ground water remediation and are only to be used for the purposes of this evaluation. Table III.D-2 presents the ground water comparison criteria assumed for the exercise.

TABLE III.D-2
GROUND WATER COMPARISON CRITERIA
FOR OU 4 IM/IRA

Contaminant	(1) Background Values at RFP and OU4		(2) Residential Risk-Based PRG	(3) Highest Value
Metals/Inorganics (mg/l)				
Barium	1.64E-01		2.56E+00	2.56E+00
Beryllium	-		1.98E-05	1.98E-05
Cadmium	4.66E-03		1.35E-05	4.66E-03
Cesium	8.68E-01		-	8.68E-01
Cyanide	9.71E-02		7.30E-01	7.30E-01
Lithium	1.60E-01		-	1.60E-01
Manganese	1.85E-01		1.82E-01	1.85E-01
Mercury	-		1.10E-02	1.10E-02
Nitrate	-		5.84E+01	5.84E+01
Nitrite	-		3.65E+00	3.65E+00
Silver	7.78E-03		-	7.78E-03
Strontium	1.03E+00		2.19E+01	2.19E+01
Uranium	-		1.10E-01	1.10E-01
Zinc	5.57E-02		1.10E+01	1.10E+01
Organics (mg/L)				
Acetone	-		3.65E+00	3.65E+00
Arochlor-1254	-		1.10E-05	1.10E-05
Benzo(a)anthracene	-		1.16E-04	1.16E-04
Benzo(a)pyrene	-		1.16E-05	1.16E-05
Benzo(b)fluoranthene	-		1.16E-04	1.16E-04
Benzo(ghi)perylene	-		1.16E-03	1.16E-03
Benzo(k)fluoranthene	-		1.16E-03	1.16E-03
Bis(2-ethylhexyl)phthalate	-		6.07E-03	6.07E-03
2-Butanone	-		2.47E+00	2.47E+00
Chloroform	-		3.90E-05	3.90E-05
Chrysene	-		1.16E-02	1.16E-02
Di-n-butyl phthalate	-		3.65E+00	3.65E+00
Fluoranthene	-		1.46E+00	1.46E+00
Indeno(1,2,3-cd)pyrene	-		1.16E-04	1.16E-04
Methylene Chloride	-		1.13E-02	1.13E-02
Phenanthrene	-		-	-
Pyrene	-		1.10E+00	1.10E+00
Toluene	-		2.02E+00	2.02E+00
Radionuclides (pCi/L)				
Americium-241	2.11E+00		1.98E-01	2.11E+00
Cesium-134	-		3.25E-01	3.25E-01
Cesium-137	2.14E+00		1.70E+00	2.14E+00
Gross Alpha	9.39E+01		-	9.39E+01
Gross Beta	3.73E+01		-	3.73E+01
Plutonium-239,240	5.80E-02		2.07E-01	2.07E-01
Radium-226	6.30E-01		3.97E-01	6.30E-01
Strontium-89	1.05E+00	a/	1.59E+01	1.59E+01
Strontium-90	1.05E+00	a/	1.44E+00	1.44E+00
Tritium	5.79E+02		1.37E+02	5.79E+02
Uranium-233,234	7.42E+01		2.98E+00	7.42E+01
Uranium-235	1.88E+00		2.98E+00	2.98E+00
Uranium-238	5.16E+01		2.98E+00	5.16E+01

(1) Background Geochemical Characterization Report (EG&G, 1993)
(2) Risk-base PRGs based on standard residential scenario per RAGS, Part B (EPA, 1991)
(3) This is the highest of either the background concentration or risk-based PRG.

Notes: a/ Value is for Strontium-89,90.

III.D.2.1. Vadose Zone Flushing Model

A very simple analytical model was developed to simulate the transfer of contaminants from vadose zone soils to the ground water when and if ground water were to saturate the soils due to a rise of the water table. The model estimates contaminant concentrations in the fluid draining from the soils as the ground water table recedes. For the purpose of this exercise, the ground water table was assumed to rise 2.2 feet above the high mean ground water table elevation. Background (initial) concentrations of all contaminants in the ground water were assumed to be zero. A representative column of vadose zone soils, 67.06 centimeters (2.2 feet) high and one square centimeter in cross section was used to calculate a column volume. The density of the soils was used to calculate the mass of the soils within the representative column. The volume of the void space within the column was calculated based on a porosity of 36.1 percent.

The total concentrations for each analyte were multiplied by the mass of soils within the column to calculate the mass of analyte within the column. Leachability efficiencies of 100 percent for nitrate/nitrite and tritium, and 10 percent for all other analytes were utilized in the calculations to estimate the mass of analyte which would transfer to the solution in the void space within the column. These percentages represent the fraction of total contaminant mass in the soil which is transferred to pore water during the initial flush and subsequent ground water flushes and thus allows the calculation of contaminant concentrations in the leachate. The selection of these percentages was based, in part, on limited observations of seasonal variations in radionuclide activity in SEP-proximal ground water and, in part, on professional judgement. These contaminant concentrations are presented in Table III.D-3. The results of the subsequent flushing events on leachate concentrations of nitrate/nitrite or tritium is presented in Figure III. D-6. The concentration of contaminants in the initial leachate, as well as the total mass of a contaminant in the leachate serves as the input to the MYGRT model. The MYGRT model was then used to calculate the ground water contaminant concentration at the downgradient IHSS boundary. Three distances to the IHSS boundary were modeled for comparison; 100, 500 and 900 feet.

III.D.2.2 Ground Water Contaminant Flow Modeling

MYGRT predicts the migration of both inorganic and organic solutes downgradient of sources (i.e. waste disposal sites or spills). The processes used in MYGRT include; advection, dispersion, retardation, and decay. MYGRT can simulate problems in one or two dimensions using either horizontal or vertical views.

TABLE III.D–3
Results of Vadose Zone Flushing Model

Analyte	Initial Concentration	Mass of Analyte in Soil	Solubility	Groundwater Concentration of Leached Analyte
Metals	(mg/kg)	(mg)		(mg/l)
Cadmium	547.000	62.303	0.1	257.375
Nitrate/Nitrite	5200.000	592.280	1.0	24467.087
Zinc	66.000	7.517	0.1	31.054
Radionuclides	(pCi/kg)	(pCi)		(pCi/l)
Americium–241	3300.000	375.870	0.1	1552.719
Tritium	50300.000	5729.170	1.0	236672.013
Uranium–235	870.000	99.093	0.1	409.353
Organics	(mg/kg)	(mg)		(mg/l)
Aroclor–1254	210.000	23.919	0.1	98.809
Cyanide	43.000	4.898	0.1	20.232
Indeno(1,2,3–cd)pyrene	0.440	0.050	0.1	0.207
Methylene Chloride	0.025	0.003	0.1	0.012

Assumptions:

Ground water elevation 2.2 feet above the mean high water table
Uniform distribution of contaminants within soil media
Solubilities based on conservative estimates
Density of soil = 1.7 grams per cubic centimeter
Porosity = 0.361

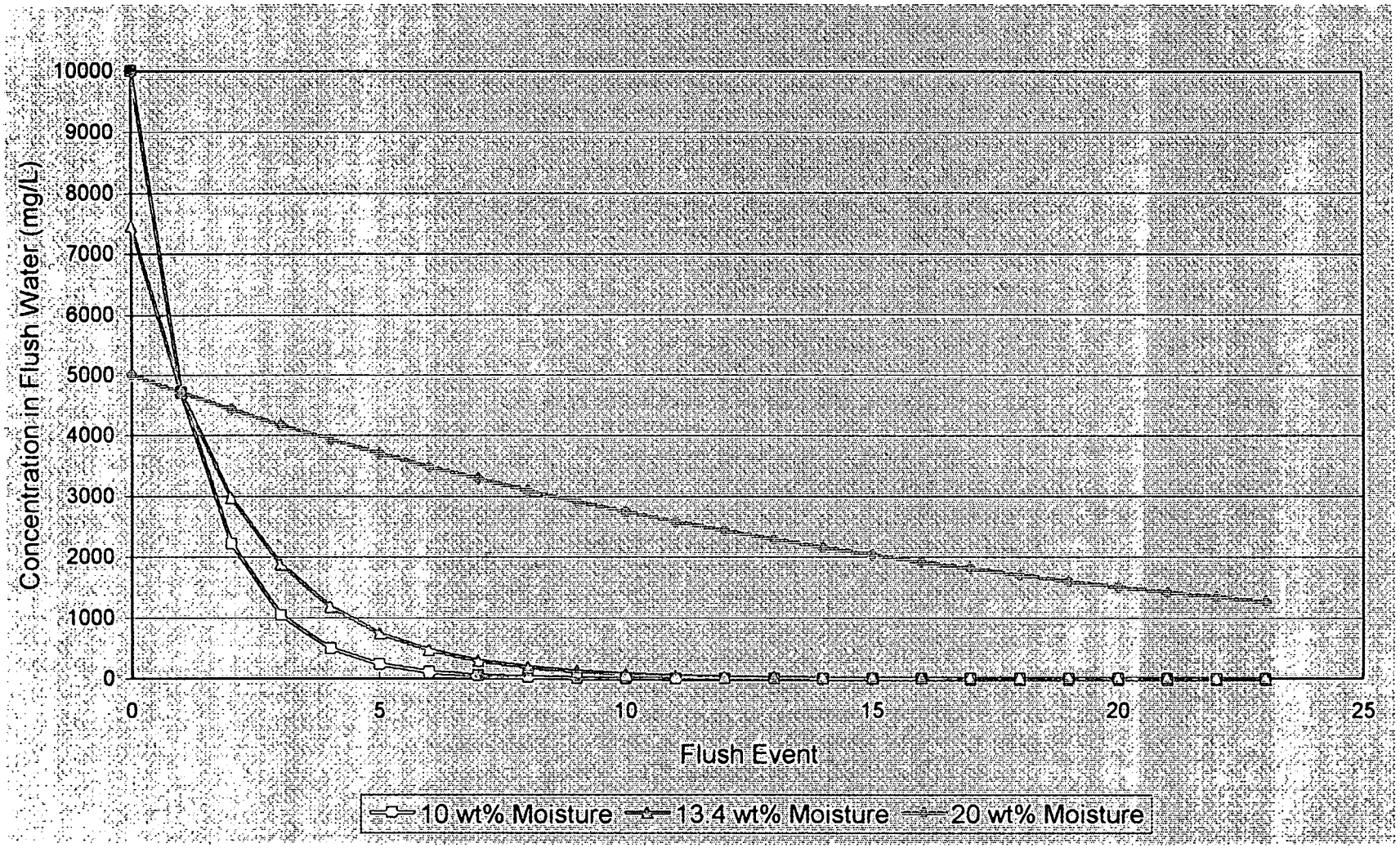

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Figure III.D-6

Solar Evaporation Ponds
Operable Unit N.4, IM/IRA EA DD
Theoretical Flushing of Nitrate or Tritium
for Various Initial Moisture Contents

rf85x11h

Theoretical Basis for MYGRT

MYGRT is designed to simulate the fate and transport of organic or inorganic solutes in ground water downgradient of a source based on the partial differential equation describing two-dimensional advection-dispersion-decay-adsorption equation:

$$D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - V_x \frac{\partial C}{\partial x} - kR_d C = R_d \frac{\partial C}{\partial x}$$

where;

- D = Diffusion coefficient,
- C = Concentration of solute in ground water,
- x = Distance from disposal site in direction of primary flow,
- y = Transverse distance from center of source perpendicular to the primary flow direction,
- R_d = Retardation factor,
- V_x = Seepage velocity along the primary, longitudinal ground water flow,
- k = Net transformation or decay rate constant.

This partial differential equation has been numerically approximated by the MYGRT code. In brief, the transport equations in the MYGRT code are built upon the assumptions that the ground water flow velocity remains constant over the modeled area and that dispersion is adequately represented by Fick's Law. MYGRT models adsorption as a linear equilibrium partitioning relationship between aqueous and solid phases. Retardation (R_d) is used as a measure of the partitioning between liquid and solid phases. Retardation is incorporated into the numerical solution using the following expression:

$$R_d = 1 + \left(\frac{1-\theta}{\theta}\right)\rho_b K_d$$

where;

- ρ_b = Bulk density of permeable material,
- θ = Volumetric moisture content (decimal fraction), at saturation = porosity,
- K_d = Retardation coefficient.

The behavior of the contaminants in the ground water was modeled as a continuous leachate source the size of the model area under investigation. MYGRT was used to calculate the contaminant concentration in the aquifer by mixing rising ground water with the leachate

simulated using the catastrophic dissolution model based on its flux and composition. The rising ground water was assumed to have concentrations of zero for this exercise.

Physical Input Parameters for MYGRT

To investigate potential impacts of contaminants leaching from surficial and vadose soil on ground water quality, a simple conceptual site model describing ground water flow was developed. The mean saturated ground water velocity of 21.8 ft/yr (6.64 m/yr) as reported in the RCRA Groundwater Monitoring Report for OU4 was used in solute transport simulations. The direction of ground water flow across the entire modeled area was assumed to be in the northeastern direction toward North Walnut Creek. Although this is most likely an oversimplification of the hydrogeology at the site, it should yield conservative results. Horizontal and transverse dispersion values were conservatively estimated. Summary of site-specific MYGRT input parameters are presented in Table III.D-4.

Chemical Input Parameters for MYGRT

The only chemical-specific parameters required by MYGRT are initial source concentration and the chemical-specific retardation coefficient (R_d). The initial source-concentrations used for each contaminant were derived from the vadose zone flushing model. Retardation coefficients of 4.01 (K_d = 1) and 7.02 (K_d = 2) were included in the MYGRT code for the radionuclides and metals for this analysis with the exception of tritium. For tritium it was assumed that all of the contaminant concentration would be in the liquid phase so only a K_d value of 1 was assumed. They represent a worst-case, and an upper bound estimate of potential impact on ground water quality at the IHSS boundary. Specific retardation factors were used for the organic contaminants. K_d values for the organics were calculated by multiplying the chemical specific sorption coefficient (K_{oc}) by the fraction of naturally occurring organic carbon (f_{oc}) in the soil. The f_{oc} value used was 0.0045, which is the value of the Rocky Flats alluvium.

MYGRT Modeling

MYGRT initially mixed the leachate volume with the ground water in the saturated interval beneath the corresponding unit area of soil. The resultant volume of contaminated ground water was then subjected to porous media transport to the IHSS boundary via the algorithms in MYGRT. The transport distance was taken the distance from the sample borehole to the downgradient IHSS boundary (northeast toe of the cover). The results of the model calculations are maximum analyte concentrations in ground water at the IHSS boundary. These values are presented in Table III.D-5, and were compared to the established site-specific ground water comparison criteria developed earlier.

TABLE III.D-4
Summary of Site-Specific MYGRT Input Parameters

Parameter	Value
Groundwater velocity (m/yr)	6.64
Horizontal dispersion coefficient (m/yr)	0.996
Transverse dispersion (m/yr)	0.329
Source Area (m^2)	8350
Infiltration rate (m/yr)	0.3
Effective porosity	0.361
Depth of mixed water (m)	5.18
Time leachate starts (yr)	0
Time leachate ends (yr)	0.25
Average distance to downgradient IHSS boundary (m)	30.5 - 274

Uncertainties Analysis

All fate and transport calculations require simplifying assumptions about site characteristics and chemical properties. It is impossible to exactly simulate actual fate and transport mechanisms, which are characteristically complex at most sites. A rudimentary sensitivity analyses on the MYGRT code using both OU4 leachate sources described above demonstrated that the model results are affected by the chemical-specific retardation value. In the absence of site-specific K_d values, the technical literature and historic site characterization data were reviewed to identify a range of potential retardation values for each contaminant. Although the model results presented herein were developed using conservative assumptions and estimates, efforts are currently underway to verify that natural attenuation of metal and radionuclide species has and is occurring at OU4. Liquid pond waste data is currently being compared to downgradient well data to determine the source and nature of contamination migration at the site. Geochemical analyses of these two solutions can be used to empirically show that metal- and radionuclide-containing waste from the SEPs have been effectively retarded, even under saturated conditions. Once these data are available, these model results will be reviewed to determine whether appropriate assumptions were used.

III.D.2.4 Constituents of Concern Based on Cross-Media Contamination

As stated previously, the focus of this report is not to estimate risks posed by contaminants in the ground water at OU4. However, the potential impacts of soil contaminants on ground water quality could not be ignored. The vadose zone flushing and MYGRT models were used to evaluate the potential for contaminants in soils to impact ground water quality. Both model used extremely conservative assumptions and/or input parameters, consequently, all results of the models should be taken to be extremely conservative as well.

Table III.D-5 presents the results of the comparison of modeled ground water concentrations to their ground water comparison criteria. Of the ten PCOCs modeled, cadmium, nitrate/nitrite, americium-241, tritium, and uranium-235 exceeded their comparison criteria. These results indicate that measures will be necessary to control the potential rise in ground water into the contaminated vadose zone soils and pore water.

TABLE III.D-5
Summary of MYGRT Modeling Results

Analyte	Concentrations at Point of Compliance (POC)						Comparison Criteria	Comments
	Distance to Point of Compliance (POC)							
	100 feet		500 feet		900 feet			
Metals (mg/l)	K_d=1	K_d=2	K_d=1	K_d=2	K_d=1	K_d=2		
Cadmium	**9.77**	**3.98**	**4.34**	**2.47**	**3.23**	**1.84**	0.005 mg/l	exceeds comparison criteria
Nitrate/Nitrite	**928.61**	**396.53**	**412.26**	**235.20**	**306.93**	**172.73**	58.4 mg/l (NO_3)	exceeds comparison criteria
							3.65 mg/l (NO_2)	exceeds comparison criteria
Zinc	1.18	0.67	0.52	0.30	0.39	0.22	10.9 mg/l	does not exceed comparison criteria
Radionuclides (pCi/l)	K_d=1	K_d=2	K_d=1	K_d=2	K_d=1	K_d=2		
Americium-241 1/	**57.56**	**38.41**	**23.25**	**14.43**	**15.72**	**9.07**	2.11 pCi/l	exceeds comparison criteria
Tritium 2/	**3242.4**	--	23.48	--	0.2798	--	578.79 pCi/l	exceeds comparison criteria
Uranium-235	**15.54**	**8.86**	**6.90**	**3.94**	**5.14**	2.93	2.98 pCi/l	exceeds comparison criteria
Organics (ug/l)								
Aroclor-1254	< 1E-06		< 1E-06		< 1E-06		0.011 ug/l	K_d=5517, does not exceed comparison criteria
Cyanide	< 1E-06		< 1E-06		< 1E-06		730 ug/l	K_d=215384, does not exceed comparison criteria
Indeno(1,2,3-cd)pyrene	< 1E-06		< 1E-06		< 1E-06		0.116 ug/l	K_d=418443, does not exceed comparison criteria
Methylene Chloride	1.51		0.687		0.051		11.3 ug/l	K_d=1.118, does not exceed comparison criteria

1/ Half-life of 458 years taken into account.
2/ Half-life of 12.3 years taken into account.

APPENDIX III-E

ARAR/TBC IDENTIFICATION AND RATIONALE

ARAR Type: Action - DOE Radiation Protection Requirements for Public Health and the Environment

Federal Citation: 10 CFR 834 (Proposed)

State Citation: None

Requirement Summary: DOE activities are to be conducted so that radiation exposures to members of the public are maintained below acceptable limits. This proposed regulation also addresses the management of real and personal property to control exposures to residual radioactive materials. DOE facilities have the capability, consistent with the types of operations conducted, to monitor routine and non-routine releases and asses doses.

Corresponding TBCs: DOE Order 5400.5

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	TBC	This standard is being invoked to ensure proper control of fugitive particulates during regrading and/or excavation activities.
II	TBC	
III	TBC	
IV	TBC	
V	TBC	

ARAR Type: Location - Evaluate Federal Projects for Potential Floodplain and Wetland Impacts

Federal Citation: Clean Water Act - 33 USC § 1344
10 CFR 1022

State Citation: CRS 25-12-101 to 25-12-108

Requirement Summary: Federal agencies are to avoid construction within a floodplain or wetland unless there are no practicable alternatives. If it is necessary to locate any of the remediation facilities within a floodplain or wetland, all practicable measures are to be taken to minimize any impacts to the floodplain or wetland. Actions must minimize destruction, loss, or degradation of wetlands, as defined by Executive Order 11990, Section 7. A floodplain or wetland assessment must be published in the Federal Register prior to taking any action within the floodplain/wetland to allow time for public review and comment.

Corresponding TBCs: Executive Orders 11988 and 11990

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Although no wetlands are expected to be impacted, all Federal actions are required to be assessed.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Worker Protection Requirements for Hazardous Waste/Remediation Operations

Federal Citation: Occupational Safety and Health Act - 29 USC §§ 657 and 667
29 CFR 1910, Subpart Z

State Citation: None

Requirement Summary: The health and safety requirements provided in 29 CFR 1910.120 apply specifically to workers engaged in the handling of hazardous waste/materials at uncontrolled hazardous waste sites. Implementation of remedial activities is required to be conducted by OSHA-trained personnel and under OSHA requirements. All remediation employers are required to develop and implement a written safety and health program for their employees involved in hazardous waste operations.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Activities associated with this GRA would not result in the potential exposure of workers to safety or health hazards.
II	Applicable	Although OSHA standards are not considered ARARs (see 55 FR 8680), 29 CFR 1910.120 applies on its own merits to maintain worker safety and health. This regulation is being listed for completeness and to ensure that these protection requirements are not overlooked when preparing the implementation plans for the selected IM/IRA.
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Occupational Safety and Health

Federal Citation: Occupational Safety and Health Act - 29 USC § 668
29 CFR 1926

State Citation: None

Requirement Summary: Federal agencies are required to establish and maintain an effective and comprehensive occupational safety and health program which is consistent with the standards promulgated under the Occupational Safety and Health Act. Specifically, 29 CFR 1926 Subpart P provides guidelines (including requirements for egress, safety, and protective systems) for workers engaged in activities related to excavations.

Corresponding TBCs: DOE Order 5483.1A
ACGIH 1992-1993
NIOSH 1993

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Although OSHA standards are not considered ARARs (see 55 FR 8680), such non-environmental OSHA requirements would apply on their own merit. These OSHA standards apply to Federal Facilities as required by the Occupational Safety and Health Act [29 USC § 668] and Executive Order 12196; however, they are not independently enforced by OSHA. These occupational safety requirements are adopted and implemented under DOE Order 5483.1A. This regulation is being listed for completeness and to ensure that these protection requirements are not overlooked when preparing the implementation plans for the selected IM/IRA.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Location - Historical and Archeological Preservation

Federal Citation: Archaeological and Historic Preservation Act - 16 USC § 469
Archaeological Resources Protection Act - 16 USC § 470
36 CFR 65
36 CFR 800

State Citation: CRS 20-80-401

Requirement Summary: The Secretary of the Interior must be notified in writing whenever DOE finds or is notified in writing by an appropriate historical or archaeological authority that the activities in connection with a project may cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archaeological data. Any data that may be lost or destroyed must be preserved by the DOE or the Department of Interior.

Corresponding TBCs: DOE Environmental Compliance Guide (DOE/EP-0098)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Although no historic and archeological sites are expected to be impacted, all Federal actions are required to be assessed.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Fugitive Particulate Emissions

Federal Citation: None

State Citation: 5 CCR 1001 - Regulation 1, III.D

Requirement Summary: Any owner or operator of land that has been cleared of greater than one acre in non-attainment areas from which fugitive emissions will be emitted shall be required to use all available and practical methods which are technologically feasible and economically reasonable in order to minimize such emissions in accordance with the requirements of Section III.D. The RFP is located in a non-attainment area for particulates.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	These GRAs include regrading of the pond area which will involve more than one acre. As such fugitive particulate emissions need to be controlled.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - NESHAP, Radionuclide Emissions

Federal Citation: 40 CFR 61, Subpart H

State Citation: None

Requirement Summary: Emissions of radionuclides to the ambient air from DOE facilities shall not cause any member of the public to receive an effective dose equivalent in excess of 10 mrem per year above background. This limit is based on an effective dose equivalent as calculated per the International Commission on Radiological Protection's Publication No. 26.

Corresponding TBCs: DOE Order 5400.5
DOE Order 5820.2A Chapter III
10 CFR 834 (Proposed)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	No potential exists for the release of radionuclides under this GRA.
II	Applicable	Closure and remediation activities could involve the generation of airbrone particulates containing radionuclides. As such, measures to control fugitive emmissions need to be implemented.
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Stormwater Management Requirements

Federal Citation: 40 CFR 122.26

State Citation: 5 CCR 1002-3

Requirement Summary: Industrial facilities (as defined in 40 CFR 122.26) are required to submit a NPDES Stormwater Discharge Permit Application to US EPA by October 2, 1992. This permit application is to identify the site-wide monitoring program (including monitoring parameters and locations) for all stormwater discharges.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	This GRA may result in modification of the current RFP water management system. Any modifications and additional controls will need to be consistent with NPDES Stormwater Discharge Permit Application submitted for the RFP.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Hazardous Waste Determinations

Federal Citation: 40 CFR Part 262.11

State Citation: 6 CCR 1007-3, 262.11

Requirement Summary: Wastes generated during remedial activities must be characterized and evaluated according to the following method to determine whether the waste is hazardous:

- Determine whether the waste is excluded from regulation under 40 CFR 261.4
- Determine whether the waste is listed under 40 CFR 261, Subpart D
- Determine whether the waste is identified in 40 CFR 261, Subpart C by testing the waste according to specified test methods or by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Wastes generated during remediation must be characterized to evaluate regulatory compliance.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Generator Requirements for Hazardous Waste

Federal Citation: 40 CFR 262, Subpart B, C, and D

State Citation: 6 CCR 1007-3, 262, Subpart B, C, and D

Requirement Summary: These recording keeping requirements are not normally considered to be ARARs since they are procedural/administrative requirements; however, off-site actions response actions must comply with all applicable regulations both substantive and procedural/administrative. The off-site shipment of hazardous waste must adhere to these requirements, including waste packing, record keeping, container labelling, manifesting, biennial reporting, exception reporting, etc. The generator also shall keep any records identifying test results, waste analyses, or other determinations made in accordance with 40 CFR 262.11.

Corresponding TBCs: DOE Order 5820.2A, Chapter III
DOE Order 5480.3

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	This GRA does not involve an off-site response action; therefore, these adminstrative requirements are not considered to be ARARs.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	Off-site actions response actions must comply with all applicable regulations both substantive and procedural/administrative. The generator record keeping and reporting requirements would only be applicable in the case where hazardous waste is shipped off-site.
V	Applicable	

ARAR Type: Location and Action - General Standards for Hazardous Waste Facilities

Federal Citation: 40 CFR 264, Subpart B

State Citation: 6 CCR 1007-3, 264, Subpart B

Requirement Summary: This subpart outlines the general requirements for the owners and operators of a new hazardous waste treatment or storage facility. The requirements include: identification numbers, required notices, general waste analysis, security, inspection requirements, personnel training, waste compatibility, location standards, and construction standards.

Corresponding TBCs: Permit Applicants' Guidance Manual for the General Facility Standards of 40 CFR 264 (SW-968)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	This implementation action does not involve the development of a new facility for treatment or storage.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	If a treatment or storage facility is built, the operations will adhere to the requirements of 40 CFR 264 Subpart B. If the generated materials are treated or stored in an existing facility, the management of the material is the responsibility of the storage/treatment facility custodian.
V	Applicable	

ARAR Type: Action - Preparedness and Prevention for Hazardous Waste Facilities

Federal Citation: 40 CFR 264, Subpart C and D

State Citation: 6 CCR 1007-3, 264, Subpart C and D

Requirement Summary: New treatment and/or storage facilities must be designed, constructed, maintained, and operated to minimize the possibility of fire, explosion, or any unplanned release of hazardous waste. As such, preparedness and prevention includes: the testing and maintenance of equipment, access to communications or alarm system, required aisle space, and arrangement with local authorities.

Subpart D requires that the owner or operator have a contingency plan for the facility. This section outlines the contents of the contingency plan, amendment of the contingency plan, and emergency procedures.

Corresponding TBCs: Permit Applicants' Guidance Manual for the General Facility Standards of 40 CFR 264 (SW-968)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	This GRA does not result in materials being placed in a treatment or storage facility.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	If a treatment or storage facility is built, the operations will adhere to the requirements of 40 CFR 264 Subpart B. If the generated materials are treated or stored in an existing facility, the management of the material is the responsibility of the storage/treatment facility custodian.
V	Applicable	

ARAR Type: Action - Groundwater Protection and Monitoring

Federal Citation: 40 CFR 264, Subpart F

State Citation: 6 CCR 1007-3, 264, Subpart F

Requirement Summary: Substantive requirements for groundwater monitoring in 40 CFR 264 Subpart F are required for land disposal facilities where hazardous wastes remain in place after closure.

Corresponding TBCs: RCRA Groundwater Monitoring Technical Enforcement Guidance Document (530/SW-86-055)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Ground water monitoring requirements are not applicable to GRAs involving "clean" closure.
II	Applicable	If hazardous waste remains in-place following the completion of closure activities, the requirements for ground water monitoring will be applicable to ensure closure integrity.
III	Applicable	
IV	Not an ARAR	Ground water monitoring requirements are not applicable to GRA involving "clean" closure. Since the SEPs contained listed hazardous waste, the treated soils could also be classified as a listed hazardous waste in accordance with the "mixture" and "derived-from" rules. If the treated soils are classified as a listed hazardous waste and are used as backfill material, the ground water monitoring requirements could be invoked unless the treated soils are delisted. The basis for this GRA is that this requirement will not be an ARAR.
V	Not an ARAR	

ARAR Type: Action - Post-Closure and Use of Property

Federal Citation: 40 CFR 264.117 to .120

State Citation: 6 CCR 1007-3, 264.117 to .120

Requirement Summary: Post-closure care of the hazardous waste management unit is subject to the requirements of Sections 264.117 to .120 and must begin after completion of closure and continue for 30 years after that date. The 30-year monitoring and maintenance period can be extended or shortened based on CDH's review. Likewise post-closure use of the property must never be allowed to disturb the integrity of the final cover or any other components associated with the final cover with out prior approval from CDH.

Corresponding TBCs: RCRA Guidance Manual for Subpart G Closure and Post-Closure Care Standards and Subpart H Cost Estimating Requirements (530/SW-87/010)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Post-closure care requirements are not applicable to GRAs involving "clean" closure.
II	Applicable	If hazardous waste remains in-place following the completion of closure activities, the requirements for post-closure care will be applicable to ensure closure integrity.
III	Applicable	
IV	Not an ARAR	Since the SEPs contained listed hazardous waste, the treated soils could also be classified as a listed hazardous waste in accordance with the "mixture" and "derived-from" rules. If the treated soils are classified as a listed hazardous waste and are used as backfill material, the post-closure care requirements could be invoked unless the treated soils are delisted. The basis for this GRA is that this requirement will not be an ARAR.
V	Not an ARAR	

ARAR Type: Action - Requirements for Container Management and Storage

Federal Citation: 40 CFR 264, Subpart I

State Citation: 6 CCR 1007-3, 264, Subpart I

Requirement Summary: All hazardous waste to be store shall be managed in appropriate containers. The containers are to be maintained to prevent leakage and/or spillage. The management requirements include segregating the containers based on the compatibility, ignitability, and reactivity of the waste; conducting inspections; and providing a secondary containment system.

Corresponding TBCs: Guidance for Permit Writers: Facilities Storing Hazardous Waste in Containers

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Waste materials are not expected to be generated under these GRAs; therefore, container management and storage is not required.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	Hazardous waste may need to be stored under these GRAs; therefore, these requirements apply. Existing permit storage facilities will be used to the extent practicable.
V	Applicable	

ARAR Type: Action - Requirements for the Treatment and/or Storage of Hazardous Waste in Tanks

Federal Citation: 40 CFR 264, Subpart J

State Citation: 6 CCR 1007-3, 264, Subpart J

Requirement Summary: These requirements apply to treatment or storage of hazardous waste in tanks. Tanks must have sufficient shell strength, be compatible with the waste, have secondary containment, and have controls to prevent overfilling. Inspections must be conducted to ensure that corrosion, cracks, and leaks are discovered and repaired. Upon closure, all hazardous waste and hazardous waste residues are to be removed.

Corresponding TBCs: Permit Writers' Guidance Manual for Hazardous Waste Tank Standards (530/SW-89/003)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Waste materials are not treated or stored in tanks under these GRAs; therefore, this requirement is not listed as an ARAR.
II	Not an ARAR	
III	Not an ARAR	
IV	Not an ARAR	
V	Applicable	Hazardous waste may need to be treated or stored under this GRA; therefore, these requirements apply.

ARAR Type: Action - Establishment of a CAMU

Federal Citation: None

State Citation: 6 CCR 1007-3, 264.552 (Proposed)

Requirement Summary: The CAMU rule facilitates the implementation of reliable, effective, protective, and cost effective remedies while not creating unacceptable risks to humans or to the environment. Currently, the State of Colorado has not adopted the CAMU rule. The implementation of these GRAs are based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate a CAMU rule which will support the planned closure/remediation activities.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	This GRA does not involve the placement of hazardous waste; therefore, a CAMU designation is not required.
II	TBC	The provisions for a CAMU could be required since these GRAs could involve the placement of contaminated media designated as a hazardous waste to improve containment design.
III	TBC	
IV	Not an ARAR	All contaminated materials (including all hazardous wastes) will be removed from OU4; therefore, a CAMU designation is not required.
V	TBC	Since the SEPs contained listed hazardous waste, the treated liners and soils could also be classified as a listed hazardous waste in accordance with the mixture rule [6 CCR 1007-3, 261.3(a)(2)(iii)] and EPA's "contained-in" [OSWER Directive 1944.1989(30) and 58FR 48123], respectively. If the treated soils are classified as a listed hazardous waste, a CAMU may be required to allow the treated soil to be used as backfill material. If the treated soils are delisted or are not clasified as a listed hazardous waste, CAMU would not be required.

ARAR Type: Action - General Standards for Interim Status Hazardous Waste Facilities

Federal Citation: 40 CFR 265, Subpart B

State Citation: 6 CCR 1007-3, 265, Subpart B

Requirement Summary: General requirements of this section apply to all owners and operators of hazardous waste facilities, except as Section 265.1 provides otherwise. Security, training, and inspection programs will need to be maintained and revised, if necessary, to ensure that public health and the environment are adequately protected during the closure activities. The location (40 CFR 265.18) and construction quality assurance (40 CFR 265.19) standards do not apply to the closure of the SEPs.

Corresponding TBCs:

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Since the SEPs are interim status units, these general requirements apply to SEP operations including closure activities.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Interim Status Facility Closure Standards

Federal Citation: 40 CFR 265.111

State Citation: 6 CCR 1007-3, 265.111

Requirement Summary: The owner or operator must close his facility in a manner that (1) minimizes the need for further maintenance and (2) controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste decomposition products to the ground or surface waters, or to the atmosphere.

Corresponding TBCs: Interim Status Standards and General Standards for Closure and Post-Closure Care (PB81-189 763)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Since the SEPs are interim status units, this requirement applies to the closure of the SEPs.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Time allowed for Closure

Federal Citation: 40 CFR 265.113

State Citation: 6 CCR 1007-3, 265.113

Requirement Summary: The owner or operator must complete partial and final closure activities in accordance with the approved closure plan and within 180 days after approval of the IM/IRA DD or per CDH approved extension.

Corresponding TBCs: Interim Status Standards and General Standards for Closure and Post-Closure Care (PB81-189 763)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Since the SEPs are interim status units, this requirement applies to the closure of the SEPs.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Disposal or Decontamination of Equipment, Structures, and Soils

Federal Citation: 40 CFR 265.114

State Citation: 6 CCR 1007-3, 265.114

Requirement Summary: During the partial and final closure periods, all contaminated equipment, structures and soils must be properly disposed of or decontaminated. These materials shall be managed based on the results of characterization.

Corresponding TBCs: Interim Status Standards and General Standards for Closure and Post-Closure Care (PB81-189 763)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	The no action GRA is not expected to generate contaminated materials.
II	Applicable	These GRAs may involve the disposal or decontamination of equipment, structures, and soils. As such, this requirement will apply.
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Certification of Closure

Federal Citation: 40 CFR 265.115

State Citation: 6 CCR 1007-3, 265.115

Requirement Summary: Within 60 days of completion of closure, the owner or operator must submit to CDH by registered mail, a certification that the SEPs have been closed in accordance with the specifications in the approved closure plan.

Corresponding TBCs: Interim Status Standards and General Standards for Closure and Post-Closure Care (PB81-189 763)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Since the SEPs are interim status units, this requirement applies to the closure of the SEPs.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Survey Plat

Federal Citation: 40 CFR 265.116

State Citation: 6 CCR 1007-3, 265.116

Requirement Summary: No later than the submission of closure certification, the owner or operator must submit to the authority with jurisdiction over local land use, and to CDH a survey plat indicating the location and dimensions of the hazardous waste disposal unit.

Corresponding TBCs: Interim Status Standards and General Standards for Closure and Post-Closure Care (PB81-189 763)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Under these GRAs, hazardous waste may remain after closure; therefore, a survey plat may be required.
II	Applicable	
III	Applicable	
IV	Not an ARAR	If the SEPs are clean closed, or if the treated soils used for backfill are not classified as a hazardous waste or delisted, a survey plat is not required. The basis for this GRA is that this requirement will not be an ARAR.
V	Not an ARAR	

ARAR Type: Action - Closure/Post-Closure Care for Interim Status Surface Impoundments

Federal Citation: 40 CFR 265.228

State Citation: 6 CCR 1007-3, 265.228

Requirement Summary: At Closure, the owner or operator must (1) Remove or decontaminate all waste residues, contaminated containment system components (liners, etc.) contaminated subsoils, structures, and equipment contaminated with waste and leachate, and manage them as required; or (2) Close the impoundment and provide post-closure care for a landfill under Subpart G and Section 265.310.

Corresponding TBCs: Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments (530/SW-89/047)

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	This GRA would need to comply with clean closure as stated in 40 CFR 265.228(a)(1).
II	Applicable	These GRAs will allow hazardous waste to remain on-site. As such, the closure and post-closure requirements of 40 CFR 265.228(a)(2) and .228(b) will need to be complied with.
III	Applicable	
IV	Applicable	
V	Applicable	This GRA would need to comply with clean closure as stated in 40 CFR 265.228(a)(1). However, if the treated soils are classified as a listed hazardous waste and are used as backfill material, the closure and post-closure requirements of 40 CFR 265.228(a)(2) and .228(b) could be invoked unless the treated soils are delisted.

ARAR Type: Action - Land Disposal Restrictions and Treatment Standards

Federal Citation: Resource Conservation and Recovery Act - 42 USC § 6924
40 CFR 268, Subpart A to D

State Citation: 6 CCR 1007-3, 268, Subpart A to D

Requirement Summary: If a CAMU/TU designation is not obtained, any hazardous waste placement will need to comply with the land disposal restrictions (LDRs). Movement of excavated materials to a new location and placement in, or on land, may the invoke LDRs. In this situation, the restricted hazardous waste can not be placed into a land disposal unit unless the waste is treated or a variance is provided in accordance with the provisions of 40 CFR 268.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	This GRA does not involve the placement of hazardous waste; therefore, LDRs are not required to be achieved.
II	Applicable	LDRs may apply if a CAMU/TU designation can not be obtained and placement of a hazardous waste occurs.
III	Applicable	
IV	Applicable	
V	Applicable	Since the SEPs contained listed hazardous waste, the treated soils could also be classified as a listed hazardous waste in accordance with the "mixture" and "derived-from" rules. If the treated soils are classified as a listed hazardous waste, a CAMU/TU designation can not be obtained, and placement of a hazardous waste occurs, then LDRs could apply to the treated soils to be returned to the SEPs and to the waste residues generated by the treatment process. If the treated soils are delisted or are not clasified as a listed hazardous waste, LDRs would not apply.

ARAR Type: Action - Prohibition on Storage of Restricted Waste

Federal Citation: 40 CFR 268, Subpart E

State Citation: 6 CCR 1007-3, 268, Subpart E

Requirement Summary: A generator can store retricted hazardous waste in a tank, container, or containment building on-site provided that the storage compiles with the respective storage requirements and is solely for the purpose of accumulating such quantities of hazardous waste as necessary to facilitate proper recvoery, treatment, or treatment. The generator may store these restricted hazardous waste for a period up to one year unless the agency can demonstrate that such storage was not required. Storage may occur beyond one year; however, the owner/operator bears the burden of proving that the storage is required.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	Waste materials are not expected to be generated under these GRAs; therefore, storage is not required.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	Restricted hazardous waste may need to be stored under these GRAs; therefore, this storage prohibition could apply to the management and storage of restricted hazardous waste generated as a result of the IM/IRA.
V	Applicable	

ARAR Type: Action - Procedures for Planning and Implementing Off-site Response Actions

Federal Citation: CERCLA Section 121(d)(3)
40 CFR 300.440

State Citation: None

Requirement Summary: The purpose of this rule is to avoid having CERCLA wastes contribute to present and future environmental problems by directing wastes to facilities determined to be environmentally sound. Facilities used for the off-site management of CERCLA wastes must:

- Be operating in compliance with all applicable Federal, State and local regulations; there must be no relevant violations at or affecting the receiving unit.
- Not have on-going releases from the receiving unit and contamination from prior releases at the receiving unit must be addressed as appropriate.
- Have a program to address releases at other units located within the receiving facility boundaries.

Corresponding TBCs: IAG Paragraph 124

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	The implementation of this GRA will not result in the off-site shipment of waste.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	The waste generated by these GRAs may be shipped to an off-site disposal facility. As such, these requirements will be included in the selection of the off-site facilities.
V	Applicable	

ARAR Type: Action - Off-Site Transport of Hazardous Waste

Federal Citation: 49 CFR 172, Parts B to F
49 CFR 173, Parts B to O
49 CFR 177

State Citation: None

Requirement Summary: The off-site shipment of hazardous waste must adhere to DOT requirements, including waste packing, record keeping, container labelling, placarding, manifesting, etc.

Corresponding TBCs: DOE Order 5480.3

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	No wastes are anticipated to be transported off-site under these GRAs.
II	Not an ARAR	
III	Not an ARAR	
IV	Applicable	These requirements would only be applicable in the case where hazardous waste is shipped off-site. Recording keeping requirements are not normally considered to be ARARs since they are procedural/administrative requirements. However, off-site actions response actions must comply with all applicable regulations both substantive and procedural/administrative.
V	Applicable	

ARAR Type: Location - Evaluate Federal Projects for Potential Impact to Endangered or Threatened Species or Critical Habitats

Federal Citation: Endangered Species Act - 16 USC § 1531
50 CFR 402

State Citation: CRS 33-2-101 to 33-2-107

Requirement Summary: Practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife. Taking is defined to include harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection. Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	All Federal projects are required to be assessed to ensure that they are conducted so as to not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

ARAR Type: Action - Requirements for Siting of Hazardous Waste Disposal Sites

Federal Citation: None

State Citation: 6 CCR 1007-2, Part 2

Requirement Summary: Part 2 requirements described in Sections 2.1 through 2.9 include: requirements for certificate of designation applications, minimum design performance criteria for off site hazardous waste disposal sites and on-site hazardous waste landfills, requirements for piling and design of the facilities mentioned above, and requirements for minimum design performance criteria and siting and design for on-site surface impoundments and waste piles.

Corresponding TBCs: None

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Not an ARAR	These siting requirements are not applicable to GRAs involving "clean" closure.
II	Applicable	CDH claims that a hazardous waste disposal site is developed in the event that hazardous waste remains in-place following the completion of closure activities. Pursuant to Part 18 of the IAG, the DOE does not have to comply with the procedural aspects of the siting regulations to obtain a Certificate of Designation for the on-site response action; however, these GRA must comply with the substantive requirements of this regulation.
III	Applicable	
IV	Not an ARAR	Since the SEPs contained listed hazardous waste, the treated soils could also be classified as a listed hazardous waste in accordance with the "mixture" and "derived-from" rules. If the treated soils are classified as a listed hazardous waste and are used as backfill material, the siting requirements could be invoked unless the treated soils are delisted. The basis for this GRA is that this requirement will not be an ARAR.
V	Not an ARAR	

ARAR Type: Location - Occupational Radiation Protection Standards

Federal Citation: 10 CFR 835

State Citation: None

Requirement Summary: At DOE facilities, the radiation protection standards contained in DOE Order 5480.11 for occupational workers, unborn children, minors, and on-site members of the public shall not be exceeded.

Corresponding TBCs: DOE Order 5480.11, Section 9

Rationale For ARAR Determination:

General Response Action	Applicable or Relevant and Appropriate	Rationale for Selection
I	Applicable	Since the SEPs are located within a Radiologically Controlled Area and the closure/remediation activities could involve the handling of and exposure to radioactive materials, radiological controls are requried to be implemented.
II	Applicable	
III	Applicable	
IV	Applicable	
V	Applicable	

APPENDIX III.F

GENERAL RESPONSE ACTION ROUGH ORDER-OF-MAGNITUDE COST ESTIMATE DEVELOPMENT

APPENDIX III.F
GENERAL RESPONSE ACTION
ROUGH ORDER-OF-MAGNITUDE
COST ESTIMATE DEVELOPMENT

OBJECTIVE:

The objective of this document is to present the estimated rough-order-of-magnitude (ROM) costs for the proposed interim remedial action alternative for the five solar evaporation ponds (SEPs): 207-A; 207-B North, Center, and South; and 207-C. The proposed alternatives incorporate the removal of the liners, base, and associated materials; removal of vadose zone soil beneath the SEPs and surrounding surface area where appropriate; and the treatment, packaging, transporting, and disposal of these soils and liners, as appropriate, to a permitted offsite disposal facility. In cases where the liners will be considered for offsite disposal, the liners are assumed to be packaged in half-size crates so that the materials may be assayed prior to leaving the site. In those cases where soils are to be considered for offsite disposal, it will be impractical to crate and assay the large volume of soil; thus it was assumed that the soil will be transported by bulk railcars. Additionaly, the relocation and removal of utilities and Building 788 debris are also included in this cost estimate.

The following is a description and breakdown of the estimated costs required to successfully complete this project.

APPROACH:

1. LINER

- Remove, crush, and either consolidate under the engineered cover or pack and transport for disposal, liner and base of five SEPs (207-A, 207-B North, 207-B Center, 207-B South and 207-C).

- The **total liner** (in-place liner and base course) for the five SEPs encompasses **317,000 cubic feet (ft^3)** (based on average depths of 6" for the liner and 6" for the base course).

2. SOIL

- Soil treatment, where applicable, for all vadose zone soils under SEPs [145,300 cubic yards (c.y.)] and surrounding areas (one foot depth)(16,800 c.y.). The total volume of soil is 162,100 c.y.

- The volumes of soil after excavation, based on a 15% expansion factor[4] are:

vadose zone soil: (145,300 c.y.)(1.15) = 167,100 c.y.
surficial soil: (16,800 c.y.)(1.15) = 19,320 c.y.
total soil: 186,415 c.y.

- The estimated density of the in-place soil is **120 pounds per cubic foot (1.62 tons/ cubic yard)** (based on field data[1]). The weights of soil are:

  Vadose zone soil = (145,300 c.y.)(1.62 ton/c.y.) = 235,386 tons.
  Surficial soil - (16,800 c.y.x 1.62 ton/c.y.) = 27,216 tons
  Total Soil: 186,415 c.y.

3. HEALTH AND SAFETY REQUIREMENTS

DESCRIPTION	QTY	UNIT	LABOR		TOTAL
			UNIT COST	TOTAL COST	
Baseline radiological/hazardous survey				$523,900	$523,900
Initial Survey					
Set-up material staging area	80	MH[a/]	$65.00	$5,200	$5,200
Set up exclusion zone	160	MH	65.00	10,400	10,400
Set up step-off/survey area	80	MH	65.00	5,200	5,200
Develop radiation worker permit for zone entry	80	MH	65.00	5,200	5,200
Baseline survey by HPT	80	MH	65.00	5,200	5,200
Obtain excavation permit	40	MH	65.00	2,600	2,600
Conduct pre-job training on sampling grid	60	MH	65.00	3,900	3,900
Phase II Activities					2,600
Modify radiation worker permit for excavation	40	MH	65.00	2,600	41,600
Write health and safety plan	640	MH	65.00	41,600	
Phase III Activities					
Daily initial surveys, surveys of equipment leaving exclusion zone, and daily end-of-day surveys of ground equipment	4,000	MH	65.00	260,000	260,000
Cover any surface contamination during operations and overnight if discovered in end-of-day survey.	2,800	MH	65.00	182,000	182,000
Monitor job site remediation/entry security				963,828	963,828
Rad technicians - four for 9 months of projects	4,536	MH	34.53	156,628	156,628
Construction personnel enter/exit job site	20,180	MH	40.00	807,200	

a/ MH = Man-hour

4. **LINER CONTAINERIZATION**

- **Estimated Usable Crate Volume:** Based on calculations attached (Attachment F), the usable crate volume (95% efficiency) is 42.9 ft^3. Estimated weight of an empty half-size crate is 460 pounds (lbs).

- Maximum load rating = **5,000 lbs** (See EG&G Attachment D).

- The estimated density of in-place liner and base is **137 pounds per cubic foot (#/ft^3)** [2].

- After crushing, the void space of removed liner material is assumed to be 30%.[2] The void space calculated from the road construction contractor data (density of in-place pavement = 2 tons/yd^3, density of crushed material = 1.5 tons/yd^3) is 25%. The assumption of 30% is acceptable and will be used.

- The estimated density of crushed liner and base is 137#/ft^3(1 - 0.3) = 95.9#/ft^3.

- The estimated weight of crushed liner and base in the volume of a half-size crate is (42.9ft^3)(95.9#/ft^3) = 4,114 lbs. (does not exceed crate capacity).

- The estimated weight of crushed liner and base plus a half-size crate is (4,114# + 460#) =4,574 lbs. Use **4,600 lbs.**

- The estimated total crushed liner and base volume is (317,000 ft^3)/(1-.3) = 452,857 ft^3. Use **453,000 ft^3**.

- The estimated total number of crates required is (453,000 ft^3)/(42.9 ft^3/crate) = 10,559 crates.

  Use **10,600** for number of crates required for liner and base.

- Cost for half-size crate = $260 (See EG&G Attachment D) (includes labor and material to build crates, and delivery).

- Therefore, ($260)(10,600 crates) = **$2,756,000**

5. **LINER AND BASE**

- **Remove liner and base**:

  - Remove liner and base, including loose debris, and transport to crusher. Use equipment and methodology suggested by demolition subcontractor. (See Attachment M.) Use $18/c.y., for excavation, crushing and loading into crates

only. Add $2.5/c.y. or $20.5/c.y., to spread and compact crushed liner instead of loading into crates.

- Therefore, (11,740 c.y.)($18/yd^3) = $211,343.
  Use **$212,000** (for loaded into crates).

- Therefore, (11,740 c.y.)($20.5/c.y.) = $240,670. Used $241,000 (for spread and compacted).

- **Crush liner and base and load into crates**:

  - Portable crusher: Demolition subcontractor shall load from stockpile, feed, and discharge; load crates; and provide dust collection and control.

  - Design crusher capacity: 200 tons/day (industry standard; subcontractor-quoted).

  - Actual working capacity: 100 tons/day (utilization; industry standard).

  - Operating cost = $400/hour (hr) (industry standard) (includes labor and mobilize/demobilize).

  - Total weight = 317,000 ft^3 (137#/ft^3)(1 ton/2000#) = 21,715 tons; Use **21,800 tons**.

  - Total cost = ($400/hr)(8 hr/day)(1 day/100 tons)(21,800 tons) = **$697,600**.

  Therefore:

  - Total working days: (21,800 tons)/(100 tons/day) = 218 + 10[3] = 228 days.

  - Total costs: = [$697,600 + (10 days) (8 hrs/day)($400/hr)] (1.25)[3] = **$912,000.**

6. **SOIL TREATMENT ALTERNATIVES**

- **Soil Washing**: Soil is excavated and 80% is returned clean to site. Soil to be disposed offsite (20%) will be hauled by 100-ton-capacity gondola railcars.

  Treatment cost = $200/ton (includes excavation).

  Therefore, (262,600 tons)($200/ton) = **$52,520,000** (treatment and excavation cost).

  Cost to return to excavation site = $2.5/c.y.

Therefore, replacement cost = (186,415 c.y.)(0.8)($2.5/c.y.) = $373,000.

Cost to move contaminated soil fraction to onsite railhead and unload into railcars = $3.5 c.y.

Therefore, cost to move soil to railheads and unload into railcars = (186,415 c.y.)(0.2)($3.5/c.y.) = $130,500.

- **Degradation**: Bioremediation. Cost = $450/ton (*ex situ*; includes excavation);

  Therefore, (262,600 tons)($450/ton) = **$118,170,000**.

- ***In Situ* Soil Stabilization**: Soils (vadose zone only) are mixed with stabilizing chemicals *in situ*. Cost = $80/yd^3.

  Therefore (145,300 c.y.)($80/yd^3) = **$11,624,000**.

7. **SOIL REMOVAL**

Cost of excavation = $2.5/c.y.

Therefore, cost to excavate:

Surficial soil = (161,800 c.y.)($2.5/c.y.) = $42,000
Total soil = (162,100 c.y.)($2.5/c.y.) = $406,000

Cost of excavation and replacement (in local area) = $5/c.y.

Therefore, cost to excavate and replace:

Surficial soil = (16,800 c.y.)($5/c.y.) = $84,000
Total soil - (162,100 c.y.) ($5/c.y.) = $811,000

8. **CRATE PREPARATION FOR SHIPMENT**

- **Install Lids on Loaded Crates:**

- Assumption of 6 lids/hour is based on engineering judgement. Therefore, 10,600 crates/6 lids/hour **1,767 labor-hours** for liners.

22,900/6	=	3,817 for soils.
4,600/6	=	767 for soil washing waste.

- **Assay Waste Crates:**[6]

  Load and move 10 crates by flatbed to assay in 1 hour (engineering judgement).

  - Move and unload 10 crates by flatbed to railcar in 1 hour (engineering judgement).

  - Assumption of 7.2 labor-hours per crate for complete assay operation is based on EG&G information (Attachment G) and transport time.

    Therefore, (7.2 hours/crate)(10,600 crates) = **76,320 labor-hours** for liners.
    (7.2)(22,900) = 164,880 labor hours for soils.
    (7.2)(4,600) = 33,120 labor hours for soil washing waste.

9. RELOCATE POWER LINES

DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		TOTAL
			UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
Relocate power lines from between 207-A and 207-B Series SEPs.				$17,846		$67,068	$84,814
Lock-out/tag-out	64	MH[a/]			81.8	5,235	5,235
Install power poles	563	MH		12,386	33.17	18,675	31,061
Install conductors	2,600	LF[b/]	$2.10	5,460	3.14	8,164	13,624
Tie-in relocated power lines	121	MH		0	33.17	4,014	4,014
Perform hi-pot test on new power lines	241	MH		0	33.17	7,994	7,994
Remove obsolete power lines and poles	392	MH		0	33.17	13,003	13,003
Transport and store power lines	181	MH		0	33.17	6,004	6,004
Shred obsolete poles and dispose in 207-A	120	MH		0	33.17	3,980	3,980

a/ MH = Man-hours
b/ LF = Linear foot

10. UTILITIES

DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		CONSTRUCTION EQUIPMENT		TOTAL
			UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
Utilities				0		$465,676		$25,817	$491,493
Design/review shoring activities	200	MH[a/]			$90.00	18,000			18,000
Shoring (excavation/removal)	5,580	LF[b/]		0	40.40	225,432			225,432
Shoring (excavation/grouting)	1,150	LF		0	8.08	9,292			9,292
Remove 3"-LD-STL	60	LF		0	27.24	1,634			1,714
Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
Remove 3"-PW-STL	570	LF			27.24	1,634	1.33	80	1,714
Remove and grout 3"-PW-SST		LF			27.24	15,527	1.33	80	16,285
Remove and grout 3"-PW-STL							1.33	80	

10. UTILITIES (CONTINUED)

DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		CONSTRUCTION EQUIPMENT		TOTAL
			UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
Remove/relocate 6"-RW-CI	550	LF		0	27.24	14,982	1.33	732	15,714
Remove 3" SROB-CAP	310	LF		0	27.24	8,444	1.33	412	8,857
Remove 8" PWF-CI	40	LF		0	27.24	1,090	1.33	53	1,143
Remove 8" PW-CI	30	LF		0	27.24	817	1.33	49	854
Remove 440V-E	130	LF		0	27.24	3,541	1.33	173	3,714
	50	A/G[c/]			27.24	1,362	1.33	67	1,429
Remove 440-V-E	620	LF U/G[d/]		0	27.24	16,889	1.33	825	17,713
Remove 15'-SD-CMP	520	LF		0	27.24	14,165	1.33	692	14,856
Remove/relocate 440V-E	320	LF		0	27.24	8,717	1.33	426	9,142
Remove/relocate telephone	350	LF		0	27.24	9,534	1.33	466	10,000
Remove @ 10" PW-PVC (VCP) 6"-PW-VCP	290	LF		0	27.24	7,900	1.33	386	8,285
		LF							

10. UTILITIES (CONTINUED)

DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		CONSTRUCTION EQUIPMENT		TOTAL
			UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
Remove 3"-SR)B-CAP	90	LF		0	27.24	2,452	1.33	120	2,571
Remove 3/4" E-PVC	90	LF		0	27.24	2,452	1.33	120	2,571
Grout 8"-RW-CAP	760	LF		0	46.98	35,705	11.08	8,421	44,126
Grout 8"-RW-CAP	390	LF		0	46.98	18,322	11.08	4,321	22,643
Remove 12"-OS-CMP	50	LF		0	27.24	1,362	1.33	67	1,429
Remove 1-1/2"-DCW-STL	320	LF		0	27.24	8,717	1.33	426	9,142
Remove 3"-SROB-CAP, Remove 3"-ROPW-CAP, Remove 3"-SROP-CAP, Remove 6"-SE-CAP	140	LF		0	27.24	3,814	1.33	186	4,000

10. UTILITIES (CONTINUED)

DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		CONSTRUCTION EQUIPMENT		TOTAL
			UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
Remove 8"-PW-CI	20	LF		0	27.24	545	1.33	27	571
Remove 8"-PW-CI (8"-PCWF-CI)	50	LF		0	27.24	1,362	1.33	67	1,429
Dispose of utilities in 207-A	6,730	LF		0	1.51	10,162	1.01	6,797	16,960
Cut, transport, and store piping (includes PPE)	6,730	LF		0	3.00	20,190		0	20,190

a/ MH = Man-hour
b/ LF = Linear foot
c/ A/G = Above-ground
d/ U/G = Under-ground

11. TRANSPORTATION

- Transportation for liner and base: [7] [Note: 100% of liners]

  - Limitations: 150,000#/railcar (based on subcontractor-quoted data).

  - Maximum number of half-size crates allowed on a railcar is 48.

  - Cost: $2,210/railcar (based on subcontractor-quoted cost).

  - Therefore, the number of crates of liner/base waste that can be loaded onto a railcar based on weight limit is:

    (150,000# per railcar / 4,600# per crate) = 32.6 crates (within the maximum number allowed on a railcar). Use **32 crates/railcar**

    and, (10,600 crates/32 crates per railcar) = 331.3 railcars. Use **332 railcars.**

    Therefore, (332 railcars)($2,210/railcar) = $733,720.

    Use **$734,000** for transportation cost.

  - Transportation for contaminated soil. [Note: 100% of soil.]

    Assume cost of railcar (gondola) is the same as for liner transport (flatcar).

    (262,600 tons)(100 ton/car) = 2,626 railcars.

    Therefore, (2,626 railcars)($2,210/railcar) = $58,804,000.

- Transportation for contaminated soil from soil washing process [Note: 20% of soil]:

  Assume cost of railcar (gondola) is the same as for liner transport (flatcar).

  (262,600 tgons)(0.2)(100 ton/car) = 526 railcars.

  (526 railcars)($2,210) = $1,163,000

12. DISPOSAL AT ENVIROCARE (UTAH)

- Half-size crate disposal volume: Nominal dimensions (2')(4')(7') = **56 ft^3**.

- Disposal cost = $57/$ft^3$ or (56 ft^3)($57/$ft^3$) = $ 3,192 per half-size crate.

Therefore,

- Liner and base (10,600 crates)($3,192 per crate) = $33,836,000.
- Soil: (186,415 c.y.)(27 c.f./c.y)($57/c.f.) = $286,893,000.
- Soil from soil washing (186,415 c.y.)(27 c.f./c.y.(0.2)($57/c.f.) = $57,379,000.

13. **FINAL SITE PREPARATION**

- Cleanup and setup = $75,000 (assumed)
- Well installations = $80,000 (based on memo from P. Nixon and L. Pivonka)
- Abandonment = $66,000 (10 wells assumed)
- Vadose zone monitoring installations = $370,000 (10 wells assumed)

The total cost of A, B, C, and D to prepare final site = **$591,000**

14. **OTHER COSTS**

Based on construction company experience and industry standards:

- Assumption for security escort labor rate: $40/hour
  - Note: Operator costs (fully burdened) @ $55 and $65/hour.
- Engineering design cost shall be assumed to be 10% of total construction cost.
- These estimates do not include future operating, maintenance, or monitoring costs.
- These estimates do not include costs for construction permits or associated fees.

ATTACHMENTS:

- A - Solar Evaporation Ponds Layout;
- B - Liner Data;
- C - Meeting Minutes: SP307:112293:02; Magnitude-of-Cost Estimating;
- D - Waste Containers Telecon;

- E - Maximum Boundary for Contaminated Ponds Area;
- F - Half-Size Crate, Volume, and Weight Calculations;
- G - Crate Assay Telecon;
- H - Estimate Telecon;
- I - Engineered Covers Preliminary Cost Estimate;
- J - Escort/Training, Labor-Hours Estimate Data;
- K - Contract HP Rates Telecon;
- L - Radiological Operations Coverage for OU4 Remediation Telecon; and
- M - Calculation for Liner Removal: includes hauling and dust control.

REFERENCES:

- (Draft) OU4 SOLAR EVAPORATION POND IM/IRA DECISION DOCUMENT REMEDIAL ALTERNATIVE DESCRIPTIONS
- COST ENGINEERING ESTIMATING MANUAL: EG&G ROCKY FLATS; Copy No. 36

FOOTNOTES:

[1] Field test sample by David B. Stevens Inc., November, 1993.

[2] Based on local asphalt demolition contractor advice, typical in-place density of asphalt concrete is 2 tons/yd^3. Base course density is 1.7 tons/yd^3, or about 137#/ft^3.

[3] Per client direction, add 10 days to stockpile a buildup to feed the crusher, and add 25% for unforeseen problems such as equipment repairs, delays, or weather conditions.

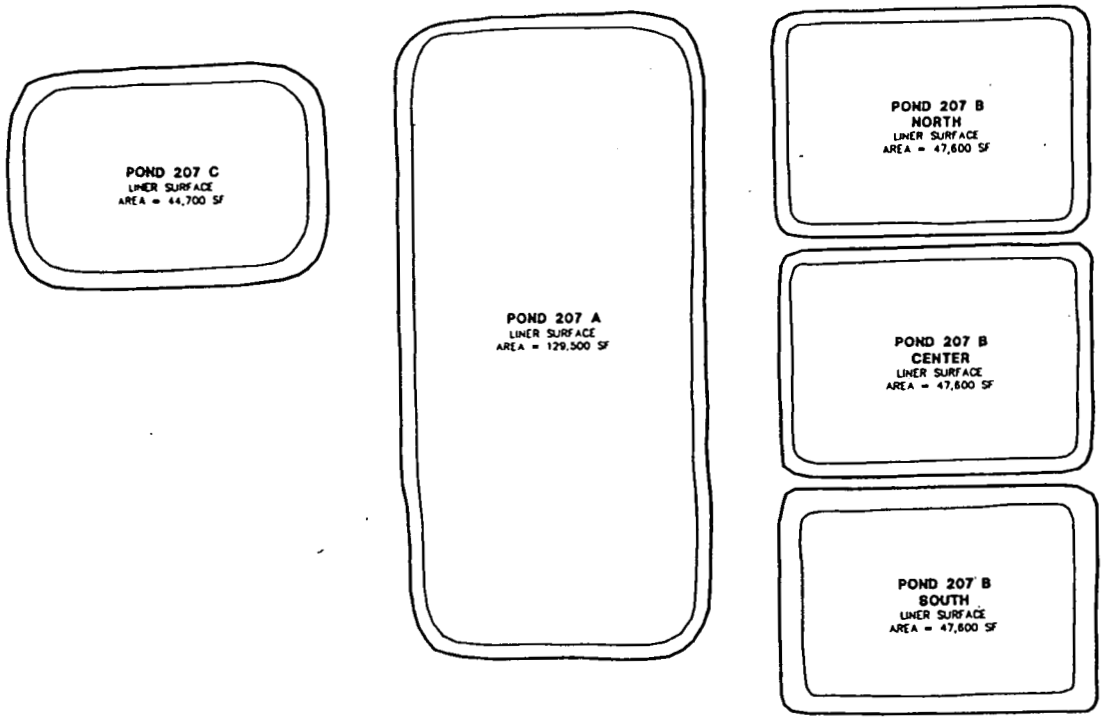
[4] According to a Denver-area geotechnical engineering firm.

[5] The \$2.50/yd^3 estimate is based on industry standards and data obtained from local subcontractor-quoted costs.

[6] The purchase price for the passive active neutron (PAN) system to assay the crates is \$807,000. The time required to install the PAN system and associated equipment is 520 hours. Source: Conceptual Design Report for Production Waste Treatment Facilities, Y-

12 Plant, Oak Ridge Reservation, TN; Cost and Schedule Document (CSD) prepared by C. T. Main, Inc., Charlotte, NC; February 20, 1991.

[7] Data source - Fritz Rahr, (713) 223-6759. Re: Rail Shipment to Envirocare via Southern Pacific Railroad which controls the spur at the Rocky Flats Plant.



SOURCE: DRAWING NO. 15510-13
15510-14
15510-15
15510-22
15510-23

Not to Scale

PREPARED FOR

U.S. DEPARTMENT OF ENERGY

ROCKY FLATS PLANT
GOLDEN, COLORADO

Attachment A

Solar Evaporation Ponds
Operable Unit 4

930N1156, 10/20/93 AT 12:55

ATTACHMENT B

SOLAR EVAPORATION PONDS - OPERABLE UNIT 4 - ROCKY FLATS PLANT

DRAWING# & DATE	POND	LINER FT^2	LINER FT^3	LINER YD^3	LINER DATA: SOURCE-DWG'S
50268-1 (5/15/92) 19379-1 (5/8/70)	207 C	44,700	52,150	1932	Asphalt = 8"; there is no information on gravel, therefore assume 6". Total = 14"
50268-1 (5/15/92) D-11120-1 (8/28/63) 1-6217-207 (9/10/59)	207 A	129,500	129,500	4797	Per field data on 10/20/93: Asphalt = 6" Gravel = 6" Total = 12"
50268-1 (5/15/92) 16887-1 (8/61) 1-6217-207 (9/10/59)	207 B (NORTH)	47,600	47,600	1763	Latest information from drawings show a liner combination of sand, asphalt & planks for a total of 12".
50268-1 (5/15/92) 16887-1 (8/61) 1-6217-207 (9/10/59)	207 B (CENTER)	47,600	47,600	1763	Latest information from drawings show a liner combination of sand, asphalt & planks for a total of 12".
50268-1 (5/15/92) 28103-101 (11/10/77) 16887-1 (8/61)	207 B (SOUTH)	47,600	47,600	1763	Latest information from drawings show a liner combination of sand, asphalt & planks for a total of 12".

ATTACHMENT 'C'

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 Denver, Colorado 80290
phone: (303) 831-8100 • telecopy (303) 831-8208

MEETING NOTES

TO: Distribution

DATE: November 18, 1993

FROM: Philip Nixon

MEMO #: SP307:112293:02

PROJECT #: Solar Pond IM/IRA

ATTENDANCE:

Mark Austin
Ken Bruscar
Dave Myers
Harry Heidkamp
Rob Riecken
Steve McConnel

DISTRIBUTION:

Attendees
R. Wilkinson
T. Kuykendall
W. Edmonson

SUBJECT: Magnitude of Cost Estimating

Mark Austin and Ken Bruscar reviewed the approach that ES is taking to provide a magnitude of cost estimate for the detailed analysis of alternatives, and provided input with respect to cost factors associated with performing construction projects at Rocky Flats. The following is a summary of the key decisions that were made and the action items that were assigned.

1) It was agreed that a contingency analysis of 30 percent was appropriate for this magnitude of cost estimate because there are a considerable number of unknowns with respect to the design requirements.

2) Waste boxes being prepared for offsite shipment may have to be passed through a radiological counter prior to being shipped. On a previous project 8 hours for 2 workers were required per box. The operators rate is $84.05 per hour. **Mark Austin will look into whether box scanning is required for low-level contaminated media. Ken Bruscar will investigate whether 8 hours per box is an appropriate estimate for the OU4 IM/IRA.**

3) Every truck entering and exiting the Protected Area will require 30 minutes for security monitoring.

4) The contractor will be required to supply the forklifts for box handling at the construction site as well as at the rail loading area.

ATTACHMENT 'C

5) A General & Administrative factor of 10.75 percent will be added to the bottom line contractor costs. It will be necessary to estimate the contractor costs separately from the EG&G costs.

6) A factor of 3 percent will be added to the bottom line contractor cost to account for the EG&G contracting and procurement services.

7) A percentage will have to be added for construction management. **Ken Bruscar will provide this factor.**

8) Each non-cleared worker will require an escort to get through the protected zone to reach the construction site. One escort is required for every 3 workers. The cost of an escort is $40.00 per hour.

9) A percentage will have to be added for EG&G project management. **Ken Bruscar will provide a reasonable factor.**

10) The cost of Health and Safety Monitoring Activities is $651 per day.

11) The construction contractor will be required to perform the final site survey.

12) The costs of the final site preparation line item should be split with respect to EG&G costs and contractor costs.

Philip R. Nixon

Philip Nixon, Project Manager

ES ENGINEERING-SCIENCE, INC.

ATTACHMENT 'D

Client EG+G-RF | Job No. DE 307.32.02 | Sheet 1 of 1

Subject P WASTE CONTAINERS | By HAH | Date 3 NOV 93

Checked | Rev.

TELECON

TO: BETTY SMITH, WASTE ASSAY + SHIPPING, 469-0259
TIME: 1340 DATE: 3 NOV 93
FROM: HEIDKAMP

BETTY CONFIRMED THAT 2 SIZES OF WOOD CRATES ARE USED TO SHIP WASTE.

1. FULL-SIZE (4'x4'x7'), ~$300 ea., WT. OF WASTE LOADED ~5,000 lbs (MAX. LOAD RATING ~7,000 lbs.)

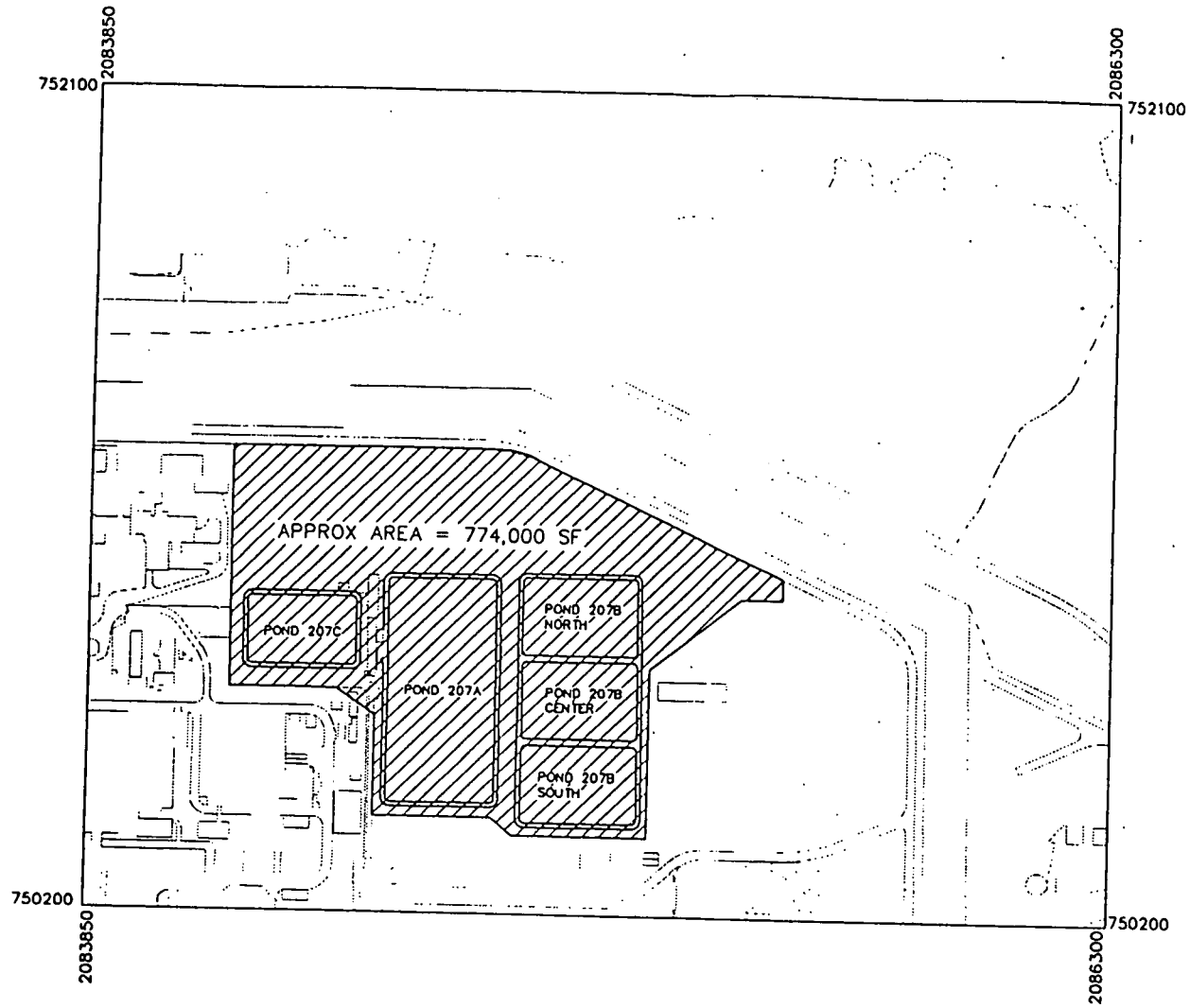
2. HALF-SIZE (2'x4'x7'), ~$260 ea., WT. OF WASTE LOADED ~3,000 lbs (MAX. LOAD RATING ~5,000 lbs.)

NOTE: RFP DOES NOT LOAD WOOD CRATES TO MAX. RATING.

3. SOME METAL BOXES ARE ON-SITE TO OVERPACK TRI-WALLS CONTAINING PONDCRETE (DOT SPEC. 7A). THESE WERE ORDERED FOR JOE ROBERTS GROUP AND ARE ALSO KNOWN AS "SAND BOXES".

NOTE: DOT SPEC. 7A 55gal DRUMS ARE ALSO USED FOR WASTE SHIPMENT. WOOD CRATES AND DRUMS ARE THE ONLY WASTE CONTAINERS USED ON-SITE CURRENTLY.

CC: R. CROPPER
K. CUTTER
S. HUGHES
K. KRUMVIEDA
T. KUYKENDALL
D. MYERS
C. [redacted]
P. NIXON
R. STEGEN
S. STENSENG
R. WILKINSON



SOURCE: DRAWING FILE - BASEMAP

Not to Scale

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

Attachment E

Maximum Boundary for Contaminated Ponds Area

93DN1156, 11/20/93 AT 10:33

ENGINEERING-SCIENCE, INC.

ATTACHMENT 1

Client EG&G, RF
Subject OUA IM/IRA
HALF-SIZE CRATE WEIGHT + INT. VOLUME

Job No. DE307.22.02
By HAM
Checked 12/9/93

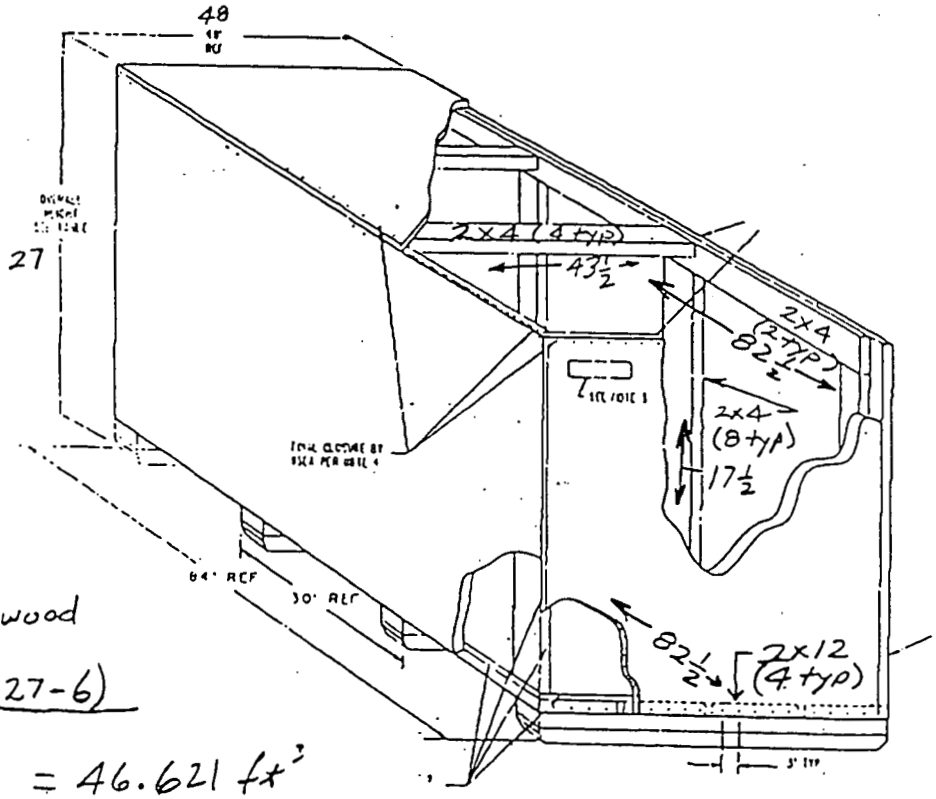
Sheet 1 of 4
Date 9 DEC 93
Rev. Ø

FIND: INTERNAL VOLUME AND WEIGHT OF HALF-SIZE CRATE

GIVEN: CRATE DIMENSIONS SHOWN ON ATTACHMENT 1

ASSUMPTIONS: 1.) $\rho_{wood} = 38\ lbs/ft^3$
2.) Usable internal volume is 95% of actual internal volume. (BASED ON ENGINEERING JUDGEMENT)

CALCULATION:



x-sect 2x4
$= 1\frac{1}{2} \times 3\frac{1}{2} = 5\frac{1}{4}\ in^2$

X-sect 2x12
$= 1\frac{1}{2} \times 11\frac{1}{4} = 16\frac{7}{8}\ in^2$

$$V_{box,\ inside\ the\ plywood} = \frac{(48-1\frac{1}{2})(84-1\frac{1}{2})(27-6)}{1728} = 46.621\ ft^3$$

$$V_{bracing} = \frac{\left[2(82\frac{1}{2}) + 4(43\frac{1}{2}) + 8(17\frac{1}{2})\right]5\frac{1}{4}}{1728} = 1.455\ ft^3$$

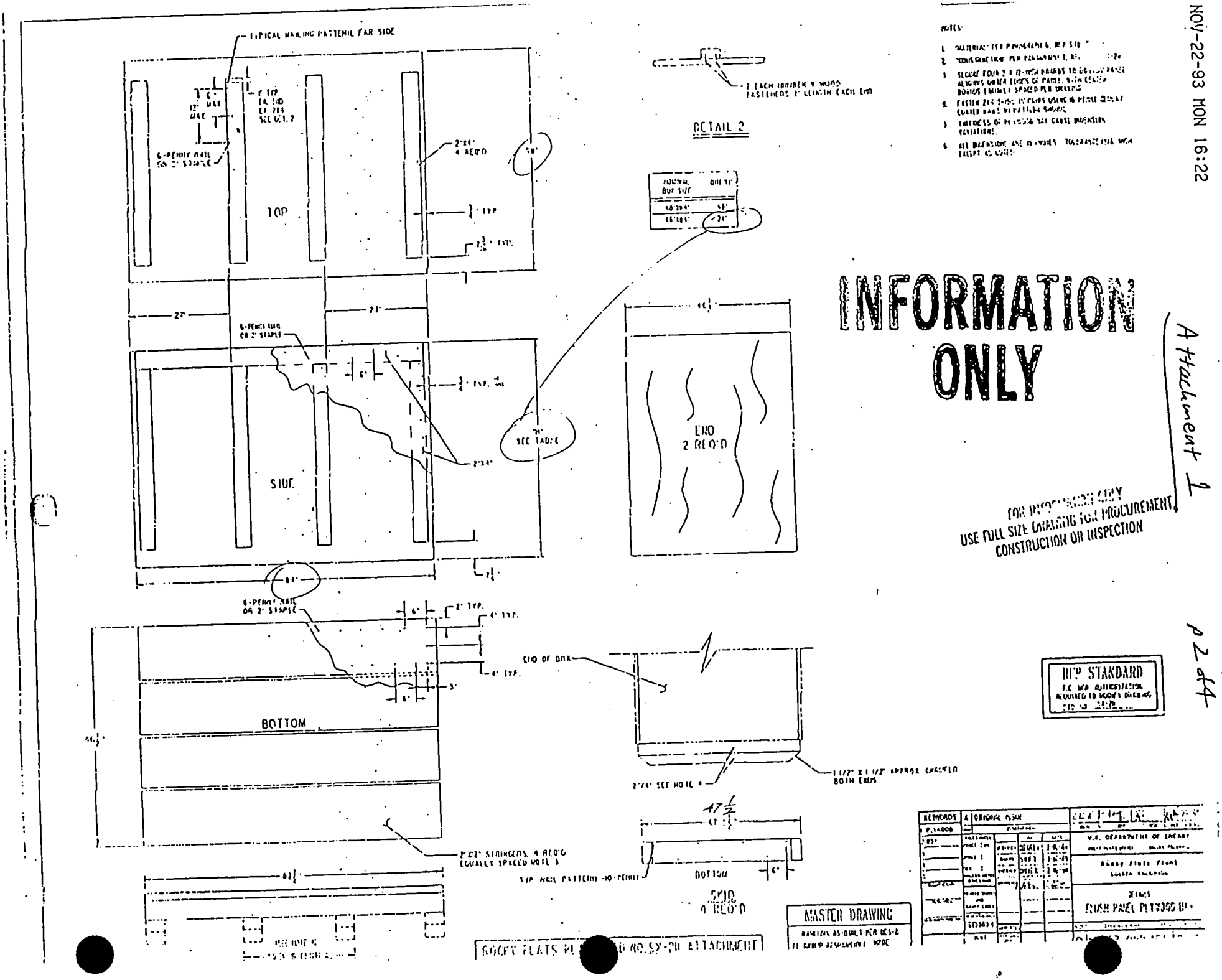
$$V_{skids} = (47\frac{1}{2} + 46)(4)(5\frac{1}{4})/1728 = 1.136\ ft^3$$

$$V_{2\times12} = (4)(16\frac{7}{8})(82\frac{1}{2})/1728 = 3.223\ ft^3$$

$$V_{ply} = \left[(84)(24)(2) + (46\frac{1}{2})(24)(2) + (48)(84) + (82\frac{1}{2})(46\frac{1}{2})\right]\frac{3}{4}/1728 = 6.134\ ft^3$$

$$W_{t,\ box} = 38\ lbs/ft^3(1.455 + 1.136 + 3.223 + 6.134) = 454\ lbs \quad say\ \boxed{460\ lbs}$$

$$V_{usable,\ internal} = (0.95)(46.621 - 1.455) = \boxed{42.9\ ft^3}$$

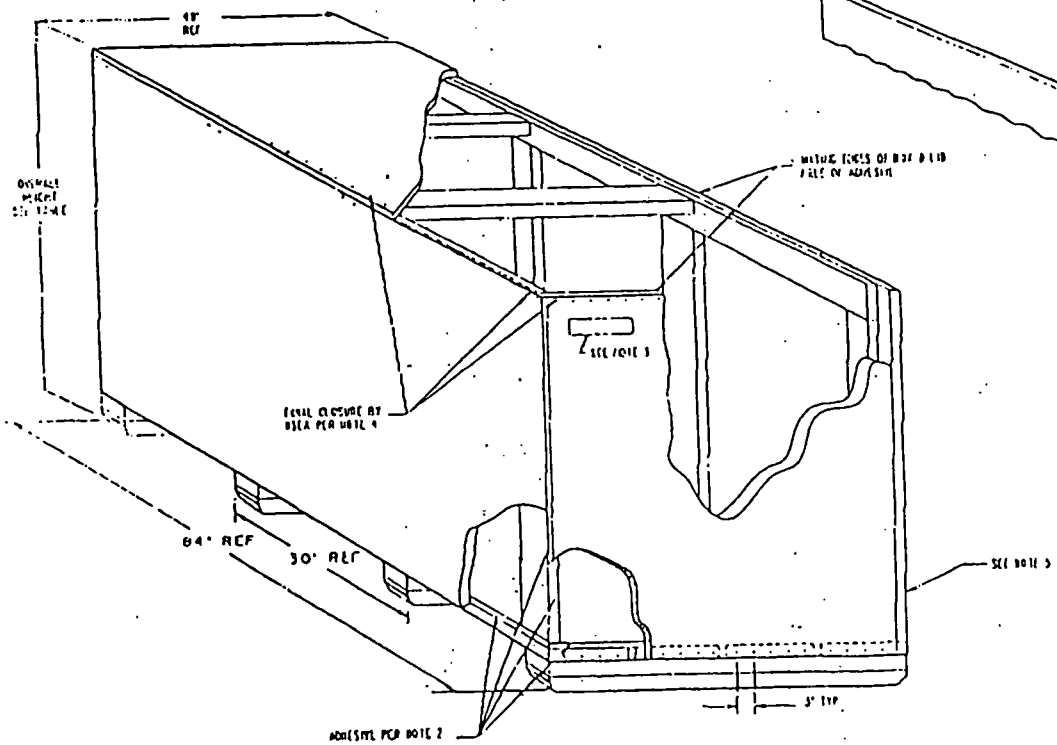

TYPICAL MARKING PATTERN FOR SIDE
TOP
SIDE
BOTTOM
END
2 REQ'D
DETAIL 2
2 EACH IDENTICAL WOOD FASTENERS 2" LENGTH EACH END
6-PENNY NAIL OR 2" STAPLE
SEE TABLE
END OF BOX
BOTH ENDS
EQUALLY SPACED NOTE 3
4 REQ'D
MASTER DRAWING
INFORMATION ONLY
FOR INFORMATION ONLY
USE FULL SIZE DRAWING FOR PROCUREMENT, CONSTRUCTION OR INSPECTION
Attachment 1
p 2 of 4
RFP STANDARD
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
FLUSH PANEL PLYWOOD BOX

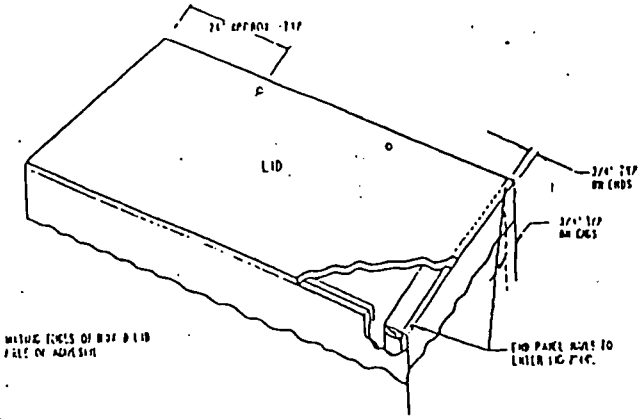
INFORMATION ONLY

NOMINAL BOX SIZE	OVERALL HEIGHT
40"X48"X64"	51"
24"X40"X64"	27"

NOTES:

1. DRAWING INTERPRETATIONS PER MSS 1143. ALL [illegible] IN INCHES. TOLERANCES FRACTION EXCEPT [illegible]
2. ASSEMBLE BOX PER PARAGRAPH 5 "MATE [illegible] DESIGNATION, B. "[illegible] AND [illegible] STAPLING" AND F "[illegible] DRAW".
3. STENCIL LEGIBLY WITH BLACK PAINT, MANUFACTURER'S NAME OR SYMBOL, SER NO AND DATE OF MANUFACTURE, 2 PLACES ON OPPOSITE ENDS USING CHARACTERS AT LEAST 3/4-INCH INCH PER PARAGRAPH 5 "IDENTIFICATION".
4. USER SHALL MAKE FINAL BOX CLOSURE WITH MATERIALS SPECIFIED IN NOTE 2. APPLY ADHESIVE ALONG TOP EDGE OF SIDES WHERE A SEAL IS FORMED BY THE 2 X 4 AND THE 3/4-INCH PLYWOOD AND ALONG THE ENDS OF THE LID WHERE THE 2 X 4 AND THE PLYWOOD FORM A 90° ANGLE. MAKE THE LID IN PLACE USING 8d NAILS ON 3-INCH CENTERS (1/4-INCH) ALONG TOP EDGE AND ENDS OF BOX AS SHOWN. DRIVE THE NAILS THROUGH SIDE PANELS INTO THE ENDS OF THE 2 X 4 ON THE LID (16 PLACES)
5. COAT INTERIOR WITH FLAMES 2" FIRE RETARDANT. PAINT PER PARAGRAPH 8 "PAINTING".





SELLER-SHIPPING PURPOSES ONLY. SEE PARAGRAPH 10, RFP STD SX-20

DETAIL 1

Attachment 1

FOR INFORMATION ONLY
USE FULL SIZE DRAWING FOR PROCUREMENT, CONSTRUCTION OR INSPECTION

MASTER DRAWING
MAINTAIN AS-BUILT PER DCS-6
FE GROUP RESPONSIBLE RFCE

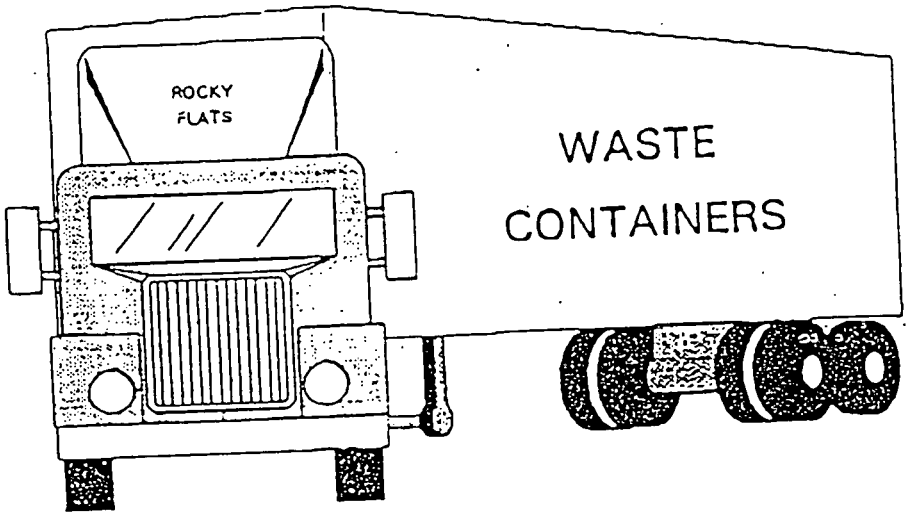
RFP STANDARD
FE, RCP AUTHORIZATION REQUIRED TO MODIFY DRAWING
STD NO SX-20

J	CHANGED NOTES 2 & 4		2-21-93	2-21-93	A/[illegible]
H	REVISED PER ECN [illegible]		3-8-89	[illegible]	[illegible]
REFERENCES					
U.S. DEPARTMENT OF ENERGY					
Rocky Flats Plant					
FLUSH PANEL FLATPACK (BS)					

ROCKY FLATS PLANT STD NO. SX-20 ATTACHMENT

ATTACHMENT 1

EG&G ROCKY FLATS, INC.
WA&S WASTE CONTAINER PROCUREMENT
PHONE #: 303-469-0259 OR 303-469-8513
FAX #: 303-469-6485



DATE: 22 Nov, 93
FACILITY: Mile High Center
ATTENTION: Harry Heidkamp
FAX #: 831-8208
MESSAGE:
If there is a problem with the copies, please call at the above numbers

ATTACHMENT 'G'

ES ENGINEERING-SCIENCE, INC.

Client 004 FM/IRA
Subject WASTE BOX ASSAY
Job No. DE307.22.02
By WAM
Checked
Sheet ___ of ___
Date 9 DEC 93
Rev.

TELECON

TO: Scott Kranker Asst. Ops. Mgr. NDA 966-5933 966-4000 x 5511(p)

SUBJECT: PLANT ORGANIZATIONS INVOLVED IN CRATE ASSAY

AS PER PREVIOUS DISCUSSION (23 NOV 93) SCOTT INDICATED THAT THE CRATE COUNTER IN BLDG 569 IS A VERY OLD PASSIVE-ACTIVE NEUTRON ACTIVATION DEVICE CAPABLE OF COUNTING HALF AND FULL-SIZE CRATES. SINCE THE FACILITY HAS LIMITED STAGING AREA, ONLY 10 CRATES CAN BE RECEIVED, COUNTED, AND RELEASED AT A TIME. IT TAKES 3-4 HOURS EACH FOR PRE- AND POST-STAGING (6-8 HOURS TOTAL). TIME TO ASSAY ONE CRATE IS 10-15 MINUTES. TIME TO ASSAY 10 CRATES INCLUDING TIME TO UNLOAD AND LOAD CRATES AND RUN STANDARDS AND BACKGROUND COUNTS IS 2 SHIFTS. THREE (3) MATERIAL HANDLING SPECIALISTS ARE REQUIRED PER SHIFT AT $90/HR BURDENED. THE CURRENT MACHINE WORK LOAD IS 6 CRATES OF LAUNDRY WASTE / MONTH THAT MUST BE DONE.

OTHERS INVOLVED (PER 10 CRATE LOT):
RADIOLOGICAL OPERATIONS SUPPORT (LORENZO UBIAS) 1 MAN @ 1 HOUR
WASTE INSPECTION (JOE KADIRKA?, BYRON TROP) 2 MEN @ 1 HOUR
NUCLEAR MATERIALS CONTROL (WAYNE THOMAS) 1 MAN @ ½ HOUR
WEMS COORDINATOR (DEBBIE CASTRO) 1 MAN @ 1 HOUR

SAFEGUARDS AND MEASUREMENT — PAPERWORK TURNAROUND IS 2 DAYS

TRAFFIC DEPT. NOT INCLUDED SINCE CONTRACTOR TRANSPORTATION HAS BEEN ASSUMED FOR PROJECT.

OTHER INFORMATION

1200 DRUMS ARE PRESENTLY STORED IN BLDG 569. IF THESE DRUMS COULD BE DISPOSITIONED (MOVED), ROOM FOR STAGING OF CRATES OR ANOTHER CRATE COUNTER COULD BE CREATED.

JOE WOLFE IS RTR SHIFT MGR x-7399 4110(p) Waste Assay + Ship

ES ENGINEERING-SCIENCE, INC.

ATTACHMENT H

Client EG+G, RF | Job No. DE301.22.02 | Sheet 1 of ___
Subject ___ | By [illegible] | Date 7 DEC [illegible]
___ | Checked ___ | Rev. 1500 h[illegible]

TELECON

FROM: Al Torrisi - EG+G, RF 966-8798

Subject: OUA Estimate

Al confirmed 1.) Half size crate cost is correct at $260

2.) Contingency is correct for now at 30%

Al requested: 1) Estimated hours for this particular cost estimate

2) Date to meet again for cost estimate review.

I told Al that our work on this estimate should be complete by COB Wednesday 8 Dec 93. Deferred man-hour estimate until reviewed by P. Nixon and next meeting date. Nixon or Heidkamp to call Torrisi Thursday afternoon 9 Dec 93 or Friday morning 10 DEC 93.

ACTION ITEM:

1.) Involved parties (Montes, Nixon, Heidkamp) must estimate man-hours used/needed to complete cost estimate. This should include support personnel (e.g., R. Ricken, A. Cozens).

CC: C. MONTES
P. NIXON

ES COR 8-5-88

ATTACHMENT I

12/30/93 1 OF 10

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
ENGINEERED COVERS
PRELIMINARY COST ESTIMATE

New Est. approx. 70% lower

SCENARIO 2	BACKFILL (LINERS IN)	2.2 MIL	1.5
SCENARIO 4	ENGINEERED COVER (LINERS IN)	7.4 MIL	5.1
SCENARIO 5	ENGINEERED COVER (LINERS IN)	7.4 MIL	5.1
SCENARIO 6	ENGINEERED COVER (LINERS OUT)	6.3 MIL	4.5
SCENARIO 7	ENGINEERED COVER (LINERS OUT)	6.3 MIL	4.5
SCENARIO 8	ENGINEERED COVER (LINERS IN)	7.4 MIL	5
SCENARIO 9	ENGINEERED COVER (LINERS OUT)	6.3 MIL	4.5
SCENARIO 10	BACKFILL (LINERS OUT)	1.8 MIL	1.3
SCENARIO 11	BACKFILL (LINERS OUT)	1.8 MIL	1.3

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 4 - ENGINEERED COVER (LINERS IN)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
BACKFILL TO FINAL GRADE (INCL. COMP.)	150,000	CY	$5.00		$5.00	$1,500,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			$650,000
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	30,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$4,444,500
CONTINGENCY						$666,675
TOTAL						$5,111,175

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 5 - ENGINEERED COVER (LINERS IN)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
BACKFILL TO FINAL GRADE (INCL. COMP.)	150,000	CY	$5.00		$5.00	$1,500,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			$650,000
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	30,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$4,445,000
CONTINGENCY						$666,750
TOTAL						$5,111,750

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 6 - ENGINEERED COVER (LINERS OUT)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
BACKFILL TO FINAL GRADE (INCL. COMP.)	100,000	CY	$5.00		$5.00	$1,000,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	$550,000
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	30,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$3,844,500
CONTINGENCY						$576,675
TOTAL						$4,421,175

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 7 - ENGINEERED COVER (LINERS OUT)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
BACKFILL TO FINAL GRADE (INCL. COMP.)	100,000	CY	$5.00		$5.00	$1,000,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	$550,000
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	50,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$3,844,500
CONTINGENCY						$576,675
TOTAL						$4,421,175

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 8 - ENGINEERED COVER (LINERS IN)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
BACKFILL TO FINAL GRADE (INCL. COMP.)	150,000	CY	$5.00		$5.00	$1,500,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	$550,000
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	30,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$5.00	$2.81	$1.70	$951
BACKFILL	200	CY	$1.60	$2.81	$4.40	$1,762
15" DIA. CMP	3,000	LF	$6.55 *		$4.00	$31,650
SUBTOTAL						$4,342,863
CONTINGENCY						$651,429
TOTAL						$4,994,292

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 9 - ENGINEERED COVER (LINERS OUT)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING		AC				
BACKFILL TO FINAL GRADE (INCL. COMP.)	100,000	CY	$5.00		$5.00	$1,000,000
COMPACTED CLAY SOILS	50,000	CY	$6.00		$5.00	$550,000
GEOSYNTHETIC CLAY LINERS	650,000	SF	$1.00			
FLEXIBLE MEMBRANE LINERS	650,000	SF	$1.00			$650,000
SAND (DRAINAGE LAYER)	30,000	CY	$6.00		$2.00	
FABRICATED DRAINAGE NET	650,000	SF	$1.00			$650,000
FILTER FABRIC	80,000	SY	$2.00			$160,000
TOPSOIL/BACKFILL (NO COMP.)	50,000	CY	$6.00		$3.00	$450,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
TOE DRAIN COMPONENTS:						
TRENCH EXCAVATION	500	CY			$5.00	$2,500
BEDDING	500	CY	$8.00		$2.00	$5,000
6" DIA. PERF. DRAIN PIPE	6,000	LF	$2.00		$2.00	$24,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$3,844,500
CONTINGENCY						$576,675
TOTAL						$4,421,175

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 10 - BACKFILL (LINERS OUT)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
TOPSOIL/BACKFILL (NO COMP.)	80,000	CY	$6.00		$3.00	$720,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$1,073,000
CONTINGENCY						$160,950
TOTAL						$1,233,950

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 11 - BACKFILL (LINERS OUT)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING	15	AC				
TOPSOIL/BACKFILL (NO COMP.)	80,000	CY	$6.00		$3.00	$720,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$1,073,000
CONTINGENCY						$160,950
TOTAL						$1,233,950

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

ROCKY FLATS PLANT
OU4 SOLAR EVAPORATION POND
SCENARIO 2 - BACKFILL (LINERS IN)
PRELIMINARY COST ESTIMATE

MATERIAL	QUANTITY	UNITS	UNIT PRICE MATERIAL	UNIT PRICE SHIPPING	UNIT PRICE INSTALLATION	TOTAL COST
COVER COMPONENTS:						
CLEARING & GRUBBING	350,000	SF			$0.50	$175,000
REGRADING						
TOPSOIL/BACKFILL (NO COMP.)	100,000	CY	$6.00		$3.00	$900,000
PEA GRAVEL (ANGULAR)	10,000	CY	$8.00		$2.00	$100,000
VEGETATION	80,000	SY	$0.50			$40,000
STORM DRAINAGE SYSTEM:						
TRENCH EXCAVATION	400	CY			$5.00	$2,000
BEDDING	100	CY	$8.00		$2.00	$1,000
BACKFILL	200	CY	$5.00		$5.00	$2,000
15" DIA. CMP	3,000	LF	$7.00		$4.00	$33,000
SUBTOTAL						$1,253,000
CONTINGENCY						$187,950
TOTAL						$1,440,950

* MATERIAL COST INCLUDES SHIPPING AND INSTALLATION

Attachment J

TO: Conrad Montes

FROM: Phil Nixon

DATE: December 23, 1993

SUBJECT: Estimate for the Number of Contractor Personnel and Number of Required Escorts.

The following table presents an estimate for the alternative durations and the contractors crew size. These estimates are based on information from the Means Heavy Construction Cost Data estimating manual. The number of escorts is based on the fact that one escort is required for every three red badged personnel entering the Protected Area (SP307:112293:02).

General Response Action	Duration (months)	Number of Contractors	Number of Escorts	Cost
Alt I	6	9	3	$116,000
Alt II-A	12	9	3	$231,000
Alt II-B	12	12	4	$308,000
Alt II-C	12	9	3	$231,000
Alt III-A	12	16	6	$461,000
Alt III-B	12	16	6	$461,000
Alt III-C	12	24	8	$615,000
Alt IV-A	12	24	8	$615,000
Alt V	18	26	9	$1,037,000

$$Cost\ (\$) = No.\ of\ Escorts\ X\ Months\ X\ \frac{4\ Weeks}{Month}\ X\ \frac{40\ Hours}{Week}\ X\ \frac{\$40}{Hour}$$

Minimum Training Requirements Per Worker

GET	24 hours
40-Hour OSHA	40 hours
RESP FIT	4 hours
Rad Worker	16 hours
Waste Gen	8 hours
Dosimeter	8 hours
Red Badge	8 hours
Haz Comm	2 hours
TOTAL	**104 hours**

ES ENGINEERING-SCIENCE, INC.

ATTACHMENT 'K'

Client EG&G RF
Subject OU4 IM/IRA

Job No. DE307.22.02
By HAH
Checked

Sheet 1 of
Date 1 DEC 93
1045
Rev.

TELECON

TO: Paul Lovendale - Bartlett Nuclear, Plymouth, MA. (800) 225-0385
FROM: Heidkamp
Subject: Contract HP monitoring

Senior HP rate: 34/hr Junior HP: 24/hr
Travel: 24¢/mile
Equipment: 250/week (2 β,γ meters, 1 μR meter, 2 friskers, 1 smear counter, 1 α meter, 1 air grab splr.)

Average Personnel Cost

Assume: 3000 mile Roundtrip
6 month job duration (26 weeks)
7 day work week (56 hr/week)
1 senior HP, 2 Junior HP personnel

Total Cost = $(3000)(0.24)(3) + [(34 + 2(24))56 + 250]26$

$= \$130,964$

Average Cost = $\frac{\$130,964}{(26)(7)(3)} = \$240$/man-day

cc: B. Cropper
W. Edmonson
C. Gee
C. Montes
D. Myers
R. Riecken

ES ENGINEERING-SCIENCE, INC.

ATTACHMENT 'L'

Client EGG
Subject OU4 IM/IRA
Job No. DE 307.22.02
By HAH
Checked
Sheet ___ of ___
Date 10 DEC 93
Rev.

TELECON

TO: LORENZO UBIAS - MGR, RADIOLOGICAL OPERATIONS 996-8231 5507(p)

SUBJECT: RAD OPS COVERAGE FOR OU4 REMEDIATION

½ - 1 HR MOVE CRATES FROM OU4

15-20 MIN/CRATE 4-6 HRS FOR 10 CRATES INCLUDES SET-UP TIME

SUGGESTED LOADING 1 MAN/SHIFT FOR AMOUNT OF WASTE GENERATED FROM OU4

BURDENED RATE IS ~~$81~~ 82/HR.

[ATTACHMENT M] SJAN 94 HAH

722446 OUA IM/IRA ESTIMATES FOR REMEDY SELECTION

SEP LINERS EXCAVATION 317,000 SF = 35,200 SY

COST DATA FROM MEANS HEAVY CONST COST DATA 1990

020 550 SITE DEMOLITION

554 1750 Pavement removal, bituminous, 4-6" thick

CREW B-38 / backhoe loader (48 hp)
/ demol. hammer (1000 lb)
/ F.E. loader (170 hp)
/ pavt rem bucket

420 SY/DAY $ 4.40/SY (bare)

(35,200 SY)(4.4) $154,900

(35,200 SY)/420 = 84 days

∴ use 3 crews = 28 days

022 200 EXCAV, BACKFILL, COMPACT

274 mobilization/demobilization

3 backhoes @ 225 ea = $675 (bare)
3 FE loaders @ 201 ea = $603 (bare)
$1280

266 0320 Hauling, ½ mile RT, 12 CY dump truck

308 CY/DAY use 2 1.59/CY (bare)

$\left(\frac{317000}{27}\right)(1.59)$ = $18,700

022 266 4500 Light Dust Control $575/day (bare)

(28)(575) = $16,100

HP coverage - seperate
Escorts/Training - seperate
Contractor OH, mark-up, profit - seperate

TOTAL $189,700

Escalate (90-93) 3%/yr 17,600

TOTAL 207,300

use $18/CY for estimate

cc: P Nixon
G DeWeese
C Montes

ATTACHMENT N

OU4 IM/IRA ALTERNATIVES SELECTION
ROUGH-ORDER-OF-MAGNITUDE (ROM) COST ESTIMATE SUMMARY

ALTERNATIVE	SCENARIO	TOTAL ESTIMATED COST
I	A	$1,437,000
II	A B C	22,422,000 21,610,000 38,845,000
III	A B C	65,899,000 64,643,000 178,059,000
IV	A	883,690,000
V	A B	453,155,000 427,741,000

1/ Alternative V, Scenario A includes an ex situ bioremediation cost of $450/ton.
2/ Alternative V, Scenario B includes an ex situ soil washing cost of $200/ton.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE I – Scenario A, No Action

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	0 CY	0
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	0 Hours	0
8	TREAT SOIL	Contractor		200 /Ton	0 Tons	0
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	0 CY	0
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	0 LS	0
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	0 CY	0
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		11.6 /CY	0 CY	0
20	ENGINEERED COVER SITE	Contractor		5,112,000	0 LS	0
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	0 LS	0
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	0 LS	0
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	0 LS	0
25	UTILITIES	Contractor		491,000	0 LS	0
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	0 LS	0
27	TRAINING	EG&G		50 /Hour	936 Manhours	47,000
28	CONSTRUCTION SUBTOTAL					585,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE I – Scenario A, No Action

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	0 LS	0
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	0 LS	0
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		148,000
32	BUILDING FACTOR b/			49 Percent		0
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		29,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		59,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		2,000
36	PROCUREMENT e/	EG&G		3 Percent		1,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		135,000
38	SUBTOTAL (Sum Items 28 through 37)					959,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		67,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					1,026,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		411,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$1,437,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26 and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario A, No Excavation or Treatment of Liners or Soils, Backfill and Seed

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	0 CY	0
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	0 Hours	0
8	TREAT SOIL	Contractor		200 /Ton	0 Tons	0
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	0 CY	0
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	0 CY	0
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		1,441,000	1 LS	1,441,000
20	ENGINEERED COVER SITE	Contractor		5,112,000	0 LS	0
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	936 Manhours	47,000
28	CONSTRUCTION SUBTOTAL					5,256,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario A, No Excavation or Treatment of Liners or Soils, Backfill and Seed

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		1,330,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		282,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		526,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		369,000
36	PROCUREMENT e/	EG&G		3 Percent		103,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		1,215,000
38	SUBTOTAL (Sum Items 28 through 37)					14,963,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		1,052,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					16,015,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		6,407,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$22,422,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario B, No Excavation or Treatment of Liners or Soils, Install Temporary Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	0 CY	0
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	0 Hours	0
8	TREAT SOIL	Contractor		200 /Ton	0 Tons	0
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	0 CY	0
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	0 LS	0
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	0 CY	0
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		1,441,000	1 LS	1,441,000
20	ENGINEERED COVER SITE	Contractor		5,112,000	0 LS	0
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	1,248 Manhours	63,000
28	CONSTRUCTION SUBTOTAL					4,951,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario B, No Excavation or Treatment of Liners or Soils, Install Temporary Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		1,253,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		267,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		496,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		334,000
36	PROCUREMENT e/	EG&G		3 Percent		94,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		1,144,000
38	SUBTOTAL (Sum Items 28 through 37)					14,421,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		1,014,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					15,435,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		6,175,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$21,610,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario C, Excavate All Soils, Install Drain, Backfill, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	20.5 /CY	11,740 CY	241,000
7	CRUSH AND SPREAD LINERS	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		200 /Ton	0 Tons	0
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	162,100 CY	811,000
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		11.6 /CY	45,000 CY	522,000
20	ENGINEERED COVER SITE	Contractor		5,112,000	1 LS	5,112,000
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	936 Manhours	47,000
28	CONSTRUCTION SUBTOTAL					11,442,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE II – Scenario C, Excavate All Soils, Install Drain, Backfill, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		2,895,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		592,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		1,145,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		1,034,000
36	PROCUREMENT e/	EG&G		3 Percent		289,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		2,644,000
38	SUBTOTAL (Sum Items 28 through 37)					25,923,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		1,823,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					27,746,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		11,099,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$38,845,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE III – Scenario A, Treat Liners and Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	0 CY	0
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	0 Hours	0
8	TREAT SOIL AND LINERS	Contractor		80 /CY	157,000 CY	12,560,000
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	16,800 CY	84,000
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		1,441,000	0 LS	0
20	ENGINEERED COVER SITE	Contractor		5,112,000	1 LS	5,112,000
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	1,664 Manhours	84,000
28	CONSTRUCTION SUBTOTAL					21,637,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE III – Scenario A, Treat Liners and Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		5,475,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		1,101,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		2,164,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		2,126,000
36	PROCUREMENT e/	EG&G		3 Percent		594,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		4,999,000
38	SUBTOTAL (Sum Items 28 through 37)					43,978,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		3,092,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					47,070,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		18,829,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$65,899,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE III – Scenario B, Crush Liners, Treat Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	0 LS	0
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	0 Manhours	0
4	PURCHASE WASTE CRATES	Contractor		260 Each	0 Crates	0
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	0 Hour	0
6	REMOVE LINERS	Contractor	Pay Loader	20.5 /CY	11,740 CY	241,000
7	CRUSH AND SPREAD LINERS	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		80 /CY	145,300 CY	11,624,000
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	16,800 CY	84,000
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	0 Manhours	0
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	0 Manhours	0
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	0 Manhours	0
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	0 Railcars	0
17	DISPOSAL	EnviroCare		57 /CF	0 CF	0
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		11.6 /CY	0 CY	0
20	ENGINEERED COVER SITE	Contractor		4,422,000	1 LS	4,422,000
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	1,664 Manhours	84,000
28	CONSTRUCTION SUBTOTAL					21,164,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE III – Scenario B, Crush Liners, Treat Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		5,355,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		1,078,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		2,117,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		2,075,000
36	PROCUREMENT e/	EG&G		3 Percent		579,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		4,890,000
38	SUBTOTAL (Sum Items 28 through 37)					43,140,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		3,033,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					46,173,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		18,470,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$64,643,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE III – Scenario C, Remove Liners, Treat Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	1 LS	807,000
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	520 Manhours	39,000
4	PURCHASE WASTE CRATES	Contractor		260 Each	10,600 Crates	2,756,000
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	883 Hour	49,000
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	11,740 CY	212,000
7	CRUSH LINERS / LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		80 /CY	145,300 CY	11,624,000
9	EXCAVATE/RELOCATE SOIL	Contractor		5 /CY	16,800 CY	84,000
10	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	1,767 Manhours	71,000
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	76,320 Manhours	6,411,000
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
16	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	332 Railcars	734,000
17	DISPOSAL	EnviroCare		57 /CF	593,600 CF	33,836,000
18	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
19	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		11.6 /CY	45,000 CY	522,000
20	ENGINEERED COVER SITE	Contractor		4,422,000	1 LS	4,422,000
21	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
22	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
23	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
24	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
25	UTILITIES	Contractor		491,000	1 LS	491,000
26	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
27	TRAINING	EG&G		50 /Hour	2,496 Manhours	125,000
28	CONSTRUCTION SUBTOTAL					66,539,000

ALTERNATIVE III – Scenario C, Remove Liners, Treat Soils In Situ, Construct Engineered Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
29	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
30	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
31	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		16,835,000
32	BUILDING FACTOR b/			49 Percent		382,000
33	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		3,347,000
34	ENGINEERING (10% of Item 28, Construction Subtotal)	EG&G		10 Percent		6,654,000
35	CONTRACTOR G&A d/	Contractor		10.75 Percent		2,456,000
36	PROCUREMENT e/	EG&G		3 Percent		1,747,000
37	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		15,371,000
38	SUBTOTAL (Sum Items 28 through 37)					118,831,000
39	ESCALATION (7.03% of Item 38, Subtotal)			7.03 Percent		8,354,000
40	ESCALATED SUBTOTAL (Sum Items 38 and 39)					127,185,000
41	CONTINGENCY (40% of Item 40, Escalated Subtotal)			40 Percent		50,874,000
42	TOTAL ESTIMATED COST (Sum Items 40 and 41)					$178,059,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 28).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 26).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 28 and 32).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, and half of Item 22.

f/ Project and Construction Management cost is 21% of the sum of Items 28 and 34.

g/ All Item Total Costs are rounded up to the nearest thousand.

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE IV – Remove Liners, Excavation and Disposal of All Contaminated Soils, Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	1 LS	807,000
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	520 Manhours	39,000
4	PURCHASE WASTE CRATES	Contractor		260 Each	10,600 Crates	2,756,000
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	883 Hour	49,000
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	11,740 CY	212,000
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		350 /Ton	0 Tons	0
9	EXCAVATE SOIL	Contractor		2.5 /CY	162,100 CY	406,000
10	HAUL SOIL / LOAD SOIL IN GONDOLAS AT RAIL SPUR	Contractor	Pay Loader	3.5 /CY	186,415 CY	653,000
11	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
12	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	1,767 Manhours	71,000
13	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
14	ASSAY WASTE CRATES	EG&G		84 /Manhour	76,320 Manhours	6,411,000
15	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
16	TRANSPORT LINERS (IN CRATES) TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	332 Railcars	734,000
17	LINER DISPOSAL	EnviroCare		57 /CF	593,600 CF	33,836,000
18	SOIL SAMPLING AND ANALYSIS	Contractor		2,000 /Gondola	2,626 Gondolas	5,253,000
19	TRANSPORT SOIL (IN GONDOLAS) TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	2,626 Railcars	5,804,000
20	SOIL DISPOSAL	EnviroCare		57 /CF	5,033,205 CF	286,893,000
21	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
22	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		1,234,000	1 LS	1,234,000
23	ENGINEERED COVER SITE	Contractor		4,422,000	0 LS	0
24	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
25	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
26	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
27	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
28	UTILITIES	Contractor		491,000	1 LS	491,000
29	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
30	TRAINING	EG&G		50 /Hour	2,496 Manhours	125,000
31	CONSTRUCTION SUBTOTAL					350,130,000

OU4 PHASE I IM/IRA – ALTERNATIVES SELECTION

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE IV – Remove Liners, Excavation and Disposal of All Contaminated Soils, Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
32	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
33	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
34	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		88,583,000
35	BUILDING FACTOR b/			49 Percent		382,000
36	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		17,526,000
37	ENGINEERING (10% of Item 31, Construction Subtotal)	EG&G		10 Percent		35,013,000
38	CONTRACTOR G&A d/	Contractor		10.75 Percent		1,477,000
39	PROCUREMENT e/	EG&G		3 Percent		10,255,000
40	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		80,881,000
41	SUBTOTAL (Sum Items 31 through 40)					589,747,000
42	ESCALATION (7.03% of Item 41, Subtotal)			7.03 Percent		41,460,000
43	ESCALATED SUBTOTAL (Sum Items 41 and 42)					631,207,000
44	CONTINGENCY (40% of Item 43, Escalated Subtotal)			40 Percent		252,483,000
45	TOTAL ESTIMATED COST (Sum Items 43 and 44)					$883,690,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 31).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 29).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 31 and 35).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 18, 21, 22, 23, 24, 27, 28, 29 and half of Item 25.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 27, 28, 29 and half of Item 25.

f/ Project and Construction Management cost is 21% of the sum of Items 31 and 37.

g/ All Item Total Costs are rounded up to the nearest thousand.

OU4 PHASE I IM/IRA – ALTERNATIVES SELECTION

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE V – Scenario A, Remove Liners, Excavate Soils and Treat (Ex Situ Bioremediation), Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	1 LS	807,000
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	520 Manhours	39,000
4	PURCHASE WASTE CRATES	Contractor		260 Each	10,600 Crates	2,756,000
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	883 Hour	49,000
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	11,740 CY	212,000
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		450 /Ton	262,600 Tons	118,170,000
9	EXCAVATE SOIL	Contractor		2.5 /CY	162,100 CY	406,000
10	RELOCATE SOIL	Contractor		2.5 /CY	186,415 CY	467,000
11	EXCAVATE SOIL/LOAD WASTE CRATES	Contractor	Pay Loader	2.5 /CY	0 CY	0
12	VEGETATION REMOVAL / STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
13	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	1,767 Manhours	71,000
14	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
15	ASSAY WASTE CRATES	EG&G		84 /Manhour	76,320 Manhours	6,411,000
16	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
17	TRANSPORT TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	332 Railcars	734,000
18	DISPOSAL	EnviroCare		57 /CF	593,600 CF	33,836,000
19	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
20	BACKFILL – DELIVER / SPREAD / GRADE / COMPACT	Contractor		1,234,000	1 LS	1,234,000
21	ENGINEERED COVER SITE	Contractor		4,422,000	0 LS	0
22	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man–Day	21 Man–Days	14,000
23	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
24	MONITOR JOB SITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
25	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
26	UTILITIES	Contractor		491,000	1 LS	491,000
27	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
28	TRAINING	EG&G		50 /Hour	2704 Manhours	136,000
29	CONSTRUCTION SUBTOTAL					170,175,000

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE V – Scenario A, Remove Liners, Excavate Soils and Treat (Ex Situ Bioremediation), Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
30	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
31	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
32	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		43,055,000
33	BUILDING FACTOR b/			49 Percent		382,000
34	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		8,528,000
35	ENGINEERING (10% of Item 29, Construction Subtotal)	EG&G		10 Percent		17,018,000
36	CONTRACTOR G&A d/	Contractor		10.75 Percent		13,596,000
37	PROCUREMENT e/	EG&G		3 Percent		4,856,000
38	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		39,311,000
39	SUBTOTAL (Sum Items 29 through 38)					302,421,000
40	ESCALATION (7.03% of Item 39, Subtotal)			7.03 Percent		21,261,000
41	ESCALATED SUBTOTAL (Sum Items 39 and 40)					323,682,000
42	CONTINGENCY (40% of Item 41, Escalated Subtotal)			40 Percent		129,473,000
43	TOTAL ESTIMATED COST (Sum Items 41 and 42)					$453,155,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 29).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 27).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 29 and 33).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20, 21, 22, 25, 26, 27, and half of Item 23.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, and half of Item 23.

f/ Project and Construction Management cost is 21% of the sum of Items 29 and 35.

g/ All Item Total Costs are rounded up to the nearest thousand.

OU4 PHASE I IM/IRA – ALTERNATIVES SELECTION

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE V – Scenario B, Remove Liners, Excavate Soils and Treat (Ex Situ Soil Washing) Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
1	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	EG&G	Monitoring	524,000	1 LS	524,000
2	PURCHASE ASSAY EQUIPMENT	EG&G	PAN assay	807,000	1 LS	807,000
3	INSTALL ASSAY EQUIPMENT	Contractor		75 /Hour	520 Manhours	39,000
4	PURCHASE WASTE CRATES	Contractor		260 Each	10,600 Crates	2,756,000
5	OFFLOAD WASTE CRATES	Contractor	Fork Truck	55 /Hour	883 Hour	49,000
6	REMOVE LINERS	Contractor	Pay Loader	18 /CY	11,740 CY	212,000
7	CRUSH LINERS/LOAD WASTE CRATES	Contractor	Crusher	400 /Hour	2,280 Hours	912,000
8	TREAT SOIL	Contractor		200 /Ton	262,600 Tons	52,520,000
9	EXCAVATE SOIL	Contractor		2.5 /CY	162,100 CY	406,000
10	RELOCATE SOIL	Contractor		2.5 /CY	149,132 CY	373,000
11	HAUL/LOAD SOIL IN GONDOLAS AT RAIL SPUR	Contractor	Pay Loader	3.5 /CY	37,283 CY	131,000
12	VEGETATION REMOVAL/STABILIZE HILLSIDE	Contractor		321,000	1 LS	321,000
13	INSTALL WASTE CRATE LIDS	Contractor		40 /Hour	1,767 Manhours	71,000
14	MOVE WASTE CRATES TO ASSAY	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
15	ASSAY WASTE CRATES	EG&G		84 /Manhour	76,320 Manhours	6,411,000
16	MOVE WASTE CRATES TO RAILCARS	Contractor	Fork Truck, Flatbed	65 /Hour	1,060 Manhours	69,000
17	TRANSPORT LINERS (IN CRATES) TO DISPOSAL FACILITY	Southern Pacific	Railcars	2,210 /Railcar	332 Railcars	734,000
18	LINER DISPOSAL	EnviroCare		57 /CF	593,600 CF	33,836,000
19	SOIL SAMPLING AND ANALYSIS	Contractor		2,000 /Gondola	526 Gondolas	1,052,000
20	TRANSPORT SOIL (IN GONDOLAS) TO DISPOSAL FACILITY	Southern Pacific	Gondolas	2,210 /Gondola	526 Gondolas	1,163,000
21	SOIL DISPOSAL	EnviroCare		57 /CF	1,006,641 CF	57,379,000
22	INSTALL SUBSURFACE DRAINAGE SYSTEM	Contractor		2.6 /CY	11,000 CY	29,000
23	BACKFILL – DELIVER /SPREAD/GRADE/COMPACT	Contractor		1,234,000	1 LS	1,234,000
24	ENGINEERED COVER SITE	Contractor		4,422,000	0 LS	0
25	FINAL SITE SURVEY	Contractor	Monitoring	651 /Man-Day	21 Man-Days	14,000
26	FINAL SITE PREPARATION	Contractor/EG&G	Drilling rig/Equip Decon	591,000	1 LS	591,000
27	MONITOR JOBSITE REMEDIATION/ENTRY SECURITY	EG&G		964,000	1 LS	964,000
28	RELOCATE POWER LINES BETWEEN PONDS 207A & B	Contractor		85,000	1 LS	85,000
29	UTILITIES	Contractor		491,000	1 LS	491,000
30	BUILDING 788 & ANCILLARY EQUIP. REMOVAL	Contractor		778,000	1 LS	778,000
31	TRAINING	EG&G		50 /Hour	2,704 Manhours	136,000
32	CONSTRUCTION SUBTOTAL					164,156,000

OU4 PHASE I IM/IRA – ALTERNATIVES SELECTION

ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATE

ALTERNATIVE V – Scenario B, Remove Liners, Excavate Soils and Treat (Ex Situ Soil Washing) Construct Backfill Cover

ITEM	TASK	RESPONSIBILITY	EQUIPMENT	UNIT COST ($/UNIT)	QUANTITY	TOTAL COST g/
33	ENGINEERING	A/E		2,500,000	1 LS	2,500,000
34	CONSTRUCTION MANAGEMENT	A/E		3,000,000	1 LS	3,000,000
35	CONTRACTOR OVERHEAD AND PROFIT a/	CONTRACTOR		25.3 Percent		41,531,000
36	BUILDING FACTOR b/			49 Percent		381,000
37	PURCHASE OF SMALL TOOLS & CONSUMABLES c/			5 Percent		8,227,000
38	ENGINEERING (10% of Item 32, Construction Subtotal)	EG&G		10 Percent		16,416,000
39	CONTRACTOR G&A d/	Contractor		10.75 Percent		6,655,000
40	PROCUREMENT e/	EG&G		3 Percent		4,675,000
41	PROJECT & CONSTRUCTION MGMT (P&CM) f/	EG&G/CM		21 Percent		37,920,000
42	SUBTOTAL (Sum Items 32 through 41)					285,461,000
43	ESCALATION (7.03% of Item 42, Subtotal)			7.03 Percent		20,068,000
44	ESCALATED SUBTOTAL (Sum Items 42 and 43)					305,529,000
45	CONTINGENCY (40% of Item 44, Escalated Subtotal)			40 Percent		122,212,000
46	TOTAL ESTIMATED COST (Sum Items 44 and 45)					$427,741,000

a/ Contractor overhead and profit is 25.3% of the construction subtotal (Item 32).

b/ Building factor is 49% of Building 778 and ancillary equipment removal (Item 30).

c/ Purchase of small tools and consumables is 5% of the sum of construction subtotal and building factor (Items 32 and 36).

d/ Contractor G&A cost is 10.75% of the sum of Items 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 22, 23, 24, 25, 28, 29, 30 and half of Item 26.

e/ Procurement cost is 3% of the sum of Items 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 28, 29, 30 and half of Item 26.

f/ Project and Construction Management cost is 21% of the sum of Items 31 and 37.

g/ All Item Total Costs are rounded up to the nearest thousand.

APPENDIX III.G

EVALUATION OF SPECIFIC ENGINEERED COVER ALTERNATIVES

APPENDIX III.G

EVALUATION OF SPECIFIC ENGINEERED COVER ALTERNATIVES

1.0 INTRODUCTION

This report evaluates specific engineered cover alternatives, including:

- 1,000-year system engineered cover,
- RCRA-compliant engineered cover, and
- Capillary-break engineered cover.

These three designs are proposed in the IM/IRA-EA Decision Document (Section III.3.2), and are considered to be the most appropriate engineered covers for the OU4 SEPs. This report is divided into six sections. Sections two, three, and four present information about each of the engineered cover alternatives. Sections five and six summarize the conclusions of the evaluation and provide recommendations.

The conceptual design strategy presented in Part III of the OU4 IM/IRA-EA Decision Document is the design basis for this comparative analysis. A subsurface drain system is provided for all three scenarios because it has been demonstrated that the existing subsurface soils beneath the engineered cover may periodically become saturated with ground water and leach at concentrations that could cause an adverse impact to ground water, thus these soils would have to be moved above the subsurface drainage system to prevent their contact with ground water.

It is important to note that the analysis does not consider a reclamation-type cover that is proposed for areas being clean-closed (backfilled and seeded). The reason for this is that the engineered cover will have to isolate contaminated soils that exceed the PRG concentrations. In addition, the engineered cover may also provide closure for contaminated debris and equipment from RCRA units in OU4 that may not be fully characterized. Therefore, the reclamation cover may not adequately meet the closure requirements of the Colorado Hazardous Waste Management regulations. The capillary-break engineered cover is essentially a reclamation cover with the capillary break/biotic barrier to prevent plants and wildlife from contacting the consolidated contaminated materials.

The design scenarios presented may not exactly reflect the final design, but they are adequate to perform a comparative analysis. All three engineered covers are expected to be

protective of human health and the environment with respect to the upward exposure pathways.

2.0 1,000-YEAR SYSTEM ENGINEERED COVER

Figure 1 presents a cross-section of the 1,000-year system engineered cover that would meet the closure requirements of the Colorado Hazardous Waste regulations. The cost of this engineered cover is estimated at approximately $33.8 million. Attachment A presents the back-up documentation for the cost estimate. The expected construction duration is 24 months. The anticipated date of construction completion is May 1997. The conceptual schedule is shown in Figure 2.

Advantages of the 1,000-year system engineered cover

- The DOE can present to the public and to the regulatory agencies that the best available technology (to date) from research at the Hanford Reservation and Los Alamos National Laboratory has been utilized for the purpose of protecting human health and the environment for 1,000 years.

- The design uses all natural materials that will maximize the durability and longevity of the engineered cover.

- This engineered cover should be the most effective at minimizing precipitation infiltration over a 1,000-year period since all natural and durable materials are used in its construction.

Disadvantages of the 1,000-year system engineered cover

- The 1,000-year system engineered cover is a conservative design with respect to the contaminant concentrations in consolidated materials and the expected low impact from leaching if water should infiltrate downward through the engineered cover.

- The use of asphalt may be a problem with respect to gaining regulatory approval because asphaltic materials are not typically used in engineered covers meeting RCRA requirements.

- The 1,000-year system engineered cover, having the greatest thickness of the three cover types, would provide the greatest structural load on the northern hillside (which is known to be potentially unstable) and may necessitate hillside stabilization measures.

- Geosynthetic materials cannot be used as components of the engineered cover.

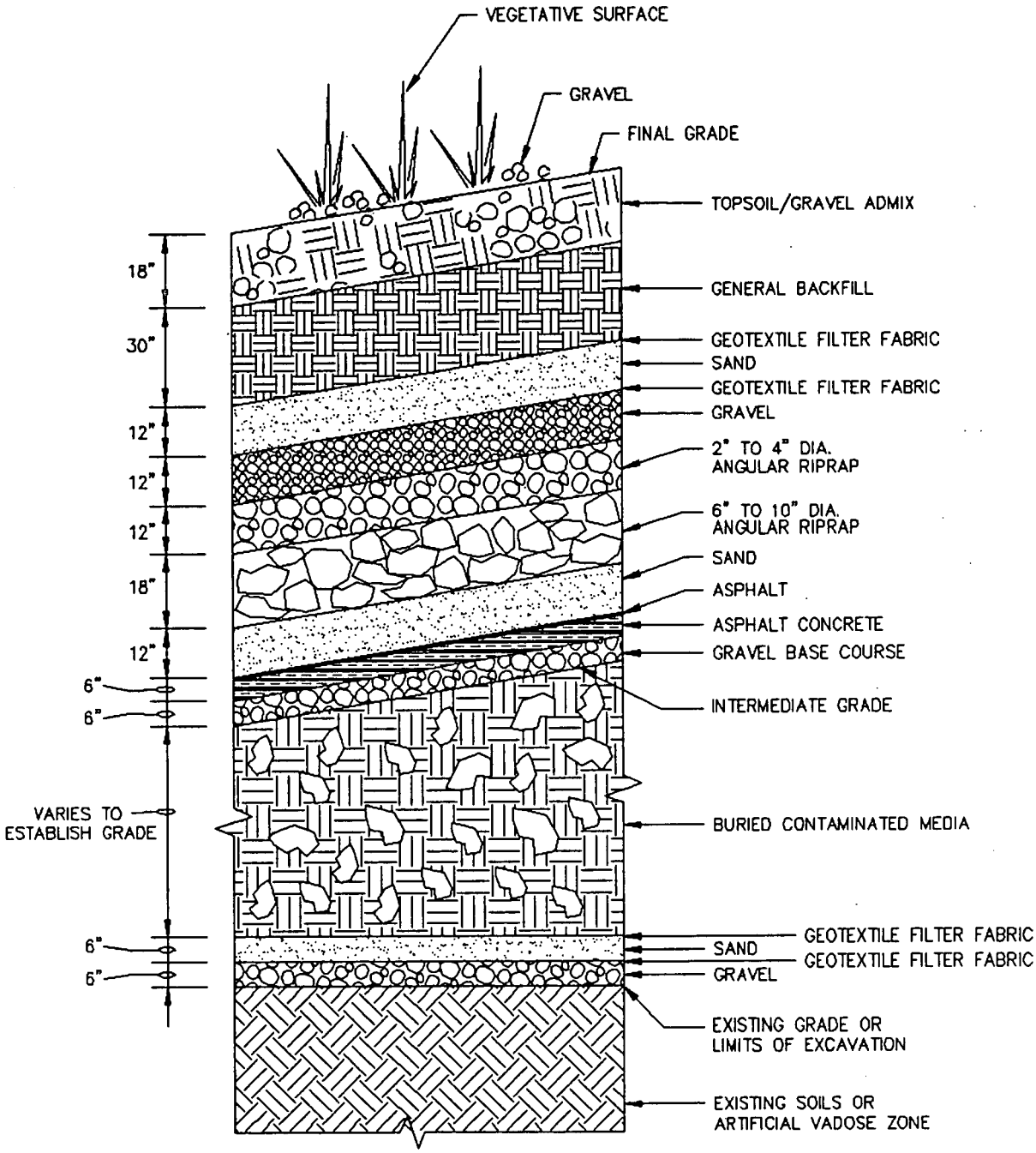


FIGURE 1
1000-YEAR SYSTEM ENGINEERED COVER SECTION

3.0 RCRA-COMPLIANT ENGINEERED COVER

A RCRA-compliant engineered cover could be implemented at the OU4 SEPs if all hazardous waste materials had COC concentrations that were less than the PRG concentrations developed for the upward exposure pathways, and if these materials were placed above the subsurface drainage layer to provide isolation from ground water. Figure 3 presents a cross-section of a proposed engineered cover that would meet the closure requirements of the Colorado Hazardous Waste Regulations. This design differs from the 1,000-year engineered cover design in that a geotextile fabric would replace the graded sand and gravel filter system above the angular riprap biotic barrier. The low-permeability asphalt layer and gravel subgrade would be replaced with a flexible membrane liner and geosynthetic clay liner system.

The construction cost of the RCRA engineered cover is estimated to be approximately $30.5 million. This is approximately $3.3 million less than the 1,000-year system engineered cover. Attachment A contains the back-up information for the cost estimate. However, additional sampling and analysis would be required in order to demonstrate that hazardous materials (liners, utilities, and Building 788 debris) have COC concentrations that are less than the PRGs established for the upward exposure pathways (ingestion, inhalation, and dermal exposure). It is estimated that these characterization costs would be $0.9 million. Therefore, the difference between the 1,000-year and RCRA-compliant engineered covers is approximately $2.4 million. It should be noted that there would be additional decontamination and/or disposal costs associated with any hazardous materials that have COC concentrations that exceed the PRGs. It would therefore be possible for the RCRA-compliant engineered cover alternative to equal or exceed the cost of the 1,000-year system engineered cover. The construction duration is expected to be 21 months. The anticipated date of construction completion for the RCRA-compliant engineered cover is March 1997. Figure 4 provides the conceptual schedule. This is approximately 2 to 3 months earlier than the anticipated completion date for the 1000-year system engineered cover.

Advantages of the RCRA-Compliant Engineered Cover

- The engineered cover meets the requirements of the Colorado Hazardous Waste Regulations in a design that is familiar to the regulatory agencies and the public. This should enhance the potential for expedient approval.

- Engineered covers of this type are designed and approved for use in areas with similar environmental conditions as the RFP.

- This engineered cover would reduce the structural load on the potentially unstable hillside north of the SEPs compared to the 1,000-year engineered cover. This engineered cover may have the least impact on the hillside stability since it may have the least overall height of the three engineered covers and therefore would impose the lowest soil-bearing load.

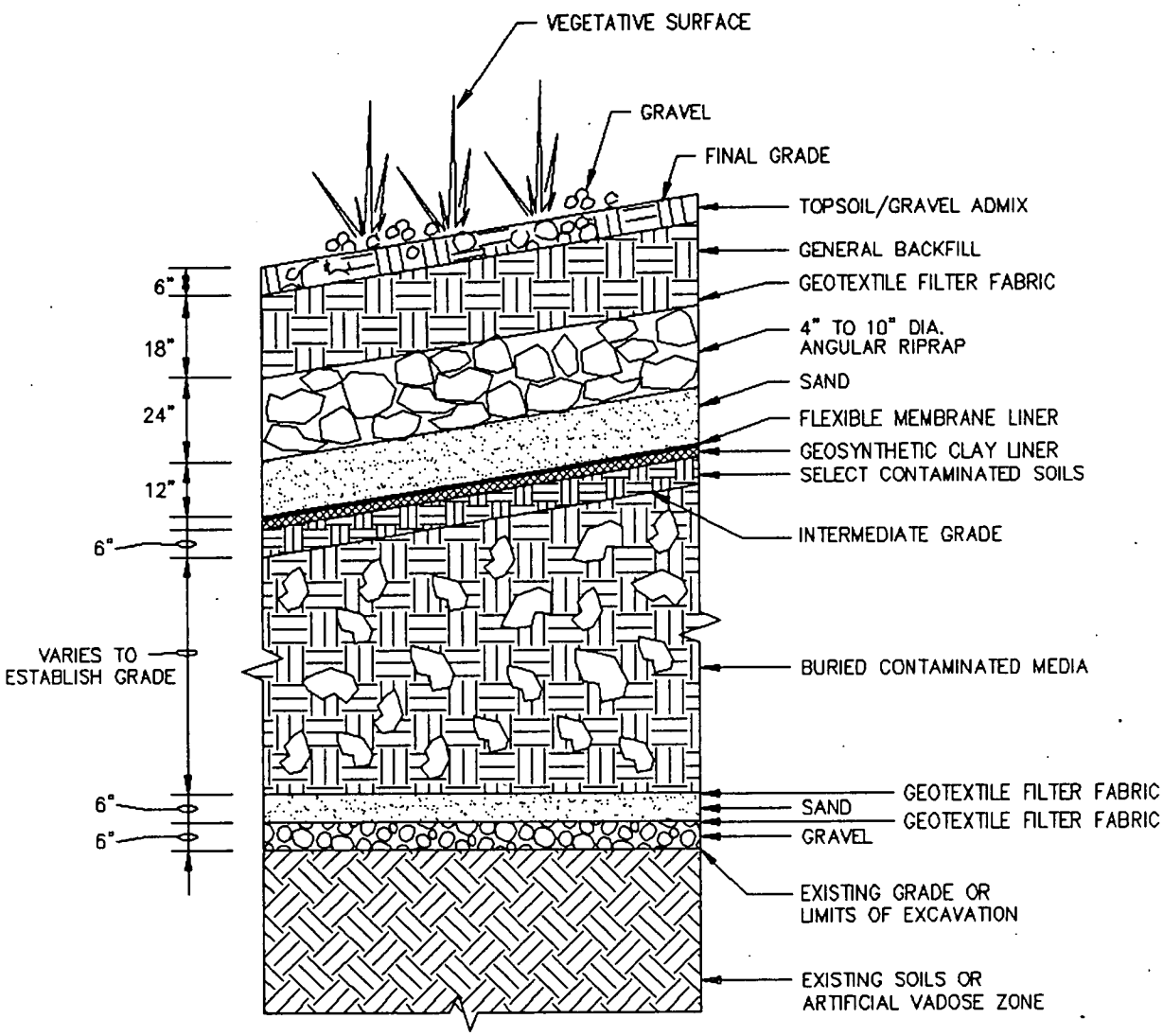


FIGURE 3
RCRA ENGINEERED COVER SECTION

- Fewer materials would have to be hauled onsite and stockpiled than for the 1,000-year system engineered cover.

Disadvantages of the RCRA-Compliant Engineered Cover

- Installation of the flexible membrane liner is sometimes difficult due to fusing of the material sheets, and integrity testing (and if necessary, repair) of the installed material.

- The design uses synthetic materials that have not been demonstrated to remain fully functional over the entire 1,000-year period. It is important to note that 1,000 years is not a design life for the final engineered cover in terms of material integrity. The criterion is to provide reasonable assurance that human health and the environment will be protected for 1,000 years.

- Additional sampling and analysis would be required for all hazardous waste materials/debris proposed to be consolidated beneath the engineered cover. Hazardous waste material/debris with COC concentrations exceeding PRGs could not be consolidated beneath the engineered cover, resulting in additional disposal costs.

4.0 CAPILLARY BREAK ENGINEERED COVER

Figure 5 presents a cross-section of the proposed capillary break engineered cover. This design differs from the RCRA-compliant engineered cover design in that the flexible membrane liner and the geosynthetic clay liner are not used. The thickness of the topsoil and backfill layers may be greater than the RCRA-compliant engineered cover because this cover relies heavily on evaporation and transpiration, which are highly dependent on the adequacy of the vegetation cover to minimize precipitation infiltration. Therefore, increasing the topsoil will ensure adequate nutrient support for the vegetation while increasing the water storage potential. The thickness of the biotic barrier may also be greater to ensure an adequate depth for the capillary break function.

The cost of the capillary break engineered cover is estimated to be approximately $30.5 million. This is approximately equal to the cost of the RCRA-compliant engineered cover and $3.3 million less than the 1,000-year system engineered cover. Attachment A provides the back-up information for the cost estimate. It should be noted that additional characterization would also be required for all hazardous materials/debris. The costs of this alternative could increase significantly if hazardous materials/debris could not be consolidated beneath the engineered cover (if materials have contaminant concentrations exceeding the calculated PRGs). The anticipated construction completion date for the capillary break engineered cover is January 1997. Figure 6 presents the conceptual schedule. This engineered cover alternative could be constructed approximately 5 to 6 months earlier than the 1,000-year system engineered cover and approximately 2 to 3 months earlier than the RCRA-compliant engineered cover.

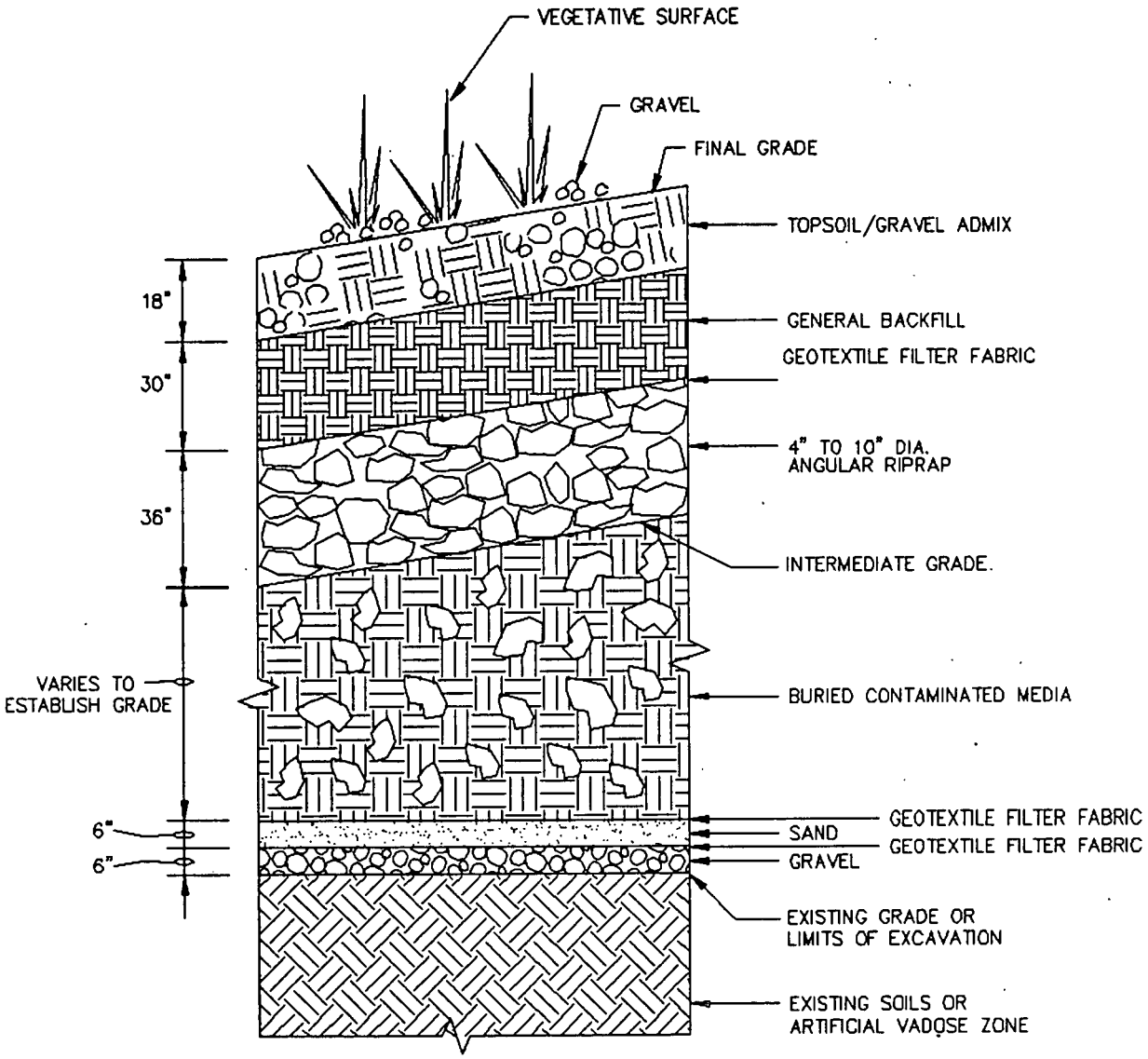


FIGURE 5
CAPILLARY BARRIER ENGINEERED COVER SECTION

Advantages of the Capillary Break Engineered Cover

- This engineered cover could be constructed in the least amount of time.

Disadvantages of the Capillary Break Engineered Cover

- Because of the absence of a low-permeability layer, this engineered cover would be the least effective at reducing the amount of precipitation that infiltrates into the consolidated materials. This cover may be particularly ineffective under melting snow conditions where a slug of moisture may not be evaporated or transpired because of low winter evaporation rates and the semi-dormant state of the vegetation respectively.

- This engineered cover may not meet the closure requirements of the Colorado Hazardous Waste Regulations because the soils beneath the SEPs have low permeabilities (the hydraulic conductivities range from 1.0x10-3 centimeters per day [cm/day] to 1.0x10-9 cm/day) and the cover materials may not be able to be constructed with an equal or lower permeability. The Colorado Hazardous Waste Regulations require that the engineered cover have a permeability equal to or less than the underlying soil. The regulatory agencies may not approve this engineered cover for use in covering utility waste, debris, and equipment from RCRA hazardous waste management units.

- The highest amount of infiltration is anticipated to percolate through this engineered cover alternative.

5.0 CONCLUSIONS REACHED FROM THE EVALUATION OF ENGINEERED COVER ALTERNATIVES

All three engineered cover alternatives are protective of human health and the environment with respect to upward exposure pathways. The selection of an engineered cover alternative is therefore primarily dependent upon the potential impacts to ground water, and the regulatory considerations associated with consolidating hazardous waste beneath the engineered cover.

The capillary break engineered cover design is the least conservative (and likely to be the least effective) of the three alternatives with respect to infiltration of precipitation and potential impacts to the ground water exposure pathway. Therefore, it would require the most technical justification via field research and computer modeling. It may be difficult to gain regulatory approval of this engineered cover design because the natural subsurface soils have a low permeability that may be difficult to equal or exceed as required by the Colorado Hazardous Waste Regulations. To address this issue, ES considers that the average permeability of the underlying soils should be used to determine the effective permeability requirement of the

engineered cover. The capillary break engineered cover is more of a risk management solution than a risk prevention solution because it is anticipated that moisture will penetrate the capillary break. The intent of the capillary break engineered cover is to control the amount of precipitation infiltration whereas the intent of the other engineered covers is to prevent infiltration. The anticipated moisture breakthrough would have to be demonstrated to be protective of human health and the environment via computer modeling and risk assessment.

The RCRA-compliant engineered cover offers several advantages over the capillary break engineered cover for an approximately equal cost. The RCRA-compliant engineered cover provides a low permeability system in accordance with the Colorado Hazardous Waste Regulations, and should be more effective at preventing risks from precipitation infiltration. The effectiveness of the RCRA-compliant engineered cover should equal the effectiveness of the 1,000-year system engineered cover over the design life of the synthetic cover components. Inclusion of the low permeability system should prevent precipitation from infiltrating into the consolidated contaminated materials. This should reduce the potential for corrective actions required due to liquids detected in the upper layers of the engineered cover.

The 1,000-year system engineered cover design uses all natural materials that are expected to maximize the long-term integrity of the closure. The costs of the additional anticipated long-term protection are not significantly greater than the cost of the RCRA-compliant engineered cover (5.1 percent or 1.6 million dollars). The cost differential would be reduced depending on the hazardous materials characterization results and the fact that decontamination or disposal costs could be incurred for contaminated materials/debris that would be consolidated beneath a RCRA-compliant engineered cover that have COC concentrations exceeding the appropriate PRGs.

6.0 RECOMMENDATIONS

ES recommends that the 1,000-year system engineered cover design be implemented at the OU4 SEPs for the following reasons:

- The cost of the 1,000-year system engineered cover design will be similar to the cost of the RCRA-compliant engineered cover because less sampling will be required to verify that materials are suitable for consolidation.

- The uncertainty associated with additional costs of decontamination or offsite disposal for hazardous materials that fail the analysis is greatly reduced.

- Regulatory agency and public approval may be enhanced if DOE can indicate that the design basis is protective of human health and the environment for 1,000 years.

ATTACHMENT A

CLIENT: EG&G
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: 05-May-94
TIME: 11:46:43 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL		LABOR		CONSTR. EQUIP		TOTAL
				UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	
0100	**Baseline radiological/hazardous survey**				**0**		**523,900**		**0**	**523,900**
	Initial survey									
	Set up material staging area	80	MH		0	65.00	5,200		0	5,200
	Set up exclusion zone	160	MH		0	65.00	10,400		0	10,400
	Set up step-off/survey area	80	MH		0	65.00	5,200		0	5,200
	Develop radiation worker permit for zone entry	80	MH		0	65.00	5,200		0	5,200
	Baseline survey by HPT	80	MH		0	65.00	5,200		0	5,200
	Obtain excavation permit	40	MH		0	65.00	2,600		0	2,600
	Conduct pre-job training on sampling grid	60	MH		0	65.00	3,900		0	3,900
	Phase II activities									
	Modify radiation worker permit for excavation	40	MH		0	65.00	2,600		0	2,600
	Write health and safety plan	640	MH		0	65.00	41,600		0	41,600
	Phase III activities				0					
	Daily initial surveys, surveys of equipment leaving exclusion zone and daily end of day surveys of ground and equipment	4000	MH		0	65.00	260,000		0	260,000
	Covering any "surface contamination" during operations and overnight if discovered in end-of-day survey	2800	MH		0	65.00	182,000		0	182,000

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0200	**Monitor job site remediation/entry security**				**0**		**963,828**		**0**	**963,828**
	Rad technicians - 4 for 9 months of project	4,536	MH		0	34.53	156,628		0	156,628
	Construction personnel enter/exit job site	20,180	MH		0	40.00	807,200		0	807,200
5000	**Indirect field costs**				**55,616**		**1,603,476**		**4,433,856**	**6,092,948**
5010	Obtain building permits	80	MH		0	40.00	3,200		0	3,200
	Cost of Permit	1	LS	500.00	500					500
5020	Mobilization - set up construction staging area and perform decon and smear tests on equipment entering the job site	1,000	MH		0	40.00	40,000		0	40,000
5040	Sanitary (portable toilets) - 8	26	MONTH		0		0	584.00	15,184	15,184
5045	Handwash unit - 4	26	MONTH					340.00	8,840	8,840
	Eyewash Unit - 4	26	MONTH					116.62	3,032	3,032
5050	Temporary utils (phone, water, 220V elec)	26	MONTH	500.00	13,000		0		0	13,000
	Temporary security fence and lighting installation									
5060	Security fence	2,090	LF	4.00	8,360	6.00	12,540		0	20,900
	Terminal posts	8	EA	70.00	560	105.00	840		0	1,400
	Security gates	4	EA	404.00	1,616	606.00	2,424		0	4,040
	Lights north of seepline	26	MONTH					4100	106,600	106,600
	Lights south of seepline	26	MONTH					4100	106,600	106,600
5100	Trucks									
	Water tanker (631ww) and operator	572	DAY		0	320.00	183,040	1,235.00	706,420	889,460
	Off highway truck (777C) and operator	572	DAY		0	320.00	183,040	1,910.00	1,092,520	1,275,560
	Wheel loader (992C) and operator	572	DAY		0	320.00	183,040	2,995.00	1,713,140	1,896,180
5110	Mobile lab for geotechnical soil testing	26	MONTH		0		0	700.00	18,200	18,200
	Geotechnical Technician	1500	MH			80.00	120,000		0	120,000
	Field Technician	3000	MH			80.00	240,000		0	240,000

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5120	Mobile analytical lab for environmental testing				0					
	Staffed lab	120	DAY		0	3,000.00	360,000		0	360,000
	Standby lab	120	DAY		0	800.00	96,000		0	96,000
5121	Site prep. trailer area									
	Road base (6") and grading	740	SY	7.54	5,580	0.06	44	0.04	30	5,654
5125	Office trailer	26	MONTH					375.00	9,750	9,750
5126	Break trailer	26	MONTH					260.00	6,760	6,760
5130	Trailer with lockers	26	MONTH		0		0	375.00	9,750	9,750
5150	Personnel decon trailer with showers	26	MONTH		0		0	550.00	14,300	14,300
5155	Lab/trailer:set-up/remove	6	LS		0		0	505	3,030	3,030
5170	Prepare backfill stockpile area	200,000	SY		0	0.10	20,000	0.07	14,000	34,000
5200	Health and Safety equipment	1	LS		0		0	605,700.00	605,700	605,700
5210	Demobilization/project site final clean up	1	LS		0	120,000.00	120,000		0	120,000
	Decontamination of equipment inside the PA	800	MH			17.84	14,272			14,272
	Decontamination of equipment - buffer zone	400	MH			17.84	7,136			7,136
	Waste crates									
5220	Purchase waste crates	100	EA	260.00	26,000		0		0	26,000
	Install lids on waste crates	100	EA		0	12.00	1,200		0	1,200
	Offload waste crates	100	EA		0	7.00	700		0	700
5230	Assay waste crates	200	MH		0	80.00	16,000		0	16,000
6000	**Relocate power lines from between Ponds 207A and 207B-series**				**17,846**		**67,068**		**0**	**84,914**
6001	Lock out/tag out	64	MH			81.8	5,235			5,235
6010	Install power poles	563	MH		12,386	33.17	18,675		0	31,061
6020	Install conductors	2,600	LF	2.10	5,460	3.14	8,164		0	13,624
6030	Tie in relocated power lines	121	MH		0	33.17	4,014		0	4,014

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6040	Perform hi-pot test on new power lines	241	MH		0	33.17	7,994		0	7,994
6050	Remove obsolete power lines and poles	392	MH		0	33.17	13,003		0	13,003
6060	Transport and Store Power Lines	181	MH		0	33.17	6,004		0	6,004
6070	Shred obsolete poles & dispose in 207A	120	MH		0	33.17	3,980		0	3,980
7000	**Vegetation removal**				**22,500**		**4,756**		**1,891**	**29,147**
	Zones E and F									
7030	Lie Down Liner (double thickness)	24	MH		0	40.00	960		0	960
	Bottom Liner	9,000	SF	1.50	13,500		0		0	13,500
7040	Excavate veg. and soils from remediation areas	2,251	CY		0	1.26	2,836	0.84	1,891	4,727
7050	Cover Piles W/Heavy Tarp	24	MH			40.00	960		0	960
	Top Liner	9,000	SF	1.00	9,000		0		0	9,000
8000	**Pond preparation for cover**				**273,058**		**232,494**		**219,639**	**725,190**
8110	Grind 207A, 207C and 207B-series liners (grinder, 3000 SY/day)	11,800	CY		0	0.24	2,832	0.08	944	3,776
8115	Move and stockpile liners	5900	CY			1.51	8,909	1.01	5,959	14,868
8120	Excavate berms and Zones B, C, D & G	21,737	CY		0	1.26	27,389	0.84	18,259	45,648
8121	Move & place backfill for Zones B,C,D & E	20,200	CY	6.27	126,654	1.51	30,502	1.01	20,402	177,558
8130	Dispose berms and Zones B, C, D & G into B pond (Vadose Zone) (scraper, 500 CY/day)	21,737	CY		0	1.51	32,823	1.01	21,954	54,777
8140	Subsurface drain									

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	Delivery of Gravel (drain trench)	3667	CY	15.07	55,262		0		0	55,262
	Move gravel	3667	CY		0	1.51	5,537	1.01	3,704	9,241
	Grade gravel	3667	CY		0	0.06	220	0.04	147	367
					0					
	Delivery of sand	3519	CY	8.28	29,137		0		0	29,137
	Move sand	3519	CY		0	1.51	5,314	1.01	3,554	8,868
	Grade sand	3519	CY		0	0.06	211	0.04	141	352
8150	Excavate C Pond Soils	27,796	CY		0	1.26	35,023	0.84	23,349	58,372
8160	Move C Pond Soils on top of Drainage	27,796	CY		0	1.51	41,972	1.01	28,074	70,046
8170	Move balance of berms on top of drainage	1,238	CY		0	1.51	1,869	1.01	1,250	3,120
8180	Spread liner material	11,800	CY		0	1.51	17,818	1.01	11,918	29,736
8190	Grade soil, liner and berm material in 207-A	37,024	CY		0	0.06	2,221	0.04	1,481	3,702
8200	Compact 207-A, and B-series ponds (Vibratory sheepsfoot, 5-ton roller, 4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
8260	Construct Equipment decon wash area	1	LS		0		0	60,000.00	60,000	60,000
8280	Move and distribute soils & veg. from the hillside north of the seepline in SEP 207-C	2,251	CY		0	1.51	3,399	1.01	2,274	5,673
8290	Grade soils in SEP 207-C	9225	SY		0	0.06	554	0.04	369	923
8300	Compact 207-C pond (Vibratory sheepsfoot, 5-ton roller, 2 passes)	18450	SY		0	0.04	738	0.03	554	1,292
8400	Reclaim Pond C area									
	Delivery of general backfill	4613	CY	6.27	28,924					28,924
	Move general backfill	4613	CY			1.51	6,966	1.01	4,659	11,625
	Grade general backfill	4613	CY			0.06	277	0.04	185	461
	Delivery of topsoil	1538	CY	19.03	29,268					29,268

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	Move topsoil	1538	CY			1.51	2,322	1.01	1,553	3,876
	Grade topsoil	1538	CY			0.06	92	0.04	62	154
	Delivery of pea gravel	246	CY	15.5	3,813	0	0	0	0	3,813
	Move pea gravel	246	CY			1.51	371	1.01	248	620
	Grade pea gravel	246	CY			0.06	15	0.04	10	25
	Seed Pond C	1.9	AC					2500	4,750	4,750
9000	**Stabilize hillside**				**223,464**		**20,620**		**47,537**	**291,621**
9060	Deliver topsoil	10,389	CY	19.03	197,703		0		0	197,703
9070	Move topsoil	10,389	CY		0	1.51	15,687	1.01	10,493	26,180
9080	Grade topsoil	10,389	SY		0	0.06	623	0.04	416	1,039
9085	Hydroseed	13.5	AC		0		0	2,500.00	33,750	33,750
9090	Deliver pea gravel	1,662	CY	15.5	25,761		0		0	25,761
9100	Move pea gravel	1,662	CY		0	1.51	2,510	1.01	1,679	4,188
9110	Grade pea gravel	30,000	SY		0	0.06	1,800	0.04	1,200	3,000
10000	**Utilities**				**0**		**465,676**		**25,817**	**491,493**
10001	Design/review shoring activities	200	MH			90.00	18,000			18,000
10005	Shoring (excavation/removal)	5580	LF			40.40	225,432			225,432
10006	Shoring (excavation/grouting)	1150	LF			8.08	9,292			9,292
10020	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10030	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10040	Remove 3"-PW-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10090	Remove and grout 3"-PW-SST, Remove and grout 3"-PW-STL	570	LF		0	27.24	15,527	1.33	758	16,285
10100	Remove & Relocate 6"-RW-CI	550	LF		0	27.24	14,982	1.33	732	15,714

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10110	Remove 3"SROB-CAP	310	LF		0	27.24	8,444	1.33	412	8,857
10120	Remove 8"PWF-CI	40	LF		0	27.24	1,090	1.33	53	1,143
10130	Remove 8"PW-CI	30	LF		0	27.24	817	1.33	40	857
10140	Remove 440V-E	130	LF A/G		0	27.24	3,541	1.33	173	3,714
		50	LF U/G		0	27.24	1,362	1.33	67	1,429
10150	Remove 440-V-E	620	LF		0	27.24	16,889	1.33	825	17,713
10160	Remove 15"-SD-CMP	520	LF		0	27.24	14,165	1.33	692	14,856
10200	Remove/relocate 440V-E	320	LF		0	27.24	8,717	1.33	426	9,142
10210	Remove/relocate telephone	350	LF		0	27.24	9,534	1.33	466	10,000
10220	Remove @ 10"PW-PVC (VCP) 6"-PW-VCP	290	LF		0	27.24	7,900	1.33	386	8,285
10260	Remove 3"-SROB-CAP	90	LF		0	27.24	2,452	1.33	120	2,571
10270	Remove 3/4" E-PVC	90	LF		0	27.24	2,452	1.33	120	2,571
10280	Grout 8"-RW-CAP	760	LF		0	46.98	35,705	11.08	8,421	44,126
10290	Grout 8"-RW-CAP	390	LF		0	46.98	18,322	11.08	4,321	22,643
10300	Remove 12"-OS-CMP	50	LF		0	27.24	1,362	1.33	67	1,429
10310	Remove 1-1/2"DCW-STL	320	LF		0	27.24	8,717	1.33	426	9,142
10320	Remove 3"-SROB-CAP, Remove 3"-ROPW-CAP, Remove 3"-SROP-CAP, Remove 6"-SE-CAP	140	LF		0	27.24	3,814	1.33	186	4,000
10350	Remove 8"-PW-CI	20	LF		0	27.24	545	1.33	27	571

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10360	Remove 8"-PW-CI (8"-PCWF-CI)	50	LF		0	27.24	1,362	1.33	67	1,429
10390	Dispose of utilities in 207-A	6,730	LF		0	1.51	10,162	1.01	6,797	16,960
10410	Cut, Transport and store piping (Includes PPE)	6,730	LF		0	3.00	20,190		0	20,190
11000	**Install Final Engineered cover over Pond 207-A and western portion of B-series ponds**				**2,213,289**		**398,104**		**227,544**	**2,838,937**
11001	Geotextile material (construction purpose only)	143,500	SY	0.45	64,575	0.75	107,625			172,200
11005	Delivery of Gravel Base	6,000	CY	15.07	90,420					90,420
11006	Move gravel base course to Pond 207-A	6,000	CY		0	1.51	9,060	1.01	6,060	15,120
11007	Grade gravel base course in Pond 207-A	6,000	CY		0	0.06	360	0.04	240	600
11008	Compact lower base course (1 pass)	36,000	SY		0	0.04	1,440	0.03	1,080	2,520
11109	Delivery of asphalt concrete and asphalt layer	36,000	SY	12.02	432,720		0		0	432,720
11120	Unload & distribute asphalt concrete and asphalt layer	36,000	SY		0	1.51	54,360	1.01	36,360	90,720
11200	Delivery of Sand (drainage)	12,000	CY	8.28	99,360		0		0	99,360
11205	Move sand for lower sand layer	12,000	CY		0	1.51	18,120	1.01	12,120	30,240
11210	Grade lower sand layer	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11220	Compact lower sand layer (2 passes)	72,000	SY		0	0.04	2,880	0.03	2,160	5,040
11300	Delivery of angular riprap	30,000	CY	18.28	548,400		0		0	548,400
11305	Move angular riprap	30,000	CY		0	1.51	45,300	1.01	30,300	75,600
11310	Grade angular riprap layer	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11320	Compact angular riprap layer (4 passes)	144,000	SY		0	0.04	5,760	0.03	4,320	10,080
11400	Delivery of gravel (filter)	12,000	CY	15.07	180,840					180,840
11405	Move gravel	12,000	CY		0	1.51	18,120	1.01	12,120	30,240
11410	Grade gravel layer	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11420	Compact gravel layer (2 passes)	72,000	SY		0	0.04	2,880	0.03	2,160	5,040

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COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
11500	Delivery of sand (filter)	12,000	CY	8.28	99,360		0		0	99,360
11505	Move sand for upper sand layer	12,000	CY		0	1.51	18,120	1.01	12,120	30,240
11510	Grade upper sand layer	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11520	Compact upper sand layer (2 passes)	72,000	SY		0	0.04	2,880	0.03	2,160	5,040
11600	Delivery of general backfill	35,000	CY	6.27	219,450		0		0	219,450
11605	Move general backfill	35,000	CY		0	1.51	52,850	1.01	35,350	88,200
11620	Grade general backfill	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11700	Delivery of topsoil/gravel admix (20%)	21,000	CY	19.03	399,630		0		0	399,630
11705	Move topsoil	21,000	CY		0	1.51	31,710	1.01	21,210	52,920
11710	Grade topsoil	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11800	Delivery of pea gravel	2,400	CY	15.5	37,200		0		0	37,200
11805	Move pea gravel	2,400	CY		0	1.51	3,624	1.01	2,424	6,048
11810	Grade pea gravel	36,000	SY		0	0.06	2,160	0.04	1,440	3,600
11820	Perimeter runoff swales									
	Delivery of Topsoil	74	CY	19.03	1,408		0		0	1,408
	Move Topsoil	74	CY			1.51	112	1.01	75	186
	Grade Topsoil	74	CY			0.06	4	0.04	3	7
	Delivery of Pea gravel	25	CY	15.5	388	0	0		0	388
	Move Pea Gravel	25	CY			1.51	38	1.01	25	63
	Grade Pea Gravel	25	CY			0.06	2	0.04	1	3
11830	Delivery of Gravel (Toe Drain)	296	CY	15.07	4,461		0		0	4,461
	Move Gravel	296	CY			1.51	447	1.01	299	746
11840	Clean fill wedge									
	Delivery of general Backfill	4,000	CY	6.27	25,080		0		0	25,080
	Move general Backfill	4,000	CY			1.51	6,040	1.01	4,040	10,080
	Grade general Backfill	4,000	CY			0.06	240	0.04	160	400

CLIENT: EG&G
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OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: 05-May-94
TIME: 11:46:43 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
11850	Reclaim Traffic areas and Misc.									
	Delivery of Pea Gravel	645	CY	15.50	9,998		0		0	9,998
	Move Pea Gravel	645	CY			1.51	974	1.01	651	1,625
	Grade Pea Gravel	645	CY			0.06	39	0.04	26	65
11855	Seed Traffic Area	5	AC		0		0	2,500.00	12,500	12,500
11860	Seed Cover	7.8	AC					2,500.00	19,500	19,500
13000	**Remove Equipment Decon Wash Area**	**1**	**LS**		**0**	**15,000.00**	**15,000**		**0**	**15,000**
14000	**Off-site disposal**				**0**		**0**		**183,620**	**183,620**
	Transportation by railcar	2	EA		0		0	2,210.00	4,420	4,420
	Envirocare	100	EA		0		0	1,792.00	179,200	179,200
15000	**Final site survey by HPT**	**160**	**MH**		**0**	**80.00**	**12,800**		**0**	**12,800**
18000	**Training**	**2,400**	**HR**		**0**	**50.00**	**120,000**		**0**	**120,000**
19000	**Postclosure (monitoring system)**	**1**	**LS**		**0**	**254,296.00**	**254,296**	**341,040.00**	**341,040**	**595,336**
20000	**Construction subtotal**				**2,805,772**		**4,682,020**		**5,480,943**	**12,968,735**
21000	**Building Factor (33.5%)**									**1,568,477**
22000	**Construction subtotal**									**14,537,211**
23000	**Engineering Costs**									**2,500,000**
24000	**Purchase small tools and consumables (5%)**									**78,000**
25000	**Project Management (6%)**									**778,124**
26000	**Contractor Construction Management**									**3,000,000**
27000	**Construction Management (15%)**									**2,180,582**
28000	**Contractor G&A (10.75% Total Const. Cost)**									**1,562,750**
29000	**Subtotal**									**24,636,667**
30000	**Escalation (9.73% Const. Cost)**									**1,414,471**
31000	**Escalated Subtotal**									**26,051,138**
32000	**Contingency (30%)**									**7,815,341**
33000	**Total Estimated Cost**									**33,866,479**

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OU4 IM/IRA PROJECT COST ESTIMATE
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30 YEAR RCRA COVER

DATE: 05-May-94
TIME: 11:12:31 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
0100	**Baseline radiological/hazardous survey**				0		523,900		0	523,900
	Initial survey									
	Set up material staging area	80	MH		0	65.00	5,200		0	5,200
	Set up exclusion zone	160	MH		0	65.00	10,400		0	10,400
	Set up step-off/survey area	80	MH		0	65.00	5,200		0	5,200
	Develop radiation worker permit for zone entry	80	MH		0	65.00	5,200		0	5,200
	Baseline survey by HPT	80	MH		0	65.00	5,200		0	5,200
	Obtain excavation permit	40	MH		0	65.00	2,600		0	2,600
	Conduct pre-job training on sampling grid	60	MH		0	65.00	3,900		0	3,900
	Phase II activities									
	Modify radiation worker permit for excavation	40	MH		0	65.00	2,600		0	2,600
	Write health and safety plan	640	MH		0	65.00	41,600		0	41,600
	Phase III activities				0					
	Daily initial surveys, surveys of equipment leaving exclusion zone and daily end of day surveys of ground and equipment	4000	MH		0	65.00	260,000		0	260,000
	Covering any "surface contamination" during operations and overnight if discovered in end-of-day survey	2800	MH		0	65.00	182,000		0	182,000

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0200	**Monitor job site remediation/entry security**				**0**		**963,828**		**0**	**963,828**
	Rad technicians - 4 for 9 months of project	**4,536**	**MH**		**0**	**34.53**	**156,628**		**0**	**156,628**
	Construction personnel enter/exit job site	**20,180**	**MH**		**0**	**40.00**	**807,200**		**0**	**807,200**
5000	**Indirect field costs**				**54,116**		**1,549,716**		**4,055,514**	**5,659,346**
5010	Obtain building permits	80	MH		0	40.00	3,200		0	3,200
	Cost of Permit	1	LS	500.00	500					500
5020	Mobilization - set up construction staging area and perform decon and smear tests on equipment entering the job site	1,000	MH		0	40.00	40,000		0	40,000
5040	Sanitary (portable toilets) - 8	23	MONTH		0		0	584.00	13,432	13,432
5045	Handwash unit - 4	23	MONTH					340.00	7,820	7,820
	Eyewash Unit - 4	23	MONTH					116.62	2,682	2,682
5050	Temporary utils (phone, water, 220V elec)	23	MONTH	500.00	11,500		0		0	11,500
	Temporary security fence and lighting installation									
5060	Security fence	2,090	LF	4.00	8,360	6.00	12,540		0	20,900
	Terminal posts	8	EA	70.00	560	105.00	840		0	1,400
	Security gates	4	EA	404.00	1,616	606.00	2,424		0	4,040
	Lights north of seepline	23	MONTH					4100	94,300	94,300
	Lights south of seepline	23	MONTH					4100	94,300	94,300
5100	Trucks									
	Water tanker (631ww) and operator	516	DAY		0	320.00	165,120	1,235.00	637,260	802,380
	Off highway truck (777C) and operator	516	DAY		0	320.00	165,120	1,910.00	985,560	1,150,680
	Wheel loader (992C) and operator	516	DAY		0	320.00	165,120	2,995.00	1,545,420	1,710,540

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5110	Mobile lab for geotechnical soil testing	23	MONTH		0		0	700.00	16,100	16,100
	Geotechnical Technician	1500	MH			80.00	120,000		0	120,000
	Field Technician	3000	MH			80.00	240,000		0	240,000
5120	Mobile analytical lab for environmental testing				0					
	Staffed lab	120	DAY		0	3,000.00	360,000		0	360,000
	Standby lab	120	DAY		0	800.00	96,000		0	96,000
5121	Site prep. trailer area									
	Road base (6") and grading	740	SY	7.54	5,580	0.06	44	0.04	30	5,654
5125	Office trailer	23	MONTH					375.00	8,625	8,625
5126	Break trailer	23	MONTH					260.00	5,980	5,980
5130	Trailer with lockers	23	MONTH		0		0	375.00	8,625	8,625
5150	Personnel decon trailer with showers	23	MONTH		0		0	550.00	12,650	12,650
5155	Lab/trailer:set-up/remove	6	LS		0		0	505	3,030	3,030
5170	Prepare backfill stockpile area	200,000	SY		0	0.10	20,000	0.07	14,000	34,000
5200	Health and Safety equipment	1	LS		0		0	605,700.00	605,700	605,700
5210	Demobilization/project site final clean up	1	LS		0	120,000.00	120,000		0	120,000
	Decontamination of equipment inside the PA	800	MH			17.84	14,272			14,272
	Decontamination of equipment - buffer zone	400	MH			17.84	7,136			7,136
	Waste crates									
5220	Purchase waste crates	100	EA	260.00	26,000		0		0	26,000
	Install lids on waste crates	100	EA		0	12.00	1,200		0	1,200
	Offload waste crates	100	EA		0	7.00	700		0	700
5230	Assay waste crates	200	MH		0	80.00	16,000		0	16,000
6000	**Relocate power lines from between Ponds 207A and 207B-series**				**17,846**		**67,068**		**0**	**84,914**

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6001	Lock out/tag out	64	MH			81.8	5,235			5,235
6010	Install power poles	563	MH		12,386	33.17	18,675		0	31,061
6020	Install conductors	2,600	LF	2.10	5,460	3.14	8,164		0	13,624
6030	Tie in relocated power lines	121	MH		0	33.17	4,014		0	4,014
6040	Perform hi-pot test on new power lines	241	MH		0	33.17	7,994		0	7,994
6050	Remove obsolete power lines and poles	392	MH		0	33.17	13,003		0	13,003
6060	Transport and Store Power Lines	181	MH		0	33.17	6,004		0	6,004
6070	Shred obsolete poles & dispose in 207A	120	MH		0	33.17	3,980		0	3,980
7000	**Vegetation removal**				**22,500**		**4,756**		**1,891**	**29,147**
	Zones E and F									
7030	Lie Down Liner (double thickness)	24	MH		0	40.00	960		0	960
	Bottom Liner	9,000	SF	1.50	13,500		0		0	13,500
7040	Excavate veg. and soils from remediation areas	2,251	CY		0	1.26	2,836	0.84	1,891	4,727
7050	Cover Piles W/Heavy Tarp	24	MH			40.00	960		0	960
	Top Liner	9,000	SF	1.00	9,000		0		0	9,000
8000	**Pond preparation for cover**				**281,638**		**247,794**		**219,639**	**749,070**
8110	Grind 207A, 207C and 207B-series liners (grinder, 3000 SY/day)	11,800	CY		0	0.24	2,832	0.08	944	3,776
8115	Move and stockpile liners	5900	CY			1.51	8,909	1.01	5,959	14,868
8120	Excavate berms and Zones B, C, D & G	21,737	CY		0	1.26	27,389	0.84	18,259	45,648

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8121	Move & place backfill for Zones B,C,D & E	20,200	CY	6.27	126,654	1.51	30,502	1.01	20,402	177,558
8130	Dispose berms and Zones B, C, D & G into B pond (Vadose Zone) (scraper, 500 CY/day)	21,737	CY		0	1.51	32,823	1.01	21,954	54,777
8140	Subsurface drain									
	Delivery of Gravel (drain trench)	3667	CY	15.07	55,262		0		0	55,262
	Move gravel	3667	CY		0	1.51	5,537	1.01	3,704	9,241
	Grade gravel	3667	CY		0	0.06	220	0.04	147	367
					0					
	Delivery of sand	3519	CY	8.28	29,137		0		0	29,137
	Move sand	3519	CY		0	1.51	5,314	1.01	3,554	8,868
	Grade sand	3519	CY		0	0.06	211	0.04	141	352
8150	Excavate C Pond Soils	27,796	CY		0	1.26	35,023	0.84	23,349	58,372
8155	Install SCH 40, PVC 4" perf. pipe	2000	LF	4.29	8,580	7.65	15,300		0	23,880
8160	Move C Pond Soils on top of Drainage	27,796	CY		0	1.51	41,972	1.01	28,074	70,046
8170	Move balance of berms on top of drainage	1,238	CY		0	1.51	1,869	1.01	1,250	3,120
8180	Spread liner material	11,800	CY		0	1.51	17,818	1.01	11,918	29,736
8190	Grade soil, liner and berm material in 207-A	37,024	CY		0	0.06	2,221	0.04	1,481	3,702
8200	Compact 207-A, and B-series ponds (Vibratory sheepsfoot, 5-ton roller, 4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
8260	Construct Equipment decon wash area	1	LS		0		0	60,000.00	60,000	60,000
8280	Move and distribute soils & veg. from the hillside north of the seepline in SEP 207-C	2,251	CY		0	1.51	3,399	1.01	2,274	5,673

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8290	Grade soils in SEP 207-C	9225	SY		0	0.06	554	0.04	369	923
8300	Compact 207-C pond (Vibratory sheepsfoot, 5-ton roller, 2 passes)	18450	SY		0	0.04	738	0.03	554	1,292
8400	Reclaim Pond C area									
	Delivery of general backfill	4613	CY	6.27	28,924					28,924
	Move general backfill	4613	CY			1.51	6,966	1.01	4,659	11,625
	Grade general backfill	4613	CY			0.06	277	0.04	185	461
	Delivery of topsoil	1538	CY	19.03	29,268					29,268
	Move topsoil	1538	CY			1.51	2,322	1.01	1,553	3,876
	Grade topsoil	1538	CY			0.06	92	0.04	62	154
	Delivery of pea gravel	246	CY	15.5	3,813	0	0	0	0	3,813
	Move pea gravel	246	CY			1.51	371	1.01	248	620
	Grade pea gravel	246	CY			0.06	15	0.04	10	25
	Seed Pond C	**1.9**	**AC**					**2500**	**4,750**	**4,750**
9000	**Stabilize hillside**				**223,464**		**20,620**		**47,537**	**291,621**
9060	Deliver topsoil	10389	CY	19.03	197,703		0		0	197,703
9070	Move topsoil	10,389	CY		0	1.51	15,687	1.01	10,493	26,180
9080	Grade topsoil	10,389	SY		0	0.06	623	0.04	416	1,039
9085	Hydroseed	13.5	AC		0		0	2,500.00	33,750	33,750
9090	Deliver pea gravel	1662	CY	15.5	25,761		0		0	25,761
9100	Move pea gravel	1,662	CY		0	1.51	2,510	1.01	1,679	4,188
9110	Grade pea gravel	30,000	SY		0	0.06	1,800	0.04	1,200	3,000
10000	**Utilities**				**0**		**465,676**		**25,817**	**491,493**

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10001	Design/review shoring activities	200	MH			90.00	18,000			18,000
10005	Shoring (excavation/removal)	5580	LF			40.40	225,432			225,432
10006	Shoring (excavation/grouting)	1150	LF			8.08	9,292			9,292
10020	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10030	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10040	Remove 3"-PW-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10090	Remove and grout 3"-PW-SST, Remove and grout 3"-PW-STL	570	LF		0	27.24	15,527	1.33	758	16,285
10100	Remove & Relocate 6"-RW-CI	550	LF		0	27.24	14,982	1.33	732	15,714
10110	Remove 3"SROB-CAP	310	LF		0	27.24	8,444	1.33	412	8,857
10120	Remove 8"PWF-CI	40	LF		0	27.24	1,090	1.33	53	1,143
10130	Remove 8"PW-CI	30	LF		0	27.24	817	1.33	40	857
10140	Remove 440V-E.	130	LF A/G		0	27.24	3,541	1.33	173	3,714
		50	LF U/G		0	27.24	1,362	1.33	67	1,429
10150	Remove 440-V-E	620	LF		0	27.24	16,889	1.33	825	17,713
10160	Remove 15"-SD-CMP	520	LF		0	27.24	14,165	1.33	692	14,856
10200	Remove/relocate 440V-E	320	LF		0	27.24	8,717	1.33	426	9,142
10210	Remove/relocate telephone	350	LF		0	27.24	9,534	1.33	466	10,000
10220	Remove @ 10"PW-PVC (VCP) 6"-PW-VCP	290	LF		0	27.24	7,900	1.33	386	8,285

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10260	Remove 3"-SROB-CAP	90	LF		0	27.24	2,452	1.33	120	2,571
10270	Remove 3/4" E-PVC	90	LF		0	27.24	2,452	1.33	120	2,571
10280	Grout 8"-RW-CAP	760	LF		0	46.98	35,705	11.08	8,421	44,126
10290	Grout 8"-RW-CAP	390	LF		0	46.98	18,322	11.08	4,321	22,643
10300	Remove 12"-OS-CMP	50	LF		0	27.24	1,362	1.33	67	1,429
10310	Remove 1-1/2"DCW-STL	320	LF		0	27.24	8,717	1.33	426	9,142
10320	Remove 3"-SROB-CAP, Remove 3"-ROPW-CAP, Remove 3"-SROP-CAP, Remove 6"-SE-CAP	140	LF		0	27.24	3,814	1.33	186	4,000
10350	Remove 8"-PW-CI	20	LF		0	27.24	545	1.33	27	571
10360	Remove 8"-PW-CI (8"-PCWF-CI)	50	LF		0	27.24	1,362	1.33	67	1,429
10390	Dispose of utilities in 207-A	6,730	LF		0	1.51	10,162	1.01	6,797	16,960
10410	Cut, Transport and store piping (Includes PPE)	6,730	LF		0	3.00	20,190		0	20,190
11000	**Install 30 Year cover over Pond 207-A and western portion of B-series ponds**				**949,304**		**383,200**		**107,836**	**1,440,341**
11100	Geotextile material (construction purpose only)	112,000	SY	0.48	53,760	0.72	80,640			134,400
11125	Geosynthetic clay liner	288,000	SF	0.28	80,640	0.42	120,960			201,600
11150	Flexible membrane liner	288,000	SF	0.16	46,080	0.24	69,120			115,200

CLIENT: EG&G
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH AUGUST 1997
30 YEAR RCRA COVER

DATE: 05-May-94
TIME: 11:12:31 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
11200	Delivery of Sand (drainage)	10,652	CY	8.28	88,199		0		0	88,199
11205	Move sand for lower sand layer	10,652	CY		0	1.51	16,085	1.01	10,759	26,843
11210	Grade lower sand layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11220	Compact lower sand layer (2 passes)	64,000	SY		0	0.04	2,560	0.03	1,920	4,480
11300	Delivery of angular riprap (4"-8" dia.)	21,304	CY	18.28	389,437		0		0	389,437
11305	Move angular riprap	21,304	CY		0	1.51	32,169	1.01	21,517	53,686
11310	Grade angular riprap layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11320	Compact angular riprap layer (4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
11600	Delivery of general backfill	18,400	CY	6.27	115,368		0		0	115,368
11605	Move general backfill	18,400	CY		0	1.51	27,784	1.01	18,584	46,368
11620	Grade general backfill	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11700	Delivery of topsoil/gravel admix (20%)	5,333	CY	19.03	101,487		0		0	101,487
11705	Move topsoil	5,333	CY		0	1.51	8,053	1.01	5,386	13,439
11710	Grade topsoil	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11800	Delivery of pea gravel	2129	CY	15.5	33,000		0		0	33,000
11805	Move pea gravel	2,129	CY		0	1.51	3,215	1.01	2,150	5,365
11810	Grade pea gravel	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11820	Perimeter runoff swales									
	Delivery of Topsoil	74	CY	19.03	1,408		0		0	1,408
	Move Topsoil	74	CY			1.51	112	1.01	75	186
	Grade Topsoil	74	CY			0.06	4	0.04	3	7
	Delivery of Pea gravel	25	CY	15.5	388	0	0		0	388
	Move Pea Gravel	25	CY			1.51	38	1.01	25	63
	Grade Pea Gravel	25	CY			0.06	2	0.04	1	3
11830	Delivery of Gravel (Toe Drain)	296	CY	15.07	4,461		0		0	4,461
	Move Gravel	296	CY			1.51	447	1.01	299	746
11840	Clean fill wedge									
	Delivery of general Backfill	4,000	CY	6.27	25,080		0		0	25,080
	Move general Backfill	4,000	CY			1.51	6,040	1.01	4,040	10,080
	Grade general Backfill	4,000	CY			0.06	240	0.04	160	400

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OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH AUGUST 1997
30 YEAR RCRA COVER

DATE: 05-May-94
TIME: 11:12:31 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
11850	Reclaim Traffic areas and Misc.									
	Delivery of Pea Gravel	645	CY	15.50	9,998		0		0	9,998
	Move Pea Gravel	645	CY			1.51	974	1.01	651	1,625
	Grade Pea Gravel	645	CY			0.06	39	0.04	26	65
11855	Seed Traffic Area	5	AC		0		0	2,500.00	12,500	12,500
11860	Seed Cover	7.8	AC					2,500.00	19,500	19,500
13000	**Remove Equipment Decon Wash Area**	**1**	**LS**		**0**	**15,000.00**	**15,000**		**0**	**15,000**
14000	**Off-site disposal**				**0**		**0**		**183,620**	**183,620**
	Transportation by railcar	2	EA		0		0	2,210.00	4,420	4,420
	Envirocare	100	EA		0		0	1,792.00	179,200	179,200
15000	**Final site survey by HPT**	**160**	**MH**		**0**	**80.00**	**12,800**		**0**	**12,800**
18000	**Training**	**2,400**	**HR**		**0**	**50.00**	**120,000**		**0**	**120,000**
19000	**Postclosure (monitoring system)**	**1**	**LS**		**0**	**254,296.00**	**254,296**	**341,040.00**	**341,040**	**595,336**
20000	**Construction subtotal**				**1,548,867**		**4,628,656**		**4,982,894**	**11,160,416**
21000	**Building Factor (33.5%)**									**1,550,600**
22000	**Construction subtotal**									**12,711,016**
23000	**Engineering Costs**									**2,500,000**
24000	**Purchase small tools and consumables (5%)**									**78,000**
25000	**Project Management (6%)**									**669,625**
26000	**Contractor Construction Management**									**3,000,000**
27000	**Construction Management (15%)**									**1,906,652**
28000	**Contractor G&A (10.75% Total Const. Cost)**									**1,366,434**
29000	**Subtotal**									**22,231,728**
30000	**Escalation (9.73% Const. Cost)**									**1,236,782**
31000	**Escalated Subtotal**									**23,468,509**
32000	**Contingency (30%)**									**7,040,553**
33000	**Total estimated cost**									**30,509,062**

CLIENT: EG&G
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes

OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH JULY 1997
CAPILLARY BARRIER COVER

DATE: 06-May-94
TIME: 08:15:37 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
0100	**Baseline radiological/hazardous survey**				0		523,900		0	523,900
	Initial survey									
	Set up material staging area	80	MH		0	65.00	5,200		0	5,200
	Set up exclusion zone	160	MH		0	65.00	10,400		0	10,400
	Set up step-off/survey area	80	MH		0	65.00	5,200		0	5,200
	Develop radiation worker permit for zone entry	80	MH		0	65.00	5,200		0	5,200
	Baseline survey by HPT	80	MH		0	65.00	5,200		0	5,200
	Obtain excavation permit	40	MH		0	65.00	2,600		0	2,600
	Conduct pre-job training on sampling grid	60	MH		0	65.00	3,900		0	3,900
	Phase II activities									
	Modify radiation worker permit for excavation	40	MH		0	65.00	2,600		0	2,600
	Write health and safety plan	640	MH		0	65.00	41,600		0	41,600
	Phase III activities				0					
	Daily initial surveys, surveys of equipment leaving exclusion zone and daily end of day surveys of ground and equipment	4000	MH		0	65.00	260,000		0	260,000
	Covering any "surface contamination" during operations and overnight if discovered in end-of-day survey	2800	MH		0	65.00	182,000		0	182,000

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CAPILLARY BARRIER COVER

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COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
0200	**Monitor job site remediation/entry security**				**0**		**963,828**		**0**	**963,828**
	Rad technicians - 4 for 9 months of project	4,536	MH		0	34.53	156,628		0	156,628
	Construction personnel enter/exit job site	20,180	MH		0	40.00	807,200		0	807,200
5000	**Indirect field costs**				**132,591**		**1,660,221**		**3,908,933**	**5,701,745**
5010	Obtain building permits	80	MH		0	40.00	3,200		0	3,200
	Cost of Permit	1	LS	500.00	500					500
5020	Mobilization - set up construction staging area and perform decon and smear tests on equipment entering the job site	1,000	MH		0	40.00	40,000		0	40,000
5040	Sanitary (portable toilets) - 8	22	MONTH		0		0	584.00	12,848	12,848
5045	Handwash unit - 4	22	MONTH					340.00	7,480	7,480
	Eyewash Unit - 4	22	MONTH					116.62	2,566	2,566
5050	Temporary utils (phone, water, 220V elec)	22	MONTH	500.00	11,000		0		0	11,000
	Temporary security fence and lighting installation									
5060	Security fence	2,090	LF	4.00	8,360	6.00	12,540		0	20,900
	Terminal posts	8	EA	70.00	560	105.00	840		0	1,400
	Security gates	4	EA	404.00	1,616	606.00	2,424		0	4,040
	Lights north of seepline	22	MONTH					4100	90,200	90,200
	Lights south of seepline	22	MONTH					4100	90,200	90,200
5100	Trucks									
	Water tanker (631ww) and operator	494	DAY		0	320.00	158,080	1,235.00	610,090	768,170
	Off highway truck (777C) and operator	494	DAY		0	320.00	158,080	1,910.00	943,540	1,101,620
	Wheel loader (992C) and operator	494	DAY		0	320.00	158,080	2,995.00	1,479,530	1,637,610
5110	Mobile lab for geotechnical soil testing	22	MONTH		0		0	700.00	15,400	15,400
	Geotechnical Technician	1500	MH			80.00	120,000		0	120,000
	Field Technician	3000	MH			80.00	240,000		0	240,000

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OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH JULY 1997
CAPILLARY BARRIER COVER

DATE: 06-May-94
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COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
5120	Mobile analytical lab for environmental testing				0					
	Staffed lab	120	DAY		0	3,000.00	360,000		0	360,000
	Standby lab	120	DAY		0	800.00	96,000		0	96,000
5121	Site prep. trailer area									
	Road base (6") and grading	740	SY	7.54	5,580	0.06	44	0.04	30	5,654
5125	Office trailer	22	MONTH					375.00	8,250	8,250
5126	Break trailer	22	MONTH					260.00	5,720	5,720
5130	Trailer with lockers	22	MONTH		0		0	375.00	8,250	8,250
5150	Personnel decon trailer with showers	22	MONTH		0		0	550.00	12,100	12,100
5155	Lab/trailer:set-up/remove	6	LS		0		0	505	3,030	3,030
5170	Prepare backfill stockpile area	200,000	SY		0	0.10	20,000	0.07	14,000	34,000
5185	Geotextile material (construction purpose only)	175,500	SY	0.45	78,975	0.75	131,625			210,600
5200	Health and Safety equipment	1	LS		0		0	605,700.00	605,700	605,700
5210	Demobilization/project site final clean up	1	LS		0	120,000.00	120,000		0	120,000
	Decontamination of equipment inside the PA	800	MH			17.84	14,272			14,272
	Decontamination of equipment - buffer zone	400	MH			17.84	7,136			7,136
	Waste crates									
5220	Purchase waste crates	100	EA	260.00	26,000		0		0	26,000
	Install lids on waste crates	100	EA		0	12.00	1,200		0	1,200
	Offload waste crates	100	EA		0	7.00	700		0	700
5230	Assay waste crates	200	MH		0	80.00	16,000		0	16,000
6000	**Relocate power lines from between Ponds 207A and 207B-series**				**17,846**		**67,068**		**0**	**84,914**
6001	Lock out/tag out	64	MH			81.8	5,235			5,235
6010	Install power poles	563	MH		12,386	33.17	18,675		0	31,061

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OU4 IM/IRA PROJECT COST ESTIMATE
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CAPILLARY BARRIER COVER

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6020	Install conductors	2,600	LF	2.10	5,460	3.14	8,164		0	13,624
6030	Tie in relocated power lines	121	MH		0	33.17	4,014		0	4,014
6040	Perform hi-pot test on new power lines	241	MH		0	33.17	7,994		0	7,994
6050	Remove obsolete power lines and poles	392	MH		0	33.17	13,003		0	13,003
6060	Transport and Store Power Lines	181	MH		0	33.17	6,004		0	6,004
6070	Shred obsolete poles & dispose in 207A	120	MH		0	33.17	3,980		0	3,980
7000	**Vegetation removal**				**22,500**		**4,756**		**1,891**	**29,147**
	Zones E and F									
7030	Lie Down Liner (double thickness)	24	MH		0	40.00	960		0	960
	Bottom Liner	9,000	SF	1.50	13,500		0		0	13,500
7040	Excavate veg. and soils from remediation areas	2,251	CY		0	1.26	2,836	0.84	1,891	4,727
7050	Cover Piles W/Heavy Tarp	24	MH			40.00	960		0	960
	Top Liner	9,000	SF	1.00	9,000		0		0	9,000
8000	**Pond preparation for cover**				**273,058**		**232,494**		**219,639**	**725,190**
8110	Grind 207A, 207C and 207B-series liners (grinder, 3000 SY/day)	11,800	CY		0	0.24	2,832	0.08	944	3,776
8115	Move and stockpile liners	5900	CY			1.51	8,909	1.01	5,959	14,868
8120	Excavate berms and Zones B, C, D & G	21,737	CY		0	1.26	27,389	0.84	18,259	45,648
8121	Move & place backfill for Zones B,C,D & E	20,200	CY	6.27	126,654	1.51	30,502	1.01	20,402	177,558
8130	Dispose berms and Zones B, C, D & G into B pond (Vadose Zone) (scraper, 500 CY/day)	21,737	CY		0	1.51	32,823	1.01	21,954	54,777

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OU4 IM/IRA PROJECT COST ESTIMATE
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CAPILLARY BARRIER COVER

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8140	Subsurface drain									
	Delivery of Gravel (drain trench)	3667	CY	15.07	55,262		0		0	55,262
	Move gravel	3667	CY		0	1.51	5,537	1.01	3,704	9,241
	Grade gravel	3667	CY		0	0.06	220	0.04	147	367
					0					
	Delivery of sand	3519	CY	8.28	29,137		0		0	29,137
	Move sand	3519	CY		0	1.51	5,314	1.01	3,554	8,868
	Grade sand	3519	CY		0	0.06	211	0.04	141	352
8150	Excavate C Pond Soils	27,796	CY		0	1.26	35,023	0.84	23,349	58,372
8160	Move C Pond Soils on top of Drainage	27,796	CY		0	1.51	41,972	1.01	28,074	70,046
8170	Move balance of berms on top of drainage	1,238	CY		0	1.51	1,869	1.01	1,250	3,120
8180	Spread liner material	11,800	CY		0	1.51	17,818	1.01	11,918	29,736
8190	Grade soil, liner and berm material in 207-A	37,024	CY		0	0.06	2,221	0.04	1,481	3,702
8200	Compact 207-A, and B-series ponds (Vibratory sheepsfoot, 5-ton roller, 4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
8260	Construct Equipment decon wash area	1	LS		0		0	60,000.00	60,000	60,000
8280	Move and distribute soils & veg. from the hillside north of the seepline in SEP 207-C	2,251	CY		0	1.51	3,399	1.01	2,274	5,673
8290	Grade soils in SEP 207-C	9225	SY		0	0.06	554	0.04	369	923
8300	Compact 207-C pond (Vibratory sheepsfoot, 5-ton roller, 2 passes)	18450	SY		0	0.04	738	0.03	554	1,292
8400	Reclaim Pond C area									
	Delivery of general backfill	4613	CY	6.27	28,924					28,924
	Move general backfill	4613	CY			1.51	6,966	1.01	4,659	11,625
	Grade general backfill	4613	CY			0.06	277	0.04	185	461

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OU4 IM/IRA PROJECT COST ESTIMATE
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CAPILLARY BARRIER COVER

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	Delivery of topsoil	1538	CY	19.03	29,268					29,268
	Move topsoil	1538	CY			1.51	2,322	1.01	1,553	3,876
	Grade topsoil	1538	CY			0.06	92	0.04	62	154
	Delivery of pea gravel	246	CY	15.5	3,813	0	0	0	0	3,813
	Move pea gravel	246	CY			1.51	371	1.01	248	620
	Grade pea gravel	246	CY			0.06	15	0.04	10	25
	Seed Pond C	1.9	AC					2500	4,750	4,750
9000	**Stabilize hillside**				**223,464**		**20,620**		**47,537**	**291,621**
9060	Deliver topsoil	10389	CY	19.03	197,703		0		0	197,703
9070	Move topsoil	10,389	CY		0	1.51	15,687	1.01	10,493	26,180
9080	Grade topsoil	10,389	SY		0	0.06	623	0.04	416	1,039
9085	Hydroseed	13.5	AC		0		0	2,500.00	33,750	33,750
9090	Deliver pea gravel	1662	CY	15.5	25,761		0		0	25,761
9100	Move pea gravel	1,662	CY		0	1.51	2,510	1.01	1,679	4,188
9110	Grade pea gravel	30,000	SY		0	0.06	1,800	0.04	1,200	3,000
10000	**Utilities**				**0**		**465,676**		**25,817**	**491,493**
10001	Design/review shoring activities	200	MH			90.00	18,000			18,000
10005	Shoring (excavation/removal)	5580	LF			40.40	225,432			225,432
10006	Shoring (excavation/grouting)	1150	LF			8.08	9,292			9,292
10020	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10030	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10040	Remove 3"-PW-STL	60	LF		0	27.24	1,634	1.33	80	1,714

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10090	Remove and grout 3"-PW-SST, Remove and grout 3"-PW-STL	570	LF		0	27.24	15,527	1.33	758	16,285
10100	Remove & Relocate 6"-RW-CI	550	LF		0	27.24	14,982	1.33	732	15,714
10110	Remove 3"SROB-CAP	310	LF		0	27.24	8,444	1.33	412	8,857
10120	Remove 8"PWF-CI	40	LF		0	27.24	1,090	1.33	53	1,143
10130	Remove 8"PW-CI	30	LF		0	27.24	817	1.33	40	857
10140	Remove 440V-E	130	LF A/G		0	27.24	3,541	1.33	173	3,714
		50	LF U/G		0	27.24	1,362	1.33	67	1,429
10150	Remove 440-V-E	620	LF		0	27.24	16,889	1.33	825	17,713
10160	Remove 15"-SD-CMP	520	LF		0	27.24	14,165	1.33	692	14,856
10200	Remove/relocate 440V-E	320	LF		0	27.24	8,717	1.33	426	9,142
10210	Remove/relocate telephone	350	LF		0	27.24	9,534	1.33	466	10,000
10220	Remove @ 10"PW-PVC (VCP) 6"-PW-VCP	290	LF		0	27.24	7,900	1.33	386	8,285
10260	Remove 3"-SROB-CAP	90	LF		0	27.24	2,452	1.33	120	2,571
10270	Remove 3/4" E-PVC	90	LF		0	27.24	2,452	1.33	120	2,571
10280	Grout 8"-RW-CAP	760	LF		0	46.98	35,705	11.08	8,421	44,126
10290	Grout 8"-RW-CAP	390	LF		0	46.98	18,322	11.08	4,321	22,643
10300	Remove 12"-OS-CMP	50	LF		0	27.24	1,362	1.33	67	1,429
10310	Remove 1-1/2"DCW-STL	320	LF		0	27.24	8,717	1.33	426	9,142
10320	Remove 3"-SROB-CAP, Remove 3"-ROPW-CAP, Remove 3"-SROP-CAP, Remove 6"-SE-CAP	140	LF		0	27.24	3,814	1.33	186	4,000

CLIENT: EG&G
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes

OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH JULY 1997
CAPILLARY BARRIER COVER

DATE: 06-May-94
TIME: 08:15:37 AM

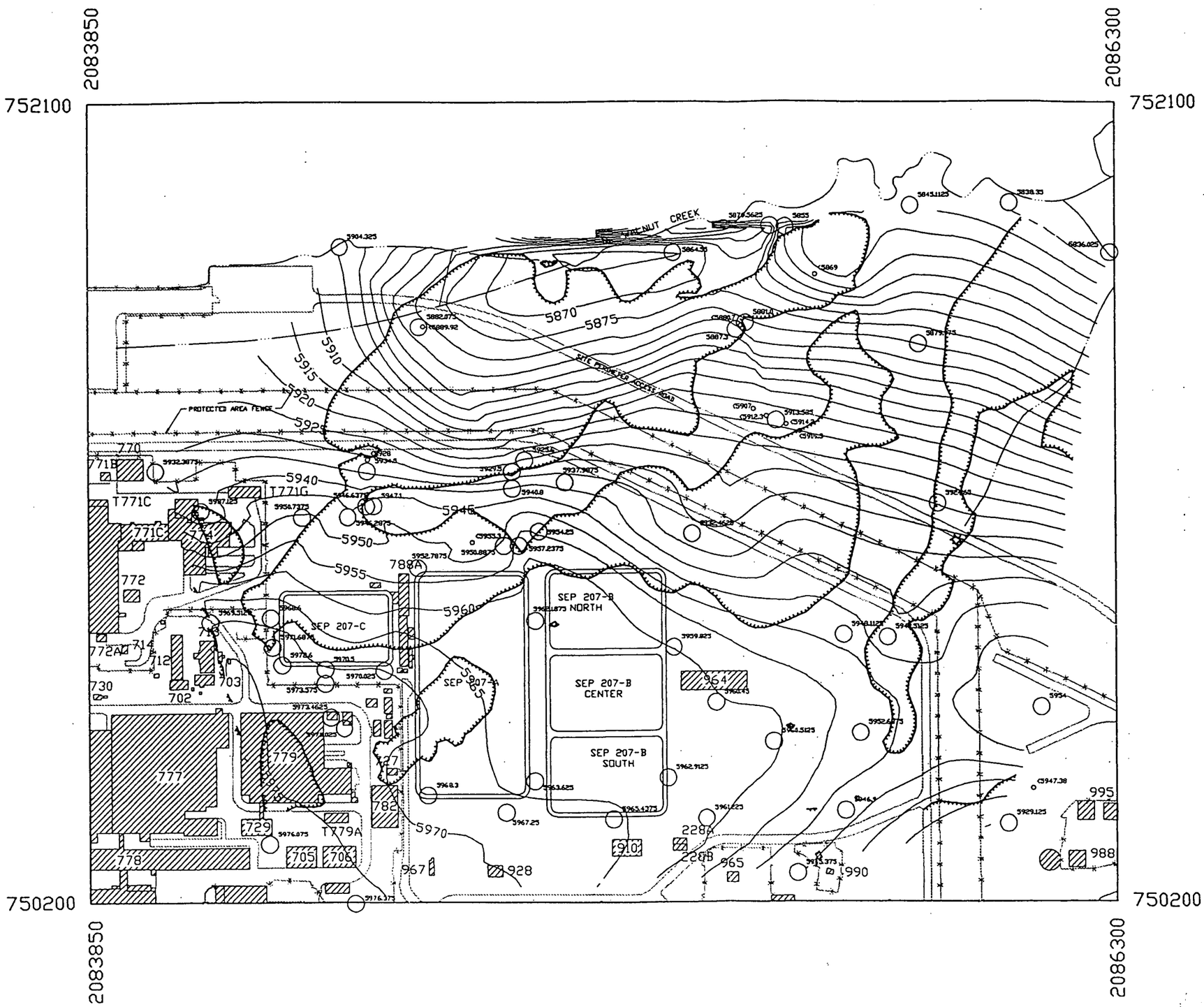
COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
10350	Remove 8"-PW-CI	20	LF		0	27.24	545	1.33	27	571
10360	Remove 8"-PW-CI (8"-PCWF-CI)	50	LF		0	27.24	1,362	1.33	67	1,429
10390	Dispose of utilities in 207-A	6,730	LF		0	1.51	10,162	1.01	6,797	16,960
10410	Cut, Transport and store piping (Includes PPE)	6,730	LF		0	3.00	20,190		0	20,190
11000	**Install Capillary Barrier cover over Pond 207-A and western portion of B-series ponds**				**1,211,159**		**147,609**		**131,130**	**1,489,898**
11300	Delivery of angular riprap	32,000	CY	18.28	584,960		0		0	584,960
11305	Move angular riprap	32,000	CY		0	1.51	48,320	1.01	32,320	80,640
11310	Grade angular riprap layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11320	Compact angular riprap layer (4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
11600	Delivery of general backfill	31,200	CY	6.27	195,624		0		0	195,624
11605	Move general backfill	31,200	CY		0	1.51	47,112	1.01	31,512	78,624
11620	Grade general backfill	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11700	Delivery of topsoil/gravel admix (20%)	18,720	CY	19.03	356,242		0		0	356,242
11705	Move topsoil	18,720	CY		0	1.51	28,267	1.01	18,907	47,174
11710	Grade topsoil	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11800	Delivery of pea gravel	2129	CY	15.5	33,000		0		0	33,000
11805	Move pea gravel	2,129	CY		0	1.51	3,215	1.01	2,150	5,365
11810	Grade pea gravel	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11820	Perimeter runoff swales									
	Delivery of Topsoil	74	CY	19.03	1,408		0		0	1,408
	Move Topsoil	74	CY			1.51	112	1.01	75	186
	Grade Topsoil	74	CY			0.06	4	0.04	3	7
	Delivery of Pea gravel	25	CY	15.5	388	0	0		0	388
	Move Pea Gravel	25	CY			1.51	38	1.01	25	63
	Grade Pea Gravel	25	CY			0.06	2	0.04	1	3
11830	Delivery of Gravel (Toe Drain)	296	CY	15.07	4,461		0		0	4,461
	Move Gravel	296	CY			1.51	447	1.01	299	746

CLIENT: EG&G
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes

OU4 IM/IRA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH JULY 1997
CAPILLARY BARRIER COVER

DATE: 06-May-94
TIME: 08:15:37 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
11840	Clean fill wedge									
	Delivery of general Backfill	4,000	CY	6.27	25,080		0		0	25,080
	Move general Backfill	4,000	CY			1.51	6,040	1.01	4,040	10,080
	Grade general Backfill	4,000	CY			0.06	240	0.04	160	400
11850	Reclaim Traffic areas and Misc.									
	Delivery of Pea Gravel	645	CY	15.50	9,998		0		0	9,998
	Move Pea Gravel	645	CY			1.51	974	1.01	651	1,625
	Grade Pea Gravel	645	CY			0.06	39	0.04	26	65
11855	Seed Traffic Area	5	AC		0		0	2,500.00	12,500	12,500
11860	Seed Cover	7.8	AC					2,500.00	19,500	19,500
13000	**Remove Equipment Decon Wash Area**	**1**	**LS**		**0**	**15,000.00**	**15,000**		**0**	**15,000**
14000	**Off-site disposal**				**0**		**0**		**183,620**	**183,620**
	Transportation by railcar	2	EA		0		0	2,210.00	4,420	4,420
	Envirocare	100	EA		0		0	1,792.00	179,200	179,200
15000	**Final site survey by HPT**	**160**	**MH**		**0**	**80.00**	**12,800**		**0**	**12,800**
18000	**Training**	**2,400**	**MH**		**0**	**50.00**	**120,000**		**0**	**120,000**
19000	**Postclosure (monitoring system)**	**1**	**LS**		**0**	**254,296.00**	**254,296**	**341,040.00**	**341,040**	**595,336**
20000	**Construction subtotal**				**1,880,617**		**4,488,270**		**4,859,606**	**11,228,493**
21000	**Building Factor (33.5%)**									**1,503,570**
22000	**Construction subtotal**									**12,732,063**
23000	**Engineering Costs**									**2,500,000**
24000	**Purchase small tools and consumables (5%)**									**78,000**
25000	**Project Management (6%)**									**673,710**
26000	**Contractor Construction Management**									**3,000,000**
27000	**Construction Management (15%)**									**1,909,809**
28000	**Contractor G&A (10.75% Total Const. Cost)**									**1,368,697**
29000	**Subtotal**									**22,262,279**
30000	**Escalation (9.73% Const. Cost)**									**1,238,830**
31000	**Escalated Subtotal**									**23,501,109**
32000	**Contingency (30%)**									**7,050,333**
33000	**Total estimated cost**									**30,551,441**



LEGEND:

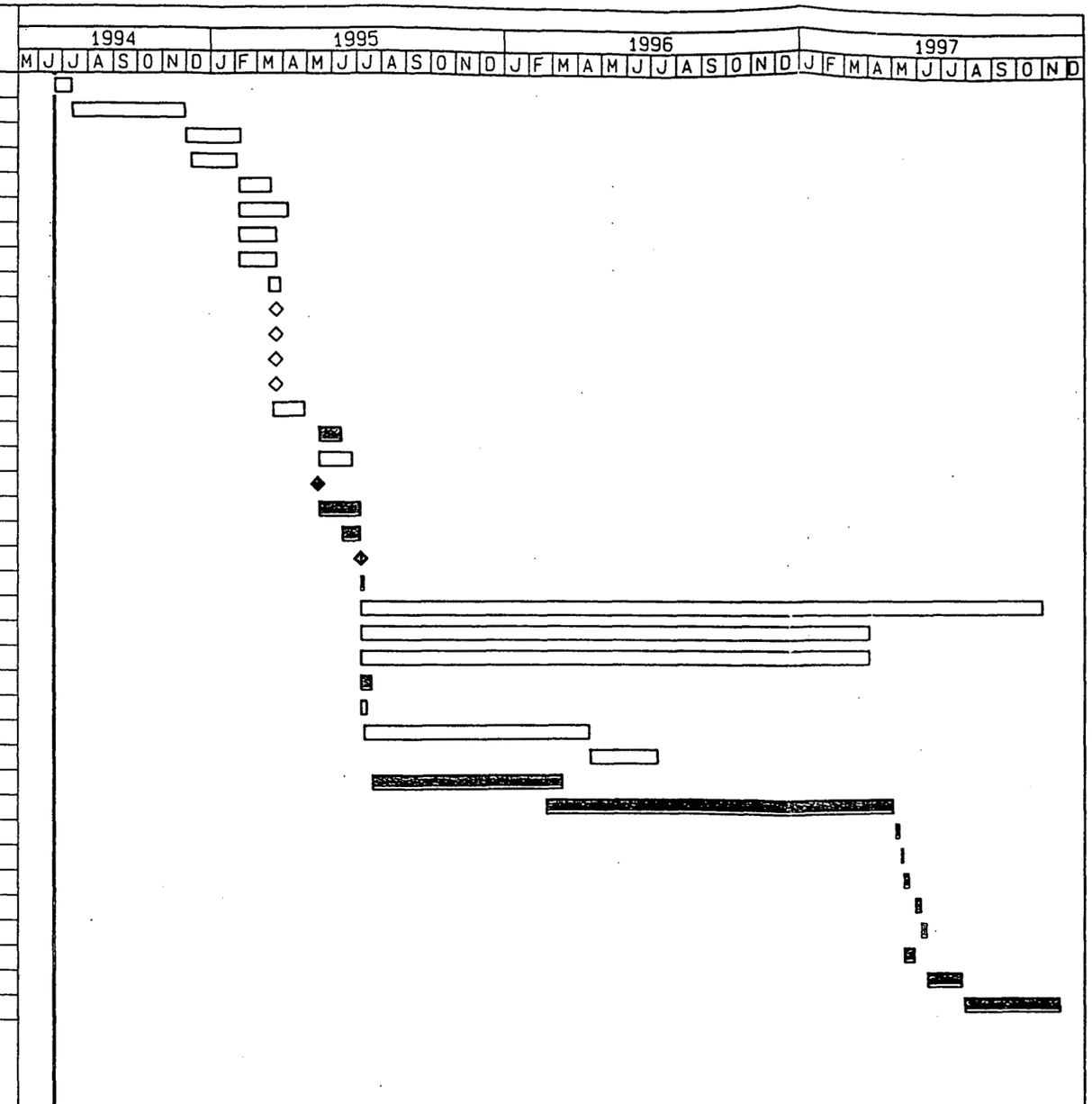
- Streams
- Paved Roads
- Buildings
- Fence
- Alluvium Monitoring Well
- Dry Wells
- Probable Flow Within Bedrock

100 0 100 200 300 FEET

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure III.D-1
OU4 IM/IRA
Potentiometric Surface Map of the Seasonal High Water Table Elevation

ACTIVITY ID	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	ORIG DUR
000	GEOTECHNICAL ANALYSES	21JUN94	12JUL94	15
005	90 % TITLE II DESIGN	13JUL94	29NOV94	97
010	FINAL TITLE II	30NOV94	8FEB95	50
015	PROPOSAL	7DEC94	3FEB95	42
020	EVALUATION	6FEB95	17MAR95	30
025	WASTE DISPOSAL PLAN	6FEB95	7APR95	45
030	EXCAVATION PERMIT	6FEB95	24MAR95	35
035	SECURITY PLAN	6FEB95	24MAR95	35
036	EXCAVATE VEG & SOILS N & S OF SEEPLINE	15MAR95	29MAR95	11
040	U/G UTILITY VERIFICATION	24MAR95		0
045	D & D BLDG. 788	24MAR95		0
046	RELOCATE POWER LINES	24MAR95		0
047	SECURITY FENCE	24MAR95		0
048	NEGOTIATIONS	20MAR95	28APR95	30
050	TRAINING	16MAY95	13JUN95	20
055	JOB SAFETY ANALYSIS	16MAY95	26JUN95	29
060	AWARD CONTRACT	15MAY95		0
065	SITE SPECIFIC H & S PLAN	16MAY95	6JUL95	36
070	MOBILIZATION	14JUN95	6JUL95	16
075	START CONSTRUCTION	7JUL95		0
100	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	7JUL95	10JUL95	2
140	PROJECT & CONSTRUCTION MANAGEMENT	7JUL95	31OCT97	592
150	CLEAN-UP & LABOR SUPPORT	7JUL95	1APR97	442
400	MONITOR JOBSITE (HEALTH & SAFETY)	7JUL95	1APR97	442
5000	INDIRECT FIELD COSTS	7JUL95	20JUL95	10
6000	REMOVE & SHRED OBSOLETE POLES	7JUL95	14JUL95	6
8000	POND LINER PREPARATION	11JUL95	15APR96	196
9000	STABILIZE HILLSIDE	16APR96	9JUL96	59
10000	UTILITIES	21JUL95	13MAR96	165
11000	INSTALL FINAL ENGINEERED COVER	22FEB96	2MAY97	305
13000	REMOVE & DECONTAMINATE STAGING AREA	5MAY97	9MAY97	5
15000	FINAL SITE SURVEY	12MAY97	14MAY97	3
15500	SEED	15MAY97	21MAY97	5
16000	FINAL SITE PREPARATION	29MAY97	5JUN97	5
16500	DEMOBILIZATION	6JUN97	12JUN97	5
A100	SLOPE STABILITY	15MAY97	28MAY97	10
A150	SETTLEMENT MONUMENT INSTALLATION	13JUN97	25JUL97	30
A200	POST CLOSURE AND SYSTEM START-UP	28JUL97	21NOV97	84



Plot Date 29MAR94
Data Date 21JUN94
Project Start 7JUN94
Project Finish 21NOV97

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

0100

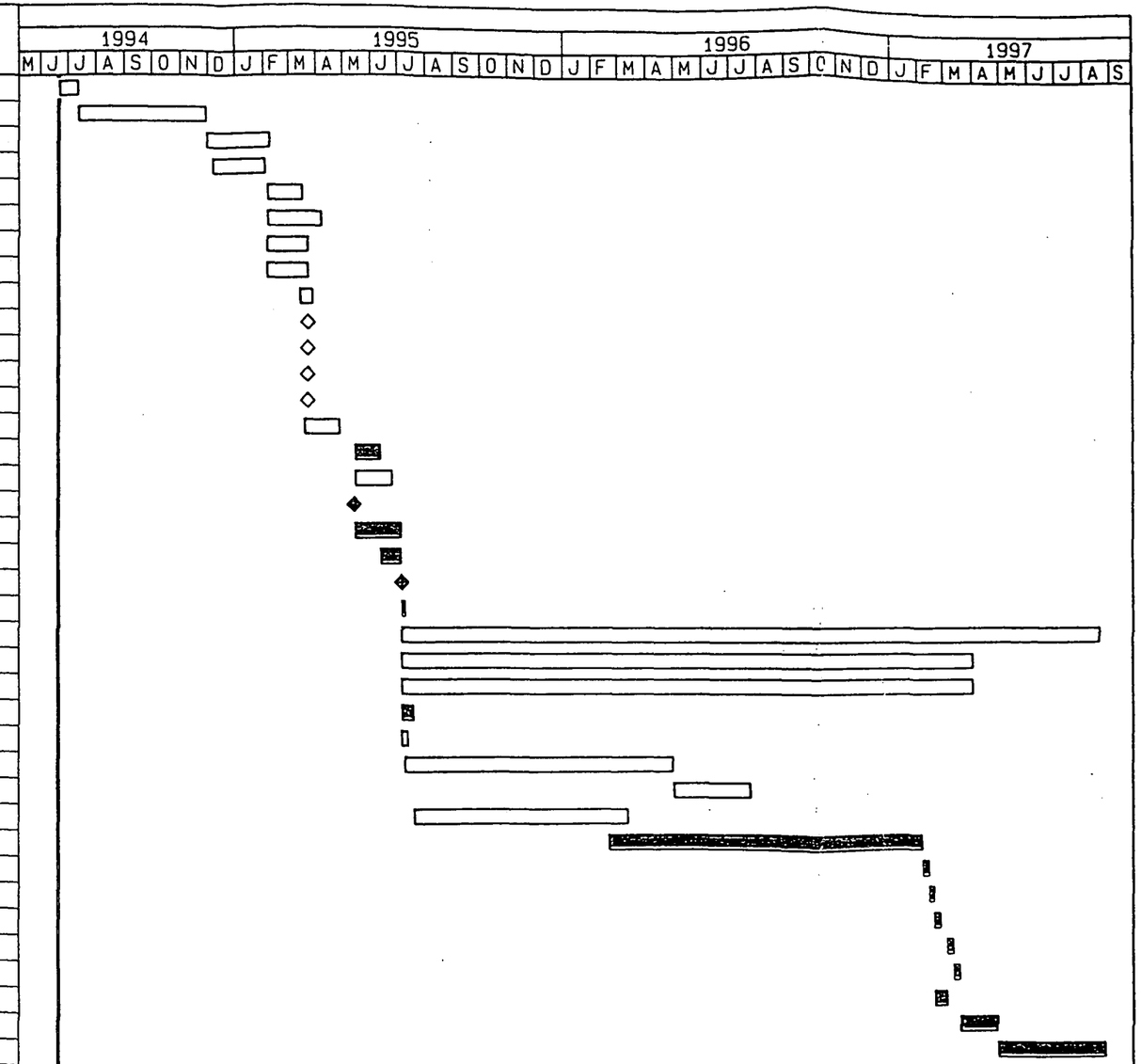
Sheet 1 of 1

FIGURE 2 OU4 IM/IRA
SUMMARY LEVEL
CONCEPTUAL SCHEDULE

-----PROJECT SCHEDULE-----

Date	Revision	Checked	Approved

ACTIVITY ID	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	ORIG DUR
000	GEOTECHNICAL ANALYSES	21JUN94	12JUL94	15
005	90 % TITLE II DESIGN	13JUL94	29NOV94	97
010	FINAL TITLE II	30NOV94	8FEB95	50
015	PROPOSAL	7DEC94	3FEB95	42
020	EVALUATION	6FEB95	17MAR95	30
025	WASTE DISPOSAL PLAN	6FEB95	7APR95	45
030	EXCAVATION PERMIT	6FEB95	24MAR95	35
035	SECURITY PLAN	6FEB95	24MAR95	35
036	EXCAVATE VEG & SOILS N & S OF SEEPLINE	15MAR95	29MAR95	11
040	U/G UTILITY VERIFICATION	24MAR95		0
045	D & D BLDG. 788	24MAR95		0
046	RELOCATE POWER LINES	24MAR95		0
047	SECURITY FENCE	24MAR95		0
048	NEGOTIATIONS	20MAR95	28APR95	30
050	TRAINING	16MAY95	13JUN95	20
055	JOB SAFETY ANALYSIS	16MAY95	26JUN95	29
060	AWARD CONTRACT	15MAY95		0
065	SITE SPECIFIC H & S PLAN	16MAY95	6JUL95	36
070	MOBILIZATION	14JUN95	6JUL95	16
075	START CONSTRUCTION	7JUL95		0
100	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	7JUL95	10JUL95	2
140	PROJECT & CONSTRUCTION MANAGEMENT	7JUL95	19AUG97	540
150	CLEAN-UP & LABOR SUPPORT	7JUL95	1APR97	442
400	MONITOR JOBSITE (HEALTH & SAFETY)	7JUL95	1APR97	442
5000	INDIRECT FIELD COSTS	7JUL95	20JUL95	10
6000	REMOVE & SHRED OBSOLETE POLES	7JUL95	14JUL95	6
8000	POND LINER PREPARATION	11JUL95	2MAY96	209
9000	STABILIZE HILLSIDE	3MAY96	26JUL96	59
10000	UTILITIES	21JUL95	13MAR96	165
11000	INSTALL 30 YEAR RCRA COVER	22FEB96	5FEB97	243
13000	REMOVE & DECONTAMINATE STAGING AREA	6FEB97	12FEB97	5
15000	FINAL SITE SURVEY	13FEB97	17FEB97	3
15500	SEED	18FEB97	24FEB97	5
16000	FINAL SITE PREPARATION	4MAR97	10MAR97	5
16500	DEMOBILIZATION	11MAR97	17MAR97	5
A100	SLOPE STABILITY	18FEB97	3MAR97	10
A150	SETTLEMENT MONUMENT INSTALLATION	18MAR97	28APR97	30
A200	POST CLOSURE AND SYSTEM START-UP	29APR97	26AUG97	84



Plot Date 29MAR94
Data Date 21JUN94
Project Start 7JUN94
Project Finish 26AUG97

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

0102

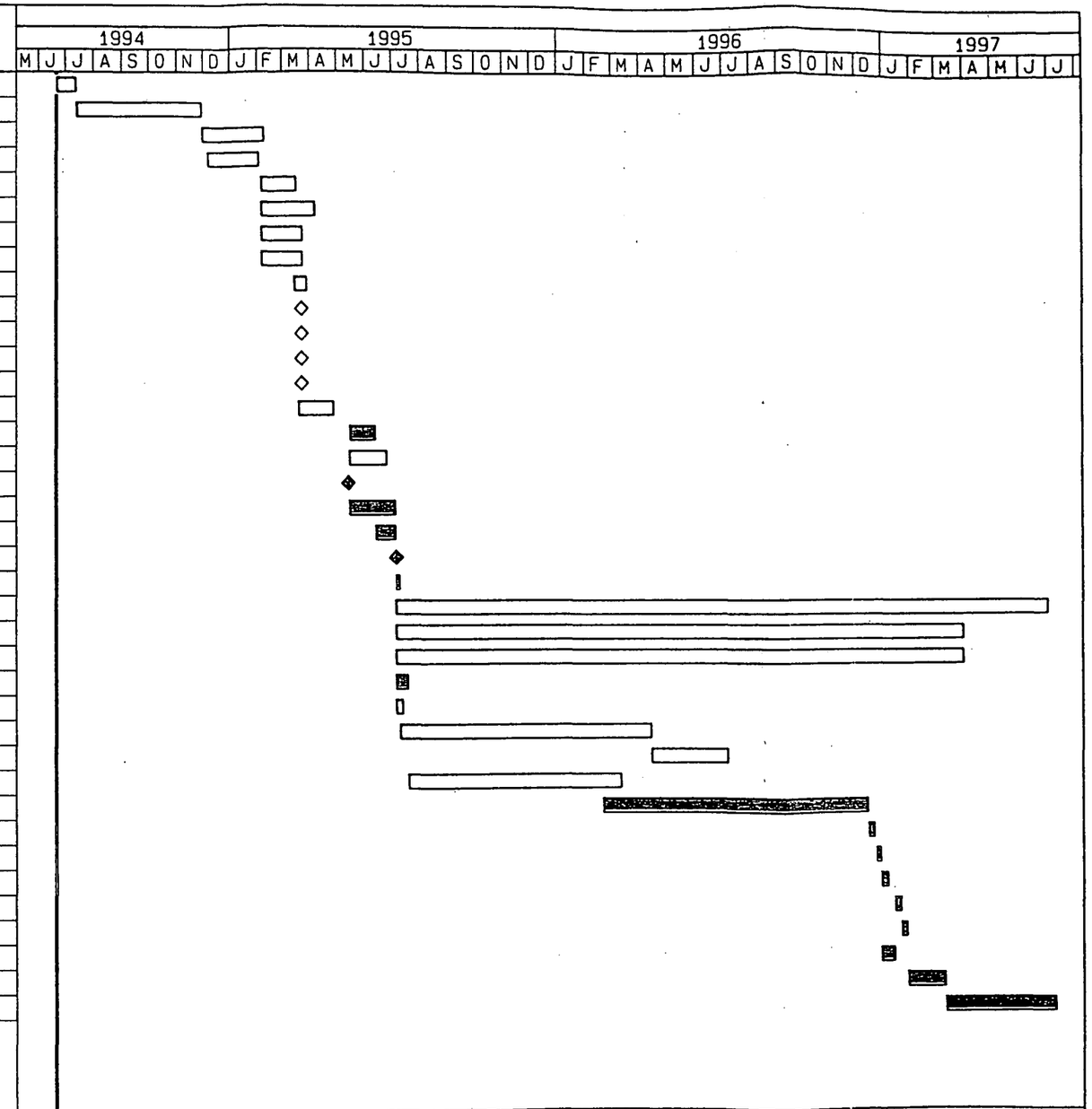
Sheet 1 of 1

FIGURE 4 OU4 IM/IRA
SUMMARY LEVEL
CONCEPTUAL SCHEDULE (30 YR RCRA)

-----PROJECT SCHEDULE-----

Date	Revision	Checked	Approved

ACTIVITY ID	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	ORIG DUR
000	GEOTECHNICAL ANALYSES	21JUN94	12JUL94	15
005	90 % TITLE II DESIGN	13JUL94	29NOV94	97
010	FINAL TITLE II	30NOV94	8FEB95	50
015	PROPOSAL	7DEC94	3FEB95	42
020	EVALUATION	6FEB95	17MAR95	30
025	WASTE DISPOSAL PLAN	6FEB95	7APR95	45
030	EXCAVATION PERMIT	6FEB95	24MAR95	35
035	SECURITY PLAN	6FEB95	24MAR95	35
036	EXCAVATE VEG & SOILS N & S OF SEEPLINE	15MAR95	29MAR95	11
040	U/G UTILITY VERIFICATION	24MAR95		0
045	D & D BLDG. 788	24MAR95		0
046	RELOCATE POWER LINES	24MAR95		0
047	SECURITY FENCE	24MAR95		0
048	NEGOTIATIONS	20MAR95	28APR95	30
050	TRAINING	16MAY95	13JUN95	20
055	JOB SAFETY ANALYSIS	16MAY95	26JUN95	29
060	AWARD CONTRACT	15MAY95		0
065	SITE SPECIFIC H & S PLAN	16MAY95	6JUL95	36
070	MOBILIZATION	14JUN95	6JUL95	16
075	START CONSTRUCTION	7JUL95		0
100	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	7JUL95	10JUL95	2
140	PROJECT & CONSTRUCTION MANAGEMENT	7JUL95	1JUL97	506
150	CLEAN-UP & LABOR SUPPORT	7JUL95	1APR97	442
400	MONITOR JOBSITE (HEALTH & SAFETY)	7JUL95	1APR97	442
5000	INDIRECT FIELD COSTS	7JUL95	20JUL95	10
6000	REMOVE & SHRED OBSOLETE POLES	7JUL95	14JUL95	6
8000	POND LINER PREPARATION	11JUL95	15APR96	196
9000	STABILIZE HILLSIDE	16APR96	9JUL96	59
10000	UTILITIES	21JUL95	13MAR96	165
11000	INSTALL CAPILLARY BARRIER COVER	22FEB96	16DEC96	209
13000	REMOVE & DECONTAMINATE STAGING AREA	17DEC96	23DEC96	5
15000	FINAL SITE SURVEY	26DEC96	30DEC96	3
15500	SEED	31DEC96	7JAN97	5
16000	FINAL SITE PREPARATION	15JAN97	21JAN97	5
16500	DEMOBILIZATION	22JAN97	28JAN97	5
A100	SLOPE STABILITY	31DEC96	14JAN97	10
A150	SETTLEMENT MONUMENT INSTALLATION	29JAN97	11MAR97	30
A200	POST CLOSURE AND SYSTEM START-UP	12MAR97	9JUL97	84



Plot Date 29MAR94
Data Date 21JUN94
Project Start 7JUN94
Project Finish 9JUL97

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

0103

Sheet 1 of 1

FIGURE 6 OU4 IM/IRA
SUMMARY LEVEL
CONCEPTUAL SCHEDULE (CAPILLARY)

-----PROJECT SCHEDULE-----

Date	Revision	Checked	Approved