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ENGINEERING EVALUATION/COST ANALYSIS SOUTH PLUME NOVEMBER 1990

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Engineering Evaluation/Cost Analysis South Plume

FEED MATERIALS PRODUCTION CENTER
Fernald, Ohio

November 1990

U. S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

FMPC-0003-6 FINAL

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COE	U.S. Army Corp of Engineers
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
HI	hazard index
IT	International Technology Corporation
MCL	maximum contaminant level
NCP	National Contingency Plan
NEPA	National Environmental Policy Act of 1969
NLO	National Lead Company of Ohio
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
O&M	operation and maintenance
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
OSHA	Occupational Safety and Health Administration

ACRONYM LIST
(Continued)

PCB	polychlorinated biphenyl
RI/FS	remedial investigation and feasibility study
SARA	Superfund Amendments and Reauthorization Act
SHPO	(Ohio) State Historic Preservation Officer
SOWC	Southwest Ohio Water Company
SSOD	storm sewer outfall ditch
TBC	to be considered
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WMCO	Westinghouse Materials Company of Ohio

DISTRIBUTION LIST

Project Director - John Wood, Fernald

Deputy Director/Technical - John Razor, Fernald

Technical Manager - Bob Galbraith, Fernald

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EXECUTIVE SUMMARY

PURPOSE FOR EE/CA

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) pertaining to environmental impacts associated with DOE's Feed Materials Production Center (FMPC) in Fernald, Ohio. The FFCA is intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly and adequately investigated so that appropriate response actions can be formulated, assessed, and implemented.

In response to the FFCA, DOE initiated a Remedial Investigation/Feasibility Study (RI/FS) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The FFCA was amended on April 9, 1990 under CERCLA Sections 120 and 106 (a) (Consent Agreement) which incorporated an operable unit approach to the RI/FS and identified specific removal actions to be conducted by DOE. The operable unit technical strategy adopted for the RI/FS is to issue distinct RI/FS reports for each of five operable units into which the FMPC has been separated. By accommodating separate schedules for each operable unit, the remedial action decision process is proceeding to completion for the most problematical units while data collection and analysis continue for other operable units.

One of the identified operable units for the FMPC includes those environmental media that serve as migration pathways and/or environmental receptors of radiological or chemical releases on and from the FMPC, referred to as Operable Unit 5. Important elements of this operable unit are the areas of the regionally important Great Miami Aquifer that exhibit elevated levels of uranium both within and outside the FMPC boundary. Because of the location of portions of a plume within developed areas south of the FMPC boundary and the associated potential threat to human health, and in providing consistency with removal action commitments in the Consent Agreement, the DOE is evaluating a removal action for this "south plume" prior to the completion of the environmental media RI/FS and the implementation of a final remedial action for the regional aquifer. Operable Unit 5 will continue to assess groundwater contamination, the migration of the south plume, and determination of the need for future actions for the south plume and any additional areas of groundwater contamination.

Removal actions, as described in the National Oil and Hazardous Substances Contingency Plan (NCP) of March 1990 (40 Code of Federal Regulations [CFR] 300.415), are primarily intended to abate, minimize, stabilize, mitigate, or eliminate a release or a threat of release prior to a final action if there is a threat to public health or welfare or the environment. A second reason for implementing a removal action is to mitigate contaminant migration pending final action if site conditions permit a straightforward mitigative action and significant migration would occur in the interim if no action is taken. Additionally, removal actions are to be consistent with the anticipated long-term remedial action and to contribute to the efficient performance of the long-term remedy to the extent practicable.

Once a removal action is deemed appropriate, if there is more than six months time available for planning (as in the case of the south plume), an engineering evaluation/ cost analysis (EE/CA) is performed to analyze removal action alternatives and to support the selection of a preferred alternative. This document represents the EE/CA for the south plume removal action at the FMPC. The National Environmental Policy Act of 1969 (NEPA) requires that federal agencies include in their decision-making processes appropriate and careful consideration of all environmental effects of proposed actions. Therefore, this document has been prepared so as to integrate both the requirements of CERCLA and NEPA. It will be used by DOE as the basis for remedy selection and implementation.

SITE BACKGROUND

The FMPC site is located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the plant.

The FMPC was constructed and operations began at the Fernald site in the early 1950s. A variety of chemical and metallurgical processes were utilized at the FMPC for the manufacture of uranium products. Large quantities of liquid and solid wastes were generated by these various operations.

Solid waste materials associated with uranium metals production are presently stored at the FMPC in steel drums awaiting further processing or off-site disposal at approved facilities. Prior to 1985, solid and slurried wastes from FMPC processes were disposed of in the Waste Storage Area. This area, which is west of the production facilities, includes six low-level radioactive waste storage pits, two earthen-bermed concrete silos containing K-65 residues (high specific activity, low-level radium-

bearing residues resulting from the pitchblende refining process), one concrete silo containing metal oxides, two lime sludge ponds, a sanitary landfill, and all affected adjoining areas.

Two fly ash piles are located approximately 3000 feet south/southeast of the Waste Storage Area. One pile remains active for the disposal of fly ash from the FMPC boiler plant. An area north of and adjacent to the fly ash piles, known as the Southfield, is believed to be the disposal site for construction debris and possibly other types of solid wastes from FMPC operations.

Surface water runoff from the Waste Storage Area, fly ash piles, and other affected areas within the western portion of the FMPC enters Paddys Run, a tributary of the Great Miami River. Paddys Run originates just north of the FMPC and flows south-southeast along the western edge of the site, and for a part of the year is a dry streamed with occasional rainfall-induced flows.

Leachate from these same areas can potentially migrate vertically to the regionally important Great Miami Aquifer which underlies the site. This aquifer serves as a principal source of domestic, municipal, and industrial water throughout the region.

Liquid waste effluent generated from FMPC process operations is sent to a general plant sump for treatment and analysis prior to release to the Great Miami River through the main effluent line. The main effluent line to the Great Miami River represents a permitted discharge for wastewater from the FMPC.

Elevated levels of uranium had been recorded as early as 1981 in groundwater south of the FMPC. As part of the ongoing RI/FS process at the site, additional monitoring wells were installed and others are proposed for locations within and outside the FMPC boundary to further evaluate the extent and magnitude of the uranium concentrations in the groundwater and to determine if other radionuclides or chemicals are present.

JUSTIFICATION FOR REMOVAL ACTION

RI/FS analytical data available as of mid-1990 were utilized for the evaluation of the south plume removal action. These data indicate the presence of radionuclides and inorganic metals in the groundwater south of the FMPC. None of the metals exceed established drinking water standards and

most of the radionuclides are found at natural background concentrations with the exception of uranium. Uranium concentrations have been detected in the groundwater in excess of levels above recommended dose exposures. Certain organic chemicals have also been observed in some samples, but these observations have not been persistent for the same monitoring wells. For these reasons, uranium has been designated as the contaminant of concern for the south plume removal action. All considered actions that account for public health and environmental protection against uranium will also provide protection against other radionuclides and chemicals due to the low levels present.

Uranium is a potential radiocarcinogen and a chemical toxin. Insoluble uranium compounds primarily pose a radiological hazard resulting from inhalation. Soluble uranium compounds pose both chemical and radiological hazards from ingestion. If ingested at sufficiently high rates, these compounds can lead to kidney damage and arterial lesions. Other potential adverse health effects that can result from ingestion of soluble uranium compounds are damage to the cardiovascular, hematopoietic, endocrine, and immunological systems.

EXTENT OF CONTAMINATION

The extent and distribution of uranium in the south plume have been established by combining groundwater monitoring data with the results of a groundwater flow/solute transport model. The monitoring data were utilized to establish the following: (1) a lower limit on the maximum concentration in the south plume, i.e., the maximum observed RI/FS value outside the southern boundary of the FMPC; (2) a conservative estimate of the shape and extent of the plume (as defined by those wells closest to the plume that exhibit background levels of uranium); (3) direct evidence of the uranium levels at actual receptor locations; and (4) the general shape of the uranium plume for use in calibrating the model.

The model was then used to interpolate between and extrapolate beyond the points of field observation. By doing so, the full distribution pattern of uranium in the south plume both today and under assumed future conditions could be estimated. The plume is predicted by the model to be an elongated ellipse oriented in a northwest/southeast direction due to the groundwater flow patterns through a narrow, north/south-trending buried channel. The center of the plume is predicted to lie approximately 800 feet south of Willey Road and north of the developed areas along Paddys Run and New Haven Road.

Based on this representation of the plume, approximately 100 acres outside the FMPC boundary is underlain by groundwater with uranium concentrations exceeding 30 µg/L. This concentration value is calculated from the 50-year committed effective dose equivalent (CEDE) of 4 millirem (mrem) from an annual intake of radioactive materials in drinking water. This concentration has been selected in the absence of a maximum contaminant level (MCL) or a proposed MCL. For the purposes of this removal action, this value has been applied to all areas outside the direct control of the FMPC where water could be used as a drinking water source.

POTENTIAL RISKS

In the case of the south plume, exposure to the contaminants can occur only if the groundwater reaches the land surface. The primary mechanisms are groundwater discharge to a surface water course and pumping. Because the model predicts that the south plume will not migrate to the Great Miami River or any other surface water course within the projected life of the removal action (i.e., within five years), groundwater discharge to surface waters is not considered as an exposure pathway for the no-action and nonpumping alternatives. However, exposure pathways associated with pumped groundwater discharged to a surface water course are considered in the evaluation of the effectiveness of the removal action alternative involving pumping.

There is no known use of groundwater with uranium levels exceeding the derived concentration limit of 30 µg/L from the south plume areas for drinking water, feedstock watering, or crop irrigation. Residences along Paddys Run Road to the west reportedly use cisterns with imported water. Groundwater monitoring results from commercial and residential wells along New Haven Road in or near the Village of Fernald indicates no uranium concentration levels exceeding the 30 µg/L limit in the water supply. These results indicate that the uranium plume either is not present at the level of aquifer pumping or has not yet migrated to these locations.

The only known users of groundwater with uranium levels exceeding the derived concentration for uranium in drinking water are two industries located along Paddys Run Road southwest of the projected center of the plume.

Potential future receptors of the uranium in groundwater south of the FMPC include: (1) persons who pump groundwater for potable use, crop irrigation, or livestock feeding from areas not currently

impacted but located along the future migration pathway of the plume, (2) persons who would use surface waters into which contaminated groundwater has been discharged, and (3) persons who would install a new well for potable use, crop irrigation, or livestock feeding from an area within the plume.

SCOPE OF REMOVAL ACTION EE/CA

The scope of the proposed removal action can be broadly defined as management of radioactively contaminated groundwater in an area south of the FMPC boundary. The fundamental objective of the removal action for the south plume is to protect public health by limiting access to and use of groundwater with uranium concentrations exceeding the derived concentration limit of 30 µg/L for uranium in drinking water, as well as other appropriate, risk-based levels for various potential exposure scenarios. For purposes of this removal action, this objective represents a minimum requirement that would have to be achieved by the removal action. Additionally, secondary objectives have been formulated for the south plume removal action which include the following:

- Protection of the groundwater environment, which in this case is represented by a sensitive, sole-source aquifer
- Control of plume migration toward additional receptors farther south

These objectives have been developed for the purposes of conducting an interim action until final actions under the RI/FS process are implemented.

Based on these identified objectives and on the preliminary results of the development and screening of specific remedial action alternatives in the RI/FS for the contaminated groundwater, the following alternatives have been selected for evaluation in the South Plume EE/CA:

- No Action
- Groundwater Monitoring and Institutional Controls
- Alternate Water Supply and Groundwater Monitoring and Institutional Controls (referred to hereafter as Alternate Water Supply)
- Groundwater Pumping and Discharge, Equivalent Uranium Removal from Existing FMPC Wastewater Discharges, Alternate Water Supply and Groundwater Monitoring and Institutional Controls (referred to hereafter as Pump and Treat)

Alternative 1 - No Action

Under the no-action alternative, no additional remediation, monitoring, or security activities in the vicinity of the south plume would be provided to further minimize risk to the public health or the environment. Any changes to the existing site environment are assumed to develop only as a result of natural occurrences. This alternative is being considered as a baseline for comparison with the other alternatives.

Alternative 2 - Monitoring and Institutional Controls

This alternative consists of the continued or additional monitoring of selected south plume wells in the study area outside the FMPC boundary. At present, no residential wells containing concentrations of uranium in excess of the derived concentration limit of 30 µg/L for uranium in drinking water are being used. The monitoring program associated with this alternative will be designed to detect increases in uranium content which may indicate movement of the plume into or toward industrial, commercial, or residential wells. Quarterly monitoring for uranium will take place in the selected wells until a modified monitoring program is implemented as part of the final remedial action. If increasing uranium concentrations are detected in any wells during the monitoring program, the potential for exceeding the derived concentration limit for uranium in drinking water will be evaluated and, if necessary, an appropriate additional response action will be taken which is not within the scope of this removal action.

Alternative 3 - Alternate Water Supply

This alternative consists of groundwater monitoring and institutional controls, as discussed in Alternative 2, and providing an alternate water supply to the two industrial receptors known to be using groundwater with uranium concentrations exceeding 30 µg/L.

Alternative 4 - Pump and Treat

This alternative consists of four parts. Part 1 involves supplying an alternate water supply to two industrial water users along Paddys Run. Part 2 involves the interception and collection of the contaminant plume via installation of recovery wells near the southern limit of the uranium plume south of the FMPC, and discharging the groundwater to the Great Miami River via the existing effluent line. Part 3 includes the installation of an "interim" 150 gpm advanced wastewater treatment system. This system is considered advanced since it utilizes ion exchange technology. This type of

treatment provides for more effective uranium removal than systems currently in use at FMPC. This system would remove a mass of uranium from the FMPC wastewater discharge which would be greater than the quantity of uranium released to the river by the discharge of south plume groundwater and other removal actions at the FMPC. These additional removal actions include the Contaminated Water Under FMPC Buildings Removal Action and the Waste Pit Area Run-off Control Removal Action. Part 4 involves groundwater monitoring and institutional controls as discussed in Alternative 2.

Each of these alternatives were evaluated according to the following criteria:

- Effectiveness
- Implementability
- Cost

The evaluation process and findings are discussed in Chapter 5.0. Table ES-1 provides a summary of this evaluation.

PREFERRED ALTERNATIVE

Based on the comparison of alternatives, Alternative 4, which includes groundwater pumping with direct discharge to the Great Miami River, an alternate water supply to two currently affected industrial users, installation of an "interim" 150 gpm advanced wastewater treatment system, and monitoring and institutional controls, has been selected as the alternative that most comprehensively satisfies the evaluation criteria.

As documented in this EE/CA, the current database and the results of the groundwater and solute transport models are considered sufficiently and adequately reliable to support the selection of Alternative 4.

ES-1

TABLE ES-1
ALTERNATIVE EVALUATION SUMMARY

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
EFFECTIVENESS				
• Time Until Action is Complete	N/A	Monitoring and institutional controls will continue for 5 years (estimated time until the remedial action is implemented).	An alternate water supply would be provided by December, 1991.	The alternate water supply portion of this alternative would be provided by December, 1991. Pumping and discharging of the groundwater would also begin by this time, and continue as part of the final remedial action or until the final action is implemented.
• Community Protection				
- Groundwater Ingestion (Present Users)	77 mrem - Maximum Exposure 39 mrem - Average Exposure Combined groundwater ingestion pathways: 1) Direct ingestion of groundwater 2) Ingestion of crops grown in fields irrigated by the groundwater 3) Ingestion of beef from cattle exposed to uranium through water and crops 4) Ingestion of milk from cows exposed to uranium through groundwater and crops 36 mrem - Maximum Exposure 18 mrem - Average Exposure (Drinking water pathway only)	For this alternative, it is assumed that south plume groundwater with concentrations exceeding the 30 µg/ℓ limit will not be used for potable water or irrigation of crops.	For this alternative, the combination of monitoring and institutional controls and an alternate water supply effectively eliminate the groundwater exposure pathways.	This alternative also provides institutional controls restricting access to groundwater within the South Plume Area.

E ES-1
(Continued)

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
EFFECTIVENESS (Continued)				
- Groundwater Ingestion (Future Users)	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.
- Surface Water Ingestion (Present Users)	0.9 mrem - Maximum Exposure 0.5 mrem - Average Exposure Pathways to man from releases to surface water are: 1) Irrigation of crops 2) Drinking water supplies downstream from the release point 3) Ingestion of beef cattle which ingest water from the river and irrigated forage 4) Ingestion of milk from cows which ingest water from the river and irrigated forage	0.9 mrem - Maximum Exposure 0.5 mrem - Average Exposure (Four pathways) 0.4 mrem - Maximum Exposure 0.2 mrem - Average Exposure (Drinking water pathway only)	0.9 mrem - Maximum Exposure 0.5 mrem - Average Exposure (Four pathways) 0.4 mrem - Maximum Exposure 0.2 mrem - Average Exposure (Drinking water pathway only)	First year of pumping: (Should increase by 2.5 percent per year over the three-year period.) 0.8 mrem - Maximum Exposure 0.4 mrem - Average Exposure (Four pathways) 0.4 mrem - Maximum Exposure 0.2 mrem - Average Exposure (Drinking water pathway only)
- Surface Water Ingestion (Future Users)	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.	Assumed historical release. Concentrations are assumed to decrease with time.
- Other Applicable Media	None	None	None	None

TABLE ES-1
(Continued)

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
EFFECTIVENESS (Continued)				
• Worker Protection	N/A	Health and safety procedures will be followed during sampling and analysis.	Necessary safety measures will be taken during construction.	Necessary safety measures will be taken during construction.
- Accidents				
- Radiological Exposures	N/A	Potential risk occurs only by ingestion or inhalation. None expected.	Potential risk occurs only by ingestion or inhalation. None expected.	Potential risk occurs only by ingestion or inhalation. None expected.
• Environmental Impacts				
- Plume Control				
Southern Migration Concentration (µg/ℓ) Plume Mixing	1100 feet (Leading edge) 510 µg/ℓ (Maximum) None	1100 feet (Leading edge) 510 µg/ℓ (Maximum) None	1100 feet (Leading edge) 510 µg/ℓ (Maximum) None	440 feet (Leading edge) 496 µg/ℓ (Maximum) None
- Source Reduction	No control of ultimate sources such as discharges to Paddy's Run or the storm water outfall ditch is considered under this South Plume removal action.	No control of ultimate sources such as discharges to Paddy's Run or the storm water outfall ditch is considered under this South Plume removal action.	No control of ultimate sources such as discharges to Paddy's Run or the storm water outfall ditch is considered under this South Plume removal action.	No control of ultimate sources such as discharges to Paddy's Run or the storm water outfall ditch is considered under this South Plume removal action.
- Surface Water				
FMPC Discharge Concentration	899 µg/ℓ- Average	899 µg/ℓ- Average	899 µg/ℓ- Average	150 µg/ℓ Lower uranium concentration in the flow from the wells will reduce the concentration in the FMPC discharge from the current release concentration of 899 µg/ℓto approximately 150 µg/ℓ.
Total Uranium Released from FMPC	1862 lbs/yr	1862 lbs/yr	1862 lbs/yr	Year 1 - 1602 lb Year 2 - 1642 lb Year 3 - 1682 lb After year 3 the advanced wastewater treatment system is operational.

TABLE ES-1
(Continued)

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
EFFECTIVENESS (Continued)				
River Water Concentration Above Background (1.2 pCi/ℓ) After Discharge	2.3 pCi/ℓ	2.3pCi/ℓ	2.3 pCi/ℓ	1.9 - 2.0 pCi/ℓ
Increase Water Flow	None	None	None	2000 gallons per minute or 4.5 cfs.
NEPA				
Aquatic Ecology	No effect if no withdrawal of water from aquifer.	No effect, reduced chance of withdrawal from aquifer.	Small, short-term disturbance to Paddys run due to need for a stream crossing by the water supply pipeline.	Same as for Alternative 3 for Paddys Run. Marginal positive impact on Great Miami River due to decreased uranium concentrations in FMPC combined effluent.
Terrestrial Ecology Habitats/Wetlands	No effect if no withdrawal. Effect of withdrawal depends on use.	No effect, reduced chance of withdrawal.	Small, short-term disturbance at wells and along pipeline route.	Small, short-term disturbance at alternate water supply and extraction wells.
Endangered Species	No impact on Indiana bat communities.	No impact.	No impact.	No impact.
Noise/Air Quality	No impact.	No impact.	Construction impacts lasting six months; not significant.	Construction impacts lasting six months; not significant.
Historical Resources	No impact.	No impact.	No impact.	No impact.
Waste Management	No change.	No change.	No change.	No change.

TABLE ES-1
(Continued)

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
IMPLEMENTABILITY				
• Ability to Construct and Operate	N/A	No construction activities are associated with this alternative.	Design and installation represent standard engineering efforts and should present no major technical difficulties. The water supply system will be fully automated, requiring daily maintenance checks.	The installation, construction and operation of a groundwater recovery system utilizes commonly practiced engineering techniques. No difficulties expected in the construction or operation of this system.
• Ease of Doing More Action if Needed	Actions can be implemented if necessary; however, this alternative would require the most time intensive effort for adding monitoring, and an alternative water supply or treatment system, if needed.	Additional actions can also be taken under this scenario if necessary. However, a time-intensive effort is required for any necessary design, construct, and implementation activities.	The addition of more action under this alternative is relatively less difficult than Alternatives 1 and 2. This would require only an expansion to an existing water supply or the addition of a pump and treat system.	The difficulty in taking more action under this alternative is less than Alternatives 1, 2 and 3. Expansion of the pumping network or the addition of a treatment system may be added, if needed.
• Ability to Obtain Approvals and Coordinate with other Agencies	The acceptance of the no-action alternative by the public and the agencies is not likely.	Individual landowner approvals needed for access; difficulties obtaining access in the past. Coordination between DOE, the State of Ohio, and local communities necessary and possible.	Property acquisition is necessary. Additionally, access to private properties and public rights-of-way are required; difficulties obtaining access in the past. Coordination with local and state agencies for permitting requirements; however, permit acquisition is not expected to be a significant factor in the implementation schedule.	Same as Alternative 3. Additional coordination and approval necessary for discharge of water to the Great Miami River.

TABLE ES-1
(Continued)

CRITERIA	NO ACTION ALTERNATIVE 1	MONITORING AND INSTITUTIONAL CONTROLS ALTERNATIVE 2	ALTERNATE WATER SUPPLY ALTERNATIVE 3	PUMP AND TREAT ALTERNATIVE 4
IMPLEMENTABILITY (Continued)				
• Availability of Services and Capabilities	N/A	Services for monitoring and analyses are readily available.	Necessary services are readily available.	Necessary services for this alternative are readily available.
• Availability of Equipment, Specialists, and Materials	N/A	Monitoring equipment, laboratory equipment, and materials are readily available.	The necessary equipment and materials associated with this operation are commonly and readily available.	The necessary materials and equipment for this alternative are readily available.
• Availability of Technologies	N/A	N/A	N/A	This alternative uses standard technologies which are readily available.
CONSISTENCY WITH FINAL REMEDIAL ACTION	N/A	This alternative is consistent with any final remedial action.	This alternative is consistent with any final remedial action,	This alternative is consistent with any final action that would remove groundwater from the aquifer. The removal of uranium and control of plume migration should reduce the final action.
REDUCTION IN MOBILITY, TOXICITY, OR VOLUME	No treatment proposed.	No treatment proposed.	No treatment proposed.	N/A
COST	No costs are associated with the no-action alternative.	Capital - $0.00 Annual - $33,600/yr Present Worth - $127,400 (5-year basis)	Capital - $900,100 Annual - $90,000/yr Present Worth - $1,241,200 (5-year basis)	Capital - $6,863,800 Annual - $930,000/yr Present Worth - $10,389,400 (5-year basis)

1.0 INTRODUCTION

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) pertaining to environmental impacts associated with DOE's Feed Materials Production Center (FMPC) in Fernald, Ohio. The FFCA is intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly and adequately investigated so that appropriate response actions can be formulated, assessed, and implemented.

In response to the FFCA, DOE initiated a Remedial Investigation/Feasibility Study (RI/FS) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The FFCA was amended on April 9, 1990 under CERCLA Sections 120 and 106(a) (Consent Agreement) which incorporated an operable unit approach to the RI/FS and identified specific removal actions to be conducted by DOE. The operable unit technical strategy adopted for the RI/FS is to issue distinct RI/FS reports for each of five operable units into which the FMPC has been separated. By accommodating separate schedules for each operable unit, the remedial action decision process is proceeding to completion for the most problematical units while data collection and analysis continue for other operable units.

One of the identified operable units (Operable Unit 5) for the FMPC includes those environmental media that serve as migration pathways and/or environmental receptors of radiological or chemical releases on and from the FMPC. One element of this operable unit is the areas of the regionally important Great Miami Aquifer that exhibit elevated levels of uranium both within and outside the FMPC boundary. Because of the location of portions of the uranium plume within developed areas south of the FMPC boundary and the associated potential threat to human health, and in providing consistency with removal action commitments in the Consent Agreement, the DOE is evaluating a removal action for this "south plume" prior to the completion of the RI/FS and the implementation of a final remedial action for the regional aquifer.

Removal actions, as described in the National Oil and Hazardous Substances Contingency Plan (NCP) of March 1990 (40 Code of Federal Regulations [CFR] 300.415), are primarily intended to abate,

minimize, stabilize, mitigate, or eliminate a release or a threat of release prior to a final action if there is a threat to public health or welfare or the environment. A second reason for implementing a removal action is to mitigate contaminant migration pending final action if site conditions permit a straightforward mitigative action and significant migration would occur in the interim if no action is taken. Additionally, removal actions are to be consistent with the anticipated long-term remedial action and to contribute to the efficient performance of the long-term remedy to the extent practicable.

Once a non-time-critical removal action is deemed appropriate (which applies to the south plume since there is more than six months time available for planning), an engineering evaluation/cost analysis (EE/CA) is performed to analyze removal action alternatives and to support the selection of a preferred alternative. The document contained herein represents the EE/CA for the south plume removal action at the FMPC. The National Environmental Policy Act of 1969 (NEPA) requires that federal agencies include in their decision-making processes appropriate and careful consideration of all environmental effects of proposed actions. Therefore, this EE/CA has been prepared so as to integrate the requirements of both CERCLA and NEPA, and will be used by DOE as the basis for remedy selection and implementation.

2.0 SITE CHARACTERIZATION

2.1 SITE BACKGROUND

The United States Atomic Energy Commission (AEC), predecessor to the DOE, established the FMPC for processing uranium and its compounds from natural uranium ore concentrates for U.S. Government needs. This integrated production complex began operations in conformance with AEC Orders in the early 1950s. In 1951, NLO Inc. (formerly National Lead Company of Ohio) entered into contract with the AEC as Operations and Maintenance (O&M) Contractor. This contractual relationship lasted until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly-owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities of the site operations and facilities for a minimum five-year period.

The FMPC site is located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. The Production Area is limited to an approximate 136-acre tract near the center of the FMPC site. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the plant (Figure 2-1).

A variety of chemical and metallurgical processes are utilized at the FMPC for the manufacture of uranium products. During the manufacturing process, high quality uranium compounds are introduced into the FMPC processes at several points. Impure starting materials are dissolved in nitric acid and the uranium is removed through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. This compound is reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal is produced by reacting UF_4 and magnesium metal in a refractory-lined reduction vessel. This primary uranium metal is then remelted with scrap uranium metal to yield a purified uranium ingot. Various uranium metal-working processes also exist.

Large quantities of liquid and solid wastes were generated by the various operations at the FMPC. Solid waste materials associated with uranium metals production are presently stored in steel drums awaiting further processing or off-site disposal at approved facilities. These wastes include oils,

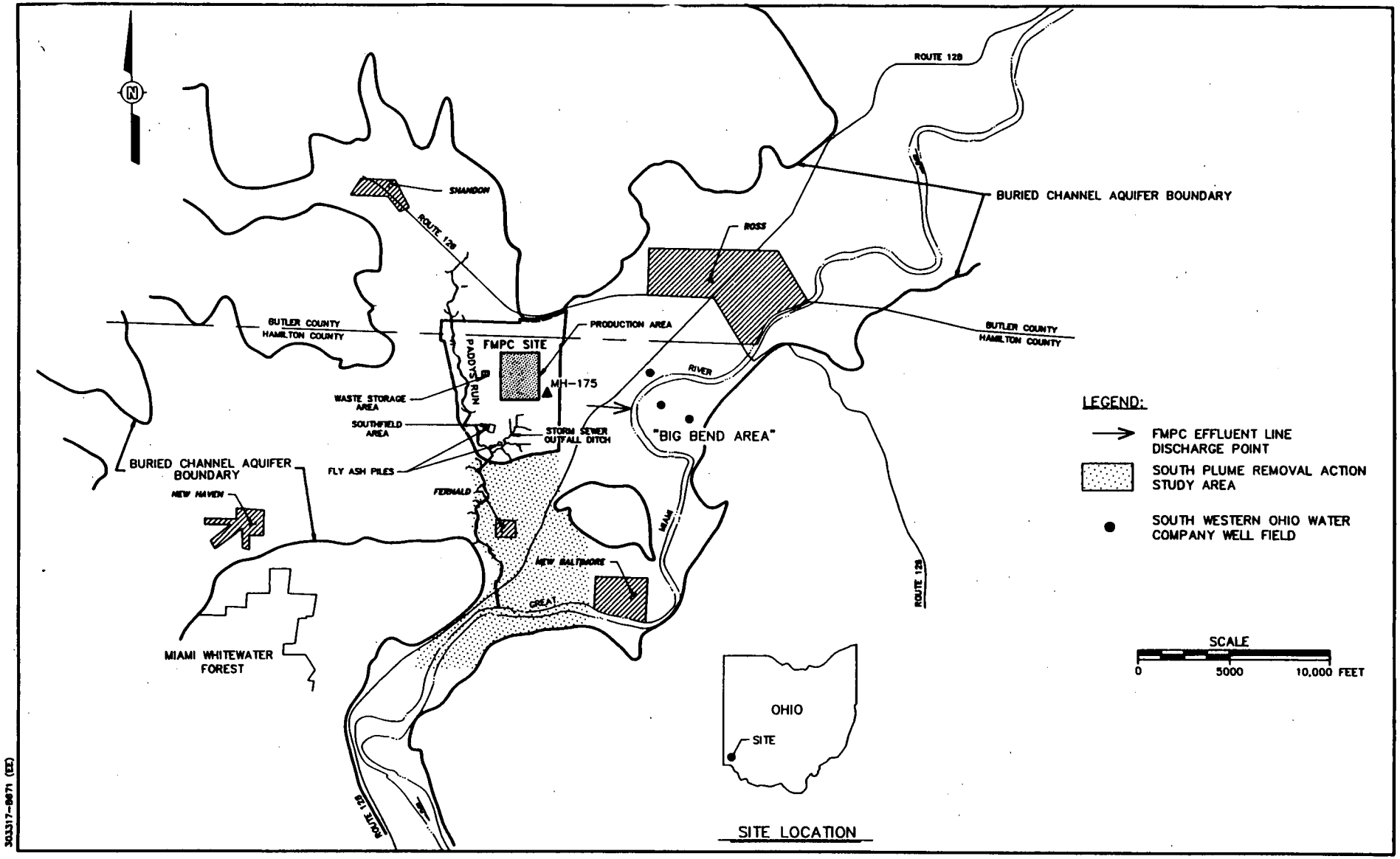


FIGURE 2-1
STUDY AREA AND VICINITY

sludges, contaminated combustibles, filter cake, off-spec UF_4 or thorium tetrafluoride (ThF_4), and reject UO_3. The drums sit on various pads and/or in warehouses and are inspected on a weekly basis. Contents of deteriorated drums are repackaged. Other waste materials, stored in drums on contained surfaces, include spent degreasing solvents and polychlorinated biphenyl-contaminated (PBC) material.

Prior to 1985, solid and slurried wastes from FMPC processes were disposed of in the on-site Waste Storage Area. This area, which is located west of the production facilities, includes six low-level radioactive waste storage pits, two earthen-bermed concrete silos containing K-65 residues (i.e., high specific activity, low-level radium-bearing residues resulting from the pitchblende refining process), a concrete silo containing metal oxides, two lime sludge ponds, and a sanitary landfill.

Two fly ash piles are located approximately 3000 feet south/southeast of the Waste Storage Area. One pile remains active for the disposal of fly ash from the FMPC boiler plant. An area north of and adjacent to the fly ash piles, known as the Southfield, is believed to be the disposal site for construction debris and possibly other types of solid wastes from FMPC operations. Surface water runoff from the Waste Storage Area, fly ash piles, and other affected areas within the western portion of the FMPC enters Paddys Run, a tributary of the Great Miami River. Paddys Run originates just north of the FMPC and flows south-southeast along the western edge of the site, and for a part of the year is a dry streambed with occasional rainfall-induced flows.

Leachate from these same areas can potentially migrate vertically to the regionally important Great Miami Aquifer which underlies the site. This aquifer serves as a principal source of domestic, municipal, and industrial water throughout the region. A portion of the flow in Paddys Run is also known to enter this aquifer downstream from the Waste Storage Area as a result of leakage through the stream bottom.

Liquid waste effluent generated from FMPC process operations is sent to a general plant sump for treatment and analysis prior to release to the Great Miami River through the main effluent line (Figure 2-1). Storm water runoff from the production area is collected in storm water retention basins to allow for solids removal prior to being analyzed and released to the Great Miami River through the same effluent line. During major storm events, storm water may be discharged through an outfall ditch to Paddys Run if the storm water retention basins overflow.

The main effluent line to the Great Miami River represents a permitted discharge for wastewater from the FMPC and would be expected to serve as the discharge facility for any groundwater pumped from the south plume. The discharge is regulated by an National Pollutant Discharge Elimination System (NPDES) permit and DOE Orders, with compliance monitoring performed at Manhole 175 before the effluent leaves the property boundary. The wastewater conveyed by the main effluent line currently comes from four principal sources:

- Treated water from raw water treatment and boiler blowdown from the general sump to Manhole 175
- Treated effluent from the sanitary sewage treatment plant
- Storm water runoff from the Production Area, via the storm sewer lift station or the storm water retention basin
- Low-concentration nitrate streams from the general sump and biodenitrification facility

The effluent line is a 4200-foot-long, 16-inch-diameter cast iron pipe constructed in 1952. Seven concrete manholes are located along the line for access and maintenance purposes. The depth of burial of the pipeline ranges from approximately 4 to 16 feet, with a maximum and minimum slope of 12.7 and 0.1 percent, respectively. The invert of the concrete-encased submerged discharge is located near the bottom of the Great Miami River, approximately 15 inches below the lowest recorded water level at the discharge point.

Because the lower reaches of the effluent pipeline would be submerged under high water conditions in the Great Miami River, the pipeline was designed to accommodate pressure flow in these lower reaches. The flow capacity of the pipeline has been computed to be about 6.5 million gallons per day (mgd), or 10 cubic feet per second (cfs) (WMCO 1989). This greatly exceeds the value that would be realized under gravity flow only. In 1987, the average rate of discharge from the pipeline was 0.576 mgd or 0.89 cfs (WMCO 1988), far below the design capacity. The maximum discharge rate observed in 1987 was 1.134 mgd (1.76 cfs), and the minimum flow rate was 0.248 mgd (0.38 cfs) (WMCO 1988).

The NPDES permit for the FMPC specifies seven sampling locations (two external and five internal), the sampling method (24-hour composite or weekly grab), and the effluent characteristics to be monitored (flow rate, biological oxygen demand, pH, suspended solids, ammonia, oil and grease,

monitored (flow rate, biological oxygen demand, pH, suspended solids, ammonia, oil and grease, residual chlorine, and nitrate). DOE Orders also require daily sampling for radionuclides, with the daily samples composited on a weekly basis for laboratory analysis.

Based on the analytical data from the weekly composites, the average concentration of total uranium in the FMPC effluent discharge in 1989 was found to be 545 picocuries per liter (pCi/L) or 810 micrograms per liter (µg/L). This was less than the average value of 720 pCi/L (1070 µg/L) measured in 1988 (WMCO 1989). Average uranium concentrations for the FMPC effluent discharge for 1987, 1986, and 1985 were 660 pCi/L (990 µg/L), 450 pCi/L (675 µg/L), and 661 pCi/L (992 µg/L), respectively (WMCO 1988, 1987, 1986).

2.2 SITE SETTING

The following description of the physical setting of the FMPC and surrounding area was derived from various existing reports. Two documents were relied on substantially (IT 1988, DOE 1987) and are not specifically referenced in the text. Other documents used to support individual statements are appropriately cited within the text.

2.2.1 Climate

Data from the Greater Cincinnati International Airport are satisfactory to characterize the climatic regime of the FMPC area. Windflow data from the Dayton Airport have been utilized as a secondary data source.

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.0 degrees Fahrenheit in January to 75.5 degrees Fahrenheit in July. The highest temperature recorded from 1950 through 1984 was 102 degrees Fahrenheit in August 1962 and the lowest was minus 25 degrees Fahrenheit in January 1977. The average number of days per year with a minimum temperature of 32 degrees Fahrenheit or less is 110 days, and the average number of days with a maximum temperature of 90 degrees Fahrenheit or above is 20 days per year. Frost depth ranges from 30 to 36 inches.

The average annual precipitation for the period 1955 through 1984 was 37.75 inches and ranged from 29.22 to 40.64 inches. The highest precipitation occurs during the spring and early summer;

precipitation is lowest in late summer and fall. The average annual snowfall for the same period was 24.0 inches, with the heaviest snowfall in January.

2.2.2 Surface Water Hydrology

The FMPC is located within the Great Miami River Basin drainage, but above the river's present day floodplain. The Great Miami River is the receiving stream for the FMPC effluent discharge and represents the main surface water feature in the vicinity of the FMPC (Figure 2-1). The river flows generally to the southwest and has a drainage area of approximately 3360 square miles at the Hamilton gage, which is located about 10 miles upstream from the FMPC discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 3000 feet. Directly east of the FMPC and within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 2-1). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FMPC point of discharge.

The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 cfs. Using drainage area scaling, the corresponding average flow at the FMPC point of discharge has been estimated to be 3460 cfs. The maximum discharge ever recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated to be 352,000 cfs. The maximum discharge since the construction of five retarding basins in 1922 was 108,000 cfs and occurred on January 21, 1959. The 10-year flood discharge has been calculated to be 81,455 cfs for the site reach. The minimum daily discharge of 155 cfs was recorded on September 27, 1941. This value is approximately half of the 7-day, 10-year low flow value (Q7-10) of 267 cfs, as computed by the U.S. Geological Survey (USGS) for the Hamilton gage. This translates to 280 cfs at the site reach.

Natural surface drainage from the FMPC is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FMPC, and eventually enters the Great Miami River approximately 1.5 miles south of the FMPC (Figure 2-1). This stream loses flow to the groundwater along much of its course due to its highly permeable channel bottom and limited elevation above the regional groundwater table. Paddys Run is an ungauged, intermittent stream that flows primarily between January and May, with an estimated discharge for this period ranging between 0.2 and 4.0 cfs. Peak flows have not been gaged.

Runoff from the FMPC Waste Storage Area flows west and southwest to Paddys Run. A separate removal action is currently underway by DOE to capture the majority of this runoff. This project is documented in the EE/CA for the Waste Pit Area Storm Water Run-Off Control which has been approved by EPA.

A principal drainage feature of the FMPC is a tributary to Paddys Run known as the storm sewer outfall ditch. This drainage course originates south of the Production Area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property (Figure 2-1). Much of the stream bottom of this drainage course, which also collects runoff from an area east of the plant, is composed of sand and gravel. For this reason vertical seepage rates through the stream bottom may be high. This drainage course is generally dry throughout most of the year with flows occurring during and immediately after precipitation.

The storm sewer outfall ditch historically conveyed surface water runoff from the Production Area directly to Paddys Run when the capacity of the storm sewer lift station, which diverts low flow to Manhole 175, was exceeded. Two storm water retention basins were recently constructed at the head of the storm sewer outfall ditch. Storm water runoff from the Production Area is now conveyed to these retention basins. The basins, designed to retain the runoff from a 10-year, 24-hour rainfall event, essentially eliminate the contribution of storm water from the Production Area to the outfall ditch. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out to the Great Miami River via the FMPC's main effluent line.

2.2.3 Groundwater Hydrology

2.2.3.1 Geologic History

The FMPC is located within the area of a two- to three-mile-wide subterranean valley known as the New Haven Trough. This valley formed as a result of Pleistocene glaciation and subsequently filled with glacial outwash materials and till. The geological history of the FMPC area is briefly summarized below:

- In Late Ordovician time (approximately 450 million years ago), sediments which would become a predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale (a part of the Cincinnatian Series) is the relatively impermeable bedrock which now underlies the FMPC site area and forms the highlands to the north.

- Sometime prior to, or perhaps contemporaneous with Pleistocene glaciation, a large watercourse (larger than the present-day Great Miami River) cut its channel into this shale bedrock to a level of more than 200 feet below that of the present-day Great Miami River. This approximately two-mile-wide channel is termed the New Haven Trough and may be an abandoned course of the ancestral Ohio River.

- During subsequent Pleistocene glacial advances and retreats across the site (Illinoisan--approximately 300,000 years to 400,000 years ago, and Wisconsin--approximately 100,000 years ago), the New Haven Trough was filled with about 200 feet of glacial sediments from the buried valley. These sediments were deposited by water running from the margins of the glaciers and consisted mainly of well-sorted sands and gravels. Deposited on top of these sediments was a blanket of clay-rich glacial till.

- Erosion by the Great Miami River and its tributaries then removed significant portions of the glacial till and left terrace remnants which stand topographically higher than surrounding bottom lands.

The FMPC site lies on top of one of these terrace remnants left after the establishment of the present day Great Miami River channel. The lower reaches of Paddys Run have cut through this till and lie on the sands and gravels of the buried outwash deposits.

2.2.3.2 Hydrogeologic Setting

The bedrock in the vicinity of the FMPC consists of predominantly flat-lying olive-gray Ordovician shales with thin, interbedded layers of limestone. This shale forms the floor and valley walls of the New Haven Trough. The buried channel is generally carved into this shale between 60 to more than 200 feet below the pre-erosional land surface in the vicinity of the FMPC.

Unconformably overlying the shales in the bedrock channel are approximately 150 feet of regionally extensive Pleistocene glacial valley fill deposits. As indicated by the study area map (Figure 2-1) and the hydrogeologic cross sections (Figures 2-2 through 2-8), the buried valley is about one-half to over two miles wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls. Interbedded glacial till deposits occur within the outwash deposits, but in most cases are of limited lateral extent. The till deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix.

Within some areas, till deposits overlie the bedrock uplands and portions of the outwash materials where they form the thick unconsolidated sediment layers beneath the soil zone. This glacial till is

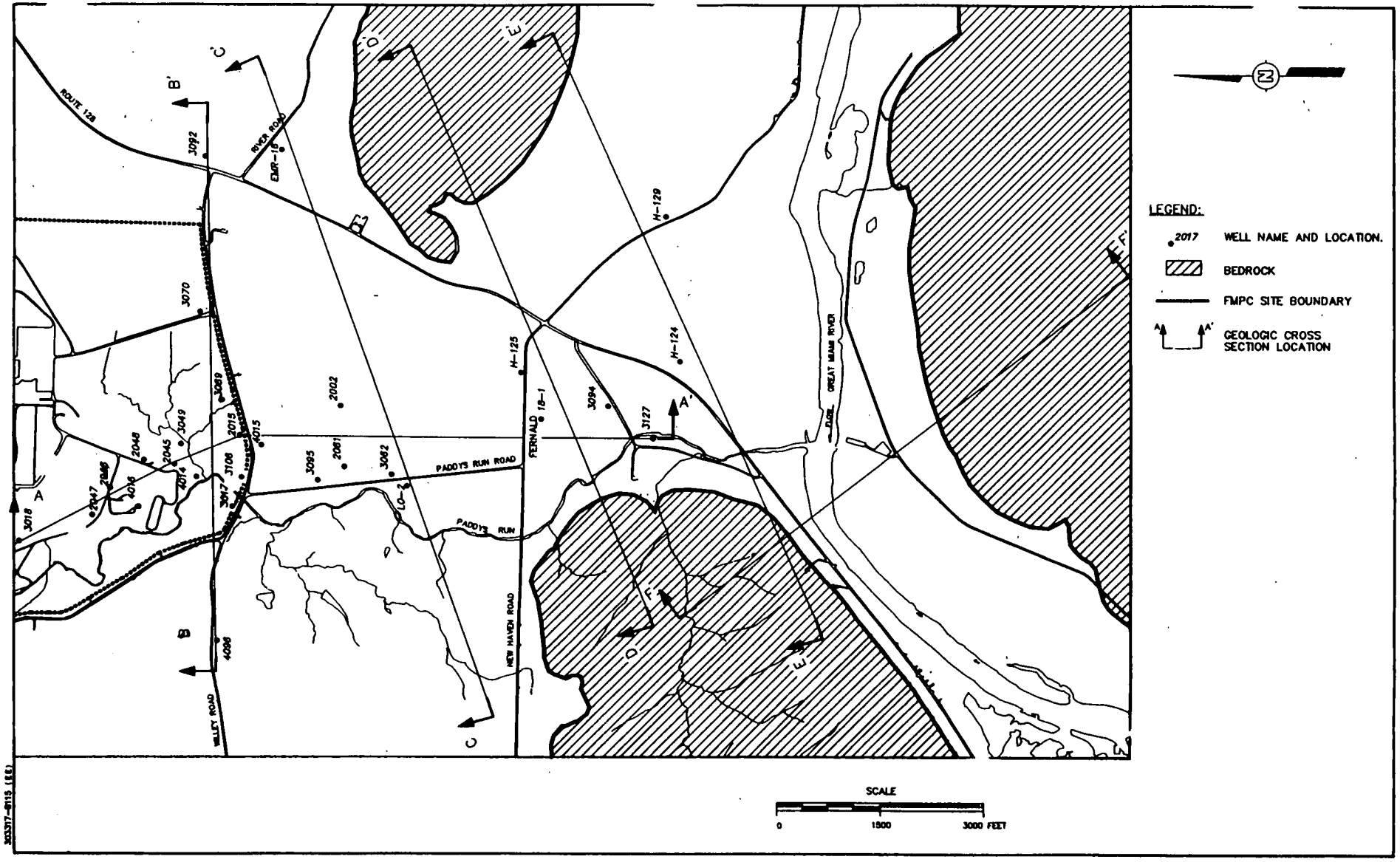


FIGURE 2-2
SOUTH PLUME GROUNDWATER STUDY
LOCATION OF CROSS SECTIONS

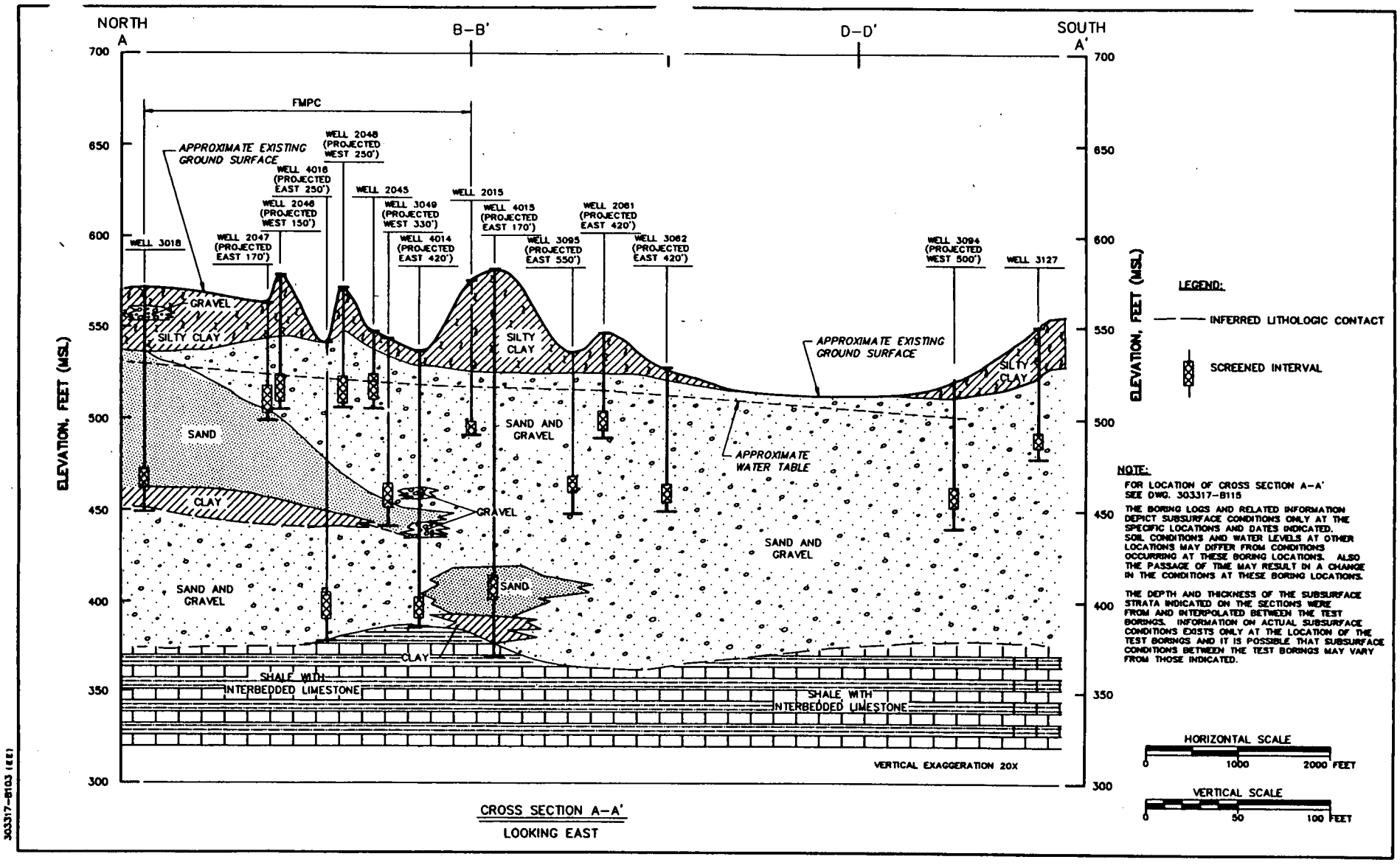
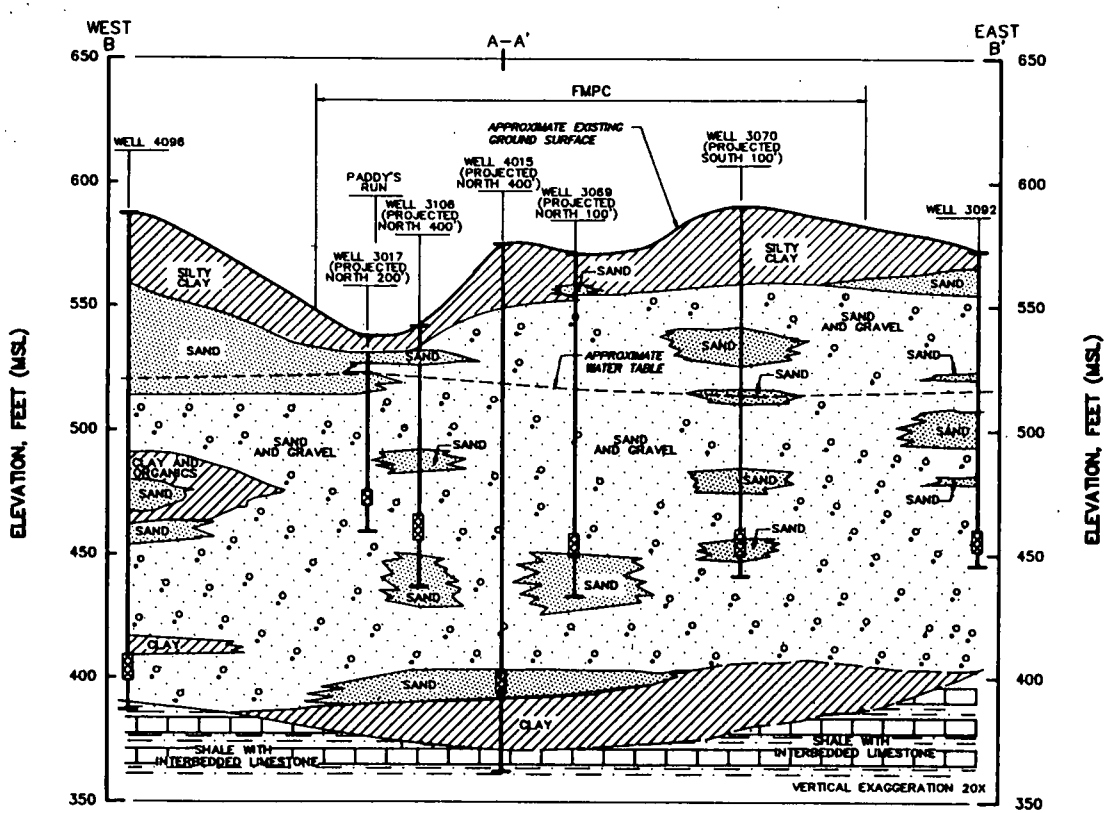


FIGURE 2-3
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION A-A'



CROSS SECTION B-B'
LOOKING NORTH

HORIZONTAL SCALE
0 1000 2000 FEET

VERTICAL SCALE
0 50 100 FEET

LEGEND:

SCREENED INTERVAL

INFERRED LITHOLOGIC CONTACT

NOTE:

FOR LOCATION OF CROSS SECTION B-B' SEE DWG. 303317-B115

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

303317-B108 (EE)

FIGURE 2-4
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION B-B'

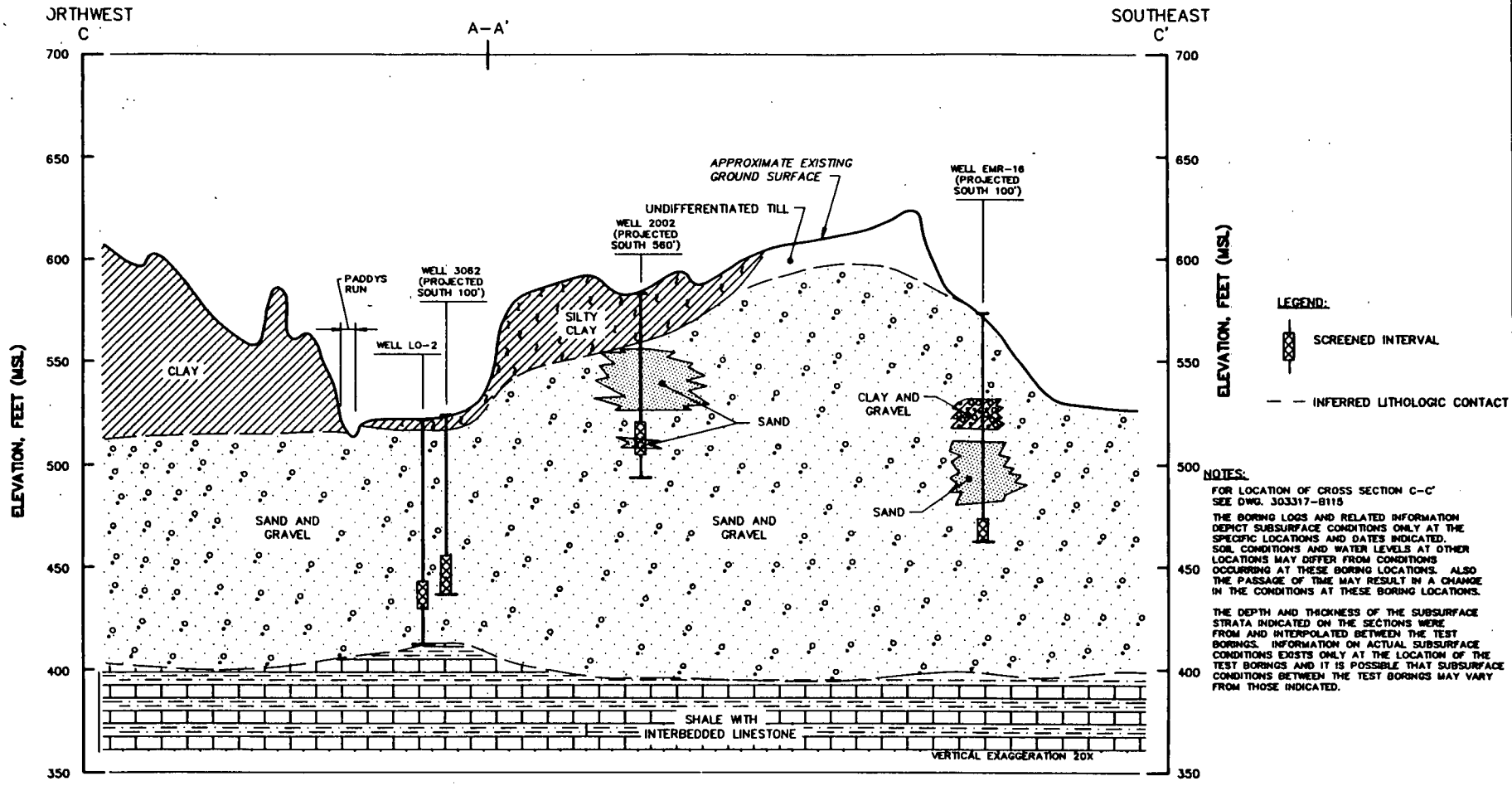


FIGURE 2-5
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION C–C'

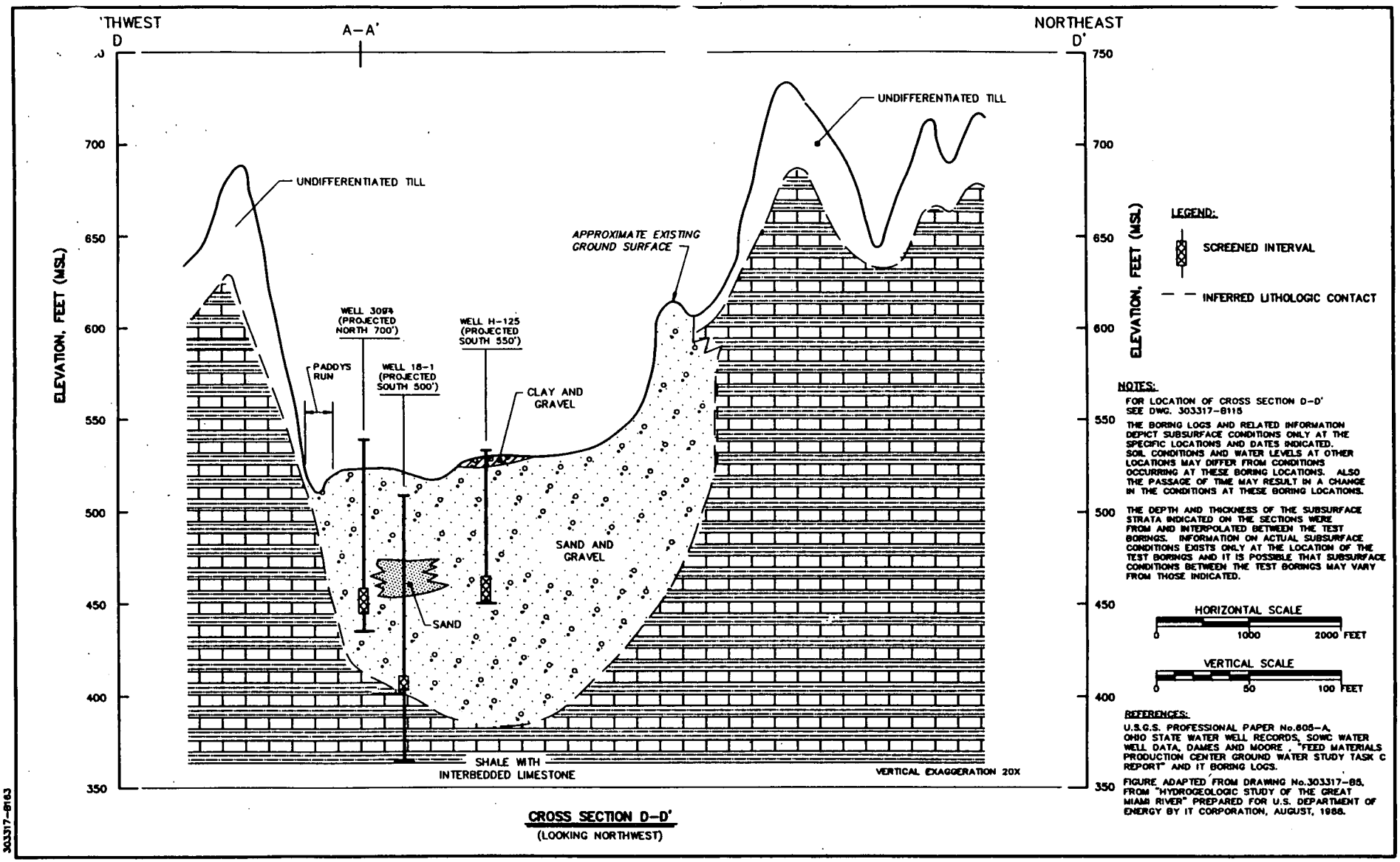


FIGURE 2–6
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION D–D'

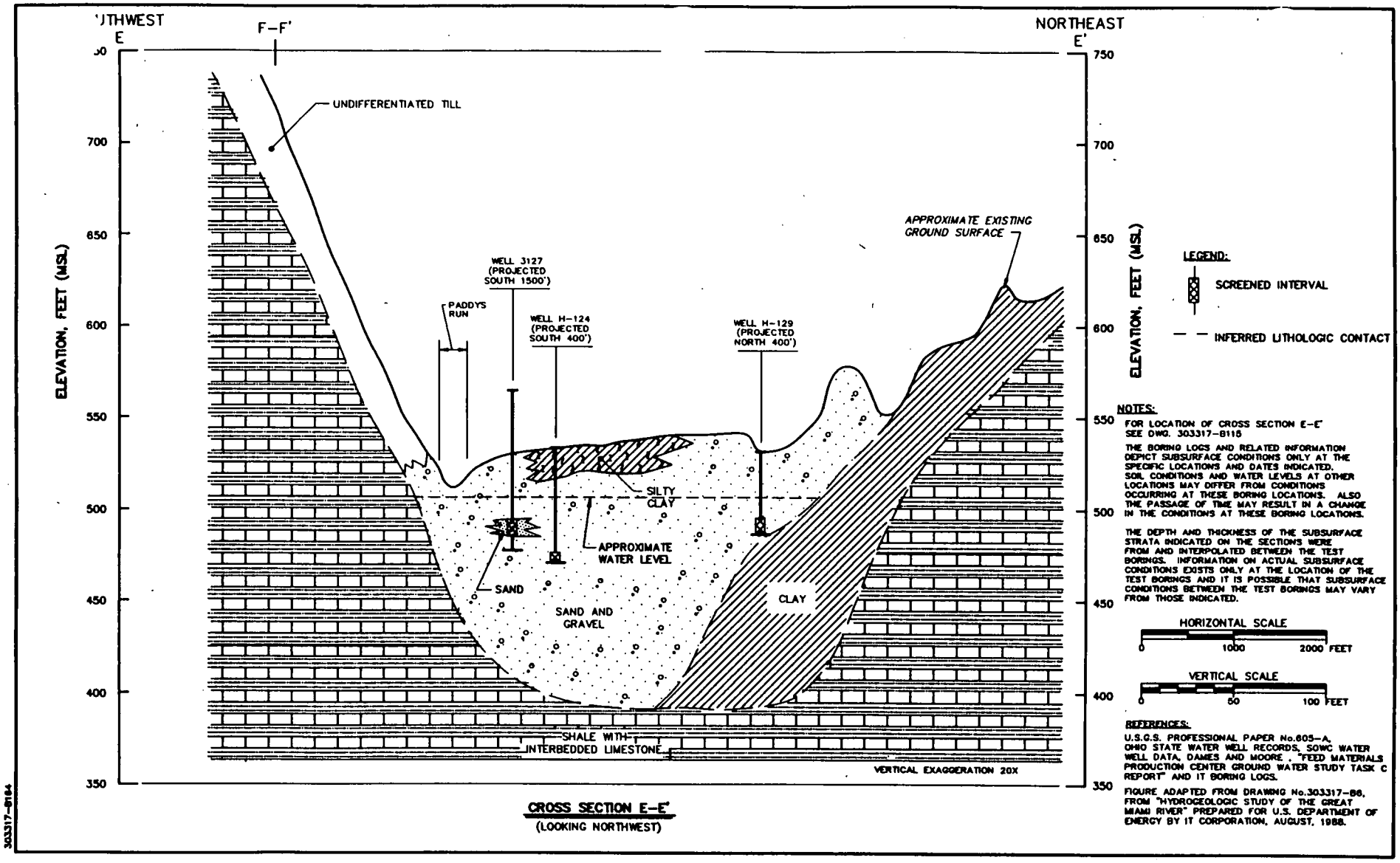


FIGURE 2-7
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION E-E'

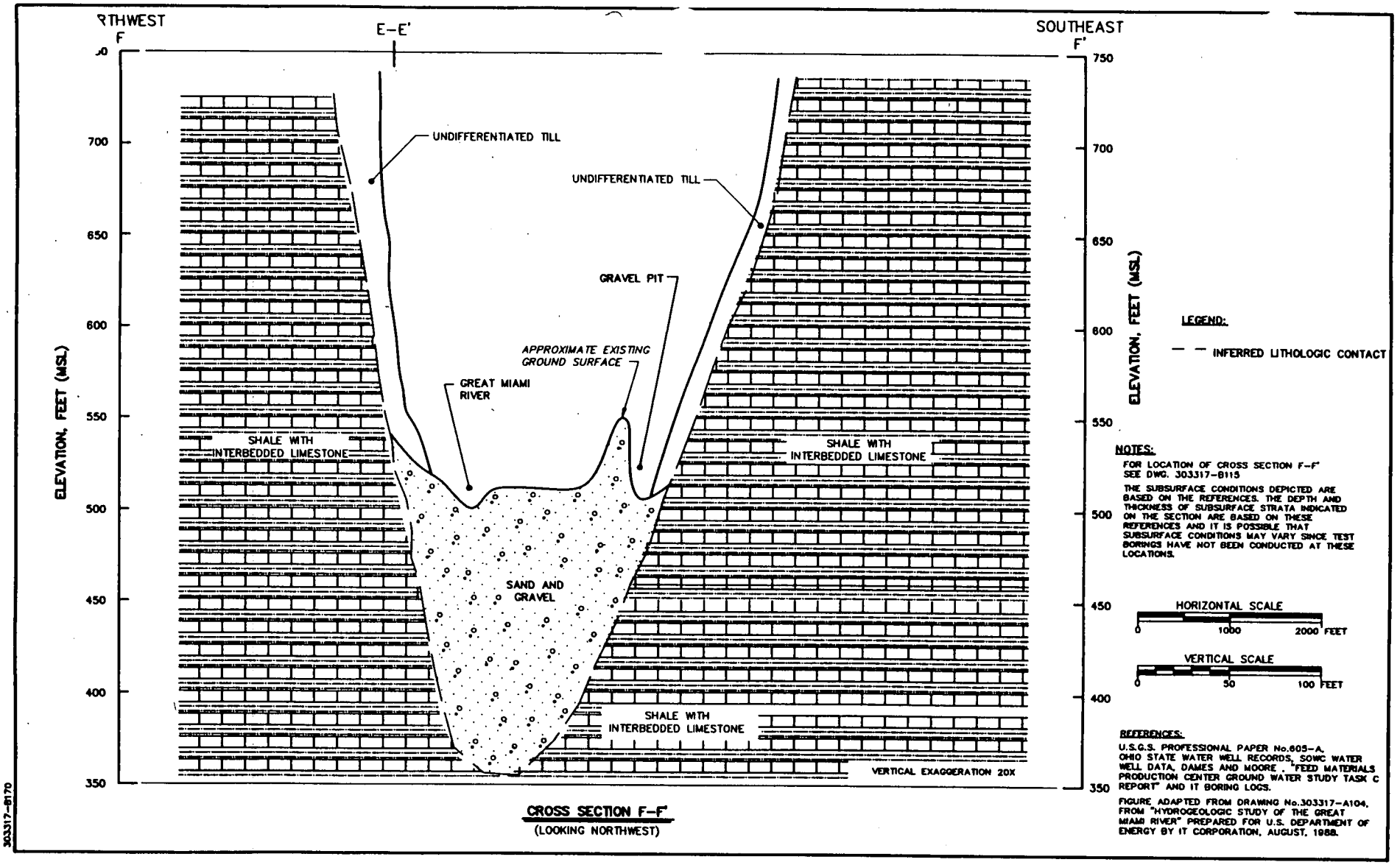


FIGURE 2-8
SOUTH PLUME GROUNDWATER STUDY
GEOLOGIC CROSS SECTION F-F'

composed of dense, silty clay that varies in composition vertically and laterally. The silty clay till contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt with layers of silty clay.

Regional hydrogeologic environments of the buried channel aquifer have been investigated and reported by the USGS. A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of aquifers in adjacent areas. Five major hydrogeologic environments have been identified and mapped in the Great Miami River Valley. Types I, III, and V environments generally describe the hydrogeologic conditions in the vicinity of the FMPC and the south plume study area. The characteristics of these aquifer environments in the area south of the FMPC are summarized in Table 2-1 and described in the following paragraphs.

The Type I Hydrogeological Environment is found along the floodplain of the Great Miami River to the south and east of the FMPC facility. The lithology of the aquifer consists principally of sand and gravel. Scattered lenses of clay and other fine-grained material may exist anywhere in the environment; however, these lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to otherwise affect groundwater movement. The potential for induced stream infiltration exists in these areas. Transmissivity values generally range from 40,000 to 67,000 square feet per day (ft^2/day). The Type I aquifer may be classified with a storage coefficient of about 0.2. Individual wells can yield as much as 3000 gallons per minute (gpm).

The Type III Hydrogeologic Environment consists of the buried channel aquifer covered by 50 or more feet of clayey till. In the region of the FMPC, the buried channel aquifer, characterized by the Type III Hydrogeologic Environment, is divided into upper and lower parts by a semipervious clay layer approximately 10 to 20 feet thick, occurring approximately 120 feet below land surface. Hence, the lower aquifer is classed as a semiconfined or leaky confined aquifer. An estimated storage coefficient of 0.001 was made for the lower sand and gravel aquifer. Estimated transmissivities range from 4700 to 40,000 ft^2/day.

The Type V Hydrogeologic Environment includes bedrock areas outside of the buried channel. These areas are uplands and consist of shale with interbedded limestone overlain by 50 or less feet of clay-rich till. Large quantities of groundwater are not generally transported through this material. Well

TABLE 2-1
GREAT MIAMI AQUIFER CHARACTERISTICS
SOUTH PLUME STUDY AREA

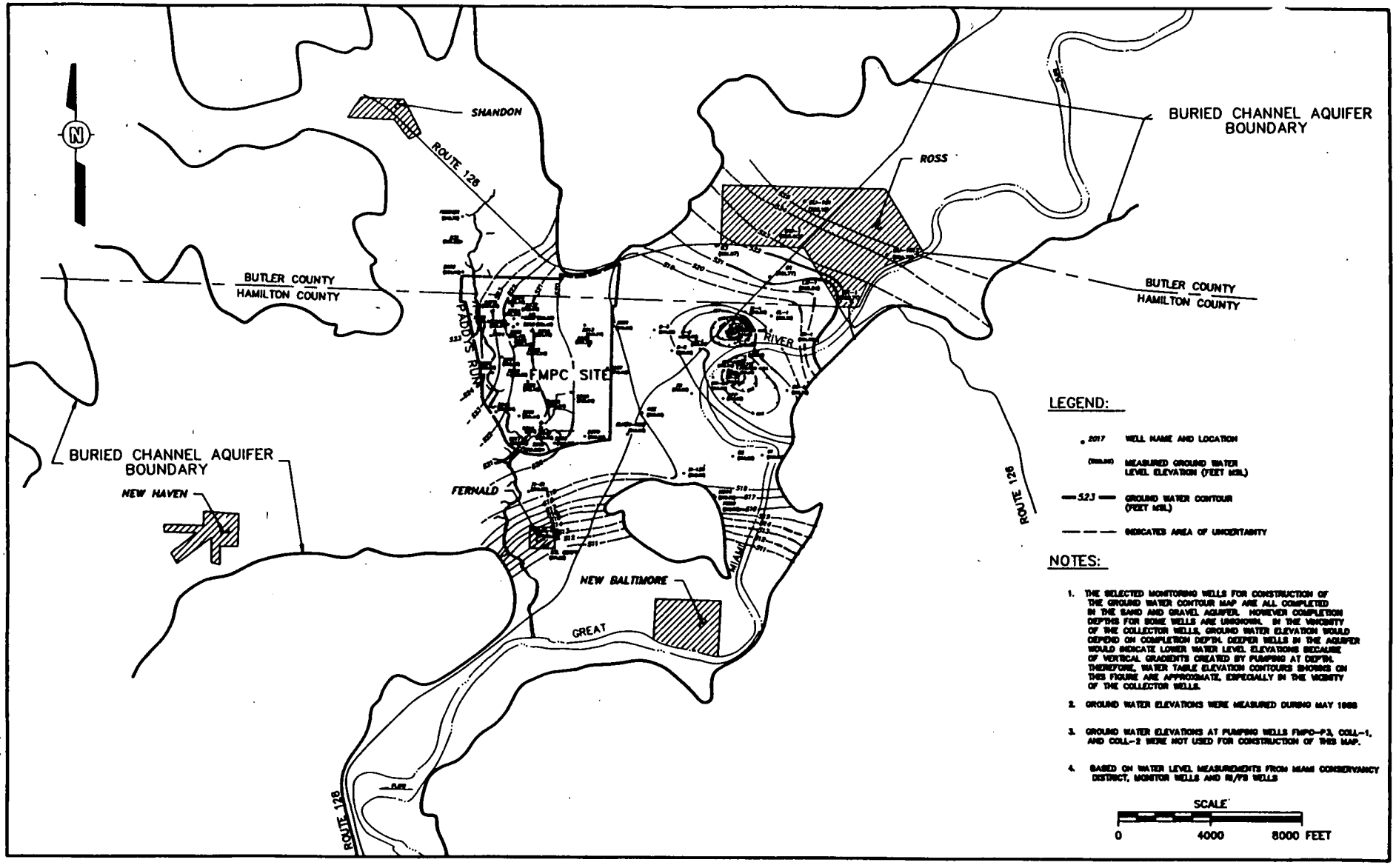
Description	Quantities/Units	References/Comments[a]
Geology	Glacial outwash sand and gravel	Reference 1
Aquifer Dimensions		
Area	South Plume Study Area - 2.5 square miles (1560 acres)	
Saturated Thickness	130 feet	Reference 1 - Average, from cross sections
Hydrogeology		
Hydraulic Conductivity	250 to 500 feet per day	Reference 1 - Transmissivity is equal to the product of the hydraulic conductivity and saturated thickness
Porosity	25 percent	Reference 1
Depth to Water	10 to 60 feet	Reference 1 - Below land surface
Contaminants in Ground Water		
Uranium	Primary contaminant	
Organics	Current data indicate organics are not prevalent	Additional analysis ongoing as part of the RI/FS project

[a]Reference:1. Hydrogeologic Study of FMPC Discharge to the Great Miami River, August 1, 1988, IT Corp. Final Report.

yields vary widely, typically ranging from near 0 to 10 gpm. However, because sand and gravel lenses are erratically distributed throughout this material, wells completed in these units may yield up to 50 gpm. Large groundwater supplies occur in the outwash deposits (buried channel aquifer) and are recharged by three principal sources: recharge from bedrock, precipitation recharge, and recharge by stream infiltration. Although the shales and limestones have a low permeability, small amounts of water occur in erratically distributed joints and cracks and produce seepage into the glacial deposits. The permeability of the bedrock has been estimated to be five gallons per day per square foot (gpd/ft^2) of contact with the glacial deposits. Recharge by precipitation amounts to approximately 570,000 gpd per square mile of catchment area. Under natural conditions, the gradient of groundwater flow is from the aquifer to the Great Miami River, except during dry periods when the gradient is reversed. Intermittent recharge to the aquifer also occurs along Paddys Run.

The groundwater in the regional aquifer beneath the FMPC flows from the buried valleys west, north, and east towards the center of the FMPC study area (Figure 2-9). Groundwater would naturally exit the area by flowing south-southwest through the branch of the buried channel aquifer west of New Baltimore. However, the large capacity pumping wells of the Southwest Ohio Water Company (SOWC) in the "Big Bend" meander of the Great Miami River east of the FMPC produce a pronounced and persistent cone of depression in the potentiometric surface centered on the pumping wells. Due to bedrock geometry, the cone of depression extends more in the east-west direction than in the north-south direction.

Groundwater elevation maps indicate that the resultant cone of depression from the SOWC wells influences groundwater flow patterns beneath the FMPC. In particular, a groundwater flow divide is created such that groundwater underlying the northern portion of the FMPC, including those areas underlying the Waste Storage Area and the Production Area, flows to the east toward the SOWC wells and the Great Miami River. Groundwater from the southern/southwestern portion of the FMPC continues to flow along the natural gradient to the south-southeast through the buried valley. In the vicinity of the south plume, a groundwater component from the west is also present due to the western leg of the buried channel (Figure 2-9). This causes the recharge from certain reaches of Paddys Run to flow to the east/southeast toward the southern plume.



303317-8870 (EE)

FIGURE 2-9
GROUNDWATER ELEVATION
MAY 1988

2.2.4 Soils

Soils in the region were formed from parent materials deposited by the action of Wisconsin and Illinoisan glaciers. These glacial till materials consist of sands, gravels, silts, and clays. Soil variations result from different parent materials, variations in relief and drainage, and differences in the time of weathering. In many areas where surficial glacial deposits contain interbeds or where erosion has occurred, sand and gravel are at shallow depths.

Soils at the FMPC site and adjacent areas are primarily categorized as Fincastle-Xenia silt loams. These soils are light colored, medium acid, and moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as is fertility and organic content. The soils have formed as 18 to 40 inches of wind-blown material (loess) over limey loam till of Wisconsin age. Fincastle soils have poor drainage; in areas where these soils are predominant, artificial drainage is required for moderate crop productivity. If artificial drainage is not used, the water content remains high for extended periods in winter and spring. Due to FMPC development projects, native soils on site have been covered by paving materials, gravels, and buildings.

Soils along Paddys Run are categorized as Fox-Genesee loams. These soils are light colored, high in productivity, and moderate in fertility and organic matter. Fox soils are slightly to medium acid, moderate in moisture-supplying capacity, and well drained. They have formed as 24 to 40 inches of silty materials over sand and gravel on level areas of the first terrace above the stream's normal floodplain. Genesee soils occur on the stream's normal floodplain. They are well drained, high in moisture-supplying capacity, and are subject to flooding.

2.2.5 Vegetation and Wildlife

The FMPC is in a region containing beech and mixed deciduous forests. Generalized habitats in the area have been described as grazed pastures, ungrazed pastures, pine plantations, riparian zones, and woodlots (WMCO 1987). Woods occur mainly along Paddys Run and north of the Production Area, and contain ash, sugar maple, sycamore, and cottonwood. Grasses and herbs dominate the pasture areas. Aquatic species such as cattails and rushes grow along drainage ditches. Area habitats support a number of species, although the habitats have not been described as unique.

Mammals in the FMPC area predominantly include the whitetail deer, eastern cottontail, fox squirrel, eastern chipmunk, wood chuck, and raccoon. Birds requiring open pasture, wooded, and shrubby field habitats have been observed on the site. These include the red-winged blackbird, mourning dove, blue jay, tufted titmouse, song sparrow, and common yellow throat.

The FMPC is within the geographic ranges of several species determined by the U.S. Fish and Wildlife Service to be endangered or threatened. These include the Indiana bat, bald eagle, peregrine falcon, and northern wild monkshood (50CFR17.11 and 17.12). The potential habitat for these species along the Great Miami River and Paddys Run is generally fair or poor. Areas along Paddys Run adjacent to the south plume project area range from poor to excellent habitat. There are no critical habitats in the vicinity of the FMPC. During the RI/FS biological sampling activity, Indiana bats were not found on or adjacent to the FMPC but were netted at a monitoring site three miles northeast of the FMPC boundary. The bald eagle and peregrine falcon do not nest in the counties surrounding the FMPC site; they would occur in the area only as rare transients along the Great Miami River. No indication of the northern wild monkshood was observed within the FMPC area.

A number of fish have been identified in the area, mainly minnows and darters in Paddys Run, and carp, gizzard shad, and sunfish in the Great Miami River (WMCO 1988). Fish populations in the Great Miami River remain healthy and have not changed appreciably since 1984 (WMCO 1988).

A study to assess the acute and chronic toxic effects of effluent from the FMPC on the algae, invertebrates, and fish in the Great Miami River is being conducted as part of the RI/FS for the environmental media operable unit. Additionally, the effects of the effluent on the macroinvertebrate community structure in the Great Miami River are being examined during the RI/FS.

2.2.6 Land Use and Population

The area surrounding the FMPC is mainly agricultural, with dairy, beef, corn, and soy bean production. Several industries, including Delta Steel, Albright & Wilson Americas, Inc., Ruetgers-Nease Chemical Company, two commercial gravel operations and a cement plant, are located south of the site. The Miami Whitewater Forest, a Hamilton County park, is located five miles to the southwest of the FMPC.

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FMPC. Downtown Cincinnati is approximately 18 miles southeast of the FMPC and the cities of Hamilton and Fairfield are eight miles to the northeast. There is an estimated population of over 24,000 within a five-mile radius of the center of the FMPC.

A number of significant archaeological and historic resources are present in the area surrounding the FMPC, both registered and as yet unrecorded. Five archaeological sites listed on the National Register of Historic Places lie within three miles of the FMPC: the Adena Circle (less than one mile northeast of the facility), Demoret Mound, the Hogen-Borger Mound Archaeological District, the Colerain Works Archaeological District, and the Dunlap Archaeological District. These represent the known archaeological sites near the FMPC. A number of additional studies have been carried out in the vicinity and all indications are that even more potentially significant sites remain undiscovered.

2.3 ANALYTICAL DATA

Elevated levels of uranium were recorded as early as 1981 in groundwater south of the FMPC. During the RI/FS process, additional monitoring wells have been installed and others are proposed for locations both outside and inside the FMPC boundary to further evaluate the extent and magnitude of the uranium plume and to determine if other radionuclides or chemicals are present. The locations of the existing monitoring wells in the south plume study area are shown in Figure 2-10. The 2000-series wells are screened approximately five feet above to 10 feet below the water table. The 3000-series wells have 10 feet of screen located near the middle of the aquifer. The 4000-series wells have 10 feet of screen near the bottom of the aquifer.

RI/FS analytical data available as of September 15, 1989 were utilized for the evaluation of the south plume removal action. The dates of the quarterly groundwater sampling program for the RI/FS are shown in Table 2-2. Wells were sampled as they were completed and on a quarterly basis for one year. Wells completed during the first year of the sampling program have already been sampled four times. Wells completed later in the program have been sampled at least twice. Additional sampling and analysis has been conducted in the south plume area in late 1989 and 1990. These analyses confirm the information obtained from the first six rounds of RI/FS data.

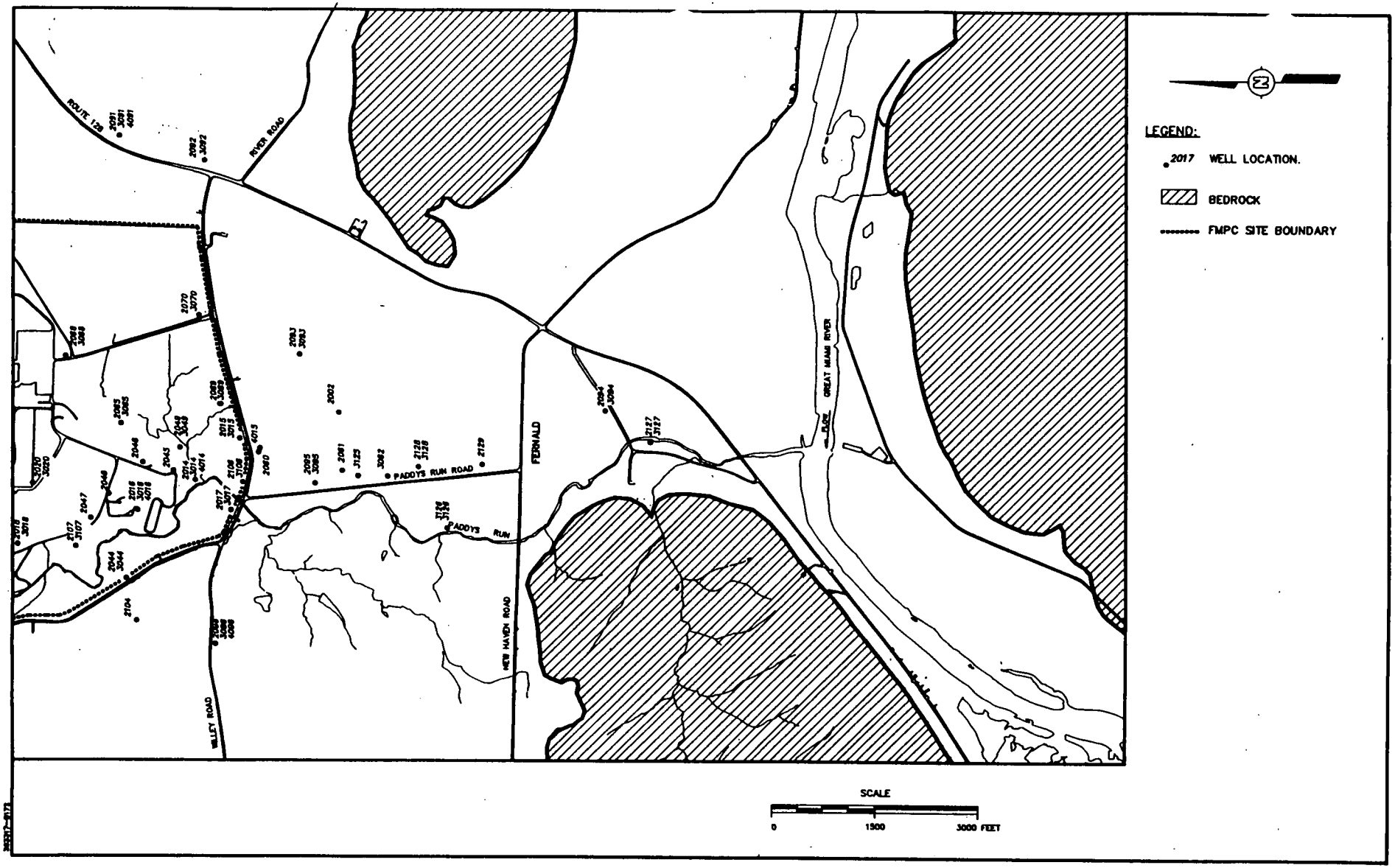


FIGURE 2-10
SOUTH PLUME GROUND WATER STUDY
MONITORING WELL LOCATIONS

TABLE 2-2
FMPC RI/FS
GROUNDWATER SAMPLING DATES

Round No.	Start Date	Finish Date	Year/Quarter
1	03/20/88	06/30/88	88/Second
2	07/13/88	09/21/88	88/Third
3	10/20/88	12/16/88	88/Fourth
4	01/09/89	04/02/89	89/First
5	04/19/89	06/07/89	89/Second
6	07/25/89	08/02/89	89/Third

All samples were analyzed for water quality parameters, metals, and radiological parameters including total uranium, total thorium, isotopic uranium, isotopic thorium, isotopic plutonium, radium-226, radium-228, neptunium-237, technetium-99, gamma-emitting radionuclides by gamma spectroscopy, and strontium-90. In addition to these analyses, selected wells (2014, 2015, 2016, 2020, 2060, 2065, 2094, 2095, 2106, 2129, 3126) were analyzed for organic volatiles, semivolatiles, pesticides, PCBs, and metals.

These data indicate the presence of radionuclides and inorganic metals in the groundwater south of the FMPC. None of the metals exceed established drinking water standards and most of the radionuclides are found at natural background concentrations with the exception of uranium. Uranium concentrations have been detected in the groundwater above the recommended dose exposure level. Certain organic chemicals have also been observed in some samples, but these observations have not been consistent for the same monitoring wells. For these reasons, uranium has been designated as the contaminant of concern for the south plume removal action.

Uranium is a potential radiocarcinogen and a chemical toxin. Insoluble uranium compounds primarily pose a radiological hazard resulting from inhalation. Soluble uranium compounds pose both chemical and radiological hazards from ingestion. If ingested at sufficiently high rates, these compounds can lead to kidney damage and arterial lesions. Other potential adverse health effects that can result from ingestion of soluble uranium compounds are damage to the cardiovascular, hematopoietic, endocrine, and immunological systems.

As discussed in Section 2.4.3.1, uranium is the principal constituent of concern to the south plume groundwater study. Uranium data from Rounds 1 through 6 of the RI/FS sampling program are tabulated in Tables 2-3 through 2-5. Data collected after these sampling rounds are presented in Tables 2-6 and 2-7. The range of uranium concentrations in groundwater in the study area is from less than 1 µg/L to approximately 907 µg/L. The highest uranium value (907 µg/L) was observed in Well 2046, which is located within the FMPC boundary near the Southfield (Figure 2-10), during the April 1990 sampling. Round 5 sampling for this same well measured a uranium value of 850 µg/L. The highest uranium value recorded outside the FMPC boundary during the April 1990 RI/FS sampling was 312 µg/L for Well 2061. Table 2-8 presents a summary of data regarding organic chemicals for the 2000-series wells.

TABLE 2-3

FERNALD RI/FS
SOUTH PLUME TOTAL URANIUM CONCENTRATIONS
2000-SERIES WELLS

Well No.	Total Uranium, µg/L Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
2002[a]	[b]	[b]	[b]	[b]	2	<1
2014[a]	32	33	35	17	[c]	33
2015	168	169	185	186	[c]	[c]
2016	21	18	17	22	[c]	[c]
2017	3	4	3	4	[c]	[c]
2018	2	<1	3	4	[c]	[c]
2020	3	<1	<1	<1	[c]	[c]
2044	2	1	33	1	[c]	[c]
2045	[b]	[b]	[b]	283	265	341
					291[d]	
2046	[b]	[b]	[b]	309	850	232
2047	[b]	[b]	[b]	15	10	9
2048	[b]	[b]	[b]	<1	<1	<1
2049	130	8	3	6	175	147
			2[d]			
2060[a]	242	225	171	250	[c]	[c]
	203[d]					
2061[a]	247	260	260	292	[c]	[c]
2065	10	9	7	9	[c]	12
				8[d]		11[d]
2068	<1	2	<1	<1	[c]	[c]
	3[d]					

See footnotes at end of table.

TABLE 2-3
(Continued)

Well No.	Total Uranium, µg/L Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
2069	6	13	12	12	[c]	[c]
2070	<1	1	<1	<1	[c]	[c]
2091[a]	[b]	<1	<1	1	1.2	[c]
2092[a]	[b]	7	<1	1	1.5	[c]
2093[a]	[b]	<1	<1	1.0	0.5	[c]
		1[d]				
2094[a]	[b]	2	<1	4.5	<0.1	[c]
2095[a]	[b]	169	177	146	208	[c]
					195[d]	
2096[a]	[b]	1	<1	0.4	1.4	[c]
2104[a]	<1	0.3	0.4	0.4	[c]	[c]
2106	[b]	[b]	[b]	61	16	[c]
2107	[b]	[b]	[b]	14	9	[c]
2127[a]	[b]	[b]	[b]	37	6	14

[a] Monitoring well location is outside the FMPC boundary.
[b] Well installation not completed.
[c] Well not sampled.
[d] Duplicate sample.
[e] Date not available.

Note: Uranium values reported with a decimal fraction reflect laboratory detection limits of 0.1 µg/L. All other values reflect laboratory detection limits of 1 µg/L.

TABLE 2-4

FERNALD RI/FS
SOUTH PLUME TOTAL URANIUM CONCENTRATIONS
3000-SERIES WELLS

Well No.	Total Uranium, µg/L Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
3014	23	29	28	30	[a]	[a]
3015	4	<1	<1	<1	[a]	[a]
3016	11	9	8	7	[a]	[a]
3017	<1	<1	<1	<1	[a]	[a]
3018	2	2	1	2	[a]	[a]
3020	<1	<1	<1	<1	[a]	[a]
3044	2	<1	<1	<1	[a]	[a]
3049	[b]	[b]	[b]	<1	<1	[a]
3062[c]	62	37	41	44	[a]	[a]
3065	[b]	[b]	[b]	<1	<1	[a]
3068	2	<1	<1	<1	[a]	[a]
		<1[d]				
3069	3	1	11	<1	[a]	[a]
3070	2	2	<1	<1	[a]	[a]
3091[c]	[b]	<1	<1	<1	0.1	[a]
3092[c]	[b]	<1	<1	<1	0.2	[a]
3093[c]	[b]	<1	<1	<1	0.5	[a]
3094[c]	[b]	<1	<1	0.6	<0.1	[a]
3095[c]	[b]	13	5	6	4	[a]

See footnotes at end of table.

TABLE 2-4
(Continued)

Well No.	Total Uranium, µg/L Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
3096[c]	[b]	<1	1	0.7	0.8	[a]
3106[c]	[b]	[b]	[b]	2	<1	[a]
3107	[b]	[b]	[b]	2	1	[a]
3127[c]	[b]	[b]	[b]	<1	<1	<1

[a] Well not sampled.
[b] Well installation not completed.
[c] Monitoring well location is outside the FMPC boundary.
[d] Duplicate sample.

Note: Uranium values reported with a decimal fraction reflect laboratory detection limits of 0.1 µg/L. All other values reflect laboratory detection limits of 1 µg/L.

TABLE 2-5

FMPC RI/FS
SOUTH PLUME TOTAL URANIUM CONCENTRATIONS
4000-SERIES WELLS

Well No.	Total Uranium, µg/L Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
4014	[a]	[a]	[a]	<1	<1	[b]
4015[c]	<1 <1[d]	<1	<1	<1	[b]	[b]
4016	[a]	[a]	[a]	<1	<1	[b]
4091[c]	[a]	2	<1 <1[d]	<1	<0.1	[b]
4096[c]	[a]	2	0.5 0.7[d]	0.5	0.8	[b]

[a]Well installation not completed.

[b]Well not sampled.

[c]Monitoring well location is outside of the FMPC boundary.

[d]Duplicate sample.

Notes: Uranium values reported with a decimal fraction reflect laboratory detection limits of 0.1 ug/L. All other values reflect laboratory detection limits of 1 ug/L.

TABLE 2-6

ADDITIONAL FMPC RI/FS
TOTAL URANIUM CONCENTRATIONS
SOUTH PLUME
2000-SERIES WELLS

Well No.	Date Sampled	Total Uranium (ug/L)
2125[a]	12/13/89	66.2
2128[a]	01/23/90	7.96
2129[a]	02/01/90	11.1
2126[a]	02/07/90	<1.0
2015	03/01/90	290
2060[a]	03/02/90	332
2106	03/02/90	88.6
2068	03/04/90	1.01
2016	03/04/90	29.4
2045	04/01/90	462
2068	04/01/90	461
2048	04/01/90	2.07
2014	04/01/90	36.0
2060[a]	04/03/90	59
2046	04/03/90	907
2047	04/03/90	13.8
2391[a]	04/03/90	14.5
2095[a]	04/04/90	87
2017	04/09/90	3.59
2065	04/09/90	11.4
2127[a]	04/10/90	8.39
2061[a]	04/12/90	312
2020	04/18/90	3.34
2018	04/18/90	5.79

See footnote at end of table

TABLE 2-6
(Continued)

Well No.	Date Sampled	Total Uranium (µg/L)
2104[a]	04/22/90	<1.5
2091[a]	04/23/90	1.88
2107	04/23/90	3.44
2386	05/10/90	6.67

[a]Monitoring well location is outside of the FMPC boundary.

TABLE 2-7

**ADDITIONAL FMPC RI/FS
TOTAL URANIUM CONCENTRATIONS
SOUTH PLUME
3000-SERIES WELLS**

Well No.	Date Sampled	Total Uranium (ug/L)
3126[a]	12/07/89	1
3125[a]	01/09/90	70.9
3128[a]	01/19/90	30.6
3126[a]	02/05/90	1.41
3015	03/01/90	108
3106[a]	03/02/90	1.93
3068	03/04/90	<1.0
3016	03/04/90	13.4
3014	04/01/90	35.3
3095[a]	04/04/90	8.85
3017	04/09/90	0.791
3065	04/09/90	0.793
3127[a]	04/10/90	1.10
3062[a]	04/12/90	43.0
3018	04/11/90	4.69
3094[a]	04/11/90	<0.75
3020	04/18/90	<0.70
3018	04/18/90	4.73
3107	04/22/90	3.69
3091[a]	04/23/90	<0.7

[a]Monitoring well location is outside of the FMPC boundary.

TABLE 2-8

DETECTED ORGANIC COMPOUI ;ROUNDWATER FROM THE 2000 SERIES WELLS[a]
(-- -a reported in mg/L)

Organic Compounds	Well Sampling Quarter	2004 2/86	2004 2/87	2006 2/89	2007 2/89	2010 2/88	2011 3/86	2011 2/88	2013 3/86	2013 2/87	2014 2/88	2015 2/86	2015 3/86	2015 4/86	2015 2/87	2015 4/87[b]	2015 2/88	2016 1/90	2016 2/87	2016 2/88	2017 4/86	2018 2/87	2019 2/88	2019 3/89	2021 3/86	2021 4/86
Volatiles																										
Acetone[c]			580			8 J		37	735	1800	2 J			120	104				930		17770	24500	13	2 J		
Benzene						1 J																				
Butanol							195																			
2-Butanone				4 J	2 J																					
Carbon disulfide							6.3	8																		
Cyclohexane			600							300					20							900				
Chloroform																		2 J								
1,1-Dichloroethane														1.1	2.3											
Ethylbenzene																										
2-Hexanone																										
Methylene chloride						1 J																				
2-Propanol									29600												45000					
Toluene				3 J				5																		
Total xylenes																										
Tetrachloroethene																										
1,1,1-Trichloroethane												5.1	2.9	7	18.9	5.13	6									11.9
Trichloroethane		4.4											3.7												10.5	
Semivolatiles																										
Butyl benzyl phthalate																										
Diethyl phthalate						7 J																				
Di-n-butyl phthalate																										
Isophorone								2 J																		
3-Nitroaniline								50																		
4-Nitrophenol																										
N-nitrosodiphenylamine								10																		
Phenol						14																				
bis(2-Ethylhexyl)phthalate											2 J						1 J			4 J				4 J		

[a]This table does not include compounds found in method blanks. Fourth quarter 1987, and second and third quarter 1989 results are from RCRA sampling program. Second quarter 1988 and first quarter 1989 results are from RI/FS sampling.
[b]Qualifier not included in data.
[c]Also known as 2-Propanone.
[d]Second quarter 1986 through second quarter 1987 results are from RCRA sampling program. Pre-Quality Assurance Project Plan analytical results; qualifiers are not included.

Qualifier: J-Compound detected; below the contract required quantitation limit. The value presented is an estimate.

T. 8 (Cont.)

DETECTED ORGANIC COMPOUNDS IN GROUNDWATER FROM THE 2000 SERIES WELLS[a,d]
(Data reported in mg/L)

Organic Compounds	Well / Sampling Quarter	2021 2/88	2022 2/88	2027 3/89	2034 2/88	2042 2/88	2051 3/89	2052 3/88	2053 2/89	2054 1/89	2060 3/86	2060 4/86	2060 2/87	2060 1/90	2061 2/87	2061 2/87c	2065 2/88	2066 3/89	2094 3/88	2094 4/88	2095 2/90	2106 1/90	2109 1/89	2307 2/88	2307 3/89
Volatiles																									
Acetone[e]						7 J	3 J	4 J					34.2			40.5	6 J								
Benzene																			160					1 J	
Butanol																									
2-Butanone									2 J																
Carbon disulfide				10																					11
Cyclohexane															42	12.5									
Chloroform																									
1,1-Dichloroethane																									
Ethylbenzene					2 J														1 J						
2-Hexanone																					1 J				
Methylene chloride						9																			
2-Propanol																									
Toluene																		4 J							
Total xylenes					3 J													7	189						
Tetrachloroethene																									
1,1,1-Trichloroethane											2	8.7		6		87					1 J	10			
Trichloroethane																						2 J			
Semivolatiles																									
Butyl benzyl phthalate						1 J																			
Diethyl phthalate			1 J											20											
Di-n-butyl phthalate										4 J										10					
Isophorone																									
3-Nitroaniline																									
4-Nitrophenol			3 J																						
N-nitrosodiphenylamine				3 J																					
Phenol																									
bis(2-Ethylhexyl)phthalate				3 J																				7 J	4 J

[a]This table does not include compounds found in method blanks. Fourth quarter 1987, and second and third quarter 1989 results are from RCRA sampling program. Second quarter 1988 and first quarter 1989 results are from RI/FS sampling.
[b]Qualifier not included in data.
[c]Also known as 2-Propanone.
[d]Second quarter 1986 through second quarter 1987 results are from RCRA sampling program. Pre-Quality Assurance Project Plan analytical results; qualifiers are not included.

Qualifier: J-Compound detected; below the contract required quantitation limit. The value presented is an estimate.

Uranium concentration distributions based on Round 4 data are shown in Figures 2-11 through 2-13 for the three levels of the aquifer monitored. This data set was selected since the greatest number of wells were sampled during Round 4. The groundwater monitoring data show that a uranium plume emanates from the FMPC site and is moving toward the south in a narrow band east of Paddys Run.

As indicated in Figures 2-11 through 2-13, the highest uranium concentrations are located in the upper layer of the aquifer (2000-series wells), with a substantial reduction in concentrations with depth (3000- and 4000-series wells). The highest uranium concentration recorded for a 3000-series well outside the FMPC boundary is 62 µg/L for Well 3062, an industrial water supply well pumping from near the middle of the aquifer (Figure 2-12). The 4000-series wells have had uranium concentrations consistently less than 1 µg/L. Wells 2060, 2061, and 3062 are located south of the FMPC (Figure 2-10). They are being used as RI/FS monitoring wells even though they were not installed and are not owned by DOE. The purpose of incorporating them into the RI/FS well network is that they have been sampled by DOE for many years and provide a substantial data base for uranium concentrations within the regional aquifer.

Elevated levels of uranium were first reported for these wells in mid-1981 (Figures 2-14 through 2-16). Uranium concentrations for Well 2060 have generally been between 200 and 300 µg/L, with values periodically fluctuating above and below this range. Uranium concentrations for Well 2061 dropped from values above 400 µg/L during the early monitoring period to current values generally between 200 and 350 µg/L. Uranium concentrations for Well 3062 have historically ranged between 40 and 80 µg/L. It is not expected that the uranium concentration levels observed in samples from Well 3062 are representative of the aquifer at this depth. Well 3062 is a pumping well used for industrial water supply purposes. The well is screened near the middle of the aquifer. It is likely that water containing higher levels of uranium is being pulled downward from the upper zone of the aquifer and then diluted by water of varying uranium concentrations being drawn radially into the well from other directions.

2.4 SITE CONDITIONS THAT JUSTIFY A REMOVAL ACTION

The threats posed by the migration of uranium in the south plume are not of a time-critical nature, i.e., no imminent or substantial endangerment of the public or the environment related to contaminants currently exists that would necessitate initiation of a response action within six months. However, the

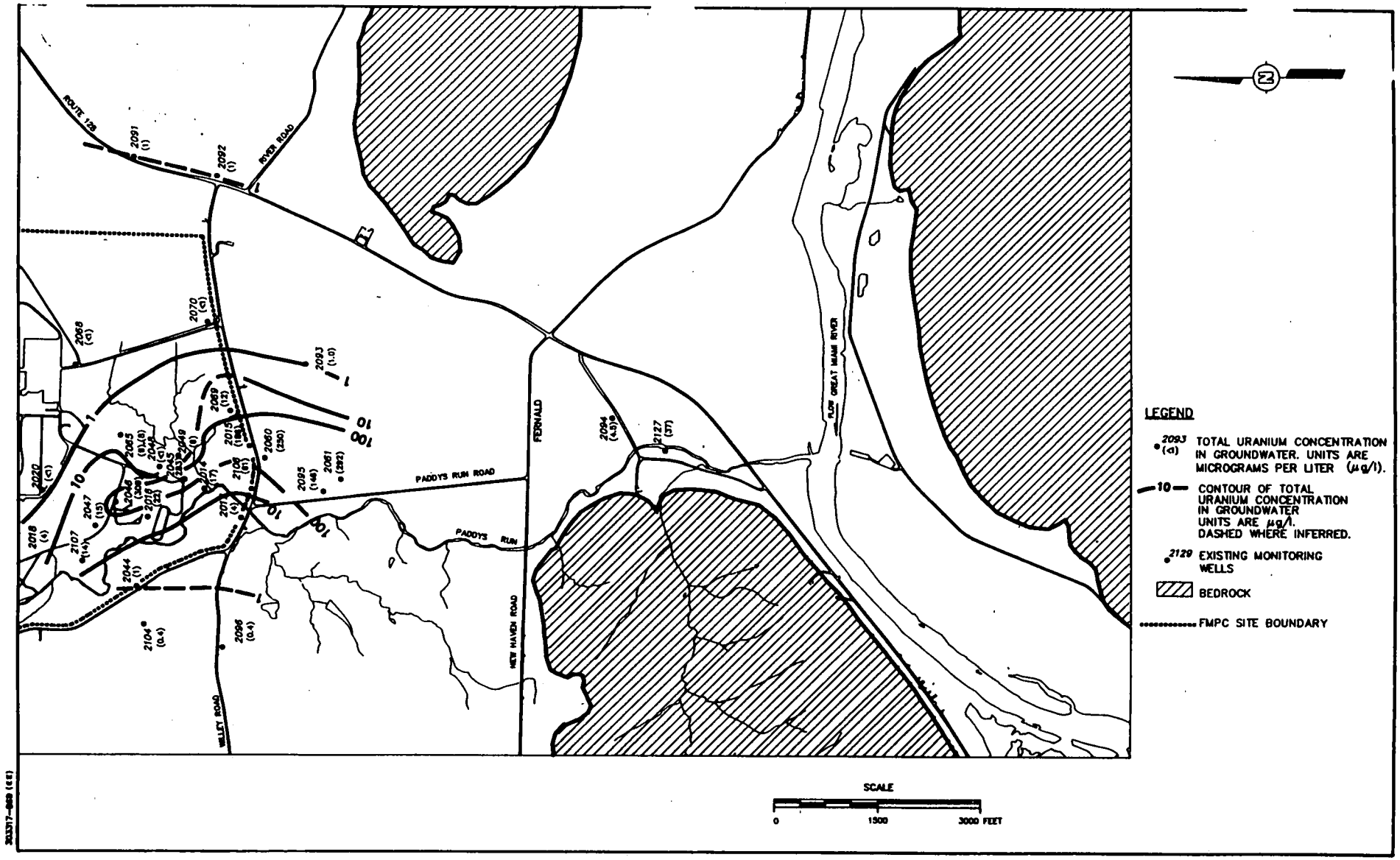


FIGURE 2-11
ROUND 4 – FIRST QUARTER 1989
URANIUM CONCENTRATION IN GROUNDWATER
2000 SERIES WELLS

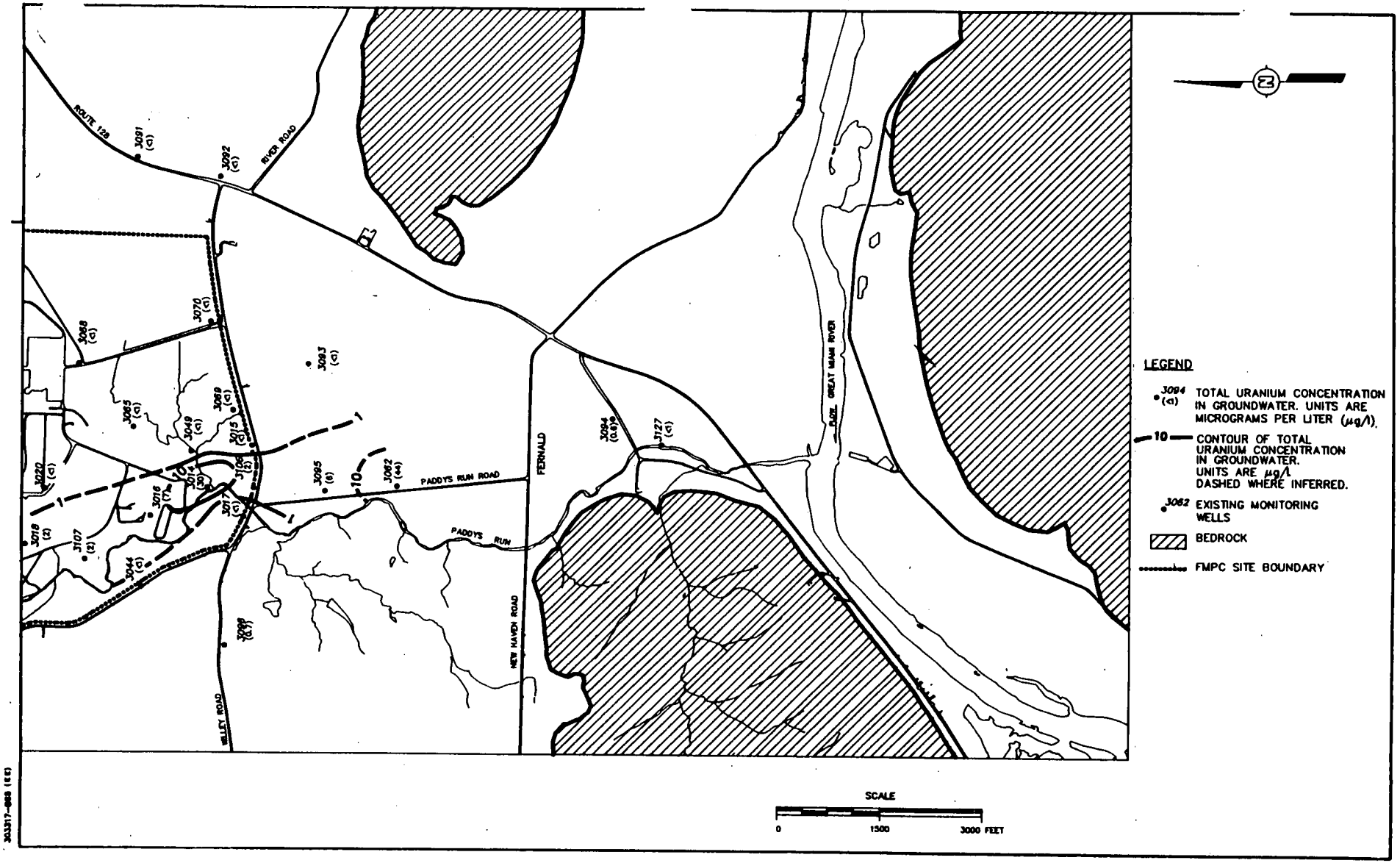


FIGURE 2-12
ROUND 4 – FIRST QUARTER 1989
URANIUM CONCENTRATION IN GROUNDWATER
3000 SERIES WELLS

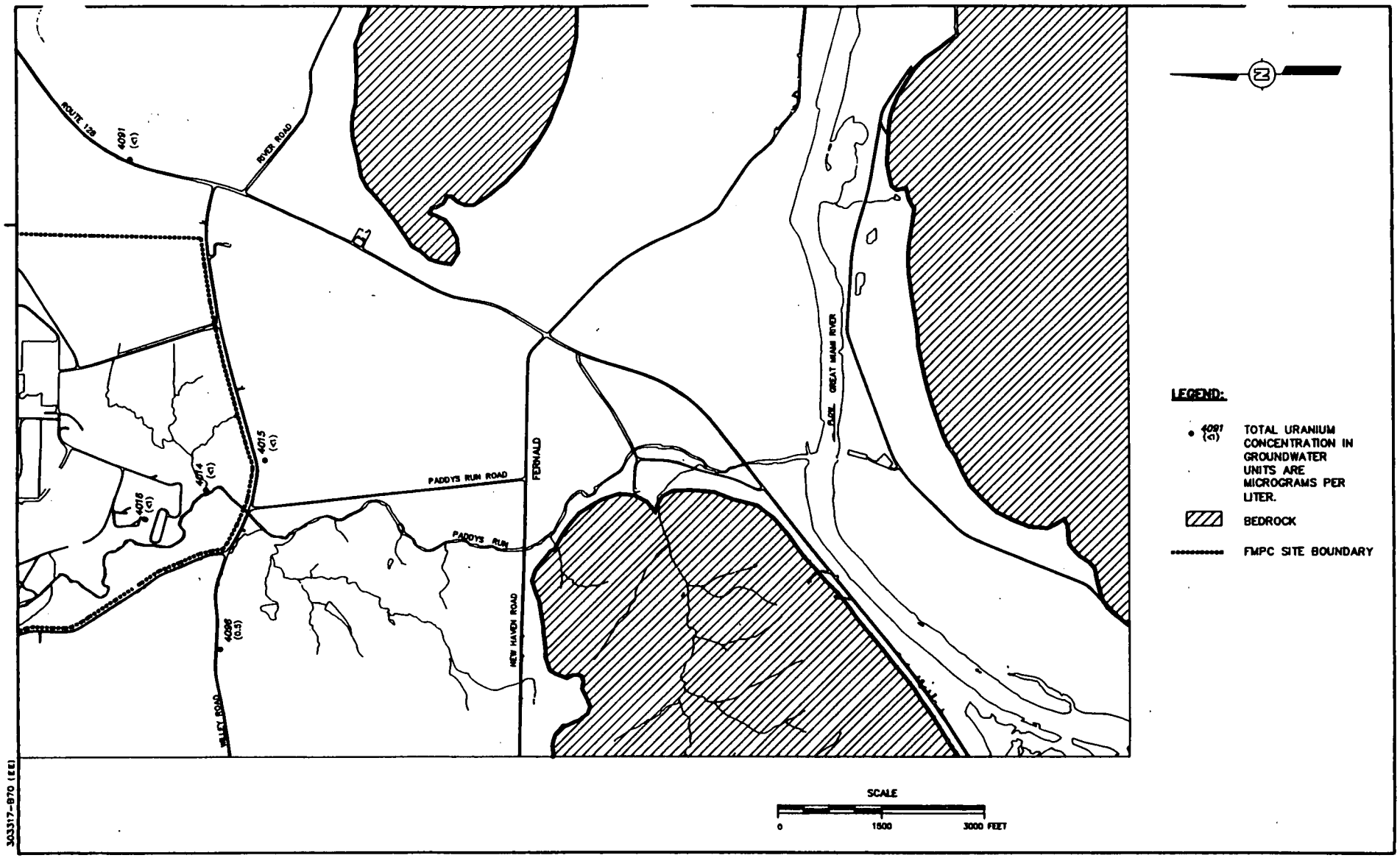
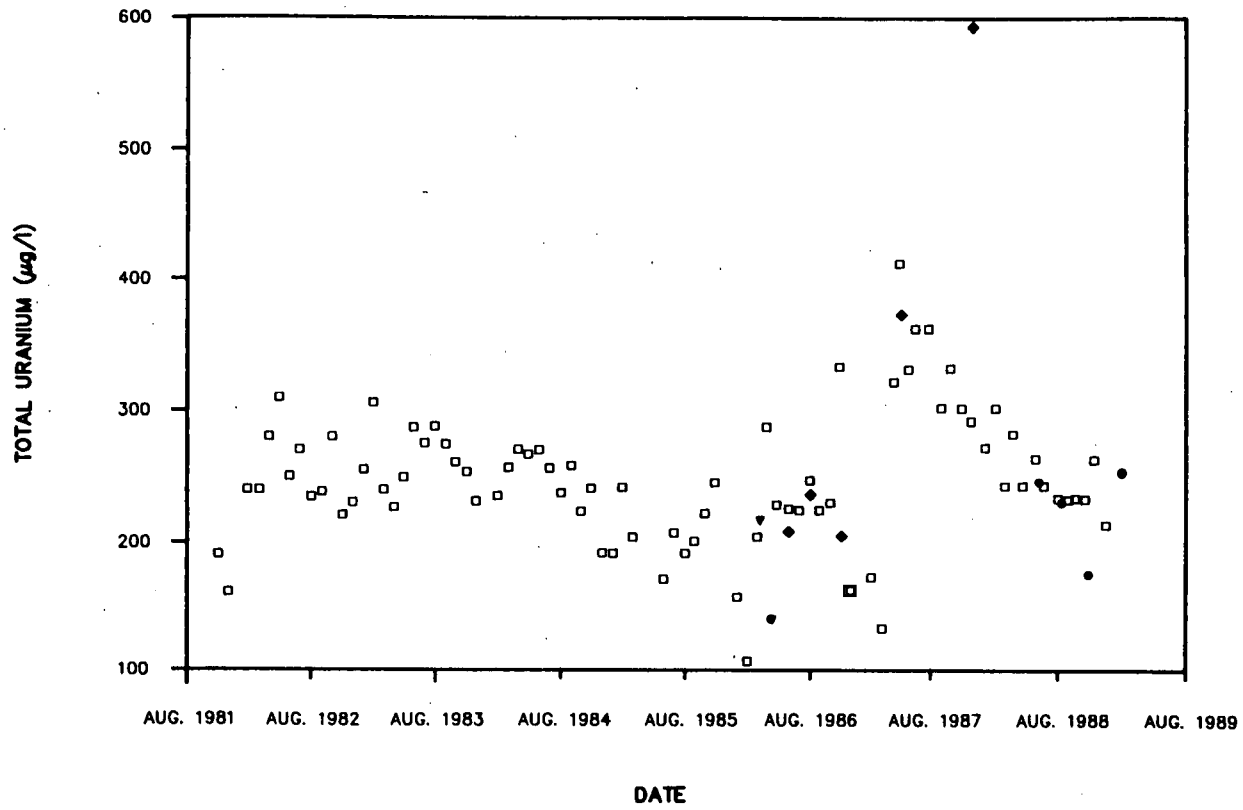


FIGURE 2-13
ROUND 4 – FIRST QUARTER 1989
URANIUM CONCENTRATION IN GROUNDWATER
4000 SERIES WELLS

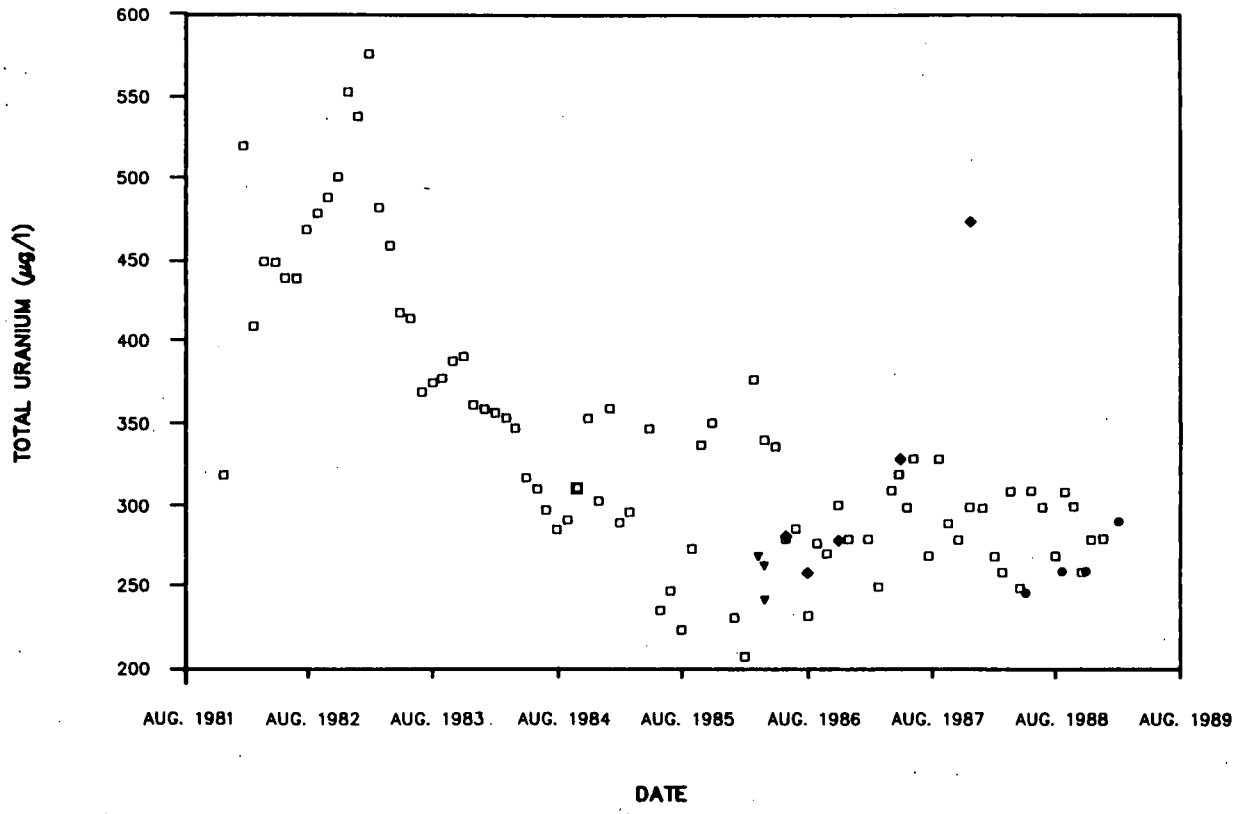


LEGEND:

- ▫ NATIONAL LEAD OF OHIO INC./ WESTINGHOUSE MATERIALS COMPANY OF OHIO, UNPUBLISHED ENVIRONMENTAL MONITORING DATA, NOVEMBER 1981–DECEMBER 1988.
- ▼ IT CORPORATION; "ADDENDUM TO FINAL INTERIM REPORT; AIR, SOIL, WATER, AND HEALTH RISK ASSESSMENT IN THE VICINITY OF THE FMPC; FERNALD OHIO;" MARCH 1986–APRIL 1986. CONVERTED FROM pCi/l TO (µg/l) USING 1pCi=1.4925 µg.
- ◆ DAMES AND MOORE, VOL. 2–5; ADVANCED SCIENCES CORPORATION AND IT CORPORATION, VOL 6; RCRA GROUND WATER MONITORING REPORT; JUNE 1986–NOVEMBER 1987. VOL. 6 DATA CONVERTED FROM pCi/l TO µg/l USING 1pCi=1.4925 µg.
- ● ADVANCED SCIENCES CORPORATION AND IT CORPORATION, REMEDIAL INVESTIGATION AND FEASIBILITY STUDY SAMPLING, MAY 1988–FEBRUARY 1989.

303317-0161(EE)

FIGURE 2–14
TEMPORAL TOTAL URANIUM VARIATION
IN GROUNDWATER
WELL 2060



LEGEND:

- ◻ NATIONAL LEAD OF OHIO INC./ WESTINGHOUSE MATERIALS COMPANY OF OHIO, UNPUBLISHED ENVIRONMENTAL MONITORING DATA, NOVEMBER 1981–DECEMBER 1988.
- ▼ IT CORPORATION; "ADDENDUM TO FINAL INTERIM REPORT; AIR, SOIL, WATER, AND HEALTH RISK ASSESSMENT IN THE VICINITY OF THE FMPC; FERNALD OHIO;" MARCH 1986–APRIL 1986. CONVERTED FROM pCi/l TO (µg/l) USING 1pCi=1.4925 µg.
- ◆ DAMES AND MOORE, VOL. 2–5; ADVANCED SCIENCES CORPORATION AND IT CORPORATION, VOL 6; RCRA GROUND WATER MONITORING REPORT; JUNE 1986–NOVEMBER 1987. VOL. 6 DATA CONVERTED FROM pCi/l TO µg/l USING 1pCi=1.4925 µg.
- ● ADVANCED SCIENCES CORPORATION AND IT CORPORATION, REMEDIAL INVESTIGATION AND FEASIBILITY STUDY SAMPLING, MAY 1988–FEBRUARY 1989.

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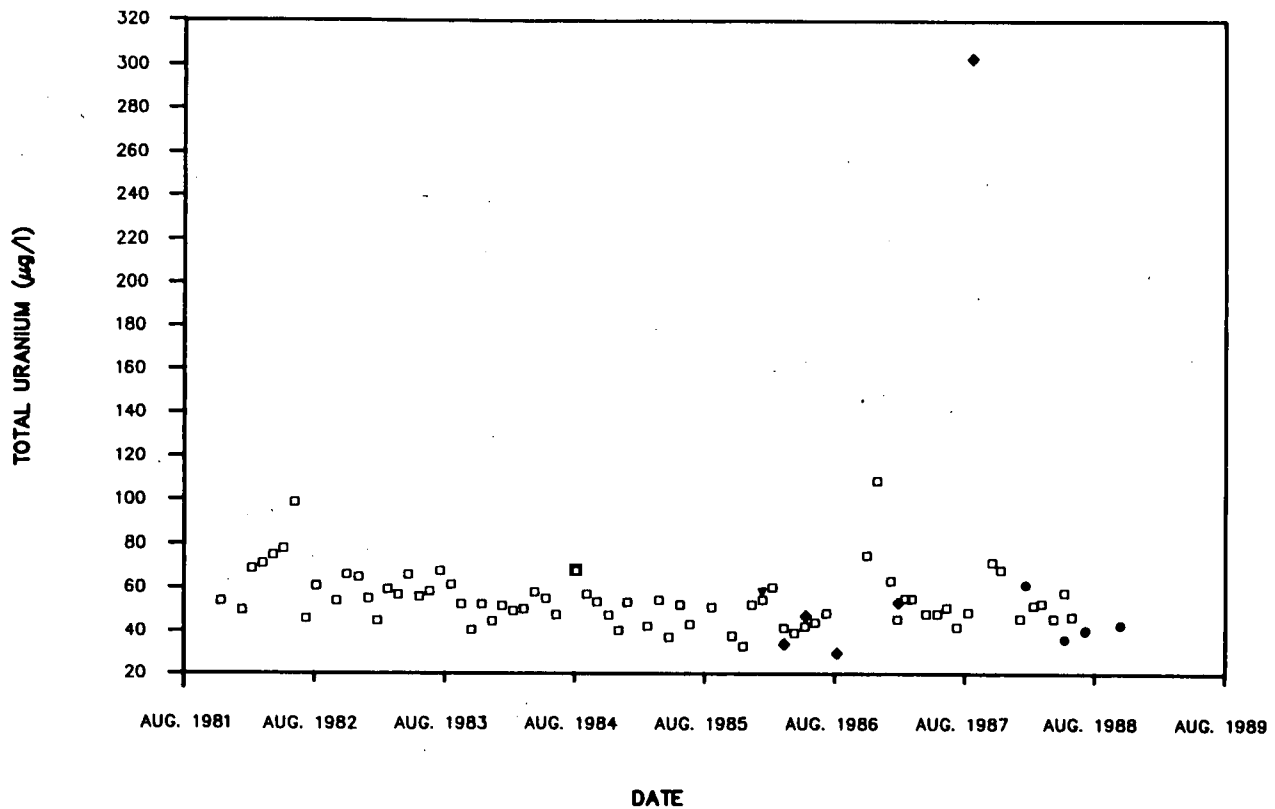
FIGURE 2-15
TEMPORAL TOTAL URANIUM VARIATION
IN GROUNDWATER
WELL 2061



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- ◻ NATIONAL LEAD OF OHIO INC./ WESTINGHOUSE MATERIALS COMPANY OF OHIO, UNPUBLISHED ENVIRONMENTAL MONITORING DATA, NOVEMBER 1981–DECEMBER 1988.
- ▼ IT CORPORATION; "ADDENDUM TO FINAL INTERIM REPORT; AIR, SOIL, WATER, AND HEALTH RISK ASSESSMENT IN THE VICINITY OF THE FMPC; FERNALD OHIO;" MARCH 1986–APRIL 1986. CONVERTED FROM pCi/l TO (µg/l) USING 1pCi=1.4925 µg.
- ◆ DAMES AND MOORE, VOL. 2–5; ADVANCED SCIENCES CORPORATION AND IT CORPORATION, VOL 6; RCRA GROUND WATER MONITORING REPORT; JUNE 1986–NOVEMBER 1987. VOL. 6 DATA CONVERTED FROM pCi/l TO µg/l USING 1pCi=1.4925 µg.
- ● ADVANCED SCIENCES CORPORATION AND IT CORPORATION, REMEDIAL INVESTIGATION AND FEASIBILITY STUDY SAMPLING, MAY 1988–FEBRUARY 1989.

303317-8180(EE)

FIGURE 2–16
TEMPORAL TOTAL URANIUM VARIATION
IN GROUNDWATER
WELL 3062

site conditions do meet certain criteria listed in the NCP for categorization of specific cleanup efforts as removal actions. The eight factors to be considered in determining the appropriateness of a removal action, as listed in Section 300.415 of the March 1990 version of the NCP, are:

1. Actual or potential exposure to hazardous substances or pollutants or contaminants of nearby populations, animals, or food chains

2. Actual or potential contamination of drinking water supplies or sensitive ecosystems

3. Hazardous substances, pollutants or contaminants--in drums, barrels, tanks, or other bulk storage containers--that may pose a threat of release

4. High levels of hazardous substances or pollutants or contaminants in soils, largely at or near the surface, that may migrate

5. Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released

6. Threat of fire or explosion

7. Availability of other appropriate federal or state mechanisms to respond to a release

8. Other situations or factors that may pose threats to public health or welfare and the environment

Of the eight factors to be considered, the potential contamination of drinking water supplies and the associated potential for exposure reflected in the first two factors are relevant to the south plume removal action.

Maximum contaminant levels (MCL) for various chemicals and radionuclides are established in 40CFR141 for public drinking supplies. No MCL for uranium in drinking water supplies currently exists, nor has an MCL been proposed by EPA. For the purposes of this removal action, DOE has selected 30 µg/L for use in decision-making. This concentration value is calculated from the 50-year committed effective dose equivalent (CEDE) of 4 millirem (mrem) from an annual intake of radioactive materials in drinking water. The 4 mrem value is used in establishing MCLs for other radionuclides. Groundwater containing uranium at concentration levels exceeding the derived concentration of 30 µg/L for uranium in drinking water is present at locations south of the FMPC boundary.

Potential groundwater users are located in and adjacent to the study area (Figure 2-17). Only two of these groundwater users currently remove groundwater at locations known to contain elevated levels of uranium exceeding the 30 µg/L value; the use of this water is limited to industrial/commercial purposes. The impacted aquifer is within the buried valley aquifer of the Great Miami River Basin, which has been designated as a sole-source aquifer by EPA under Section 1424(e) of the Safe Drinking Water Act (Federal Register, Vol. 53, No. 131, Friday, July 8, 1988). Under this designation, the EPA Administrator of Region V has determined that this aquifer is the sole or principal source of drinking water for this area and that if contaminated would create a significant hazard to public health.

2.4.1 Release Mechanisms

If left unattended, the plume of elevated uranium concentrations in groundwater south of the FMPC would be expected to continue to migrate south-southeast along the regional groundwater flow path in the buried channel aquifer. This projected path would carry the plume beneath New Haven Road near State Highway 128 and eventually to the Great Miami River just upstream from the confluence of Paddys Run with the river. Groundwater flow velocities along this path are estimated to be about 1300 feet per year. The migration rate of the plume would be less than the estimated groundwater flow velocities as a result of the retardation effects caused by the physicochemical interchange of the dissolved uranium with the solid matrix through which it is flowing. Results of the groundwater flow/solute transport model indicate a calculated plume movement of approximately 220 feet per year.

Current data indicate that two distinct areas of elevated uranium concentrations exist in the groundwater within the southerly flow regime beneath the FMPC and adjacent areas. The primary focus of the south plume removal action is a plume that is centered outside the FMPC boundary to the northeast of the industrial/commercial facilities along Paddys Run Road. A second plume exists within the boundary of the FMPC in the vicinity of the Southfield and the fly ash piles. Considerably lower levels of uranium have been measured in wells between these two areas during several of the sampling rounds.

Based on the current understanding of plant operations and records, site hydrology, and results of the groundwater modeling study, the principal source of the plume south of the FMPC boundary has been determined to be historical releases of uranium-enriched water from Paddys Run and the storm sewer

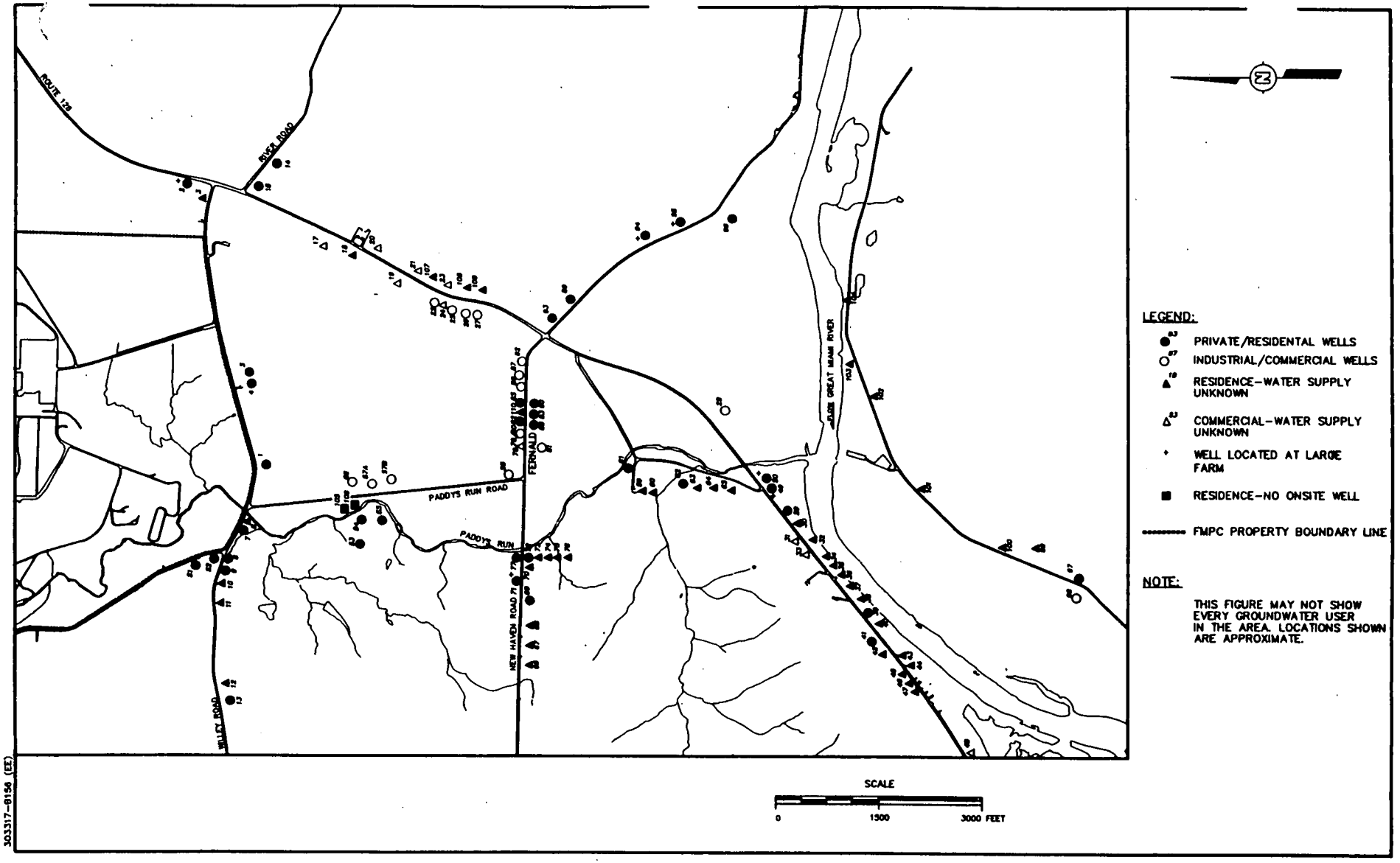

FIGURE 2-17
POTENTIAL AND KNOWN
GROUNDWATER USERS
SOUTH OF THE FMPC

outfall ditch. Because the bottom sediments of these water courses are highly permeable in the reaches north and west of the south plume, the uranium-enriched water directly entered the regional aquifer. This recharge water became part of the groundwater flow which was moving toward the south plume area (Figures 2-1 and 2-9). The uranium in Paddys Run is the result of storm water runoff from the waste storage area and contaminated areas south of the waste storage area (e.g., Fly Ash/Southfield). The majority of the uranium in the storm sewer outfall ditch is the result of releases of contaminated storm water from the production area prior to construction of the storm water retention basin. Infiltration along Paddys Run also continues, but the associated uranium levels are greatly reduced. Another possible explanation for the two concentration distributions is that the current recharge of water containing much lower levels of uranium along the storm sewer outfall ditch dilutes the more recent, southerly migrating groundwater plume. Additional field studies of this area are planned under the RI/FS to accurately define the source(s) and concentrations of uranium. Any remedial actions deemed necessary to prevent a continuing problem due to releases across the FMPC site boundary will be addressed under the RI/FS for the environmental media operable unit. The elimination or reduction of the ultimate sources of the releases is the focus of the other operable units concerned with the various waste areas.

The RI/FS study area for the environmental media (Operable Unit 5) has been defined to include both the areas of the Great Miami Aquifer within and outside the boundaries of the FMPC. This definition is consistent with the requirement that long-term migration potential and remediation goals be considered in the RI/FS. Only the existing plume outside the FMPC boundary is being considered for the south plume removal action. The reasons are the apparent historic nature of the plume area, the current conclusion that no continuing source contributes significantly to further groundwater contamination in the south plume, and the anticipated accelerated movement of the existing plume as it passes through the narrow buried channel south of the FMPC.

2.4.2 Environmental Fate

While uranium is radioactive and will decay to become other radioisotopes and ultimately stable lead, the half-lives of uranium-238, -235, and -234 are 4.9×10^9, 7.04×10^8, and 2.47×10^5 years, respectively. Relative to these half-lives, and since the uranium has been present at and near the site for a very short time, the uranium isotopes will remain in their present form with little decay over an extended period of time.

As described in the previous section, the south plume is expected to continue to migrate southward and will eventually be released into the Great Miami River. Upon release to the river, the uranium concentrations would be significantly less than at the current observation points due to the dispersion and dilution of the plume along its migration path. Additionally, substantial dilution of the groundwater will occur as it discharges to the river and mixes with surface water. Unless contaminated groundwater is removed via pumping, no other environmental exposure is expected due to the depth of the plume.

Imposed pumping stresses can highly influence groundwater migration pathways, as evidenced by the effects of the SOWC wells on groundwater behavior beneath the FMPC. No pumping of this magnitude currently exists in the south plume area and none is projected unless as part of a removal or final remedial action. The effects of the existing industrial wells have been accounted for in the interpretation of field data and the evaluation of removal action alternatives.

2.4.3 Potential Risks

Public health risk requires the presence of contaminants that pose either a radiological or chemical hazard, pathways for potential exposure, and human and environmental receptors subject to exposure. Each of these components is summarized in the following sections for the plume of uranium in groundwater south of the FMPC boundary.

2.4.3.1 Contaminants of Concern

Groundwater data collected to date from the sand and gravel aquifer indicates the presence of radionuclides and inorganic metals in the south plume. Most of the radionuclides are found at natural background concentrations. None of the radionuclides or metals exceed established or derived drinking water limits with the exception of uranium. Certain organic chemicals have also been observed in some samples, but these observations have not been persistent for the same monitoring wells and are below regulatory allowable maximum concentration levels for organics detected. For this reason, uranium has been designated as the contaminant of concern for the south plume removal action.

Uranium is a potential radiocarcinogen and a chemical toxin. Insoluble uranium compounds primarily pose a radiological hazard resulting from inhalation. Soluble uranium compounds pose both chemical

and radiological hazards from ingestion. If ingested at sufficiently high rates, these compounds can lead to kidney damage and arterial lesions. Other potential adverse health effects that can result from ingestion of soluble uranium compounds are damage to the cardiovascular, hematopoietic, endocrine, and immunological systems.

For purposes of the South Plume EE/CA, the extent and distribution of uranium in the south plume have been established by combining groundwater monitoring data with the results of a groundwater flow/solute transport model (Appendix A). The monitoring data were utilized to establish the following: (1) a lower limit on the maximum concentration in the south plume; (2) a conservative estimate of the shape and extent of the plume (as defined by those wells closest to the plume that exhibit background levels of uranium); (3) direct evidence of the uranium levels at actual receptor locations; and (4) the general shape of the uranium plume for use in calibrating the model.

The model was then used to interpolate between and extrapolate beyond the points of field observation. By doing so, the full distribution pattern of uranium in the south plume both today and under assumed future conditions could be estimated. Figure A-3 presents the estimated current distribution of uranium in the upper aquifer (2000-series wells) as developed from model results. These results could vary depending on the actual parameter values assumed in the model. The plume is shown as an elongated ellipse oriented in a northwest/southeast direction due to the groundwater flow patterns through a narrow, north/south trending buried channel. The center of the plume is predicted to lie approximately 800 feet south of Willey Road and north of the developed areas along Paddys Run and New Haven Road. The maximum concentration predicted with the model is approximately 600 µg/L and exceeds the maximum value observed outside the FMPC boundary during the current RI/FS sampling by a factor of approximately two.

Based on this representation of the plume, approximately 100 acres of property outside the FMPC boundary is underlain by groundwater exceeding the derived concentration of 30 µg/L for uranium in drinking water. This value is based on the 50-year CEDE limit of 4 mrem from an annual intake of radioactive materials in drinking water and corresponds to an excess cancer risk of 0.5 to 2 cancers per year per one million people who drink this water at a rate of 730 liters per year. (The basis for this value is discussed further in Section 5.1.1.) DOE has specified that this CEDE limit shall apply to releases to areas where water could be used as a drinking water source (DOE Order 5400.5).

2.4.3.2 Exposure Pathways

In the case of the south plume, exposure to the contaminants can occur only if the groundwater reaches the ground surface. The primary mechanisms are groundwater discharge to a surface water course and pumping.

Modeling results of the migration path of the south plume indicate that the plume will not experience large lateral migration as it approaches the Great Miami River. Rather, it will narrow slightly as it passes through the Fernald trough and then widen again just prior to entering the river (Figure 2-18). Based on current model calibrations, it is projected that no uranium will enter the Great Miami River within the five-year projected life of the removal option. At the end of this period, the 30 µg/L uranium front will have moved approximately 1200 feet closer to the river and will still have approximately 3000 feet to go before entering the Great Miami River (Appendix A). Loadings will occur to the river before the 30 µg/L front reaches it, but these loadings will come from very low-concentration groundwater and will also not reach the river until after the projected life of the removal action and thus are not a concern for this study. Because the model predicts that the south plume will not migrate to the Great Miami River or any other surface water course within the projected life of the removal action (e.g., 5 years until the RI/FS action), groundwater discharge to surface waters is not considered as an exposure pathway for nonpumping alternatives discussed in this EE/CA. This exposure pathway is, however, considered in the evaluation of the effectiveness of the removal action alternative involving pumping of the groundwater for discharge to the Great Miami River.

Pumping occurs and will continue to occur in the south plume area. The principal potential exposure pathways associated with pumping include direct ingestion of groundwater used as drinking water, ingestion of plants after use of the groundwater for irrigation, and ingestion of meat or milk from livestock exposed to the groundwater through direct intake or from irrigated crops. Other minor potential exposure pathways exist but do not represent a significant risk to the receptors.

2.4.3.3 Potential Receptors

There is no known use of groundwater with uranium levels exceeding the derived concentration limit of 30 µg/L from the south plume area for drinking water, feedstock watering, or crop irrigation. Residences along Paddys Run Road to the west reportedly use cisterns with imported water. Groundwater monitoring results from commercial and residential wells along New Haven Road in or

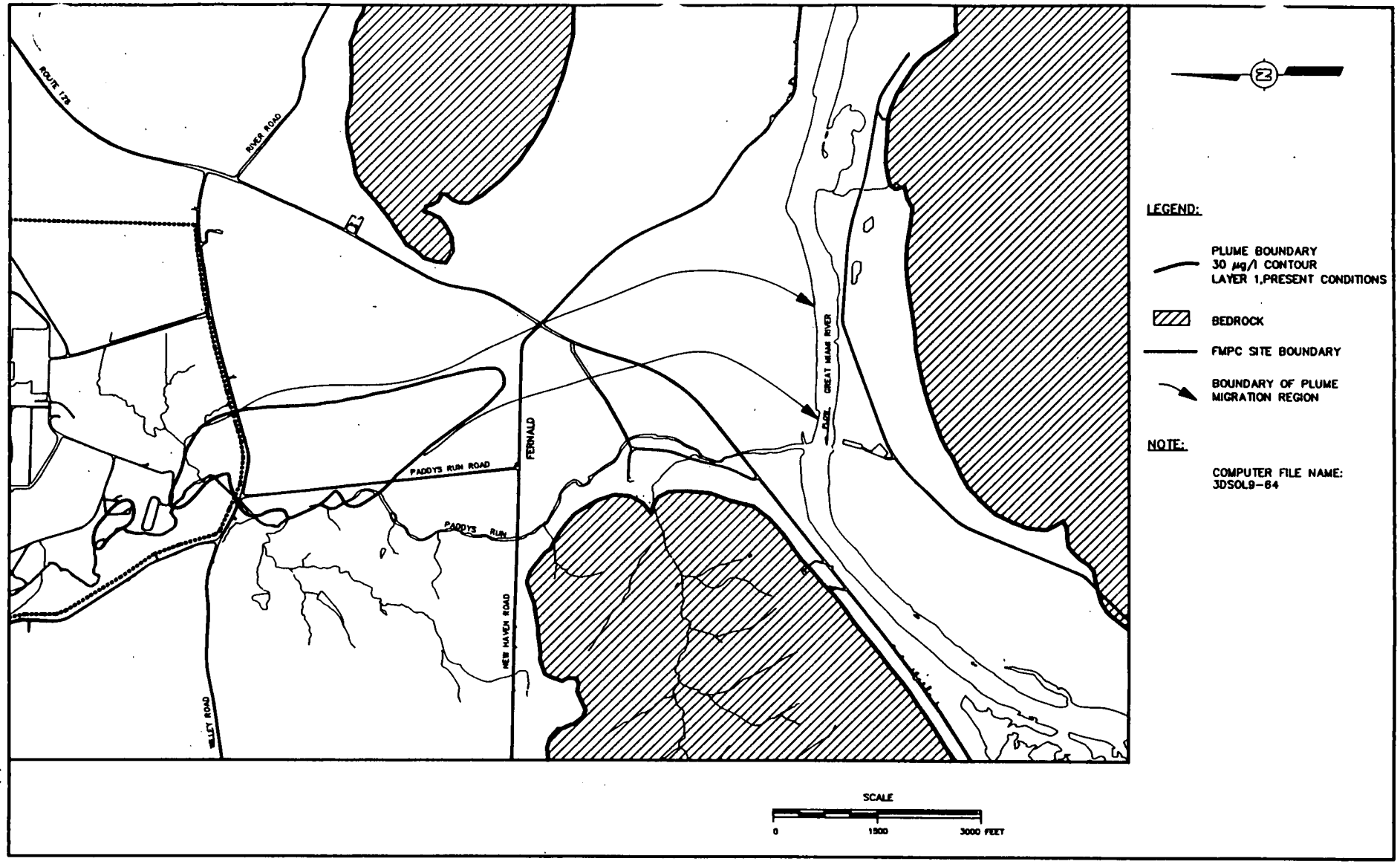

FIGURE 2-18
PREDICTED REGION OF URANIUM
DISCHARGE TO GREAT MIAMI RIVER

near the Village of Fernald indicate no elevated levels of uranium in the water supply. These results indicate that the uranium plume either is not present at the level of aquifer pumping or has not yet migrated to these locations.

The only known users of groundwater with uranium levels exceeding the derived concentration for uranium in drinking water are the industries located along Paddys Run Road southwest of the projected center of the plume. One of the two industries treats the water to remove uranium, other radionuclides and chemicals prior to its use. Untreated water at the two industries is not used for drinking water supplies or for other purposes which represent a significant risk to users. Potential future receptors of the uranium in groundwater south of the FMPC include the following:

- Persons who pump groundwater for potable use, crop irrigation, or livestock feeding from areas not currently impacted but located along the future migration pathway of the plume
- Persons who would use surface waters into which contaminated groundwater has been discharged following pumping
- Persons who would install a new well for potable use, crop irrigation, or livestock feeding from an area within the plume

Locations of known and potential groundwater users south of the FMPC are shown in Figure 2-17.

3.0 REMOVAL ACTION OBJECTIVES

Before determining appropriate removal actions for evaluation within the South Plume EE/CA, the identification of removal action objectives was conducted. The development of these objectives was a critical step in the development of this EE/CA, as the objectives determine the scope, the level of detail and the selection of the mitigative approach, i.e., what is to be accomplished by the removal action. Establishing the objective as the cleanup of the total site was considered inappropriate due to the complex nature of the site and in recognition of the ongoing RI/FS being conducted for this purpose. Therefore, this removal action is focused on a specifically identified area and problem within the overall site, the contaminated groundwater south of the FMPC site boundary. In addressing this area and in adhering to the intent of a removal action to abate, prevent, minimize, stabilize, mitigate, or eliminate the release or the threat of release, the principal objective of reducing or mitigating the potential threat to the public or the environment from elevated uranium concentrations in groundwater was established. This and other objectives are further defined in Sections 3.1 through 3.3 in terms of response authority, scope and purpose, and compliance with applicable or relevant and appropriate requirements (ARARs) and other criteria or guidelines to be considered (TBCs).

3.1 RESPONSE AUTHORITY

Authority for responding to releases or threats of releases from a hazardous waste site is addressed in Sections 104 and 106 of CERCLA. Executive Order 12580 delegates Section 104 response authority to the Secretary of Energy for DOE sites. EPA maintains response authority if an action is carried out in response to Section 106 of CERCLA. The 1990 Consent Agreement specifies the scope and schedule for this removal action. CERCLA removal authorities are contained in 40CFR300.415.

3.2 SCOPE AND PURPOSE

The scope of the proposed removal action can be broadly defined as management of radioactively contaminated groundwater in an area south of the FMPC boundary. As discussed in Section 2.4.3.1, the only contaminant of concern for the south plume removal action is uranium. Although the nature and extent of the south plume are not precisely known at this stage, bounds have been determined to the south, east, and west based on the current understanding of local geology and hydrology, groundwater monitoring data, and groundwater modeling results. A reduced, yet continuing source of uranium appears to exist from areas to the north within the FMPC property boundary. Although not a

focal point of the removal action, this continuing source will be considered in the evaluation of removal action alternatives.

The fundamental objective of the removal action for the south plume is to protect public health by limiting access to and use of groundwater with uranium concentrations exceeding the derived concentration limit of 30 µg/L for uranium in drinking water, as well as other appropriate risk-based levels for various potential exposure scenarios. For purposes of this removal action, this objective represents a minimum requirement that would have to be achieved by any removal action. Additionally, secondary objectives have been formulated for the south plume removal action which include the following:

- Protection of the groundwater environment, which in this case is represented by a sensitive, sole source aquifer
- Control of plume migration to additional receptors further south

As will be discussed in Section 5.0, the removal action alternatives being considered for the south plume will satisfy these secondary objectives to varying degrees. There is no one alternative that will fully satisfy all of these objectives. Therefore, the final selection of the preferred removal action will balance the effectiveness of each alternative in satisfying the secondary objectives against any additional cost and time required for implementation. Potential adverse impacts of each alternative will also be considered. This selection strategy is being executed so as not to hinder or foreclose viable options for a long-term remedial action for the regional aquifer that will fully satisfy all applicable or relevant and appropriate requirements established for that important environmental unit.

3.3 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND OTHER CRITERIA TO BE CONSIDERED

CERCLA requires that remedial actions obtain a level or standard of control which is applicable or relevant and appropriate to any hazardous substances, pollutants, or contaminants that will remain on site. Although Section 121 does not require that removal actions attain all ARARs and TBCs, EPA policy on removal actions is that ARARs and TBCs will be identified and attained to the extent practicable.

Three classifications of ARARs and TBCs are considered. These include: (1) contaminant specific ARARs and TBCs, (2) location specific ARARs and TBCs, and (3) action specific ARARs and TBCs. Contaminant-specific ARARs and TBCs address the acceptable amount or concentration of a specific pollutant that may be found in or discharged to soil, water, and air. Location-specific ARARs and TBCs are based on the specific setting and nature of the site, and action-specific ARARs and TBCs relate to technology- or activity-based requirements or limitations on the specific response actions taken with respect to the types of waste.

The identification of potential ARARs and TBCs for the south plume removal action will be based on the nature of the contamination (radioactively contaminated groundwater), the location of the site (within a populated groundwater-usage area and within 1.5 miles of the Great Miami River), and the general scope of the identified removal action alternatives. A summary of these ARARs and TBCs and a discussion as they pertain to the proposed alternatives are included in Chapter 5.0.

4.0 REMOVAL ACTION ALTERNATIVES

4.1 DEVELOPMENT OF INITIAL ALTERNATIVES

The ongoing Feasibility Study for the environmental media operable unit has already proceeded through the development and preliminary screening of alternatives, in accordance with the EPA's current CERCLA guidance (EPA 1989). Based on the preliminary results of the development and screening of specific remedial action alternatives in the RI/FS for contaminated groundwater, and considering the identified removal action objectives, the following removal action alternatives have been selected for evaluation in the South Plume EE/CA:

- No Action
- Groundwater Monitoring and Institutional Controls
- Alternate Water Supply with Groundwater Monitoring and Institutional Controls (subsequently referred to as Alternate Water Supply)
- Groundwater Pumping and Discharge, Equivalent Uranium Removal From Existing FMPC Wastewater Discharges, Alternate Water Supply and Groundwater Monitoring and Institutional Controls (subsequently referred to as Pump and Treat)

Since the groundwater treatment alternatives are being evaluated within the FS for the environmental media operable unit, they were also considered within the initial stages of development of the alternatives for this removal action. However, because of the following factors these alternatives have not been included in the EE/CA. Currently, no facility exists at the FMPC that is capable of processing the projected volumes of groundwater required for cleanup of the south plume. A preliminary estimate of the schedule required for design, construction, and implementation of a treatment facility for this purpose is approximately three years. This would not allow for a timely response under the removal action process. Additionally, treatment is being evaluated for other areas of the site under the FS. The coordination of the final solution for water treatment from the site is best coordinated within the FS process to insure the most effective and efficient system. It is the intent that removal actions, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release concerned, as stated in the NCP.

4.2 DESCRIPTION OF REMOVAL ACTION ALTERNATIVES

A description of each proposed removal action is provided in the following sections.

4.2.1 Alternative 1 - No Action

Routine monitoring and security activities will continue to occur at the FMPC in accordance with DOE and WMCO operational requirements. Under the no-action alternative, no additional remediation, monitoring, or security activities would be provided in the vicinity of the south plume to further minimize risk to public health or the environment. Any changes to the existing site environment is assumed to develop only as a result of natural occurrences. This alternative is being considered as a baseline for comparison with the other alternatives.

4.2.2 Alternative 2 - Monitoring and Institutional Controls

This alternative consists of the continued or additional monitoring of selected existing wells in the south plume study area. At present, no residential wells containing concentrations of uranium in excess of the derived concentration limit of 30 µg/L for uranium in drinking water are being used. The monitoring program associated with this alternative will be designed to detect increases in uranium content which may indicate movement of the plume into or toward industrial, commercial, or residential wells. Quarterly monitoring for uranium will take place in the selected wells until a modified monitoring program is implemented as part of the final remedial action. If increasing uranium concentrations are detected in any wells during the monitoring program, the potential for exceeding the derived concentration limit for uranium in drinking water will be evaluated and, if necessary, an appropriate additional response action will be taken, which is not within the scope of this removal action.

DOE cannot exercise direct access control over the areas outside the FMPC boundary. Therefore, the institutional controls will be limited to the following: (1) regular communications with state and local officials responsible for well installation applications and approvals, (2) formal notification by the same officials to DOE of any well applications and approvals within the south plume area and, (3) monitoring of wells upon installation and quarterly thereafter as part of the aforementioned monitoring network.

4.2.3 Alternative 3 - Alternate Water Supply

This alternative consists of groundwater monitoring and institutional controls, and providing an alternate water supply to the two industrial receptors known to be using groundwater with uranium

concentrations exceeding 30 µg/L. The monitoring and institutional control program will be the same as that described for Alternative 2.

The alternate water supplies provided for each of the two industries will be drawn from areas of the aquifer that are not impacted by site contaminants. The new supplies will also convey a sufficient volume of water to meet the usage demand required for each industry. A conceptual layout of possible well locations and associated piping for this alternative is presented in Figure 4-1. This conceptualization is intended for preliminary and comparative costing purposes. Details of the alternate water supply alternative, if selected, will be presented in the work plan for implementation of the alternative.

Evaluation of the impact on groundwater quality and the south plume of a pumping well completed near the bottom of the aquifer was conducted utilizing a 3-dimensional flow model. A well with a capacity of 50 gpm was selected as a maximum pumping rate for the replacement well at the industry with a small usage demand. The flow model revealed that water entering the replacement well originates from upgradient areas in the lower half of the Great Miami aquifer. At no time does this water travel through or originate from the shallow zone of the aquifer which contains contaminated groundwater. Furthermore, the effects on the contaminated groundwater in the shallow zone are minor, as the 50 gpm pumping rate does not produce enough of a cone of depression to significantly influence the south plume. This analysis is considered a worst-case study, as 50 gpm is the maximum pumping rate for the replacement well, not the average rate.

Prior to selecting replacement wells for detailed evaluation in this alternative, other methods of providing alternate water supplies were examined and rejected. The options of supplying bottled drinking water or filling cisterns from either the Cleves Waterworks or the Cincinnati Waterworks were not applicable for the replacement of industrial water supplies.

An extension of the nearest public water supplies was also investigated. The largest supplier, Cincinnati Waterworks, is a possible future source of water to Crosby Township. Service for the area near Miamitown is scheduled to begin in two to five years and service for the New Baltimore area is tentatively scheduled for the next five to ten years. This schedule is inconsistent with the near-term

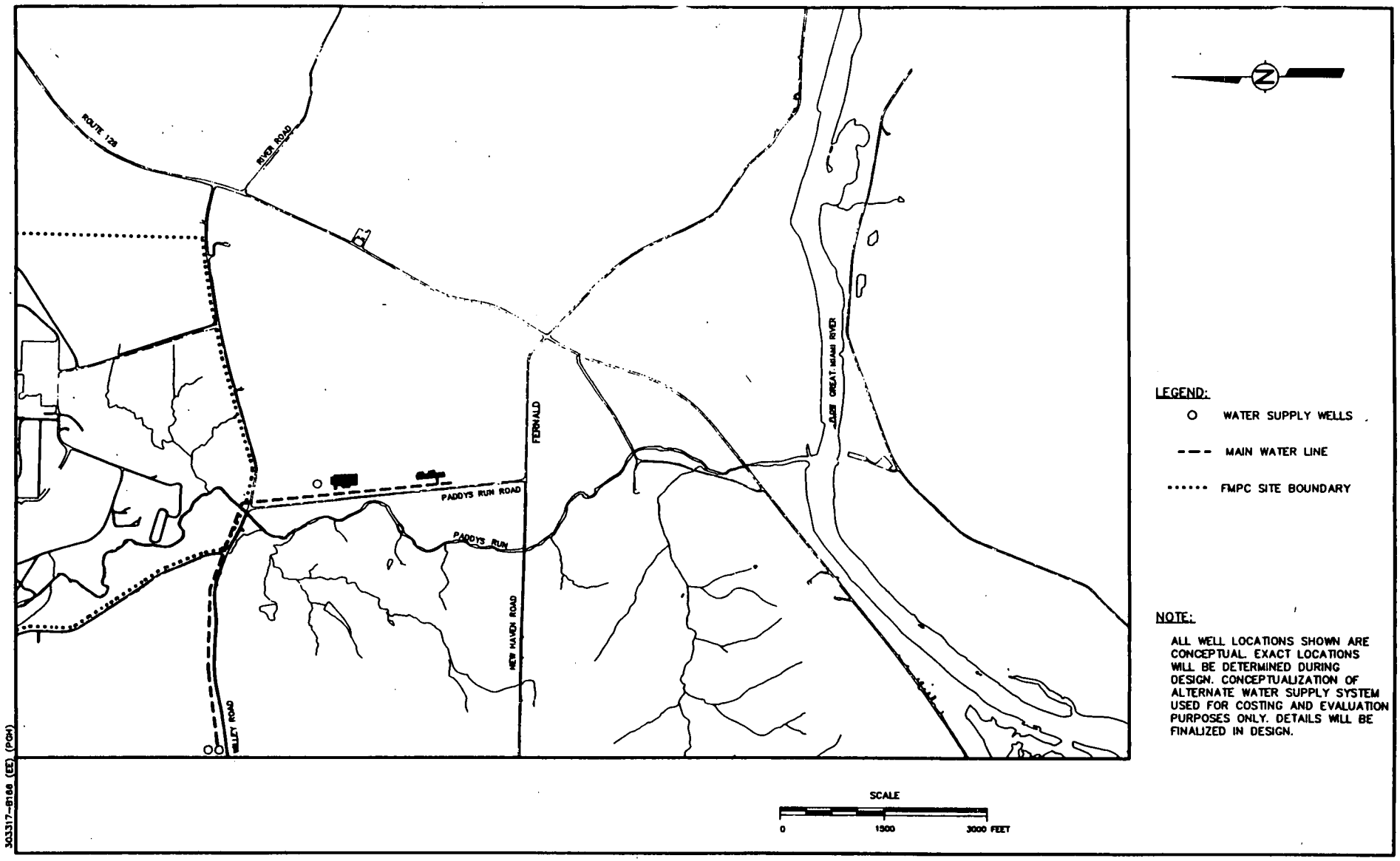

FIGURE 4-1
ALTERNATIVE 3
ALTERNATE WATER SUPPLY

objectives of the removal action. A small supplier, Cleves Waterworks, serves portions of Miami town approximately five miles southwest of Fernald. The current service is incapable of being extended north to Fernald at the flow rates required for the industrial users.

4.2.4 Alternative 4 - Pump and Treat

This alternative includes four parts. Part 1 involves an alternate water supply to two industrial water users along Paddys Run. Part 2 involves the interception and collection of the contaminant plume via installation of recovery wells near the southern limit of the uranium plume south of the FMPC. Part 3 involves installation of an interim 150 gpm advanced wastewater treatment system. Part 4 involves continued monitoring and institutional controls as discussed in Alternative 2.

4.2.4.1 Equivalent Mass Treatment Unit

A new interim advanced wastewater treatment system will be installed within FMPC boundaries to treat an existing FMPC effluent. The system will process approximately 150 gallons per minute of existing plant effluent and remove a quantity of uranium greater than the quantity of uranium that will be released to the Great Miami River as a result of the extraction and discharge of groundwater from the south plume and various other removal actions. These additional removal actions include the contaminated water under FMPC Buildings Removal Action and the Waste Pit Area Run-off Control Removal Action. The treatment system will prevent any net increase of uranium into the Great Miami River.

4.2.4.2 Well Location

Three to five recovery wells are tentatively planned for installation just south of New Haven Road to intercept the plume. Four recovery wells are shown conceptually in Figure 4-2. The exact number and location of these wells will be determined by exploratory drilling and sampling to verify the location of the extent of the plume exceeding the 30 µg/L limit. This wellfield is designed to intercept the plume while not reversing the aquifer flow south of the wellfield.

The wells will be screened in the top 40 feet of the aquifer and provide a combined pumping rate from 1500 to 2500 gpm. These well locations, pumping rates, and depths are based on results obtained from the site investigation and groundwater modeling programs. Details of the modeling effort are

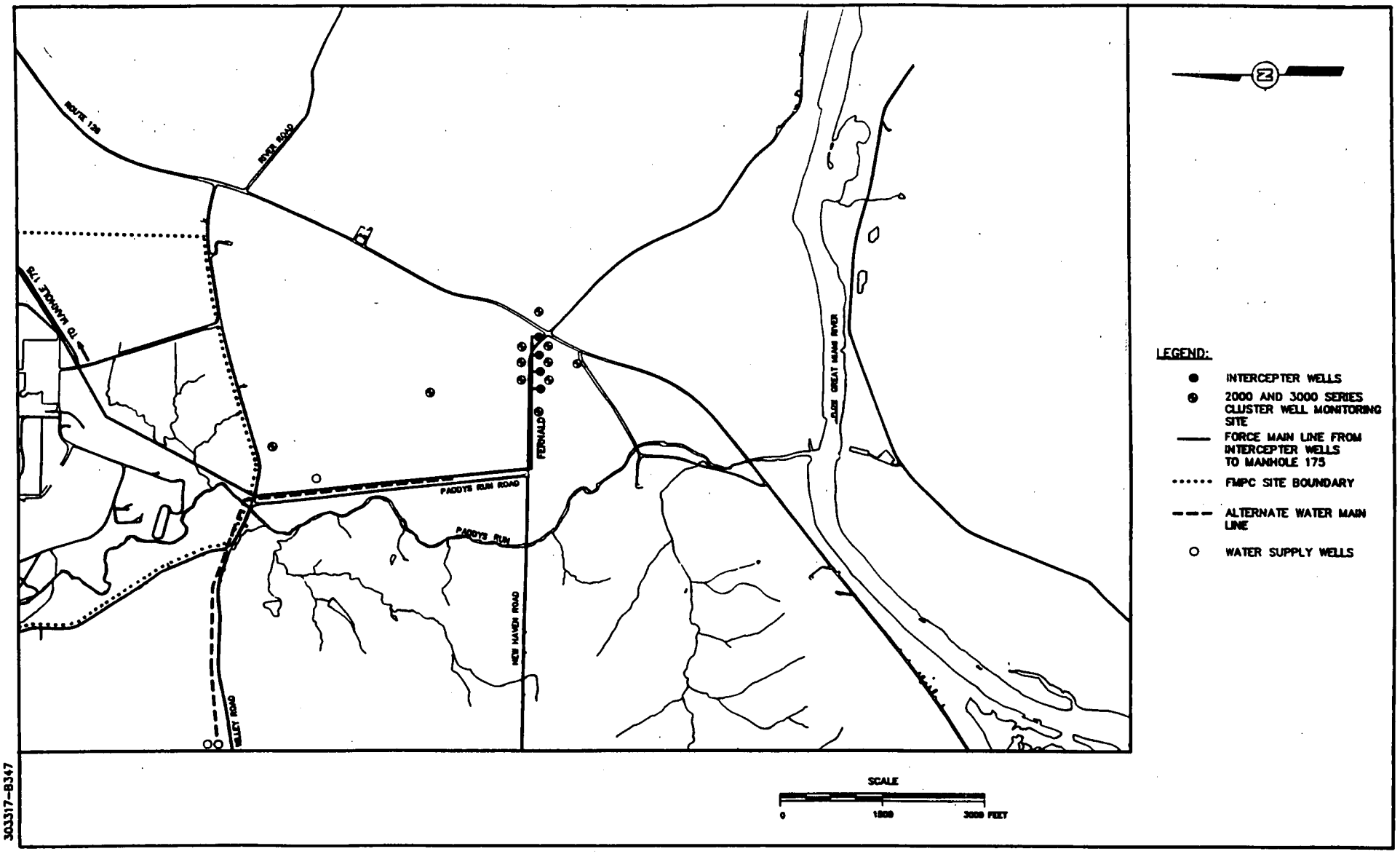

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FIGURE 4-2
ALTERNATIVE 4 - PUMP AND TREAT

presented in Appendix A. The current evaluation of the recovery system indicates that initial pumping of four recovery wells at 500 gpm (1.1 cfs) each would capture the uranium in the plume north of the wellfield. Although the recovery system is designed to capture groundwater from the upper layer of the sand and gravel aquifer containing concentrations of uranium greater than 30 µg/L, groundwater containing lower concentrations of uranium will also be captured. The well location and flow rates may be modified based on ongoing monitoring programs and refinement to the groundwater modeling program which will continue to support the RI/FS.

4.2.4.3 Groundwater Discharge

The water extracted from the recovery wells will be pumped first via underground piping to a 60,000-gallon capacity surge tank. Pumps will draw water from the surge tank and pump it through a force-main piping system to the main FMPC discharge line. The surge tank, force main pumps, electrical equipment, and monitoring instrumentation will be located within a pumphouse.

4.2.4.4 Monitoring and Institutional Controls

The monitoring and institutional control program will be the same as that described for Alternative 2.

5.0 EVALUATION OF ALTERNATIVES

The evaluation of the removal action alternatives is presented in this chapter. Section 5.1 describes the evaluation criteria. The evaluations of the individual alternatives are presented in Sections 5.2 through 5.5, respectively, and a separate discussion of the ARARs and TBCs is presented in Section 5.6.

5.1 EVALUATION CRITERIA

The four alternatives described in Section 4.0 are evaluated according to the following criteria:

- Effectiveness
- Implementability
- Cost

To achieve consistency with the removal action objectives identified in Section 3.0 and to accommodate the selection of a preferred alternative in Section 6.0, the effectiveness criterion is divided into two components. The first reflects the effectiveness in achieving the principal objective of public-health protection, while the second addresses the effectiveness in meeting the two secondary objectives of environmental protection and plume migration control.

5.1.1 Effectiveness: Public Health

The first component of the effectiveness of an alternative is defined by its ability to ensure the protection of and to minimize impacts to public health. The evaluation of this factor will focus on the extent to which the completed action reduces or mitigates identified threats, as well as compliance with chemical-specific ARARs and TBCs. This component also involves an assessment of the potential for future exposure to residual conditions at the site, as well as the potential for failure of the alternative and any potential threats from such a failure.

5.1.1:1 Exposure Pathways

Uranium is the only constituent of the south plume that could present a public health risk from chemical or radiological exposures. The assessment of public health risks will, therefore, be limited to the radiation doses from and chemical toxicity of uranium.

In the absence of any penetrations into the groundwater plume, there are no exposure pathways to humans or to flora and fauna in the area. Only when water containing uranium is drawn from the plume will there be pathways for exposure to both humans and the environment. If access to the groundwater is not prevented, it is possible that groundwater taken from the aquifer could be ingested directly as drinking water by man and animals, used for the irrigation of human food crops and animal forage, or released into surface water pathways. Each of these scenarios presents exposure pathways to both the chemical and radiological properties of uranium in the water. Each of these scenarios was considered in an environmental pathways analysis. Although numerous exposure pathways were considered, the following four pathways emerged as principal contributors to the potential exposure of the public in relation to the south plume: (1) direct ingestion of water; (2) ingestion of crops grown in fields irrigated by the water; (3) ingestion of beef from cattle exposed to uranium through water and crops; and (4) ingestion of milk from cows exposed to uranium through water and crops.

The calculation methodology presented in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (NRC 1977) was used to assess the transport of uranium from groundwater and surface water to off-site receptors. From this methodology, an environmental transport model was developed which used site-specific transport parameters whenever possible and recommended generic parameters otherwise. The model for mixing liquid effluents from the FMPC effluent discharge line into the Great Miami River was taken from the "Hydrogeologic Study of FMPC Discharge to the Great Miami River" (IT 1988). The irrigation rate was obtained from the "Ohio Irrigation Guide" (USDA 1970).

The environmental transport model was used to calculate the annual intake of uranium by humans via drinking water, vegetables, meat, and milk. The radiation dose (50-year CEDE) was calculated by multiplying the annual intake rate of uranium by the respective dose conversion factors for isotopes of uranium (DOE 1988b).

The annual intake rate calculated by the environmental transport model was also used to evaluate the potential for chemical toxicity from uranium. A hazard index (HI) for adults and children was calculated by dividing the estimated daily intake by the acceptable daily intake. The uranium chemical toxicity reference dose of 3 μg/kg/day is used as the acceptable intake rate (EPA 1989). An HI greater than or equal to one implies that exposure at this level is potentially detrimental to human

health and, conversely, an HI less than one implies that exposure is acceptable with respect to an individual's risk of chemical toxicity.

5.1.1.2 Chemical-Specific ARARs and TBCs

The chemical-specific TBC, which is the lowest proposed value for protection of public health and the environment from chemical and radiological constituents in the south plume, is the 50-year CEDE limit of 4 mrem from an annual intake of radioactive materials in drinking water. The DOE has specified that this CEDE limit shall apply to releases to all areas where water could be used as a drinking water source (DOE 1990). It is important to note that this referenced DOE limit does not exclude uranium (which is specifically excluded by the EPA Drinking Water Standards, 40CFR141).

Uranium isotopes are the only radioactive materials which exceed background concentrations in the south plume outside the FMPC boundary. The concentration of uranium in drinking water which corresponds to the 4 mrem radiation dose limit is derived to be equal to 20 pCi/L, or 30 µg/L.

This derivation assumes equal activity concentrations of uranium-234 and uranium-238, which is equivalent to the natural abundance of uranium isotopes. This condition has been generally satisfied in groundwater at the FMPC based on the isotopic data collected in support of the RI/FS. The derivation also assumes that the intake pathway is via ingestion of two liters of water with the specified uranium concentration every day of the year (i.e., 730 liters per year [DOE 1990]). No other environmental transport pathways are considered for this derivation.

A concentration of uranium in drinking water at the limit of 30 µg/L is less than the concentration threshold derived from the acceptable daily intake based on chemical toxicity. For an adult (70 kg) assumed to ingest two liters of water per day, the acceptable daily intake of 3 µg/kg/day based on chemical toxicity (EPA 1989) corresponds to a drinking water concentration of 105 µg/L. Consequently, the radiological-based limit, which is a lower value and would make the assessment more conservative, is utilized as the chemical-specific TBC for uranium in drinking water.

Water from the south plume outside the FMPC boundary can be released to surface waters of the Great Miami River, where dilution occurs. This water may be a source of drinking water for persons downstream. For purposes of this evaluation, the concentration of uranium in the Great Miami River

following dilution is directly compared with the drinking water limit, even though an additional reduction in uranium concentration in drinking water will most likely result as a consequence of municipal water treatment processes.

The evaluation of the effectiveness of each alternative will be made first with respect to the derived concentration limit for uranium in drinking water. Any alternative for which the drinking water concentration limit is exceeded will not be considered as acceptable. Alternatives for which the drinking water concentration limit is not exceeded will then be evaluated for public health risk under other exposure pathways.

A second TBC, which is less restrictive than the radiation dose limit for drinking water, is the total annual CEDE limit of 100 mrem for off-site individuals from all radiation exposures due to the site via all environmental transport pathways. The total radiation dose from all pathways is calculated for each alternative and compared with the annual radiation dose limit of 100 mrem.

5.1.2 Effectiveness: Other Factors

The degree to which the alternatives satisfy the secondary removal action objectives will be used to define the second component of effectiveness. Environmental protection will consider the degree to which uranium will be physically removed from the groundwater environment, thereby reducing the potential for exposure to environmental receptors such as fish, crops, irrigation water, cattle, etc. Additionally, the environmental evaluation will consider factors necessary to meet requirements mandated under NEPA. This includes the consideration of environmental impacts that may result from implementing the removal action. This evaluation will also consider the extent to which the actions meet the location-specific ARARs and TBCs, particularly those pertaining to environmentally sensitive areas.

The objective of plume control will be evaluated with respect to the degree of hydraulic control of plume migration being effected by an alternative, as well as the portion of the south plume that will be controlled. A precise quantification of the effect of an alternative on the degree of hydraulic control of plume migration is limited by the remaining uncertainties as to the nature and extent of the leading, southern edge of the plume. The leading edge of the plume is based on results of the calibrated

transport model and limited confirmatory data. Currently additional wells are being installed and sampled to confirm the southern boundary of the south plume. The final selection of well placement will not be made until all data is reviewed.

For purposes of this evaluation, the control of the plume migration is limited to the containment of the contaminated groundwater to the presently affected area. No control of other potential sources, such as discharges to Paddys Run or the storm sewer outfall ditch, is considered under the south plume removal action.

There remains a lack of direct observations on both the chemical plume to the south of the FMPC (pending completion of the Paddys Run RI) and the degree to which the plumes may have mixed. Model results indicate, however, that a mixing of the plumes will not occur, due to distinct and generally parallel migration pathways from the respective sources.

5.1.3 Implementability

The implementability of an alternative is defined by its technical feasibility, the availability of applicable technologies, and administrative feasibility. Factors evaluated regarding an alternative's technical feasibility include the ability to construct and operate the alternative considering unknowns that may lead to schedule delays, the ability to meet the required process efficiencies or performance goals, compliance with action-specific ARARs and TBCs, and the previously demonstrated performance of a technology. The technical feasibility evaluation also considers if the action is consistent with the long-term remedy for the site.

The availability criterion is used to evaluate the availability of necessary equipment, materials, personnel, and adequate storage or disposal capacity, if appropriate. Availability also considers any measures that may be required at the completion of the action, including monitoring and the availability of a responsible party to assume these activities. The evaluation of administrative feasibility of an alternative includes the likelihood of public acceptance, activities necessary for coordination with other agencies, and the ability to obtain necessary approvals or permits.

5.1.4 Cost

The total cost of an alternative is the final factor considered. This factor includes direct capital costs, indirect capital costs, and any postremoval site control costs. The cost estimates are intended to provide an accuracy of ±25 percent. A present-worth analysis is conducted to provide a common basis of comparison. A discount rate of 10 percent is used over a five-year project duration. The five-year period is used in all alternatives as the expected duration of the removal action. Even though the associated activities may continue beyond this period, it has been assumed that the activities will be performed as part of the final remedial action after five years and the costs will be accounted for in the FS for the environmental media operable unit.

The cost criterion is applied differently than the effectiveness and implementability criteria. The objective of the cost evaluation is to eliminate removal action alternatives whose cost greatly exceeds that of other alternatives while providing the same or only a marginal increase in the degree of satisfaction of the removal action objectives.

5.2 ALTERNATIVE 1: NO ACTION

5.2.1 Effectiveness: Public Health

Since there are no groundwater use restrictions assumed for the no-action alternative, it is assumed that an off-site receptor can use groundwater directly from the well having the highest measured concentration of uranium for potable water and for irrigation of crops. The calculated radiation doses for the assumed conditions via the drinking water pathway are 36 mrem for the hypothetical, maximally exposed off-site receptor and 18 mrem for an off-site receptor having average exposure conditions. The difference in these two scenarios is in the assumed rate of ingestion of drinking water. The maximum rate is twice the average rate for an individual.

The calculated radiation doses for all pathways considered are approximately 77 mrem for the hypothetical maximally exposed off-site receptor and 39 mrem for the hypothetical average exposed off-site receptor. The difference in these two hypothetical receptors is the assumed rates of ingestion of drinking water, vegetables, meat, and milk.

For the no-action alternative, it is assumed that the two industrial users of groundwater from the south plume continue to use this water and release it into the Great Miami River as part of their industrial effluent streams. The concentration of uranium in the liquid effluent from each of these users is assumed to be equal to the concentration of uranium drawn from the aquifer. This results in a conservatively high concentration value since water treatment is provided by the largest industrial user. If treatment is provided, uranium-bearing sludges would be produced that would represent an additional public health and environmental concern. Liquid effluents from the FMPC which go to the Great Miami River are also included in this environmental pathway and dose calculation scenario. Under this no-action scenario, a total of 578 millicuries (mCi), or 1900 pounds, of uranium is calculated to be discharged from the FMPC and the industrial effluent streams to the Great Miami River each year at an average concentration of 525 pCi/L (788 µg/L). The FMPC effluent line contributes 1862 pounds of uranium in an average flow rate of 0.680 mgd for an average uranium concentration of 899 µg/L. These values are representative of the conditions observed over the last several years at the FMPC. A calculated uranium contribution of 30 pounds from the industries is based on observed concentrations of 40 µg/L in the groundwater and a typical pumping rate of less than 200 gpm.

Pathways to man from these releases to surface water are via irrigation of crops, drinking water supplies downstream from the release point, and beef cattle and milk cows which ingest water from the river and irrigated forage. Assuming a level of dilution commensurate with low-flow conditions in the Great Miami River and the measured natural background concentration of uranium in the river of 1.2 pCi/L, the calculated above-background radiation doses (CEDE) from this scenario are approximately 0.9 mrem for the hypothetical maximally exposed off-site receptor and approximately 0.5 mrem for the hypothetical average exposed off-site receptor. Essentially all of these calculated radiation doses are a consequence of the uranium in the liquid effluents from the FMPC.

The no-action alternative is not effective in preventing potential risk to public health via the drinking water pathway since the calculated doses exceed the limit of 4 mrem. The overall off-site dose limit of 100 mrem is not exceeded even for the hypothetical maximally exposed off-site receptor; however, other exposure pathways from airborne particulate releases, radon releases, and direct external exposure from the FMPC have not been included in this analysis.

The HI calculated for the no-action alternative is 6.0 for the hypothetical maximally exposed off-site adult and 3.1 for the average exposed off-site adult. These values indicate that the daily intakes of uranium for the exposure pathways considered exceed the acceptable intake level of 3.0 µg/kg/day for uranium.

Details of the public health evaluation for no action are presented in the risk assessment in Appendix C.

5.2.2 Effectiveness: Other Factors

Under the no-action alternative, none of the secondary objectives would be satisfied to any extent. No lessening of environmental concentrations would occur except for the continued dispersion of the plume as it migrates, uncontrolled, toward the south-southeast.

The leading edge of the plume is not expected to reach the Great Miami River within the five-year time frame of the proposed action. Therefore, there would be no significant impact on aquatic or terrestrial communities unless contaminated water was withdrawn from the aquifer. Withdrawal of contaminated water could cause an adverse impact on aquatic and terrestrial communities depending on the use and disposal of the water. For example, irrigating crops with contaminated water would contaminate soil, vegetation, and any adjacent wetlands via runoff.

This alternative would have no impact on the Indiana bat habitat or the historical resources in the area. There would be no noise or air quality impacts related to this alternative and no change in existing land use practices or waste management requirements.

The amount of uranium crossing the FMPC boundary would continue at the currently projected level until an on-property removal or remedial action was implemented as part of another operable unit. Plume mixing may occur in the future if hydraulic conditions result in the crossing of the two migration paths. However, such hydraulic conditions are not expected based on the model and will be verified by field data.

5.2.3 Implementability

The evaluation of the technical feasibility and availability factors related to implementability is not applicable to the no-action alternative. No construction, monitoring, or permitting activities are involved with this alternative. Acceptance of the no-action alternative by the public and the agencies is not likely.

5.2.4 Cost

There are no capital or operation and maintenance costs associated with the no-action alternative.

5.3 ALTERNATIVE 2: MONITORING AND INSTITUTIONAL CONTROLS

5.3.1 Effectiveness: Public Health

For this and all remaining alternatives, it is assumed, due to the implementation of institutional controls, that south plume groundwater with uranium concentrations exceeding the 30 µg/L limit will not be used for potable water or irrigation of crops. This assumption has the greatest impact on dose calculations. The condition of nonuse of the south plume for potable water or irrigation will necessarily require that monitoring and institutional controls remain fully effective in preventing access to the aquifer in the south plume. If increasing uranium concentrations are detected in any wells during the monitoring program, the potential for exceeding the derived concentration limit for uranium in groundwater will be evaluated and an appropriate response action will be taken as necessary.

Under this alternative, the assumption is made that the two industrial users of water from the south plume will continue to draw water from their existing wells at the current rate and to ultimately release this water into the Great Miami River at the same concentration as drawn from the aquifer. This results in a conservatively high concentration value since water treatment is provided by the largest industrial user. Liquid effluents discharged annually from the FMPC to the Great Miami River are again included in the source term for uranium to the river under this alternative.

Under this scenario, a total of 578 mCi (1900 pounds) of uranium is estimated to be discharged to the river each year at a concentration of 525 pCi/L (788 µg/L). Dilution by the river under low-flow conditions is assumed. Water from the river is assumed to be used for irrigation of crops and for

drinking water supplies downstream from the release point. The four pathways of importance for surface water release are potable water for humans, irrigation of food crops and animal feed, beef from cattle, and milk from cows.

The calculated above-background concentration of uranium in the river is 2.3 pCi/L. The calculated above-background radiation dose for the hypothetical maximally exposed off-site receptor considering all pathways is approximately 0.9 mrem. For the hypothetical receptor with average ingestion levels, the calculated radiation dose is approximately 0.5 mrem. As with releases to the surface water considered in Alternative 1, essentially all of these calculated radiation doses are a consequence of the uranium in the FMPC liquid effluent released to the Great Miami River and not from the release of groundwater after industrial use. These doses are well below the 100 mrem limit.

The calculated above-background radiation doses for the assumed conditions via the drinking water pathway are approximately 0.4 mrem for the hypothetical maximally exposed off-site receptor and approximately 0.2 mrem for the off-site receptor having average exposure conditions. These doses are well below the radiation dose limit of 4 mrem for drinking water.

The HI calculated for this alternative is 0.07 for the hypothetical maximally exposed off-site adult and 0.04 for the average exposed off-site adult. These values were derived from intake rates which included the calculated annual intake as a consequence of natural background concentrations of uranium in the river water. These values are less than the HIs for the no-action alternative (Alternative 1) by a factor of more than approximately 100. The details of this assessment are presented in Appendix C.

5.3.2 Effectiveness: Other Factors

The nature of the actions to be taken under this alternative do not change conditions of the plume or its sources. Consequently, the secondary factors would not be satisfied to any extent, although the probability of any impact on aquatic or terrestrial communities is reduced due to the decreased likelihood of contaminated water being withdrawn from the aquifer. The consequences of withdrawal and use of contaminated water would be the same as those for Alternative 1.

There would be no impacts related to endangered species, noise and air quality, historical resources, or waste management practices. The treatment of groundwater by the affected industries would generate a similar volume of sludges as is currently being produced. There may be some land use restrictions on well installation applications due to the institutional controls as implemented by state and local officials.

The discussion pertaining to the effectiveness of the no-action alternative (Section 5.2.2) in relation to other factors is also applicable to the monitoring and institutional control alternative and is not repeated herein.

5.3.3 Implementability

No construction activities are associated with the groundwater monitoring or institutional controls provided in this alternative. Approvals will be needed from individual landowners to gain access for well sampling and analysis. Coordination among DOE, the State of Ohio, and local communities will also be necessary to coordinate any future installation of new wells by owners in the study area so that the monitoring network can be expanded accordingly.

Although this alternative is consistent with any final remedial action, public and agency opposition is expected due to the lack of more direct action on the plume itself. The perception would be that this action involves no more than what is being routinely performed by the FMPC.

5.3.4 Cost

The costs estimated for Alternative 2 are annual operating costs only, since no new wells will be installed under this alternative, and include the sampling and laboratory analysis costs for the monitoring program at selected existing wells. These costs are estimated to be $33,600 per year (see Appendix B). A present-worth value of $127,400 was calculated using a 10 percent discount factor over a five-year project duration.

5.4 ALTERNATIVE 3: ALTERNATE WATER SUPPLY

5.4.1 Effectiveness: Public Health

The incorporation of an alternate water supply into Alternative 3 creates a more substantial "zero access" condition for groundwater in the south plume since treatment of the water by current industrial users would not have to be assumed. An alternate water supply will be provided only to the known users of the affected groundwater although provision is made for an alternate water supply if other users are affected in the future. Monitoring and institutional controls will reduce the likelihood of receptors being affected in the future. These conditions effectively eliminate the groundwater exposure pathways.

Under the assumptions described in Sections 5.2.1 and 5.3.1, the use of an alternate water supply by the industries will reduce the total quantity of uranium released to the Great Miami River by the FMPC and these industries by approximately 2 percent.

The net effect of providing an alternate water supply on radiation doses from the surface water-based exposure scenarios is minimal. The calculated above-background concentration of uranium in the river is 2.3 pCi/L. The calculated above-background radiation doses to the hypothetical receptors of the four pathways as a consequence of releases to the river are approximately 0.9 mrem and 0.5 mrem for the hypothetical, maximally exposed receptor and average receptor, respectively. Since the only remaining source of uranium into the surface water environment is the liquid effluent from FMPC operations, these calculated radiation doses are due entirely to liquid effluents from the FMPC and are not reflective of groundwater conditions in the south plume.

The calculated above-background radiation doses for the assumed conditions via the drinking water pathway are 0.4 mrem for the hypothetical maximally exposed off-site receptor and 0.2 mrem for the off-site receptor having average exposure conditions. These doses are well below the radiation dose limit of 4 mrem for the drinking water pathway. Similarly, the total radiation dose calculated for all pathways is below the 100 mrem annual limit.

The HI values calculated for this alternative are 0.07 and 0.04 for the maximum adult and average adult, respectively. These values are equal to the HI values calculated for Alternative 2 and also

include the contribution from natural background concentrations of uranium in the river water. (See Appendix C for details of the risk assessment for this alternative.)

5.4.2 Effectiveness: Other Factors

As with the no-action and monitoring alternatives, Alternative 3 does not extract contaminated water from the subsurface environment and does not provide control of plume migration. Therefore, although this alternative provides public health protection, it is ineffective in satisfying the secondary removal action objectives.

As with the first two alternatives, there should be no significant impact on aquatic or terrestrial communities if no contaminated water is withdrawn from the aquifer, since the plume is not expected to reach the Great Miami River within the five-year time frame of the proposed action.

It is assumed that the existing industrial wells will be shut down once an alternate water supply is provided. Based on the results of the modeling of this situation, the shutdown of the larger industrial wells will cause a beneficial effect on the environment by reducing the vertical migration of the plume from the 2000-series level in the aquifer downward to the 3000-series depths from which the wells pump.

Implementation of this action will have several short-term environmental impacts. Air quality impacts could occur as the result of dust emissions from earth-moving activities and increased traffic during construction of the recovery wells, water and surge tanks, pump station, and water lines. These impacts are not expected to be significant and could be minimized by sprinkling roads and other exposed soil surfaces as necessary.

Alternative 3 would result in only minimal soil disturbance. No major soil excavation or grading would be required during construction, and negligible soil loss through water or wind erosion would be anticipated since controls would be implemented. Following construction, disturbed areas would require reseeding or resurfacing. The lower half of Paddys Run Road between Willey and New Haven roads lies in the 100-year floodplain of the Great Miami River and Paddys Run. New Haven Road,

from just west of Paddys Run to just east of S.R. 128 also lies in the 100-year floodplain. However, construction activities in the floodplain would be minimal and would have no impact on surface water flow or quality.

Construction impacts, including visual disturbance, noise, and dust, would be expected to have only a minimal impact on local vegetation and wildlife. Although habitats could be disturbed and mobile species displaced during construction, surrounding areas could absorb the displaced species. Habitats within the affected area do not appear to be unique or distinctly important compared to adjoining areas. It is anticipated that the disturbed areas would be repopulated after the construction period. Aquatic organism in Paddys Run could be temporarily disturbed due to the pipeline stream crossings required, but the long-term impact would be minimal. A U.S. Army Corp of Engineers (COE) permit may be required for the stream crossings. There would be no impact on the endangered species in the area.

The Ohio State Historic Preservation Officer (SHPO) has stated that remedial activity within the boundaries of the FMPC will not adversely affect any properties listed on or eligible for the National Register of Historic Places (NRHP) (Luce 1987). However, because there is potential for the discovery of cultural resources in the area, the SHPO has requested that an archaeological survey be performed in the recovery-well area prior to any drilling (Kitchen 1990). These areas to be surveyed include any and all areas that are to be disturbed by construction activity, such as well sites, pipeline locations, and any access roads constructed to the well sites. The rainbow arch bridge spanning Paddys Run on Willey Road has been designated eligible for inclusion in the NRHP and must not be negatively affected by any construction, such as laying the pipelines to the proposed well sites west of the FMPC.

Construction activities associated with this alternative could cause temporary traffic, dust, and noise disturbances to the agricultural and scattered residential areas near the site. The action would not, however, significantly impact land use following construction. The ancillary structural facilities would be low maintenance and would not require a large land area.

5.4.3 Implementability

The design and installation of water supply wells and associated facilities represent standard engineering efforts and should present no major technical difficulties. Although the system will be fully automated, daily maintenance checks will be required for valves, pumps, and instruments for flow regulation due to the expected variations in water demand. The necessary equipment, materials, and services associated with this option are commonly and readily available.

Acquisition of property is necessary for construction of the water supply wells. Additionally, access to private properties and public rights-of-way is required for installation of the water line. Coordination with local and state agencies is required to meet various permitting requirements for this alternative. The drilling contractor must be licensed and approval must be obtained from the county for drilling activities. Permits would also be required from the county for installation and operation of a water supply system. A permit from the state is also required for major construction activities. Approval for these types of permits can typically be obtained within several weeks and is not expected to be a significant factor in the implementation schedule. It is anticipated that the alternate water supply would be provided within 16 months of approval of the EE/CA.

The monitoring component of this alternative will require approval from and coordination with residents for gaining access to private wells for sampling and analysis.

5.4.4 Cost

Capital costs for this alternative include direct capital costs for the equipment, labor, and materials necessary to install the water supply system and wells. Indirect costs for engineering, subcontracting, and contingencies are also included. The total capital investment for this alternative is $900,100. A summary of this estimate is presented in Appendix B.

Annual costs associated with this alternative include sampling, laboratory analysis, and operation and maintenance of the alternate water supply wells and distribution system. The total estimated annual costs are $90,000 per year.

A present-worth cost was calculated using a 10 percent discount factor and a five-year project period. The resultant present-worth cost is $1,241,200.

5.5 ALTERNATIVE 4: PUMP AND TREAT

5.5.1 Effectiveness: Public Health

Alternative 4 provides for zero access by current and potential users of the groundwater within the south plume outside the FMPC boundary by the installation of an alternate water supply and the initiation of a monitoring and institutional control program (as in Alternative 2). Additionally, initiation of a groundwater pumping program to remove uranium-bearing water from the aquifer will prevent plume migration to potentially affected users. An interim 150 gpm advanced wastewater treatment facility will be installed to remove uranium from existing FMPC wastewater discharges. However, the mass of uranium removed from the FMPC wastewater will exceed the amount that the south plume and other removal actions will be contributing to the Great Miami River.

Water will be pumped from the recovery wells continuously at an estimated rate of 2000 gpm to achieve the desired hydraulic control barrier, with the concentration of the pumped water varying with time. Water pumped from the recovery wells will be released into the Great Miami River along with the treated liquid effluent from the interim advanced wastewater treatment system. The effect of pumping will increase the total mass loading of uranium with time as the plume moves southward toward the recovery wells (Figure A-10 and A-11). However, with the treatment of a more concentrated effluent stream from the FMPC, it is estimated that the annual uranium loading to the river will decrease from its current level of 556 mCi (1862 pounds) to 487 mCi (1602 pounds) during the first year of pumping. With the varying loading of uranium due to pumping, the annual net loading to the river will increase to 499 mCi (1642 pounds) during the second year and 511 mCi (1682 pounds) during the third year.

However, the lower uranium concentration in the flow from the recovery wells will reduce the concentration in the FMPC discharge from the current release concentration limit of approximately 600 pCi/L (899 µg/L) to approximately 100 pCi/L (150 µg/L) for each of the three years.

The calculated above-background concentration of uranium in the river ranges from 1.9 to 2.0 pCi/L over the three-year removal period. The calculated above-background radiation doses to the hypothetical off-site receptors for each of the three years of this removal action are approximately 0.8 mrem for the maximally exposed off-site receptor and approximately 0.4 mrem for the off-site receptor

having average exposure parameters. The calculated above-background radiation doses for the assumed conditions via the drinking water pathway are 0.4 and 0.2 mrem for the hypothetical maximally exposed off-site receptor and the average receptor, respectively. Radiation doses calculated for this alternative are well below both the drinking water limit and the total dose limit, and will remain so even if the concentrations of uranium in the pumped water increases over the three-year project life.

The HI values calculated for this alternative are 0.06, and 0.03 for the maximum exposed adult and average exposed adult, respectively. These values indicate that the hypothetical intake rates are well below the level of potential chemical toxicity for uranium.

5.5.2 Effectiveness: Other Factors

This alternative, which includes groundwater pumping and discharge along with treatment of 150 gpm of the FMPC effluent, meets the secondary removal action objective of the protection of the groundwater environment to a limited extent. The positioning of the recovery wells near the southern edge of the plume is minimally effective in reducing environmental concentrations over the short term. Figure A-9 indicates that the maximum uranium concentrations in groundwater north of the recovery wells will experience a minimal decrease over a three-year period due to the plume control measures and natural plume dispersion processes.

This alternative would have no effect on the mass loading of uranium to the Great Miami River, but would decrease the concentration of uranium in the effluent from approximately 600 pCi/L to approximately 100 pCi/L, due to dilution by the less concentrated south plume water. Therefore no adverse impacts to aquatic biota are expected. Any existing impacts in the mixing zone of the effluent may improve, due to the decrease in uranium concentration.

Control of plume migration, the other secondary objective, is fully achieved by this alternative. Particle-tracking algorithms were used to demonstrate that the proposed wells will be effective in capturing the uranium plume in these areas (Figure A-6).

The projected pumping rates of the recovery wells are not expected to impact local groundwater availability or effect flow in Paddys Run. Once the industrial wells are replaced with the alternate

water supply, no private wells with significant withdrawal requirements will be located in the vicinity of the recovery wells. Water levels will drop in the cone of depression of the wells, but the drawdown will not be significant in terms of the extent of the aquifer and withdrawal rates should not be reduced by the new recovery wells (Figure A-6).

An added benefit is provided to the environment due to the shutdown of these industrial wells. As mentioned under Alternative 3, modeling of this situation indicates that there will be a reduction of vertical migration of the plume from the 2000-series level in the aquifer downward to the 3000-series depths from which the larger industrial wells pump.

Impacts on air quality, soils, vegetation, land use, and floodplains would be similar to those discussed under Alternative 3. However, the degree of impacts will be slightly greater under Alternative 4 due to additional construction activities for the recovery wells, a pump house, and the pipeline. The associated increase in the time of implementation will prolong the duration of such impacts, particularly if the alternate water supply and the pumping system are installed in two parts as currently planned. However, construction activities in the floodplain would be minimal and would have no impact on surface water flow or quality.

The construction period would last 12 months. There would be a short-term disturbance of three acres of land and the permanent commitment loss of 400 square feet of land for concrete pads for the wells. There would be no significant impact to endangered species. Waste management requirements would be reduced under the assumption that a currently affected industry would no longer produce uranium-bearing sludges as the result of groundwater treatment. A Corps of Engineer (COE) permit may be required for the stream crossing.

As noted for Alternative 3, the Ohio State Historic Preservation Officer (SHPO) has requested that an archaeological survey be performed in the recovery-well area prior to any drilling (Kitchen 1990). These areas to be surveyed include any and all areas that are to be disturbed by construction activity, such as well sites, pipeline locations, and any access roads constructed to the well sites.

Under this alternative a 150 gpm advanced wastewater treatment facility will be installed to remove a mass of uranium from FMPC effluent greater than the average mass of uranium pumped from the

south plume and other removal actions, as mentioned previously, into the Great Miami River. The total mass of uranium released via the effluent pipeline will not exceed the existing FMPC release value. Treatment of the FMPC effluent will generate sludge, suspended solids captured in the treatment filters, and the uranium that will be removed by the ion exchange resin. This sludge will be stored in drums and will be disposed of in accordance with the applicable state and federal regulations.

The interaction between the existing FMPC discharge, the Great Miami River, and the SOWC wellfield located east of the FMPC has been extensively studied (IT 1988). The study found that the incremental impact of the existing effluent on the water quality of the SOWC wells was nondetectable. It is unlikely, therefore, that the increased flow from the discharge line would cause a detectable change in conditions.

5.5.3 Implementability

The installation, construction, and operation of a groundwater recovery system will utilize commonly-practiced engineering techniques and pose no unusual technical difficulties. The necessary materials, equipment, and services are readily available.

The alignment of the force main and location of the recovery wells will require obtainment of easments from private property owners.

The discharge of the pumped groundwater to the Great Miami River will require coordination with and may require approval from OEPA through the NPDES permitting program. A modification to the FMPC's existing discharge permit may be required. Although uranium is not regulated under the NPDES program, other constituents currently regulated, such as nitrates, could be problematical since any additional discharge to the river would increase the mass loadings of any chemicals present, regardless of the concentration levels.

Construction permits may also be required from the state. In addition, the installation of the monitoring wells may require access approvals. The alternate water supply portion of this alternative would be provided in December, 1991. In this alternate water supply portion, it is also projected that the pumping and discharging of groundwater would also begin in December, 1991. The incorporation of these recovery wells will be evaluated within the FS for the environmental media of operable unit 5.

The implementability of the alternate water supply and monitoring components of this alternative is the same as that discussed for Alternatives 2 and 3.

The principle components of the advanced wastewater treatment system may include:

- Ion exchange and regeneration equipment
- Regenerant mixing equipment
- pH adjustment equipment
- Containment and sump pump
- Final filtration equipment
- Water tanks and pumps

These components of the treatment system represent standard treatment processes and equipment that are commonly available. The components can be obtained from manufacturers regularly engaged in the design and production of such equipment for similar applications. The treatment equipment, piping, valves, and other instrumentation will be of proven reliability and design.

5.5.4 Cost

Capital, annual, and present-worth costs were estimated for Alternative 4. Capital costs for this alternative include direct capital costs for equipment, labor costs, and the cost of materials necessary to install the alternate water supply system and the groundwater extraction and piping systems, including monitoring well installation and the interim wastewater treatment system. Indirect costs for engineering, subcontracting, and contingencies are also included. The total capital cost for this alternative is estimated to be $6,863,800 (see Appendix B).

Annual costs for this alternative include the costs of groundwater sampling and analysis of residential, commercial, and monitoring wells and the operation and maintenance of the water supply, groundwater extraction systems and the interim wastewater treatment system. Estimated annual costs are $930,000 per year.

Based on a 10 percent discount factor and a five-year project period, the present worth value of this alternative is estimated to be $10,389,400. The interim wastewater treatment system will be used for three years. However, for the sake of comparative analysis with the other alternatives, a five year projected period is assumed to obtain the present-worth value. After three years the Advanced

Wastewater Treatment Plant will be commissioned and put into operation. Based on a 10 percent discount factor and a three-year project period, the present-worth value of this alternative is estimated to be $9,176,800.

5.6 REQUIREMENTS POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED FOR THE PROPOSED ACTIONS

The ARARs and TBCs for the proposed actions for the south plume are listed in Table 5-1. These potential ARARs and TBCs for the south plume are categorized into the following EPA-recommended classifications: chemical-specific ARARs and TBCs, location-specific ARARs and TBCs, and action-specific ARARs and TBCs. A discussion of each group and its relation to the proposed actions is given below.

5.6.1 Chemical-Specific ARARs and TBCs

The chemical-specific ARARs and TBCs apply to all of the proposed removal actions since the contaminant concentration drives the action level for implementation of the removal action. The chemical-specific ARARs and TBCs identified for the south plume pertain to uranium and are derived from DOE Order 5400.5. The chemical-specific TBC, which provides protection of public health from chemical and radiological constituents in groundwater, is the 50-year CEDE limit of four mrem froman annual intake of radioactive materials in drinking water. The second chemical-specific TBC for the south plume is the total annual CEDE limit of 100 mrem for off-site individuals from all radiation exposure due to the site via all environmental transport pathways. These limits are discussed in Section 5.1.1 and are used as the basis for the public health evaluations for each alternative.

5.6.2 Location-Specific ARARs and TBCs

Since the south plume currently has no definable impact on surface waters, wetlands, or wildlife, location-specific ARARs and TBCs are not applicable to the site for the no-action or monitoring and institutional-control alternatives. These ARARs and TBCs will become applicable if an action is implemented which removes contaminated water from the aquifer for treatment and/or discharge and for the proposed removal actions which include disposal outside of the FMPC boundary or pipelines which cross streams:

- Executive Order 11988, Floodplain Management. Application: This order may affect the administrative ability of alternatives which involve actions in a floodplain.

TABLE 5-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED FOR THE SOUTH PLUME EE/CA

Contaminant-Specific ARARs and TBCs

Requirement	Application to the South Plume
Radiation Protection of the Public and Environment (DOE 5400.5)	Chapter II.1.d sets the annual not-to-exceed effective dose limit of 4 mrems for human consumption through drinking water and 100 mrems from all radiation exposure via all environmental transport pathways
Ohio Water Quality Standards (OAC3745-1)	3745-01-04(D) set the criterion applicable to all waters, 3745-01-05 sets fourth the antidegradation policy for waters of the state, and 3745-1-21 describes the use designations for the Great Miami River, 3745-1-32(c)(9) specifically excludes uranium from the Ohio River stream criteria
Ohio Drinking Water Rules (OAC3745-81)	3745-81-15 and -16 establishes MCLs for gross alphas and beta particle activity but specifically excludes uranium
Ohio Radiation Protection Standards (OAC3745-38)	3701-38-13(D) provides concentration limits for discharge of radioactive materials into air or water in unrestricted areas
NRC Regulations for Standards for Protection Against Radiation (10CFR20)	Establishes radiation dose limits in unrestricted areas (10CFR20.105-106) and for waste disposal (10CFR20.301-302)
U.S. EPA Regulations for Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40CFR192)	40CFR192.32 establishes cleanup limits for radionuclides in groundwater (excluding uranium) pursuant to the Ground Water Protection Program 40CFR264.92, but also designates uranium as a hazardous constituent under 40CFR264.93-94
Safe Drinking Water Act	
a. mandated for	Maximum Contaminant LevelsGroundwater MCLs for uranium are (MCLs)promulgation, but not yet proposed
b.	Maximum Contaminant Level GoalsConsidered pursuant to SARA (MCLGs)Section 121(d)(2)(A(ii))
Clean Water Act (PL92-500) Federal Ambient Existing Source and New Source Water Quality Criteria (AWQC)	Specifically excludes uranium from consideration in discharges to surface water

TABLE 5-1
(Continued)

Location-Specific ARARs and TBCs

Requirement	Application to the South Plume
Regulation of Activities Affecting Waters of the U.S. (33CFR320-329), for Ohio (OAC3745-32)	Corps of Engineers regulations apply to both wetlands and navigable waters. Pipeline construction may require 401 water quality certifications
U.S. EPA's Ground Water Protection Strategy	The classification of groundwater at the site will affect the level of remedial response
Endangered Species Act of 1978 (16USC1531)	The effects of No Action and the construction and discharge activities must be considered if endangered species are located in area impacted by the South Plume
Fish and Wildlife Coordination Act (16USC661)	The effects on wetlands and protected habitats by No Action, and by the construction and discharge portions of each alternative must be considered if any wetlands or protected habitats are located in the South Plume area
Fish and Wildlife Improvement Act of 1978 (16USC742)	The effects on wetlands and protected habitats by No Action, and by the construction and discharge portions of each alternative must be considered if any wetlands or protected habitats are located within the South Plume area
Executive Order 11990 Protection of the Wetlands	This order may affect the administrative ability of alternatives which cause disturbance or destruction of wetlands
Ohio Location Standards (OAC3745-54-18)	Governs the location of hazardous waste treatment, storage, or disposal with respect to seismic conditions and floodplains
Ohio Conservancy District Rules governing activities within the boundaries of a conservancy district (ORC 6109.19)	Erection of obstruction/facilities within the bounds of the Great Miami River Conservancy District will require permit from the Board of Directors

TABLE 5-1
(Continued)

Action-Specific ARARs and TBCs

Requirement	Application to the South Plume
Ohio water well standards, (including plan approval and well and test hole abandonment) for new water wells intended for human consumption (OAC3745-9)	Plan approvals will be required for the well replacement and community water supply alternatives
Ohio rules which provide standards, procedures, and plan approval for construction or abandonment of private water systems (OAC3701-28)	Approvals from the Department of Health will be required for the well replacement and treatment at the tap alternatives
Ohio drinking water rules for public drinking water (MCLs) (OAC3745-81)	Rules governing water quality for the alternate water supply alternatives which use bottled water or a community well system
Ohio secondary contaminant standards for public drinking water (OAC3745-82)	Rules governing water quality for the alternate water supply alternatives which use bottled water or a community well system
Ohio operational requirements for community and major noncommunity drinking water systems; industrial disinfection, approval of chemicals, minimum pressure, reporting (OAC3745-83)	Rules governing water quality for the alternate water supply alternatives which use bottled water or a community well system
Ohio plans approval for construction or significant changes to public water systems requiring OEPA approval of plans (OAC3745-91)	Approvals and rules governing the alternative water supply replacement with a community well system alternative
Ohio backflow prevention and cross connections control for water service connections to public water supply systems (OAC3745-95)	Approvals and rules governing the alternative water supply replacement with a community well system alternative
Ohio criteria for issuing permits to construct new wastewater treatment facilities (OAC3745-31)	On-site plant may be exempt under CERCLA

TABLE 5-1
(Continued)

Action-Specific ARARs and TBCs

Requirement	Application to the South Plume
CWA NPDES Requirements (40CFR121-125) and Ohio requirements for NPDES permit to discharge wastewater to the waters of the state (OAC3745-33)	Program is mandated to state control; there are no standards for uranium discharge, but other limitations or criteria may be set by a permit (pH, flow, etc.) for all alternatives which have a discharge component
Ohio River Quality Standards Antidegradation Policy [OAC3745-1-05(A) and OAC3745-1-05(B)]	Applies to all alternatives which discharge to surface waters
RCRA Requirements (40CFR260-279)	Uranium does not qualify as a solid or hazardous waste, but was added to the list of hazardous constituents subject to RCRA Groundwater Protection Program rules (40CFR264.92.94) under the uranium mill tailings regulations (40CFR192.32)
Ohio Solid Waste Management Facility operating rules and permit requirements (OAC3745-27 and 37)	These rules may apply to residuals disposal from groundwater treatment facilities
Ohio Hazardous Waste Management Facility operating rules and permits (OAC3745-50 through 70)	These rules may apply to groundwater treatment plant construction operations and permitting
Ohio Groundwater Protection Rules for Hazardous Waste Management Facilities, including groundwater protection standards, point of compliance, and monitoring programs (OAC3745-54-90 through 99)	These rules may apply to groundwater cleanup for the south plume
Ohio Corrective Action Program (groundwater protection) (OAC3745-55)	Includes monitoring requirements for hazardous waste management facilities
Ohio restrictions on fugitive dust emissions (OAC-17-08)	Requires dust control during any construction activities which may take place during the remedial response

TABLE 5-1
(Continued)

Action-Specific ARARs and TBCs

Requirement	Application to the South Plume
OSHA Requirements (29CFR1910, 1926, and 1904)	Required worker safety requirements for exposure while engaged in on-site activities
Ohio General Radiation Protection Standards; all facilities that receive, possess, use, store, transfer, install, service, or dispose of any source of radiation require registration by their handlers (OAC3701-70 and 71)	Required worker safety requirements for exposure while engaged in on-site activities
DOE Order for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Program (5400.4)	Authorizes CERCLA activity by DOE at the FMPC
DOE Order for National Environmental Policy Act (NEPA) (5400.1C)	Establishes environmental policies and goals applicable to DOE and the FMPC
DOE Order for Radiological Effluent Monitoring and Environmental Surveillance (5400.XY)	Monitoring requirements for DOE facilities applicable to all alternatives
DOE Order for Hazardous and Radioactive Mixed Waste Management (5480.2)	Regulations by which FMPC currently operates for waste management
DOE Order for Radiation Protection of the Public and the Environment (5400.5)	Establishes exposure limits for public and the environment; this regulation is the basis for current cleanup levels
DOE Order for Environmental Protection, Safety, and Health Protection Information Reporting Requirements (5481.1)	Safety requirements for FMPC operations to be followed during remedial response actions
DOE Order for Quality Assurance (5700.6B)	Establishes the level of quality assurance for any work done at the FMPC for remedial response
DOE Order for Radioactive Waste Management (5820.2)	Policies and guidance for FMPC waste and contaminated facility management

TABLE 5-1
(Continued)

Action-Specific ARARs and TBCs

Requirement	Application to the South Plume
The Atomic Energy Act of 1954 (42USC2011)	This act authorizes the conduct of atomic energy activities
The DOE Organization Act (42USC7101)	Established powers and responsibilities of the DOE
The National Environmental Policy Act (NEPA) of 1969 (42USC4341)	Requires consideration of environmental concerns by the DOE at the FMPC consistent with national environmental policies and goals and provides a method for accomplishing these goals
Federal Compliance with Pollution Control Standards Executive Order (12088)	Requires the DOE to comply with applicable pollution control standards at the FMPC
Superfund Implementation Executive Order (12580)	Delegates CERCLA and SARA responsibilities to the DOE and to the U.S. EPA
NRC Rules for Land Disposal of Radioactive Wastes (10CFR61)	NRC rules may apply to alternatives containing groundwater treatment, disposal, or residual handling components
NRC Regulations for Standards for Protection Against Radiation (10CFR20)	NRC standards may apply for exposure limitations at the FMPC
U.S. EPA Regulations for Environmental Radiation Protection Standards for Nuclear Power Operations (40CFR190)	NRC standards for radiation doses received by members of the public in the general environment and to radioactive materials introduced into the general environment as a result of operations which are part of the nuclear fuel cycle
U.S. EPA Regulations for Health and Environmental Protection Standards for Uranium and Thorium Mill Tailing (40CFR192)	Established cleanup standards for inactive uranium mill tailing sites

- 10CFR1022, DOE Compliance with Floodplains/Wetlands Environmental Review Requirements. Application: Same as for E.O. 11988

It is assumed for the purposes of this document that residual disposal from treatment processes will take place at the FMPC or as part of approved off-site disposal practices. Therefore, the only ARARs and TBCs applicable to disposal/discharge activities will be those associated with discharge to surface water. The location-specific ARARs listed in Table 5-1 apply to Alternative 4 (pump and treat) only. In addition, a COE wetlands permit may be required for the stream crossings necessary for the alternate water supply in Alternatives 3 and 4.

5.6.3 Action-Specific ARARs and TBCs

Action-specific ARARs and TBCs regulate the process and operation of removal actions taken to mitigate the impact of the south plume. Executive Order 12088 defines the authority and scope of DOE compliance with environmental statutes. DOE programs of compliance with specific environmental statutes are defined in DOE5400.4 (CERCLA), Executive Order 12580 (Superfund), and 42USC4341 (NEPA). DOE Orders 5400.5 and 5480.11 and NRC regulation 10CFR20 set the radiation protection requirements for the public and the environment.

Monitoring and reporting requirements for DOE operations (including releases) are governed by DOE Order 5484.1 and by NRC requirements listed in 10CFR61.80 and 40CFR300. Management of residuals from the treatment and disposal actions will be regulated under the NRC land disposal rules (10CFR61) and DOE Order 5820.2A.

Worker safety requirements for radiation exposure while handling contaminated wastewater and residuals, or while installing or operating wells in the contaminated plume, are governed by OSHA requirements in 29CFR1910, 1926, and 1904.

Construction activities in areas unrelated to contamination (i.e., alternate drinking water supply) will be governed under standard OSHA requirements for worker safety in 29CFR.

Discharge of treated or contaminated water to surface water will be regulated under the Clean Water Act NPDES requirements, as delegated to the state of Ohio (40CFR121-125 and OAC3745-33). The discharges must meet national and State of Ohio ambient water quality and antidegradation criteria.

6.0 SELECTION OF PREFERRED ALTERNATIVE

In Section 5.0, the four removal action alternatives were evaluated on an individual basis against four criteria. These criteria included the effectiveness of the alternative in achieving the principal removal action objective of protecting public health, the effectiveness in achieving two secondary objectives, the implementability of the alternative, and the total present-worth cost. A comparative evaluation of the alternatives against these same criteria to support the selection of a preferred alternative is the subject of this section.

6.1 BASIS FOR SELECTION

To fully support the selection process within the context of a CERCLA-based removal action, two additional criteria are introduced into the final comparison. The first is the degree to which the alternative uses treatment to address the principal threats posed by the site (40CFR300.430). Although consideration of this factor is not a requirement for removal actions, it is a requirement for remedial actions. Since it is expected, based on both the south plume problem and the alternatives under consideration, that the removal action will be directly incorporated into the final remedial action, this criteria will be evaluated. The second additional factor is the anticipated degree of consistency between the removal action and the remedial alternatives still under consideration in the companion feasibility study for the environmental media operable unit.

With the exception of cost, each of the criteria is given equal weight in the comparative evaluation. Cost is considered separately in order to differentiate those alternatives that satisfy the criteria to a similar extent but have very different costs.

6.2 ELIMINATION OF NONRESPONSIVE ALTERNATIVES

Based on the evaluation reported in Section 5.0 and detailed in Appendix C, the no-action alternative was shown not to satisfy the minimum objective of being fully protective of public health. Specifically, the calculated radiation doses via the drinking water pathway exceed the limit of 4 mrem. This alternative is, therefore, eliminated from further consideration.

The minimum action of continued monitoring and institutional controls has likewise been eliminated due to its general nonresponsiveness to the removal action objectives. It does not proactively address

the fact that a uranium plume exceeding DOE's derived concentration standards exists off property and is being utilized as an industrial water supply. In addition, because of the location of the plume outside the FMPC property boundary, future usage of the groundwater cannot be controlled to the extent that would be necessary to ensure public health protection.

6.3 COMPARATIVE EVALUATION

This evaluation compares the two remaining alternatives in relation to the six evaluation criteria; effectiveness: public health; effectiveness: other factors; implementability; cost; preference for treatment; and consistency with final action. Each alternative is shown to satisfy the public health protection criterion. The pumping scenario has been assigned a slight preference due to the proactive position in removing uranium from the aquifer to minimize future exposure. Even though treatment is not included as a component of this alternative, it is important to note that acceptable dose and exposure limits will not be exceeded.

The remaining effectiveness criteria, which include an evaluation of the two secondary objectives and the environmental impacts, are satisfied to a significant degree only by the pumping scenario.

While both Alternatives 3 and 4 provide an environmental benefit by providing an alternate water supply for two industries drawing from the plume, thus eliminating vertical migration of contaminants from the existing industrial recovery wells, only Alternative 4 extracts contaminated water from the subsurface environment and provides control of the plume migration.

Both alternatives are implementable from a technical standpoint and should pose no unusual technical difficulties. Administrative factors and time of implementation are also the same for Alternative 3 and the alternate water supply portion of Alternative 4. Also, although it is estimated that the pump and treat portion can be implemented within the same time frame as the alternate water supply, additional administrative approvals may be required concerning the discharge to the Great Miami River.

The preference for treatment is not satisfied by Alternative 3 or 4. However, the pump and treat alternative, Alternative 4, provides a removal mechanism for the groundwater from the aquifer if treatment is required at some point in the future. But, because the pumping is targeted at the leading edge of the plume, the concentration of uranium in the pumped groundwater will be near the DOE-

derived drinking water standard for the initial years of operation and will have no significant effect on the aquatic environment or public health.

Alternatives 3 and 4 can each be viewed as being consistent with a final action for the south plume. Alternative 4 was again given preference, since the consequent removal of uranium and the control of plume migration should reduce the scope of the final action under the environmental media operable unit. It is even possible that no further action for the off-site plume will be required since the recovery wells will control plume migration. The decision on the need for an additional action will be dependent on forthcoming conclusions regarding the source(s) of uranium to the south plume and the continuing strength of the source(s).

6.4 PREFERRED ALTERNATIVE

Alternatives 3 and 4 have total present-worth costs generally proportionate to the level to which these alternatives satisfy the evaluation criteria. Given this comparable level of cost-effectiveness, the selection of the preferred alternative becomes focused on the alternative that most comprehensively and uniformly satisfies the full set of criteria. Based on the previous discussions, this is shown to be Alternative 4, which includes groundwater pumping and discharge, an alternate water supply for two currently affected industrial users, installation of an interim 150 gpm advanced wastewater treatment system, and enhanced monitoring and institutional controls.

As documented in this EE/CA, the current database and the results of the groundwater and solute transport models are considered sufficient and adequately reliable to support the selection of Alternative 4. This action is not highly sensitive to a limited redefinition of field conditions based on future data acquisition. Remaining uncertainties in the informational base must still be resolved prior to a final decision on the location, number, and design flow-rate of the recovery wells. This enhancement of the current understanding is necessary to confirm that the wells are indeed located at or beyond the leading edge of the plume and that the lateral extent of the plume will be captured; that is, to confirm that the removal action objectives will be achieved. Current groundwater monitoring plans and the follow-up refinement of model calibration in the south plume area will provide for the resolution of these issues. The installation of the 150 gpm advanced wastewater treatment system as part of Alternative 4 is cost effective, technically efficient in preventing an increase in uranium discharged to the Great Miami River, and can be installed in a timely manner.

APPENDIX A

EE/CA GROUNDWATER MODELING

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ACRONYM LIST

EE/CA	engineering evaluation/cost analysis
FMPC	Feed Materials Production Center
RI/FS	remedial investigation and feasibility study

A.1.0 PURPOSE AND SCOPE

The purpose of this groundwater modeling investigation was to support the engineering evaluation and cost analysis (EE/CA) of removal action alternatives for the south plume at the Feed Materials Production Center (FMPC) in Fernald, Ohio. The alternatives include no action, aquifer monitoring and institutional control, installation of an alternate water supply, groundwater pumping to control plume migration, and combinations thereof. The modeling study was necessary to supplement direct field observations so that the combined informational base would be sufficient to support: (1) the understanding of the current situation (i.e., the nature and extent of the contamination); (2) the public health and environmental risk assessment; and (3) the evaluation of the removal action alternatives.

Groundwater monitoring data provides insight into the nature and extent of contamination by establishing whether contamination is present at a specific location and to what level. The results of the modeling study utilize these same data as calibration points to approximate, through interpolation between and extrapolation beyond the field observations, the concentration distribution throughout the area of interest. This exercise can be used to establish the probable location and value of the absolute maximum concentration; estimate the total mass of a contaminant present in the aquifer; help explain the occurrence of the field observations; indicate whether or not any field observations should be considered as outliers; and determine the uncertainties for the planning of additional data collection efforts.

The public health risk assessment involves the evaluation of risk under both existing conditions and anticipated conditions (with and without an action). Direct field observations are often sufficient for the evaluation of current risk since groundwater at the specific locations of all known users can be monitored. On the other hand, model results can be used for the prediction of future conditions. Model predictions describe expected uranium distribution (and thus potential levels of exposure) in both space and time.

The evaluation of alternatives is only sparingly supported by direct field observations. This is due to

the limitation in utilizing current observations for the direct evaluation of future performance. The primary use of the field observations is to establish the present condition and to support the calibration of the model, which in turn is used to evaluate remedial action alternatives. In the case of the south plume, the model is intended to support the following:

- Projection of the likelihood that additional receptors would require an alternate water supply during the life of the action (Alternate Water Supply)
- Identification of the most susceptible receptor locations for additional "early warning" wells or control prioritization (Monitoring/Institutional Controls)
- Evaluation of the effects on plume migration if the industrial wells are shut down (Alternate Water Supply)
- Determination of the size and location of extraction wells to control plume migration (Pump and Treat)
- Evaluation of the effects of pumping on plume behavior at other locations (Pump and Treat)
- Estimation of the discharge rate, average concentration, and mass of uranium removed from extraction wells, support the evaluation of effects of the discharge on surface waters (Pump and Treat)
- Time required to reach the target level for cleanup (Pump and Treat)

The EE/CA, including the groundwater modeling study, was based on information available as of mid-1990. The available water level data from numerous monitoring wells was sufficient for a complete and successful calibration of the groundwater flow model. The results of all applications of the model that involved the groundwater flow component are, therefore, considered very reliable for their intended use.

On the other hand, the predictions of present and future uranium concentrations in the plume resulting from the application of the solute transport model should be viewed as approximations based on the best available data. The extent of the southern, leading edge of the plume remains uncertain due to a scarcity of field data in the area predicted (by the model) to contain the plume front. Results of

additional field investigations forthcoming from the Remedial Investigation/Feasibility Study (RI/FS) for the Environmental Media Operable Unit will improve the reliability of solute transport model predictions in this area.

Because uranium migration is influenced by geochemical factors, the anticipated results of the ongoing geochemical program will also increase the level of confidence in the predictions of future conditions from the solute transport model. Even though concentrations predicted in the present report may be revised as a result, the level of change is not expected to be significant enough to cause a change in the overall findings and conclusions of the EE/CA.

A.2.0 MODEL DESCRIPTION

The groundwater model used in support of the EE/CA for the south plume is a finite-difference computer model of groundwater flow and solute transport. The computer program is SWIFT III, Version 2.25. A detailed presentation of the model, its development, and the baseline input data will be issued as part of the overall modeling report being prepared under the RI/FS. Only the most pertinent information is provided here. A comprehensive verification study of the SWIFT III code has also been completed and a report will be forthcoming under separate cover.

Steps in the development of the model for application to the FMPC have included:

- Construction and calibration of a regional, two-dimensional, steady state, groundwater flow model
- Construction and calibration of a regional, three-dimensional, steady state, groundwater flow model
- Application of two-dimensional analytical solute transport models to help strategize the numerical solute transport model
- Construction of a local, two-dimensional, transient solute transport model
- Construction of a local, three-dimensional, transient solute transport model
- Calibration of the solute transport part of the local model with uranium concentration data from the monitoring wells

The local model covers a smaller area than the regional model (Figure A-1). The smaller area allowed the use of a refined grid with a small cell size, which is necessary for solute transport modeling. The smaller grid area was established to include the area of the existing uranium plume. The local model also covered the area for which uranium concentration data is available from monitoring wells. The interrelationship between the local and regional models is established by imposing the steady-state flow field predicted by the regional model on the solute transport model.

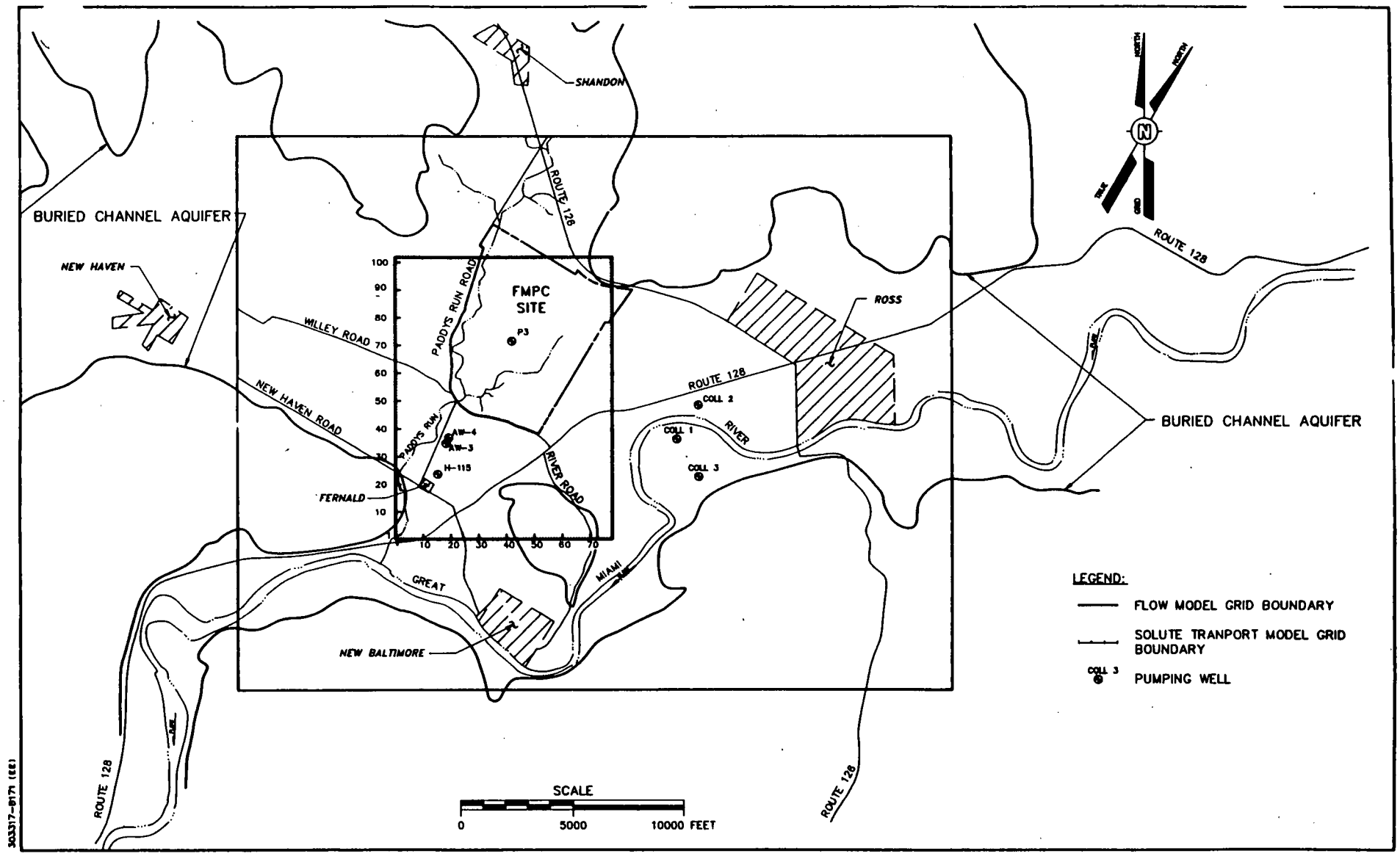

FIGURE A-1
GROUNDWATER MODEL GRID BOUNDARY

The model contains five layers. The uppermost two layers represent the upper and lower parts of the upper alluvial aquifer that underlies the area. The middle layer represents a clay bed that is present in the immediate vicinity of the FMPC site, and the lowermost two layers represent the upper and lower parts of the lower alluvial aquifer. The layers extend laterally into bedrock at the edges of a buried valley that contains the alluvium.

The model uses varying hydraulic conductivity values for the five layers, based on calibration results of the regional model using April, 1986 water level data. This period was used as it represents average groundwater conditions and water level elevations. From the calibration results of the regional three-dimensional flow model, the uppermost and middle layers were assigned a hydraulic conductivity value of 450 ft/day, and the lowermost layers used 600 ft/day. In addition, a portion of the middle layer which underlies the FMPC site was assigned 0.0003 ft/day as a hydraulic conductivity value to represent the area the clay interbed exists in (as shown by geologic borings). This simulated the presence of a low permeability clay and created semiconfining layer underneath part of the site and the surrounding area.

In addition to changing hydraulic conductivity values between layers, the number of aquifer cells presently in each layer was reduced the deeper the layer lies. This was done to simulate the downward narrowing U-shaped buried valley within which the Great Miami Aquifer lies and was accomplished using bedrock topography maps of the region.

Transmissivity values were not used as input for the model; instead, they were calculated by the model during its execution. As saturated thicknesses vary throughout the model, transmissivities vary as well and thus could not be calculated except on a cell-by-cell basis.

Recharge rates for the local model were also taken from the calibration results of the regional three dimensional flow model (Figure A-2). Recharge zones represent the varying soil types, with 6 inches/year representing sand and gravel aquifer overlain by glacial till, 14 inches/year representing sand and gravel aquifer overlain by nothing, and 32 inches/year representing the channel in which

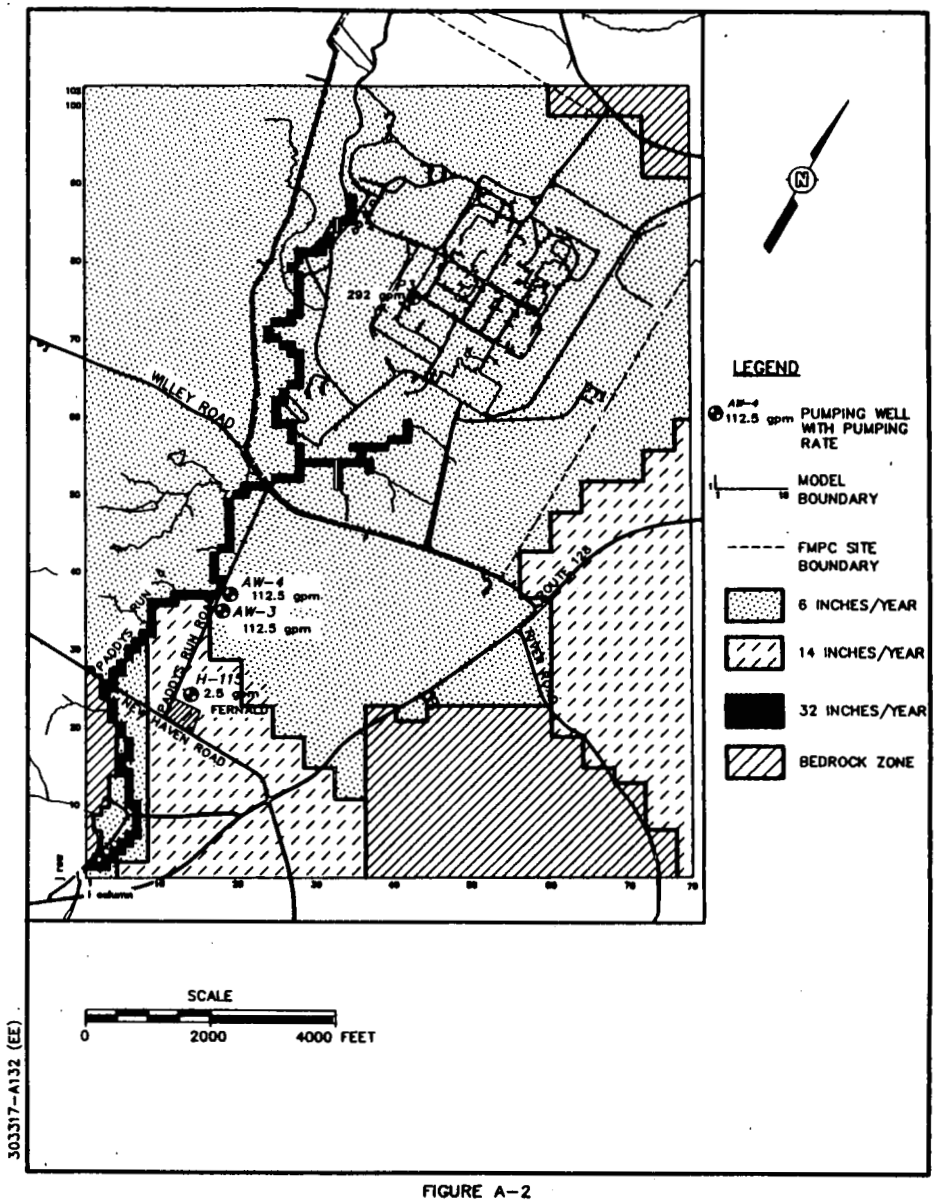

FIGURE A-2
3-DIMENSIONAL
SOLUTE TRANSPORT MODEL
RECHARGE AND PUMPING WELL RATES

Paddys Run flows. The divisions between the zones are based on surficial soil maps of Butler and Hamilton counties (Speiker 1968). Recharge values were derived initially from soil infiltration data and were modified during regional model calibration.

Pumping wells are located in the area spanned by the local model. These include an FMPC production well and three industrial wells located south of the FMPC site. Pumping from each of these wells was assigned to the proper cell and layer in the model. The three industrial wells are within the south plume study area (Figure A-2).

A.3.0 MODEL CALIBRATION

The calibration of the groundwater flow model was performed by comparing hydraulic heads calculated by the model against heads measured in numerous monitoring wells throughout the FMPC and surrounding areas.

This calibration was performed using the regional flow model. Reasonable estimates of hydraulic conductivity and recharge were initially input to the model and then varied within an acceptable range to adjust model-computed heads to agree with observed monitoring well heads. The monitoring well heads used for calibration were measured in 1986.

Both Paddys Run and the Great Miami River were included in the regional flow model and were modeled as being hydraulically linked with the groundwater system. As Paddys Run is basically a losing stream in the model area, it was modeled using a higher recharge rate than surrounding areas in regions where it flows over the alluvial aquifer. In areas where it flows over the glacial till deposits, it was assigned the same recharge rate as surrounding areas (Figure A-2).

The Great Miami River cannot be classified as either a totally gaining or losing river, as it does both within the model area. Where it flows by Collector Wells 1 and 2, (Figure A-1), it is a losing river, but upstream and downstream of this area it is a gaining river. To model this effect, a river leakage coefficient of 0.5 day^{-1} was set in all cells where the river was located. This river leakage coefficient represents the permeability of the river bed materials, and is approximately three orders of magnitude lower than the surrounding aquifer. The river cells also had river elevations set in them, based on river-gaging stations and predicted elevations from river profiles. By using both the river elevations and leakage coefficient, the model is able to calculate inflow/outflow to/from the river based on aquifer heads in the same cells. In this way, both gaining and losing conditions were simulated in the Great Miami River.

Groundwater flow conditions simulated by the model were successfully made to reproduce the observed flow conditions throughout the study area. Based on water levels from 55 wells, the mean residual (observed head minus calculated head at a monitoring well) for the calibrated flow model was 0.21 feet. The excellent fit portrayed by this residual value is realized when compared to a total change in hydraulic head of approximately 20 feet over the south plume area. The mean of the absolute values of the residuals was 1.08 feet. When the local model was constructed, a computer program was used to check, cell by cell, the correspondence of heads in the local model with heads in the regional model. The correspondence verified that the flow model calibration was preserved in the solute transport model.

The calibration of the solute transport model involved the following steps:

- Designating appropriate cells as source cells where uranium may enter the groundwater system, based on the current understanding of historic patterns of uranium release
- Dividing the model time into source loading periods corresponding to intervals during which source loading was probably significantly different from other periods
- Introducing reasonable initial estimates of uranium source loading for each source cell
- Establishing the best initial values of longitudinal and transverse dispersivity, as well as a distribution coefficient for uranium
- Adjusting source loading, source loading periods, dispersivities, and the distribution coefficient until concentrations calculated by the model are close to concentrations measured in the field

Source areas in the model were derived from site historic data which defined regions of contamination and pathways for contaminant transport. Based on this data, a number of regions, including Paddys Run, the storm sewer outfall ditch, the waste pits, the sewage treatment plant, and point sources within the FMPC production area, were all defined as potential source areas. Although all these areas were recognized as potential source areas, not all of them were used to load uranium contamination into the model. Rather, areas during calibration which caused concentrations to match those from field data were used primarily, while other areas were not used at all.

Initial loading rates and time periods were taken from literature reviews of the site's operation and estimates of the rates of contaminant escape. This data, for the most part, dealt with leakage rates from the waste pits and outflow events through the storm sewer outfall ditch. Comparison of leakage periods to each other showed four distinct time periods during which different source loading rates existed. These four periods represent the various operational times of the waste pits and in total encompass a 37-year period, extending from 1952 (when Waste Pit 1 was constructed) to 1989 (when the modeling study was ended).

Calibration of the model against measured site concentration data changed the active source areas and loading rates originally derived from the literature reviews. At no time were the loading periods or the potential source areas changed during the calibration; these were assumed to be fixed and unchangeable. Source rates and active source areas were allowed to be changed during calibration, as these were the variables that were used to match the site concentration data.

Modeling the south plume in this manner not only matched the present site groundwater data but also allowed the model to simulate the historical development of the groundwater plume. As predicted loading rates from the literature review were used as a basis for initial model-loading rates, the model was able to simulate the development of the plume from older source areas and not just as a large loading pulse from new sources. This allowed the formation of the general shape of the south plume by older periods, while newer source periods gave the plume more definition and finer detail. In this way the model derived the south plume, not as a large pulse of contaminant but rather as a long-term groundwater plume sourced by both older and newer source areas.

The distribution coefficient was set at 0.016 cubic feet per pound, which corresponds to a retardation factor of 9. After attempting calibrations with distribution coefficients corresponding to retardation factors of 1, 6, and 12, a retardation factor of 9 was selected as the most reasonable compromise between two competing goals. These goals were to keep the dispersivities as close to 100 feet as possible and to keep the distribution coefficient as low as possible. The preference for a dispersivity of 100 feet was based on information in the scientific literature. Walton (1985, Figure 2.16) presents a

graph of mean travel distance versus longitudinal dispersivity. Assuming a mean travel distance in the south plume of 2500 feet, Walton's graph yields a longitudinal dispersivity of a little over 100 feet. Walton also shows representative longitudinal dispersivities for areal models of alluvial sediments and glacial deposits to be between 39 and 200 feet. The desire to keep the distribution coefficient low was based on preliminary results of the geochemical investigation, which suggest that the uranium is in complexes which have neutral or negative charges. Such charges imply low retardation.

Because the plume is narrow and has high concentration gradients away from the center, the concentration patterns could be matched by having either a sufficiently high retardation factor or a sufficiently low dispersivity. Calibration with a retardation factor of 9 yielded a longitudinal dispersivity of 50 feet and a transverse dispersivity of 1 foot. The model uses transverse dispersivity for vertical dispersivity, so the calibrated transverse dispersivity tends to be low. Although the outcome of the geochemical investigation may result in a different retardation factor, the value of 9 is sufficiently realistic to allow for provisional application of the solute transport model in this study.

Statistics used to characterize the degree of calibration were based on monitoring data from wells that yielded detectable uranium in all samples. The object of the calibration was to produce a representative simulated plume. Calibration was performed by comparing calculated concentrations to the mean values of concentrations measured at the individual wells. Since the mean of observed concentrations at a well where only a few concentrations have been measured is not an accurate estimate of the most representative value for that well, such means were not matched more closely than their accuracy warranted. Instead, the model calibration emphasized (1) avoidance of excessive clumping of positive or negative residuals (observed mean concentration at a well minus the calculated concentration at the well), and (2) keeping the absolute values of the residuals reasonably low.

The first calibration criterion, clumping, was examined by calculating the unit normal deviate from a modification of Moran's I (IT Corporation 1987). A value greater than 1.645 indicates a nonrandom distribution of residuals at the 0.05 level of significance. The optimal value is zero. The value calculated for the calibrated run was 0.144.

The second calibration criterion, reasonably low absolute values of residuals, was examined by using a statistical procedure to determine whether the calculated concentration at an observation well differs from the mean concentration observed there by an improbable amount. The statistical testing procedure used for this purpose followed methods described by Grubbs (1969). This method of testing goodness of fit is more informative than simply measuring deviations from means because it includes uncertainty related to the representativeness of the observed concentrations (sample) at a given well. It allows less deviation from means of large samples and/or samples with little variation in values, but allows greater deviation from means based on only a few samples (only two samples had been collected at some wells) and/or means based on samples with much variation in values. The result of applying this procedure was that no calculated concentration within the plume defined by the 30 microgram per liter (µg/L) contour was significantly different from the observed mean for the well when tested at a level of significance of 2.5 percent. The calculated concentrations were judged to be sufficiently representative of the true mean concentrations in the plume.

Calibration of the solute transport model is provisional. As mentioned above, geochemical work which might supply a better estimate of the distribution coefficient is not complete. A different distribution coefficient would require compensating adjustments in the dispersivity value and the source loading rates to maintain the model calibration.

A.4.0 MODEL APPLICATION

A.4.1 BASELINE CONDITION: NO-ACTION ALTERNATIVE

The model results representing the current distribution of uranium in the south plume are shown in Figure A-3. Only the uranium values in the uppermost layer of the aquifer are shown since the highest observed values were from this layer. The maximum concentration in the plume is predicted to be approximately twice the maximum observed value and to lie northeast of the well with the highest observed level. The maximum concentration is also some distance downgradient from the source locations. This result indicates that the plume is affected by source loadings that were greater in the past than they are now. It is also important to note that a steep gradient of uranium concentrations is predicted to exist near several potential receptors and existing monitoring wells along Paddys Run Road.

For purposes of this study, the boundary of the plume has been defined to be the 30 µg/L isoconcentration contour, which is equivalent to the derived concentration limit for uranium in groundwater. It is also noted that the 30 µg/L uranium concentration limit represents elemental uranium, but uranium present in the Great Miami Aquifer is generally in the form of uranium complexes. Geochemical modeling indicates that uranium most commonly occurs as the complexes $UO_2(CO_3)_3^{-4}$ and $UO_2(CO_3)_2^{-2}$ in groundwaters from the aquifer. In some cases $UO_2(H_2PO_4)_3$ may form when inorganic phosphates are present, which they are through parts of the aquifer. All three of these complexes are fairly mobile, and thus can be expected to migrate in the present groundwater system. Thus, the presence of high concentrations of phosphorus around Paddys Run Road will not adversely impact the removal action of the interceptor wells. Rather, it is expected the phosphorus will simply change complexes to become $UO_2(H_2PO_4)_3$, which is expected to be slightly more mobile due to its neutral charge than the other species and thus will be extracted more efficiently. The boundary of the existing plume, as produced by the model, is shown in Figure A-3.

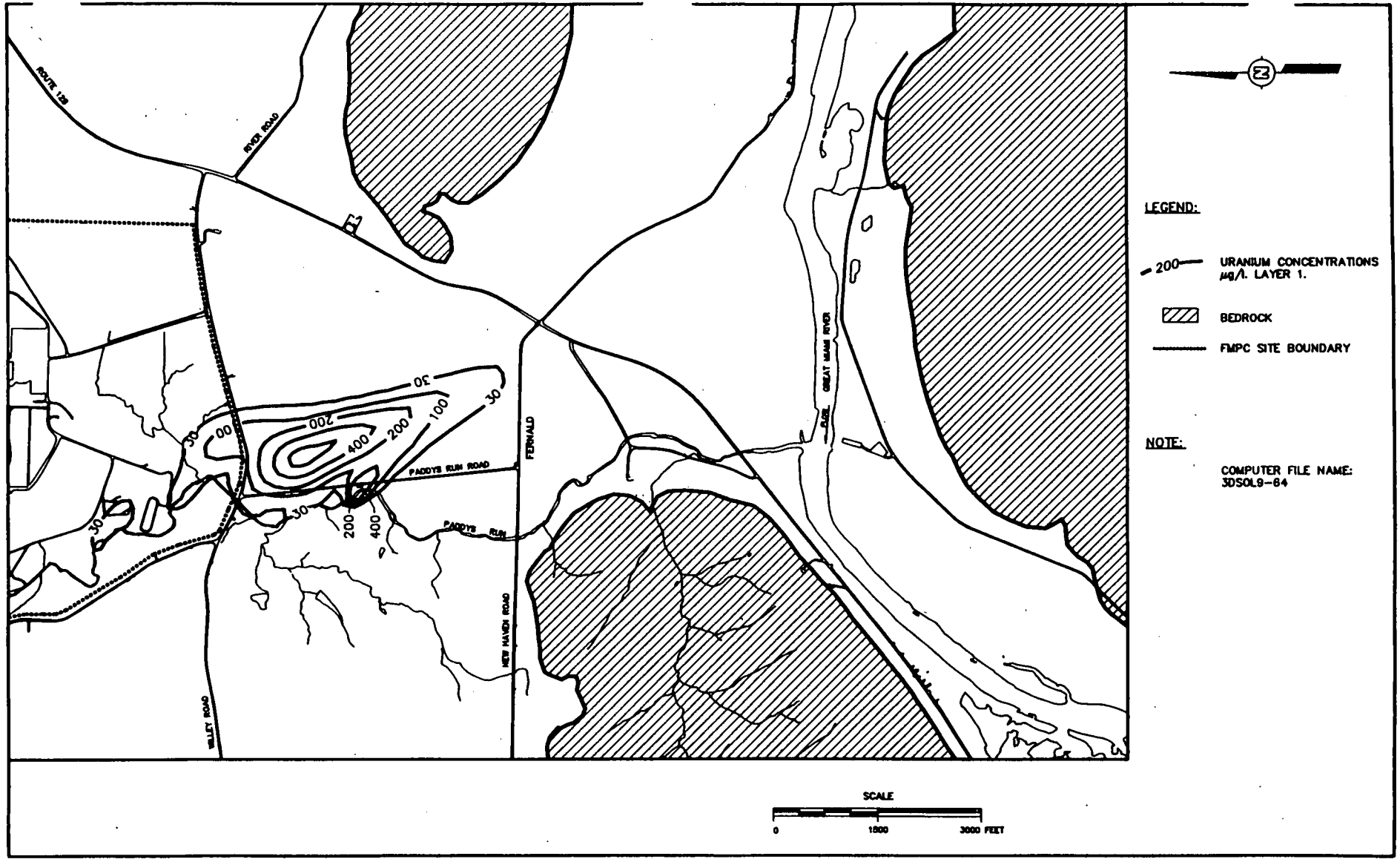

FIGURE A-3
SIMULATED URANIUM CONCENTRATIONS
PRESENT CONDITIONS

Modeling future concentrations under the no-action alternative was completed by extending the estimates of present source loadings five years into the future. This scenario results in the conditions shown in Figure A-4. The crest of the plume moves south about 1100 feet and the maximum concentration declines about 170 µg/L, or approximately 25 percent, due to plume dispersion.

The results presented in Figures A-3 and A-4 were generated by the solute transport model and are thus subject to the uncertainties discussed in previous sections. However, the presentation of existing conditions should not be greatly affected by such uncertainties since it represents the model run that was calibrated against field observations. The overall shape of the plume and the general magnitude of the values for both existing and future conditions are considered to be representative of field conditions.

A.4.2 ALTERNATE WATER SUPPLY ALTERNATIVE

The proposed source of the alternate water supply is a well located near Willey Road, 1750 feet west of the FMPC boundary. Particle tracking was used in conjunction with the groundwater flow model to investigate whether operation of this well at a 500 gpm flow rate would pull water from the plume. The results are presented in Figure A-5. These results show that the particle tracks in the plume are not distorted by the simulated production well; therefore, the well would not draw water from the plume. To verify this, these particle tracks were compared with the no-action scenario, again showing that the simulated production well has little effect on the particle tracks.

A.4.3 PUMPING ALTERNATIVES: PLUME INTERCEPTION

The location and pumping rates for interceptor wells that will produce a hydraulic control to the southward movement of contaminated water in the south plume were selected by introducing a line of wells with various spacings and pumping rates into the model. Particle tracking was used to determine whether water upgradient from the wells and within the lateral and vertical boundaries of the plume would be drawn into them.

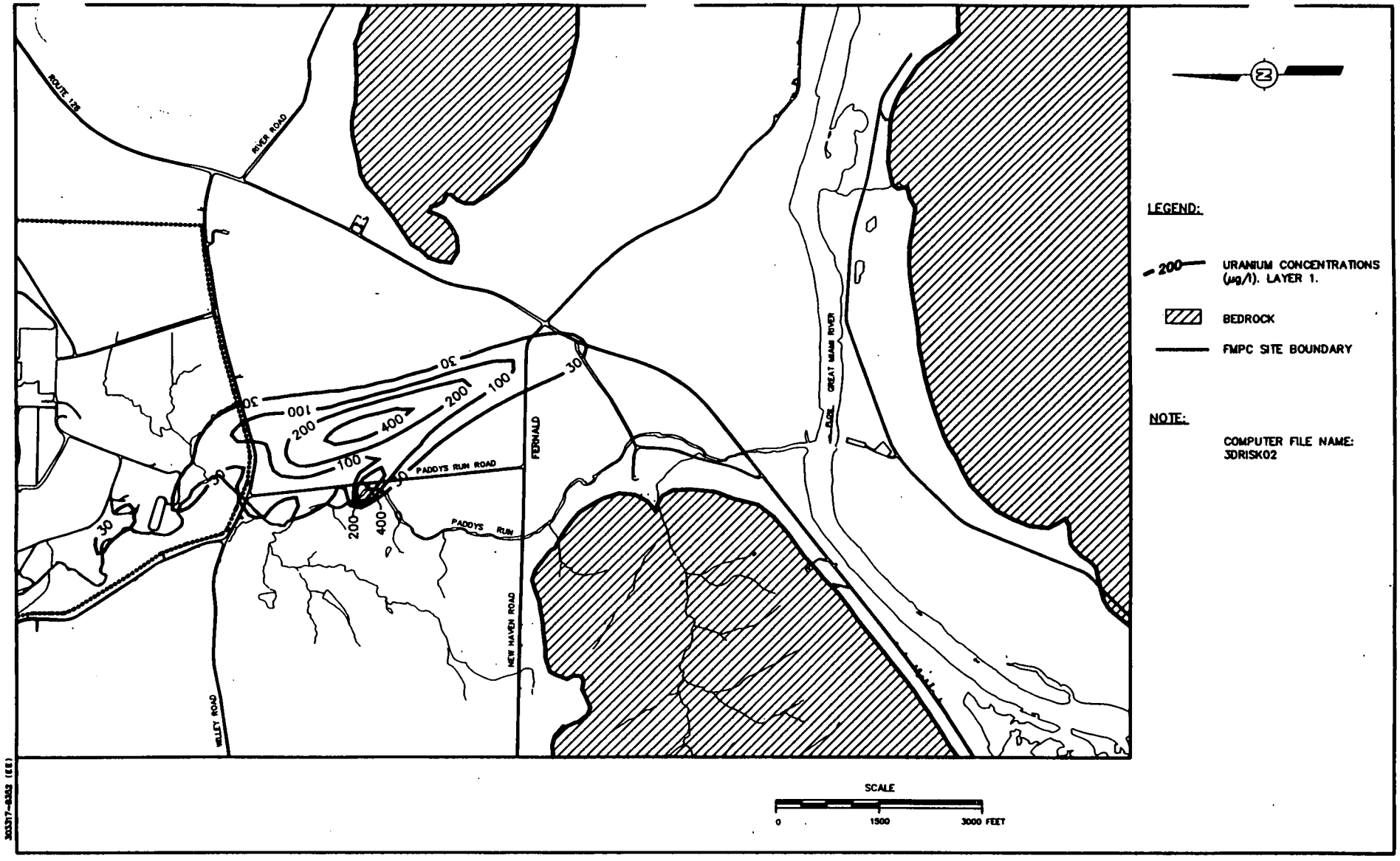

FIGURE A-4
SIMULATED URANIUM CONCENTRATIONS
NO - ACTION CONDITIONS
FIVE YEARS FROM PRESENT

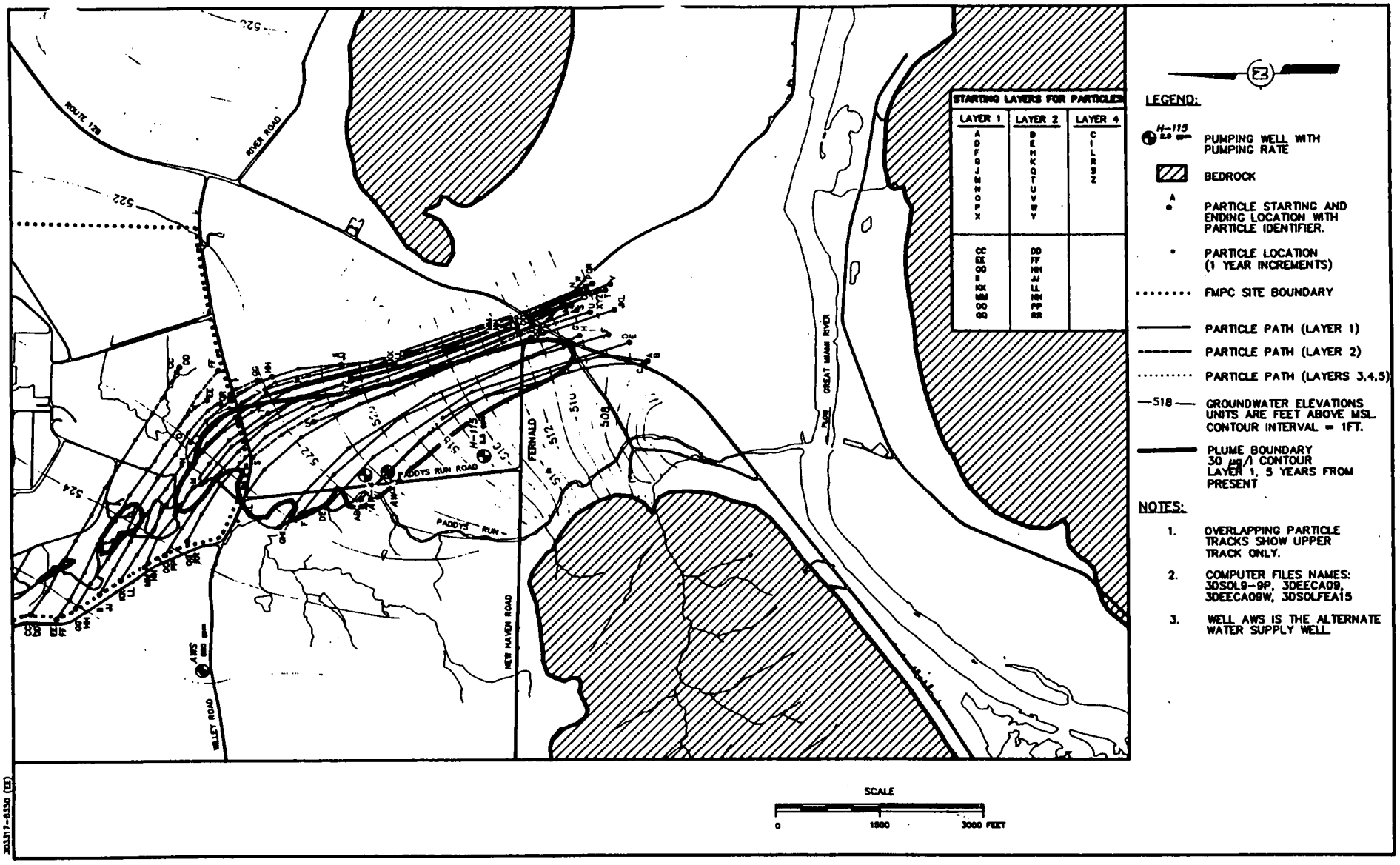

FIGURE A-5
PARTICLE TRACKING
ALTERNATE WATER SUPPLY
ALTERNATIVE

Particle tracking is a technique for determining and depicting the three-dimensional movement of groundwater in a finite-difference flow model. In the present investigation it involved processing output from the local SWIFT III model via a computer program named STLINE (GeoTrans 1987). STLINE computes the positions of particles moving in the direction of flow and at the average velocity of water in the porous material. The STLINE program accepts particle initial positions supplied by the user and computes the positions of the particles at the ends of specified time periods. The STLINE output describes the tracks of the particles as they move through the system.

Initial positions of particles were placed within the plume, along the lateral and vertical boundaries of the plume upgradient from the general location of future pumping, and along Paddys Run. Figure A-4 shows the particle tracking if no action is taken (i.e., no pumping). The plume is shown to migrate in a south-southeasterly direction. The focusing of flow lines from all along Paddys Run into the narrow trough of the aquifer is also demonstrated by the particle tracking.

The particles were then strategically placed in a sufficient number of locations to determine whether all water in the plume upgradient from any pumping wells would be intercepted. The results of the particle tracking for the recommended interceptor well system are shown in Figure A-6. The interceptor well system shown in Figure A-6 was selected after trying and rejecting several other possibilities. The rejected well systems included the following:

- Three wells spaced 560 feet apart and pumped at 500 gpm each did not capture all of the particles from the central part of the plume.
- Three wells near the center of the plume spaced 280 feet apart and pumped at 500 gpm each also did not intercept all particles from the eastern part of the plume.
- Five wells spaced 280 feet apart and pumped at 500 gpm each captured all particles from the plume, but involved pumping more water than the selected option described below.
- Three middle wells pumped at 500 gpm each and two end wells pumped at 250 gpm each, with all wells spaced 280 feet apart, failed to capture particles from lower layers in the eastern part of the plume.

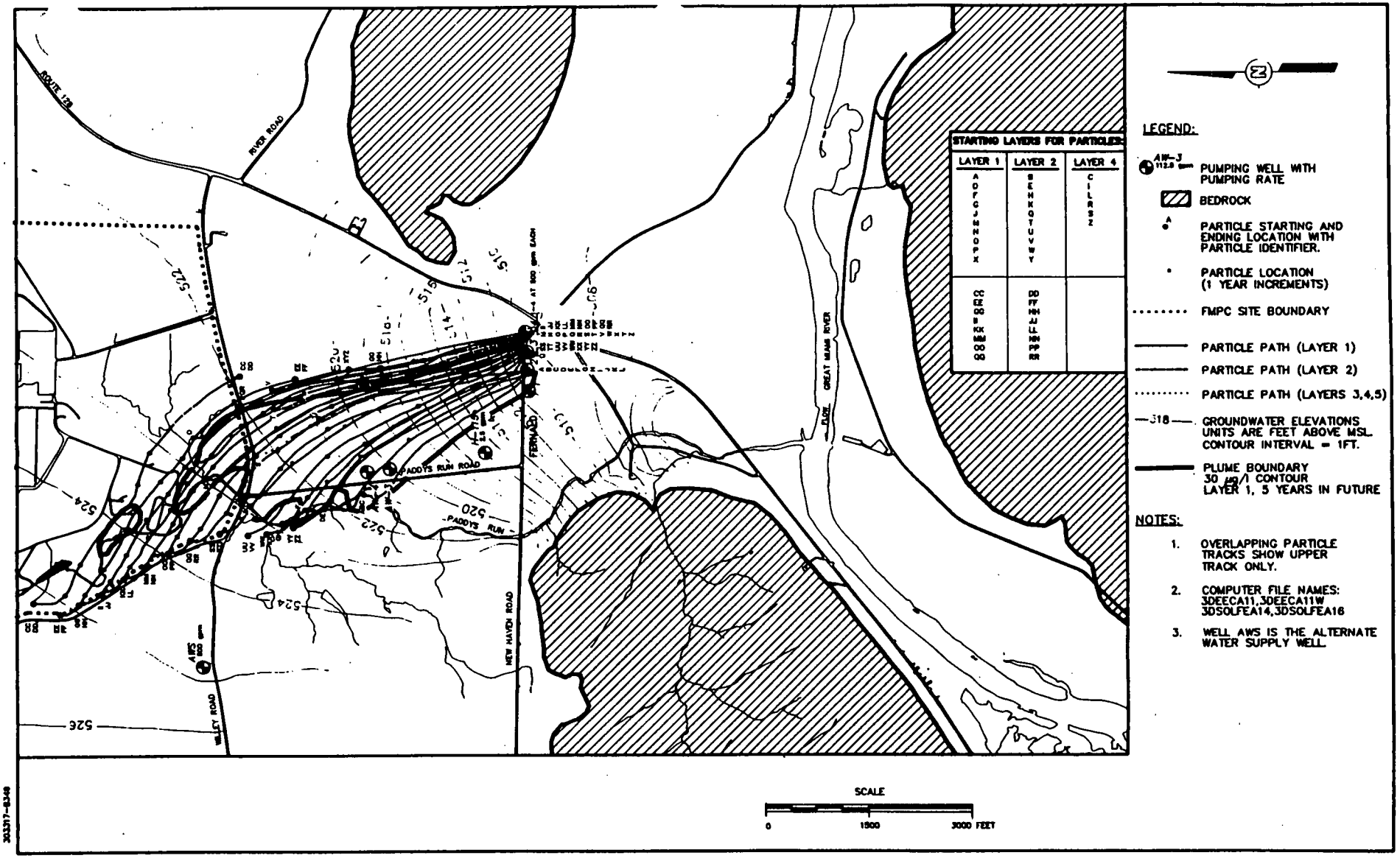

FIGURE A-6
PARTICLE TRACKING
FOR PLUME INTERCEPTION
ALTERNATIVE

The system selected used four wells spaced 280 feet apart with each well pumping at 500 gpm. This case was subjected to detailed particle-tracking analysis and captured all particles seeded in the plume north of the wells. Drawdown at the wells after five years of pumping was calculated at 8.1, 8.5, 8.5, and 8.2 feet from west to east. Well loss was not included in these calculations so the values represent drawdown in the aquifer. Contours of drawdown caused by the interceptor wells are shown in Figure A-7.

The alternately proposed scenario of four pumping wells located in the center of the south plume was also evaluated in the same manner. Four wells utilizing the same 280 foot spacing and 500 gpm pumping rate were located in a line near the center of the plume. Results of both the particle-tracking analyses and predicted plume shape are shown in Figure A-8. As can be seen, although the wells are able to effectively capture and remove all particles seeded north of themselves, they are unable to reverse gradients enough to affect the portion of the plume that has already moved past them. As the southern half of the plume is the portion which will reach potential receptors first, this scenario is deemed unacceptable as it is unable to affect or contain the critical portion of the plume. The analysis of the location and number of pumping wells utilized only the groundwater flow model, which has been thoroughly calibrated against a considerable database of field observations. Consequently, there exists a high level of confidence that the recommended system will be effective in capturing the plume north of the pumping wells.

A.4.4 PLUME BEHAVIOR

Simulated uranium concentrations in the plume corresponding to existing conditions were shown in Figure A-3. This distribution of uranium provided the initial condition for the evaluation of the effects of the pumping alternatives on plume behavior. (Note that no other alternative would have a significant effect on the future migration of the plume.) The simulated concentrations in the plume after five years with the selected well system in operation are shown in Figure A-9.

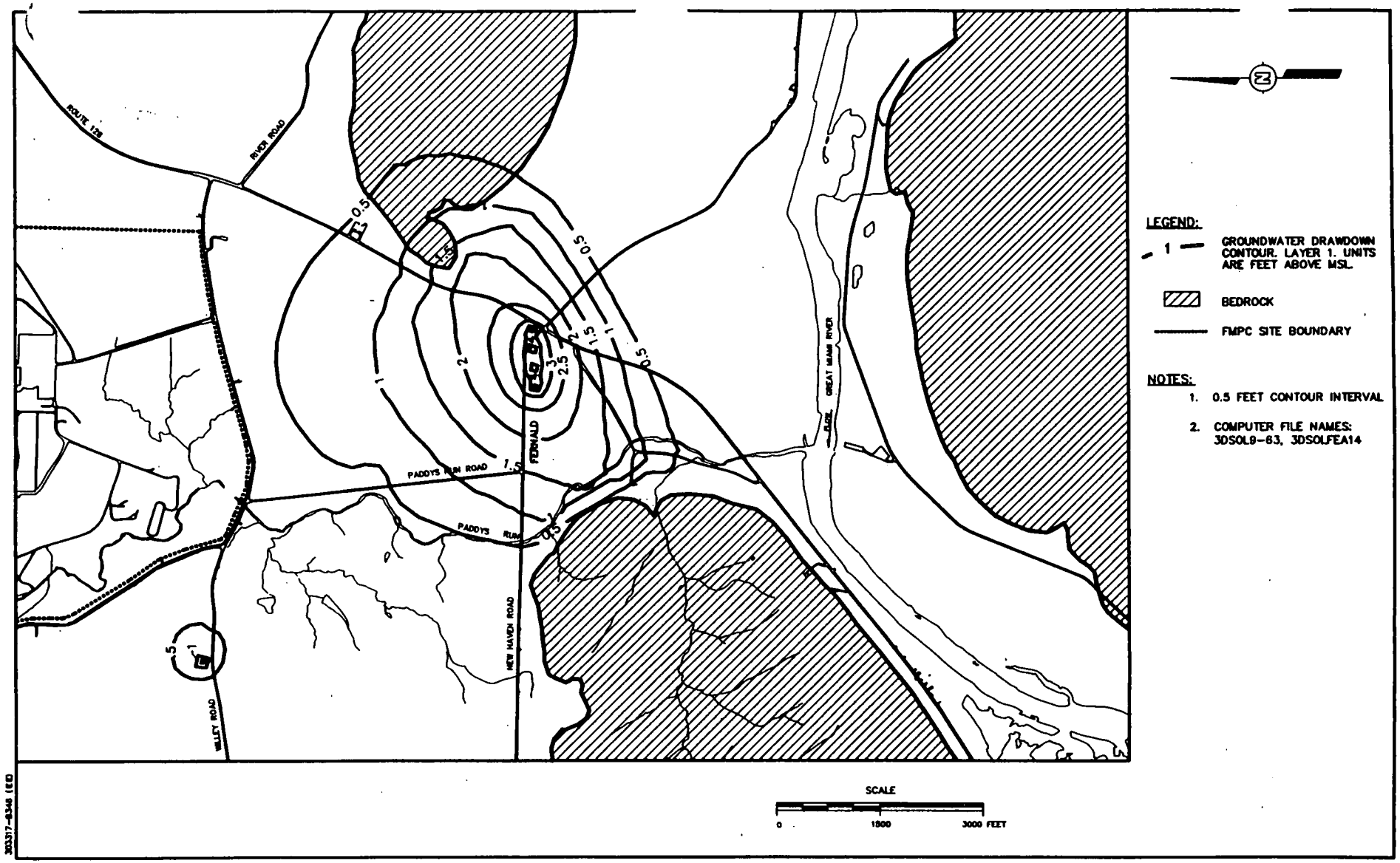

FIGURE A-7.
DRAWDOWN DUE TO
GROUNDWATER INTERCEPTOR WELLS

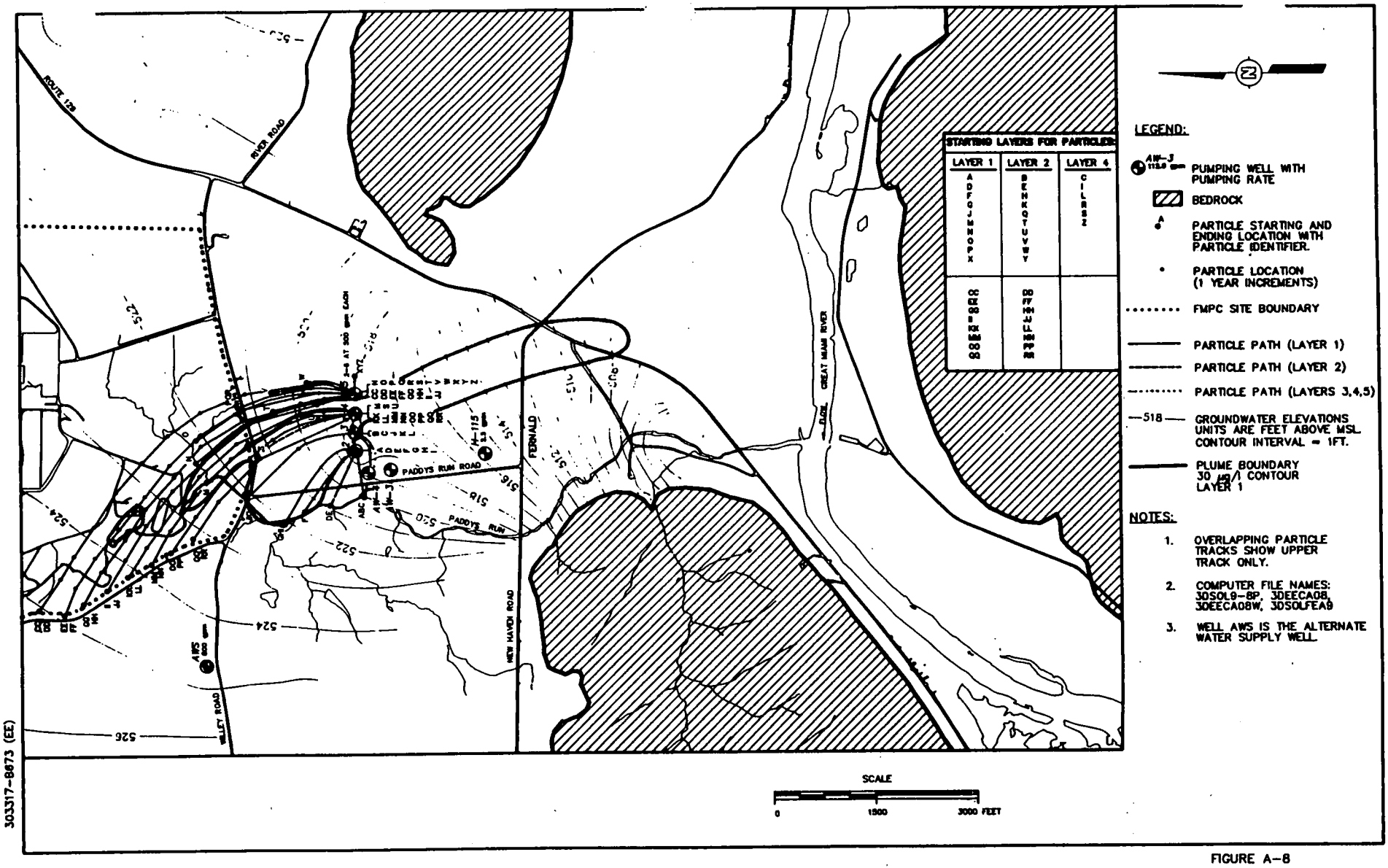

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FIGURE A-8

PARTICLE TRACKING FOR CENTRAL PLUME INTERCEPTION ALTERNATIVE

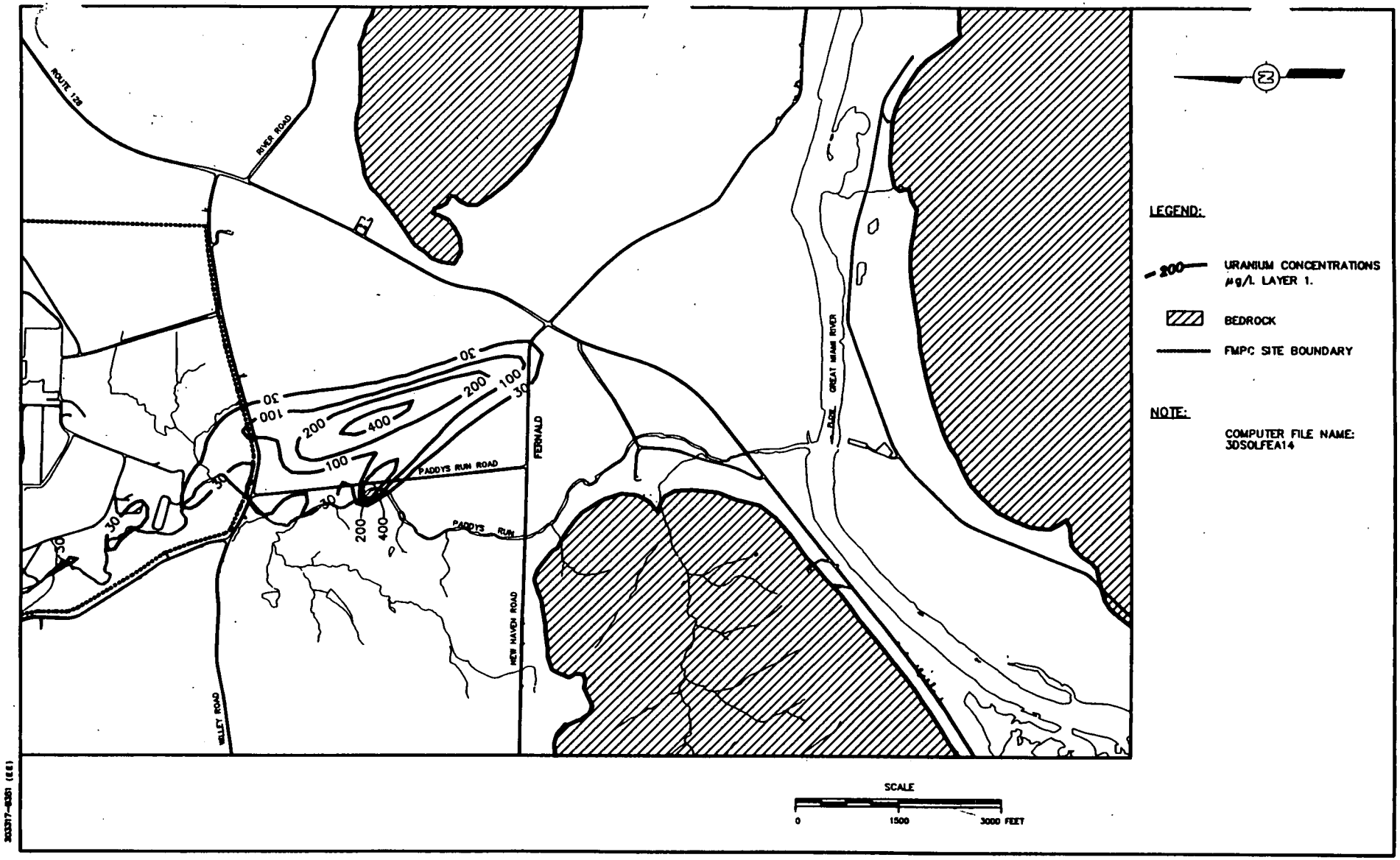

FIGURE A-9
SIMULATED URANIUM CONCENTRATIONS
FIVE YEARS FROM PRESENT WITH
INTERCEPTOR WELLS

The effect of the interception well system on the concentrations in the plume may be seen by comparing Figure A-9 with Figure A-3, which showed the predicted concentrations after the same time period under a no-action scenario. The plume is shown to be less dispersed as a result of the pumping action, which is important to the eventual selection of a final remedy to supplement the proposed removal action. The maximum concentration in the plume after five years of operation is predicted to be reduced from 509 µg/L for the case when interceptor wells are not operating (i.e., no action) to 490 µg/L when the wells are in operation. This minor reduction in the maximum concentration is due to the fact that the wells are placed at the leading edge of the plume and high concentrations of uranium are not removed by the wells within the first few years of operation. The placement of the wells near the southern leading edge of the plume was intended to protect groundwater users at downgradient locations.

The change in uranium concentration over time at the pumping wells is shown in Figure A-10. The calculated amount of uranium removed by the wells during five years of continuous operation is shown in Figure A-11. Although these results are approximations limited by the reliability of the solute transport model, the temporal patterns and the general magnitude of the mass removed are sufficiently accurate to draw two important conclusions. First, the amount of uranium removed increases with each year as the higher concentrations within the plume move southward toward the pumping wells. Second, it is likely that the goal of equivalent mass removal can be met during the later years of pumping when the removal amounts are at a maximum. Future refinement of the model results are not expected to change these general conclusions.

After the removal action has been selected and implemented, field validation of the solute transport model is recommended. Strategically placed monitoring wells could be used to track the response of the real system to the alternative selected, and appropriate action could be taken if the observed uranium concentrations deviate significantly from the expected values.

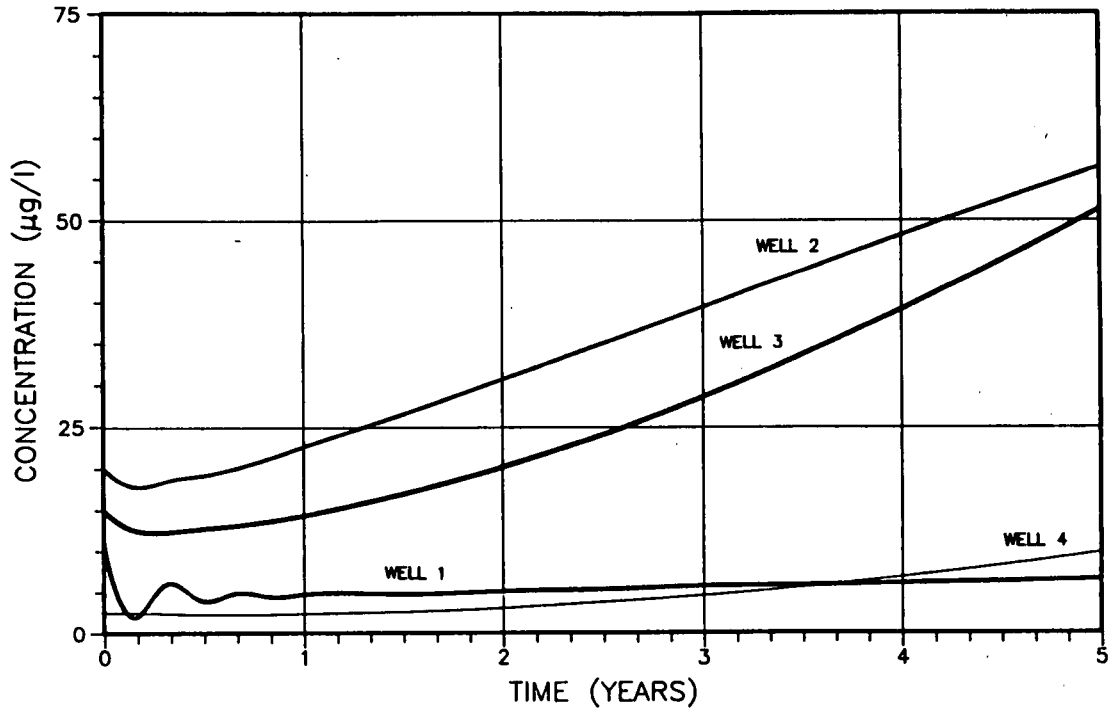

FIGURE A-10
URANIUM CONCENTRATION VS TIME
FOR INTERCEPTOR WELLS

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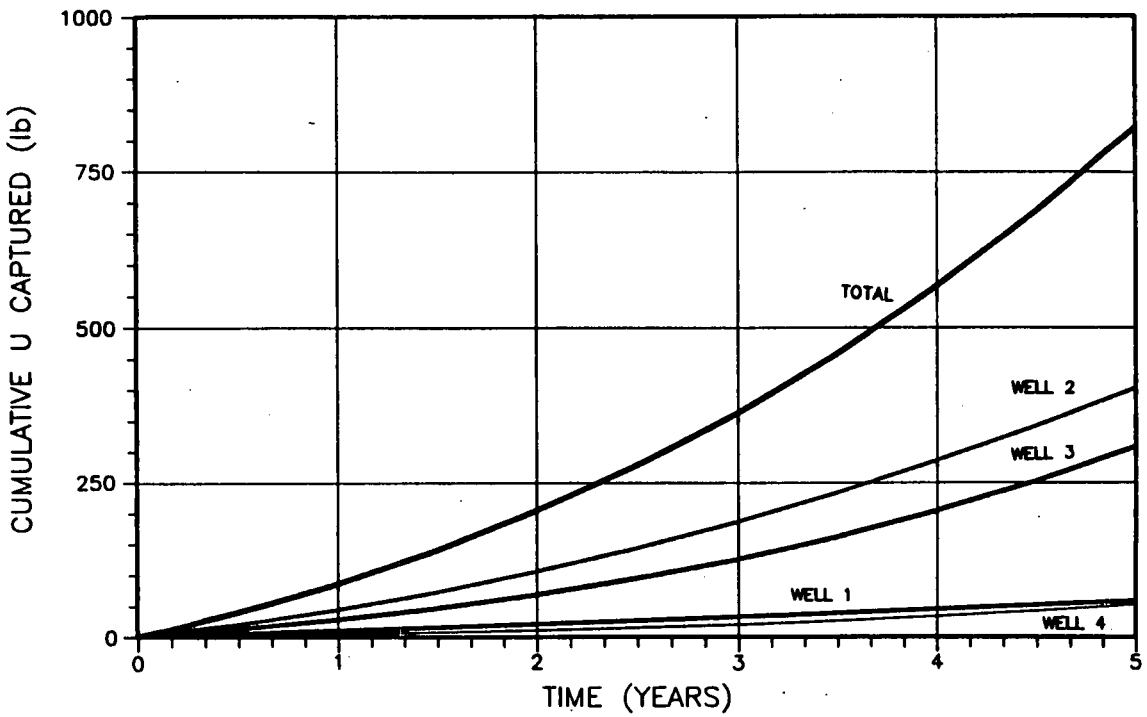

FIGURE A-11
CUMULATIVE URANIUM CAPTURED
VS TIME
FOR INTERCEPTOR WELLS

REFERENCES

REFERENCES

Geotrans, Inc., 1987, "STLINE, Version 1.9," User's Manual, Geotrans, Inc., Herndon, VA.

Grubbs, F. E., 1969, "Procedures for Detecting Outlying Observations in Samples," Technometrics, Vol. II, No. 1, pp. 1-21.

IT Corporation, 1987, "GEOSTAT, A Statistical Program for Examining the Goodness of Fit of Groundwater Modeling Data," Users Manual, IT Corp., Monroeville, PA.

Speiker, A.M., 1968, "Groundwater Hydrology and Geology of the Lower Great Miami River, Ohio", U.S. Geological Survey, Professional Paper 605-A, 37 pp., available from U.S. Government Printing Office, Washington, DC.

Walton, William C., 1985, "Practical Aspects of Groundwater Modeling," National Water Well Assn., Worthington, OH.

U.S. Department of Energy, August 1990, "Engineering Evaluation/Cost Analysis - Waste Pit Area Stormwater Runoff Control," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

APPENDIX B
COST ESTIMATES

COST ESTIMATE FOR ALTERNATIVE 2
MONITORING AND INSTITUTIONAL CONTROLS

Assumptions

- Access to the property is granted by all landowners
- Multiple visits are not required
- Work is done by local (on site) personnel
- Sampling equipment is available
- More than ten samples are taken in any one sampling event
- Samples are taken quarterly (four events per year)
- Analyzed for total uranium only
- Sample twenty wells

I.	Labor/Equipment	
	Two persons for six days per event with all sampling equipment	$ 2,000
II.	Shipping	
	$100/day X 6 days	600
III.	Analytical	
	$120/well X 20 wells	2,400
IV.	Report Preparation	
	30 Copies	2,000
	SUBTOTAL	**$ 7,000**
	X 4 events/year	28,000
	Contingency @ 20%	5,600
	TOTAL	**$ 33,600**

COST ESTIMATE FOR ALTERNATIVE 3
ALTERNATE WATER SUPPLY

I.	Mechanical	
	- Trenching: 6000 LF (2 ft. wide X 5 ft. deep)	$ 93,500
	- Piping: 6000 LF (6 in. diam. X 5 fittings/100 ft.)	$ 266,000
	- Sleeving: Under Roadway	$ 27,700
	- Valves, Fittings	$ 6,500
	SUBTOTAL	**$ 393,700**
II.	Wells	
	Industry Replacement: Two @ 350 gpm	$ 111,300
	Industry Replacement: One @ 50 gpm	$ 15,000
	SUBTOTAL	**$ 126,300**
III.	Electrical	$ 5,500
	SUBTOTAL	**$ 525,500**
	Rust Construction Management @ 24%	$ 126,100
	SUBTOTAL	**$ 651,600**
	Engineering and Subcontractor Administration	$ 54,000
	SUBTOTAL	**$ 705,600**
	Escalation (To 1Q FY91 @ 6.3%)	$ 44,500
	SUBTOTAL	**$ 750,100**
	Contingency 20%	$ 150,000
	TOTAL	**$ 900,100**

COST ESTIMATE FOR ALTERNATIVE 3

(Continued)

IV.	Operating & Maintenance Costs:	
	Monitoring Costs (See Alternative 2 Estimate)	$ 33,600/yr
	OPERATOR:	
	(For periodic inspection and routine maintenance of pumps.) 8 hrs/month - 96 hrs/yr x $25.35/hr	$ 2,400/yr
	WATER SAMPLE ANALYSIS:	
	2 sample analysis/year - analysis $2000 x 2	$ 4,000/yr
	SUBMERSIBLE PUMPS, VALVES:	
	Pumps, valves maintenance (oiling, valve packings, replacement, etc.)	$ 600/yr
	INSTRUMENTATION/ELECTRICAL ADJUSTMENT:	
	2 times/year - 1 day each time 16 hrs/yr x $25.85/hr	$ 400/yr
	ELECTRICITY:	
	50 HP pump - 60% eff. (15 hrs/day - 365 days/yr) - 340,360 kw hr/yr	
	$0.10/kw hr x 340,360 kw hr/yr	$ 34,000/yr
	SUBTOTAL	**$ 75,000/yr**
	Contingency @ 20%	$ 15,000
	TOTAL	**$ 90,000/yr**

COST ESTIMATE FOR ALTERNATIVE 4

PUMP AND TREAT

I.	Mechanical:	
	Pumphouse Equipment	$ 41,100
	Forced Main (Pumphouse to MH 175)	$1,851,800
	SUBTOTAL	**$1,892,900**
II.	Tank Erection	$ 19,800
III.	Well Subcontract:	
	Recovery Wells and Pumps	$ 297,100
	Monitoring Wells	$ 158,600
	SUBTOTAL	**$ 485,500**
IV.	General Subcontract:	
	Site Improvements	$ 23,800
	New Building (Pumphouse)	$ 138,400
	SUBTOTAL	**$ 162,200**
V.	Seeding	$ 63,700
VI.	Structural Materials - Pumphouse	$ 63,200
VII.	Masonry	$ 20,000
VIII.	Painting	$ 7,000

COST ESTIMATE FOR ALTERNATIVE 4

(Continued)

IX.	Electrical:	
	New Building - Lighting	$ 18,300
	Power	$ 35,400
	Pumphouse - Electrical Dist.	$ 6,600
	Communications	$ 23,700
	SUBTOTAL	**$ 84,000**
X.	Instrumentation	$ 114,200
	SUBTOTAL	**$2,892,700**
	Rust Construction Management @ 24%	$ 694,200
	SUBTOTAL	**$3,586,900**
	Sales Tax @ 5.5%	$ 131,600
	SUBTOTAL	**$3,718,500**
	Escalated 3Q FY 92 @ 11.4%	$ 423,900
	SUBTOTAL	**$4,142,400**
	Contingency @ 15%	$ 621,400
	SUBTOTAL	**$4,763,800**
	Alternate Water Supply (See Alternative 3 Estimate)	$ 900,000
	SUBTOTAL	**$5,663,800**
	"Interim" Advanced Wastewater Treatment System	$1,200,000
	TOTAL	**$6,863,800**

COST ESTIMATE FOR ALTERNATIVE 4

(Continued)

XI. OPERATING & MAINTENANCE COSTS:

Monitoring Costs (See Alternative 2 Estimate)	$ 33,600/yr
Alternative Water Supply (See Alternative 3 Estimate)	$ 90,000/yr
PUMP & TREAT:	
Operation for inspection & routine maintenance 1 hr/wk x 52 wk/yr = 52 $\frac{hr}{yr}$ x $25.35/hr	$ 1,300/yr
Sampling and Analytical Costs 1/wk x 52 wk/yr = 52/yr x $500/sample	$ 26,000/yr
ELECTRICITY:	
350 HP pump - 60% eff (24 hrs/day - 365 $\frac{days}{yr}$) - 3,812,060 $\frac{kw\ hr}{yr}$ $0.10/kw hr x 3,812,060 $\frac{kw\ hr}{yr}$	$ 381,200/yr
Maintenance Costs (pumps, valves & other accessories) (3% - Capital Cost $4,763,800)	$ 142,900/yr
Operating and Maintenance of the "Interim" Advanced Wastewater Treatment System	$ 100,000/yr
SUBTOTAL	**$ 775,000/yr**
Contingency @ 20%	$ 155,000/yr
TOTAL	**$ 930,000/yr**

APPENDIX C
RISK ASSESSMENT

APPENDIX C
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LIST OF ACRONYMS

CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
HI	hazard index
ICRP	International Commission on Radiological Protection
LOAEL	lowest observed adverse effect level
NCRP	National Council on Radiation Protection and Measurements
RfD	reference dose
RI/FS	remedial investigation and feasibility study
SARA	Superfund Amendments and Reauthorization Act

C.1.0 INTRODUCTION

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) pertaining to environmental impacts associated with DOE's Feed Material Production Center (FMPC) in Fernald, Ohio. The FFCA is intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly and adequately investigated so that appropriate response actions can be formulated, assessed, and implemented.

In response to the FFCA, DOE initiated a Remedial Investigation/Feasibility Study (RI/FS) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The FFCA was amended on April 9, 1990, by a Consent Agreement which incorporated an operable unit approach to the RI/FS and identified specific removal actions to be conducted by DOE.

One of the identified operable units for the FMPC includes those environmental media that serve as migration pathways and/or environmental receptors of radiological or chemical releases on and from the FMPC. Important elements of this operable unit are the areas of the regionally important Great Miami Aquifer that exhibit elevated levels of uranium both within and outside the FMPC boundary. Because of the location of portions of the uranium plume within developed areas south of the FMPC boundary and the associated potential threat to human health, and in providing consistency with removal action commitments in the Consent Agreement, DOE is evaluating a removal action for this area or "south plume" prior to the completion of the RI/FS and the implementation of a final remedial action for the regional aquifer.

Once a non-time-critical removal action is deemed appropriate (which applies to the south plume since there is more than six months time available for planning), an engineering evaluation/cost analysis (EE/CA) is performed to analyze removal action alternatives and to support the selection of a preferred alternative. An essential part of the EE/CA is the assessment of health risks associated with each removal action alternative. This appendix presents the results of the human health risk assessment for

the EE/CA for the south plume. The risk assessment is performed for the "no action" alternative as well as for each removal action alternative. The results of this risk assessment are used as part of the evaluation of removal action alternatives.

The process used in this risk assessment for the south plume generally follows EPA guidance for human health risk assessments (EPA 1989a). The first step in the completion of the risk assessment involves the identification of all constituents, both radionuclides and hazardous chemicals, of potential concern. Results of this step of the risk assessment are given in Section C.2.0.

Once chemicals and radionuclides of potential concern are identified, the process is directed toward the exposure assessment (Section C.3.0) that includes both the characterization of an exposure setting and the identification of exposure pathways. Exposure pathways are identified by describing how humans may be exposed to contaminants originating from the south plume. Each pathway consists of:

- A source of contamination
- A mechanism for transporting the contaminant through an environmental medium to a point of exposure
- A potential receptor at the location of exposure
- A route of exposure

The concentrations of contaminants are estimated at potential exposure points for the present and future time intervals. Where possible, direct measurements are used to determine current exposure point concentrations. In other cases, environmental transport models are used to predict current and future concentrations. Intakes of the constituents of concern are estimated on the basis of hypothetical exposure scenarios for both present and future land-use conditions.

The toxic characteristics of chemicals of concern are then evaluated to identify potential adverse effects on human health. These effects include impacts on the function of body organs and the induction of cancer. When possible, an estimate is made of the relationship between the extent of potential exposure to the contaminant and the probability and/or severity of identified adverse effects. Section C.4.0 presents toxicity information for the chemicals of potential concern.

The characterization of risk follows the exposure and toxicity assessments. In this step, the probability that an individual may develop cancer over a lifetime from potential exposures to chemicals within the south plume is estimated from potential intakes and contaminant-specific dose-response relationships. In addition, comparisons are made between estimated potential intakes and the threshold values for noncarcinogenic effects. The risk characterization is presented in Section C.5.0.

The results of the risk assessment are summarized in Section C.6.0. A discussion of the uncertainties associated with the risk assessment is also presented in Section C.6.0.

C.2.0 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

Elevated levels of uranium have been recorded as early as 1981 in groundwater south of the FMPC. As part of the ongoing RI/FS process at the site, additional monitoring wells were installed and others are proposed for locations within and outside the FMPC boundary to further evaluate the extent and magnitude of the uranium plume and to determine if other radionuclides or chemicals are present.

Groundwater data collected to date from the sand and gravel aquifer indicate the presence of radionuclides and inorganic metals in the south plume. Most of the radionuclides are found at natural background concentrations. None of the radionuclides or metals detected in the south plume exceed established or derived drinking water limits with the exception of uranium.

There is no evidence to indicate or suspect the presence of organic chemical contaminants in the area where the elevated uranium values occur. This conclusion is based on historical data gathered in Resource Conservation Recovery Act (RCRA) sampling at the FMPC that preceded the RI/FS sampling program and on data collected during field sampling and analysis as part of the RI/FS. The RI/FS data included the Hazardous Substance List (HSL) of parameters for 36 wells in the Waste Storage Area, for the 2000-series wells in the Production Area, for samples which have been collected from Paddys Run, and for samples from wells located along Willey Road which lie along a line perpendicular to the flow of the south plume.

There is no evidence to suggest that there are any hazardous substances other than uranium in the plume of elevated uranium south of the FMPC. All the source locations, where hazardous substances have been found or where they could be found within the study area, are located far to the west and south of the location selected for the removal action wells. The model predicts that while the flow path may be distorted, water particles from locations within the Paddy's Run Road Site source will not be drawn into the removal actions wells. Therefore the only chemical of potential concern in the south plume is uranium.

C.3.0 EXPOSURE ASSESSMENT

This chapter presents the estimation of contact, or exposure, between human and environmental receptors and uranium removed from the south plume. The general procedure for conducting an exposure assessment is (EPA 1989a):

- Characterization of exposure setting
- Identification of exposure pathways
- Quantification of exposures.

This chapter addresses each step of the exposure assessment.

C.3.1 CHARACTERIZATION OF EXPOSURE SETTING

A complete description of the physical setting of the FMPC and surrounding area is given in Section 2.2 of the report and from the references cited therein. The following is a brief summary of that description.

The FMPC is located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the plant.

The FMPC was constructed and operations began at the Fernald site in the early 1950s. A variety of chemical and metallurgical processes were utilized at the FMPC for the manufacture of uranium products. Large quantities of liquid and solid wastes were generated by these various operations.

Leachate from materials processed and stored at the FMPC appear to have migrated to the regionally important Great Miami Aquifer which underlies the site. The aquifer serves as a principal source of domestic, municipal, and industrial water throughout the region. A portion of the flow in Paddys Run, the primary surface-water drainage receptor at the FMPC, is also known to enter this aquifer downstream from the waste storage areas as a result of leakage through the stream bottom.

Above-background concentrations of uranium have been measured at several groundwater well locations south of the FMPC. Although insufficient in themselves to determine the extent and distribution of uranium in groundwater in this area, they have been combined with the results of a groundwater flow/solute transport model to characterize the uranium contamination of the south plume. The model was used to interpolate between and extrapolate beyond the points of field measurements in order to estimate the current and future distribution pattern of uranium in the south plume. The predicted extent of the south plume is described in detail in Appendix A.

Based on the modeled representation of the south plume, approximately 100 acres of property outside the FMPC boundary is underlain by groundwater having a uranium concentration exceeding 30 µg/L. The center of the plume is predicted to be approximately 800 feet south of Willey Road and north of the developed areas along Paddys Run and New Haven Road.

C.3.2 IDENTIFICATION OF EXPOSURE PATHWAYS

In the case of the south plume, exposure to the contaminants can occur only if the groundwater reaches the ground surface. The primary mechanisms are groundwater discharge to a surface water course and pumping. Because the regional groundwater model predicts that the south plume will not migrate to the Great Miami River or any other surface water course within the projected life of the removal action (three years), natural groundwater discharge to surface waters via flow of the regional aquifer is not considered as an exposure pathway for purposes of the EE/CA. Exposure pathways associated with pumped groundwater discharged to the Great Miami River are considered in the evaluation of the effectiveness of the removal action alternatives that involve pumping.

Groundwater which is pumped to the surface may be released to a surface water system (e.g., a stream or pond), used for irrigation, or used as a potable water source. Numerous potential exposure pathways are associated with groundwater which is pumped to the surface. These include:

- Ingestion of drinking water
- Ingestion of irrigated food crops

- Inhalation of resuspended materials following irrigation
- Inhalation of materials released from water during showering
- Ingestion of meat from cattle which have ingested drinking water and/or irrigated forage
- Ingestion of milk from cattle which have ingested drinking water and/or irrigated forage
- Ingestion of fish from streams into which groundwater was pumped
- Ingestion of fowl which have ingested drinking water and/or irrigated feed
- Ingestion of eggs, cheese, or other animal products from animals which have ingested drinking water and/or irrigated feed
- External radiation dose from submersion in air near resuspended radioactive materials following irrigation
- External radiation dose from radioactive materials deposited onto soil following irrigation
- External radiation dose from radioactive materials deposited in sediment from a stream into which groundwater was pumped
- External radiation dose from immersion in a stream into which groundwater was pumped
- External radiation dose at the stream surface from radioactive materials in a stream into which groundwater was pumped

There is no known use of groundwater with uranium levels exceeding the derived concentration limit of 30 μg/L from the south plume area for drinking water, livestock watering, or crop irrigation. Residences along Paddys Run Road to the west reportedly use cisterns with imported water. Groundwater monitoring results from commercial and residential wells along New Haven Road in or near the village of Fernald indicate no elevated levels of uranium in the water supply. These results indicate that the uranium plume either is not present at the level of aquifer pumping or has not yet migrated to these locations.

The only known uses of groundwater with uranium concentrations exceeding the derived concentration limit for uranium in drinking water are the industries located along Paddys Run Road southwest of the

projected center of the plume. One of the two industries treats the water to remove uranium and other radionuclides and chemicals prior to its use. Untreated water at the two industries is not used for drinking water supplies.

Potential future receptors of the uranium in groundwater south of the FMPC include the following:

- Persons who pump groundwater for potable use, crop irrigation, or livestock feeding from areas not currently impacted but located along the future migration pathway of the plume
- Persons who would use surface waters into which contaminated groundwater has been discharged following pumping
- Persons who would install a new well for potable use, crop irrigation, or livestock feeding from an area within the plume.

Locations of known and potential groundwater users south of the FMPC are shown in Figure 2-17 (Section 2.0 of the EE/CA report).

Evaluation of the relative contribution of each of these pathways to the overall exposure of potential receptors to uranium in the groundwater was performed by considering the chemical-specific environmental transport parameters for uranium, along with typical human activities reported for the area. From this evaluation, three exposure pathways contributed more than 95 percent of the total calculated dose from uranium. These pathways are:

- Ingestion of drinking water
- Ingestion of irrigated vegetables
- Ingestion of meat and/or milk from cattle which have ingested drinking water and irrigated forage

One additional exposure pathway which was included because of typical perception of its significance, although it contributes approximately two percent of the total dose, is ingestion of milk from cattle which have ingested drinking water and irrigated forage.

C.3.3 QUANTIFICATION OF EXPOSURES

Uranium is potentially ingested as a consequence of each exposure pathway. The quantity of uranium which could be ingested via each exposure pathway is estimated with standard mathematical models (equations). Although these models are taken from Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (1977), subsequent guidance documents, calculation models, and computer codes from the NRC and other federal agencies use these standard models. Unless stated otherwise, all parameteres and equations are taken from the NRC Regulatory Guide 1.109.

Each model is presented in the following sections along with the values of the parameters used within the model.

C.3.3.1 Ingestion of Drinking Water

Intake via ingestion of contaminated drinking water is calculated using the following equation:

$$I_{DW} = (C_w)\ (IR)\ (EF)\ (ED)\ (FI)\ /\ (BW)\ (AT)$$

where

I_{DW}	=	normalized daily intake of uranium in contaminated drinking water, (mg/kg/day),
C_w	=	concentration of uranium in drinking water, (mg/L),
IR	=	ingestion rate, (L/day),
EF	=	exposure frequency, (days/yr),
ED	=	exposure duration, (yrs),
FI	=	fraction of ingested water from contaminated source, (unitless),
BW	=	body weight, (kg), and
AT	=	averaging time, (equal to ED x EF), (days).

The radiation dose received via ingestion of contaminated drinking water for one year is calculated using the following equation:

$$CEDE = (C_w)\ (DCF)\ (IR)\ (EF)\ (FI)$$

where

CEDE	=	committed effective dose equivalent, (mrem),
C_w	=	concentration of uranium in drinking water, (pCi/L),
DCF	=	dose conversion factor for ingestion of uranium, (mrem/pCi),
IR	=	ingestion rate, (L/day),
EF	=	exposure frequency, (days/yr), and
FI	=	fraction of ingested water from contaminated source (unitless).

The values used for the parameters in this section are given below:

Parameter	Value	Reference
IR	2 L/day (maximum)	EPA 1989c
	1 L/day (average)	NRC 1977
EF	365 days/yr	Assumed
ED	70 yrs	EPA 1989a
FI	1.0	Assumed
BW	70 kg	EPA 1989c
DCF	2.5E-04 mrem/pCi	DOE 1988

Substituting the parameter values into each equation yields the following:

I_{DW} (mg/kg/day)	$\simeq$	C_w (mg/L) x 2.86E-02	(maximum)
I_{DW} (mg/kg/day)	$\simeq$	C_w (mg/L) x 1.43E-02	(average)
CEDE (mrem)	$\simeq$	C_w (pCi/L) x 1.83E-01	(maximum)
CEDE (mrem)	$\simeq$	C_w (pCi/L) x 9.13E-02	(average)

Note that in each equation the intake or radiation dose is proportional to the uranium concentration in drinking water. Calculation of the intake or radiation dose is performed by multiplying the uranium concentration in drinking water (in appropriate units mg/L or pCi/L) by the factor in each equation.

C.3.3.2 Ingestion of Irrigated Vegetables

Intake via ingestion of contaminated vegetables is calculated using the following equation:

$$I_v = (C_v)\ (IR)\ (EF)\ (ED)\ (FI)\ /\ (BW)\ (AT)$$

where

I_v = normalized daily intake of uranium-contaminated vegetables, (mg/kg/day),

C_v = concentration of uranium in vegetables, (mg/kg),

IR = ingestion rate, (kg/day), and

FI = fraction of ingested vegetables from contaminated source, (unitless).

The remaining parameters are the same as those defined in Section C.3.3.1.

The radiation dose received via ingestion of contaminated vegetables for one year is calculated using the following equation:

$$CEDE = (C_v)\ (DCF)\ (IR)\ (EF)\ (FI)$$

where

C_v = concentration of uranium in/on vegetables, (pCi/kg),

DCF = dose conversion factor for ingestion of uranium, (mrem/pCi),

IR = ingestion rate, (kg/day),

EF = exposure frequency, (days/yr), and

FI = fraction of ingested vegetables from contaminated source, (unitless).

The value for C_v is calculated for uranium with the following equation:

$$C_v = (C_w)\ (R)\ [\{(FC)\ [1 - \exp\ (-E)\ (TW)]\ /\ (Y)\ (E)\} + [(FR)\ (B_v)\ (TS)\ /\ (SD)]]$$

where

C_w = concentration of uranium in water used for irrigation, (pCi/L),

R = average irrigation rate, ($L/m^2/hr$),

FC = fraction of deposited activity retained on crops, (unitless),

E = effective removal rate constant, (hr^{-1}),

TW = duration of irrigation during growing season, (hrs),

Y = agricultural productivity per unit area, (kg/m^2),

FR = fraction of the year crops are irrigated, (unitless),

B_v = concentration factor for uptake of uranium from soil by edible parts of the crop, (mg/kg or pCi/kg net weight per mg/kg or pCi/kg dry soil),

TS = duration of exposure of soil to contaminated water, (hrs), and

SD = effective surface density for soil, [kg (dry soil)/m^2].

The values used for the parameters in this section are given below:

Parameter	Value	Reference
IR	0.219 kg/day (maximum), 0.079 kg/day (average)	NRC 1977
EF	365 days/yr	Assumed
ED	70 yrs	EPA 1898a
FI	1.0	Assumed
BW	70 kg	EPA 1989c
DCF	2.5E-04 mrem/pCi	DOE 1988
R	0.118 $L/m^2/hr$	NRC 1977

FC	0.25	NRC 1977
E	2.1E-03 1/hr	NRC 1977
TW	2160 hrs	NRC 1977
Y	2 kg/m^2	NRC 1977
FR	0.25	NRC 1977
B_v	2.0E-03	NCRP 1976
TS	8.8E+03 hrs	Assumed
SD	240 kg/m^2	NRC 1977

Substituting these parameter values into each equation yields the following:

I_v (mg/kg/day) $\simeq$ C_w (mg/L) x 2.17E-02(maximum)

I_v (mg/kg/day) $\simeq$ C_w (mg/L) x 8.08E-03(average)

CEDE (mrem) $\simeq$ C_w (pCi/L) x 1.39E-01(maximum)

CEDE (mrem) $\simeq$ C_w (pCi/L) x 5.03E-02(average)

C.3.3.3 Ingestion of Beef

Intake via ingestion of uranium-contaminated beef is calculated using the following equation:

$$I_B = C_B\ (IR)\ (EF)\ (ED)\ (FI)\ /\ (BW)\ (AT)$$

where

I_B = normalized daily intake of uranium-contaminated beef, (mg/kg/day),

C_B = concentration of uranium in beef, (mg/kg),

IR = ingestion rate, (kg/day), and

FI = fraction of ingested meat from contaminated beef, (unitless).

The remaining parameters are the same as those defined in Section C.3.3.1.

The radiation dose received via ingestion of contaminated beef for one year is calculated using the following equation:

$$CEDE = (C_B)\ (DCF)\ (IR)\ (EF)\ (FI)$$

where

C_B = concentration of uranium in beef, (pCi/kg).

The remaining parameters are the same as those defined previously.

The value of C_B is calculated for uranium with the following equation:

$$C_B = (TC)\ [(C_v)\ (IF) + (C_w)\ (IW)]$$

where

TC = transfer coefficient for uranium in forage and water, (mg/kg per mg/kg/day),

C_v = concentration of uranium in vegetation (forage) as calculated by the equation of Section C.3.3.2, (mg/kg),

IF = ingestion rate of contaminated forage, (kg/day),

C_w = concentration of uranium in water as calculated by the equation of Section C.3.3.1, (mg/L), and

IW = ingestion rate of contaminated water, (L/day).

The values used for these parameters in this section are:

Parameter	Value	Reference
IR	0.301 kg/day (maximum), 0.260 kg/day (average)	NRC 1977
EF	365 days/yr	Assumed
ED	70 yrs	EPA 1989a
FI	1.0	NRC 1977
BW	70 kg	EPA 1989c

DCF	2.5E-04 mrem/pCi	DOE 1988
R	0.118 $L/m^2/hr$	NRC 1977
FC	0.25	NRC 1977
E	2.1E-03 hr^{-1}	NRC 1977
TW	2160 hrs	NRC 1977
Y	2 kg/m^2	NRC 1977
FR	0.25	NRC 1977
B_v	2.0E-03	NCRP 1986
TS	8.8E+03 hrs	Assumed
SD	240 kg/m^2	NRC 1977
TC	1.0E-02 day/kg	NCRP 1986
IF	25 kg/day	NRC 1977
IW	50 L/day	NRC 1977

Substituting these parameters into each equation yields the following:

I_B (mg/kg/day) $\simeq$ C_W (mg/L) x 9.64E-03(maximum)

I_B (mg/kg/day) $\simeq$ C_W (mg/L) x 8.35E-03(average)

CEDE (mrem) $\simeq$ C_W (pCi/L) x 6.15E-02(maximum)

CEDE (mrem) $\simeq$ C_W (pCi/L) x 5.33E-02(average)

C.3.3.4 Ingestion of Milk

Intake via ingestion of contaminated milk is calculated using the following equation:

$$I_M = C_M\ (IR)\ (EF)\ (ED)\ (FI)\ /\ (BW)\ (AT)$$

where

C_M = concentration of uranium in milk, (pCi/L), and

where the remaining terms are analogous to the terms listed in Section C.3.3.3.

The radiation dose received via ingestion of contaminated milk for one year is calculated using the following equation:

$$CEDE = (C_M)\ (DCF)\ (IR)\ (EF)\ (FI)$$

where the terms are analogous to the terms previously defined in this section and in Section C.3.3.3.

The value of C_M is calculated for uranium with the following equation:

$$C_M = (TC)\ [(C_V)\ (IF) + (C_W)\ (IW)]$$

where the terms are analogous to the terms previously defined.

The values used for these parameters are the same as those listed in Section C.3.3.3, with the following exceptions:

Parameter	Value	Reference
IR	0.849 kg/day (maximum) 0.301 kg/day (average)	NRC 1977 NRC 1977
TC	6.0E-04 day/L	NCRP 1986
IW	60 L/day	NRC 1977

Substituting these parameters into each equation yields the following:

$I_M \simeq C_W$ (mg/L) x 1.69E-03 (maximum)

$I_M \simeq C_W$ (mg/L) x 6.42E-04 (average)

CEDE $\simeq C_W$ (pCi/L) x 1.08E-02 (maximum)

CEDE $\simeq C_W$ (pCi/L) x 4.10E-03 (average)

C.3.3.5 Intake From All Pathways

Since each equation for calculating the intake of uranium or the CEDE is linear with respect to C_W the total intake or CEDE from all pathways can be expressed as follows:

$$I\ (mg/kg/day) = I_{DW} + I_V + I_B + I_M$$

or

$$I\ (mg/kg/day) = C_W\ (mg/L) \times 6.16E\text{-}02 \quad \text{(maximum)}$$

$$I\ (mg/kg/day) = C_W\ (mg/L) \times 3.14E\text{-}02 \quad \text{(average)}$$

$$CEDE\ (mrem) = C_W\ (pCi/L) \times 0.394 \quad \text{(maximum)}$$

$$CEDE\ (mrem) = C_W\ (pCi/L) \times 0.199 \quad \text{(average)}$$

Therefore, in order to calculate the normalized daily average intake of uranium or the radiation dose (CEDE), the concentration of uranium in the water supply is substituted into the equations shown above.

C.3.3.6 Uranium Concentration in Water Supplies

For the "no-action" alternative, groundwater could be pumped from the regional aquifer and used as drinking water for humans and animals and for irrigation of food crops and forage. The highest measured concentration of uranium in groundwater from a well in the south plume is approximately 195 pCi/L (0.292 mg/L). To calculate the normalized daily intake or the radiation dose from an annual intake, this concentration is used in the equations given in Section C.3.3.5 to give:

$$I = 0.018\ mg/kg/day \quad \text{(maximum)}$$

$$I = 0.0092\ mg/kg/day \quad \text{(average)}$$

$$CEDE = 77\ mrem \quad \text{(maximum)}$$

$$CEDE = 39\ mrem \quad \text{(average)}$$

In each of the alternatives, the above-background concentration of uranium in the Great Miami River is calculated for releases from the FMPC and the regional aquifer. Dilution of the released quantities

is assumed to occur throughout the year under low-flow conditions (280 cfs or 2.5E+11 L/yr). This assumes that the Great Miami River flows all year at a rate of only one-fifteenth (6.7%) of the average annual flow rate.

A summary of the calculated above-background concentrations (C_w) of uranium in the Great Miami River for each alternative is given in Table C.3-1.

C.3.4 UNCERTAINTIES WITHIN THE EXPOSURE ASSESSMENT

A major source of uncertainty in the exposure assessment is associated with modeling transport of uranium pumped from the south plume through environmental media to human receptors. Site-specific transport parameters were not always available for use in Section C.3.3 and, as a consequence, parameter values were chosen which would not underestimate the intake of uranium. An excellent example of this is the assumption that all drinking water, vegetables, meat, and milk was ingested throughout each year from pathways contaminated with uranium from the south plume.

Another major source of uncertainty which necessarily overestimates the average annual intake and radiation dose is the assumption that dilution of groundwater pumped to the Great Miami River will occur at low flow conditions throughout each year. If average flow conditions for the Great Miami River had been used in the exposure assessment, the calculated above-background concentrations, the calculated uranium intakes and the calculated uranium doses would have been lower by a factor of approximately 15.

C.3.5 SUMMARY OF EXPOSURE ASSESSMENT

Four potential exposure pathways to human receptors from water pumped from the south plume have been identified. The intakes of uranium and the radiation doses have been calculated for each pathway and each removal action alternative. The risks associated with exposures from all pathways are addressed quantitatively in the risk characterization presented in Section C.5.0.

TABLE C.3-1

ABOVE-BACKGROUND URANIUM CONCENTRATIONS IN RIVER WATER

Alternative	Annual Quantity of Uranium Released (mCi)	Volume of Water Released (L/yr)	Effective Concentration Discharged (pCi/L)	Above-Background River Water Concentration After Discharge (pCi/L)(µg/L)
1	578	1.1 E+09	525	2.3 3.5
2	578	1.1 E+09	525	2.3 3.5
3	566	9.4 E+08	602	2.3 3.4
4 - year 1	487	4.9 E+09	99	1.9 2.8
4 - year 2	499	4.9 E+09	102	1.9 2.8
4 - year 3	511	4.9 E+09	104	2.0 3.0

Each of these above-background concentrations of uranium is used to calculate the intakes and radiation doses due to the releases. These are summarized in Table C.3-2.

TABLE C.3-2

CALCULATED INTAKES AND RADIATION DOSES

Alternative	I (max) (mg/kg/day)	I (avg) (mg/kg/day)	CEDE (max) (mrem)	CEDE (avg) (mrem)
1	2.2 E-04	1.1 E-04	0.90	0.46
2	2.2 E-04	1.1 E-04	0.90	0.46
3	2.1 E-04	1.1 E-04	0.90	0.46
4 - year 1	1.7 E-04	8.8 E-05	0.75	0.38
4 - year 2	1.7 E-04	8.8 E-05	0.75	0.38
4 - year 3	1.8 E-04	9.4 E-05	0.79	0.40

C.4.0 TOXICITY ASSESSMENT

As explained in Section C.2.0, uranium is the only chemical of potential concern associated with the south plume. Potential health hazards from exposure to uranium are reviewed in this section.

Uranium is a heavy metal found in several isotopic states, all of which are radioactive. Both radiocarcinogenic and chemical toxicity health hazards are presented by uranium when taken into the body. The target organ for uranium chemical toxicity is the kidney; the primary target organs for the radiocarcinogenic effects are the lung and bone.

C.4.1 NONCARCINOGENIC EFFECTS

The chemical toxicity of uranium is the only noncarcinogenic health effect from potential exposure pathways from the south plume. Pharmacokinetic and pharmacodynamic studies used to understand the toxicity of uranium and to develop a threshold effect dose limit are summarized below.

C.4.1.1 Pharmacokinetics

The primary chemically-induced health effect of uranium is nephritis, or kidney damage. Symptoms of this include albuminuria (elevated protein in the urine) and glycosuria (elevated sugar in the urine). In general, uranium compounds are not easily absorbed across the human gastrointestinal tract. Soluble uranium compounds demonstrate the best absorption, but in a study where patients drank a solution of uranyl nitrate hexahydrate, a water soluble compound, only 0.5 percent of the ingested quantity was found to be absorbed (Hursh et al. 1969). Most recently, uranium metabolic models have estimated the fractional gastrointestinal (GI) absorption from the GI tract to the blood to be 0.6 percent (Wrenn et al. 1987). Although human data for dermal exposure are minimal, water-insoluble uranium compounds are not absorbed in significant amounts across the skin and are not believed to pose a risk to humans under this exposure route (Yuile 1973).

Once absorbed into the bloodstream, uranium compounds are metabolically converted to uranyl ions. The uranyl ion acts as a ligand in the systemic circulation, binding to the plasma proteins and bicarbonate present in the circulation. While this uranyl-bicarbonate complex is stable at the pH of the

plasma, the pH change that occurs at the kidney as the urine is acidified favors dissociation of the complex. This leaves the uranyl ion free to bind to the tissues in the proximal tubule wall, resulting in cellular necrosis (Leggett 1989).

In addition to being the only soft tissue that stores uranium in any appreciable amount, the kidney is also the main organ of excretion (Hursh and Spoor 1973). Approximately 70 percent of an uptake of uranium has been estimated to be excreted by the kidney within 24 hours of intake (Berlin and Rudell 1979). Uranium not excreted is stored in both the kidney and the bone. While uranium has an affinity for kidney tissue, it also has an affinity for the phosphate groups in the bone structure.

C.4.1.2 Human Studies

Data on human exposure to uranium compounds came mainly from acute studies on terminal and/or volunteer patients in the years 1940 to 1960. Single injections of 70 to 100 µg/kg of uranium nitrate to terminally ill patients resulted in proteinuria and increased levels of catalase in the urine (Berlin and Rudell 1979, Luessenhop et al. 1958). In another study, patients were given uranyl nitrate injections ranging from 6.3 to 71 µg U/kg. One of the early signs of renal damage, the appearance of the enzyme catalase in the urine, occurred in patients receiving 55 or 71 µg U/kg (Hursh and Spoor 1973, Leggett 1989).

C.4.1.3 Animal Studies

Laboratory animals demonstrate a great deal of variation in their responses to acute intravenous toxicity studies, with rabbits and guinea pigs appearing to be the most sensitive. The acute intravenous toxicity of soluble uranium compounds like uranyl nitrate is very high: the approximate dose at which 50 percent of the test organisms did not survive (LD_{50}) for rabbits is 0.1 mg/kg; for guinea pigs, 0.3 mg/kg; for rats, 1 mg/kg; and for mice, 10-20 mg/kg (Stokinger 1982).

In chronic animal experiments, sublethal threshold doses of uranium have been demonstrated (Leggett 1989). Though the exact mechanism of tolerance is not known, it is believed that regenerated kidney tissue is associated with tolerance. When uranium exposure ceases, the regenerated epithelium will be transformed into renal tubular tissue (Yuile 1973).

An extensive chronic feeding study was performed on rabbits, rats, and dogs, for periods of 30 days, one year, and two years (Maynard and Hodge 1949). These animals received uranium doses of 2.8, 14, and 71 mg/kg/day in the diet. Rabbits were maintained for 30 days, dogs for one year, and rats for one and two years. For all species, water soluble compounds were more toxic than insoluble compounds, and lowest observed adverse effect levels (LOAELs) were established for all compounds and each species (Maynard and Hodge 1949). In all cases, the LOAEL could be established within the first 30 days (EPA 1989c). Of the three species, rabbits appeared to be the most sensitive, with renal damage exhibited at all administered dose levels. The renal damage was judged to be only moderate at the lower doses, but moderately severe at the highest dose. Based on this, the lowest uranium dose of 2.8 mg/kg/day was established as the LOAEL by EPA (Maynard and Hodge 1949, EPA 1989c).

C.4.1.4 Regulatory Guidance

The EPA (1989c) has recently established a reference dose (RfD) for uranium of 3 µg/kg/day. This reference dose is based on the LOAEL of 2.8 mg/kg/day from the Maynard and Hodge (1949) bioassay study and an uncertainty factor of 1000. The uncertainty factor accounts for intraspecies and interspecies variability in toxicological response and for the use of the LOAEL. No factor of 10 has been included to account for the short duration of the exposure (30 days), because it has been shown that chronic nephrotoxic effects can be adequately characterized with experiments of acute/subacute duration (EPA 1989c).

Because of the numerous uncertainties associated with the determination of an acceptable intake, a pharmacokinetic model and the suggested acceptable threshold dose for uranium levels in the kidney are used to calculate an acceptable uranium intake. The National Council on Radiation Protection and Measurements (NCRP) (Wrenn et al. 1985) proposed a single compartment model with long-term retention in the kidney.

Based on the NCRP model, the acceptable daily intake of uranium is 186 µg/day. In terms of intake by a 70-kilogram adult, the acceptable intake is 2.7 µg/kg/day, or approximately 3 µg/kg/day, in good agreement with the RfD determined using animal data. An RfD of 3 µg/kg/day is used in Section C.5.0.

C.4.2 CARCINOGENIC EFFECTS

Assessment of the lifetime radiocarcinogenic risk of fatal cancer from exposure to radiation is performed using a somatic whole-body risk coefficient of 125 x 10^{-6} rem^{-1} published by the NCRP (NCRP 1987). The NCRP presents a tabulation of risk coefficients associated with various body tissues. The sum of the tissue-specific risk coefficients equals the total whole-body risk coefficient of 165 x 10^{-6} rem^{-1}. The total whole-body risk coefficient of 165 x 10^{-6} rem^{-1} includes the somatic whole-body risk of 125 x 10^{-6} rem^{-1} and the genetic risk of 40 x 10^{-6} rem^{-1}. The somatic whole-body risk is used in the risk characterization in Section C.5.0 to quantify the risk of fatal cancers in individuals exposed to ionizing radiation. The risks of health effects in offspring of individuals exposed to ionizing radiation (genetic risks) have not been demonstrated in humans.

All of these risk coefficients quantify risk as deaths per unit dose equivalents received (rem^{-1}). The risk coefficients presented by the NCRP are consistent with the recommendations of the International Commission on Radiological Protection (ICRP) in Publication 26 (ICRP 1977).

The somatic whole-body risk coefficient is used for radiation exposure of specific tissues from internally-deposited radionuclides after the committed dose equivalents are expressed as risk-weighted committed dose equivalents. Risk-weighted committed dose equivalents are those for each tissue that have been multiplied by the appropriate risk-weighting factor for each tissue (ICRP 1977). The risk-weighted committed dose equivalents for tissues are summed over all tissues to give the committed effective (whole-body) dose equivalent (CEDE). The CEDE is the quantity of radiation dose used throughout this exposure and risk assessment.

C.4.3 UNCERTAINTIES RELATED TO TOXICITY INFORMATION

Toxicity information used in the human health assessment incorporates considerable uncertainty. This is because toxicity information is often based upon modeled projections that are based upon empirical studies of animals or humans exposed to radiological or hazardous agents under circumstances that differ from the circumstances of exposure in a site-specific human health assessment. Four principal sources of uncertainty that are incorporated into the human health assessment for both chemical and radiological toxicity are:

- The use of dose-response relationships (models) based on exposures at high doses to predict low-dose effects
- The use of dose-response relationships based on acute exposures to predict effects from chronic exposures
- The use of dose-response relationships based on laboratory animal studies to predict effects on humans
- The use of dose-response relationships based on human study populations that may be significantly different from the populations of concern in the site-specific human health assessment

The radiological risk coefficient and the uranium chemical toxicity reference dose presented in this toxicity assessment incorporate conservative assumptions that are considered to overestimate risk. This conservatism is built into the risk estimates because of the uncertainties that are associated with risk estimation.

The whole body risk coefficient selected by the NCRP incorporates a conservative assumption for radiation protection purposes. This assumption is that the dose-response relationship used to estimate risk is linear without threshold throughout the range of dose equivalent and dose equivalent rates of importance in routine radiation protection (NCRP 1987).

The EPA uranium chemical toxicity reference dose of 3 μg/kg/day (EPA 1989c) is based on a published LOAEL of 2.8 mg/kg/day (Maynard and Hodge 1949) and an uncertainty factor of 1000. The uncertainty factor is included to compensate for intraspecies and interspecies variability in toxicological response.

C.5.0 RISK CHARACTERIZATION

This chapter provides a characterization of the potential health effects associated with the intake of uranium which could be pumped from the south plume. In accordance with methods described by EPA (1989a), a health-protective approach that is likely to overestimate rather than underestimate risk is used. A quantitative evaluation of the lifetime risk associated with exposure to uranium for the three-year period of the removal action is presented.

C.5.1 CARCINOGENIC EFFECTS

Radiocarcinogenic risks from exposure to uranium are calculated using the estimated radiation dose (CEDE) and the risk coefficient presented in Section C.4.0. The total radiation doses from the annual exposure to uranium via the four pathways for each removal action alternative are given in Table C.3-2. The total radiation dose as a consequence of releases during the three years of the removal action are listed in Table C.5-1. Risks of fatal cancer are calculated by multiplying the total radiation dose by the radiation risk coefficient of 125×10^{-6} rem^{-1} or 1.25×10^{-7} $mrem^{-1}$. These calculated risks are also given in Table C.5-1.

TABLE C.5-1

RADIATION DOSES AND CANCER RISKS FOR REMOVAL ACTION ALTERNATIVES

	CEDE (mrem)		Risk	
Alternative	(max)	(avg)	(max)	(avg)
1	2.7	1.4	3E-07	2E-07
2	2.7	1.4	3E-07	2E-07
3	2.7	1.4	3E-07	2E-07
4	2.3	1.2	3E-07	2E-07

Not included with the dose and risk for Alternative 1, the "no-action" alternative, are the dose and risk associated with direct use of the groundwater. These values are (exposure for three years):

CEDE (max)	≃	230 mrem
CEDE (avg)	≃	120 mrem
Risk (max)	≃	3E-05
Risk (avg)	≃	1E-05

C.5.2 NONCARCINOGENIC EFFECTS

The potential health consequence of the noncarcinogenic effects of chemicals is evaluated by comparing estimated intakes (Section C.3.0) with the RfD, which represents an estimate of the level of intake that would not result in adverse health effects (i.e., a "threshold" effect). The parameter of interest is the hazard index (HI) defined as:

$$HI = I/RfD$$

where

HI	=	hazard index (unitless),
I	=	intake (µg/kg/day), and
RfD	=	reference dose (µg/kg/day).

This approach is different from the probabilistic approach used to evaluate carcinogens. Note that an HI ratio of 0.01 does not imply a 1-in-100 chance of adverse effect, but indicates that the estimated intake is 100 times less than the reference dose.

The identified potential exposure to elemental uranium from the south plume is from ingestion of drinking water, vegetables, meat, and milk. Table C.3-2 presents the estimated uranium intake for each removal action alternative. The proper RfD to use in this evaluation may be a subchronic RfD because the exposure occurs over only three years of the total 70-year lifetime. It is assumed that the chronic RfD is appropriate for use in this situation because the chronic effect of uranium toxicity, nephrotoxicity, is the same effect that would be of concern during the three-year exposure.

The calculated intake and HI for each alternative, assuming maximum exposure conditions and average exposure conditions, are given in Table C.5-2.

TABLE C.5-2

URANIUM INTAKE AND HAZARD INDICES FOR REMOVAL ACTION ALTERNATIVES

Alternative	I (mg/kg/day) (max)	I (mg/kg/day) (avg)	HI (max)	HI (avg)
1	2.2E-04	1.1E-05	0.07	0.04
2	2.2E-04	1.1E-05	0.07	0.04
3	2.1E-04	1.1E-05	0.07	0.04
4 Year 1	1.7E-04	8.8E-05	0.06	0.03
Year 2	1.7E-04	8.8E-05	0.06	0.03
Year 3	1.8E-04	9.4E-05	0.06	0.03

Not included with the intake and HI for Alternative 1 are the intake and HI associated with direct use of the groundwater (293 µg/L). These values are:

I (max)	=	0.018 mg/kg/day
I (avg)	=	0.0092 mg/kg/day
HI (max)	=	6.0
HI (avg)	=	3.1

Although the HI values are less than 1.0 for each alternative where groundwater is pumped from the aquifer discharged to the Great Miami River prior to use, direct pumping of the groundwater at the highest measured concentration (293 µg/L) yields a HI in excess of 1.0.

C.5.3 UNCERTAINTIES

The risk characterization integrates environmental sampling, transport analysis, exposure analysis, and toxicological data. Uncertainties associated with each step of the risk assessment process impact the results of the risk characterization. The uncertainties associated with analysis of the environmental sampling data, transport results, exposure estimates, and toxicological data have been qualitatively presented in previous chapters. This risk characterization strives to minimize the probability that uncertainties may result in an underestimation of the actual health hazards associated with the operable unit. Thus, each step of the process has incorporated bias intended to overestimate the potential hazards being addressed.

C.6.0 SUMMARY

Although numerous samples of groundwater from the south plume have been collected and analyzed, uranium is the only chemical which exceeds established or derived drinking water limits. There is no evidence to indicate or suspect the presence of organic chemical contaminants in the south plume. Therefore the only chemical of potential concern in the south plume is uranium.

Four exposure pathways were determined to contribute nearly all of the potential exposure from uranium pumped from the south plume. These hypothetical pathways all involved ingestion of materials contaminated with uranium from the pumped groundwater. These materials are drinking water, vegetables, meat, and milk. An exposure assessment was performed using standard models and transport parameters to determine the intake and radiation dose from each exposure pathway. The contributions from these pathways were combined to yield relationships between concentrations of uranium in water and uranium intakes and radiation doses.

Radiation doses (CEDE) calculated for each removal action alternative ranged from 0.38 mrem to 0.90 mrem per-year of intake for pumping to the Great Miami River. Groundwater pumped for direct use was calculated to yield a radiation dose of from 39 mrem to 77 mrem per year of intake, depending on the assumptions of average or maximum exposure parameters.

Radiocarcinogenic risks calculated for the three-year period of the removal action ranged from 2E-07 to 3E-07 for groundwater which is pumped from the south plume. The differences between the calculated radiation doses and cancer risks for each of the alternatives are insignificant, with the notable exception being direct use of groundwater from the south plume for drinking water and irrigation of food crops, forage crops, and livestock. The radiocarcinogenic risk for this direct use is 3E-05 for three years of intake.

The chemical intakes calculated for the potential exposure scenarios did not exceed the chronic reference dose of 3 μg/kg/day for any of the alternatives, with the previously noted exception of direct use of groundwater from the south plume.

In conclusion, there are no significant differences in the calculated intakes, radiation doses, and radiocarcinogenic risks associated with each of the alternatives for which water from the south plume is not directly used for irrigation or as a potable water supply.

REFERENCES

Berlin, M. and B. Rudell, 1979, "Uranium," Handbook on Toxicology of Metals, L. Friberg et al., eds., North-Holland Biomedical Press, New York, NY.

Hursh, J.B., W.R. Neuman, T. Toribara, H. Wilson and C. Waterhouse, 1969, "Ingestion of Uranium by Man," Health Physics, Vol. 17, pp. 619-621.

Hursh, J.B. and N.L. Spoor, 1973, "Data on Man" (Chapter 4), Uranium, Plutonium and the Transuranic Elements, C.H. Hodge, J.N. Stannard and J.B. Hursh, eds., Springer-Verlag, New York, NY.

International Commission on Radiological Protection, 1977, "Recommendations of the International Commission on Radiological Protection," Annals of the International Commission on Radiological Protection, Publication 26, Pergamon Press, New York, NY.

Leggett, R.W., 1989, "The Behavior and Chemical Toxicity of U in the Kidney: A Reassessment," Health Physics, Vol. 57:3, pp. 365-383.

Luessenhop, A.J., J.C. Gallimore, W.H. Sweet, E.G. Struxness and J. Robinson, 1958, "The Toxicity in Man of Hexavalent Uranium Following Intravenous Administration," American J. of Roentgenology, Vol. 79, pp. 83-100.

Maynard, E.A. and H.C. Hodge, 1949, "Studies of the Toxicity of Various Uranium Compounds When Fed to Experimental Animals," in: Pharmacology and Toxicology of Uranium Compounds, Vol. 1, C. Voegtlin and H.C. Hodge, eds., McGraw-Hill, New York, NY.

National Council on Radiation Protection and Measurements, 1986, "Screening Techniques for Determining Compliance with Environmental Standards," Commentary No. 3, NCRP, Bethesda, MD.

National Council on Radiation Protection and Measurements, 1987, "Recommendations on Limits for Exposure to Ionizing Radiation," Report 91, NCRP, Bethesda, MD.

Stokinger, H.E., 1982, "Uranium," Patty's Industrial Hygiene and Toxicology, 3rd edition, John Wiley & Sons, New York, NY.

U.S. Department of Energy, 1988, "Internal Dose Conversion Factors for Calculation of Dose to the Public," DOE/EH-0071, DOE, Assistant Secretary for Environment, Safety and Health, Washington, DC.

U.S. Environmental Protection Agency, 1989a, "Risk Assessment Guidance for Superfund, Human Health Evaluation Manual (Volume I), Interim Final," EPA 540/1-89/002, EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency, 1989b, "Integrated Risk Information System (IRIS)," computer database, EPA, Office of Health and Environmental Assessment, Cincinnati, OH.

REFERENCES
(continued)

U.S. Environmental Protection Agency, 1989c, "Exposure Factors Handbook," EPA 600/8-89/043, EPA, Office of Health and Environmental Assessment, Washington, DC.

U.S. Nuclear Regulatory Commission, 1977, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Regulatory Guide 1.109, NRC, Office of Standards Development, Washington, DC.

Wrenn, M.E., P.W. Durbin, B. Howard, J. Lipsztein, J. Rundo, E.T Still and D.L. Wilis, 1985, "Metabolism of Ingested U and Ra," Health Physics, Vol. 48:5, pp. 601-633.

Wrenn, M.E., P.W. Durbin, D.L. Wilis and N.P. Singh, 1987, "The Potential Toxicity of U in Water," J. of the American Water Works Assn., Vol. 79, pp. 177-184.

Yuile, C.L., 1973, "Animal Experiments" (Chapter 3), Uranium, Plutonium and the Transuranic Elements, C.H. Hodge, J.N. Stannard and J.B. Hursh, eds., Springer-Verlag, New York, NY.