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RE-INJECTION DEMONSTRATION TEST PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

INFORMATION ONLY

FEBRUARY 1998

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This test plan is the controlling document (Project Specific Plan) for a one-year field scale groundwater re-injection demonstration in the Great Miami Aquifer (GMA) at the Fernald Environmental Management Project (FEMP). The demonstration will involve the re-injection of groundwater (which has been extracted from the Great Miami Aquifer and treated in the FEMP Advanced Waste Water Treatment (AWWT) Expansion Facility to remove uranium contamination) into five Great Miami Aquifer re-injection wells located along the southern property boundary of the FEMP, Figure 1-1.

Data from the demonstration will be used to determine what role, if any, re-injection technology will play in the FEMP aquifer restoration. As a cost conscious measure, the re-injection demonstration presented in this test plan has been incorporated into the final aquifer remedy for the FEMP so that if field scale re-injection proves successful the application to the remedy will be immediate.

6 Groundwater re-injection was determined to be a potentially viable strategy for shortening the duration required to achieve aquifer restoration. This strategy was presented in the Baseline Remedial Strategy Report Remedial Design for Aquifer Restoration (DOE 1997a). In addition to shortening the remediation time frame, the following benefits are anticipated:

- Re-injection will increase the rate of aquifer flushing in the more highly contaminated areas thereby reducing the time required to achieve clean-up.
- Re-Injection will help minimize pumping related drawdown impacts at neighboring properties beyond the FEMP property by returning pumped water back into the aquifer following extraction and treatment.
- Re-Injection is expected to provide a hydraulic barrier at the southern boundary of the FEMP to minimize the potential for further off-property contaminant migration.
- 4 Re-injection will help minimize excessive drawdown of water levels in the target cleanup zones by maintaining high water levels in the areas where re-injection is occurring. This will help reduce the amount of residual contamination left in the unsaturated portion of the aquifer.

54 Uncertainties exist with the field-scale application of re-injection technology at the FEMP based on two short-term injection tests conducted in individual wells (DOE 1995b, DOE 1996a). These uncertainties need to be addressed before a commitment can be made to continue re-injection as a part of the aquifer remedy. The Re-Injection Demonstration presented in this Test Plan will critically examine these

field-scale uncertainties and resolve the remaining questions regarding the long-term viability of the technology at the FEMP. This test plan follows guidelines issued by the Ohio EPA Division of Drinking and Ground Waters (DDAGW) unit of Underground Injection Control (UIC) in a document titled 5X26 Aquifer Remediation Projects (OEPA 1997).

1.1 DEMONSTRATION OBJECTIVES

The long term viability of re-injection at the FEMP is uncertain due to field-scale uncertainties in the re-injection process; specifically, the cost of maintaining and operating re-injection wells for extended periods of time and the effect that re-injection could have on the 20 μg/L total uranium plume. The objective of the Re-injection Demonstration is to address these field-scale uncertainties. The re-injection demonstration will:

- Determine if a re-injection rate of 200 gpm per well can be sustained at the field scale for a time period of one year
- Determine the operational and maintenance costs required to sustain re-injection rates of 200 gpm at the field scale
- Determine if extraction and re-injection wells are working together as modeled to maintain capture of the 20 μg/L total uranium plume
- Determine if a hydraulic barrier has been produced at the southern boundary of the FEMP
- 5 Determine if hydraulic patterns and profiles that indicate increased flushing in the aquifer, and minimized pumping related drawdown are being achieved as predicted by the groundwater model.

1.2 RE-INJECTION EVALUATION STRATEGY

The final Record of Decision (ROD) for Operable Unit 5 presents groundwater extraction and treatment as the selected remedy for restoring the Great Miami Aquifer. The ROD presents a 28 well extraction system pumping at a maximum rate of 4000 gallons per minute (gpm) to restore the aquifer in an estimated 27 years. In the Operable Unit 5 ROD, the U.S. Department of Energy (DOE) agreed to continue evaluating emerging or innovative technologies which might enhance the aquifer restoration. Examination of the feasibility of applying re-injection of groundwater into the aquifer as a remedy enhancement fulfills this ROD commitment. Figure 1-2 illustrates the strategy that is being followed for evaluating groundwater re-injection at the FEMP, and illustrates how the re-injection demonstration fits into this strategy. The shaded upper portion of Figure 1-2, identifies steps in the evaluation process that have already been completed (groundwater modeling and single well injection tests).

55 The first step in the evaluation process was to predict if and how the aquifer remedy could be improved by using re-injection. Groundwater re-injection was modeled to determine if the modeling results would support the feasibility of using groundwater re-injection as part of the aquifer remedy. The FEMP groundwater model uses the SWIFT/486 computer code (version 2.54) marketed by HSI GeoTrans. Groundwater model construction, calibration, and validation is documented in the SWIFT Great Miami Aquifer Model, Summary of Improvements Report (DOE 1994).

56 Re-injection was added to the model of the remediation strategy presented in the Operable Unit 5 ROD (i.e., a 27-year remediation involving 28 extraction wells). The modeling results are presented in the Baseline Remedial Strategy Report (BRSR) Remedial Design for Aquifer Restoration (DOE 1997a). Modeling re-injection as part of the remediation strategy predicted a shorter duration for the aquifer remedy. The use of re-injection allows for additional extraction wells without increasing the net overall rate at which groundwater would be removed from the aquifer. This is important because without re-injection it is predicted that additional extraction wells with the associated increase in the extraction rate would lower the water level in the Great Miami Aquifer to unacceptable levels during the restoration. The current aquifer remediation for the FEMP, as detailed in the BRSR, is predicted to be completed in approximately 10 years. Achievement of the 10-year clean-up of the aquifer is also based upon:

- Other operable units completing their accelerated clean-up objectives so that surface access is available for aquifer remediation wells
- The accelerated removal of source terms which will allow recovery wells to be located closer to the center of uranium plumes
- Refinements in the understanding of the uranium desorption process.

Since post-ROD groundwater modeling for the BRSR supported the feasibility of using re-injection technology as part of an enhanced remedy, a single well injection test was conducted to further assess the implementability of re-injection at the FEMP. Limitations in water treatment capacity (i.e., only 200 gpm of treated groundwater was available for re-injection) and in delivery of injection water to a well (i.e., a temporary piping system had to be used) constrained the field test to a single well for a short time period. Two single well injection tests were conducted, the first in October 1995, and the second in March and April of 1996.

In October 1995, a single well injection test was conducted in which groundwater was extracted from the South Plume Area and injected into a South Field Extraction Well without undergoing any treatment process (DOE 1995b). The groundwater which was injected into the aquifer had a total uranium concentration below 20 μg/L. The test was conducted over 72-hours at a constant injection rate of 300 gallons per minute (gpm). After approximately 600 minutes, water levels in the injection well began to rise which indicated plugging of the formation and/or the well screen was occurring. Test results confirmed iron precipitation and iron bacteria worked synergistically to plug the screen of the injection well. Sampling and geochemical modeling conducted after the test indicated that injecting treated effluent would not result in well screen plugging from iron precipitation and iron bacteria (DOE 1996a). A second single well injection test was conducted in March and April of 1996 in which groundwater treated in the South Plume Interim Treatment (SPIT) system was injected into a South Field Well (DOE 1996a). The test was conducted for approximately 114 hours at a constant injection rate of 200 gpm. The results of the second test indicated that groundwater which had been treated for uranium could be injected into the aquifer without plugging the well screens. During the treatment for uranium, aeration reduces the iron concentration.

As mentioned earlier, the treatment and delivery of groundwater to the re-injection test wells limited field testing of re-injection to single well, short duration tests. Results of the single well tests indicate that re-injection should work at the FEMP. However, the long term dependability and costs associated with a field scale re-injection program (i.e., the cost required to keep the screen unplugged) need to be better understood before a commitment is made to continue full-scale re-injection as part of the aquifer remedy.

As Figure 1-2 illustrates, the re-injection demonstration presented in this test plan is the next step to determine if re-injection technology is workable at the FEMP. The demonstration needs to determine if re-injection technology can be applied in several wells over an extended period of time. One year of cost data and data on the vertical and horizontal expansion of the total uranium plume will be collected. If the cost data is favorable, and the plume expansion data is consistent with modeled predictions, then a decision will be made to continue using re-injection technology as part of the aquifer remedy. It is possible that the demonstration can be a success, but that re-injection technology be dropped from the aquifer remedy. The decision criteria for continuing with re-injection technology as a part of the FEMP aquifer remedy is presented in Section 1.3 of this test plan.

1.3 DECISION CRITERIA

As Figure 1-2 illustrates, a question being evaluated at the FEMP is whether or not re-injection technology is workable at the FEMP on a field scale. The decision criteria for evaluating workability focuses on:

- Maintenance and operational costs of re-injection
- Vertical and horizontal expansion of the 20 μg/L total uranium plume
- Effectiveness in shortening the remedy
- Creation of a hydraulic barrier at the Southern FEMP property boundary.

As presented above, it is predicted that the aquifer can be remediated in a much shorter time period if re-injection is used and assumptions about uranium desorption and surface access are realized. Significant cost savings could be realized by shortening the time required to operate extraction and/or re-injection wells and to treat groundwater.

The re-injection demonstration will provide cost data for one year of actual operation for the re-injection wells. Following the re-injection demonstration, this cost data will be used to conduct a life cycle cost analysis on the use of re-injection at the field scale. This life cycle cost analysis will be compared to the estimated life cycle cost analysis for completing the aquifer remediation without using re-injection. A positive benefit/cost ratio would support a decision to continue using re-injection.

Re-injection will affect the total uranium plume, and could lead to vertical and/or horizontal expansion of the plume. Although expansion is not desirable, the added benefit from a remedy which is shorter in duration would out weigh the negative impact of plume expansion as long as the expansion was limited to inside the plume capture zone and therefore would ultimately be remediated. If expansion of the plume occurs such that the overall capture zone of the remediation system is no longer maintaining effective capture of the 20 μg/L total uranium plume, then pumping and injection rate adjustments will be implemented to determine if capture of the plume can be maintained. Operational philosophy for the aquifer remediation system is presented in the Operations and Maintenance Master Plan for the Aquifer Restoration and Wastewater Treatment Project (DOE 1997d). A determination that capture can be maintained with re-injection would support a decision to continue using re-injection.

In addition, decision criteria will also focus on two other effects that re-injection is predicted to have on the aquifer and the plume. As described in the BRSR, groundwater modeling predicts that re-injection helps to shorten the time needed to clean up the aquifer because it helps to create hydraulic patterns and profiles within the aquifer that result in increased flushing and removal of the uranium plume. The hydraulic barrier is further explained in Section 1.4. Data that indicates that both these effects are occurring as predicted would support a decision to continue using re-injection.

1.4 START-UP SEQUENCE FOR THE DEMONSTRATION

The start-up of the re-injection demonstration will be coordinated with the continued pumping of the South Plume Module and the start-up of the:

- AWWT Expansion Water Treatment Facility
- Phase I South Field Extraction System Module
- South Plume Optimization Module.

A summary description of the site aquifer remedy, as specified in the BRSR and the Remedial Action Work Plan for Aquifer Restoration at Operable Unit 5 (RAWP) for Aquifer Restoration, is presented in Section 2.2.

Figure 1-3 shows the location of each of these facilities and modules. The Phase I South Field Extraction System Module consists of 10 extraction wells located up gradient of the Re-injection Demonstration Module. The South Plume Optimization Module consists of 2 extraction wells, and the existing South Plume Module consists of 4 operating extraction wells; both are located down gradient of the Re-injection Demonstration Module. The re-injection module itself consists of 5 re-injection wells. Start-up dates for the AWWT Expansion Facility, Phase I South Field Extraction Module, South Plume Optimization Module, and the Re-Injection Demonstration Module are provided in the Remedial Action Work Plan for Aquifer Restoration at Operable Unit 5 (DOE 1997c).

The start-up sequence outlined below is preferred as it will provide data to assess how the addition of each module affects water levels and capture of the total uranium plume. This information will be useful in the future if operational adjustments to the pumping or injection rates are required.

1. Begin operation of the AWWT Expansion Water Treatment Facility. Sample effluent to confirm acceptability of treated groundwater supply for the re-injection demonstration. The sampling program is presented in Section 4.1.

2. Begin operation of the Phase I South Field Extraction Module. Do not start-up any other modules until water levels in the aquifer have stabilized. Pumping from the South Field will establish a new hydraulic gradient and slow the migration of uranium contamination into the re-injection demonstration area. It is planned that this module will later work with the re-injection wells to produce a hydraulic barrier across the re-injection demonstration area.

3. When water levels in the aquifer have stabilized, begin pumping from the South Plume Optimization Wells. Do not start-up any other modules until water levels in the aquifer have stabilized.

61 4. Begin re-injection and observe aquifer water levels to assess and verify that they have reached stabilization.

62 It is anticipated that operating the re-injection wells along with the other extraction and re-injection wells will create a hydraulic barrier along the southern FEMP property boundary, as shown by the water table elevation profile in Figure 1-4. The water table elevation profile is oriented north to south as identified in Figure 1-3. As Figure 1-4 illustrates, prior to any pumping in this area, the groundwater gradient was to the south at about 0.56 feet of elevation per 1000 feet of lateral distance. When pumping in the South Plume began in 1993, the water table was lowered by approximately 1.5 feet to 3.5 feet by the pumping and the gradient to the south was increased to about 1.1 feet elevation per 1000 feet lateral distance. When more pumping and injection begin in 1998, it is predicted that the water table will be lowered by an additional 1.5 feet to almost 3 feet. In addition, the re-injection wells will create a small mound of water in the re-injection demonstration area (Re-injection Well #10). This mound in conjunction with the south field extraction system wells will cause the hydraulic gradient north of the re-injection wells to reverse creating the desired hydraulic barrier along the southern FEMP property boundary.

8 Re-injection will begin sequentially starting with the western most Well 22107, and proceeding to 22108, 22109, 22240, and finally 22111, see Figure 1-1. A start-up goal will be to get re-injection, at a rate of 200 gpm per well, going in all five wells as quickly as possible (1 day) to achieve the net system re-injection rate of 1000 gpm. Water levels and flow rates in the re-injection wells will be closely monitored for stability, using pressure transducers and flow meters, for approximately two hours following startup before a decision will be made to move to the next re-injection well to begin operations there.

The re-injection wells are scheduled for maintenance checks every three months during the demonstration. Maintenance checks involve the evaluation of each re-injection well screen for plugging and possible screen rehabilitation using physical and/or chemical methods. Corrective maintenance will be implemented as needed.

If the demonstration substantiates the viability of re-injection and the decision is made to continue re-injection, the re-injection wells will continue operation and preventive maintenance schedules will be implemented. If at the conclusion of the demonstration the decision is made not to continue re-injection, then operation of the re-injection wells will cease.

1.5 DEMONSTRATION PARTICIPANTS

The evaluation of re-injection technology at the FEMP is being sponsored by the Department of Energy's Office of Science and Technology Subsurface Contaminants Focus Area, at the request of the FEMP. The FEMP is an ideal place for evaluation of this technology because:

- A commitment was made by the DOE to the EPA in the OU5 ROD to evaluate the incorporation of innovative technologies into the aquifer remedy to try to shorten the duration of the aquifer remedy.
- As a result of the FEMP's intensive CERCLA site characterization efforts, in conjunction with previous regional studies, the contaminated Great Miami Aquifer at the FEMP is one of the most well studied aquifers in the world.
- The presence of educated, informed and supportive stakeholders.
- Cooperative regulatory agencies involved with the restoration project.
- A groundwater model has been developed that simulates flow and transport in the aquifer beneath the FEMP site.

- The opportunity existed to integrate the demonstration into an actual Site remedy (i.e., the timing was right).

The evaluation is being conducted with a group of industry partners:

- MSE-Western Energy Technology Office (WETO)
  P.O. Box 4078
  Butte, Montana 59702

- Rio-Algom Environmental Services Inc.
  6305 Waterford Blvd.
  Oklahoma City, Oklahoma 73118

- In-Situ Inc.
  210 South 3rd. Street
  P.O. Box 1
  Laramie, Wyoming 82070-0920

MSE-WETO brings additional general groundwater hydrology expertise to the evaluation, and is the coordinator of the industry partnership with Rio-Algom and In-Situ Inc. Rio-Algom has conducted "in situ uranium leaching" (ISL) demonstrations in the western US and has experience pertaining to aquifer geochemistry, re-injection well maintenance, and re-injection system operations. In-Situ Inc. is a recognized industry leader in groundwater monitoring instrumentation. They bring expertise in velocity profile measurements in re-injection wells.

As part of the re-injection demonstration, DOE EM-50 and the three industry partners mentioned will review this test plan and be available for technical support upon request throughout the duration of the demonstration.

1.6 RELATIONSHIP TO OTHER DOCUMENTS

This test plan provides for the monitoring which will be conducted to support the Re-Injection Demonstration, above and beyond the monitoring that is already prescribed in the Draft Integrated Environmental Monitoring Plan (IEMP) and the Draft Operations and Maintenance Master Plan for the Aquifer Restoration and Wastewater Treatment Project (OMMP, DOE 1997d). Monitoring activities outlined in this test plan are not considered long term "routine" activities, therefore they have been separated from the long term monitoring programs presented in the IEMP and the OMMP. If re-injection is continued after the demonstration, long term routine monitoring requirements for re-injection will be identified and incorporated into the IEMP and OMMP.

Maintenance of the re-injection wells will begin by incorporating lessons learned from operating the South Plume Extraction Wells and from the two single well injection tests conducted at the FEMP. Corrective maintenance activities for the South Plume Module Wells are presented in Appendix A of the OMMP. Some of the activities carried out for the South Plume Wells will also be conducted for the re-injection demonstration wells. It is anticipated that the re-injection maintenance program will evolve as the re-injection demonstration proceeds.

1.7 TEST PLAN ORGANIZATION

The Re-Injection Test Plan is comprised of nine sections and one appendix. The first seven sections focus on conducting the demonstration. The last two sections present the management structure and safety and quality assurance. The sections and their contents are as follows:

Section 1.0 — Provides an overview of the re-injection demonstration. The overview gives general background information concerning demonstration objectives, re-injection evaluation strategy, decision criteria for the demonstration, a startup sequence for the demonstration, participants, and the relationship of the test plan to other documents.

Section 2.0 — Considerations for the design of the re-injection demonstration are presented in this section.

Section 3.0 — The set-up of the re-injection demonstration is presented in this section. The general design used for the re-injection wells is presented along with actual installation information for the five re-injection wells installed to support the demonstration. The section also outlines the need for additional observation wells to support monitoring of the demonstration.

Section 4.0 — This section presents testing activities that will be conducted during the demonstration. Testing activities include: analysis of the injectate, downhole camera surveys, biological sampling, ground water quality sampling, water level monitoring, maintenance checks, and surface water quality sampling.

Section 5.0 — This section outlines the data evaluation strategy for the data collected during the re-injection demonstration.

Section 6.0 — Schedules, deliverables, and reporting are discussed in this section.

Section 7.0 — This section discusses the plugging and abandonment of re-injection demonstration wells following completion of the aquifer remedy.

Section 8.0 — This section presents an overview of the management structure for the demonstration and outlines responsibilities for demonstration activities.

Section 9.0 — This section presents activities which will be conducted to support the test (i.e., data management, health and safety, quality assurance/quality control, waste disposition, and decontamination).

References Cited

Appendix A Presents previously collected water quality data for the re-injection demonstration area.

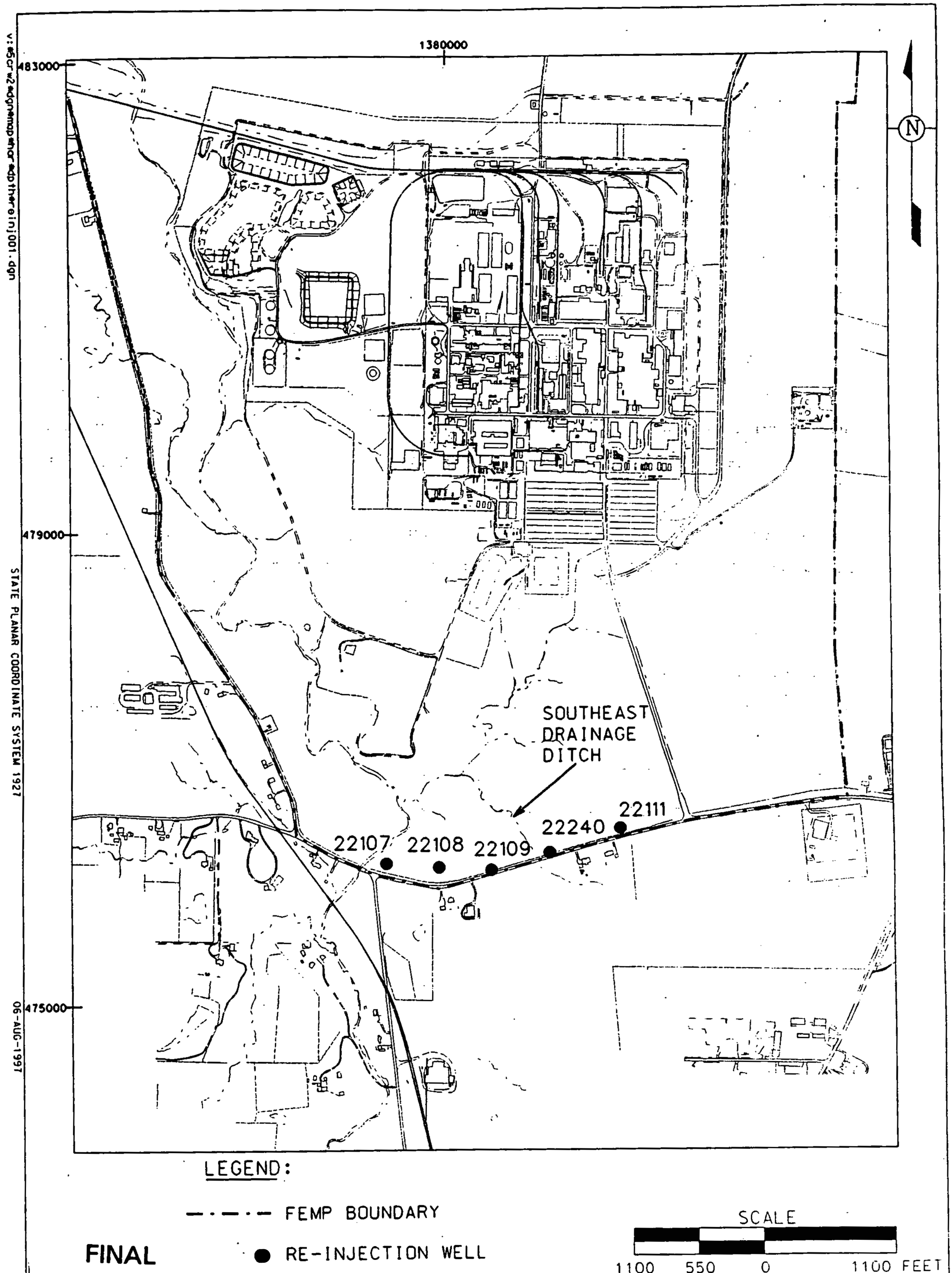

FIGURE 1-1. LOCATION OF RE-INJECTION DEMONSTRATION TEST WELLS

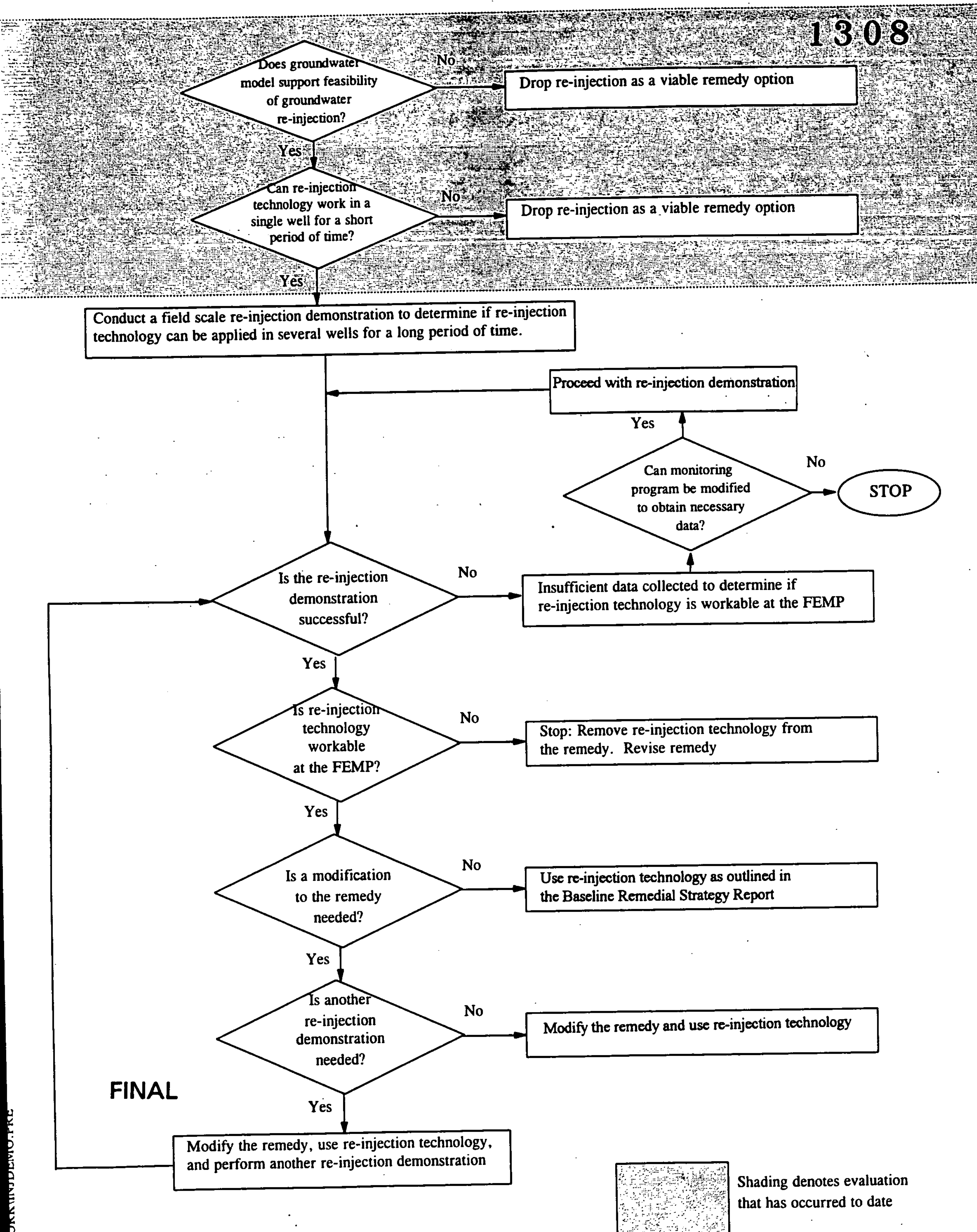

Figure 1-2. Re-injection Technology Evaluation Flowchart

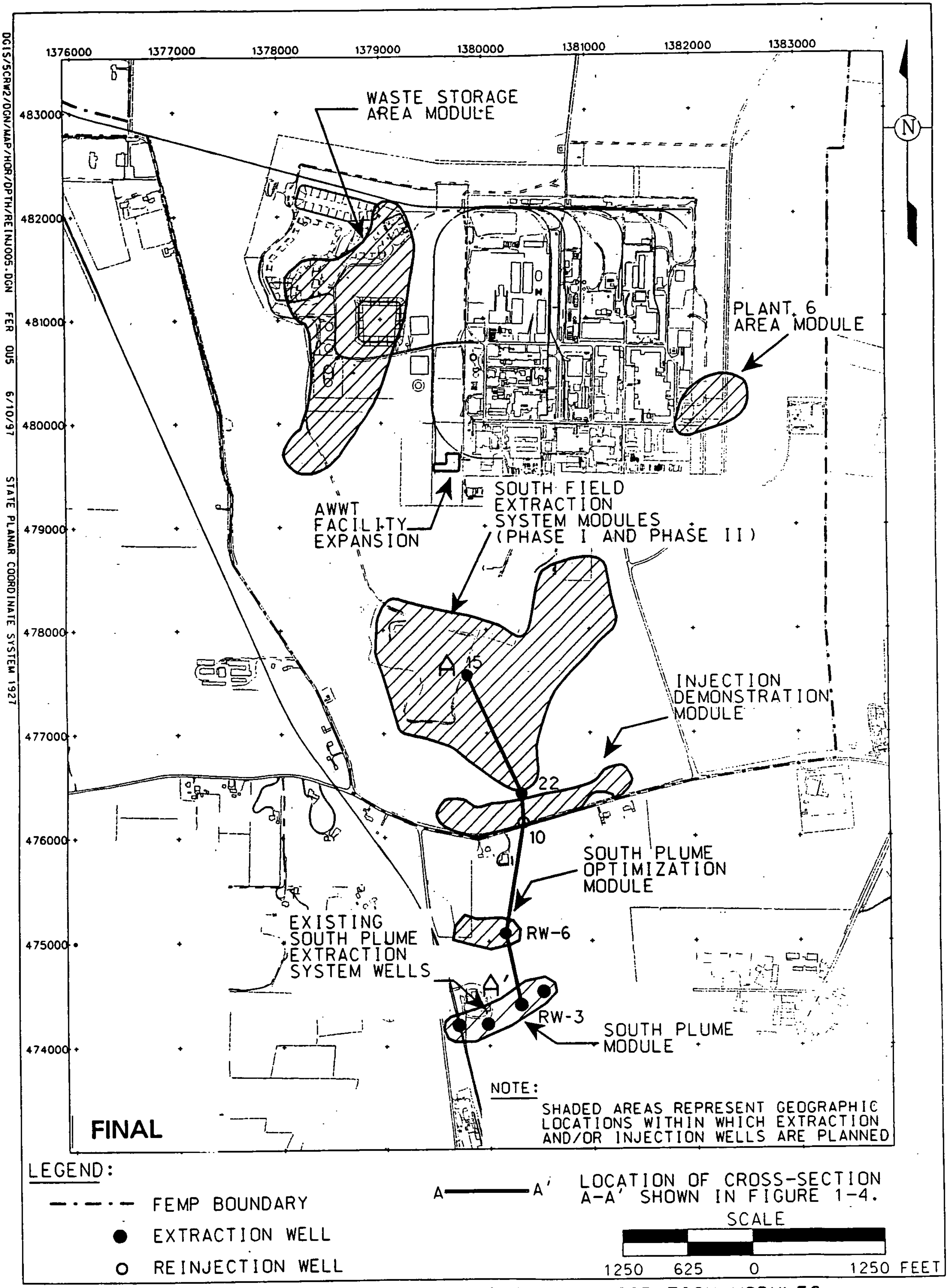

FIGURE 1-3. LOCATION OF AQUIFER RESTORATION MODULES

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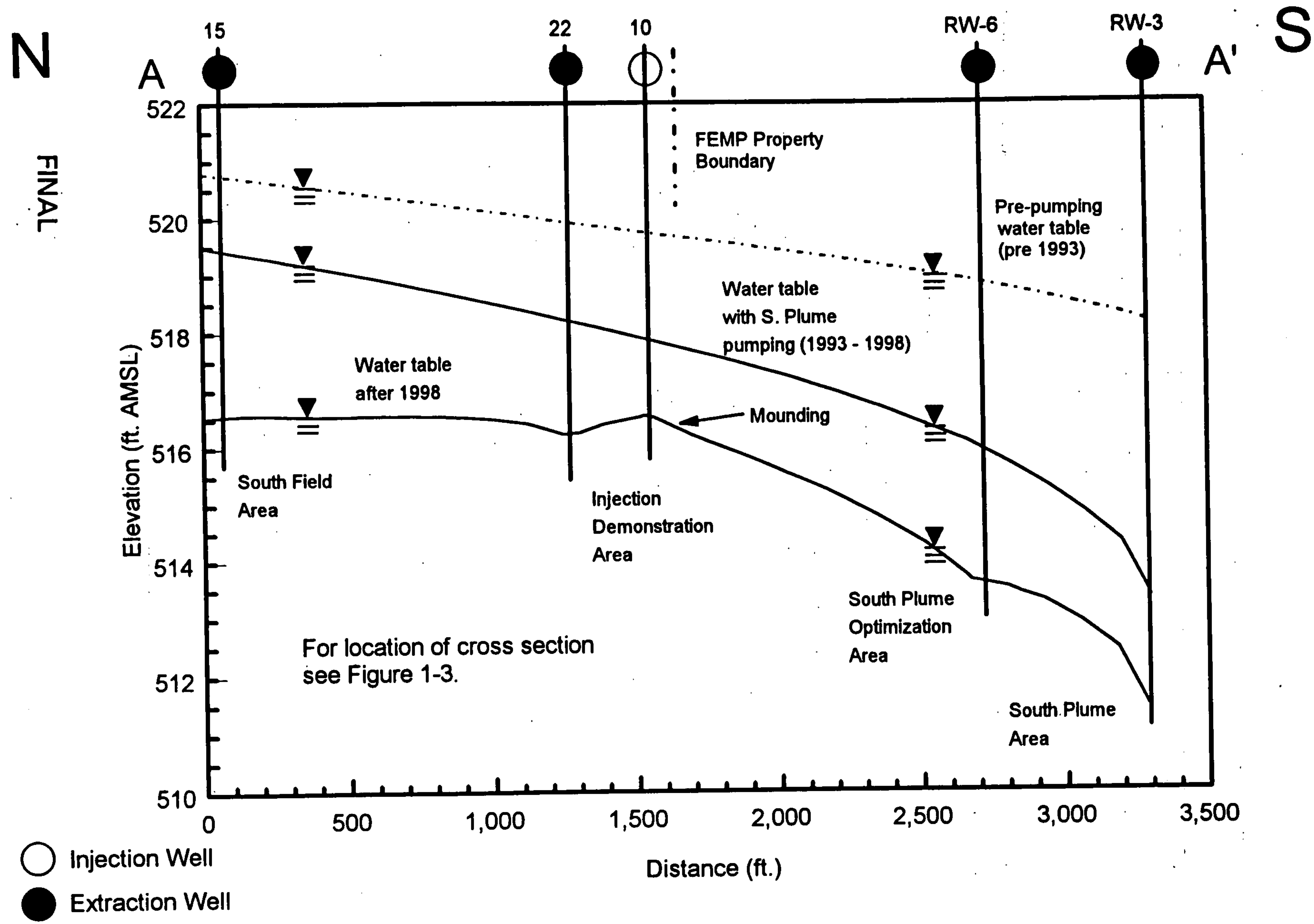

Figure 1-4. Water Table Elevation Profile

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2.0 DESIGN CONSIDERATIONS

The design considerations for the re-injection demonstration project are:

- Ohio EPA re-injection guidelines
- Aquifer characteristics
  - Hydrogeology
  - Groundwater quality
- The aquifer remedy
  - Aquifer restoration modules and facilities
  - Source and quality of injectate
  - Volume and rate of re-injection
  - The effect that re-injection will have on the 20 μg/L total uranium plume
- Industry knowledge on the design of re-injection wells
- Previous site experience
  - Single well injection tests
  - Water quality sampling in the re-injection demonstration area
  - Operation of the South Plume Extraction System
- Previous commitments made in other plans for work to be conducted as part of the re-injection demonstration

These considerations are discussed in each of the following subsections.

2.1 OHIO EPA RE-INJECTION GUIDELINES

The Ohio EPA Division of Drinking and Ground Waters (DDAGW) Underground Injection Control (UIC) has regulatory authority for re-injection in the State of Ohio. The re-injection demonstration will follow Ohio EPA Guidance (OEPA 1997). This guidance allows underground injection wells, used for the purpose of remediation, to operate without a permit provided that the injectate does not exceed any Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs) or Health Advisory Limits (HAs).

65 The Re-Injection Demonstration is already exempted (under 40 CFR 300.400(e)(1)) from requiring a permit as it is a CERCLA action. However, the injectate will need to be evaluated with respect to the Operable Unit 5 Record of Decision established final remediation levels (FRLs) for affected groundwater at the FEMP. The injectate sampling strategy is provided in Section 4.1.

Ohio EPA guidance requires the following elements to be included in this test plan:

- A hydrogeologic site description (Section 2.2) including groundwater flow direction
66 - A detailed description of the aquifer remedy that explains the method of restoration and number of wells (Section 2.3)
- A complete analysis of fluids to be re-injected (Section 4.1)
- The volume and rate of fluid to be re-injected (Section 2.3)
- The results of ground water monitoring in the test area (Section 2.2)
- The name of the Ohio EPA staff member overseeing any related site activities (Section 6.0)
- Plugging and abandonment of the re-injection wells (Section 7.0).

The Ohio EPA guidelines also request that monthly operating reports be prepared and submitted that include:

- Analysis of the injectate
- Volume and rate of re-injected fluid
- A description of any well maintenance and rehabilitation procedures
- The results of groundwater monitoring at the re-injection site.

A copy of the monthly reports and the test plan will be submitted to the Ohio Division of Drinking and Ground Waters - UIC Unit, P.O. Box 1049, 1800 Watermark Drive, Columbus, Ohio 43216-1049.

2.2 AQUIFER CHARACTERISTICS

This section presents the hydrogeology and groundwater quality of the re-injection demonstration area.

Hydrogeology

As a result of the FEMP's intensive CERCLA site characterization efforts, in conjunction with other previous studies, the Great Miami Aquifer at the FEMP is one of the most well studied aquifers in the world. A detailed hydrogeologic site description of the FEMP can be found in Chapter 3 of the OU5 Remedial Investigation Report (DOE 1995a). A brief overview is provided below.

The re-injection demonstration is situated over the New Haven Trough, a large buried valley filled with glacial sand and gravel outwash deposits with an axis running northeast-southwest. Figure 2-1 is a bedrock topographic map that defines the base of the valley floor. The floor and walls of the New Haven Trough consist of Ordovician age shale and limestone. During the Pleistocene the New Haven Trough was carved into the shale and limestone bedrock, filled with sand and gravel, and capped by a layer of Wisconsin age clay-rich glacial overburden. The sand and gravel forms the matrix of the regionally extensive Great Miami Aquifer.

12 The Great Miami Aquifer is unconfined, anisotropic, and heterogeneous and has been federally designated a sole-source aquifer by the U.S. EPA. As recorded during the drilling of Monitoring Well 4398, the lithology in the area of the Re-Injection Demonstration, in descending order, consists of approximately 24 feet of silty clay and approximately 167 feet of sand and gravel. Bedrock is approximately 191 feet below ground surface (bgs).

13 As explained in Section 2.3, four extraction wells have been pumping south of the re-injection demonstration area since August of 1993. Figure 2-2 is a water table map from 1996 that illustrates groundwater levels in the re-injection demonstration area with the four existing extraction wells pumping.

Groundwater Quality

To facilitate monitoring and remediation the Great Miami Aquifer, the area of the FEMP site has been subdivided into five zones, Figure 2-3. Re-injection will take place in aquifer zone two but very close to aquifer zone four. The groundwater which will be treated for re-injection will be pumped from wells located in both aquifer zones two and four. Therefore, the groundwater quality in aquifer zones two and four will impact, and be impacted by, the re-injection demonstration.

A CERCLA Remedial Investigation/Feasibility Study (RI/FS) has been completed at the FEMP. During the RI/FS a very rigorous groundwater monitoring program was conducted to characterize the nature and extent of contamination in the Great Miami Aquifer at the FEMP. Over 200 groundwater monitoring wells were installed in the aquifer. Groundwater analyses included radiological constituents, full Hazardous Substance List (HSL) constituents, Appendix IX constituents, and general groundwater quality parameters. Process knowledge at the FEMP was used to guide the monitoring program and keep the program focused on those contaminants which were used at the FEMP. A detailed summary of the groundwater quality of the Great Miami Aquifer beneath the FEMP can be found in Chapter 4 of the Remedial Investigation (RI) Report for Operable Unit 5 (DOE 1995a). The study resulted in a list of Contaminants of Potential Concern (CPCs) for the FEMP site.

A detailed risk assessment, which focused on the FEMP CPCs, was conducted to determine which constituents posed an unacceptable risk to target receptors via the groundwater pathway. The result of the risk assessment was the identification of 50 site-specific groundwater constituents of concern (COCs) that were carried forward into the Operable Unit 5 Feasibility Study where preliminary remediation goals were developed. Remediation goals for the selected remedy were then carried forward and established as final remediation levels (FRLs) in the Operable Unit 5 Record of Decision (DOE 1996b). Remediation of the Great Miami Aquifer is based on achieving Final Remediation Level (FRL) concentrations for the 50 identified FRL constituents. The FRLs for these constituents are set at the MCL, proposed MCL, a risk-based level, analytical detection limit, or background.

A full assessment of the groundwater quality (against FRL concentrations) in all five aquifer zones is presented in Appendix A of the Integrated Environmental Monitoring Plan. FRL constituents that have had at least one validated FRL exceedance in either aquifer zone two or four are listed in Table 2-1. The first column of Table 2-1 lists the FRL parameter for which an FRL exceedance has been recorded. The second column lists the FRL concentration for the parameter. The third column gives the range of concentration that has been detected in the aquifer zones two and four combined. The fourth column lists the number of detections above the FRL, and the fifth column lists the total number of samples considered. The sixth column of Table 2-1 identifies whether or not the constituent is considered mobile and persistent "MP" or *not* mobile and persistent "N." The terms mobile and persistent are used to describe those constituents that are predicted to be able to migrate vertically through the glacial overburden reach the aquifer, and create an unacceptable risk in the absence of source control actions (i.e., identified as failing the Operable Unit 5 model screening in Table F.2-2, Operable Unit 5 Feasibility Study, DOE 1995c). Those FRL constituents that do not have the ability to migrate through the glacial overburden to the aquifer and create an unacceptable risk (not mobile and persistent) are identified with an N. If an N constituent has been detected in the aquifer above its FRL it must have short circuited the pathway through the overlying glacial overburden and into the aquifer. These "short circuits" are present where the glacial overburden has been removed by erosion such as in Paddys Run and in the Storm Sewer Outfall Ditch. The last column in Table 2-1 identifies the basis for the FRL.

The principal contaminant of concern in aquifer zones two and four is total uranium. In the immediate area of the re-injection demonstration wells, total uranium concentrations have been recorded as high as 490 μg/L, see BRSR, Figure G-22, (DOE 1997a).

2.3 AQUIFER REMEDY

64 A detailed description of the planned aquifer remedy, the groundwater modeling which was conducted to design the remedy, and the proposed system that will implement the remedy can be found in the BRSR (DOE 1997a).

17 The aquifer at the FEMP will be remediated with a pump-and-treat remedy supplemented by groundwater re-injection. The remedy consists of 37 pumping wells and 10 re-injection wells (Figure 2-4) which will be installed as phased modules as described below. Figure 1-3 shows the locations of the modules. The continued use of re-injection as part of the aquifer remedy is contingent upon the outcome of the re-injection demonstration.

The extraction and re-injection wells are grouped into seven modules located in four distinct areas of aquifer contamination, Figure 1-3. Each module is designed to remediate a specific portion of the aquifer. The modules are scheduled to be installed and operational at different times during the life of the remedy as surface remediation activities are completed and as access becomes available for well installation.

Four existing recovery wells located off property in the South Plume Area have been pumping contaminated groundwater since August of 1993 as part of a removal action. These wells will continue to operate during the aquifer remedy. In 1998, two additional South Plume Optimization Wells located off property and north of the existing recovery wells are scheduled to become operational. The South

Plume, and South Plume Optimization wells are scheduled to operate through the year 2003 or until groundwater monitoring in the South Plume Area indicates that COC concentrations are below the FRLs established in the Operable Unit 5 Record of Decision (DOE 1996b) or a technical impracticability waiver is approved. Also in 1998, ten wells located on property in the South Field Area are scheduled to begin pumping groundwater. The South Field Phase I wells are scheduled to be operational until 2005 or until the remedy is completed.

Five re-injection wells have been installed along the southern FEMP boundary as part of the re-injection demonstration. These wells are scheduled to begin to operate in 1998 and continue through the year 2003 if the demonstration concludes that it is feasible and beneficial.

In 2004, ten extraction wells are scheduled to become operational in the Waste Storage Area if surface remediation activities are complete. These wells will pump contaminated groundwater from beneath the former Waste Pit Area of the site. At the same time, two extraction wells are scheduled to be installed in the former process area to remediate a small uranium plume at the Plant-6 area. These wells will pump contaminated groundwater for two years or until groundwater monitoring in the area indicates COC concentrations are below the FRLs.

Also in 2004, the South Field Phase II system is scheduled to become operational to provide additional pumping capacity in the South Field Area and to complement the South Field Phase I wells discussed above. If the demonstration proves that re-injection technology is viable at the FEMP, then an additional line of re-injection wells immediately north of the South Field Area will be installed and begin operating in 2004. The aquifer remedy is scheduled for completion in 2005.

Source and Quality of Injectate

For the purpose of this test plan, the treated groundwater that will be re-injected into the Great Miami Aquifer will be called "injectate." The source of injectate for the re-injection demonstration will be treated groundwater from the AWWT Expansion Facility. Groundwater from aquifer zones two and four will be pumped from the aquifer and conveyed to the AWWT Expansion Facility for treatment prior to re-injection into aquifer zones two and four. See Section 2.2 for a discussion of the quality of groundwater in aquifer zones two and four.

Since the AWWT Expansion Facility is not yet operational it is not possible to analyze the effluent. However, prior to re-injection, in accordance with OEPA guidelines, effluent from the AWWT Expansion Facility will be sampled. As presented in the RA Work Plan, the AWWT Expansion Facility is scheduled to begin operation in April of 1998. A sampling strategy for the injectate that begins before re-injection is scheduled to take place is presented in Section 4.1.

Volume and Rate of Re-Injection

The aquifer remedy will be operating during the re-injection demonstration. As shown in Table 5-2 of the BRSR (DOE 1997a) it is planned that:

- Groundwater will be pumped from the aquifer at a net rate of 3400 gpm.
- 2000 gpm of groundwater will be sent to treatment, 1400 gpm will go to the AWWT Expansion facility.
- 1000 gpm of treated-groundwater will be re-injected back into the aquifer for the re-injection demonstration.
- 2400 gpm of groundwater (mixture of treated and untreated) will be discharged to the Great Miami River.

Given a re-injection rate of 1000 gpm, and a re-injection duration of 1 year, it is estimated that up to approximately 5.26×10^8 gallons of water could be injected into the aquifer during the demonstration. This estimate assumes re-injection will take place through 5 wells at an individual rate of 200 gpm and each well operate continuously during the demonstration. However, some downtime is expected. At a minimum the re-injection wells will be shut down quarterly for a short period of time for maintenance checks.

The Affect That Re-injection Will Have on the 20 μg/L Total Uranium Plume

If re-injection takes place above the top of the plume, the injectate might push the plume deeper into the aquifer. If re-injection occurs below the plume the injectate might not effectively flush contamination to the extraction wells. Re-injection within the plume itself would flush contamination to the extraction wells, but depending upon the thickness of the plume in relation to the length of the zone of active injection, the injectate might serve to split the plume and push some of the plume deeper into the aquifer. Data collected from the spinner tool (discussed below) indicates that the active zone of re-injection is much smaller than the total length of the well screen, so it is quite likely that if re-injection occurs in an area where the plume is very thick, relative to the length of the re-injection well screen, that some of the total uranium plume might be pushed deeper into the aquifer. The concern, should this occur, is whether or not capture of the entire plume would still be maintained. A strategy to monitor the effect that re-injection has on the 20 $\mu g/L$ total uranium plume is presented in Section 4.

2.4 INDUSTRY KNOWLEDGE ON THE DESIGN OF RE-INJECTION WELLS

Based on industry reports, re-injection wells are much more likely to fail than typical water producing wells because of plugging due to water-chemistry problems. As recommended in Driscoll 1986, the design criteria commonly used for extraction wells should be used to design re-injection wells, with the exception of entrance velocity and screen length. For the purpose of this test plan, "entrance velocity" for an extraction well will be referred to as "exit velocity" for a re-injection well. The screens of re-injection wells should be designed for an average exit velocity that does not exceed 0.05 feet/second. Since clogging of the well screen is the most serious problem expected in re-injection wells, an effort should be made to maximize the length of the well screen.

2.5 PREVIOUS SITE EXPERIENCE

Previous site experience consists of the two single-well injection tests (conducted in 1995 and 1996), water quality sampling results in the area of the re-injection demonstration, and operation of the South Plume Extraction System. Test results are presented in two separate reports (DOE 1995b) and (DOE 1996a).

Single Well Injection Tests

During the first single well injection test (DOE 1995b) it was learned that in order for the re-injection process to work at the FEMP, only waters with similar pH, Eh, and low iron content should be mixed. If the waters are not similar and high concentrations of ferrous iron are present, the ferrous iron can oxidize to ferric iron and form an iron-hydroxide precipitate which in turn promotes the growth of iron bacteria and leads to rapid screen plugging.

During the second single well injection test (DOE 1996a) a spinner tool was used in the re-injection well to determine a vertical flow profile over the length of the well screen. The spinner tool indicated that 80 percent of the injectate flowed out of the upper three feet of a 15 foot well screen. This indicates that the injectate will move out of the upper portion of the well screen unless it is physically forced down into the lower levels of the screen. This can be accomplished by grading the size of the exit holes in the base of the downcomers so that they are larger at the bottom and smaller at the top. A downcomer is the piping within the re-injection well that carries the injectate down the well. The holes in the downcomers used for the re-injection demonstration will be graded as described above.

Sampling Results

Water quality sampling conducted in the area of the re-injection demonstration indicates that:

- Iron concentrations vary vertically and horizontally in the Great Miami Aquifer, increasing with depth
- Both aerobic and sulfate-reducing bacteria are naturally present in the aquifer at the re-injection demonstration area
- Dissolved oxygen concentrations decrease with depth
- The redox potential decreases with depth.

Results of the water quality sampling for major anions and cations, in situ water quality parameters (i.e., temperature, pH, specific conductance, dissolved oxygen, and redox potential) and bacterial analyses are presented in Appendix A.

19 Sampling data indicates that the potential exists for iron plugging of the re-injection well screens and that the potential increases with depth in the aquifer. Geochemical modeling using geochemical data collected from Well 31567 (a well used in earlier injection tests), which is located in the Southfield, indicated that a total iron concentration in the aquifer above 0.15 ppm may result in precipitation of ferric iron. Sampling results presented in Table A-1 indicate that the iron concentration in the re-injection demonstration area, in the shallow zone being targeted for re-injection (2000 series results) is below this concentration. The precipitation of ferric iron plugs the well screen and promotes the growth of iron bacteria which leads to further plugging. The two single-well injection test reports both discuss the process of iron precipitation and iron-bacteria plugging (DOE 1995b, DOE 1996a).

Operation of the South Plume Extraction System

The South Plume Extraction System has been pumping groundwater from the Great Miami Aquifer since August 1993. Various problems have been encountered during the operational life of the South

Plume Module. Lessons learned from operation of the South Plume system will be incorporated into the maintenance and operation of the Re-Injection Demonstration Wells.

In particular, iron fouling of system components, including well screens, control valves, flow meters and check valves has occurred in the South Plume wells. The South Plume wells have been placed on a quarterly preventive maintenance program to address the iron fouling. The preventive maintenance program for the South Plume Wells is presented in the OMMP (DOE 1997d). The maintenance program for the Re-Injection Demonstration Wells will be based off of the South Plume program. It is expected that the program for the Re-Injection Wells will evolve as the demonstration progresses and information on the operation of the re-injection wells is collected and evaluated. The maintenance program for the re-injection wells is presented in Section 4.

2.6 PREVIOUS COMMITMENTS

The top of the 20 μg/L total uranium plume in the area of Monitoring Well 3069, which is next to a ponding feature in the South East Drainage Ditch, is located approximately 30 feet beneath the water table. Recharge from the drainage ditch could be diluting the plume at the water table. A comparison of the chemistry of the surface water found in the ditch to groundwater found in the aquifer directly beneath the ditch will be used to indicate how similar the waters are. Similar chemistries will support the recharge theory. Page seven of the Restoration Area Verification Sampling Program Project Specific Plan (DOE 1997e) states that the surface water chemistry in the Southeast Drainage Ditch will be measured and compared to the groundwater chemistry of the underlying aquifer in an effort to verify that the ditch recharges the aquifer. The location of the Southeast Drainage Ditch is shown on Figure 1-1. This work will be conducted as part of the Re-Injection Demonstration.

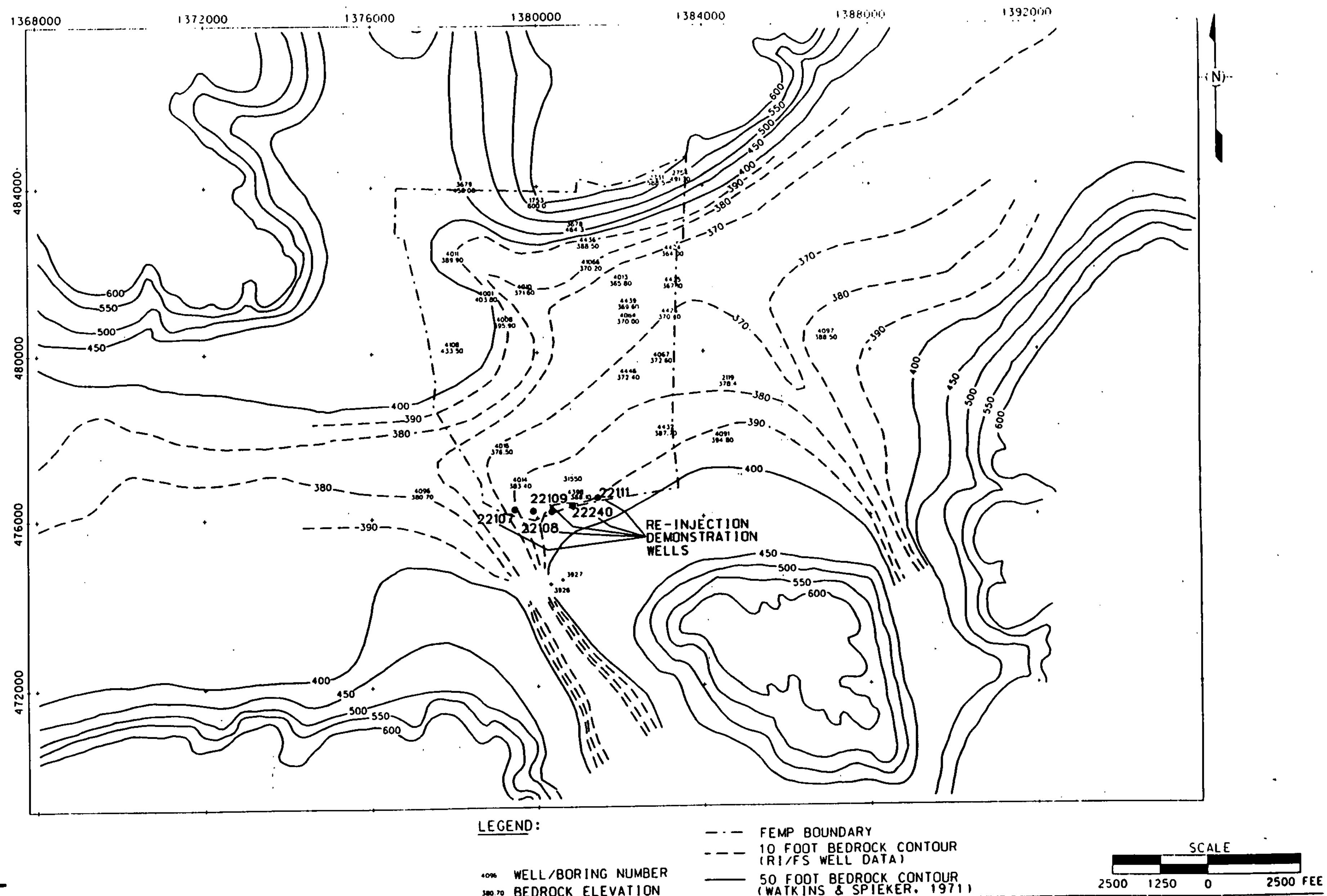
TABLE 2-1

16 **CONSTITUENTS IDENTIFIED IN AQUIFER ZONES 2 AND 4 AT CONCENTRATIONS ABOVE THEIR FRL**

Constituents	Groundwater FRL[a]	Range Detected in Aquifer in Zones 2 & 4	No. Samples > FRL	Total Number of Samples	Constituent Type	Basis for FRL
General Chemistry	**mg/L**					
Nitrate	11.0	0.01- 43.2	3	296	MP	B
Inorganics	**mg/L**					
Antimony	0.006	0.0012 - 0.0958	8	476	N	A
Arsenic	0.05	0.00084 - 0.35	40	1121	N	A
Barium	2.0	0.0081 - 8.69	2	713	N	A
Beryllium	0.004	0.001 - 0.178	1	469	N	A
Cadmium	0.014	0.001 - 0.211	4	746	N	B
Chromium	0.022	0.0021 - 2.017	154	745	MP	R
Cobalt	0.17	0.002 - 0.528	2	469	N	R
Lead	0.015	0.001 - 0.3	18	730	N	A
Manganese	0.9	0.001 - 139.0	12	746	N	B
Mercury	0.002	0.00015 - 0.0123	6	744	MP	A
Nickel	0.1	0.0042 - 0.791	13	748	N	A
Selenium	0.05	0.0009 - 0.246	4	741	N	A
Silver	0.05	0.0011 - 0.12	3	743	N	A
Vanadium	0.038	0.0038 - 0.29	7	609	N	R
Zinc	0.021	0.0019 - 1.12	37	467	N	B
Radionuclides	**pCi/L**					
Neptunium-237	1.0	0.036 - 3.25	2	371	MP	R*
Radium-226	20.0	0.181 - 39.8	1	699	N	A
Strontium-90	8.0	0.723 - 17.4	1	486	MP	A
Thorium-228	4.0	0.01- 14.2	25	757	N	R*
Thorium-232	1.2	0.008 - 2.7	6	756	N	R*
	μg/L					
Total Uranium	20.0	0.063 - 2070	246	808	MP	A
Organics	**μg/L**					
Bis(2-ethylhexyl)phthalate	6.0	0.4 - 13.0	1	71	N	A
Carbon disulfide	5.5	1.0 - 26	1	342	N	A
1,1-Dichloroethene	7.0	ND - 110	1	317	N	A
1,2-Dichloroethane	5.0	0.2 - 310	1	317	MP	A
Trichloroethene	5.0	1.0 - 34	2	343	N	A

[a]From Table 9-3 in OU5 ROD. Fluoride and lead FRLs reflect values presented in the Remedial Design Fact Sheet for Operable Unit 5 Aquifer Restoration - Groundwater FRLs for Fluoride and Lead.
A - Applicable or relevant and appropriate requirement based (MCL, PMCL, etc.).
B - Based on 95th percentile background concentrations.
R - Risk Based Preliminary Remediation Goal (CPRG)
R* - Risk Based Preliminary Remediation Level includes the radionuclide risk-based PRG plus its 95th percentile background concentration.

NOTES:
- Unfiltered and filtered validated data was used to prepare table. Any data qualified as "R" or "Z" was not used.
- Data was pulled from Site Environmental Database (SED) (which contains sampling results from 1-1-94 to 7-31-97) and the Operable Unit 5 remedial investigation groundwater data set (which contains data prior to 1-1-94).
- If duplicate data was available, the highest value was used.

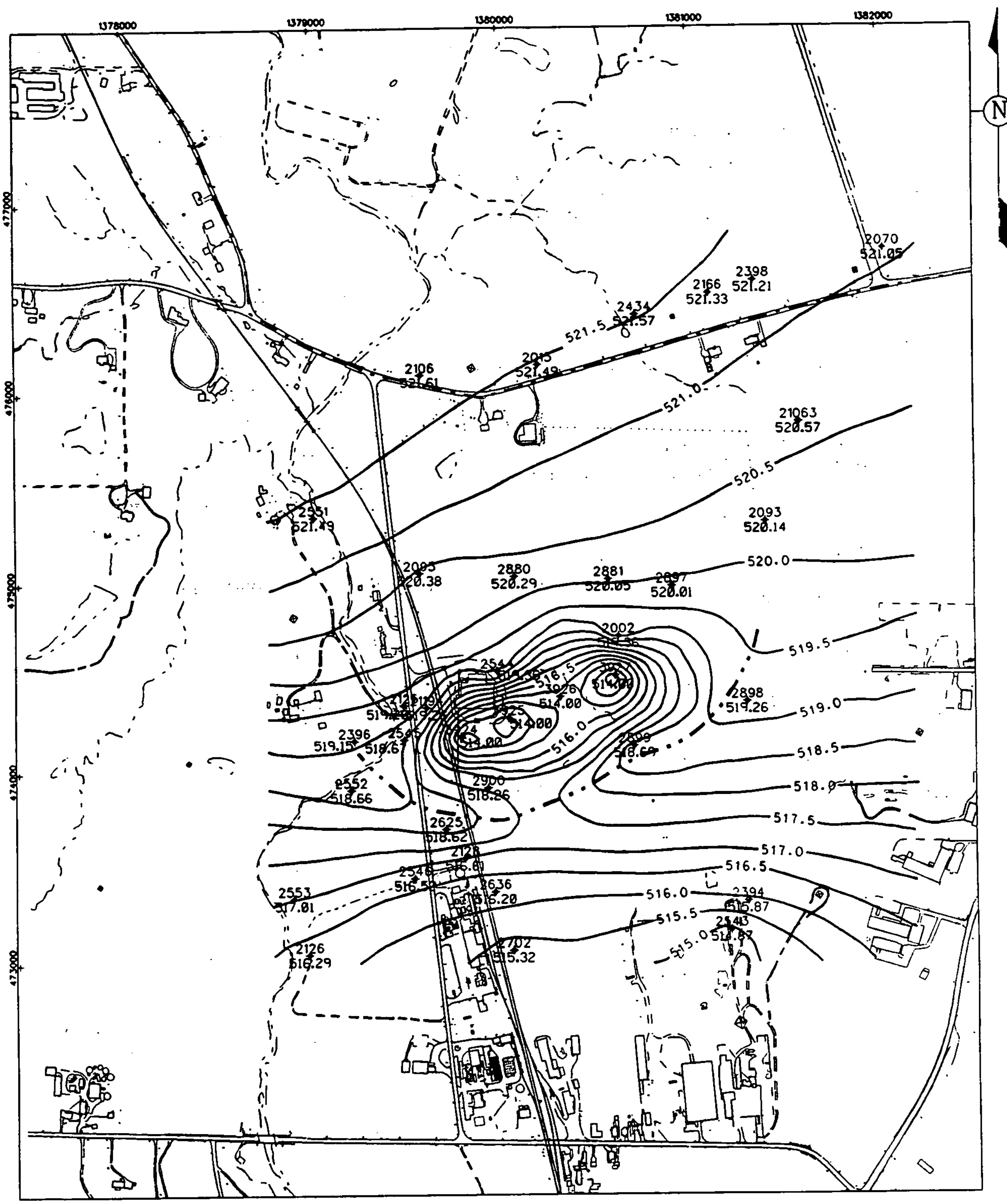


FINAL

FIGURE 2-1. BEDROCK TOPOGRAPHIC SURFACE

/USR/ERMA5/5CRW2/DGN/MAP/HOR/DPTH/REINJ003.DGN STATE PLANAR COORDINATE SYSTEM 1927

/USR/ERMAS/SCRW2/DGN/MAP/HDR/DPTH/REINJ004.DGN FER OU5 1/28/97 STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

- FEMP BOUNDARY
- FLOW DIVIDE
- 515.0 GROUNDWATER ELEVATION CONTOUR (AMSL)

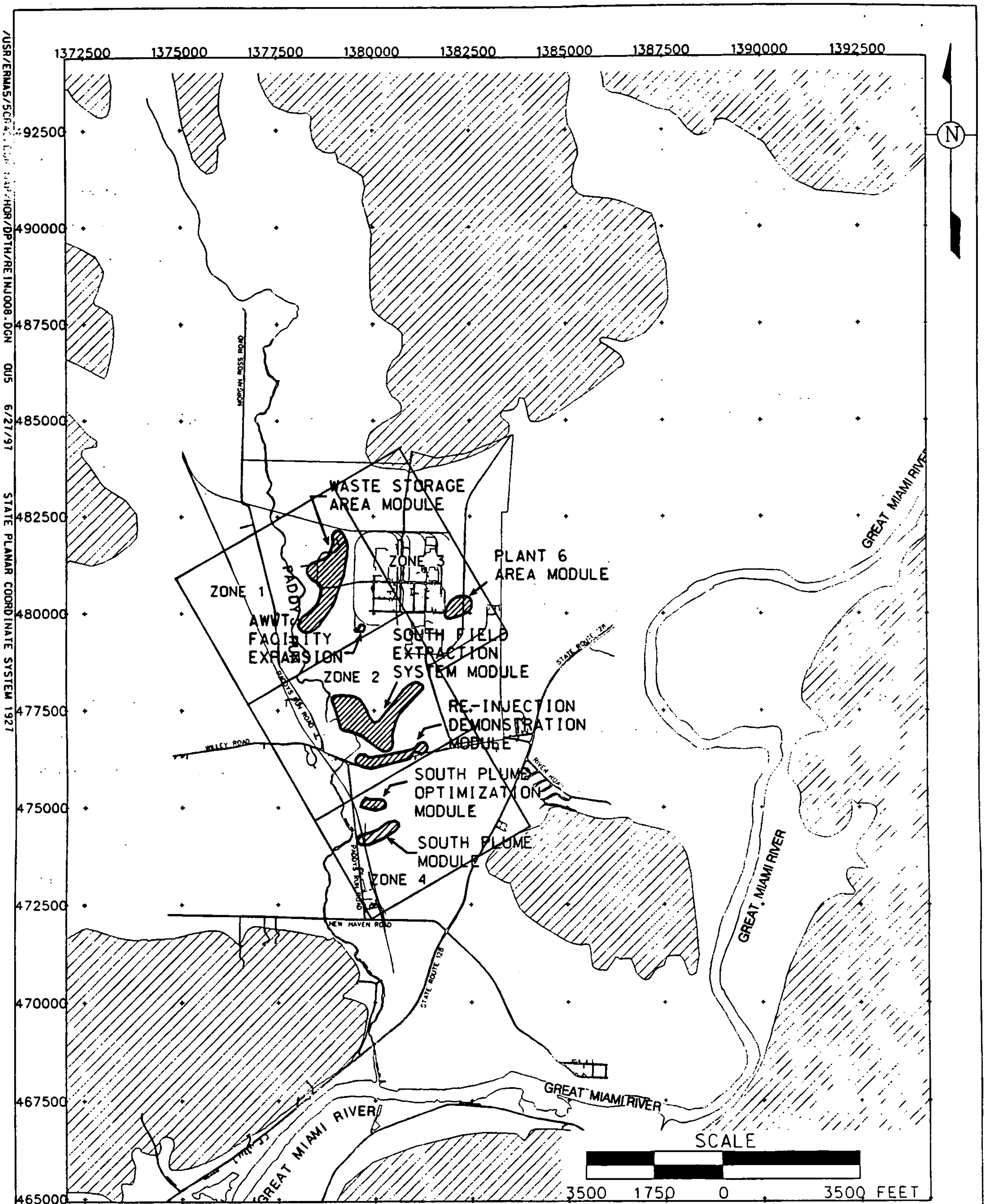
SCALE

800 400 0 800 FEET

FINAL

FIGURE 2-2. GROUNDWATER ELEVATIONS AUGUST 1996

000032



LEGEND:

—·—·— FEMP BOUNDARY

NOTE:
SHADED AREAS REPRESENT GEOGRAPHIC LOCATIONS WITHIN WHICH EXTRACTION AND/OR INJECTION WELLS ARE PLANNED
ZONE 0 CONSISTS OF ALL AREAS OUTSIDE ZONES 1, 2, 3, AND 4.

FINAL

FIGURE 2-3. GROUNDWATER AQUIFER ZONES

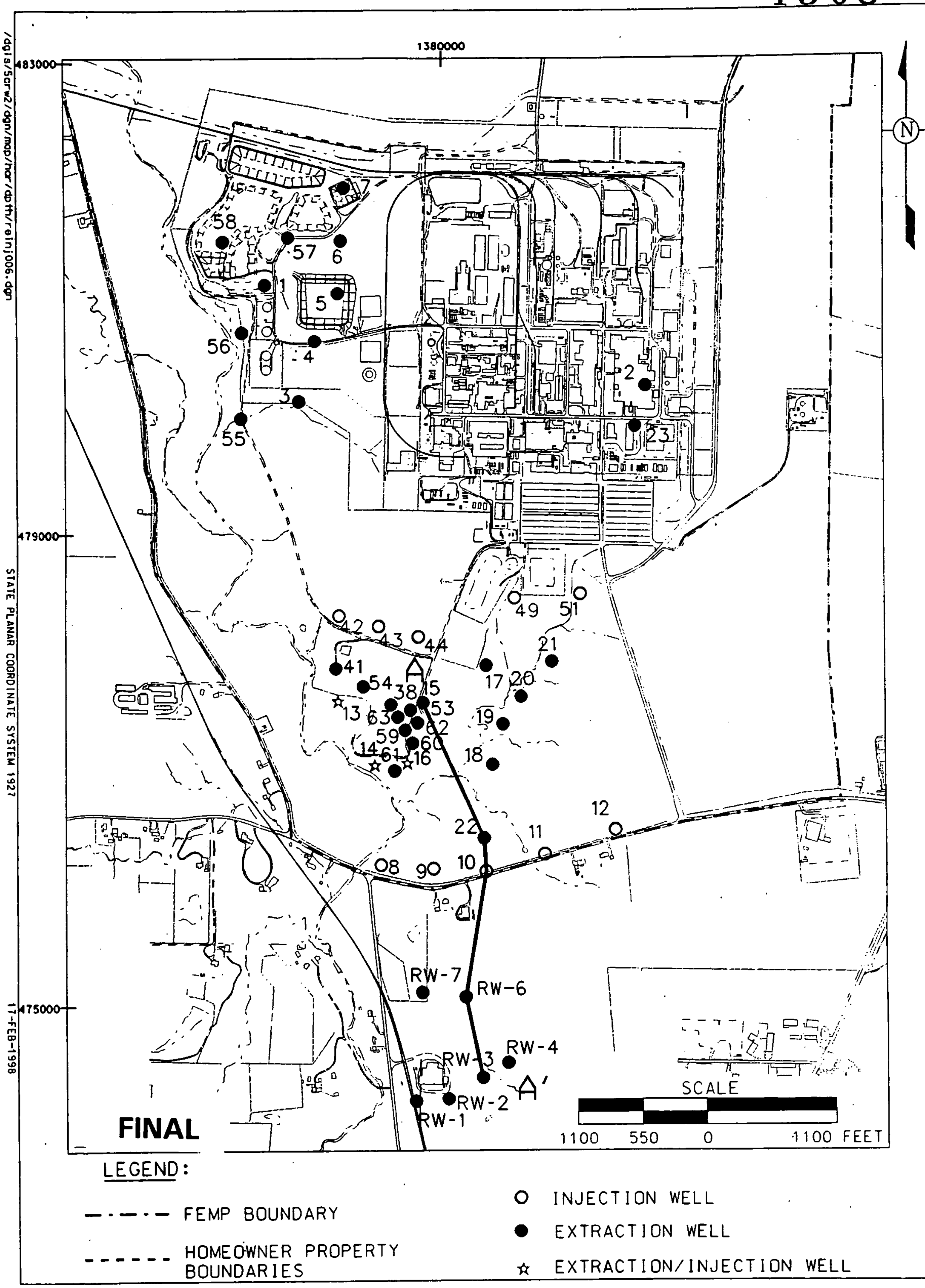


FIGURE 2-4. WELL LOCATIONS FOR THE BASELINE GROUNDWATER REMEDIAL STRATEGY

3.0 DEMONSTRATION SET-UP

The Re-Injection Demonstration System will consist of five re-injection wells (already installed) located along the southern FEMP property line. With the exception of re-injection Well 22111, each re-injection well will have a shallow and deep observation well (located within approximately 25 feet of the re-injection well). Well 22111 will only have a shallow observation well. The re-injection wells have all been installed. The nine observation wells will be installed before the South Field Extraction System begins operation in 1998.

During the demonstration 1000 gpm of treated groundwater called "injectate," coming from the AWWT Expansion Facility, will be re-injected into the 5 re-injection wells at a rate of 200 gpm per well. The injectate will contain less than 20 μg/L total uranium and less than 0.1 ppm total iron. The uranium concentration limit is the OU5 ROD established FRL. The iron concentration limit is deemed necessary to prevent the buildup of iron precipitate and bacteria in the wells and is based on geochemical modeling conducted to support the second single well injection test at the FEMP (DOE 1996a, Appendix F). The injectate will flow from the AWWT Expansion Facility to a 50,000 gallon surge tank to the injection wells via a pipe network. The injection flow rate will be controlled remotely from the AWWT Control Room. It will be possible to control the flow rate locally at each well head, but any change made locally will be detected in the AWWT Control Room. The design of the re-injection demonstration system is contained in the Certified for Construction Design Package for Task 4: Injection Demonstration (DOE 1997b).

3.1 <u>GENERAL DESIGN OF THE RE-INJECTION WELLS</u>

As discussed in Section 2.4, re-injection wells are much more likely to fail than typical water production wells. Problems associated with water-chemistry, air entrainment, and sand pumping are considerably more serious and common for re-injection wells. Given the increased chance for maintenance problems, several factors were considered in the general design of the re-injection wells:

- The design needs to be simple and flexible to facilitate later modifications if necessary.
- The design needs to facilitate routine maintenance and work-over of the screen area for iron encrustation and plugging.
- The design needs to reduce the possibility that air bubbles will be injected into the well and pushed out into the aquifer material. This happens if the injectate is allowed to cascade

down the well. The air bubbles will displace groundwater around the well, reducing effective porosity for the injectate.

- The design needs to allow for the monitoring of sand content in the injectate. Injectate with a sand concentration as low as 1 mg/L can clog re-injection wells over time. If sand concentration in the re-injection well becomes a problem, an in-line filter can be installed.

- The demonstration will determine if a larger diameter re-injection well will incur less maintenance costs than a smaller diameter re-injection well. In theory, given the same injection rate and slot opening size, the screen of a larger diameter well should have a lower average entrance velocity than the screen of a smaller diameter re-injection well. The lower entrance velocity should lower the probability of the screen plugging and decrease maintenance costs. Another advantage of a larger diameter well is that it is easier to work in during maintenance operations.

71 The general design of each re-injection well is illustrated in Figure 3-1. Each re-injection well has protective casing constructed of Schedule 40 PVC with a 304 stainless steel wire wrapped screen. It is anticipated that the stainless steel screen will hold up better than other materials if numerous screen work-overs are needed due to well plugging. The use of a telescoped protective casing was considered but not used. The thought was that the screen of the re-injection well might become so clogged that it would need to be replaced. A larger fixed casing could be installed through which a smaller retrievable screen could extend. It was decided though, that if the screen was so badly plugged that it needed to be replaced, then chances would be good that the porosity of the surrounding aquifer would also be reduced. It would be more cost effective in these circumstances to re-drill at a new location rather than install a new screen at the old location.

A flow controller will operate at each re-injection well with a flow meter and control valve to maintain a preset nominal 200 gpm (± 10%) flow rate into the well. This flow will be directed down one of two injection tubes called "downcomers." One downcomer is designed for a nominal flow of 200 gpm, the other is slightly smaller and designed for a nominal flow of 150 gpm. The smaller downcomer can be used temporarily to maintain needed back pressure should the re-injection rate temporarily fall to 150 gpm or less. The base of the downcomer will be sized to maintain a 1 psi pressure at the downcomer inlet so that injectate will not cascade down the downcomer and create air entrainment. Downcomer perforations increasing in size with depth will help distribute flow across the well screen. The downcomers are essentially a passive delivery system. The use of a downhole packer was also considered for controlling the delivery of the injectate. An inflatable packer would restrict flow within the well creating the positive pressure needed to prevent cascading of the injectate. It was decided though, that the maintenance and operation of a packer was more complicated than using a passive downcomer. To keep the design simple downcomers were selected. The wells could be modified with a packer at a later date if the use of a packer is found to be beneficial.

The design also includes the following features:

- A chemical injection port at each well head which can be used for possible maintenance activities during the demonstration
- A downhole pressure transducer installed in a stilling pipe within each re-injection well. The transducer will measure water levels and signal operators if the water level in a re-injection well is getting too high
- A sampling port at each re-injection well head for installing a centrifugal sand sampler which can be used to measure the sand content of the injectate.

General Design of the Well Screen

The general design of the re-injection well screens was based upon the following:

72 - Used a continuous wire wrapped well screen and conducted a sieve analysis to select a screen slot size to maximize the open area of the screen
- Set the top of the well screen so that it would remain below the surrounding water table during the aquifer remedy

21 - Restricted re-injection to areas of the aquifer where total iron concentration is below 0.15 ppm
- Designed for an average screen exit velocity of 0.05 feet/second or less
- Designed for a natural completion, but if velocity calculations indicated a screen exit velocity that was greater than 0.05 feet/second, then used a filter pack
- Based screen length on the thickness and depth of the total uranium plume, spinner tool data collected from the second single-well re-injection test (DOE 1996), and total iron concentration of the groundwater in the re-injection demonstration area

18 - Maximized the length of the screen within the constraints imposed by the location and thickness of the 20 μg/L total uranium plume.

3.2 INSTALLATION OF THE RE-INJECTION WELLS

The five re-injection wells were installed during late 1996 and early 1997. From west to east they are numbered as follows: 22107, 22108, 22109, 22240, and 22111. Figure 3-2 illustrates the completion method, diameter, and screen position of each well.

- Well 22107 is an 8-inch diameter well completed with a Global #4 sand filter pack. The screen is wire wrapped, 15 feet in length, and has a slot size of .060 inches.
- Well 22108 is a 12-inch diameter well completed with a Global #4 sand filter pack. The screen is wire wrapped, 15 feet in length, and has a slot size of .060 inches.
- 23 Well 22109 is a 16-inch diameter well completed with a natural filter pack. The screen is wire wrapped, 15 feet in length, and has a slot size of .040 inches.
- Well 22240 is a 16-inch diameter well completed with a Global #4 sand filter pack. The screen is wire wrapped, 15 feet in length, and has a slot size of .060 inches.
- Well 22111 is a 16-inch diameter well completed with a Global #4 sand filter pack. The screen is wire wrapped, 15 feet in length, and has a slot size of .060 inches.

The re-injection wells were designed so that the top of the well screen would remain submerged during the aquifer restoration. Submergence of the well screen helps to limit screen corrosion and plugging. Water level data collected from surrounding monitoring wells over the past decade were used to define high and low water levels. In this area the recorded water table elevation range was 514 feet amsl to 517 feet amsl. Groundwater modeling in the BRSR (DOE 1997a) indicates that operation of the planned extraction wells during the remedy will lower the water table in the re-injection demonstration area as much as 3.5 feet. This estimation includes the expected rise in water levels due to re-injection. Providing for approximately 5 feet of uncertainty (or insurance), the top of the screen in each re-injection well was positioned 8.5 feet below the lowest recorded water table elevation for the immediate area.

Screen slot sizes were determined from grain size data collected from sieve analyses. The screen length was set at 15 feet so as to maximize the length of the screen but limit the depth of reinjection to the upper regions of the aquifer where the total uranium plume is situated and the iron concentrations are lower. The positioning of the screen in relation to the total uranium plume is explained further below.

3.3 SCREEN LOCATIONS IN RELATION TO THE 20 μg/L TOTAL URANIUM PLUME

Of the five re-injection wells, four screens are located within the 20 μg/L total uranium plume, and one screen is located outside of the 20 μg/L total uranium plume. Figures 3-3 and 3-4 illustrate the vertical position of the re-injection well screens in relation to the vertical thickness and location of the 20 μg/L total uranium plume.

The dimension and location of the edge of the 20 μg/L total uranium plume has been well characterized in the re-injection demonstration area. From the late Fall of 1996 through Spring of 1997 additional characterization work was conducted in the re-injection demonstration area to support remedy design and the installation of the re-injection wells. The controlling document for the work was the Restoration Area Verification Sampling Program Project Specific Plan (DOE 1997e). The additional characterization of the uranium plume was conducted using a Geoprobe™ mill slot sampling tool to complete vertical plume profiles. The results of the work can be found in Appendix G of the BRSR (DOE 1997a).

The Geoprobe™ work indicates that, with the exception of the area around re-injection Well 22240, the top of the 20 μg/L total uranium plume is located at the water table. In the area of re-injection Well 22240, the top of the 20 μg/L total uranium plume is located approximately 30 feet below the water table. With the exception of re-injection Well 22240, the screens in the re-injection wells are positioned as shallow as possible to maintain submergence (i.e., 8.5 feet below the lowest recorded water level for the area of the well). A shallow screen depth is preferred because iron concentrations increase with depth increasing the possibility for iron encrustation and plugging of the well screen and surrounding formation.

In re-injection Well 22111, the screen is positioned to intercept the leading edge of the 20 μg/L total uranium plume Figure 3-3. Re-injection at this location should help to confine the plume to its present geometry. Monitoring of water level and water quality during the demonstration will be conducted to document how the plume is behaving in response to re-injection. Details of the monitoring are presented in Section 4 of this test plan.

The well screens in re-injection Wells 22107, 22108 and 22109 are positioned within the 20 μg/L total uranium plume, Figure 3-3. Re-injection at these locations could cause the total uranium plume to migrate deeper into the aquifer. This possibility will be monitored during the demonstration through deep observation wells installed at the a depth that corresponds to the top of groundwater model layer four. The top of groundwater model layer four corresponds to the top of a clay interbed layer that is found to the north of the re-injection demonstration area (DOE 1994). Groundwater modeling shows that during the remediation particles seeded at the depth of re-injection travel no deeper than the top of model layer four as a result of re-injection (Figure E-20 of the BRSR, DOE 1997a). Monitoring at this depth will confirm model predictions concerning vertical movement. Details of the monitoring are presented in Section 4 of this test plan.

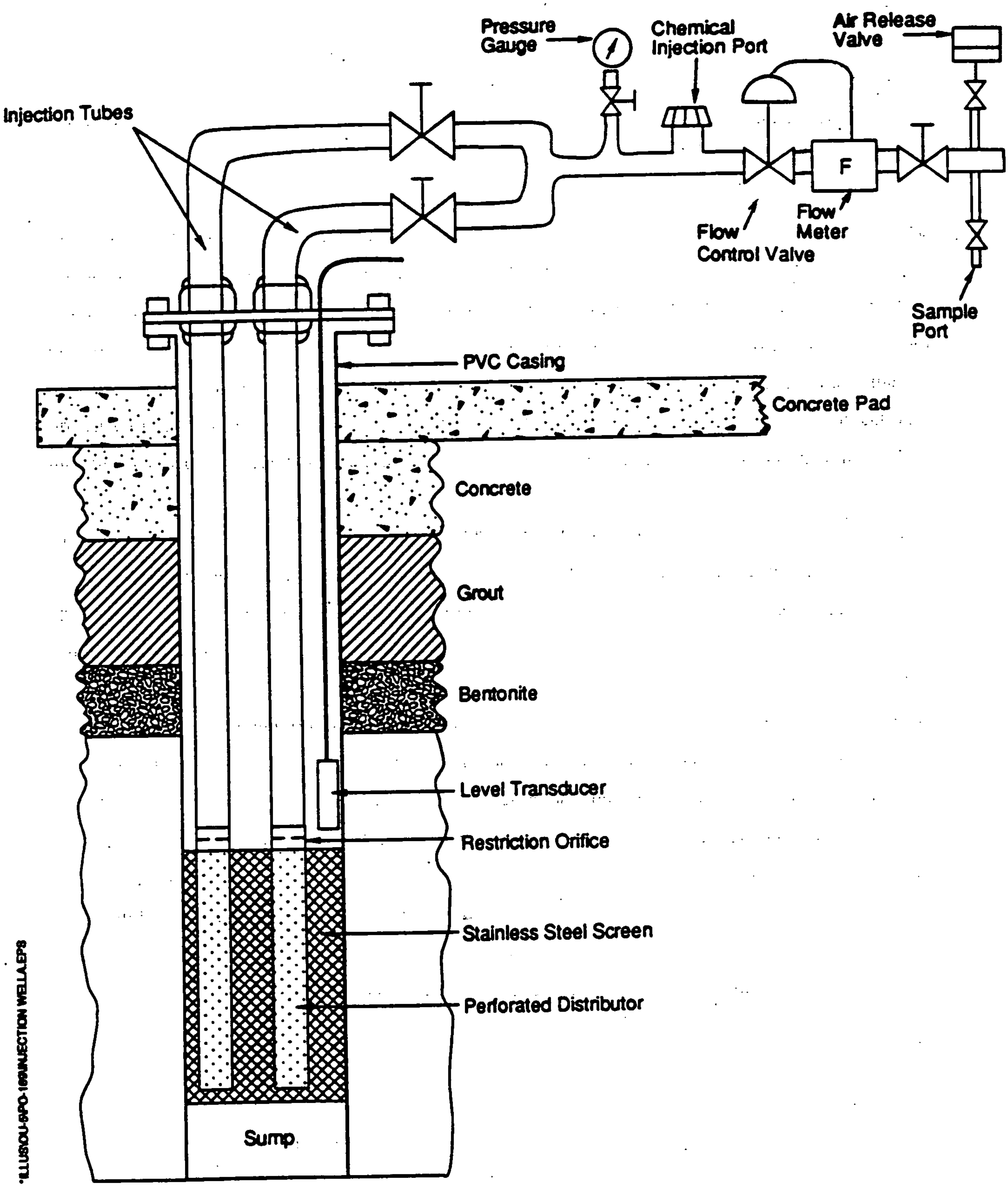
Pumping in the upgradient South Field Phase I wells prior to re-injection in the demonstration area will serve to hold back the source of uranium contamination migrating into the demonstration area. Finally the screen in re-injection Well 22240 is positioned within the leading edge of the 20 μg/L total uranium plume whose top surface is approximately 30 feet below the water table (Figure 3-4).

3.4 RE-INJECTION OBSERVATION WELLS

In order to monitor the effect that re-injection is having on the aquifer, five new shallow groundwater observation wells and four new deep groundwater observation wells will be installed and monitored during the re-injection demonstration. The observation wells will be installed prior to the start of pumping in the South Field Extraction System, which is scheduled before re-injection begins.

A shallow observation well will be located within approximately 25 feet of each re-injection well. The screens of the shallow observation wells will be 5 feet in length and the top of each screen will be set at the same depth as the top of the screen in the closest re-injection well. Monitoring of the shallow observation wells will provide data on the changing geochemistry within the aquifer due to the re-injection within close proximity to the re-injection wells. As discussed in Section 4, biological monitoring will be conducted in the shallow observation wells in an attempt to monitor for bacteria changes within the aquifer due to re-injection without having to stop re-injection and sample the re-injection well itself.

A new deep re-injection observation well will also be installed within 25 feet of re-injection Wells 22107, 22108, 22109, and 22240 (Figure 3-3). The screens of the four deep observation wells will be five feet in length, and set at the top of model layer 4. Monitoring in these four observation wells will be used to determine if re-injection is pushing the uranium plume deeper into the aquifer than predicted by the groundwater model. If the plume were to be pushed deeper it would most likely be pushed deeper beneath the point of re-injection. Since re-injection Well 22111 is located outside of the plume there is no need for deep monitoring at that location.



\ILLUS\OU-5\PO-169\INJECTION WELLA.EPS

FIGURE 3-1. GENERAL DESIGN OF RE-INJECTION WELLS

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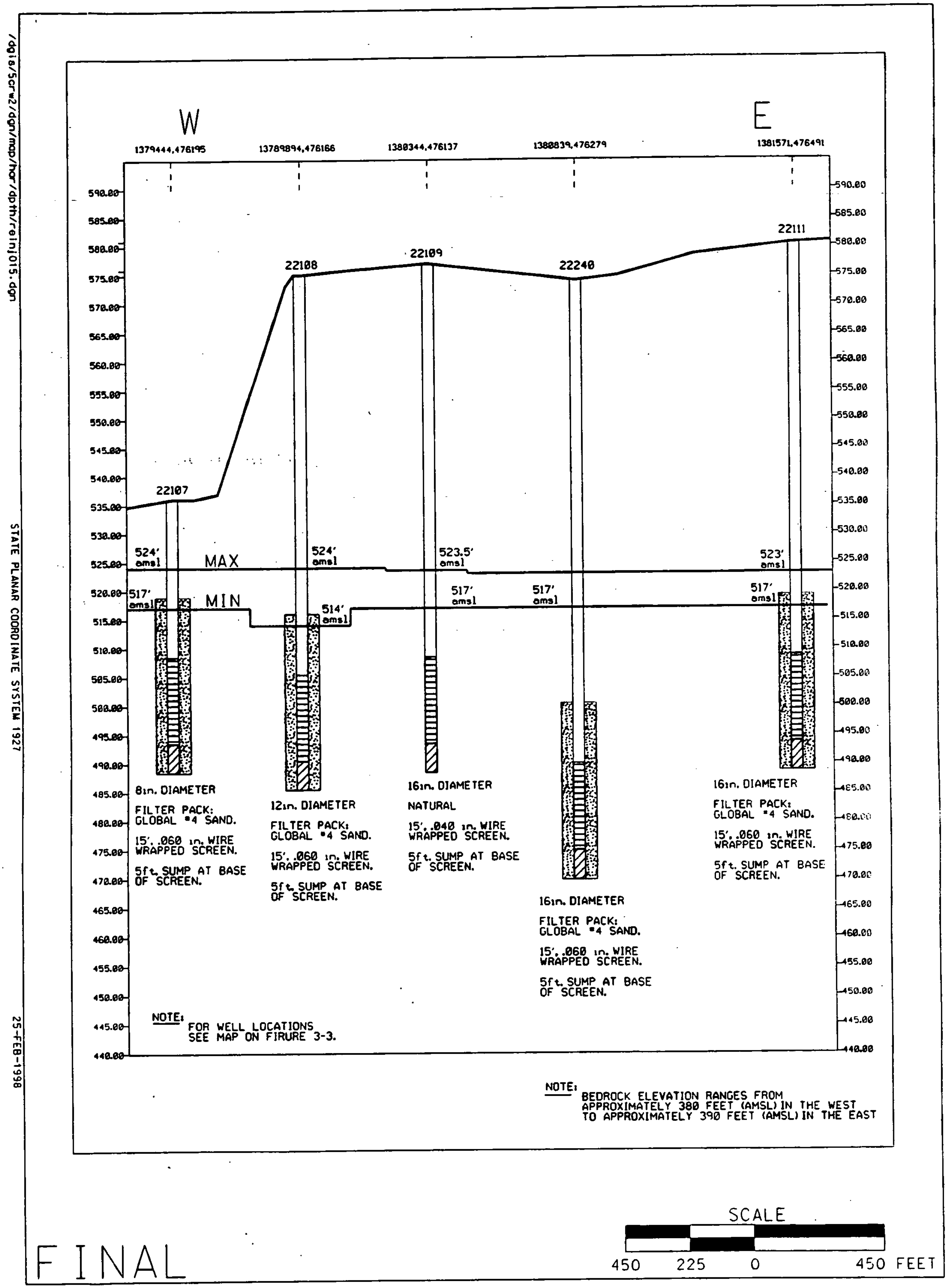
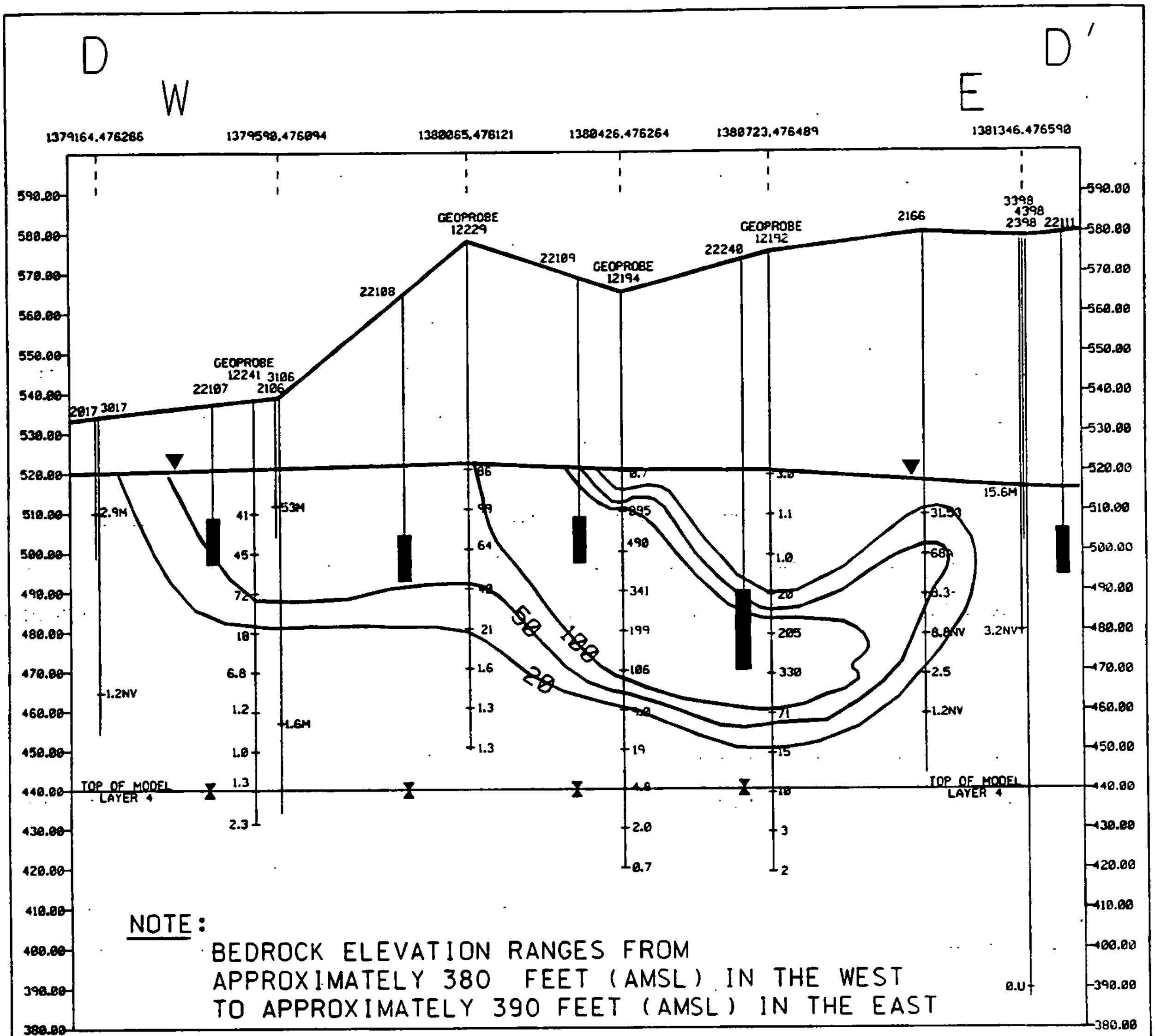


FIGURE 3-2. COMPLETION ILLUSTRATION OF THE 5 RE-INJECTION WELLS.

/dgia/5crw2/dgn/map/hor/dpth/reinj014.dgn

STATE PLANAR COORDINATE SYSTEM 1927

25-FEB-1998



LEGEND:

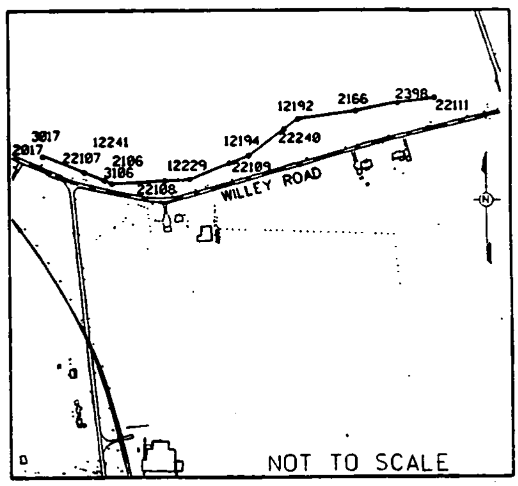
- TOTAL URANIUM IN GROUNDWATER (ppb)
- RE-INJECTION WELL SCREEN
- DEEP RE-INJECTION OBSERVATION WELL

DATA QUALIFIERS:

U = UNDETECTED
NV = NONVALIDATED
\- = VALIDTED, NOT QUALIFIED
J = VALIDATED, ESTIMATED
M = MAXIMUM OF 1996 3rd. AND 4th. QUARTER DATA

NOTE:

NON-GEOPROBE VALUES ARE FROM 1993 SNAPSHOT DATA UNLESS QUALIFIED WITH AN "M". THE WATER ELEVATION SHOWN IS ESTIMATED.



SCALE

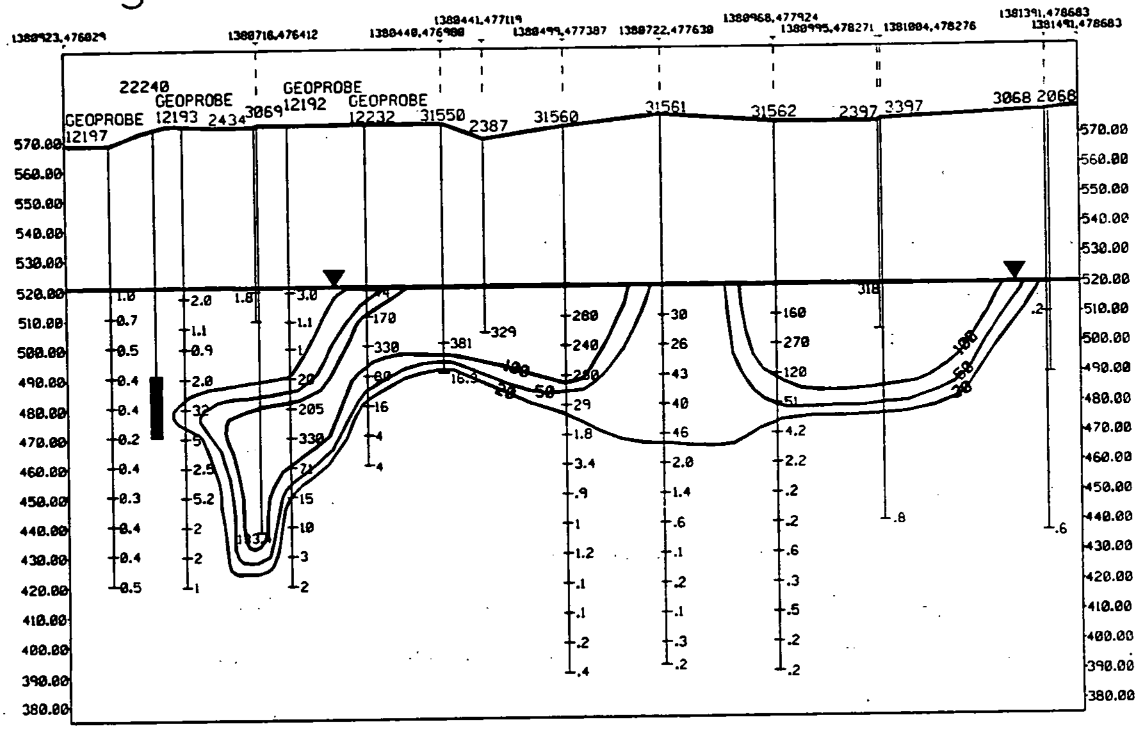
450 225 0 450 FEET

FINAL

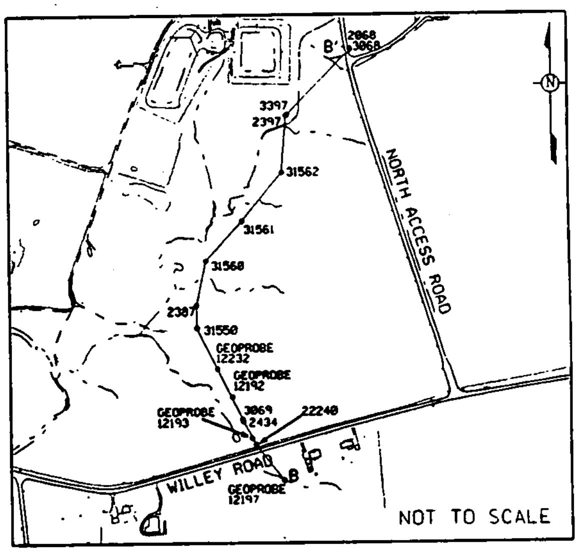
FIGURE 3-3. LOCATION OF RE-INJECTION WELL SCREENS IN RELATION TO THE 20 $\mu g/L$ TOTAL URANIUM PLUME

000044

/dgl8/5crw2/dgn/map/hor/dpth/reinj007.dgn



NOTE:
BEDROCK ELEVATION RANGES FROM APPROXIMATELY 370 FEET (AMSL) IN THE NORTH TO APPROXIMATELY 395 FEET (AMSL) IN THE SOUTH



LEGEND:

TOTAL URANIUM IN GROUNDWATER (ug/L)

RE-INJECTION WELL

NOTE:
NON-GEOPROBE VALUES ARE FROM 1993 SNAPSHOT DATA. VALUES FOR EXTRACTION WELLS 31550, 31560, 31561 AND 31562 WERE COLLECTED WHEN THE WELLS WERE INSTALLED BY HYDROPUNCH

STATE PLANAR COORDINATE SYSTEM 1927

25-FEB-1998

SCALE

650 325 0 650 FEET

FINAL

FIGURE 3-4. LOCATION OF RE-INJECTION WELL SCREEN IN 22240 IN RELATION TO THE 20 μg/L TOTAL URANIUM PLUME

4.0 TESTING PROGRAM

The testing program for the one-year re-injection demonstration focuses on determining maintenance and operation costs for the re-injection wells and determining the effects that re-injection has on the chemistry of the aquifer and the dimension of the 20 μg/L total uranium plume.

Testing activities will include:

- Monthly sampling of the injectate.
- Quarterly downhole camera surveys of the re-injection wells. The surveys will be used to look for evidence of screen plugging or iron precipitation.
- Quarterly biological sampling of the re-injection wells and the aquifer immediately around the re-injection wells. Data will be used to determine if such sampling can reveal the on-set of plugging conditions prior to actual screen plugging taking place.
- Groundwater Quality Sampling. Uranium and major cations and anions will be collected to determine the morphology of the 20 μg/L total uranium plume and changing water chemistry.
- Geoprobe™ sampling to determine if the 20 μg/L total uranium plume is migrating either between or beneath the re-injection wells. Samples will provide a vertical profile of the plume geometry at selected sampling locations.
- In-situ monitoring of water quality parameters to determine how water chemistry of the aquifer immediately around the re-injection wells is affected by the re-injection process.
- Monthly water level monitoring. The collection of water levels will be integrated with the IEMP Water Level Monitoring Program. Water levels will be used to monitor plugging within the re-injection wells and to construct water table maps of the aquifer and to interpret capture zones in the aquifer.

73

- Collection of borescope data. Borescope data will be used to document flow direction at selected locations within the aquifer during the demonstration.
- Quarterly maintenance checks. Maintenance checks will be conducted to assess screen plugging conditions and to develop a long term preventive maintenance program for the wells should the decision be made following the demonstration to continue re-injection.
- Surface water sampling. A one time grab sample will be collected from the Southeast Drainage Ditch so that the water chemistry can be compared to the water chemistry of

the groundwater found beneath the ditch to lend support to the interpretation that water from the ditch is recharging the aquifer in the area of Monitoring Well 3069.

Each of these activities is discussed in detail below.

4.1 ANALYSIS OF INJECTATE

In accordance with the Ohio EPA re-injection guidelines 5X26 Aquifer Remediation Projects (OEPA 1997), injectate will be analyzed monthly both prior to and during the re-injection demonstration. This information will be furnished to the Ohio EPA Division of Drinking and Ground Waters (DDAGW) Underground Injection Control (UIC) Unit. Analysis of the injectate will begin as soon as the AWWT Expansion Facility begins operating, and monthly during the re-injection demonstration. If the decision is made to continue re-injection technology after the completion of this demonstration, monthly injectate sampling will continue.

As explained in Section 2, the FEMP has completed a CERCLA characterization that has identified what contamination is present and the OU5 ROD (DOE 1996b) has established levels for the 50 constituents of concern for groundwater. It is appropriate that the FRL list serve to guide the injectate sampling program during the re-injection demonstration. FRLs are set at MCLs, proposed MCLs, risk-based levels, analytical detection limits, or background. The FRL constituents and limits are therefore appropriate for determining the protectiveness of the injectate.

Monthly injectate sampling will begin by focusing on those FRL constituents that have had a validated exceedance of their FRL in either aquifer zones two or four (Table 2-1). The basis for the FRL for Nitrate and Cadmium is the 95th percentile background concentration. This places the FRL at a higher concentration than the MCL for these two constituents only. After an initial testing of the injectate has been completed and the quality of the injectate has been documented, it is proposed that FRL constituents listed in Table 2-1 as mobile and persistent (MP) be sampled monthly, and those listed as *not* mobile and persistent (N) be sampled quarterly. The MP and N designations are explained in more detail in Section 2.2.

Table 4-1 presents the sampling protocols that are used at the FEMP for monitoring groundwater. These same protocols will be used to sample the injectate. Injectate samples will be collected as they leave the AWWT Expansion facility but before flow is diverted to individual re-injection wells.

4.2 DOWNHOLE CAMERA SURVEYS

Each re-injection well will be surveyed with a downhole camera (according to site procedure EQT-08 Down-Hole Camera Operation) five times during the demonstration; once at the start, and after every three months of operation (corresponding to maintenance checks of the wells). Camera surveys performed just prior to the start of re-injection will serve as baselines for comparisons. The camera surveys will be helpful in establishing a preventive maintenance program for the re-injection wells should the decision be made at the conclusion of the demonstration to continue with re-injection as part of the aquifer remedy.

4.3 BIOLOGICAL SAMPLING

Biological sampling will be conducted in the re-injection wells and the shallow observation wells during the re-injection demonstration. Plugging of the well screen, gravel pack, and formation immediately surrounding the re-injection well screen can occur due to bacterial growth. Single well injection tests conducted at the FEMP revealed that the oxidation of ferrous iron to ferric iron synergistically promotes the growth of iron bacteria within and surrounding the well screen, resulting in a plugged well screen and poor well performance (DOE 1995b, DOE 1996a). Sampling for bacteria in the area of the re-injection demonstration has revealed that both aerobic and sulfate-reducing bacteria are naturally present in the aquifer (Appendix A). Therefore biological monitoring will be conducted as part of the re-injection demonstration in an attempt to detect and control bacterial growth before well plugging becomes a problem. Monitoring will take place within the re-injection wells (when re-injection is not taking place) and within the five shallow observation wells (while re-injection is taking place).

If bio-fouling conditions, due to bacteria, are present in the re-injection well then a grab sample collected from the well, when re-injection is not taking place, should detect the presence of bacteria. The results interpreted along with the visual results of down hole camera surveys will be useful in determining if biofouling conditions are developing that could, if untreated, lead to well plugging problems.

In an effort to detect biofouling conditions around the re-injection wells, biological sampling will also take place in the five shallow observation wells. The attempt to detect biofouling conditions developing around the re-injection wells by monitoring the nearby observation wells is based on the assumption that if biofilm bacteria and their characteristic structures are present around the re-injection wells then they will be present in the water (planktonic phase) moving out of the re-injection wells and past the observation wells. The movement of injectate away from the re-injection wells should carry the bacteria (if present) to the nearby observation wells.

The sampling methodology which will be used considers the way in which biofilms move through the sub-surface. Because portions of biofilms intermittently slough off, a one time sampling event in an observation well might not detect adverse concentrations of bacteria. Biological shedding events can provide transient increases in microbial counts. Analysis of samples taken after prolonged re-injection may fail to detect the presence of chemical and microbiological parameters that would indicate the presence of biofilms near wells, but samples collected immediately following start-up of re-injection may provide better indicators of the biological environment surrounding the re-injection wells.

Biofilm sloughing occurs preferentially on start-up after a period of rest or "quiescence," (two hours to several days). Samples taken: 1) just prior to shut-down, 2) immediately after restart, 3) a few hours after restart, and 4) a few days after restart provide the best potential for detecting biological activity (Smith 1995, pg. 89).

A comprehensive sampling program will therefore be used in the five shallow observation wells during the re-injection demonstration to attempt to detect the transient biofilm sloughing if it is occurring. Groundwater samples will be collected from the observation wells just prior to the start of re-injection, immediately after re-injection is started, a few hours after the start of re-injection and after one day of re-injection. In instances where a re-injection well is scheduled to be shutdown, the closest observation wells will be sampled for evidence of biofouling just prior to the shutdown. Upon the re-start of re-injection the same sampling program outlined above would be followed in the closest observation wells. Duplicate samples may be taken periodically to further help overcome the limitation of grab sampling.

29 Prepared Biological Activity Reaction Test culture methods are the most promising approach for routine biological monitoring purposes (Smith 1995, pg. 85) and will be used during the re-injection demonstration. Each sample event will test for iron-related bacteria, slime-forming bacteria, and total aerobic bacteria. If biological sampling and groundwater quality sampling, (discussed in the next section) coincide at a particular location, the biological sample will be collected first.

4.4 GROUNDWATER QUALITY SAMPLING

Groundwater quality sampling will take place during the re-injection demonstration to monitor the morphology of the 20 μg/L total uranium plume and to monitor the water chemistry of the aquifer in the area around the re-injection wells. The sampling effort will be coordinated with quarterly IEMP sampling. Groundwater quality sampling to support the re-injection demonstration will be conducted within the nine new re-injection observation wells, 14 existing FEMP groundwater monitoring wells, and at select locations in the re-injection demonstration area using a Geoprobe™ sampling tool, Figure 4-1.

Monitoring the Morphology of the 20 μg/L Total Uranium Plume

During the re-injection demonstration, groundwater quality data will be collected to monitor the morphology of the 20 μg/L total uranium plume. Specifically, monitoring will determine:

- If breakthrough of the 20 μg/L total uranium plume is occurring beneath the re-injection wells
- If breakthrough of the 20 μg/L total uranium plume is occurring between the re-injection wells.

The groundwater model predicts that re-injection in 5 wells, at a rate of 200 gpm in each well, along the southern FEMP property boundary, in concert with pumping in extraction wells upgradient and downgradient of the re-injection wells, will create a hydraulic barrier within the aquifer that should effectively stop the further southern migration of the 20 μg/L total uranium plume across the FEMP property boundary, Figure 1-4. The plume downgradient of the re-injection wells will be flushed into downgradient extraction wells. The plume upgradient of the re-injection wells will be recovered by upgradient extraction wells.

The four deep observation wells, five shallow observation wells, and 14 existing monitoring wells (2106, 3106, 2434, 3069, 2398, 3398, 4398, 2070, 3070, 2017, 2015, 3015, 2060, and 2166) will be sampled for total uranium and the major anions and cations listed in Table 4-2 prior to the start of re-injection and quarterly during the re-injection demonstration.

Table 4-1 presents the sampling protocols that are used at the FEMP for monitoring groundwater. Each sampling event will be evaluated to determine the size of the total uranium plume and changing water chemistry within the plume. The sampling will be coordinated with other IEMP groundwater sampling to maximize the amount of data available for interpretation. Quarterly sampling of the 14 existing groundwater monitoring wells for total uranium is part of the current IEMP program. Nine of these wells are currently sampled under the IEMP as property boundary wells and five are currently sampled under the IEMP as part of the South Plume Module.

All monitoring and observation wells will be purged and sampled using guidelines specified in SCQ Section 6.2. All analyses will be conducted by the appropriate FEMP or contract laboratory using procedures which meet ASL B as established in the SCQ as referenced in Table 4-1. ASL B is specified for this program since the data will be used for surveillance monitoring purposes. Sample collection protocols are identified in the SCQ and in specific procedures referenced in the SCQ. The following procedures and guidance sections of the SCQ are used to conduct groundwater monitoring:

Standard Operating Procedures	
ADM-02	Field Project Prerequisites
SC-GWM-FO-201	Groundwater Sampling Activities
EP-GWM-202	Groundwater Sample Shipment

Sitewide CERCLA Quality (SCQ) Assurance Project Plan	
Section 5	Field Activities
Section 6	Sampling Requirements
Section 7	Sample Custody
Section 9	Analytical Procedures
Appendix I	Field Calibration Requirements
Appendix J	Field Activity Methods
Appendix K	Sampling Methods

Samples will be sent to either an on-site or "acceptable" off-site laboratory. Samples will be sent to the FEMP on-site laboratory if capacity is available and if the analysis can be performed, and if required detection limits can be achieved.

Geoprobe™ Sampling

32 Analysis of groundwater samples obtained with a Geoprobe™ sampling tool will be used to determine if the 20 μg/L total uranium plume is migrating either between or beneath the re-injection wells. As was done for the Restoration Area Verification Sampling (RAVS) project (DOE 1997e), the Geoprobe™ tool will be used to collect groundwater samples from different vertical locations within the aquifer, rather than at a fixed monitoring point. Collection of groundwater samples at several vertical locations in the aquifer, throughout the re-injection demonstration, is the best way to detect if the uranium plume is moving past the re-injection wells. A groundwater sample will be collected at the water table and at ten foot intervals beneath the water table until it can be verified that the entire vertical thickness of the 20 μg/L total uranium plume has been sampled. Samples collected will be analyzed for total uranium. An attempt will also be made to analyze for the major anions and cations listed in Table 4-2. It is uncertain if results, especially iron, will be representative. Iron from the sampling tool could bias the analysis. Data will be assessed and if it is determined that the data is representative then the analysis for major anions and cations will continue. If the results do appear to be compromised due to the sampling tool and method, then sampling will only continue for uranium.

Prior to the start up of the South Field Extraction System Wells, Geoprobe™ sampling will take place at seven locations, one location downgradient of each re-injection well, one location between Re-injection Wells 22108 and 22109 and one location between re-injection Wells 22109 and 22240, Figure 4-1. The samples will be analyzed for the constituents listed in Table 4-2. The results of the analysis will be used to establish a baseline of plume dimensions and groundwater geochemistry prior to re-injection.

33 During the re-injection demonstration, Geoprobe™ sampling will take place at three locations. The area of re-injection that corresponds to the highest total uranium concentrations in the aquifer was targeted for this monitoring activity. This area is located around re-injection Well 22109 Figure 4-1. Geoprobe™ locations 1 and 2 are between re-injection Wells 22108 and 22109, and 22109 and 22240 respectively. Monitoring here will provide data to determine if the plume is moving between either of these three re-injection wells. Geoprobe™ location 3 is located downgradient of re-injection Well 22109 and will provide data to determine if the uranium plume is migrating beneath re-injection Well 22109.

1 All three Geoprobe™ locations will be sampled prior to the start of pumping in the South Field Extraction Wells. The next round of Geoprobe™ sampling at these three locations will take place just prior to the start of re-injection. Geoprobe™ sampling will then take place after 3, 6, 9, and 12 months of re-injection. The data collected will be used to construct cross sections that illustrate the vertical dimension of the total uranium plume through time.

During the last round of Geoprobe™ sampling, all 7 locations sampled prior to the start of pumping in the South Field Extraction System will be sampled again to determine how the vertical dimension of the total uranium plume and aquifer geochemistry has changed in response to one year of pumping and injection operations.

<u>In-situ Monitoring of the Water Chemistry Around the Re-Injection Wells</u>

Two Hydrolab™ downhole water quality probes and data loggers will be used to monitor specific conductivity, temperature, pH, Eh, and dissolved oxygen in the re-injection demonstration area. The probes will be used to:

- Collect pre re-injection baseline conditions at all five re-injection locations
- Monitor how quickly the slug of injectate affects the geochemistry of the aquifer next to and beneath a re-injection well
- Provide routine monitoring checks of how the water chemistry has changed at each re-injection location compared to baseline conditions throughout the re-injection demonstration.

Baseline conditions prior to re-injection will be established by monitoring each re-injection location once every hour for 48 hours with the data logger. Deep and shallow re-injection observation wells will be monitored at re-injection Wells 22107, 22108, 22109, and 22240. The shallow re-injection observation well will be monitored at re-injection Well 22111.

The re-injection well that is installed in the highest concentration of uranium (22109) will be used to monitor how quickly the re-injected groundwater effects the geochemistry of the aquifer next to and beneath a re-injection well. At the start of re-injection, the two probes will be used to monitor changing conditions in the shallow observation well next to Well 22109 and the deep observation well beneath 22109. The data loggers will collect a reading every hour until values appear to have stabilized.

34 Following parameter stabilization next to and beneath re-injection Well 22109, the water quality probes will be rotated among the five shallow and four deep re-injection observation wells. Hourly monitoring for 24 hours at each observation well will take place monthly during the re-injection demonstration. Data collected while re-injection is taking place will be compared to data collected prior to re-injection to document changing conditions. Monitoring results from both the deep and shallow observation wells will be used to assess depth variations.

4.5 WATER LEVEL MONITORING

Water levels will be collected both within the re-injection wells (to control the re-injection process and to monitor for the effects of plugging within the re-injection well screen) and in a network of new observation and existing monitoring wells surrounding the re-injection wells to determine capture of the total uranium plume. Water level monitoring activities for the re-injection demonstration will be coordinated with IEMP water level monitoring activities.

Monitoring within the Re-Injection Wells

Plugging is defined as "the increasing resistance to flow" (Pyne 1995, pg. 111). The primary sites for plugging during re-injection are the screen, gravel pack, and the formation immediately surrounding the screen. Plugging processes include: 1) entrained air and gas binding, 2) deposition of total suspended solids (TSS) from the injectate, 3) biological growth, 4) particle rearrangement in the aquifer material adjacent to the injection well, and 5) geochemical reactions.

35 An effect of plugging will be an increase in resistance to flow within the re-injection well, Figure 4-2. This resistance to flow can be measured as a rise in water level within the re-injection well. Water level monitoring within the re-injection wells will be conducted continuously using down hole pressure transducers which will be installed in stilling pipes. The transducers will be connected to water level sensors and recorders. The sensors will automatically shut off flow to the well should the water level within the re-injection well rise to a specific level. The water level sensor will operate continuously and it will be possible to monitor the sensor from the AWWT control room. As operational experience

with the wells is collected the water level in the re-injection well will be used to indicate when maintenance of the well screen is required.

Monitoring in the Aquifer

Water levels will be monitored in the aquifer during the re-injection demonstration. The activity will consist of two phases: start-up monitoring and routine monitoring.

Just prior to the start of re-injection, water levels will be collected from 50 monitoring wells (both Type 2 and Type 3) located around the immediate area of the re-injection demonstration. Table 4-3 lists the 50 monitoring wells that will be monitored and Figure 4-3 illustrates where the wells are located. Water level measurements will be collected again immediately following start-up of re-injection and will continue on a weekly schedule until water levels in the aquifer have stabilized to the new stresses induced by the re-injection.

After water levels in the aquifer have stabilized to the re-injection, water level monitoring will be cut back to a monthly schedule. The same 50 wells will be monitored. The monthly monitoring effort will be integrated with the quarterly water level monitoring program outlined in the IEMP. In the IEMP, water levels are monitored quarterly in 159 monitoring wells (both Type 2 and Type 3). Figure 4-4 illustrates the location of the 159 monitoring wells.

4.6 COLLECTION OF BORESCOPE DATA

The colloidal borescope has been used at the FEMP for over a year to evaluate flow directions in the South Plume Area. Data and results have been reported in the South Plume Removal Action Design Monitoring Evaluation Program Plan System Evaluation Reports. The instrument gives reliable flow directions in the vicinity of pumping wells.

The colloidal borescope will be used to help determine what influence pumping and re-injection is having on the groundwater flow direction at discrete locations within the aquifer. Prior to start up of the South Field Extraction System, the colloid flow direction in the four new deep re-injection observation wells will be recorded. Following start-up of the South Field Extraction System and after the aquifer has stabilized, the colloid flow direction will be recorded in the same wells. Results will be compared to pre-pumping results to determine what effect the South Field System is having on the base of the 20 μg/L total uranium plume.

After re-injection has begun and water levels have equilibrated to the new influx of water, colloid flow directions will be measured in the same four deep re-injection observation wells. Data will be compared to baseline data to determine what effect re-injection has had on the flow at these locations. The data collected from the colloidal borescope should be useful in determining if the base of the 20 μg/L total uranium plume is being captured. Colloidal borescope measurements will be completed every three months in the same wells during the demonstration. Colloidal borescope measurements will be qualified with the operating conditions that were taking place during the collection of the measurements. The colloidal borescope will be used periodically at other wells in the re-injection demonstration area to help determine if the 20 μg/L total uranium plume is being captured.

4.7 MAINTENANCE CHECKS

Lessons learned from operation of the South Plume Extraction Wells will be used to establish a maintenance program for the re-injection wells. During the demonstration the re-injection wells will undergo quarterly maintenance checks. If indications of screen plugging are found then the screen will be scrubbed and chlorinated prior to resuming re-injection in a manner similar to procedures outlined in the OMMP (DOE 1997d). Maintenance checks at the re-injection wells will include:

- Visual inspection of the well screen, possible cleaning and chlorination
- Flow controller calibration
- Flow totalizer calibration
- Flow meter cleaning and calibration
- Flow control valve maintenance (i.e., inspection, cleaning, re-building)
- Biological sampling

4.8 SURFACE WATER QUALITY SAMPLING

The top of the 20 μg/L total uranium plume in the area of Monitoring Well 3069, which is next to a ponding feature in the South East Drainage Ditch, is located approximately 30 feet beneath the water table. Recharge from the drainage ditch could be diluting the plume at the water table. A comparison of the chemistry of the surface water found in the ditch to groundwater found in the aquifer directly beneath the ditch will be used to indicate how similar the waters are. Similar chemistries will support the recharge theory.

Surface water sampling in the South East Drainage Ditch will be conducted to verify that surface water from the ditch is recharging the aquifer in the area around Monitoring Well 3069. Water samples will be analyzed for the major anions and cations listed in Table 4-2.

TABLE 4-1
SAMPLING PROTOCOLS

Constituent	Method	Sample Type	ASL	Holding Time[a]	Preservation[a]	Container[a,b]
General Chemistry:						
Alkalinity	310.1[d] or 2320B[e]	Grab	B	14 Days	Cool to 4°C	Plastic or glass
Ammonia	350.1[d], 350.3[d], 4500C[e], or 4500F[e]	Grab	B	28 Days	Cool to 4°C, H_2SO_4 to pH < 2	Plastic or glass
Bicarbonate	33.076[h]	Grab	B	14 Days	Cool to 4°C	Plastic or glass
Carbonate	33.076[h]	Grab	B	14 Days	Cool to 4°C	Plastic or glass
Chloride	352.2[d], 300.(all)[d] or 4500B[e]	Grab	B	28 Days	None	Plastic or glass
Fluoride	340.2[d] or 4500C[e]	Grab	B	28 days	None	Plastic
Nitrate/Nitrite	353.1[d], 353.2[d], 4500D[e], or 4500E[e]	Grab	B	28 days	Cool to 4°C, H_2SO_4 to pH < 2	Plastic or glass
Phosphorus	365.(all)[d] or 4500E[e]	Grab	B	28 days	Cool to 4°C, H_2SO_4 to pH < 2	Plastic or glass
Sulfate	375.2[d], 300.0[d], or 4500E[e]	Grab	B	28 days	Cool to 4°C	Plastic or glass
Total Dissolved Solids	160.1[d] or 2540C[e]	Grab	B	7 Days	Cool to 4°C	Plastic or glass
Total Suspended Solids	160.2[d] or 2540D[e]	Grab	B	7 Days	Cool to 4°C	Plastic or glass
Inorganics:						
Metals Excluding Mercury	7000[c] or 6010[c]	Grab	B	6 months	HNO_3 to pH < 2	Plastic or glass
Mercury	7470A[c]	Grab	B	28 days	HNO_3 to pH < 2	Plastic or glass
Radionuclides: (All Radiological)	SCQ[f]	Grab	B[g]	Six months or 5 x half-life, whichever is less	HNO_3 to pH < 2	Plastic or glass
Volatile Organics:	8260[c]	Grab	B	7 days	Cool to 4°C	Glass vial with Teflon lined septum cap
		Grab	B	14 days	Cool to 4°C H_2SO_4, HCl, or solid $NaHSO_4$ to pH < 2	Glass vial with Teflon lined septum cap
Field Parameters[i]:		Grab	A	NA[j]	NA[j]	NA[j]

[a]Appropriate preservative, holding time, and container requirements will be used for the corresponding method.
[b]Container size is left to the discretion of the individual laboratory.
[c]"Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846.
[d]"Methods for Chemical analysis of Water and Wastes, EPA 600/4-79-020.
[e]"Standard Methods for the Analysis of Water and Wastewater," 17th edition.
[f]Radionuclide analyses do not have standard methods; however, the analytical specifications for these parameters are provided in Appendix G of the SCQ.
[g]The ASL may become more conservative, if it is necessary to meet detection limits.
[h]"Official Methods of Analysis of the Association of Official Analytical Chemist"
[i]Field parameters include dissolved oxygen, pH, specific conductance, temperature and turbidity.
[j]NA = Not applicable.

TABLE 4-2

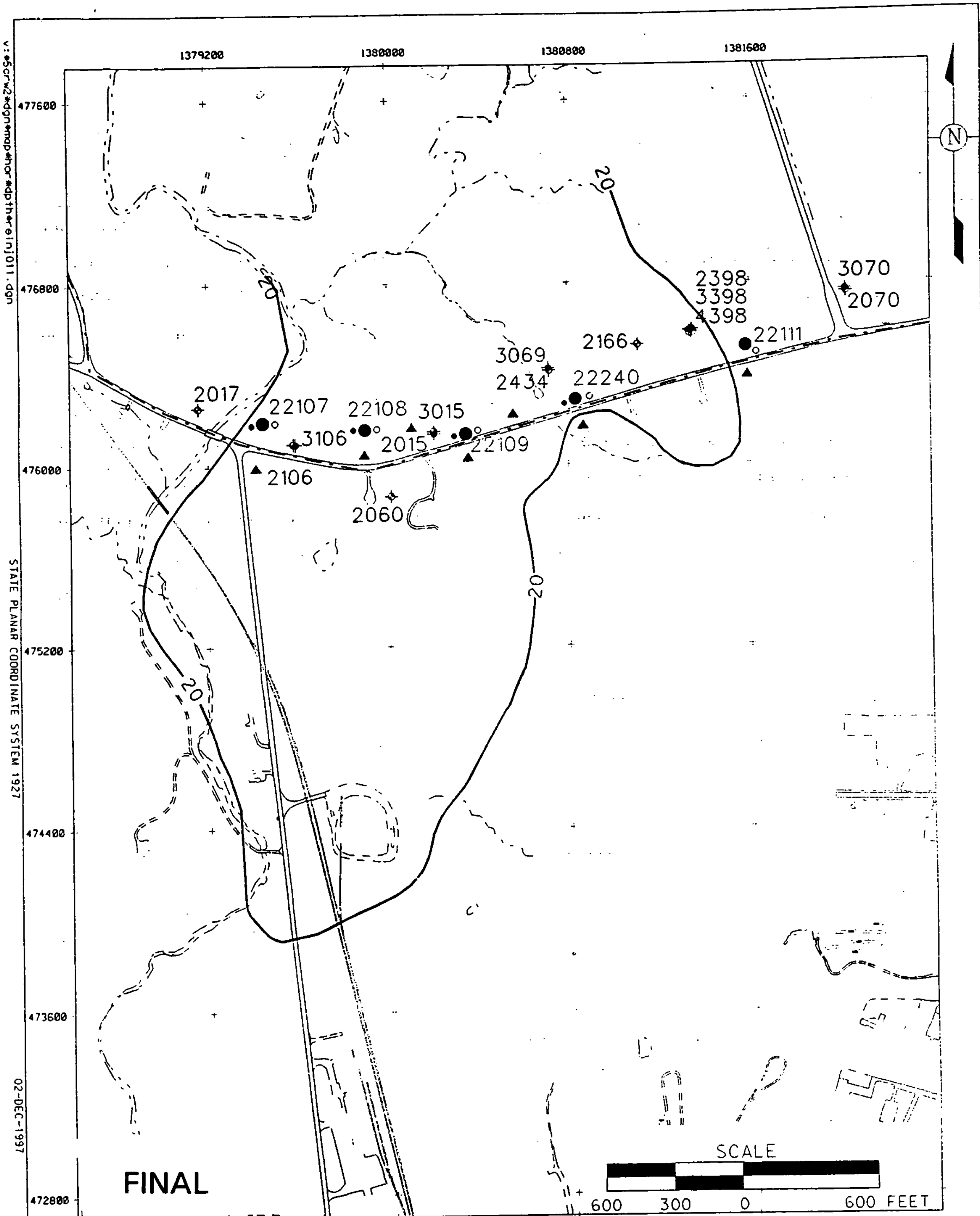
ANALYTE LIST FOR MONITORING WELLS FOR GEOPROBE™ SAMPLES

List of Analytes		
aluminum	fluoride	potassium
alkalinity	iron	silicon
ammonia	magnesium	sodium
bi-carbonate	manganese	solids
calcium	NO_3-N	sulfate
carbonate	phosphate	TDS
chloride	total uranium	

TABLE 4-3

MONTHLY WATER LEVEL MONITORING WELLS

List of Wells			
2002	2166	3015	3881
2014	2387	3017	3897
2015	2390	3049	Observation Well 1
2016	2397	3069	Observation Well 2
2017	2398	3070	Observation Well 3
2045	2399	3093	Observation Well 4
2048	2434	3095	Observation Well 5
2049	2550	3096	Observation Well 6
2070	2551	3106	Observation Well 7
2093	2880	3390	Observation Well 8
2095	2881	3398	Observation Well 9
2096	2897	3551	
2107	3014	3880	



LEGEND:

- FEMP BOUNDARY
- EXISTING MONITORING WELL
- RE-INJECTION WELL
- GEOPROBE™ SAMPLING LOCATIONS
- DEEP OBSERVATION WELL
- SHALLOW OBSERVATION WELL
- 20 TOTAL URANIUM PLUME AS OF SPRING, 1997

FIGURE 4-1. GROUNDWATER QUALITY SAMPLING LOCATIONS

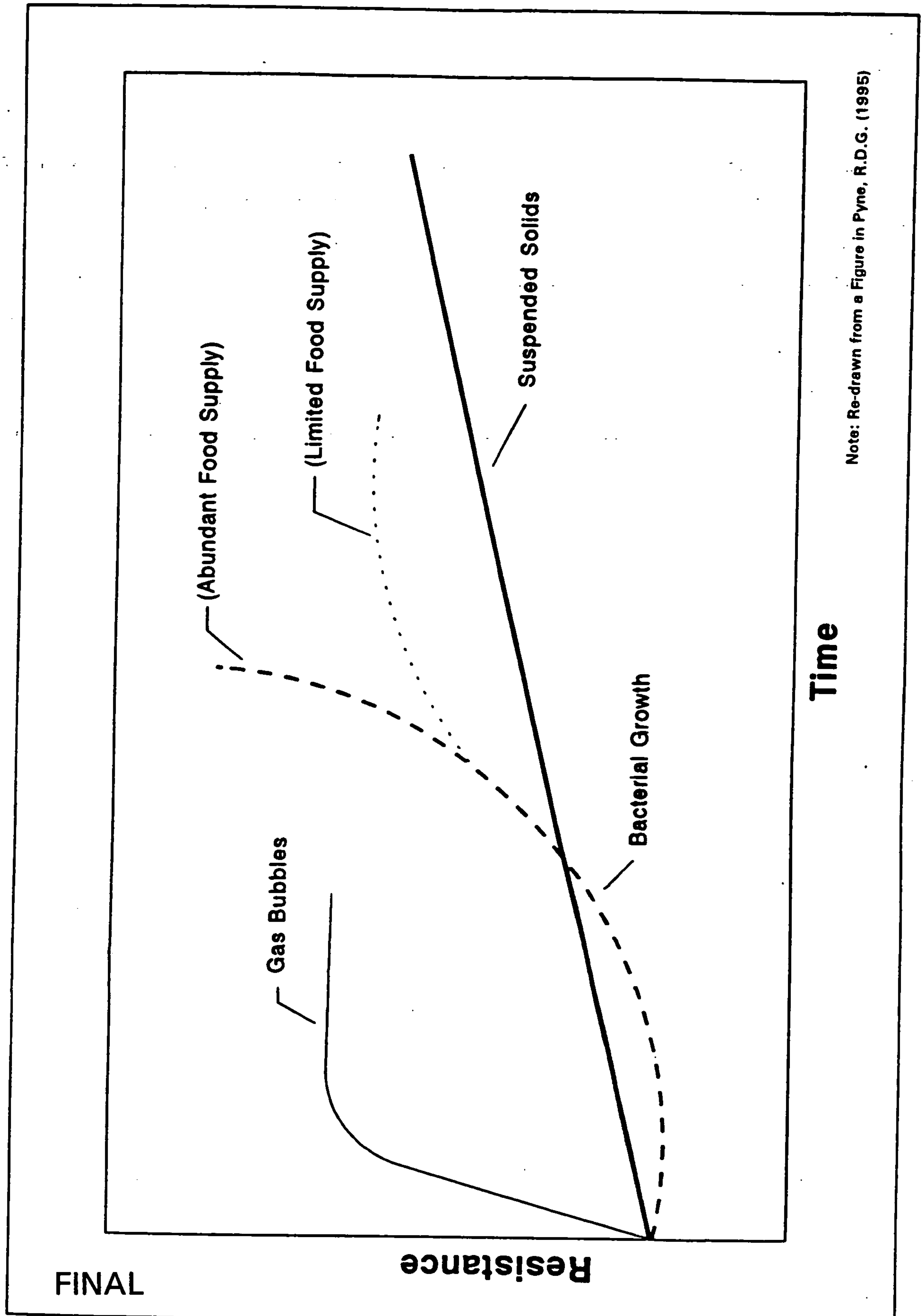
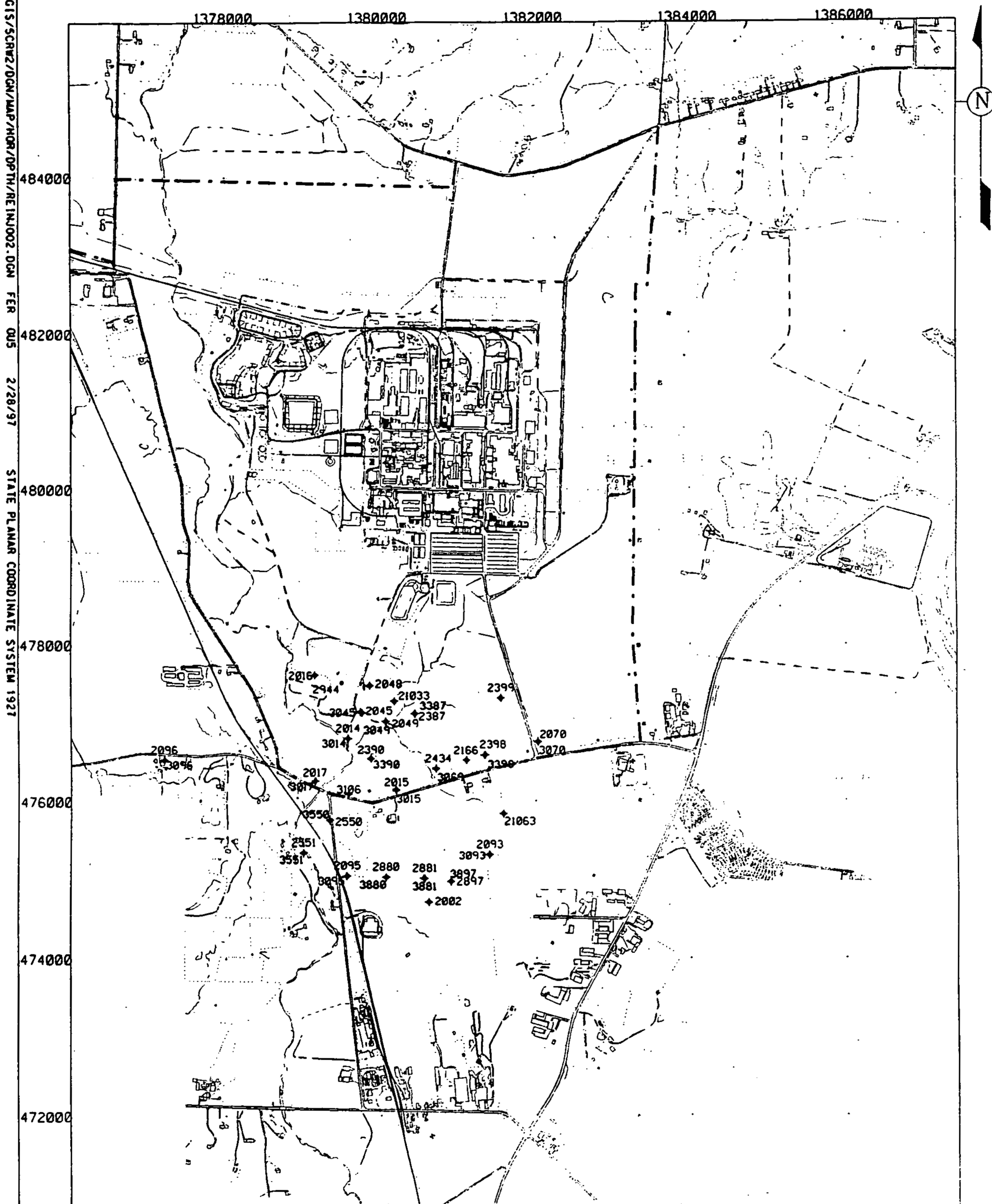


FIGURE 4-2. TYPICAL PLUGGING PROCESSES



LEGEND:

— · — · — FEMP BOUNDARY

◆ 2046 TYPE 2 MONITORING WELL

+ 3046 TYPE 3 MONITORING WELL

SCALE

1800 900 0 1800 FEET

FINAL

FIGURE 4-3. GROUNDWATER ELEVATION MONITORING WELLS

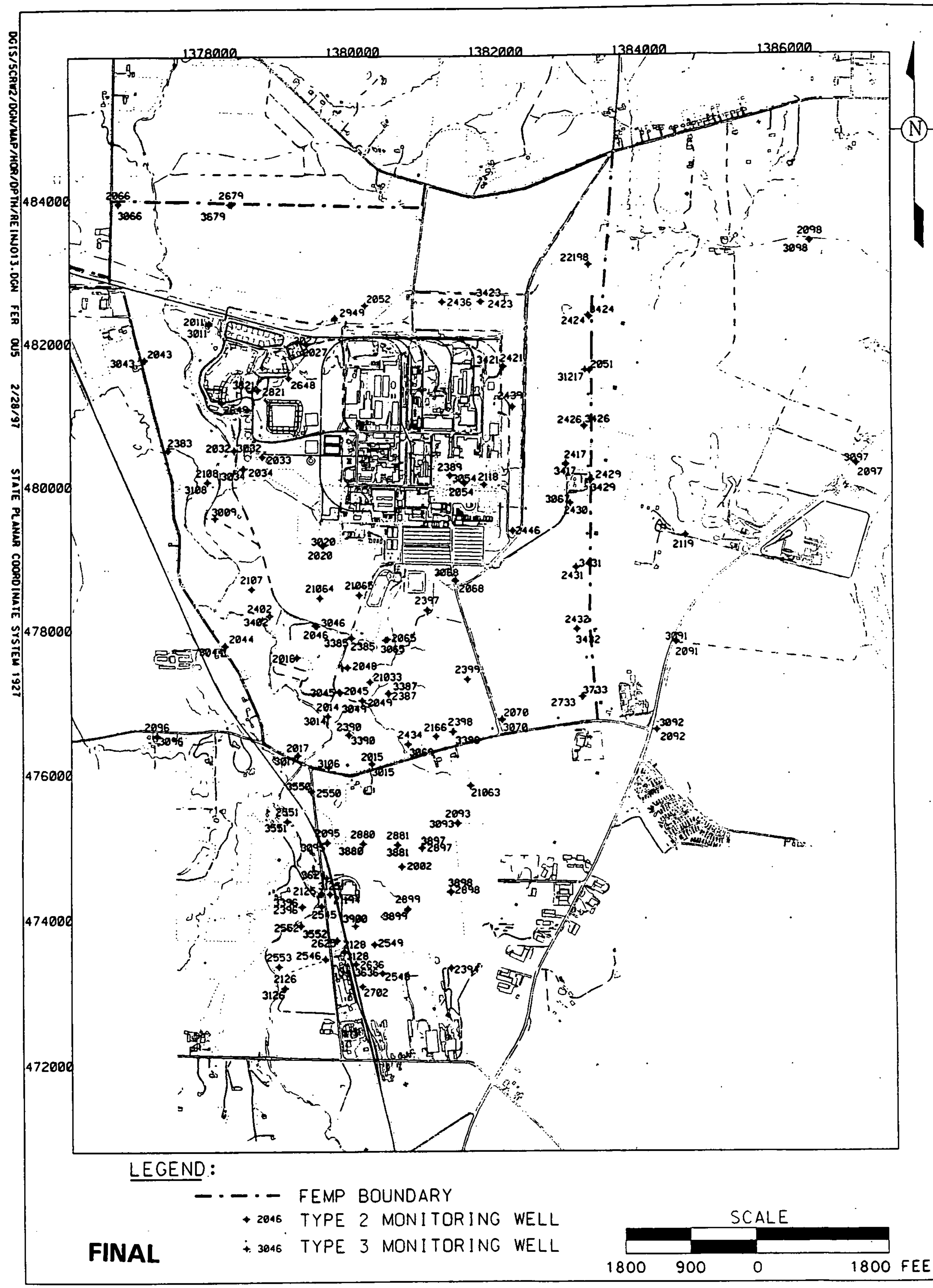


FIGURE 4-4. IEMP GROUNDWATER ELEVATION MONITORING WELLS

000063

5.0 DATA EVALUATION

During the re-injection demonstration, large quantities of data will be collected and evaluated to answer the following questions regarding the viability of re-injection at the FEMP:

- What is the quality of the injectate?
- Are the screens in the re-injection wells becoming plugged?
- What are the biological conditions around the re-injection wells?
- What are the resultant hydraulic patterns and capture zone for the system?
- Is the water quality of the area around the re-injection wells changing?
- Has a hydraulic barrier been created at the southern boundary of the FEMP?
- Is the South East Drainage Ditch recharging the aquifer in the area of Well 3069?
- 41 Does re-injection cause the uranium plume to go deeper in the Great Miami Aquifer?

These questions are explained in more detail below.

<u>What is the quality of the injectate?</u>

43 The quality of the injectate will be evaluated monthly. Sampling data will be tabulated and compared against FRL values to identify if any FRL exceedances occur.

<u>Are the screens in the re-injection wells becoming plugged?</u>

44 Plugging within the re-injection wells will be evaluated continuously by monitoring water levels within the re-injection well, and quarterly by conducting maintenance checks which include downhole camera surveys, and biological sampling.

Water levels collected from within the re-injection wells will be tabulated and graphed so that trends can be visually observed. Data collected during routine maintenance checks will also be tabulated. Downhole camera survey tapes will be viewed and archived for later reference. A brief write-up of the results of the survey will be prepared that will state when the survey was conducted, the well being surveyed, whether or not any indications of screen plugging were observed and if conditions have changed since the last survey was conducted. Biological sampling data will be tabulated and selected data may be graphed to illustrate trends.

What are the biological conditions around the re-injection wells?

Biological sampling data will be evaluated quarterly and tabulated by well. Tables will list the well being sampled, the date and time that the sample was collected, and the results of each sample collected. Results for different sampling events will be compared so that changes or trends can be noted.

What are the resultant hydraulic patterns and capture zone for the system?

Hydraulic patterns, profiles and capture zones will be evaluated monthly. Capture of the 20 μg/L total uranium plume will be evaluated quarterly.

5 Water level data will be tabulated and used to create monthly water level maps. Capture zones will be
42 etermined for the monthly water table maps. Actual data will be compared to modeled predictions to assess whether or not the modeled predictions (i.e., pumping related drawdown in the aquifer both on and off-property) are being realized. The strategy which will be used for verifying groundwater model predictions of remedy performance is presented in Section 3.7.1 of the IEMP.

Total uranium sampling of the plume is conducted quarterly as part of the IEMP. Quarterly determinations will be made on whether or not the 20 μg/L total uranium plume is being captured by overlaying quarterly capture zone maps on top of the quarterly plume maps. Major anion and cation data collected during the re-injection demonstration will be tabulated. Select parameters may be graphed to illustrate concentration changes.

Is the water quality of the area around the re-injection wells changing?

Water quality data will be tabulated. Select data may be graphed. Data collected at different times during the demonstration will be compared to determine if changes or trends are occurring.

Has a hydraulic barrier been created at the southern boundary of the FEMP?

45 Evaluating whether or not the total uranium plume is migrating between or beneath the re-injection wells will be based on water quality data collected using the Geoprobe™ sampling tool, water level data, and groundwater flow data collected using the colloidal borescope.

45 Water quality data obtained with a Geoprobe™ sampling tool will be used to construct vertical profiles of the uranium plume. Cross sections of the uranium plume will be prepared and compared through

time to determine if the plume is migrating between or beneath the re-injection wells. Water level data will be used to prepare water level maps to interpret capture zones and groundwater flow divides.

Velocity and flow data will be collected at select monitoring locations using the colloidal borescope to provide additional data concerning fluid movement in response to the re-injection.

Is the South East Drainage Ditch recharging the aquifer in the area of Well 3069?
Major anion and cation data collected from the drainage ditch will be tabulated and compared to major anion and cation data collected from the aquifer beneath the South East Drainage Ditch to determine if the two waters have similar chemistries. Similar chemistries would support the recharge interpretation.

41 Does re-injection cause the uranium plume to go deeper in the Great Miami Aquifer?
Water quality sampling results from the deep observation wells as well as vertical profile samples will be used to asses whether or not re-injection is causing the uranium plume to migrate deeper in the Great Miami Aquifer. As was discussed in Section 1.3, the concern, should this occur, is whether or not capture of the entire plume can still be maintained.

Potential Decisions
As presented in Section 1.2, the final decision which will be made using data collected during this re-injection demonstration will be one of the following:

1) Do not continue groundwater re-injection as part of the aquifer remedy. The long term application of the technology at the FEMP is just too costly or capture of the 20 μg/L total uranium plume cannot be maintained and still achieve the benefits of re-injection.

2) Continue groundwater re-injection technology as part of the aquifer remedy with no modification to the strategy presented in the BRSR. The long term application of the technology at the FEMP is not too costly and capture of the 20 μg/L total uranium plume can be maintained while still achieving the benefits of re-injection predicted in the BRSR.

3) Continue groundwater re-injection technology as part of the aquifer remedy but revise the remediation strategy presented in the BRSR. The long term application of the technology at the FEMP is not too costly and with a change to pumping and or re-injection rates capture of the 20 μg/L total uranium plume can be achieved.

During the re-injection demonstration, potential actions may be taken in response to monitoring results. The main monitoring observations and resulting potential actions are presented in Figure 5-1.

Figure 5-1

DEMONSTRATION MONITORING AND POTENTIAL ACTIONS

Monitor:
- Quality of Injectate
- Injection Rate
- Capture of the 20μg/l total Uranium Plume
- Hydraulic Barrier at FEMP Property Line
- Chemistry of Aquifer

If injectate exceeds FRLs:
- The Ohio EPA UIC unit will be notified
- A determination will be made as to why the exceedance is occurring
- A change to the treatment process for the injectate will be considered
- Depending on the magnitude and persistence of the exceedance, a decision to stop re-injection may be made

If a hydraulic barrier is not produced along the FEMP property boundary line:
- A determination will be made as to why the barrier is not present
- Pumping/injection rates may be adjusted in an attempt to create/maintain the barrier
- Additional extraction wells may be considered

If re- injection wells do not operate at an injection rate of 200 gpm without becoming plugged:
- Well maintenance will be performed to clean out plugging material
- A determination will be made as to why plugging is occurring
- More frequent routine maintenance checks will be initiated to determine the best method to control the plugging problem
- Depending on the magnitude and persistence of the plugging , a decision to stop re-injection may be made at a specific well or select number of wells

If re-injection causes adverse impact to the chemistry of the aquifer:
- A determination as to why adverse impact is occurring will be made
- A change to the injectate treatment process may be considered
- Depending on the magnitude and extent of the impact, a decision to stop re-injection may be made

If capture of the 20 μg/l total uranium plume is not maintained:
- A determination will be made as to why the plume is not being captured
- Pumping/injection rates may be adjusted in an attempt to maintain capture
- A decision to stop re-injection may be made if the magnitude of the excursion is unacceptable

6.0 SCHEDULES, DELIVERABLES AND REPORTING

Enforceable schedules for the aquifer remedy can be found in the Remedial Action Work Plan for Aquifer Restoration at Operable Unit 5 (DOE 1997c). The RA Work Plan lists start up dates for the AWWT Expansion Facility, the South Field Phase I Module, the Re-Injection Demonstration Module, and the South Plume Optimization Module.

Per Ohio EPA guidelines (OEPA 1997) a copy of this test plan and all monthly and final data reports will be submitted to the U.S. EPA and Ohio EPA Office of Federal Facilities Oversight, and the Division of Ohio EPA Drinking and Ground Waters-UIC Unit. The Ohio EPA contact for the FEMP aquifer remedy is Mr. Tom Schneider. Mr. Schneider is the Fernald Project Manager within the Office of Federal Facilities Oversight Unit, Southwest District Office, in Dayton Ohio. Monthly operating reports will include the following information:

- Analysis of the injectate
- The volume and rate of the injection
- A description of any well maintenance and rehabilitation procedures which were conducted
- Results of groundwater monitoring at the re-injection test site.

If the decision is made to continue using re-injection as part of the aquifer remedy, then the monthly reporting will continue. Monitoring updates for the re-injection demonstration will be provided quarterly as part of the IEMP quarterly reporting program. The quarterly monitoring updates will supplement the monthly reports by including:

- An assessment of how the demonstration is proceeding, and
- The latest water table map and capture zone interpretation.

Following completion of the re-injection demonstration a recommendation will be made concerning whether or not re-injection should continue. The recommendation to continue or discontinue re-injection will likely be made ahead of issuance of a final report. In the interim time period following the demonstration but before the recommendation, re-injection will continue unless data has already been collected indicating that the continuation of re-injection would adversely impact the aquifer remedy.

If the decision is made not to continue the use of re-injection, the baseline remedy presented in the BRSR (DOE 1997a) will need to be modified. The final re-injection demonstration report will include tabulations of all the data used to decide whether or not re-injection will continue as part of the site aquifer remedy. The final report will be issued within 90 days following the compilation of the data collected in support of the demonstration. Table 6-1 lists the monitoring and reporting commitments for the re-injection demonstration.

The final test report will be sent to the EPA, the Ohio EPA Office of Federal Facility Oversight, and the Ohio EPA Division of Drinking and Ground Waters - UIC Unit for review and approval.

47, 48

TABLE 6-1

RE-INJECTION DEMONSTRATION TEST MONITORING AND REPORTING COMMITMENTS

Activity	Schedule	Commitment/Requirement
Analyze Injectate	Monthly	Collect one grab sample each month. Begin in April, prior to re-injection, when AWWT expansion facility is operational. Analyze for all constituents that have had a recorded FRL exceedance in Aquifer Zones 2 and 4. A list of those constituents is found in Table 2-1.
Downhole Camera Surveys	Quarterly	Survey the five re-injection wells (22107, 22108, 22109, 22240, and 22111) at the start of the re-injection demonstration, at every quarterly scheduled well maintenance, and at the end of the re-injection demonstration.
Biological Sampling	Quarterly	Sample five re-injection wells (22107, 22108, 22109, 22240, and 22111) and five shallow observation wells (not yet installed) at the start of the re-injection demonstration, at every quarterly scheduled well maintenance, and at the end of the re-injection demonstration. Sample for iron-related bacteria, slime-forming bacteria, and total aerobic bacteria using prepared biological activity reaction test kits.
Groundwater Quality Sampling	Quarterly	Integrate with quarterly IEMP sampling. Collect samples from nine new observation wells (not yet installed), and 14 existing wells (2106, 3106, 2434, 3069, 2398, 3398, 4398, 2070, 3070, 2017, 2015, 3015, 2060, and 2166). Analytes are defined in Table 4-2. Sampling protocols are defined in Table 4-1.
Geoprobe™ Sampling	Variable	Seven locations prior to re-injection. Three locations every three months during demonstration. Seven locations at the end of the demonstration. Analytes are defined in Table 4-2.
In-situ Water Quality Monitoring	Monthly	Monitor each re-injection well (22107, 22108, 22109, 22240, and 22111) for 48 hours prior to the start of re-injection. Record measurements for specific conductivity, temperature, pH, Eh, and dissolved oxygen every hour. Monitor the deep and shallow observation wells next to Re-Injection Well 22109 continuously at the start of re-injection. Record measurements for specific conductivity, temperature, pH, Eh, and dissolved oxygen every hour until parameters have stabilized. Rotate the two water quality probes between the nine observation wells monthly during the demonstration. Collect hourly measurements for specific conductivity, temperature, pH, Eh, and dissolved oxygen for 24 hours at each well.
Water Level Measurements	Weekly at startup, then monthly	Integrate with quarterly IEMP water level monitoring. At the start of re-injection monitor fifty wells weekly until water levels have stabilized. A list of the 50 wells can be found in Table 4-3. Collect water levels from the same 50 wells monthly during the demonstration except for those months that coincide with quarterly IEMP water level monitoring. On months that coincide with IEMP monitoring just use the IEMP data.

TABLE 6-1
(Continued)

Activity	Schedule	Commitment/Requirement
Identify Well-Specific Groundwater Flow Directions.	Quarterly	Use the colloidal borescope to measure colloidal flow directions in four deep wells prior to start-up of South Field Module, four deep wells prior to start of re-injection, and four deep wells quarterly during the demonstration
Surface Water Sampling	One time event	Collect a grab sample from the Southeast Drainage Ditch. Sample for analytes listed in Table 4-1.
Operating Reports	Monthly	Monthly reports will provide an analysis of quality of the injectate, volume and rate of injection, description of any well maintenance and rehabilitation procedures which were conducted, results of groundwater monitoring at the re-injection test site. Reports will be sent to the U.S. EPA, and Ohio EPA Office of Federal Facilities Oversight and the Division of Drinking and Ground Waters (DDAGW) Underground Injection Control (UIC) Unit.
Up-date Reports	Quarterly	Quarterly reports will supplement the monthly reports by providing an assessment of how the demonstration is proceeding, latest water table map and captive zone interpretation. Reports will be sent to the U.S. EPA, and Ohio EPA Office of Federal Facilities Oversight and the Division of Drinking and Ground Waters (DDAGW) Underground Injection Control (UIC) Unit.
Life Cycle Cost Analysis of Re-injection Costs	Following completion of the demonstration	Results will be incorporated into the Final Re-Injection Demonstration Test Report
Final Re-Injection Demonstration Report	Following completion of the demonstration	Issue to EPA approximately nine months following completion of the Re-Injection Demonstration

7.0 PLUGGING AND ABANDONMENT OF THE RE-INJECTION WELLS

As recommended in Ohio EPA guidance document titled 5X26 Aquifer Remediation Projects (EPA 1997) upon completion of remedial activities at the FEMP, all re-injection wells will be permanently plugged and abandoned in a manner that will limit migration of fluids into an underground source of drinking water. The plugging and abandonment will begin within 120 days of the DOE, EPA and Ohio EPA reaching agreement and declaring that the aquifer remedy objectives for the FEMP have been achieved. Wells will be plugged and abandoned following guidelines presented in Appendix J of the SCQ, and following site procedure DRL-01 Well Plugging and Abandonment.

8.0 MANAGEMENT AND RESPONSIBILITIES

This section defines the roles and responsibilities of key management and technical personnel associated with the completion of the work defined in this test plan. Sampling activities defined in this test plan will be performed by Fluor Daniel Fernald. Descriptions of some of the key technical responsibilities of project personnel or organizations are provided below.

The DOE Operable Unit 5 Team Leader is responsible for:

- Providing direction and oversight to the completion of test plan activities
- Acting as the point of contact within DOE and for the regulators and stakeholders for all communications concerning work carried out under this test plan.

The Fluor Daniel Fernald Aquifer Restoration Project Director is responsible for:

- Providing overall project management and technical guidance to the Fluor Daniel Fernald team
- Ensuring the necessary resources are allocated to the project for the efficient and safe completion of test plan activities
- Overseeing and auditing test plan activities to ensure that the work is being performed efficiently and in accordance with all regulatory requirements and commitments, DOE Orders, site policies and procedures, and safe working practices.

The Fluor Daniel Fernald Project Manager is responsible for:

51 - The safe, prompt, and correct completion of work outlined in the test plan
- Oversight and programmatic direction of sampling activities
- Providing a technical lead for the collection and interpretation of sampling data
- Establishing and maintaining the scope, schedule, and cost baseline
- Reporting to the DOE Operable Unit 5 Team Leader and Fluor Daniel Fernald Aquifer Restoration Project Director on the status of test plan activities and on the identification of any problems encountered in the accomplishment of the test plan
- Managing the funding to complete the sampling and data analysis activities.

The Fluor Daniel Fernald Technical Lead is responsible for:

- Reporting to the Fluor Daniel Fernald Project Manager on the progress of test plan activities
- Collection, interpretation, and reporting of sampling data.

Groundwater Monitoring Team will be responsible for:

- Down hole camera surveys
- Biological monitoring in re-injection wells and observation wells
- 53 Collection of water level data in monitoring wells
- Collection of water quality data from re-injection wells and monitoring wells
- Collection of water quality data from the South East Drainage Ditch
- Data management.

Waste Water Treatment Operations Team will be responsible for:

- Analysis of the injectate
- Conducting Predictive and Preventive Maintenance
- Operation of the re-injection system.

9.0 SUPPORTING ACTIVITIES

9.1 DATA MANAGEMENT

Field and analytical data will be managed to meet test criteria evaluation needs. Field documentation and analytical data results will be verified to ensure conformance to the appropriate SCQ sections and appendices. The process for management of the field and analytical data is described in the Environmental Data Management Plan (EDMP) (FDF 1996).

Field documentation will be verified for accuracy and completeness by the sampling team followed by an independent field data validation in accordance with SCQ requirements for the corresponding ASL. The project team leader must have processes in place to verify that chemical and radiological data results meet all applicable quality requirements specified in the SCQ for the respective ASL (SCQ Section 11.0 and Appendix F). The quality of analytical data will be evaluated by independent project personnel qualified to determine accuracy, completeness and applicable statistical data necessary to evaluate data useability and data quality required for environmental monitoring reporting.

Both the field and analytical data will be entered into a controlled database using a double key or equivalent method to ensure accuracy. The hard copy data will be managed in the project files in accordance with FEMP record keeping procedures and DOE orders.

9.2 HEALTH AND SAFETY

The Fluor Daniel Fernald (FDF) Health and Safety Department is responsible for the development and implementation of health and safety requirements for this test plan. Hazards (physical, radiological, chemical, and biological) typically encountered by personnel when performing the specified field work will be addressed.

All involved personnel will receive adequate training to the health and safety requirements prior to implementation of the field work required by this test plan. Daily safety meetings will be conducted prior to beginning field work to address specific health and safety issues.

All FDF employees and subcontractor personnel who will be performing field work required by this test plan are required to have completed all site required training. For areas subject to more restrictive radiological controls where the potential for exposure is greater, Radiation Work Permits (RWPs) are necessary and will be obtained prior to the field work being performed in those areas. A radiological control technician will be assigned to each field crew performing any activities in an area requiring an RWP.

9.3 QUALITY ASSURANCE/QUALITY CONTROL

Groundwater Monitoring Sampling events will follow Quality Assurance/Quality Control (QA/QC) protocol established in Section 4 and Appendix K of the SCQ.

9.3.1 Project Requirements for Surveillances

Self-assessment of work processes and operations will be undertaken to assure quality of performance. Self-assessment will be performed by the Project Manager, and will encompass technical and procedure requirements. Such self-assessment may be conducted at any point in the project.

Independent assessment will be performed by the FEMP QA organization by conducting surveillances. At a minimum, one surveillance will be conducted, consisting of monitoring/observing ongoing project activity and work areas to verify conformance to specified requirements. Surveillances will be planned and documented in accordance with Section 12.3 of the SCQ.

9.3.2 Field Changes to the Test Plan

Prior to the implementation of field changes, the Project Manager will be informed of the proposed field changes. Once approval has been obtained (verbal or written) from the Project Manager and QA representative for the field changes to the test plan, the field changes may be implemented. Field changes to the test plan will be noted on a Variance Request form. QA must receive the completed Variance Request form, which includes the signatures of the Project Manager, and the QA/QC Representative, within one week of the granting of the verbal approval.

9.3.3 Quality Assurance Samples

Field quality control samples will be taken according to the frequency recommended in the SCQ. These samples will be collected and analyzed in order to evaluate the possibility that some controllable practice, such as decontamination or sampling technique, may be responsible for introducing bias in the projects analytical results. The following types of quality control samples will be collected: sampling equipment rinsates, trip blanks, field blanks, and duplicate samples as outlined in Section 6 and Appendix K of the SCQ. Each QC sample is preserved using the same method for groundwater samples. The QC sample frequencies will be tracked to ensure the proper frequency requirements are met as follows:

- Trip Blanks: Prepared for each sampling team on each day of sampling when volatile organic compounds are included in the respective analytical program.
- Equipment Blanks: Collect one rinsate sample every 20 groundwater samples that are collected using reusable sampling equipment. If less than 20 samples are collected a rinsate is still required. Rinsates are not required when dedicated well equipment or disposable sampling equipment is utilized.
- Field Blanks: Collect one field blank for each day of groundwater sampling.
- Field Duplicates (blind): One duplicate sample will be collected for every 20 groundwater samples or fraction thereof if less than 20 samples are collected.

The field samples associated with each QC sample will also be tracked to ensure traceability in the event that contaminants are detected in the QC sample.

9.4 WASTE DISPOSITION

The following wastes will be generated during sampling activities:

- Purge water
- Contact Wastes
- Equipment decontamination solutions

The following subsections provide the proposed disposition methodology for each type of water generated.

Purge Water and Decontamination Solutions

Groundwater purged from the wells and solutions used to decontaminate equipment used during sampling will be contained and transported to the FEMP wastewater system for proper disposal. If historic data for a well indicate the purge water is potentially a RCRA waste, the purge water will be drummed at the well and moved to the FEMP's controlled holding area until analytical results are returned and appropriate disposition can be made.

Contact Wastes

Contact wastes such as personal protective equipment (PPE), paper towels, and other solid investigation-derived waste will be placed in plastic bags or 55-gallon drums and transported to the FEMP for appropriate disposition.

9.5 DECONTAMINATION

Sampling equipment will be decontaminated following sample collection from each well to prevent cross-contamination of samples. The decontamination of equipment will be performed in accordance with the Level II method referenced in Appendix K.11 and described in Section 6.4.1 of the SCQ.

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APPENDIX A

WATER QUALITY IN THE RE-INJECTION DEMONSTRATION AREA

APPENDIX A

A.1 WATER QUALITY SAMPLING IN THE RE-INJECTION DEMONSTRATION AREA

Following the second single well injection test, conducted in Extraction Well 31567 in April of 1996 (see Figure A-1), groundwater samples were collected from 12 existing groundwater monitoring wells in the re-injection demonstration area (2017, 3017, 2106, 3106, 2015, 3015, 2434, 3069, 2398, 3398, 2070, and 3070), Figure A-1. The groundwater samples were analyzed for:

- Major anions and cations
- Iron bacteria (wells 2106, 2434, and 2398 only).

The collection of iron bacteria samples was limited to three wells due to the expense of the analysis used. During the re-injection demonstration, prepared BART kits will be used at a fraction of the cost, see Section 4.3.

In addition to the lab analyses, a Hydrolab™ Model H2OG downhole probe was used to measure in situ readings of temperature, pH, specific conductance, dissolved oxygen, and redox potential.

The objective of the sampling effort was to document geochemical conditions in the re-injection demonstration area. Results of the sampling effort are presented below.

A.2 RESULTS

Major anion and cation analytical results, in-situ water chemistry measurements, and iron bacteria analytical results are presented in Tables 1, 2, and 3, respectively. The data indicate that:

- Iron concentrations vary vertically and horizontally in the Great Miami Aquifer, increasing with depth
- Dissolved oxygen concentrations decrease with depth
- The redox potential decreases with depth
- Both aerobic and sulfate-reducing bacteria are naturally present in the aquifer in the re-injection demonstration area.

Iron Concentrations

In the re-injection demonstration area, groundwater collected from five Type-2 monitoring wells (2106, 2017, 2015, 2434, and 2398) had iron concentrations which were at or below 100 μg/L, Table A-1. The iron concentration measured in a sixth Type-2 monitoring well (2070) was 1363 μg/L, Type-2 monitoring wells have a fifteen foot screen that is completed across the water table.

Iron concentrations were also measured in groundwater collected from six Type-3 monitoring wells (3106, 3017, 3015, 3070, 3398 and 3069). Three of the six locations (3017, 3070, and 3398) had iron concentrations which were relatively high, ranging from 1363 μg/L to 3994 μg/L. Two of the six wells (3106, and 3069) had iron concentrations below 100 μg/L. Monitoring Well 3015 had an iron concentration of 169.9 μg/L. Type-3 monitoring wells have a ten foot screen positioned approximately 60 feet below the water table.

The data indicates that in the re-injection demonstration area the aquifer is zoned vertically with respect to iron. Shallow depths are relatively low in iron and deeper intervals are relatively high in iron.

It is common for iron concentrations in some aquifer systems to be relatively low near recharge areas, increasing as the groundwater migrates away from the source of the recharge. Precipitation and surface water runoff are usually low in iron, making the concentration in groundwater near aquifer recharge points relatively low. As groundwater migrates through the aquifer, iron leaches from the sediment through which the water is passing, raising the dissolved concentration of iron in the groundwater. Iron is a constituent of shale and is found as impurities in carbonate rocks. Both shale and carbonate rocks are in contact with the Great Miami Aquifer. Because iron plugging of the re-injection well is a concern it is important to understand what iron concentrations can be expected in the area of the re-injection demonstration and if the concentration is uniform across the area.

The apparent zonation of iron observed in the re-injection demonstration area should be favorable for the planned re-injection program. Re-injection is being targeted to the shallow portion of the aquifer where iron concentrations are low. Because treated water which is low in iron will be re-injected into groundwater which is low in iron, the precipitation of iron hydroxide should be minimized. Therefore the growth of iron bacteria that thrives on the precipitation reaction should be minimized.

In-Situ Groundwater Chemistry Measurements

In situ measurements of temperature, pH, specific conductance, dissolved oxygen, and redox potential collected from monitoring Wells 2017, 3017, 2106, 3106, 2015, 3015, 2434, 3069, 2398, 3398, 2070, and 3070) are listed in Table A-2.

In-Situ measurements were collected hourly over a time period of approximately 24 hours. The data listed in Table A-2 contains the range of representative data recorded.

The data indicates that the aquifer in the area of the re-injection demonstration is zoned with respect to dissolved oxygen and redox potential. Dissolved oxygen concentrations generally decrease with depth, and lateral distance from an aquifer recharge location. In the Type-2 monitoring wells (with the exception of Well 2070) the dissolved oxygen ranged from 5.91 mg/L to 10.13 mg/L and in the 3000-series wells the dissolved oxygen concentration ranged from 0 mg/L to 1.03 mg/L. In the Type-2 monitoring wells (with the exception of 2070) the redox potential ranged from 288 mV to 392 mV, and in the Type-3 monitoring wells the redox potential ranged from 58 mV to 303 mV.

Iron Bacteria Results

Iron bacteria results for the re-injection demonstration area are presented in Table A-3. Three monitoring wells were sampled, 2106, 2398, and 2434. The data indicated that monitoring Well 2106 had very low counts of bacteria in general. The aerobic heterotroph count was below 10,000 CFU/dl and therefore not considered significant in regard to biofouling potential. Yeast and fungi are commonly associated with aerobic heterotrophs so the high count is considered normal.

The results for the other two wells though did indicate biofouling problems. Well 2398 had an aerobic heterotroph count of 162,000 CFU/dl. Anything over 10,000 CFU/dl is reported to be a concern. The water sample also exhibited a very prominent population of iron-oxidizing bacteria as well as sulfur-oxidizing bacteria, indicative of a iron biofouling problem.

The water sample collected from Well 2434 had a sphaerotilus/Leptothrix count of 2,700 CFU/dl. It was reported by the lab that counts of Sphaerotilus/Leptothrix exceeding 2000 to 3000 CFU/dl typically indicate the beginning of an iron bacteria biofouling problem. The sample also had a population of sulfate-reducing bacteria and a high count of anaerobic heterotrophs, indicative of a more reduced environment compared to the other two samples.

Judging by these results, bacteria conditions vary across the re-injection demonstration area from no observable problem in Well 2106, to observable problems with both oxidized and reduced forms of bacteria in Wells 2398 and 2434 respectively.

A.3 CONCLUSIONS

The water quality data collected in the re-injection demonstration area indicate that favorable conditions are present in the aquifer for the re-injection demonstration. The aquifer in the re-injection demonstration area is relatively oxidized and has a low iron concentration. Water treated through the FEMP groundwater treatment system is also relatively oxidized and has a low iron concentration. Re-injection of treated groundwater into the aquifer should not promote the oxidation of ferrous iron to ferric iron or promote the growth of iron bacteria.

Iron bacteria data collected in the area of the re-injection demonstration indicates that different bacteria conditions are present across the area. The three monitoring wells which were sampled all exhibited different iron bacteria results.

The presence of iron bacteria in the aquifer, prior to re-injection, should not be a problem for the re-injection demonstration unless the re-injection process alters the chemistry of the groundwater such that reactions favorable for the growth of the iron bacteria occur.

TABLE A-1

INJECTION DEMO AREA, WATER QUALITY DATA MAJOR ANIONS AND CATIONS

Parameter	Units	2106	3106	2017	3017	2015	3015	2434	2070	3070	2398	3398	3069	Detection Limit[b]
Aluminum	μg/L	U	U	U	U	U	U	U	U	U	U	U	U	200
Calcium	μg/L	90,610	94,670	122,220	136,700	82,960	86,400	102,800	83,710	75,230	84,930	111,190	85,180	NA
Iron	μg/L	100	U	U	2838	U	169.9	U	3898.1	3994	U	1363	U	100
Magnesium	μg/L	22,210	24,620	30,280	28,930	20,390	20,700	27,720	22,890	17,920	21,960	26,940	21,110	NA
Manganese	μg/L	U	U	U	385.7	U	261.5	U	352.6	262.5	U	340.7	26.7	15
Potassium	μg/L	U	U	U	U	U	U	U	U	U	U	U	U	5000
Silicon	μg/L	3192	4083	5286	4818	3190	3568	4584	3623	3928	4125	4248	3813	NA
Sodium	μg/L	16,870	14,890	8,322	12,820	12,910	9803	23,060	10,030	6967	19,780	9718	10,560	NA
Alkalinity	N	U	U	U	U	U	U	U	U	U	U	U	U	0.01
Fluoride	mg/L	0.3	0.2	0.2	0.1	0.44	0.18	0.23	0.18	0.18	0.16	0.15	.18	NA
NO_3-N	mg/L	2.6	0.2	2.0	U	2.1	0.1	3.9	0.24	U	0.70	U	1.05	0.2
Solids	mg/L	U	U	U	4	U	8	4	3	8	15	3	U	2
Chloride	mg/L	43	33.8	7.2	32.6	36.6	33	63.4	36.6	28.6	58.8	32.4	38.4	NA
Sulfate	mg/L	66.5	88.5	58	205	81	98.5	82.5	85	75.5	76.5	157.5	93	NA
TDS	mg/L	399	450	446	578	348	350	475	397	504	422	525	392	NA
Ammonia	mg/L	U	U	U	U	U	U	U	U	0.14	U	U	U	0.10
Phosphate	mg/L	0.52	.08	.08	0.15	0.18	0.15	0.23	0.23	0.45	0.20	0.15	0.7	NA
Uranium	μg/L	42	1.8	3.5	0.9	140	1.2	1.2	0.8	0.2	11	1.0	110	NA
Carbonate	μg/L	U	U	U	U	U	U	U	U	U	U	U	U	0
Bi-carbonate	μg/L	246,000	266,000	346,000	300,000	228,000	230,000	271,000	276,000	270,000	246,000	264,000	250,000	NA

[a] U = Undetected
[b] NA = Not applicable

TABLE A-2

INJECTION DEMO AREA, WATER QUALITY DATA
IN-SITU WATER QUALITY PARAMETERS

Wells	Temp (°C)	pH	Sp. Cond. (mS/cm)	DO (mg/L)	Redox (mV)
2017	10.61-10.94	7.0-7.18	0.592-0.628	9.13-10.13	316-329
3017	11.83-11.96	6.84-6.99	0.784-0.794	0.72-1.03	197-239
2106	13.59-13.68	7.07-7.20	0.665-0.716	6.40-7.12	329-392
3106	10.78-10.94	7.02-7.22	0.881-0.791	0.05-0.10	259-285
2015	9.63-9.97	7.15-7.40	0.642-0.720	6.04-4.48	304-314
3015	9.29-9.31	7.36-7.38	0.680-0.682	0.6-0.8	120-147
2434	9.27-9.42	6.89-7.1	0.787-0.819	9.33-10.29	316-332
3069	9.38-9.48	7.15-7.32	0.711-0.756	0.38-0.45	270-303
2398	10.86-11.14	7.03-7.24	0.773-0.796	5.91-6.24	288-365
3398	10.53-10.65	7.06-7.23	0.787-0.812	0-0.39	117-215
2070	10.99-11.50	6.99-7.31	0.663-0.741	0.03-0.52	82-155
3070	10.67-10.80	6.99-7.39	0.694-0.723	0.07-0.76	58-76

TABLE A-3

INJECTION DEMO AREA, WATER QUALITY DATA
BACTERIAL ANALYSIS

Parameter	Units[a]	2106	2434	2398
Aerobic Heterotrophs, Total	CFU/dL	7200	5400	162,000
Anaerobic Heterotrophs, Total	CFU/dL	40	2700	320
Fungi and Yeast, Total	CFU/dL	4800	7200	27,000
Gallionella	CFU/dL	2.0	66.0	8100
Sphaerotilus/Leptothrix	CFU/dL	720	2700	9000
Thiobacillus	CFU/dL	10	1400	27,000
Sulfate-Reducing Bacteria	CFU/dL	<1	800	<1
Sulfide/Sulfer-Oxidizing Bacteria	CFU/dL	<1	<1	1800
Geobacter	CFU/dL	<1	<1	<1

[a]Colony forming unit per deciliter

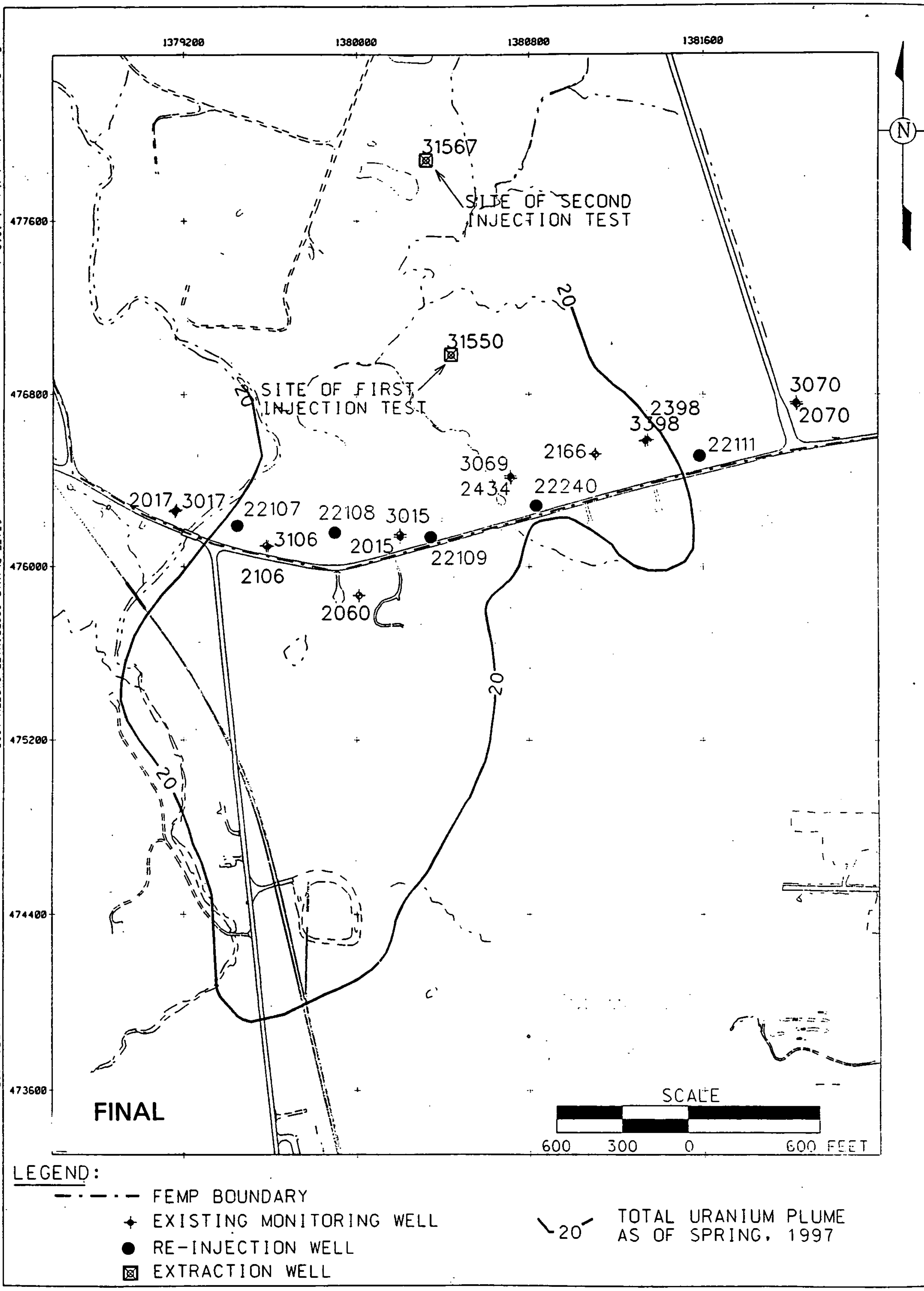

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FIGURE A-1. GROUNDWATER QUALITY SAMPLING LOCATIONS