Redacted

Enclosure C

1 - Remedial Alternatives Analysis – Source Control Project, August 1999

2 - 1st Semi-annual 2009 Full Scale Data Package, February 23, 2010

3 - BOS 100 Injection Services, March 30, 2007

4 - 2010 Facility Action Plan, January 2010

5 - 2009 Facility Action Plan, January 2009

6 - Railroad Well Capture Zone Analysis

Redacted

RAI 7

Attachment 1

Remedial Alternatives Analysis – Source Control Project, August 1999

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CSM-99-022

Remedial Alternatives Analysis - Source Control Project

Nuclear Fuel Services, Inc./Erwin, Tennessee
SWMU 20/Maintenance Shop Area

ARCADIS
GERAGHTY & MILLER

Address:
97 Midway Lane
Oak Ridge, Tennessee 37830

REPORT

August 1999

ARCADIS GERAGHTY&MILLER

Remedial Alternatives Analysis
Source Control Project
SWMU 20/Maintenance Shop Area
PO # 9930013001
Nuclear Fuel Services, Inc.
Erwin, Tennessee

August 6, 1999

Prepared by ARCADIS Geraghty & Miller, Inc.

Jeffrey G. Meyers
Jeffrey G. Meyers, PE # 102596
Senior Engineer

Gregory B. Page
Gregory B. Page
Project Engineer

Jerry A. Archer
Project Officer, PG # 1060

Jeffrey G. Meyers
Aug 5, 1999

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TABLES

FIGURES

FIGURES (continued)

LIST OF ACRONYMS AND ABBREVIATIONS

bls	below land surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
COPCs	constituents of potential concern
DCE	dichloroethene
DQOs	data quality objectives
FR	Federal Register
ft	feet
GAC	granular activated carbon
gpm	gallons per minute
GRAs	general response actions
GWTF	groundwater treatment facility
H_2O_2	hydrogen peroxide
HI	hazard index
MCLs	maximum contaminant levels
MCLGs	maximum contaminant level goals
MEME	Mobile Enhanced Multiphase Extraction
mg/L	milligrams per liter
mV	millivolts
NCP	National Contingency Plan
NFS	Nuclear Fuel Services, Inc.
O&M	operation and maintenance
ORP	oxidation-reduction potential
PCE	tetrachloroethene
pCi/L	picoCuries per liter
POTW	publicly-owned treatment works
PPE	personal protection equipment
PRGs	Preliminary Remediation Goals
psig	pounds per square inch gage
RAA	Remedial Alternatives Analysis
RAGS	Risk Assessment Guidance for Superfund
RAOs	remedial action objectives
RBCs	risk-based calculations
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RPOs	representative process options
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
Site	SWMU 20/Maintenance Shop Area

SVE	soil vapor extraction
SWMU	Solid Waste Management Unit
TBP	tributyl phosphate
TCE	trichloroethene
TSD	treatment, storage, and disposal
UCL	upper confidence level
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
UV	ultraviolet
VC	vinyl chloride
VER	vacuum-enhanced recovery
VOCs	volatile organic compounds

Executive Summary

At the request of Nuclear Fuel Services, Inc. (NFS), ARCADIS Geraghty & Miller, Inc. has performed the enclosed alternatives analysis for groundwater remediation (source control) at the Solid Waste Management Unit (SWMU) 20 - Maintenance Shop Area (Site) of the NFS Plant located in Erwin, Tennessee. The analysis has been prepared to include the development, screening, and detailed analysis of remedial alternatives for the Site to satisfy the following objectives: 1) prevent further migration (source zone containment); 2) remediate or enhance the degradation of chlorinated solvents from the "hot spot" area; and 3) remediate or enhance the degradation of dissolved uranium (complex/chelate) from the "hot spot" area. The analysis builds on previous investigations of the Site including monitoring events, modeling, and risk assessment.

The following is a general description of the process that was used [modeled after the Comprehensive Environmental Response, Conservation, and Liability Act (CERCLA)] to prepare this alternatives analysis. Initial steps included: presentation of site assessment data; summarization of risk assessment data; identification of remedial action objectives (RAOs); development of general response actions (GRAs); identification, evaluation, and screening of remedial technologies and process options; and selection of representative process options (RPOs). Following these steps, remedial alternatives were developed and then screened using a two-tiered screening approach. The screening process reduced the number of alternatives for detailed and comparative analysis. Finally, a preferred remedial alternative was selected.

The Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997) concluded that there are currently no unacceptable risks associated with the Site. However, primarily due to volatile organic constituents (VOCs) [mainly tetrachloroethene (PCE)] present in groundwater, potential risks associated with an on-site construction worker and future hypothetical off-site receptors (construction worker and/or recreational users) may exist. Therefore, RAOs for the Site focus on the protection of a potential future on- and off-site receptor from accidental ingestion, inhalation, and dermal contact associated with impacted groundwater.

Utilizing six GRAs, ranging from "no action" to removal and disposal, associated remedial technologies were identified, screened, and combined to form site-wide remedial alternatives for further evaluation. After the alternatives screening (involving effectiveness, implementability, and cost), four alternatives were carried forward for detailed analysis.

The four alternatives are:

Alternative R-1: No Action;

Alternative R-2: Deed restrictions, fencing, site monitoring (of natural attenuation), vacuum-enhanced recovery (VER), air-phase thermal oxidation, air stripping, chemical precipitation, liquid-phase adsorption, and discharge to the local publicly-owned treatment works (POTW);

Alternative R-3: Deed restrictions, fencing, site monitoring (of natural attenuation) and in-situ oxidation; and

Alternative R-4: Deed restrictions, fencing, site monitoring (of natural attenuation), in-situ enhanced anaerobic bioremediation, and in-situ reductive precipitation.

A detailed analysis of alternatives was conducted using the following seven criteria: 1) protection of human health, welfare, and the environment; 2) compliance with applicable regulations; 3) long-term effectiveness and permanence; 4) reduction of mobility, toxicity, or volume through treatment; 5) short-term effectiveness; 6) implementability; and 7) cost. Alternatives R-2 through R-4 would provide varying degrees of protection and treatment and were subjected to a comparative analysis of their relative merits. The "no action" alternative (Alternative R-1) does not meet RAOs, but was also included as a basis of comparison.

The results of the detailed and comparative analyses were used to identify a preferred remedial alternative. Alternative R-4, incorporating deed restrictions, fencing, a long-term monitoring program, in-situ enhanced anaerobic bioremediation (for PCE and daughter products), and in-situ reductive precipitation (for uranium) is identified as the preferred alternative for the Site pending review and concurrence by NFS. Components of Alternative R-4, which would address the principal concerns associated with the Site, include:

- Implementation of deed restrictions at the Site;
- Inspection of boundary fencing to restrict access;
- Monitoring program for constituents of potential concern (COPCs) and biogeochemical parameters to demonstrate natural attenuation and monitor in-situ treatment performance;
- Performance of in-situ enhanced anaerobic bioremediation and reductive precipitation treatment to remove and/or stabilize COPCs and expedite degradation; and

- Reevaluation every 5 years of the effectiveness of the remediation and the degree to which other emerging remediation technologies may be suited for the Site.

Alternative R-4 is the preferred alternative because it provides a high degree of overall protectiveness to human health, welfare, and the environment. In addition to eliminating or minimizing long-term management of impacted groundwater at the Site, Alternative R-4 will eliminate potential for contact with impacted groundwater. Under Alternative R-4, the site groundwater biogeochemistry will be enhanced to facilitate reductive precipitation/bioremediation and provide in-situ treatment of COPCs through natural degradation/stabilization processes. The preferred alternative is implementable, reliable, and is expected to meet the RAOs within 8 years. The estimated cost for Alternative R-4 ($784,200) is less than the cost of Alternative R-3 ($1,016,000) and nearly one-fifth the cost of Alternative R-2 ($3,852,000).

A conceptual design for the monitoring program and enhanced reductive precipitation/ bioremediation treatment, which may be modified during the final design phase, will be performed in the next phase of work.

1.0 Introduction

This Remedial Alternatives Analysis (RAA) has been prepared for Nuclear Fuel Services, Inc. (NFS) and encompasses the development, screening, and detailed analysis of remedial alternatives for remediation of groundwater at the Solid Waste Management Unit (SWMU) 20 - Maintenance Shop Area (Site). The RAA process consists of the identification of remedial action objectives (RAOs); development of general response actions (GRAs); identification, evaluation, screening of remedial process options; selection of the representative process options (RPOs); development, screening, and detailed analysis of remedial alternatives; and preferred remedial alternative selection.

The RAA Report involves the formation of remedial alternatives, the screening of remedial alternatives (based on effectiveness, implementability, and cost), and the detailed analysis of the alternatives that pass the screening process. The screening process reduces the number of alternatives for detailed analysis while retaining flexibility of choice of process options during remedial design. This RAA Report includes the detailed analysis of alternatives using seven of the nine criteria as presented in Chapter 40 of the Code of Federal Regulations (CFR) Part 300 and the Guidance for Conducting Remedial Investigations/Feasibility Studies under CERCLA (U.S. Environmental Protection Agency 1988).

The specific items included in this RAA Report are as follows:

1) identification of chemical constituents of potential concern (COPCs);
2) identification of chemical-specific, location-specific, and action-specific applicable regulations;
3) determination of Preliminary Remediation Goals (PRGs) for site media;
4) identification of impacted areas and comparison of the environmental data to applicable regulations;
5) calculation of areas and volumes of impacted media;
6) development and screening of remedial technologies and process options;
7) development and screening of alternatives;
8) detailed analysis of the remedial alternatives; and
9) recommendation of a preferred alternative.

This report addresses items based upon existing information of present technologies and analytical data. The findings and conclusions presented herein may be revised based on the results of additional information and data that may be collected.

2.0 Site Information

2.1 Site Location and History

The NFS facility, located in Unicoi County, is within the city limits of Erwin and is immediately west of the community of Banner Hill. NFS is a nuclear fuel fabrication and uranium recovery facility that has been operational since the late 1950s. The NFS facility, approximately 64 acres in size, is located in the mountainous region of East Tennessee, east of the Nolichucky River and adjacent to the CSX Railroad (Figure 2-1).

Situated in a narrow valley surrounded by rugged mountains, the Site occupies a relatively level area approximately 20 to 30 feet (ft) above the elevation of the Nolichucky River. To the west, east, and south, the mountains rise to elevations of 3,500 to 5,000 ft within a few miles of the Site. The CSX Railroad adjoins the Site on the northwest boundary. A light industrial park is located opposite the Site on the northwest side of the railroad. Residential, commercial, and industrial lands constitute 19 percent of the surrounding area, with approximately 7 percent covered by farms and suburban homes (Figure 2-1). The remaining area is forested and mountainous land.

2.2 Hydrogeology/Groundwater

The aquifer underlying the SWMU 20/Maintenance Shop Site is composed of two principal hydrostratigraphic units: an unconsolidated unit and a bedrock unit. The water-table aquifer occurs in the unconsolidated surficial sediments at the Site which are predominantly alluvial in origin. This alluvial aquifer is limited in areal extent and is found mainly in the lowland areas. The alluvial aquifer pinches out just north and south of the Site due to the presence of shallow bedrock.

Alluvial deposits are generally very heterogeneous in sediment size, composition, pattern, and hydraulic properties. The alluvial aquifer system is characterized by two hydrostratigraphic units that are commonly referred to as the shallow alluvium zone and cobble/boulder zone. The shallow alluvium, the uppermost unit, consists of clay, silt, and sand. In general, the grain size associated with the shallow alluvium increases with depth. The cobble/boulder zone underlies the shallow alluvium and is characterized by pebbles, cobbles, and boulders. The grain size associated with the cobble/boulder zone increases with depth and the most coarse materials are in contact with the underlying bedrock.

The bedrock aquifer beneath the Site occurs in the Rome Formation. Even though the alluvial aquifer is of greater permeability than the bedrock aquifer, regional groundwater flow patterns exist in the bedrock aquifer beneath the Site to a depth of at least 350 ft. Groundwater originating in the upland areas flows through the Shady and Honaker Dolomite before exiting the groundwater flow system through surface water in the valley.

Previous investigations have determined that groundwater in the Rome Formation in the site area occurs under weak artesian conditions for the range of depths investigated. Locally, the Rome bedrock surface is shallow and intersects the water table in several areas.

The Erwin valley is characterized as a discharge zone for groundwater, as evidenced by the number of springs in the valley and along its hillsides. Groundwater occurs beneath the Site in both the unconsolidated alluvium and bedrock lithologies. The water table is present in the alluvium from where it intersects the land surface to as much as 14 ft below land surface (bls) in the southwestern area of the plant. Water-level data is available throughout the Site. Recent drilling and monitor-well installation has provided significant water-level information northwest of the Site toward the Nolichucky River.

Monitoring wells at the SWMU 20/Maintenance Shop Site are completed in four hydrostratigraphic zones: 1) across the water table in the shallow alluvium; 2) the deep alluvium (cobble zone); 3) shallow bedrock; and 4) the intermediate depth bedrock, from 50 to 120 ft bls (Figure 2-2). Generally, groundwater flows in a northwest direction toward the Nolichucky River (Figure 2-3). The general groundwater flow direction in the cobble/boulder zone and shallow bedrock (Figure 2-4) is roughly uniform to that in the alluvium zone, exhibiting flow toward the northwest.

2.3 Nature and Extent of Impact

Previous activities in the study area have resulted in the presence of radionuclides and organic constituents in groundwater below the facility. The prime source areas are associated with Buildings 111, 130, and 120/131, located in the northern portion of the NFS Site (Figure 2-2). Total uranium is present onsite above the proposed U.S. Environmental Protection Agency (USEPA) drinking water maximum contaminant level (MCL) (U.S. Environmental Protection Agency 1996a) [30 picoCuries per liter (pCi/L)] within the unconsolidated sediments (Figure 2-5 and Table 2-1). Total uranium is present in off-site shallow bedrock but concentrations are well below the proposed MCL. Elevated uranium concentrations are present throughout the central and northern area of the Site near known source areas. Tetrachloroethene (PCE) concentrations in the alluvium (Figure 2-6) and shallow bedrock (Figure 2-7) encompass the northern portions of the NFS Site and extend offsite toward the Nolichucky River (Table 2-1).

The uranium plume is located on NFS property extending approximately 180 ft north-northwest of the source areas with concentrations ranging from 50 to 1,100 pCi/L, and is positioned only within the alluvium aquifer. The observed total uranium plume, when compared to PCE distribution, indicates that uranium is moving very slowly in the alluvial aquifer material.

The USEPA drinking-water MCLs (U.S. Environmental Protection Agency 1996a) were exceeded for uranium (30 pCi/L) (proposed) and PCE [0.005 milligrams per liter (mg/L)] in various wells within the subject area of Buildings 130, 120, and 131.

The uranium plume remains onsite emanating from a source area on NFS property (Figure 2-5). Current uranium concentrations in the plume range from 50 to 1,100 pCi/L and remain confined to the alluvial aquifer. The PCE plume extends offsite to the northwest emanating from source areas on NFS property (Figures 2-6 and 2-7). Current PCE concentrations in the plume range from 0.005 mg/L up to 14 mg/L. The vertical extent is well-defined, however, PCE detections up to 1 mg/L at greater than 40 ft bls have been detected in the bedrock (Figure 2-8).

NFS performed one monitoring event in 1998 analyzing the biogeochemistry of the site groundwater. Although the selected monitoring wells are not ideal for a thorough evaluation of natural attenuation of site constituents, the data does indicate 1) the reductive dechlorination of the parent compound PCE evident by daughter products [i.e., 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC)]; 2) an increase in Cl- ions; and 3) utilization of oxygen, nitrates, iron, and other electron acceptors by in-situ bacteria populations (Table 2-2). These data can be further evaluated upon establishing a Natural Attenuation Sampling and Analysis Plan and subsequent monitoring events within the plume area.

2.4 Building 130 Scale Pit and Adjoining Buildings 131 and 120

Building 130 was constructed in the late 1950s. Operations in Building 130 included thorium processing, HEU processing, and cleaning uranium hexaflouride cylinders. Building 120 was constructed in the late 1950s. Building 131 was constructed in the early 1960s adjacent to Building 120. The Building 120/131 area has been used for maintenance, product storage, and as a pilot plant. Currently, the Building 120/131 complex houses the maintenance department and a research and development laboratory. Chlorinated solvents were thought to have been used and stored in the vicinity of Buildings 120 and 131.

2.5 Summary of Baseline Risk Assessment

An evaluation of potential risk to human health was conducted for the Site and the adjacent industrial park, located to the northwest (Nuclear Fuel Services, Inc. 1997). The risk assessment identified seven COPCs: 1,2-DCE (total), *cis*-1,2-DCE, *trans*-1,2-DCE, PCE, trichloroethene (TCE), VC, and tributyl phosphate (TBP). Identified as potential receptors onsite were construction workers. The potential receptors identified offsite include construction workers and recreational users. The risk assessment identified one potentially complete pathway under the current land use scenario and two potentially complete pathways under the future land use scenario (Table 2-3). The NFS risk assessment determined preliminary remediation goals for various levels of risk and hazard exposure values (Table 2-4).

2.5.1 Selection of the Constituents of Potential Concern

The Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997) and data obtained during NFS monitoring events were used to establish the COPCs for groundwater investigated at the Site and adjacent industrial park. The COPCs represent constituents which were detected at significant levels which were carried through the risk assessment and are not an indication of media requiring remediation. As part of the data evaluation conducted during the Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997), occurrence tables were constructed to statistically represent site data [e.g., detection frequency: minimum, maximum, and mean concentrations; upper confidence level (UCL), etc.]. Data were divided within a single media (groundwater) as appropriate for properly evaluating exposure.

Data were reduced and analyzed and COPCs were determined using the guidelines provided by USEPA (U.S. Environmental Protection Agency 1988). The process used to eliminate and identify COPCs is presented in detail in the Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997). Groundwater was determined to be the only media of concern onsite. Groundwater and surface water (off-site pond) were determined to be the only media of concern offsite. Additional information on the selection of COPCs is available in the Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997).

2.5.2 Conceptual Site Model

A conceptual site model for potential exposure pathways to site constituents is presented in Figure 2-9 and considers only groundwater and/or groundwater discharge to surface water. Three potentially complete exposure pathways were identified: 1) dermal contact and/or vapor inhalation of groundwater by a future on- and off-site construction worker; 2) dermal contact, ingestion, and/or fish ingestion of groundwater by a current off-site recreational user; and 3) dermal contact, ingestion, and/or fish ingestion of groundwater by a future off-site recreational user. The conceptual model also identifies the media, exposure points, and potential receptors.

2.5.3 Risk Assessment Results

Risk estimates for future exposure pathways for a future on- and off-site construction worker were within USEPA regulatory guidelines. Excess lifetime cancer risks were below 10^{-6} and the Hazard Index (HI) was less than 1.0 (Nuclear Fuel Services, Inc. 1997). Current and future off-site recreational users was excluded because surface-water analytical results are below the State of Tennessee Water Quality Standards (Tennessee Department of Environment and Conservation 1995).

NFS has prepared this RAA Report to select a remedial alternative and implement the selected alternative to address potentially unacceptable risks associated with on-site recreational users and a future hypothetical on- and off-site construction worker and/or recreational users. Overall, no information currently exists which indicates that adverse impacts to ecological receptors have occurred at the Site as a result of exposure to constituents detected in the groundwater. Concentrations of volatile constituents were detected above MCLs in groundwater; however, consistent with EPA Region IV Supplemental Guidance to RAGS (U.S. Environmental Protection Agency 1995b), an ecological risk assessment has not been required because COPCs in surface water are below the State of Tennessee Water Quality Standards (Tennessee Department of Environment and Conservation 1995).

Of the COPCs listed in the risk assessment, seven constituents were determined to occur at high enough levels in groundwater to be considered COPCs (Table 2-4) (Nuclear Fuel Services, Inc. 1997). Based upon the Risk Assessment conclusions, and NFS objectives to address uranium at the Site, the RAA will be conducted using these eight COPCs (seven organics plus uranium) as the target constituents requiring remediation.

2.6 Physical Obstacles

The NFS facility, like most other industrial facilities, is characterized by a complex network of surface and subsurface features that make up the infrastructure of the facility. These features within SWMU 20/Maintenance Shop will be significant obstacles for the implementation of a groundwater remedy. Therefore, this constraint will be thoroughly considered when evaluating groundwater remediation technologies. Aboveground physical obstacles that will be considered during the alternative screening and design process include:

- Northern Security Fence;
- Buildings;
- Overhead Power Lines;
- Traffic Areas; and
- Surface-Water Drainage Features.

In addition to these aboveground obstacles, subsurface infrastructure must also be considered during the evaluation, analysis, and design of an effective remedy. These features include:

- Storm Drains;
- Water Lines; and
- Sanitary Sewer Lines.

Not only do these features present significant physical obstacles for the installation of remedial technologies, but they may also serve as preferential pathways for groundwater flow. Consequently, these features must also be considered when evaluating technologies that require the alteration of the groundwater flow system. Because of the large expense associated with moving these features, technologies may be screened out if they will not be effective or cannot be implemented with the existing subsurface infrastructure.

In addition to the aforementioned physical obstacles, security issues related to the NFS facility must also be considered during the alternative screening process. Although the physical obstacles and security issues present significant challenges for the successful design and implementation of a groundwater remedy, they are not insurmountable or unique to the NFS facility.

2.7 Alternatives Analysis Process Description

The various steps, or phases, of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process have been used in the preparation of this RAA Report for continuity and clarity of alternative screening and selection. The phases of the process and how they have been presented to satisfy the needs of NFS are summarized below:

2.7.1 Scoping

Scoping is the initial planning phase of the investigation/characterization process. Many of the planning steps are continued and refined in the later phases of investigation/characterization. This step involves 1) collection and analysis of existing data; 2) identification of the initial project (i.e., NFS - SWMU 20/Maintenance Shop); 3) identification of potential RAOs; 4) initial identification of federal and state applicable regulations; 5) identification of the initial data quality objectives (DQOs); and 6) preparation of project plans.

2.7.2 Remedial Investigation

Two concepts are essential to the phased remedial investigation (RI) approach: site characterization and treatability investigations. Site characterization involves: 1) performance of (additional) field investigation; 2) definition of the nature and extent of impacted areas (waste types, concentrations, and distributions); 3) identification of federal/state action-, chemical-, and location-specific applicable regulations; and 4) the performance of a baseline risk assessment. Treatability investigations involve the performance of bench- or pilot-scale treatability tests as necessary. No treatability investigations have been performed at the Site. However, natural attenuation parameters were analyzed in the field and laboratory to evaluate natural degradation of the COPCs (Table 2-2).

2.7.3 Alternatives Analysis

The alternatives analysis portion of the process involves the identification and screening of potential remedial technologies, identification of the media to which they would be applied, and selection of RPOs. The specific items addressed in this RAA include the following:

- identification of RAOs, methods, and rationale;
- identification and screening of technologies and process options based on effectiveness, technical implementability, and cost;
- determination of chemical constituents and media of concern;
- evaluation of applicable regulations;
- estimation of areas and volume of impacted media based on available analytical data;
- identification of GRAs;
- assembly of RPOs into site-wide alternatives;
- presentation of an appropriate range for development of alternatives;
- evaluation of individual alternatives against guidance criteria;
- comparisons of the alternatives against each other;

- presentation of the preferred alternative for the Site; and
- preparation of detailed cost estimates.

Following this RAA, a Preliminary Design Report will be prepared to 1) provide a brief summary description of the remedial alternatives evaluated in the detailed analysis, 2) identify and provide a discussion of the rationale that supports the preferred alternative(s), 3) a detailed description of the selected technology; 4) general construction parameters; and 5) a preliminary cost and schedule.

3.0 Remedial Action Objectives

This RAA presents RAOs and the approach used to screen the remedial technologies and associated process options, including determination of the COPCs, regulations, and PRGs that affect the remediation of impacted areas.

3.1 Regulatory Requirements

The RAA is being conducted under voluntary action of NFS and is not mandated by a state or federal regulatory program. However, for completeness, regulatory requirements are evaluated in the development of RAOs. Applicable requirements include clean-up standards, standards of control (technology- or activity-based), and other environmental protection criteria promulgated under federal or state law that specifically address constituent(s), remedial action, location, or other circumstances at the Site. Applicable regulations can be any promulgated standard, requirement, criterion, or limitation under federal and state environmental laws and regulations. Applicable regulations may be chemical-, location-, or action-specific. Primary consideration is given to remedial alternatives for the Site that are consistent with these requirements.

Chemical-specific regulations are usually health- or risk-based numerical values or methodologies that establish concentration or discharge limits for particular chemical constituents. Location-specific regulations may restrict activities within specific locations such as floodplains or historical areas. No location-specific regulations were identified to be applicable or relevant and appropriate to the Site. Action-specific requirements may set controls or restrictions for particular treatment and disposal activities related to the management of wastes. The lists of potential federal and State of Tennessee regulations used to develop GRAs are presented in Table 3-1. These are regulations that potentially regulate the release of chemical constituents to on-site and off-site air, surface water, groundwater, and land. These regulations may also restrict the implementation of some GRAs.

3.2 Determination of Preliminary Remediation Goals

The Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997) presents initial remedial goal objectives for groundwater at the Site (Table 2-4). PRGs are concentrations of COPCs that may remain at the area and still be adequately protective of human health, welfare, and the environment. The PRGs are developed and used for estimating volumes of impacted media before establishing remedial action goals (i.e., clean-up levels) and also help to ensure that 1) proposed analytical methods will have adequate quantitation limits, and 2) the remedial alternatives can achieve the target clean-up levels identified in the RAA (Section 7.0).

Following the CERCLA process, PRGs are determined by chemical-specific regulations and risk-based calculations (RBCs). Groundwater chemical-specific regulations are non-zero Maximum Contaminant Level Goals (MCLGs) and Maximum Contaminant Levels (MCLs). Paragraphs (e)(2)(i)(B) and (C) of 40 CFR 300.430 require the use of non-zero MCLGs and MCLs for groundwater remedial actions. MCLs are the maximum permissible levels of constituents in water delivered to any user of a public water system. MCLGs are non-enforceable concentrations of drinking-water contaminants that are protective of adverse human health effects and allow an adequate margin of safety. MCLG and MCL values are published in 40 CFR 141.11 (Drinking Water Regulations and Health Advisories). Paragraphs (e)(2)(i)(A)(1) and (2) of 40 CFR 300.430 require the use of RBCs for systemic toxicants and for known or suspected carcinogens. RBCs were performed in accordance with RAGS (U.S. Environmental Protection Agency 1991) in the Groundwater Risk Assessment (Nuclear Fuel Services, Inc. 1997).

MCLs and MCLGs are promulgated under the Safe Drinking Water Act (SDWA) and are revised periodically and published in USEPA's Drinking Water Regulations and Health Advisories (U.S. Environmental Protection Agency 1996a). RBCs are based on USEPA risk assessment guidance (U.S. Environmental Protection Agency 1991).

PRG values for groundwater will be determined by one of three methods: promulgated non-zero MCLGs, MCLs, or site-specific RBCs. Background concentrations are considered to be zero for the organic COPCs, and therefore, are not considered in the determination of PRGs. Non-zero MCLGs established under the SDWA are used as groundwater PRGs, if available. If a constituent does not have a non-zero MCLG, then a MCL is used to determine PRGs, if available. Non-zero MCLGs and MCLs are considered "relevant and appropriate" to the groundwater PRGs even if less than 25 persons are using the shallow aquifer as a drinking-water source.

No secondary MCLs are used for PRG comparisons because COPCs at secondary MCL levels are of aesthetic concern and are not expected to adversely impact environmental quality or the public welfare and safety. The COPCs at these levels do not make groundwater unfit for use nor present objectionable characteristics since the affected groundwater is not currently used for drinking-water purposes.

If a non-zero MCLG or MCL is not available, a PRG is determined using RBCs that are protective of human health and the environment, if the risk information is available. Calculated RBCs are based on experimentally determined risk factors, exposure pathways, and realistic exposure scenarios. In summary, PRG values are determined for each chemical according to the following hierarchy:

1. non-zero MCLG promulgated under the SDWA;
2. MCL;
3. carcinogenic or noncarcinogenic RBC, whichever is less; and
4. if a RBC cannot be made due to nonavailability of chemical-specific risk data, and there is no non-zero MCLG or MCL, then no value is assigned as a PRG.

A PRG will be proposed for all COPCs that have a chemical-specific regulation or risk-based information. If no risk-based information is available, then a toxicity equivalent factor will be used to determine an RBC, if possible. If no chemical-specific regulation exists or no RBC can be calculated, then no PRG will be determined. If no PRG is proposed for a COPC, then it is not used to define the areas requiring remediation. Most likely, other COPCs that have PRGs are located in the same area that will define the remedial requirements.

3.2.1 Chemical-Specific Regulations

Table 3-1 summarizes potential regulations, some of which may not apply during remediation. Key regulations for the Site, however, include: 1) SDWA MCLs/MCLGs; and (2) Tennessee MCLs.

Federal and Tennessee MCLs. SDWA MCLs/MCLGs and Tennessee MCLs are considered "relevant and appropriate" because the aquifer may be considered to be a potential source of drinking water. Also, the Tennessee Superfund Rules for defining remediation goals require evaluation of specific criteria for domestic water supply (i.e., MCLs, as promulgated by the Water Quality Control Board). The SDWA MCLs/MCLGs and Tennessee MCLs provide numerical standards for a wide range of organic and inorganic constituents, and may be considered for actual or potential sources of drinking water.

3.2.2 Groundwater Risk-Based Concentrations

In determining the risk-based goals, consideration is given to the projected future uses of the land. The SWMU 20/Maintenance Shop Site is presently a non-residential area, will not be used for agricultural purposes, and is expected to continue to serve as a non-residential area in the foreseeable future. Risk estimates for all current pathways at the Site were within USEPA regulatory guidelines. Therefore, only risks for a on-site construction worker and a future hypothetical off-site construction worker and/or recreational users exposed to groundwater are evaluated. Calculated lifetime cancer and HI values for the Site are presented in Table 2-4.

3.2.3 Background Concentrations

Background concentrations are representative of natural constituent concentrations in groundwater. Background concentrations are used as a baseline to determine if detections are elevated above natural levels. Background values would be used as the PRG if a chemical-specific regulation or the RBC is less than the background concentration. Organic constituent background levels are assumed to be zero since the organic constituents on the COPC list (Table 2-4) do not occur naturally in the environment.

3.2.4 Comparison of SWMU 20/Maintenance Shop Data to Preliminary Remediation Goals

SWMU 20/Maintenance Shop PRGs are presented in Table 3-2. SWMU 20/Maintenance Shop site data (maximum detection) for groundwater samples are compared to the PRGs (Table 3-3) to determine the magnitude and extent of remediation required, and which COPCs exceed those PRGs so that applicable technologies can be effectively evaluated for the Site. COPCs in the SWMU 20/Maintenance Shop Site groundwater that exceed PRGs are PCE, TCE, 1,2-DCE (*cis*- and *trans*-), VC, TBP, and uranium (Table 3-3).

3.3 Development of Remedial Action Objectives

RAOs have been identified to develop media-specific goals for protecting human health, welfare, and the environment. An RAO includes the medium of concern, the COPCs, the overall remediation goal, the pathway, and the receptor. Three RAOs have been developed for the SWMU 20/Maintenance Shop Site.

3.3.1 Objective 1

To protect current and future on- and off-site construction workers and off-site recreational user from carcinogenic and noncarcinogenic risks associated with the accidental ingestion of, inhalation of, and dermal contact with impacted groundwater. In accordance with accepted USEPA guidelines, an excess cancer risk of 10^{-6} (1 in 10,000 chance of occurrence of cancer cases) is selected as the appropriate risk standard for carcinogenic risks, and a HI of 1.0 is selected as the appropriate risk standard for noncarcinogenic risks.

3.3.2 Objective 2

To protect human health and the environment by preventing or minimizing further migration of COPCs in groundwater beyond the NFS property boundary.

3.3.3 Objective 3

To comply with federal and state applicable regulations (see Section 3.1). Based on these RAOs, chemical- and site-specific remediation goals are determined which specify allowable residual concentrations of constituents in specific media. Remedial action goals will be established in conjunction with the NFS and appropriate regulatory agencies, if required.

4.0 General Response Actions

4.1 Area and Volume of Impacted Media

Groundwater is the only medium at the Site which exhibits characteristics which require remedial action. Soil at the SWMU 20/Maintenance Shop Site is not believed to contain COPC concentrations and/or exposure conditions requiring active remediation. In this RAA, the alluvial aquifer unit and the bedrock unit groundwater are considered one media at the Site, and the parameters describing this media are quantified for use throughout the RAA. The quantities provided herein do not necessarily represent actual quantities which may be remediated during the remedial action phase of the project. The quantities provided reflect reasonably accurate and conservative estimates and are provided for comparing different remedial alternatives on an equal basis and may be further refined in this RAA Report. Based on available data, the estimated study area is 1.6 acres (chlorinated hydrocarbons) and 0.5 acres (uranium). Assuming an average saturated thickness of impact of 50 ft and an average porosity of 0.25 percent, the estimated volume of impacted media is approximately 3.3M gallons (chlorinated hydrocarbons) and 1.1M gallons (uranium).

4.2 General Response Actions

GRAs are defined as generic, environmental medium-specific remediation measures that satisfy the RAOs developed for the Site. The GRAs were developed for the Site to address groundwater that currently exceed PRGs. The constituents identified that exceed PRGs are PCE, TCE, 1,2-DCE (*cis*- and *trans*-), VC, TBP, and uranium. Therefore, GRAs will focus on the remediation of organic and radionuclide constituents and some of the technologies and process options may be viable for both types of constituents.

The following are GRAs that will be considered for groundwater remediation at the SWMU 20/Maintenance Shop Site:

- "No Action";
- Minimal Action;
- Containment;
- In-Situ Treatment;
- Ex-Situ Treatment; and
- Disposal.

These GRAs are briefly discussed below.

4.2.1 No Action

The "No Action" GRA consists of no additional action and discontinuation of monitoring at the SWMU 20/Maintenance Shop Site. Based on existing information available for the Site, the "No Action" GRA will not be the recommended alternative for the SWMU 20/Maintenance Shop Site. However, "No Action" is required by the National Contingency Plan (NCP) and is considered to serve as a baseline consideration.

4.2.2 Minimal Action

Minimal action involves institutional controls such as access restrictions, groundwater restrictions, fencing, and groundwater monitoring (of natural attenuation). Institutional controls are those activities designed to minimize potential risks to human health by prohibiting or controlling access to constituents, such as through deed restrictions and policies. Groundwater restrictions would be applied to the development and domestic use of groundwater on properties within potentially-impacted areas. Fencing would assist in the implementation of such restrictions. Groundwater monitoring is not a separate response objective, but is necessary to verify that one or more of the remedial objectives has been or will likely be attained. Monitoring would be included to 1) assess the quality of groundwater beneath the Site for detection of any COPC movement, increase/decrease of COPC concentrations, and attenuating parameters in groundwater, and 2) for the monitoring of the integrity of fencing, as required.

4.2.3 Containment

Containment is used to control access to, and hydraulic migration of, COPCs present in groundwater. Containment using vertical barriers, such as slurry walls, a conventional pumping system, vacuum-enhanced recovery (VER), permeable reaction walls, or a combination, can be used to minimize potential contact risks and downgradient migration of COPCs. The on-site areal extent of the impacted groundwater is approximately 1.6 acres (PCE) and 0.5 acre (uranium) would require containment to downgradient areas. The length required for a containment system perpendicular to groundwater flow is approximately 300 ft, and vertical containment depths ranging from 10 ft in the alluvial unit to 60 ft in the bedrock unit.

4.2.4 In-Situ Treatment

In-situ treatment is the treatment of impacted groundwater "in place." In-situ treatment allows groundwater to be treated in place, either chemically or biologically, with minimal disturbance. Chemical treatment processes include permeable reactive walls, volatilization (air sparging), in-well air stripping, mobile enhanced multiphase extraction (MEME), and oxidation. Biological processes include permeable reactive walls, phytoremediation, reductive precipitation, and enhanced bioremediation. Permeable reaction walls may also be utilized as a containment GRA. The estimated in-situ treatment volume of impacted on-site groundwater is approximately 4M gallons.

4.2.5 Ex-Situ Treatment

Ex-situ treatment consists of treating any recovered groundwater onsite or offsite to an appropriate level for disposal using recovery processes such as traditional groundwater recovery, vacuum-enhanced groundwater recovery, and ex-situ treatment processes such as chemical reduction/oxidation, liquid-phase adsorption, air stripping, chemical precipitation, and biological treatment. After treatment, the residual would be disposed of as a waste and the treated groundwater discharged (Section 4.2.6). Certain ex-situ treatment technologies may transfer COPCs from the dissolved-phase to air-phase, thus requiring further treatment through biological, adsorptive, and/or thermal emission treatment technologies. The estimated treatment to achieve PRGs would involve removing and treating approximately 12M gallons (three pore volumes) disregarding natural attenuation.

4.2.6 Disposal

Disposal consists of discharging treated groundwater to an on-site reinjection system, on-site groundwater treatment facility (GWTF), or direct-spray irrigation. Off-site disposal options include discharge to a stream or the publicly-owned treatment plant (POTW). The estimated volume of impacted material which may require disposal for ex-situ treatment technologies is approximately 12M gallons (three pore volumes) disregarding natural attenuation.

5.0 Identification and Screening of Technologies and Process Options

5.1 Introduction

The screening of remedial technologies is performed in two steps, a preliminary screening step and a more detailed screening step. First, potentially applicable technology types and process options are reduced by evaluating the process options with respect to technical practicability. The technology type and its various process options are examined with respect to their technical practicability at the Site based on physical/chemical characteristics of the COPCs and site-specific conditions. Those technologies and process options that are not practicable are eliminated from further evaluation.

In the second screening step, the technologies and process options remaining after the preliminary screening for technical practicability are then evaluated further for 1) effectiveness, 2) implementability, and 3) cost. Among process options retained after the screening, one process option is chosen to represent a technology type, so that fewer alternatives can be developed for detailed analysis, without losing flexibility. In some cases, more than one process option may be selected for a technology type where process options are sufficiently different in their performance. The second screening step criteria are described below.

The effectiveness evaluation focuses on: 1) the potential effectiveness of process options in handling the estimated areas or volumes (small or large) of media and meeting the remediation goals identified in the RAOs; 2) the potential impacts to human health and the environment during the construction and implementation phase; and 3) how proven and reliable the process is with respect to COPCs and site conditions.

The implementability evaluation encompasses both the technical and administrative feasibility of implementing a process option, such as the ability to obtain permits; availability of treatment, storage, and disposal (TSD) services; and the availability of necessary equipment and resources.

The cost evaluation plays a key role in the screening of process options. Relative capital and operation and maintenance (O&M) costs within a remedial technology type are used rather than detailed estimates. The cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type.

5.2 Preliminary Screening

In this section, potential remedial technologies and process options are identified using USEPA's Updated and Expanded Version of Remediation Technologies Screening Matrix and Reference Guide (U.S. Environmental Protection Agency 1995a); USEPA's Evaluation of Technologies for In-Situ Cleanup of DNAPL Contaminated Sites (U.S. Environmental Protection Agency 1994); Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites (U.S. Environmental Protection Agency 1996b), and other innovative technologies, and screened according to their overall applicability (technical practicability) to the media, COPCs, and current conditions at the SWMU 20/Maintenance Shop Site.

A brief description and summary of the preliminary screening of technologies and process options are presented in Table 5-1. The technologies and process options that passed this preliminary screening and a summary process flow diagram for the technology and process options screening are presented in Figure 5-1.

5.3 Secondary Screening

The purpose of the secondary screening step is to evaluate the technologies and process options remaining after the preliminary screening described in Section 5.2. The secondary screening is based on effectiveness, implementability, and cost and will determine RPOs to be used in the development of alternatives for groundwater remediation at the Site.

5.3.1 No Action

The "No Action" alternative is used as a baseline for comparison to evaluate the potential impacts associated with not implementing any remedial action. It is a required alternative under the NCP. "No Action" is defined as the absence of existing or future active steps to remediate the affected media. There are no process options associated with "No Action." The "No Action" alternative will be retained as a stand-alone remedial technology for future evaluation and will be carried forward in the RAA process for further use in formulating remedial measures for the Site.

The "No Action" technology would not be effective in preventing future risk and monitoring COPC concentrations and potential movement. "No Action" would be readily implementable. Permits would not be required. The availability of TSD services and equipment and resources would not be applicable to this option. There are no costs associated with "No Action." Although easily implementable, "No Action" would not be effective to achieve RAOs for the Site. However, it is retained as a baseline consideration.

5.3.2 Minimal Action

Institutional controls are used to limit the exposure to hazardous substances by limiting human activities at or near facilities where hazardous substances will remain onsite. They include, but are not limited to, land and water access/use restrictions; well drilling prohibitions; and deed notices. In NCP preamble at 55 Federal Register (FR) 8706 (Federal Register 1990), USEPA states that "Institutional controls are a necessary supplement when some waste is left in place, as it is in most response actions", Id. Institutional controls will be considered in this RAA as a supplement to active remediation. As a remedial technology for groundwater, institutional controls may include restrictive covenants and easements, deed notices, NFS industrial requirements, physical access restrictions (fencing), and groundwater monitoring (of natural attenuation).

5.3.2.1 Deed Restrictions

If not previously implemented by NFS, deed restrictions would involve establishing a conservation easement and restrictive covenant involving annotating the deed for the subject property to limit future activities that could expose humans to waste or affected media. Deed restrictions would prevent human exposure by restricting the future use of the property. They are a proven, reliable, and established method of institutional control. No maintenance is required and no health risks are associated with implementation of this action. Costs associated with deed restrictions would include filing and legal fees and are anticipated to be in the low range. There may be low O&M costs associated with this process option. Deed restrictions are applicable for implementation at the Site and are retained for further consideration.

5.3.2.2 Fencing

Access restrictions (i.e., fencing) can be effective in preventing human exposure to affected areas, thereby limiting the potential for direct contact with hazardous substances. Existing fencing and NFS security currently limit human and vehicular access to the Site. The site perimeter is fenced to restrict access to plant activities and the areas of concern.

Fencing is typically easily installed (if required) and generally requires minimal maintenance. Health and safety risks associated with implementation of this remedial technology are minimal. Costs associated with installation (if required) of fencing are expected to be in the low range with O&M costs also in the low range. Fencing is a potentially applicable and effective process option for the Site and is retained for further consideration.

5.3.2.3 Monitoring

Monitoring consists of sampling and laboratory analyses of groundwater to 1) confirm groundwater quality at the Site, and 2) determine the effectiveness of any active remedial alternatives (e.g., natural attenuation). Currently, NFS performs monthly and quarterly monitoring of select monitoring wells within the SWMU 20/Maintenance Shop Site area. Costs associated with groundwater monitoring would include sampling labor, laboratory fees, and data validation/ reporting and are expected to be in the low to moderate range. Groundwater monitoring is applicable for implementation (i.e., wells currently exist at the Site) and is retained for further consideration.

5.3.3 Containment

Containment of the groundwater at the Site is a potentially applicable remedial response. Containment refers to the isolation of impacted groundwater through engineering controls thus reducing the potential exposure of waste to humans and the environment. The remaining hydrodynamic containment remedial technologies after preliminary screening are traditional groundwater extraction (pump and treat) and VER.

Traditional groundwater extraction or an applied vacuum (VER) use a vertical well/pump system and are proven and effective processes for increasing groundwater yield in low permeability aquifers such as the Site. The flexibility inherent in VER allows application to a wide variety of site conditions and in combination with other technologies (e.g., treatment). VER will have the general ability and technical reliability to meet the RAOs.

VER technical implementability at the Site is dependent on access and hydrogeology. Select existing wells may be modified to apply the VER process option. The site RAOs make long-term O&M requirements critical to implementability of the process option. Proper O&M is especially important because breakdown may result in loss of containment. The capital cost of a traditional extraction or VER systems is moderate and O&M costs are moderate, however, treatment of the extracted water and vapors from VER may increase cost. Traditional groundwater extraction and VER is retained for further consideration.

5.3.4 In-Situ Treatment

In-situ technologies including phytoremediation, air sparging, vertical circulation systems, permeable reaction walls, enhanced aerobic bioremediation, and MEME were eliminated from further evaluation during the preliminary screening because of technical practicability. Biological (enhanced anaerobic) and physical (reductive precipitation, and oxidation) treatment processes are the technologies passing the preliminary screening for consideration of in-situ treatment of site groundwater.

5.3.4.1 Enhanced Anaerobic Bioremediation

Anaerobic biodegradation is similar to aerobic biodegradation in that sufficient nutrients and an organic carbon source [i.e., native organic carbon or anthropogenic carbon (benzene, toluene, ethylbenzene, and xylenes {BTEX})] are required. Additionally, a method to deplete oxygen in the subsurface is necessary to maintain anaerobic conditions. Groundwater monitoring data indicate anaerobic conditions are present in the site groundwater in the area of concern. However, because the chlorinated constituents are used as electron acceptors during reductive dechlorination, a supplemental source of carbon for microbial growth will be required. Anaerobic biodegradation is effective in decreasing high chlorine chain constituents (i.e., PCE) and TBP, but enhancement by addition of a carbon source is necessary. Enhancement of anaerobic bioremediation by the addition of an organic carbon source is warranted and feasible, and is therefore retained for further consideration.

5.3.4.2 Reductive Precipitation

Radionuclides can be present in the environment in several valence forms. Hexavalent uranium (U^{6+}) can be reduced to the less mobile U^{4+}. Uranium dissolved in groundwater, can be remediated in-situ by manipulating the groundwater chemistry toward more reducing conditions, which induces precipitation. These reducing conditions provide the geochemical environment necessary for dissolved uranium in the groundwater to form an insoluble precipitate immobilized in the aquifer matrix. Based on demonstrated effectiveness on uranium (Gu, et al. 1998) (Jacobs 1999), reductive precipitation is retained for further consideration.

5.3.4.3 Oxidation

In-situ chemical oxidation is based on the introduction of an oxidant, such as hydrogen peroxide (H_2O_2), into the subsurface. The resulting hydroxyl radicals (OH^-), strong chemical oxidizers, can create an environment which oxidizes chlorinated and petroleum hydrocarbons. The reaction is a nearly instantaneous oxidation of these compounds upon contact with hydroxyl radicals thus reducing the source term and overall remedial time.

The oxidant can be blended with metal salts to assist in the in-situ precipitation of metals and radionuclides as oxides and/or hydroxides depending on the biogeochemistry of the aquifer. The ultimate breakdown products of this reaction are water, oxygen, and precipitate iron. Based on demonstrated effectiveness on chlorinated and metal constituents, oxidation is retained for further consideration.

5.3.5 Ex-Situ Treatment

Ex-situ biological treatment was eliminated from evaluation during the preliminary screening because of technical practicability. Physical/chemical treatments, such as chemical precipitation, air stripping, liquid-phase adsorption, and chemical reduction/oxidation will be considered for ex-situ treatment of groundwater. Ex-situ groundwater treatments assume that groundwater will be extracted using the VER process at an estimated flow rate of 2 gallons per minute (gpm) per well.

5.3.5.1 Chemical Precipitation

Chemical precipitation chemically converts dissolved metal and/or other inorganic ions in groundwater into an insoluble form, or precipitate. Ions generally precipitate out as hydroxides, sulfides, or carbonates and are removed as solids through clarification and filtration. Chemical precipitation is performed using oxidizing and reducing agents, as well as pH adjustment and solids (sludge) removal steps.

Chemical precipitation would be implementable at the Site. Capital costs for implementation of ex-situ chemical precipitation are high and O&M costs would be high due to the large amounts of sludge that may be produced and will require disposal. Based on demonstrated effectiveness in treating recovered uranium in groundwater within the NFS wastewater treatment facility, chemical precipitation is retained for further consideration.

5.3.5.2 Air Stripping

Air stripping is a proven, reliable technology that would be effective in removing the primary VOCs and TBP from groundwater at the Site. Removal efficiencies of COPCs greater than 99 percent could be achieved. Since air stripping only removes the COPCs from the aqueous to vapor phase, the off-gas may have to be subsequently treated by other means such as air-phase adsorption or thermal oxidation. Granular activated carbon (GAC) adsorption has limited effectiveness in removing VC from high flow air streams and expected site concentrations, therefore, thermal oxidation would be the most effective off-gas treatment for air stripping. With chlorinated hydrocarbons also being released in the stripping process and exposed to thermal treatment, hydrochloric acids would be released as a byproduct. Therefore, an emissions scrubber would be required.

Air stripping would be implementable at the Site provided that the groundwater recovery could provide a sustainable flow rate amenable to low profile diffusers or tray strippers. Low flow and clogging from iron, suspended solids, and calcium carbonate may warrant the need for pretreatment and batch operation modes. Capital costs for implementation of ex-situ air stripping are high and O&M costs would be high due to the large amounts of energy required to run the off-gas treatment. Although moderate flow rates are expected and air stripping is non-effective for uranium, air stripping is retained for further consideration for treatment of VOCs.

5.3.5.3 Liquid-Phase Adsorption

Activated carbon adsorption is a well-proven, reliable technology that would be effective in removing COPCs from recovered groundwater at the Site. Activated carbon only concentrates the COPCs; thus the spent GAC would have to subsequently disposed of in a hazardous waste landfill or regenerated at a Resource Conservation and Recovery Act (RCRA) permitted facility. GAC also has a low adsorption capacity for VC.

GAC adsorption would be readily implementable at the Site and would not be dependent on a sustainable flow rate from the VER process. Low flow and clogging from iron, suspended solids, and calcium carbonate may warrant the need for pretreatment and possible batch operation modes. Space requirements are small; start-up and shut-down are rapid. Capital costs for implementation of ex-situ liquid-phase adsorption are moderate and O&M costs would be moderate to high depending on carbon life and regeneration/disposal. Due to the ability to handle the anticipated flow rate and low cost, liquid-phase adsorption is retained for further consideration.

5.3.5.4 Chemical Reduction/Oxidation

Oxidation involves the use of air or highly reactive chemicals such as ozone, permanganate, H_2O_2, chlorine dioxide, or chlorine to convert undesirable chemical species by the addition of oxygen or the removal of electrons. Ozone and H_2O_2 alone may be less effective in the complete oxidation of COPCs at the Site. Therefore, enhancement through ultraviolet (UV) light which induces photochemical oxidation of the COPCs is considered here. The combination of UV light with H_2O_2 (or ozone) treatment results in the oxidation of COPCs at a rate many times faster than obtained from applying UV light or H_2O_2 or ozone alone. Pretreatment of influent groundwater may be required to reduce suspended solids and iron. With oxidation/UV treatment, no toxic VOCs are emitted to the atmosphere or adsorbed onto media that require further treatment or disposal.

Capital costs are high and O&M costs are moderate to high because UV/oxidation systems have large power requirements. Although very effective, UV/oxidation is eliminated from further consideration because of anticipated moderate flow rate, high capital and O&M costs, and non-effectiveness for uranium treatment.

5.3.6 Disposal

Based on preliminary screening, disposal technologies for extracted, treated, or partially treated groundwater can be best achieved using on-site discharge to the GWTF or discharge to the local POTW.

The on-site GWTF is designed to treat the majority of the industrial wastewater generated from plant operations at the Site. The existing treatment train for the on-site GWTF includes air stripping, chemical precipitation, and liquid-phase adsorption. The on-site GWTF would be effective in removing dissolved COPCs from recovered, treated, or partially-treated groundwater under these treatment processes. Disposal to the on-site GWTF could be easily implemented as it is located within 200 ft of the area of concern and is currently below design capacity for hydraulic and constituent loading. Capital costs are low and O&M costs are low because the on-site GWTF is presently operating and maintained. However, based on the limited capacity remaining at the NFS GWTF, disposal of recovered groundwater to the on-site GWTF is eliminated for further consideration.

Groundwater recovered and properly treated may be discharged to the City of Erwin POTW. Disposal to the POTW could be easily implemented as it is located within 200 ft of the area of concern and is currently able to accept hydraulic loading. Capital costs are low and O&M costs are low because the POTW is available and maintained. Therefore, disposal of recovered groundwater to the local POTW is retained for further consideration.

5.4 Screening Summary

Figure 5-1 presents the logic diagram for development of the RPOs and a summary of the secondary screening and the technologies and process options that have been retained for the remediation of impacted groundwater. These technologies and process options will be assembled into various remediation alternatives and evaluated further during the development and detailed analysis of alternatives.

6.0 Development and Screening of Alternatives

The Guidance for Conducting Remedial Investigations/Feasibility Studies under CERCLA (U.S. Environmental Protection Agency 1988) identifies six steps to develop alternatives that were used in this RAA. The six steps as specified by USEPA are as follows:

1) Develop RAOs specifying the chemicals and media of interest, exposure pathways, and PRGs that permit a range of treatment and containment alternatives to be developed. The PRGs are developed on the basis of chemical-specific regulations, when available, and site-specific risk-related factors.

2) Develop GRAs for each medium of interest defining containment, treatment, recovery, or other actions, singly or in combination, that may be taken to satisfy the RAOs for the Site.

3) Identify volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the RAOs and the chemical and physical characterization of the Site.

4) Identify and screen the technologies applicable to each GRA to eliminate those that cannot be implemented technically at the Site. The GRAs are further defined to specify remedial technology types (e.g., the GRA of treatment can be further defined to include chemical or biological technology types).

5) Identify and evaluate technology process options to select an RPO for each technology type retained for consideration. Although specific processes are selected for alternative development and evaluation, these processes are intended to represent the broader range of process options within a general technology type.

6) Assemble the selected RPOs into alternatives representing a range of treatment and containment combinations, as appropriate.

6.1 Representative Process Options for the Site

One RPO will be selected for each technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design (Section 6.0, Step 5). Although specific process options are selected for alternative development and evaluation, they are intended to represent the broader range of process options within a general technology type. The RPO provides a basis for developing performance specifications during preliminary design. However, the specific process option used to implement the remedial action at a site may be modified during the remedial design until the final design has been completed.

Innovative technologies are selected as RPOs only if effectiveness is proven. Treatability studies, which demonstrate whether or not innovative technologies are effective, may be used as the basis for retaining innovative technologies as RPOs. The retention of innovative technologies to the maximum extent possible also satisfies the USEPA's guidance to evaluate innovative technologies.

All process options were initially screened for effectiveness, implementability, and cost in Section 5.0, and remaining process options were retained for further consideration and for alternative formation. Table 6-1 presents the RPOs and the corresponding technology types. The SWMU-20 Site remedial alternatives are formulated from these RPOs.

6.2 Alternative Range Development

The alternative development process consists of the six steps described in Section 6.0. Step 6 assembles the selected RPOs into alternatives representing a range of treatment and containment combinations, as appropriate. The purpose of providing a range of alternatives is to ensure that all reasonable GRAs are represented and evaluated.

Alternatives are developed by combining different RPOs to address the problems at the Site. A range of alternatives is developed encompassing all probable actions from a baseline "No Action" alternative to a maximum practical response. The range of alternatives is not necessarily listed in order of increased protection of human health, welfare, and the environment. At least one alternative will be developed for each alternative type and may be compared with the evaluation criteria unless threshold criteria are not met during screening of alternatives. The range of alternatives developed for groundwater remediation at the Site is presented in Table 6-2.

The first alternative type is "No Action." The "No Action" alternative is used as the lowest level of remedial action and is used to provide a baseline in comparing alternatives.

The second alternative type is Containment/Limited Action. The Containment/Limited Action alternatives usually provide source containment, which restricts the exposure pathways to receptors. This alternative type provides little or no intervening active treatment but protects human health, welfare, and the environment by preventing potential exposure to and/or reducing the mobility of constituents through active recovery, containment, and/or natural attenuation. For organic constituents, natural processes eventually degrade the constituents over time. Metal constituents are demobilized and concentrations are reduced by dilution and adsorption through natural attenuation processes.

The third alternative type is Treatment which addresses the principal threats to human health, welfare, and the environment. Several different alternatives may be formed which fall into the third alternative type. For remedial responses, the time frame for the third alternative type is usually moderate. Response actions are usually provided upgradient of the points of exposure to collect and treat COPCs.

The fourth alternative type is Treatment/Disposal that Eliminates or Minimizes Long-Term Management. This alternative type is the upper bound of the alternative range and relies on an aggressive treatment approach. Harmful constituents are irreversibly treated to less harmful forms, and/or removed from the Site. For remedial responses, the time frame for the fourth alternative type is usually short relative to other alternative types. Often, a combination of various aggressive treatment systems is employed to reduce or eliminate any harmful constituents in a timely manner.

6.3 Assembly of Alternatives

Alternatives are developed to provide an appropriate range of options for the Site. Sufficient information is included to adequately evaluate and compare alternatives against each other and to determine which alternative is the most appropriate. Alternatives are developed around the expectations summarized as follows:

- Engineering controls will be used for COPCs that poses a relatively low long-term threat and where treatment is impracticable.
- Principal threats (i.e., highly mobile or highly toxic COPCs) will be treated, if practicable.
- A combination of engineering controls and treatment will be used as appropriate to achieve protection of human health and the environment. An example would include treatment of "hot spots" in conjunction with containment of the remaining impacted groundwater.
- Administrative controls, such as access restrictions, will be used to supplement engineering controls, as appropriate, to prevent exposure to COPCs.
- Innovative technologies will be considered when such technologies offer the potential for superior treatment performance or lower costs for performance similar to that of other technologies.

In developing groundwater alternatives, the range of options accounts for various site conditions. A combination of RPOs is used to address not only clean-up levels but also the time frame within which the remedial objectives will be achieved.

Alternatives are developed that achieve applicable regulations and other protective health-based levels within varying time frames using different methodologies.

Six alternatives are assembled for the SWMU 20/Maintenance Shop Site which represent the four alternative types (Table 6-3). The first alternative, "No Action", is carried forward because the NCP requires consideration of the "No Action" alternative. The "No Action" alternative is also used as a basis for comparison with other alternatives.

Alternative 2 is a containment/limited action alternative. Deed restrictions and fencing are used to restrict access and future land use and physically control access, respectively. Monitoring is used to detect COPC concentrations that exceed PRGs at the point of compliance and provide information on natural attenuation conditions and remediation (natural attenuation) progress. Monitoring may also be used to assess the integrity of the fencing and/or industrial requirements/security.

Alternative 3 is also assembled to address the principal threats through deed restrictions, fencing, site monitoring, vacuum-enhanced groundwater recovery, ex-situ air-phase thermal oxidation treatment, construction of a separate ex-situ groundwater treatment system (air stripping, chemical precipitation, and liquid-phase adsorption), with final discharge to the local POTW. Long-term management may be minimized because the groundwater actions may cease upon achieving RAOs. Remedial time is limited by groundwater recovery rates and retardation of the COPCs.

Alternative 4 is assembled to eliminate or minimize long-term management through deed restrictions, fencing, site monitoring, VER, ex-situ air-phase thermal oxidation treatment, construction of a separate ex-situ groundwater treatment system (air stripping, chemical precipitation, and liquid-phase adsorption), with final discharge to the local POTW. This action will ensure COPC containment while implementing in-situ treatment via reductive precipitation or uranium and enhanced anaerobic bioremediation of PCE. Remedial time is reduced by the implementation of this aggressive action.

Alternative 5 is assembled to eliminate or minimize long-term management through deed restrictions, fencing, site monitoring, and in-situ treatment via oxidation. This alternative will minimize long-term treatment by effectively treating COPCs in place within a reduced remedial time.

Alternative 6 is assembled to eliminate or minimize long-term management through deed restrictions, fencing, site monitoring, and in-situ treatment via reductive precipitation of uranium and enhanced anaerobic bioremediation of PCE. This alternative will minimize long-term treatment by effectively treating COPCs in place within a reduced remedial time.

6.4 Screening of Alternatives

The alternatives for the Site that will undergo detailed analysis are determined by the screening of alternatives. Alternative screening is performed to remove alternatives that do not satisfy effectiveness, implementability, and cost.

The effectiveness criterion is used to evaluate each alternative in protecting human health, welfare, and the environment and achieving reduction in toxicity, mobility, or volume. Both short-term (during construction and implementation) and long-term (after completion of remediation) effectiveness are considered.

The implementability criterion involves the technical and administrative feasibility of constructing, operating, and maintaining the remedial action alternative. Technical feasibility considers the ability to construct, reliably operate, and maintain the alternative. Administrative feasibility considers the ability to obtain approval or necessary permits from regulatory agencies and the availability of equipment and disposal services.

The cost criterion is used to provide comparative estimates of relative cost of the alternatives. Relative costs are based on prior similar site cost experience, vendor estimates, and engineering judgment.

During screening, each of the assembled alternatives is evaluated to ensure that human health, welfare, and the environment are protected (effectiveness), that the alternative is implementable, and that it is not excessively expensive. An alternative is removed from further consideration if it is evaluated unfavorably by any one of the three criteria. By applying the three criteria, alternatives are screened and the number of alternatives for detailed analysis is reduced.

6.4.1 Screening Criteria

6.4.1.1 Effectiveness

PCE, TCE, 1,2-DCE (*cis-* and *trans-*), VC, TBP, and uranium are the COPCs that currently exceed PRGs at the Site. Under current on-site conditions, there are points of exposure for humans to surface water. Potable water at the NFS facility is supplied by the City of Erwin. The potential exposure pathways for a current on-site recreational users and future on- and off-site construction worker and recreational users include contact with, ingestion, and inhalation of groundwater. Therefore, to be effective, an alternative must address the potential exposure pathway of dermal, inhalation, and ingestion on and offsite, and remove, treat, and/or contain impacted groundwater. All alternatives contain institutional controls for effectively controlling potential contact with groundwater by humans. Hypothetical future exposure to groundwater from the alluvial water-bearing unit is possible, but not likely, based on the current industrial land use and anticipated future land use (Nuclear Fuel Services, Inc. 1997). All alternatives contain institutional controls to effectively minimize risk to potential receptors and eliminate risk to a hypothetical future receptor through deed restrictions.

All alternatives pose short-term risk to the community and workers during implementation except Alternatives 1 and 2. However, these risks may be reduced through engineering controls such as phased implementation and personal protection equipment (PPE). All alternatives for the Site, except Alternative 1 and Alternative 2, are believed to be effective. The "No Action" alternative and monitoring only alternative (Alternative 2) fail to meet the criteria for protection of human health, welfare, and the environment and are not acceptable for remedial action for the Site; however, Alternative 1 is retained for baseline comparison.

6.4.1.2 Implementability

Alternative 1 would be easily implementable. Alternative 2 involves extensive construction near the property boundary and within the plume area. This implementability causes concern with the existing infrastructure, but through engineering controls is retained for consideration. Alternatives 3 and 4 use the VER process to extract groundwater from the impacted groundwater zone. The majority of existing wells are 4-inch diameter and feasible for implementing VER. However, additional recovery wells may be required. Alternatives 3 and 4 would also require construction of ex-situ air-phase adsorption treatment and extensive conveyance piping for recovered and treated groundwater.

With Alternatives 3 and 4, additional ex-situ treatment equipment (i.e., liquid-phase adsorption, air stripping, and chemical precipitation) would require siting and construction. This may be difficult as the impacted zone is within an industrialized area where aboveground structures are not permitted inferences may be caused from underground utilities, but are retained for consideration. Remaining Alternatives 5 and 6 would be implementable with additional treatment wells being required. Alternative 5 may also require a small aboveground treatment system to deliver oxidizing agents on the property boundary.

6.4.1.3 Cost

Alternative 2 provides for the lowest cost of screened alternatives but was previously eliminated based on effectiveness. Alternatives 3 and 4 involve the installation of VER wells and the construction of a groundwater treatment facility. The high cost of treatment equipment, maintenance, and disposal/regeneration and the potential for counter productivity of recovery versus in-situ treatments, warrant the elimination of Alternative 4 from further consideration. Alternative 3 also involves a VER system and treatment but the cost is warranted to achieve RAOs. Remaining Alternatives 5 and 6 involve in-situ treatments at varying cost treatment but the cost is justified based on lower costs of operation to achieve RAOs.

6.4.2 SWMU 20/Maintenance Shop Alternatives for Detailed Analysis

The screening step removed Alternative 2 based on effectiveness and Alternative 4 based on cost effectiveness. The remaining alternatives after the screening step are Alternatives 1, 3, 5, and 6. Table 6-4 presents the alternatives for the Site that will be evaluated and analyzed using the evaluation criteria in Section 7.0.

7.0 Detailed Analysis of Alternatives

7.1 Introduction

The objective of the individual detailed analyses is to provide adequate information for each alternative to facilitate the selection of remedial actions for implementation at the Site. Remedial alternatives developed for the Site are assessed against the evaluation criteria during detailed analysis of alternatives. The evaluation criteria are beneficial in evaluating the remedial alternatives. Uncertainties associated with specific alternatives are included in the evaluation when changes in assumptions or unknown conditions could affect the analyses.

A two-phase approach is used in the detailed analysis with the evaluation criteria. Figure 7-1 presents a summary of the criteria for detailed analysis of alternatives. The "threshold" criteria are utilized during the initial evaluation step of an alternative. In order for an alternative to advance to the next set of criteria, it must 1) be protective of human health, welfare, and the environment and 2) comply with applicable regulations. The "balancing" criteria are used to weigh the pros and cons of alternatives against one another. These criteria consist of 1) long-term effectiveness and permanence; 2) reduction of mobility, toxicity, or volume through treatment; 3) short-term effectiveness; 4) implementability; and 5) cost. Descriptions of the evaluation criteria are provided below.

7.1.1 Threshold Criteria

7.1.1.1 Overall Protection of Human Health and the Environment

Evaluation of the overall protectiveness of an alternative focuses on whether a specific alternative provides adequate protection and describes how risks associated with the potential site-specific exposure pathways are eliminated, reduced, or controlled through treatment, engineering, and/or deed restrictions. This evaluation criterion also allows for consideration of whether an alternative poses any unacceptable short-term (during remedial activities) or cross-media impacts. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with applicable regulations.

7.1.1.2 Compliance with Applicable Regulations

This evaluation criterion is used to determine whether an alternative specific to the Site will satisfy all the federal and state applicable regulations discussed in Section 3.1 of this document including compliance with chemical-, action-, and location-specific applicable regulations. Applicable requirements are those clean-up standards, standards of control (technology or activity-based), and substantive environmental protection requirements promulgated under federal or state law that specifically address a situation encountered at the Site. Chemical-specific regulations are numerically represented by the PRGs. Action-specific regulations are represented by such regulations as the Clean Air Act (CAA) regulations. No location-specific regulations were found applicable or relevant and appropriate for the Site. The final determination of regulations and/or requirements that are relevant and appropriate will be made by NFS.

7.1.2 Balancing Criteria

7.1.2.1 Long-Term Effectiveness and Permanence

The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of post-remediation effectiveness, magnitude of residual risk, and adequacy and reliability of any remedial controls needed to manage treatment residuals or untreated COPCs (i.e., institutional controls, monitoring) after RAOs have been satisfied. This evaluation focuses on the extent and effectiveness of controls that may be required to manage risks posed by treatment residuals and/or untreated constituents. The following components of the criterion are addressed for each alternative:

- Magnitude of residual risk - assessment of the residual risk (on a pathway basis) remaining from treatment residuals and/or untreated constituents at the conclusion of remedial activities. Issues for evaluation of the residual risk include identifying the remaining sources of risk and the requirement of a 5-year review.

- Adequacy and reliability - assessment of the adequacy and reliability of remedial controls, if any, that are used to manage treatment residuals or untreated constituents remaining at the Site. Issues for evaluation are type and degree of long-term management, long-term monitoring, O&M functions, and degree of confidence.

The use of qualitative terms such as high, medium, low, certain, and uncertain are used to define how an alternative satisfies the requirements of the evaluation criteria in achieving the RAOs.

7.1.2.2 Reduction in Mobility, Toxicity, or Volume Through Treatment

This evaluation criterion addresses the preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce mobility, toxicity, and/or volume of the COPCs in groundwater as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at an area through the destruction of toxic constituents, irreversible reduction in constituent mobility, and/or reduction of the total volume of impacted media.

This evaluation focuses on the following specific factors for each alternative as summarized below:

- the treatment process employed;
- the amount of COPCs destroyed or treated;
- the degree of expected reduction in mobility, toxicity, or volume;
- the degree to which the treatment is irreversible;
- the type and quantity of treatment residuals that will remain following treatment; and
- the degree to which the alternative satisfies the statutory preference for a principal treatment element.

The use of qualitative terms such as high, medium, low, certain, and uncertain are used to define how an alternative satisfies the requirements of the evaluation criteria in achieving the RAOs.

7.1.2.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction, implementation, and operational phases of remedial action until RAOs are achieved. Under this criterion, the alternatives are evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The following factors are summarized and are addressed as appropriate for each of the remedial action alternatives:

- Protection of the community and workers during construction phases: This aspect of short-term effectiveness addresses risk and inconvenience (such as odor) that may result from implementation of the proposed remedial action. This includes worker and community threats during remedial action and the effectiveness and reliability of available worker protective measures.

- Environmental impacts: This factor addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of available mitigation measures to prevent or reduce potential impacts.

- Time: Time required to complete construction, implementation, O&M activities, and achieve remedial objectives. Estimated remedial times are based on the time required to remediate sites with similar conditions, analytical models, and professional judgment.

The use of qualitative terms such as high, medium, low, certain, and uncertain are used to define how an alternative satisfies the requirements of the evaluation criteria in achieving the RAOs.

7.1.2.4 Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of services and materials required during implementation. This criterion involves analysis of the following factors:

- Technical Feasibility
    - Ability to construct and operate the technology includes an evaluation of difficulties and uncertainties associated with the alternative.
    - Reliability of the technology focuses on the likelihood that technical problems associated with implementation could lead to schedule delays.
    - Ease of undertaking additional remedial action includes a discussion of any future remedial actions that may be required and the difficulty of implementing such additional actions. This criterion addresses the ability of the remedy to accommodate future technologies, capacities, and/or changing constituent concentrations.
    - Monitoring considerations concern the ability to monitor the effectiveness of the remedy and include the effects of exposure if monitoring is insufficient to detect a system failure.
- Administrative Feasibility
    - Ability to coordinate with other offices and agencies for construction or operating permits, necessary access to treatment facilities, etc. is assessed.
- Availability of Services and Treatment
    - Availability of TSD facilities that have the required capacity is evaluated.
    - Availability of equipment, specialists, and provisions required to perform the remediation is evaluated.
    - Availability of sources for competitive services and materials is determined.

The use of qualitative terms such as high, medium, low, certain, and uncertain are used to define how an alternative satisfies the requirements of the evaluation criteria in achieving the RAOs.

7.1.2.5 Cost

The cost criterion addresses the capital costs and annual O&M costs. Costs are estimates for the scope of the remedial action described. A present worth analysis is used to evaluate remedial alternatives that occur over several years. The life cycle cost is limited to a maximum of 30 years for all the alternatives. The estimated present worth of each remedial alternative is determined based on a combined interest and inflation rate of 10 percent and an estimate for the time required for short- and long-term maintenance/monitoring. Short-term maintenance/monitoring of alternatives includes the completion of remedial actions until PRGs are achieved. Long-term maintenance/monitoring of alternatives begins upon completion of remedial actions and achievement of PRGs. Costs are presented for comparison and evaluation purposes, and assumptions are the same for all chosen alternatives (i.e., impacted media volumes, extraction rates, and equipment/labor rates). Because uncertainties associated with the definition of alternatives often remain after the RAA, definitions of costs of alternatives is defined within a +50 percent to -30 percent accuracy.

The cost estimates are prepared from information including the Means Environmental Remediation Cost Data (Means 1999), estimates for similar ARCADIS Geraghty & Miller projects, telephone quotes provided by vendors, and information from TSD facilities personnel. A discussion of each component of the cost criterion is given below.

Capital Costs

Total capital costs are defined as those expenditures required to initiate and implement a remedial action. These are short-term costs and are exclusive of costs required to maintain the action throughout the project lifetime. These direct costs include construction costs or expenditures for equipment, labor, disposal, permits, start-up, and materials required during the remedial action installation. A single contingency (30 percent of present worth project total) is included for each alternative for any bid and scope changes. The bid contingency accounts for factors that tend to increase costs associated with constructing a given project scope, such as economic/bidding climate, contractor's uncertainty regarding liability and insurance on waste sites, adverse weather, strikes by material suppliers, and/or geotechnical unknowns. The bid contingency also covers changes during final design and implementation. Scope contingencies include provisions for inherent uncertainties like expanding the extent of monitoring needed and regulatory or policy changes that may affect the initial assumptions. The cost for engineering design (20 percent of the capital cost) is included in the capital cost. Allowances for price inflation and abnormal technical difficulties are not accounted for in the contingencies.

O&M Costs

Short-term annual O&M costs are costs associated with ongoing remediation at the Site. These costs include labor, monitoring, materials, utilities, energy, disposal, administrative support, services, rehabilitation, and site reviews that are required to operate and maintain remedial action activities. Long-term annual O&M costs include costs incurred after remediation is complete and may also include labor, monitoring, materials, administrative support, and site reviews.

7.1.3 Groundwater Flow Modeling

Groundwater flow modeling was performed to evaluate remedial alternatives that were retained after screening. As part of this effort, the groundwater flow model developed by ARCADIS Geraghty & Miller for the NFS facility (ARCADIS Geraghty & Miller, Inc. 1999) was applied to estimate the hydraulic response associated with the following three alternatives: 1) groundwater extraction and treatment; 2) oxidant injection; and 3) carbon source injection. The model was developed using the MODFLOW code, a finite-difference modeling code developed by the United States Geological Survey (USGS) (McDonald and Harbaugh 1988). The MODFLOW model developed for the NFS facility was constructed and calibrated to simulate three-dimensional groundwater flow for a 38-square mile area surrounding the NFS facility. The model consists of five layers of finite-difference cells that represent shallow alluvium; the boulder/cobble zone; weathered bedrock; and competent bedrock.

The groundwater flow model was used to estimate the number and location of extraction wells, the number and location of injection wells, groundwater extraction rates, oxidant injection rates, and carbon source injection rates. Particle tracking, using the USGS MODPATH code (Pollack 1989), was used to evaluate groundwater capture and to investigate the groundwater flow paths associated with injecting oxidant and carbon source. Particle tracking analysis is a simple, cost-effective form of contaminant transport which ignores the effects of dispersion, retardation, and chemical reactions. In effect, the particles represent the motion of groundwater in the model. The MODPATH code uses the flow terms and velocities computed by MODFLOW for use in the calculations. A limitation of particle tracking is that it does not calculate contaminant concentrations.

Several predictive simulations were performed for each of the alternatives to obtain a general understanding of the flow system and to obtain estimates of the design parameters affecting costs (i.e., pumping rates, number of wells, etc.). Figures 7-2 and 7-3 illustrate the distribution of COPCs (PCE and uranium) under the "No Action" alternative (Alternative R-1) which accounts only for natural attenuation. Figures 7-4, 7-5, and 7-6 present the extraction wells and injection points that were simulated using the model for Alternatives R-2, R-3, and R-4, respectively. The oxidant and carbon source injection rates were estimates based on the modeling analysis.

A rigorous modeling analysis focused on optimizing each of the alternatives was not deemed necessary for the purpose of evaluating the proposed alternatives, conducting a comparative analysis of the alternatives, or developing the conceptual level design; consequently, a detailed modeling analysis was not performed. A more rigorous modeling analysis focusing on contaminant fate and transport is recommended in the future to assist with the detailed design and optimization of the preferred alternative.

7.2 SWMU 20/Maintenance Shop Alternatives

The SWMU 20/Maintenance Shop Site includes all groundwater within the study area containing COPCs that exceed PRGs. The Site includes approximately 2 acres containing 4M gallons of impacted groundwater.

The four alternatives for the Site represent a range of actions including "No Action", an action that addresses principal threats, and two actions that eliminate or minimize long-term management. The four alternatives that provide a sufficient range of remediation for the Site are as follows:

Alternative R-1: "No Action";

Alternative R-2: Deed Restrictions, Fencing, Site Monitoring, VER Process, Air-Phase Thermal Oxidation, Air Stripping, Chemical Precipitation, Liquid-Phase Adsorption, and Discharge to the Local POTW;

Alternative R-3: Deed Restrictions, Fencing, Site Monitoring, and In-Situ Oxidation; and

Alternative R-4: Deed Restrictions, Fencing, Site Monitoring; In-Situ Enhanced Anaerobic Bioremediation, and In-Situ Reductive Precipitation.

7.2.1 Alternative R-1: No Action

7.2.1.1 Description

The "No Action" alternative is considered in the RAA to serve as a baseline consideration or to address areas that do not require any active remediation. "No Action" assumes that no current or future remedial action will occur and establishes a basis for comparison with the other alternatives. This alternative is included as a requirement of the NCP (40 CFR 300). No remedial action, treatment, deed restrictions, or monitoring of conditions will remain or be implemented under the "No Action" alternative. Natural attenuation of COPCs would occur under Alternative R-1, however, monitoring of effectiveness would not be performed.

7.2.1.2 Assessment

Threshold Criteria

Overall Protection of Human Health, Welfare, and the Environment

This alternative allows unacceptable risks to a current and future on-site recreational users and the environment. The "No Action" alternative does nothing to effectively prevent potential exposure to constituents nor reduce potential migration of groundwater offsite. Alternative R-1 would not block the future residential exposure scenario as it assumes the absence of deed restrictions and would allow hypothetical future residential development of the Site.

Compliance with Applicable Regulations

Since "No Action" would be taken under this alternative, no action-specific regulations are triggered. On the basis of an impractical remedial time (greater than 30 years), Alternative R-1 does not satisfy chemical-specific regulations, including the SDWA MCLs and RBCs for protecting human health, welfare, and the environment.

Balancing Criteria

Long-Term Effectiveness and Permanence

Alternative R-1 provides no long-term effectiveness or permanence for the Site. As indicated in Section 2.5, organic constituents present at the Site would pose a risk for a hypothetical on-site future resident. The magnitude and potential of residual risk within the Site are relatively unchanged by the "No Action" alternative. This alternative offers no reduction in risk except over a long period of time as the constituents potentially leach, migrate, and attenuate. Figures 7-2 and 7-3 present the predicted concentrations of PCE and uranium, respectively, under conditions of Alternative R-1 indicating greater than 30 years to attenuate and off-site migration of the uranium plume. The adequacy and reliability of controls is not applicable for Alternative R-1 because no construction, installation, equipment, or monitoring protocol are associated with the alternative. Management of the alternative is required for as long as COPC concentrations in the groundwater within the Site exceed PRGs. However, a 5-year review is required to assess the degree of remaining risk.

Reduction of Mobility, Toxicity, or Volume Through Treatment

Because Alternative R-1 involves "No Action", the mobility, toxicity, and volume of constituents at the Site will not change significantly. Under this alternative, none of the affected groundwater present at the Site would undergo further treatment or alteration beyond natural attenuation. Natural attenuation involves natural subsurface processes such as dilution, adsorption, and chemical reactions within the subsurface materials that could reduce constituent concentrations and toxicity to acceptable levels over time.

The target constituents for natural attenuation are chlorinated hydrocarbons and uranium. The processes of natural attenuation and natural biodegradation can provide irreversible treatment. However, the potential risk may actually increase due to VC production from the anaerobic degradation of chlorinated solvents and/or off-site migration of uranium.

Short-Term Effectiveness

The "No Action" alternative provides no short-term effectiveness and results in no risks. Because no construction or implementation will occur, there are no short-term risks to workers, the community, or the environment. There is no implementation time associated with the "No Action" alternative. The time required to achieve remedial objectives under the "No Action" alternative is estimated to be greater than 30 years.

Implementability

No technical implementability issues exist since no remedial action will occur. There is no need to coordinate with other agencies or acquire permits. Services and materials are not required. Future actions, if needed, are not hindered by the "No Action" alternative.

Cost

Because no remedial action will occur other than natural attenuation, active remediation is implemented, and there are no costs associated with the "No Action" alternative.

7.2.2 Alternative R-2: Deed Restrictions, Fencing, Site Monitoring, VER Process, Air Phase Thermal Oxidation, Air Stripping, Chemical Precipitation, Liquid-Phase Adsorption, and Discharge to the Local POTW

7.2.2.1 Description

This alternative represents the treatment that addresses principal threats. Deed restrictions are land use controls written into a real estate deed and recorded with the deed in the county in which the property lies. Deed restrictions prevent activities such as excavation, well drilling, and residential construction. The restrictions also inform future purchasers about limits placed on the use of the property. NFS and/or governmental agencies may also execute policies to restrict land use. All such mechanisms are referred to as deed restrictions in the following discussions.

Existing fencing and security currently limits vehicular and personnel access to the NFS Site. The Site is bordered to the north by dense forest which further restricts access to the plant area. The combination of existing fencing, security, and the natural restrictions due to dense forest will provide adequate protection against trespassers and the maintenance of Alternative R-2 remedial components.

Site monitoring consists of groundwater monitoring and monitoring of the integrity of the security fencing. Because groundwater is not a current source of drinking water at the Site, monitoring results will not be collected for the sole purpose of comparison with groundwater standards. Rather, the results can provide assurance that COPC concentrations do not increase to the point that potential receptors would be threatened. A long-term monitoring plan and Sampling and Analysis Plan (SAP) will be prepared to further outline the objectives, methodologies, and data evaluation procedures for site monitoring. Long-term monitoring wells are intended to determine if the behavior of the plume is changing. Point-of-compliance (or point-of-action) wells are intended to detect movements of the plume outside the negotiated perimeter of containment, and to trigger an action to mange potential expansion. Groundwater monitoring consists of sampling and analysis of groundwater for COPCs and biogeochemistry within and downgradient of areas within the NFS Site at existing monitoring wells (Figure 7-4).

The term "monitored natural attenuation" refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site clean-up approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by other more active methods. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants. Other terms associated with natural attenuation in the literature include "intrinsic remediation", "intrinsic bioremediation", "passive bioremediation", "natural recovery", and "natural assimilation." While some of these terms are synonymous with "natural attenuation", others refer strictly to biological processes, excluding chemical and physical processes. Therefore, it is recommended that for clarity and consistency, the term "monitored natural attenuation" be used throughout the RAA unless a specific process (e.g., reductive dechlorination) is being referenced.

Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of contaminants present and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways:

1) The contaminant may be converted to a less toxic form through destructive processes such as biodegradation or abiotic transformations;
2) Potential exposure levels may be reduced by lowering of concentration levels (through destructive processes, or by dilution or dispersion); and
3) Contaminant mobility and bioavailability may be reduced by sorption to the soil or rock matrix and/or co-precipitation.

Where conditions are favorable, natural attenuation processes may reduce contaminant mass or concentration at sufficiently rapid rates to be integrated into a site's groundwater remedy. Following source control measures, natural attenuation may be sufficiently effective to achieve remediation objectives at some sites without the aid of other (active) remedial measures.

The VER process was developed for the remediation of VOCs and other contaminants in low to moderate permeability subsurface formations. VER is more comprehensive than the traditional soil vapor extraction (SVE) technology. Unlike SVE, VER simultaneously extracts both groundwater and soil vapor. Negative pressures applied to the pumping wells result in increased pumping rates by increasing the net effective drawdown. Soluble VOCs present in the extracted groundwater are removed more quickly than with traditional pump and treat methods. The increased pumping rates and drawdown also more effectively dewater the saturated materials, thereby creating a larger unsaturated zone for application of the SVE process. Stripping and removal of volatile compounds sorbed on the previously saturated soil are thus facilitated. The VER technology has been successfully applied to low- and moderate-permeability sites and consistently proven to be more effective at removing subsurface VOCs than conventional pump-and-treat or SVE systems alone. A conceptual VER layout for the NFS Site is presented in Figure 7-4.

Treatment of recovered groundwater would consist of air stripping, chemical precipitation, liquid-phase adsorption, and discharge to the City of Erwin POTW. High iron levels may be present in the area groundwater which can potentially foul the air stripping unit, GAC adsorbers, and associated piping, and increase sludge production. Therefore, pretreatment may be necessary. Greensand filters and bag filters may be evaluated for solids removal however, their performance is uncertain at the anticipated flow rates (>30 gpm). Dissolved metals (i.e., calcium, iron, magnesium) may also be sequestered prior to the air stripping unit through pH adjustment and equalization.

Following pretreatment/equalization, an air stripping unit would be installed to remove VOCs and TBP from the groundwater stream. Air stripping uses volatilization to transfer contaminants from the groundwater to the air. In general, water is contacted with an air stream to volatilize dissolved contaminants into the air stream. Contaminants are not destroyed by air stripping but are physically separated from the contaminated groundwater to the air. Air strippers may be conventional fixed pack columns or a series of vertically stacked trays. The groundwater is pumped directly through the air stripping media concurrent to air flow. For Alternative R-2, a 36-inch diameter low profile stacked tray air stripper with approximately 600 cubic feet per minute (cfm) countercurrent air flow could effectively remove VOCs from the extracted groundwater.

It is likely based on current COPC concentrations and anticipated VER dissolved and vapor VOC concentrations, that liquid- and air-phase treatment will be required. Additional polishing of the aqueous effluent from the air stripper will be required using series of 1,000 pounds, 100 pounds per square inch gage (psig) GAC vessels to ensure compliance with Erwin POTW discharge requirements.

Air stripper and VER emissions will most likely require treatment by thermal oxidation prior to discharge to the atmosphere. Assuming a 800 cfm vapor emission rate from the air stripper and the anticipated VOC concentrations from the VER process, a thermal oxidizer unit with a direct-fired burner in an insulated combustion chamber sustaining a temperature of 1,500 degrees Fahrenheit would be employed. The burning chamber would be sized to allow the residence time at a certain air flow velocity. Also, with chlorinated hydrocarbons, HCL is formed and emissions will have to be scrubbed prior to discharge. Liquid- and vapor-phase treatment design and permitting parameters can be further defined after pilot testing and incorporation of the treatment train for recovered groundwater.

Chemical precipitation will be performed to remove uranium from recovered groundwater. Common precipitation agents are lime, caustic, and sulfide, each having advantages and disadvantages. Removal of uranium is proposed using lime treatment based on cost and effectiveness at the existing NFS GWTF. A lime application, mixing, flocculation, and settling package plant able to handle the >30 gpm flow rate would be implemented under Alternative R-2. However, laboratory jar tests should be used to verify the treatment method and determine ultimate lime dosage rates.

Final effluent would be discharged to the City of Erwin POTW. The water-quality requirements for the treated groundwater effluent will be determined by considering the existing POTW discharge permit and the potential hydraulic impact the recovered groundwater would have on Erwin utilities.

7.2.2.2 Assessment

Threshold Criteria

Overall Protection of Human Health, Welfare, and the Environment

Alternative R-2 provides protection to human health, welfare, and the environment by eliminating all potential exposure pathways because access to groundwater is restricted by deed restrictions, fencing, and a secured monitoring well network system. Immediate risk to current workers from potential exposure during maintenance activities is dependent on 1) the effectiveness of the VER and natural attenuation in recovering and/or reducing COPCs and 2) the ability of the ex-situ treatment train to reduce COPC concentrations prior to discharge. Alternative R-2 does involve active treatment of constituents at the NFS Site but also relies on natural attenuation to reduce constituent concentrations. There are no significant risks to human health or the environment during implementation of Alternative R-2 if normal construction, operating, sampling, and handling procedures are conducted and direct worker contact with impacted materials is minimized. However, as COPCs are either transferred to another phase (i.e., liquid-phase to vapor-phase) or bound within a precipitate, potential exposure and handling risks exist. Therefore, for protection of human health, welfare, and environmental resources, Alternative R-2 is judged to provide a moderate level of protection.

Compliance with Applicable Regulations

Alternative R-2 will satisfy chemical-specific regulations guidance in achieving remedial objectives including the SDWA MCLs and RBCs within a reasonable time frame. The O&M Plan and SAP would be constructed and/or maintained under this alternative to satisfy action-specific regulations including the SDWA and Tennessee MCLs. Location-specific regulations are not applicable. Constituent exposure and chemical-specific regulations for workers and the public will define the degree of worker protection required during implementation of Alternative R-2.

Balancing Criteria

Long-Term Effectiveness and Permanence

The degree of long-term effectiveness and permanence provided by Alternative R-2 through active remediation and the natural attenuation program will be high assuming the VER is effective and the monitoring well network is kept in place to prevent potential direct contact. The magnitude and potential of residual risk is low for future receptors, and the exposure pathways are eliminated as long as the deed restrictions, fencing, and monitoring remain in place. Management of the alternative is required for as long as constituent concentrations in the groundwater within the NFS Site exceed PRGs. However, a 5-year review is required to assess the effectiveness of the VER process and ex-situ treatment in removing COPCs, and monitoring well network in detecting the COPCs and their degradation at the Site.

VER would capture and remove groundwater with COPC concentrations exceeding PRGs and remove adsorbed contaminants from the alluvial matrix. VER and ex-situ treatment technologies are considered reliable. Components used (blowers, pumps, etc.) are considered reliable. However, as with any mechanical system, active maintenance is required. Some equipment (i.e., pumps) may require replacement periodically. Pretreatment equipment (if required) ,wells, stripping media, thermal oxidizer, and precipitation equipment will require periodic maintenance and cleaning, and carbon adsorption required to treat effluent may require frequent replacement. Deed and land use restrictions would limit future land use and prohibit development of groundwater.

To maintain long-term reliability of Alternative R-2, a performance monitoring program within the SAP and an O&M program will be developed, implemented, and maintained for the monitoring of groundwater and the VER/ex-situ treatment train. VER and ex-situ treatment system components also must be periodically calibrated, cleaned, and/or replaced and O&M must be performed by qualified personnel. The adequacy and reliability of deed restrictions and fencing are sufficient to restrict access to impacted groundwater. Monitoring of the integrity of the fencing and monitoring wells will be required. Fencing may require replacement and/or repair due to wear, weather damage, vehicular accidents, and/or vandalism. Design life expectancy for the

VER system is 20 years; the ex-situ treatment equipment is 20 years, and the monitoring wells is 30 years.

Reduction of Mobility, Toxicity, or Volume Through Treatment

Alternative R-2 provides a high degree of irreversible treatment and mobility and volume reduction through COPC removal, treatment, and natural attenuation processes. Regeneration/disposal of GAC, destruction of vapor-phase COPCs by thermal oxidation, and sludge disposal will also reduce volume and toxicity of COPCs. Ex-situ treatment processes will also effectively reduce toxicity and volume of COPCs. Minor inorganic constituent residuals will eventually attenuate with the implementation of Alternative R-2.

Short-Term Effectiveness

The short-term risk to workers and the public from implementing Alternative R-2 is controllable and results from VER well installation, ex-situ treatment system construction, piping network, and the long-term operation and monitoring program of the remedial alternative. Health and safety issues include potential release of volatiles during sampling and proper decontamination procedures, GAC or thermal oxidation "breakthrough", sludge disposal, and/or ex-situ treatment process downtime. Construction time to implement Alternative R-2 is 6 months. A more detailed evaluation during design may identify 1) components required for the VER, air-phase treatment , and ex-situ treatment systems; 2) other COPCs that require monitoring, 3) concurrent constructability of components; 4) site construction details; and 5) on- and off-site monitoring details. Minimal risk to the community is expected from implementation.

Alternative R-2 will have effectiveness in eliminating all exposure pathways. The time required to achieve remedial response objectives by eliminating all exposure pathways is estimated to be less than 1 year.

Implementability

Deed restrictions, fencing, and monitoring are easily implementable, and there are numerous vendors available to conduct this work. However, limited vendors are available to construct the VER and ex-situ treatment system. VER well, piping, and aboveground system implementation within the impacted area will be difficult due to existing site utilities and space requirements. VER and monitoring of groundwater can be accomplished, with some implementability concerns. Monitoring of the integrity of the fencing will also be required. O&M activities are of high intensity and involve monitoring, system adjustments, media replacement, residuals disposal, and fence maintenance. All components of Alternative R-2 are reliable in the protection of human health, welfare, and the environment. The need for future remedial actions depends on the effectiveness of Alternative R-2 in eliminating exposure pathways. Future remedial actions are somewhat hindered by the implementation of Alternative R-2 because of the volume of above- and below-ground hardware required. However, changing or adding deed restrictions, system component replacement, fencing replacement/removal, well abandonment, and monitoring program addenda may be required. Coordination with regulatory agencies is attainable.

The key to designing an effective full-scale VER system is to perform a pilot study beforehand. Pilot study results provide key parameters (i.e., effective well vacuum, groundwater and vapor radii of influence, groundwater and vapor extraction flow rates, groundwater and vapor VOC concentrations). These parameters are essential for the selection and design of vacuum pumps, submersible pumps, and, eventually, groundwater and vapor treatment systems.

Cost

The estimated total project present worth cost for Alternative R-2 is $3,852,000, including a capital cost of $504,000, an annual O&M cost of $319,500, an O&M present worth cost of $2,430,100 (for 15 years), and site closure cost of $29,000. The capital cost is for the implementation of deed restrictions, the SAP, pilot testing, design, oversight, VER well installation, piping, ex-situ treatment system construction, and connection to the Erwin POTW. The annual O&M costs are for the VER and ex-situ treatment system O&M, POTW effluent compliance sampling, fencing maintenance, and reporting. Table 7-1 presents the estimated capital, O&M, and present worth costs of implementing and operating Alternative R-2.

7.2.3 Alternative R-3: Deed Restrictions, Fencing, Site Monitoring, and In-Situ Oxidation

7.2.3.1 Description

Alternative R-3 is the most aggressive remedial action examined for the NFS Site and is intended to eliminate or minimize long-term management. This alternative addresses the impacted groundwater at the Site through containment, treatment, and in-situ oxidation which minimizes long-term management by reducing remedial time. Deed restrictions, fencing, and site monitoring are as previously described in Alternative R-2.

In-situ chemical oxidation is based on the introduction of an oxidant, such as hydrogen peroxide (H_2O_2), into the subsurface. The resulting hydroxyl radicals (OH^-), strong chemical oxidizers, can create an environment which oxidizes chlorinated hydrocarbons.

The reaction is a nearly instantaneous oxidation of these compounds upon contact with hydroxyl radicals thus reducing the source term and overall remedial time.

A combination of H_2O_2 and ferrous sulfate (Fenton's Reagent) can be used to cost-effectively create hydroxyl radicals. Other oxidizers (such as potassium permanganate [$KMnO_4$] and ozone [O_3]) can also be used in the chemical oxidation of chlorinated hydrocarbons; however, Fenton's Reagent may be the most effective oxidant depending on existing biogeochemistry at the Site.

The general chemistry for the creation of hydroxyl radicals with Fenton's Reagent is shown in the following reaction:

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + OH^- + OH$$

The ultimate breakdown products of this reaction are water, oxygen, and precipitate iron. A Fenton's Reagent mixture can be created immediately prior to injection into the subsurface to maximize remedial effectiveness. The oxidation of a PCE molecule is a multi-step, multi-pathway reaction. The hydroxyl radical breaks the chemical bonds between the carbon and chlorine atoms to produce a molecule with one less chlorine atom. The removal of chlorine from the chlorinated hydrocarbon continues as TCE is oxidized to DCE, VC, and finally to ethene or ethane. Chloride ions and carbon dioxide are the major end products of the complete oxidation process.

In-situ oxidation at the source area would involve the creation of a reactive zone (Figure 7-5) of H_2O_2, ferrous sulfate and acid (for pH control) injection points and potentially recirculated. This process maximizes the dispersion and diffusion of the reagent through the soil and/or affected aquifer. Application of in-situ oxidation must be carefully controlled within industrial environments such as the NFS facility. Industrial-strength H_2O_2 is a strong oxidizer, and as such requires special handling and safety precautions. Oxidation increases subsurface temperatures and pH through H_2O_2 decomposition. However, with Fenton's Reagent, this reaction can be controlled and there is no toxic gaseous release or chemical residues that may be associated with other chemical oxidants.

The addition of metal salts (such as ferrous sulfate) with the oxidant will create ferric iron within the subsurface. Depending on the current and resulting biogeochemistry of the subsurface, this ferric iron may react with uranium to form insoluble uranyl oxides and/or uranyl oxyhydroxides. This process is slower than oxidation of the PCE but will result in reduced mobility of the uranium plume.

7.2.3.2 Assessment

Threshold Criteria

Overall Protection of Human Health, Welfare, and the Environment

Alternative R-3 provides protection to human health, welfare, and the environment by eliminating all potential exposure pathways because access to groundwater is restricted by deed restrictions, fencing, and a secured monitoring well network system. Immediate risk to current workers from potential exposure during maintenance and treatment activities is dependent on 1) the effectiveness of the oxidation and natural attenuation in destroying and/or reducing COPCs and 2) the safety aspects associated with in-situ oxidation treatments. Alternative R-3 does involve active treatment of constituents at the NFS Site but also relies on natural attenuation to reduce constituent concentrations. There are no significant risks to human health or the environment during implementation of Alternative R-3 if normal construction, operating, sampling, and handling procedures are conducted and direct worker contact with impacted materials and oxidizing reagents is minimized. Therefore, for protection of human health, welfare, and environmental resources, Alternative R-3 is judged to provide a high level of protection.

Compliance with Applicable Regulations

Alternative R-3 will satisfy chemical-specific regulations in achieving remedial objectives including the SDWA MCLs and RBCs within a reasonable time frame. The O&M Plan and SAP would be constructed and/or maintained under this alternative to satisfy action-specific regulations including the SDWA and Tennessee MCLs. Location-specific regulations are not applicable. Constituent exposure and chemical-specific regulations for workers and the public will define the degree of worker protection required during implementation of Alternative R-3.

Balancing Criteria

Long-Term Effectiveness and Permanence

The degree of long-term effectiveness and permanence provided by Alternative R-3 through active in-situ oxidation and the natural attenuation program will be high assuming 1) the oxidation is effective in the source area as well as the site boundary; 2) there is sufficient contact between the reagent and groundwater/COPCs; 3) oxidation is effective for complete dechlorination of the PCE (including VC); and 4) the monitoring well network is kept in place to prevent potential direct contact. The magnitude and potential of residual risk is low for future receptors, and the exposure pathways are eliminated as long as the deed restrictions, fencing, and monitoring remain in place. Management of the alternative is required for as long as constituent concentrations in the groundwater within the NFS Site exceed PRGs. However, a 5-year review is required to assess the effectiveness of the in-situ treatment in destroying/reducing COPCs, and monitoring well network in detecting the COPCs and their degradation at the Site.

In-situ oxidation will remediate groundwater with COPC concentrations exceeding PRGs. The in-situ oxidation technology is also considered reliable. Components used (injection wells, pumps, etc.) are considered reliable. However, because the oxidation process is instantaneous, a continuous oxidizing reactive zone will be required to maintain containment at the site boundary. As with any mechanical system, active maintenance is required. Some equipment (i.e., pumps) may require replacement periodically. Reagent mixing and delivery equipment and wells may require periodic maintenance and cleaning. As with Alternative R-2, deed and land use restrictions would limit future land use and prohibit development of groundwater. However, because clean-up levels may be achieved rapidly under this alternative, deed and land use restrictions could perhaps be removed sooner, pending verification of removal effectiveness obtained by monitoring groundwater.

To maintain long-term reliability of Alternative R-3, a performance monitoring program within the SAP and an O&M Program will be developed, implemented, and maintained for the monitoring of groundwater and the oxidant delivery system. Oxidizing injection system components also must be periodically calibrated, cleaned, and/or replaced and O&M must be performed by qualified personnel. The adequacy and reliability of deed restrictions and fencing are sufficient to restrict access to impacted groundwater. Monitoring of the integrity of the fencing and monitoring wells will be required. Fencing may require replacement and/or repair due to wear, weather damage, vehicular accidents, and/or vandalism. Design life expectancy for the oxidizing system is 10 years and the injection/monitoring wells is 20 to 30 years.

Reduction of Mobility, Toxicity, or Volume Through Treatment

Current data indicate that reductive dechlorination of chlorinated compounds is presently occurring at the Site. With the addition of in-situ oxidation, Alternative R-3 provides a high degree of irreversible treatment and mobility, toxicity, and volume reduction through COPC destruction and natural attenuation enhancement processes. With the high potential for precipitation of uranium to uranyl oxides and oxyhydroxides, drastic changes in pH or redox potential may cause precipitates to become soluble and remobilize uranium.

Short-Term Effectiveness

The short-term risk to workers and the public from implementing Alternative R-3 is controllable and results from deed restrictions, fencing integrity, injection well installation, in-situ oxidation treatments at the source area, and the long-term monitoring program of the remedial alternative. Health and safety issues include potential release of volatiles during sampling and proper decontamination procedures and high subsurface temperatures and corrosivity during source and containment oxidation. Construction time to implement Alternative R-3 is 6 months. A more detailed evaluation during design may identify: 1) components required for the site boundary injection system; 2) other COPCs that require monitoring; 3) concurrent constructability of components; 4) site construction details; and 5) on- and off-site monitoring details. Minimal risk to the community is expected from implementation.

Alternative R-3 will have effectiveness in eliminating all exposure pathways. The time required to achieve remedial response objectives by eliminating all exposure pathways is estimated to be less than 1 year.

Implementability

Deed restrictions, fencing, and monitoring are easily implementable, and there are numerous vendors available to conduct this work. However, limited vendors are available to implement source area oxidation and construct/operate the site boundary oxidizing treatment system. Injection well implementation within the impacted area and the site boundary will be difficult due to existing site utilities and space requirements. Oxidation and monitoring of groundwater can be accomplished, although high subsurface temperatures and corrosivity cause some implementability concerns related to the effects on subsurface utility piping. Monitoring of the integrity of the fencing will also be required. O&M activities are of high intensity and involve monitoring, system adjustments, oxidant replacement/mixing/delivery, and fence maintenance. All components of Alternative R-3 are reliable in the protection of human health, welfare, and the environment. The need for future remedial actions depends on the effectiveness of Alternative R-3 in eliminating exposure pathways. Future remedial actions are not hindered by the implementation of Alternative R-3. However, changing or adding deed restrictions, system component replacement, fencing replacement/removal, well abandonment, and monitoring program addenda may be required. Coordination with regulatory agencies is attainable.

The key to designing an effective full-scale in-situ oxidation system is to perform a pilot study beforehand. Pilot study results provide key parameters (i.e., effective well radii of influence, reagent delivery rates, and resulting COPC concentrations). In addition, some bench-scale testing may be required to determine the effectiveness of uranium precipitation.

Cost

The estimated total project present worth cost for Alternative R-3 is $1,016,000, including a capital cost of $367,600, a short-term annual O&M cost of $120,000 (source control for 1 year), a long-term annual O&M cost of $68,700, a total O&M present worth cost of $369,500 (for 5 years), and site closure costs of $44,400. The capital cost is for the implementation of deed restrictions, the SAP, pilot testing, design, oversight, oxidizing injection well installation, injection/delivery piping, and continuous injection treatment system construction. The annual O&M costs are for the periodic oxidation treatments at the source area, continuous injection system maintenance, fencing maintenance, and reporting. Table 7-2 presents the estimated capital, O&M, and present worth costs of implementing and operating Alternative R-3.

7.2.4 Alternative R-4: Deed Restrictions, Fencing, Site Monitoring, In-Situ Enhanced Anaerobic Bioremediation, and In-Situ Reductive Precipitation

7.2.4.1 Description

Although less aggressive than Alternative R-3, this alternative also represents a treatment to eliminate or minimize long-term management. Deed restrictions, fencing, and site monitoring (of natural attenuation) would be implemented as described for Alternative R-2.

Enhanced Anaerobic Bioremediation

Chlorinated hydrocarbons are typically transformed by reductive dechlorination (or dehalogenation) mechanisms. Reductive dechlorination involves the sequential removal of a chlorine atom from the chlorinated hydrocarbon, while substituting with a hydrogen atom (Figure 7-7). The degradation sequence for PCE is presented below:

PCE → TCE → DCE → VC → ethene → ethane → carbon dioxide and water.

The later steps of this process, such as degradation of *cis*-1,2-DCE to VC, and degradation of VC to ethene, generally require much more strongly-reducing conditions in groundwater [typically in the range of -200 to -400 millivolts (mV)] than do the initial degradation steps. The more highly-chlorinated compounds (i.e., PCE) are most susceptible to reductive dechlorination because of their higher state of oxidation. Often a groundwater environment is not reducing enough [i.e., the oxidation-reduction potential (ORP) is not negative enough] to allow for the complete degradation to occur and an accumulation of daughter products is observed (such as an accumulation of *cis*-1,2-DCE or VC). As a result, the ORP of the groundwater system is dependent on and can influence the specific reductive dechlorination processes.

Reductive dechlorination mechanisms primarily occur in anaerobic (or oxygen-deficient) groundwater. That is, the indigenous microbes utilize an organic carbon source as a primary substrate for obtaining energy. The organic carbon serves as an electron donor and is oxidized during this process. The chlorinated hydrocarbons serve as electron acceptors and are subsequently reduced, while nitrate, iron, manganese, sulfate, and/or carbon dioxide, also serve as electron acceptors and are also reduced in these reactions. Enzymes and co-factors produced during these reactions fortuitously degrade the source chlorinated hydrocarbons. The organic carbon necessary for these reactions to occur can either be natural (i.e., in the aquifer formation) or anthropogenic (such as the existing BTEX within the site aquifer). For reductive dechlorination to occur, there must be a sufficient source of carbon to support microbial growth, through co-metabolism, as the chlorinated hydrocarbons are used solely as an electron acceptor.

Alternative R-4 relies on enhancing the reductive dechlorination reactions by supplying an additional organic carbon source as an energy substrate to the groundwater system and driving the ORP to lower, more strongly-reducing conditions that can not only degrade PCE, but also dechlorinate daughter products such as VC. This can be accomplished by supplying the groundwater system with a sucrose and carbohydrate source.

The dilute carbon source solution would be periodically injected through the network of existing wells and/or other injection points within the source area and downgradient property boundary to create reactive zones that impacted groundwater flows into, or through (Figure 7-6). The carbon source is readily degraded by indigenous heterotrophic microorganisms that are typically present in all aquifers. This metabolic degradation process utilizes the available dissolved oxygen contained in the groundwater, and drives the system to a more anaerobic and reduced state. The performance of this enhancement is measured by monitoring for chlorinated hydrocarbon reductions and relative concentrations of degradation products; as well as, other indicator biogeochemical parameters in groundwater.

<u>Reductive Precipitation</u>

As the environmental chemistry of individual heavy metals varies greatly, the potential for the precipitation of each heavy metal in an anaerobic reactive zone must be evaluated separately. This technology is most well-established for chromium, which is very similar in chemical speciation and susceptibility to precipitation as uranium.

Chromium, like uranium, can be present in the environment in several valence forms. Hexavalent chromium (Cr^{6+}) is the mobile and most toxic form, while trivalent chromium (Cr^{3+}) is significantly less toxic and less mobile. Similarly, hexavalent uranium (U^{6+}) can be reduced to the less mobile U^{4+}. These metals, dissolved in groundwater, can be remediated in-situ by manipulating the groundwater chemistry toward more reducing conditions, which induces precipitation. These reducing conditions also created by additional organic carbon source injection, provide the geochemical environment necessary for dissolved chromium/uranium in the groundwater to form an insoluble precipitate immobilized in the aquifer matrix. For chromium, this precipitation process is essentially irreversible while with uranium, a U^{4+} precipitate can become soluble if reducing conditions are not currently conducive and/or can be maintained (remain below 0 mV ORP). Creation of the reducing conditions results in the reduction of Cr^{6+} and U^{6+} to Cr^{3+} and U^{4+}. Several chemical mechanisms for the reduction of these metals have been elucidated. Potentially, the most important mechanisms are reduction by ferrous iron into an oxide (Gu, Liang et al. 1998), contact with hydrogen sulfide gas into a sulfide (Jacobs Environmental Management Team 1999), and lastly as a hydroxide (Gu, Liang et al. 1998).

In addition, the anaerobic biological degradation of TBP results in 1-butanol and phosphoric acid (Russell, Russell et al. 1996). The liberated 1-butanol will be utilized by bacteria as a biomass growth substrates and the co-released phosphate within the phosphoric acid will be coupled with the uranium as a hydrogen uranyl phosphate and immobilized.

7.2.3.4 Assessment

Threshold Criteria

Overall Protection of Human Health, Welfare, and the Environment

Alternative R-4 provides protection to human health, welfare, and the environment by eliminating all potential exposure pathways because access to groundwater is restricted by deed restrictions, fencing, and a secured monitoring well network system. Immediate risk to current workers from potential exposure during maintenance and treatment activities is dependent on the effectiveness of the in-situ treatments and natural attenuation in destroying and/or reducing COPCs. Alternative R-4 does involve active treatment of constituents at the NFS Site without hazardous reagents but also relies on enhanced natural attenuation to reduce constituent concentrations. There are no significant risks to human health or the environment during implementation of Alternative R-4 if normal construction, operating, sampling, and handling procedures are conducted and direct worker contact with impacted groundwater is minimized. Therefore, for protection of human health, welfare, and environmental resources, and based on the "natural" and non-hazardous remediation aspects of the technologies, Alternative R-4 is judged to provide the highest level of protection.

Compliance with Applicable Regulations

Alternative R-4 will satisfy chemical-specific regulations in achieving remedial objectives including the SDWA MCLs and RBCs within a reasonable time frame. The O&M Plan and SAP would be constructed and/or maintained under this alternative to satisfy action-specific regulations including the SDWA and Tennessee Underground Storage Tank. Location-specific regulations are not applicable. Constituent exposure and chemical-specific regulations for workers and the public will define the degree of worker protection required during implementation of Alternative R-4.

Balancing Criteria

Long-Term Effectiveness and Permanence

The degree of long-term effectiveness and permanence provided by Alternative R-4 through active in-situ treatments and the natural attenuation program will be high assuming 1) the enhanced anaerobic bioremediation and reductive precipitation are effective in the source area as well as the site boundary; 2) there is sufficient contact between the reagent and groundwater/COPCs; 3) reductive dechlorination and precipitation is effective for complete dechlorination of PCE (including VC) and precipitation of U^{6+}, respectively; and 4) the monitoring well network is kept in place to prevent potential direct contact. The magnitude and potential of residual risk is low for future receptors, and the exposure pathways are eliminated as long as the deed restrictions, fencing, and monitoring remain in place. Management of the alternative is required for as long as constituent concentrations in the groundwater within the NFS Site exceed PRGs. However, a 5-year review is required to assess the effectiveness of the in-situ treatment in destroying/reducing COPCs, and monitoring well network in detecting the COPCs and their degradation at the Site.

The combination of these in-situ treatments will remediate groundwater with COPC concentrations exceeding PRGs. Both technologies are considered reliable and proven but the degree of effectiveness is highly dependent on the current biogeochemistry. Components used (injection wells, pumps, etc.) are considered reliable. Because injections are performed on a periodic basis, low O&M is required for injection equipment. As with Alternatives R-2 and R-3, deed and land use restrictions would limit future land use and prohibit development of groundwater.

To maintain long-term reliability of Alternative R-4, a performance monitoring program within the SAP and an O&M program will be developed, implemented, and maintained for the monitoring of groundwater. The adequacy and reliability of deed restrictions and fencing are sufficient to restrict access to impacted groundwater. Monitoring of the integrity of the fencing and monitoring wells will be required. Fencing may require replacement and/or repair due to wear, weather damage, vehicular accidents, and/or vandalism. Design life expectancy for the injection/monitoring wells is 20 to 30 years.

Assuming the natural pH range encountered in the groundwater system at the Site is amenable, uranium precipitates have extremely low solubilities. Only extreme changes to the pH or redox conditions in the groundwater could resolubilize the precipitate to any significant extent. Extreme conditions are defined as either very low (less than 4) or very high (greater than 10) pH, or a strongly-oxidizing environment (such as that caused by the continuous injection of hydrogen peroxide or ozone).

Reduction of Mobility, Toxicity, or Volume Through Treatment

Current data indicate that reductive dechlorination of chlorinated compounds is presently occurring at the Site. With the addition of in-situ enhanced anaerobic bioremediation and reductive precipitation, Alternative R-4 provides a high degree of irreversible treatment and mobility, toxicity, and volume reduction through COPC destruction, precipitation, and natural attenuation enhancement processes.

Short-Term Effectiveness

The short-term risk to workers and the public from implementing Alternative R-4 is controllable and results from deed restrictions, fencing integrity, injection well installation, in-situ injection treatments at the source area, and the long-term monitoring program of the remedial alternative. Health and safety issues include potential release of volatiles during sampling and proper decontamination procedures. Construction time to implement Alternative R-4 is 6 months. A more detailed evaluation during design may identify 1) components required for the site boundary injection system; 2) other COPCs that require monitoring, 3) concurrent constructability of components; 4) site construction details; and 5) on- and off-site monitoring details. Minimal risk to the community is expected from implementation.

Alternative R-4 will have effectiveness in eliminating all exposure pathways. The time required to achieve remedial response objectives by eliminating all exposure pathways is estimated to be less than 1 year.

Implementability

Deed restrictions, fencing, and monitoring are easily implementable, and there are numerous vendors available to conduct this work. However, limited vendors are available to implement enhanced anaerobic bioremediation and reductive precipitation systems. Injection well implementation within the impacted area and the site boundary may be difficult due to existing site utilities and space requirements. Treatment and monitoring of groundwater can be accomplished easily. Monitoring of the integrity of the fencing will also be required. O&M activities are of low intensity and involve monitoring, system adjustments, reagent replacement/ mixing/delivery, and fence maintenance. All components of Alternative R-4 are reliable in the protection of human health, welfare, and the environment. The need for future remedial actions depends on the effectiveness of Alternative R-4 in eliminating exposure pathways. Future remedial actions are not hindered by the implementation of Alternative R-4. However, changing or adding deed restrictions, system component replacement, fencing replacement/removal, well abandonment, and monitoring program addenda may be required. Coordination with regulatory agencies is attainable.

The key to designing an effective full-scale in-situ enhanced anaerobic bioremediation and reductive precipitation system is to perform a pilot study beforehand. Pilot study results provide key parameters (i.e., effective well radii of influence, reagent delivery rates, and resulting COPC concentrations). In addition, some bench-scale testing may be required to determine the effectiveness of uranium precipitation.

Cost

The estimated total project present worth cost for Alternative R-4 is $784,200, including a capital cost of $176,100, an annual O&M cost of $25,200, an O&M present worth cost of $401,900 (for 8 years), and site closure cost of $25,200. The capital cost is for the implementation of deed restrictions, the SAP, pilot testing, design, oversight, and injection well installation. The annual O&M costs are for the periodic injection treatments at the source area and boundary wells, fencing, and reporting. Table 7-3 presents the estimated capital, O&M, and present worth costs of implementing and operating Alternative R-4.

7.2.5 Summary of SWMU 20/Maintenance Shop Detailed Analysis

As part of the individual analysis of alternatives for the Site, one alternative involving "No Action", one alternative addressing principal threats, and two alternatives to eliminate or minimize long-term management are evaluated. Alternative R-1 is the only alternative that does not satisfy the threshold criteria to the full extent but is retained for comparison purposes. Alternatives R-2 through R-4 provide varying degrees of protection and treatment and will be viable for the selection as a preferred alternative. The relative merits of all alternatives against each other will be evaluated in Section 8.0. The detailed analysis of remedial alternatives for the Site is summarized in Table 7-4.

8.0 Comparative Analysis for Alternatives

The comparative analysis evaluates the relative performance of each alternative in relation to each specific evaluation criterion. This analysis is in contrast to the preceding evaluation (Section 7.0) in which each alternative was analyzed independently without a consideration of other alternatives. The comparative analysis focuses on the key differences between the alternatives and attempts to highlight critical issues of concern to the decisionmaker selecting the preferred remedial action. The following sections provide a summary of the key comparative features and relative performance of each site-specific alternative against the other alternatives with respect to the evaluation criteria (Figure 7-1).

A summary of the comparative analyses including costs for the alternatives is presented in Table 8-1. Table 8-1 also provides a comparison between each alternative using the evaluation criteria.

8.1 Overall Protection of Human Health, Welfare, and the Environment

This evaluation criterion is used to assess whether an alternative provides for adequate protection of human health, welfare, and the environment. The assessment of protection draws on the analyses conducted under other evaluation criteria, with emphasis on short-term effectiveness, long-term effectiveness and permanence, and compliance with applicable regulations. The evaluation of the overall protectiveness of an alternative focuses on whether that alternative achieves adequate protection over time and describes how site risks posed through each exposure pathway are eliminated or reduced by either the treatment, engineering controls, or institutional controls of the alternative. Overall protection from impacted groundwater that exceeds PRGs is based largely on the certainty that the remedy can achieve and maintain clean-up levels or eliminate potential exposure pathways. This criterion must be satisfied in order for an alternative to be considered as the selected remedy.

The current on-site recreational users and future on-site and hypothetical off-site construction worker and/or recreational users exposure pathways to humans at the NFS Site are dermal contact, incidental ingestion, and inhalation with impacted groundwater. However, off-site migration of impacted groundwater is a potential exposure pathway to the environment. Therefore, for an alternative to be protective of human health and environment, it must protect humans from all potential exposure pathways and protect the environment from the further migration of impacted groundwater.

Alternatives R-2 through R-4 would meet the general RAOs for groundwater by eliminating potential direct contact. This would be accomplished by fencing and NFS facility requirements. Additionally, deed restrictions would strengthen the effectiveness and long-term reliability of the alternatives in restricting future land use and access.

Alternative R-4 will provide the highest level of overall protection through institutional controls and enhanced natural COPC degradation and precipitation. Because the treatment is with a non-hazardous reagent, degradation of chlorinated constituents is irreversible, uranium is precipitated and immobilized, and natural attenuation processes are enhanced, this alternative will reduce the risks associated with all potential exposure pathways in a reasonable period of time.

Alternatives R-2 and R-3 will provide direct and immediate protection primarily by institutional controls, fencing, and monitoring. Alternative R-2 further protects human health, welfare, and the environment through groundwater recovery to remove COPC mass and increase natural attenuation capacity. However, because COPCs are transferred to another phase (i.e., air stripping) or ex-situ precipitated in a sludge, potential risk is present. Alternative R-3 ensures reduced risk from all potential pathways by in-situ instantaneous destruction of chlorinated COPCs and a high potential for uranium precipitation. Alternative R-2 provides protection of human health, although less than provided by Alternative R-3. Table 8-1 presents a summary for the overall protectiveness of human health, welfare, and the environment for all alternatives.

8.2 Compliance with Applicable Regulations

This evaluation criterion is used to determine whether an alternative meets all federal and state regulations. Applicable requirements are those clean-up standards, standards of control, and substantive environmental protection requirements promulgated under federal or state law that specifically address a situation encountered at the NFS Site. Section 3.0 presents chemical-, action-, and location-specific regulations that apply to the NFS Site. NFS, in consultation with appropriate regulatory agencies, will make the actual determination of which requirements are applicable or relevant and appropriate. This criterion must be satisfied in order for an alternative to be considered in the selection process.

Alternatives R-2 through R-4 will comply with chemical-specific regulations concerning worker and public safety by providing worker protection and a monitoring well network. Also, PRGs are numerical values that represent chemical-specific regulations. All alternatives will meet PRGs at the site boundary upon implementation and meet PRGs within site boundaries over varying time frames. Action-specific regulations, such as the SDWA MCLs, would be achieved through the enforcement of deed restrictions over time. Location-specific regulations are not applicable to Alternatives R-2 through R-4. Unless a waiver has been obtained for a particular regulation, the selected remedy must comply with all regulations. Table 8-1 presents a summary of regulatory compliance for each alternative.

8.3 Long-Term Effectiveness and Permanence

This criterion addresses 1) the effectiveness of an alternative in terms of residual risk remaining at the Site after response objectives have been completed (e.g., after groundwater plume management activities are concluded) and 2) the reliability and maintenance of controls that are used to manage the risk posed by treatment residuals and untreated wastes. The evaluation assesses any residual chemical constituents that may remain in the groundwater after the remedial action has been completed. However, for an alternative such as Alternative R-2, this criterion assessment period begins after the system complies with clean-up levels and active collection and treatment has ceased because the response action is treatment. In addition, the effectiveness of the treatment technologies is evaluated in terms of the risk posed by the groundwater quality after implementation/operation. Further, any residual constituents remaining in the groundwater (or adsorptive media generated by the alternative) are assessed.

8.3.1 Magnitude of Residual Risks

Alternatives R-3 and R-4 provide a higher level of long-term effectiveness and permanence than Alternative R-2 by providing a degree of in-situ active treatment of impacted groundwater that exceeds PRGs at the Site, thereby reducing residual risk from impacted groundwater left at the Site. Alternatives R-3 and R-4 are expected to eliminate or significantly reduce all residual risks to acceptable levels to potential future receptors as well as to provide long-term reliability through the deed restrictions, collection, irreversible treatment, and natural attenuation capacity. Alternatives R-3 and R-4 can expedite remediation of groundwater by providing improved COPC removal efficiency for treatment through in-situ processes.

Alternative R-4 will reduce residual risks to a greater degree than other site alternatives since enhancing in-situ biodegradation will more effectively remediate the aquifer matrix. Alternative R-4 can also be used to remediate the off-site plume by enhancing natural attenuation processes. Alternative R-3 provides the next highest level of long-term effectiveness because the oxidation treatments will destroy COPC mass; however, oxidation is somewhat counter productive (highly aerobic) in the degradation of off-site chlorinated hydrocarbons and may be inefficient in the precipitation of uranium.

Alternative R-2 will not have as high a level of long-term effectiveness as Alternatives R-3 and R-4 since COPC recovery is dependent solely on COPC travel velocities and natural attenuation. Alternatives R-3 and R-4 are expected to eliminate or significantly reduce all risks to acceptable levels to both on-site workers and potential off-site receptors as well as provide long-term reliability through the in-situ treatment of impacted groundwater. Alternative R-2 involves ex-situ treatment of groundwater and will produce treatment residuals such as VER process water, spent GAC, and filtration sludge. These residuals will require treatment and/or disposal to eliminate any future potential risk to the environment. All alternatives require management and 5-year reviews for as long as COPCs exceed PRGs.

8.3.2 Adequacy and Reliability of Controls

Alternatives R-2 and R-3 contain mobile and fixed groundwater treatment systems, respectively, and will operate until the clean-up levels are achieved. Because the risks will be irreversibly reduced, the potential need for system restart is expected to be minimal for these alternatives. After clean-up goals have been achieved, the long-term controls will consist of administrative controls and monitoring. Administrative controls and monitoring will also adequately protect human health and monitor the success of the remediation. Alternative R-4 uses mobile treatment units at periodic intervals, thus reducing the need for additional or fixed equipment. Alternatives R-3 and R-4 are proactive and proven technologies for mass removal. Alternative R-2 uses VER and ex-situ treatment system that will produce spent residuals. Alternatives R-3 and R-4 provide a higher level of reliability and lower potential need for system restart than Alternative R-2 because of the use of in-situ biological and physical COPC removal and faster clean-up times.

Table 8-1 provides a summary of the comparative evaluation of the long-term effectiveness and permanence including magnitude of future residual risk, long-term reliability of controls, prevention of exposure to residuals, potential need for replacement of technical components, and long-term management requirements of each site alternative.

8.4 Reduction of Mobility, Toxicity, or Volume Through Treatment

This criterion addresses the degree to which alternatives permanently and significantly reduce mobility, toxicity, or volume of COPCs in the groundwater. This criterion considers: 1) the treatment process used; 2) the amount of groundwater treated; 3) the degree of expected reduction in mobility, toxicity, or volume; 4) the degree to which treatment is irreversible; and 5) the type and quantity of residuals remaining after treatment, both in the groundwater and from any treatment process.

Alternative R-2 will significantly reduce the mobility of the COPCs. Alternative R-3 will provide reduction of toxicity and volume through physical in-situ destruction but will not affect mobility. Alternative R-4 will permanently and significantly reduce the mobility, toxicity, and volume of chemical constituents to the highest level for the Site. All alternatives are considered irreversible treatments if the biogeochemistry is favorable and controlled. Alternatives R-3 and R-4 are designed to provide the greatest combined reduction through treatment because the treatment technologies destroy, degrade, and/or immobilize groundwater constituents. Alternatives R-3 and R-4 provide in-situ treatments, thus expediting the remedial time. Alternative R-2 will produce treatment residuals.

All alternatives rely on some degree of natural attenuation to aid in the remediation of the groundwater. However, the concentrations of residuals remaining in the groundwater matrix after any treatment considered for the Site will be below PRGs.

Table 8-1 provides a summary of the comparative evaluation of the constituents destroyed; reduction of mobility, toxicity, or volume; irreversibility of treatment; and residuals remaining after treatment for each alternative.

8.5 Short-Term Effectiveness

This criterion addresses the effects of each alternative during the implementation and construction phases until remedial response objectives are achieved (e.g., clean-up levels are achieved). Alternatives are evaluated under this criterion based on their effects on human health, welfare, and the environment during initial phases of the remedial project. The evaluation considers 1) the protection of the community during remedial actions, 2) the protection of workers during remedial actions, 3) the environmental impacts of construction and operation, and 4) the time until remedial response objectives are achieved.

Currently, the NFS Site poses no known off-site risks to the community. For all alternatives, short-term effectiveness for the monitoring well network is high because sufficient monitoring well network is presently in use to detect any further migration of constituents to off-site property. The more complex and involved alternative, Alternative R-2, takes progressively longer when considering the time needed to construct and install treatment equipment. Alternatives R-2 through R-4 have estimated remedial times to reach objectives (PRGs) of 15 years, 5 years, and 8 years, respectively, based on current source term, estimated removal rates, COPC biodegradation half-lives, and modeling. Alternatives R-2 and R-3 create higher short-term risks of worker exposure and the potential of fugitive dust during trenching, drilling, and system installation(s) than other alternatives. These risks appear manageable by using appropriate engineering and construction management controls. Only minor short-term risk is associated with injection well drilling during implementation of Alternative R-4.

Table 8-1 provides a summary of the comparative evaluation of the short-term effectiveness including construction time, remedial time to completion, community protection during implementation, and worker protection during implementation of each alternative.

8.6 Implementability

This criterion addresses whether or not there are any technical problems or administrative issues associated with an alternative that would halt or delay the remediation. This includes analyzing the availability of various services and materials required during its implementation. This criterion considers 1) the ability to construct and operate the technology; 2) the reliability of technology; 3) the ease of undertaking future remedial actions; 4) monitoring; 5) the coordination with other agencies; 6) the availability of TSD services; and 7) the availability of necessary equipment, specialists, and materials.

Alternative R-2 may require federal, state, and/or local permits because of air emissions and discharge to the POTW. This alternative is anticipated to take longer to implement. Alternative R-3 will take the next longest because of the number of injection wells required for containment, injection permit, and reagent delivery piping installation. Alternative R-4 will take the shortest time to implement as fewer injection wells are needed for containment and the monitoring well network is currently in place. All remedial technologies are proven and reliable. If future remedial actions are deemed necessary, such actions could be conducted with minimal disruption to Alternative R-4, however, Alternatives R-2 and R-3 involves conveyance piping that may prove difficult in future actions if removal is required. All alternatives provide varying degrees of flexibility in design and operation.

All alternatives, which meet threshold criteria, require monitoring of groundwater and/or treatment system effluents. All alternatives require coordination with other agencies for deed recordations and/or permitting. Alternative R-2 will require the use of TSD facilities or services for treatment residuals (such as sludges and/or spent carbon) and/or excavated impacted soils from monitoring well and trench installation. Equipment, specialists, materials, and TSD capacity for all alternatives are available.

Table 8-1 provides a summary of the comparative evaluation of implementability including the ability to construct and operate the technology, ability to phase actions, ease of future remedial actions, ability to monitor effectiveness, ability to obtain approval from other agencies, availability of services and capacities, and availability of equipment, specialists, materials, and TSD capacity for each alternative.

8.7 Cost

This criterion addresses the "study estimate" cost for each alternative. Costs evaluated include capital, O&M, and present worth.

The increases in present worth value reflect the increases in complexity and/or remedial period of the alternatives. Alternative R-2 provides the highest present worth cost for active remediation over 15 years mainly due to high construction and O&M costs; Alternative R-3 provides for a 5-year remedial period for a cost of nearly one-third the cost of Alternative R-2 with the cost drivers being the continuous injection system and high cost associated with source control treatments and safety. Alternative R-4 provides for an estimated remedial period of 8 years for approximately one-fifth the cost of Alternative R-2 and less than Alternative R-3 with cost savings provided by no permanent aboveground treatment systems and more effective in-situ treatment. Table 8-1 provides the capital, first year annual O&M, O&M present worth, and total project costs for each alternative.

9.0 Preferred Alternative

The results of the detailed analyses, and especially the comparative analyses, serve to highlight the relative advantages and disadvantages of each alternative and its respective components so that important comparative aspects can be identified. The combination of these results and the risk management judgments made by the decisionmaker become the rationale for selecting a preferred alternative. The logical progression for selecting the preferred alternatives presented in this RAA Report serves as the basis for the selection rationale and provides a transition between the investigation/remediation process, the development of the design, and ultimately the remedial action. A general description and rationale for selection of the preferred alternative for the NFS Site is presented below.

9.1 SWMU 20/Maintenance Shop Preferred Alternative

Alternative R-4, incorporating deed restrictions, fencing, site monitoring (of natural attenuation), in-situ enhanced anaerobic bioremediation, and in-situ reductive precipitation, is identified as the preferred alternative for the SWMU 20/Maintenance Shop Site. Components of Alternative R-4 address the principal concerns and objectives associated with the Site including: 1) the protection of human health, welfare, and the environment; 2) compliance with applicable regulations; 3) containment of COPCs within the impacted groundwater that may pose future risk; and 4) the in-situ treatment of COPCs below land surface by biodegradation and precipitation. Alternative R-4 includes the following actions:

- Implementation of deed restrictions over the Site;
- Inspection and maintenance of site boundary fencing;
- Monitoring the groundwater for COPCs and biogeochemistry, the integrity of fencing, and remedial action (i.e., natural attenuation and in-situ treatments) performance;
- Performance of periodic carbon source injection treatments on new injection and existing monitoring wells (as needed); and
- Reevaluation every 5 years of the effectiveness of the remediation and the degree to which other emerging remediation technologies may be suited for the Site.

The following subsections describe the key components of Alternative R-4. Although details of the various methods or designs of these components are based on information presented in Sections 7.0 and 8.0, the final design details and possible substitution of a more feasible process options will be addressed during the remedial design and action phases.

Alternative R-4 is capable of complying with all RAOs associated with the COPCs identified within the Site. The alternative is an action intended to eliminate unacceptable risk by performing groundwater monitoring (of natural attenuation) and injection treatments that have the benefits of in-situ remediation. The components of Alternative R-4 will also prevent potential future exposure to any remaining COPC residuals within the Site.

9.1.1 Deed Restrictions

Deed restrictions prohibit the use of and access to impacted groundwater through legal actions taken to modify the deed for the subject property at the Unicoi County Courthouse. Deed restrictions impose limitations and restrictions on the land and groundwater use (e.g., well drilling, residential construction) until the groundwater is remediated to acceptable levels. NFS and governmental agencies may also execute policies to restrict land use for the Site. All such mechanisms are referred to as deed restrictions. The enforcement of deed restrictions is not difficult due to the present industrial nature and security procedures at the NFS facility.

9.1.2 Fencing

Existing site vehicular security fencing at the site entrance and along site boundaries will limit unauthorized access to monitoring wells and groundwater within the Site. Fencing is required to restrict physical access to impacted groundwater where physical barriers and/or warning signs do not already exist. Existing fencing at the NFS facility is elaborate and in excellent condition. Additional fencing will not be required under Alternative R-4 as deed restrictions are (or will be) in place.

9.1.3 Site Monitoring

Monitoring will be conducted for groundwater quality (both COPCs and biogeochemistry), fence integrity, and in-situ treatment effectiveness. Groundwater monitoring consists of groundwater sampling and laboratory analyses for COPCs and biogeochemical parameters from designated monitoring wells to 1) detect constituent migration and COPC concentrations, and 2) determine the effectiveness of enhanced anaerobic bioremediation and reductive precipitation treatments and natural attenuation activities in remediating the groundwater. Groundwater monitoring is used to confirm and/or identify potential new routes of migration of constituents and to confirm and evaluate the progress of the remedial action. This information allows other decisions to be made such as optimizing operating parameters. The integrity of the fence will also be monitored according to NFS procedures for fence inspections.

9.1.4 In-Situ Enhanced Anaerobic Bioremediation

Reducing conditions conducive to enhancing reductive dechlorination of PCE and daughter products would be accomplished through the in-situ injection of an additional organic carbon source for anaerobic bacteria to utilize in the breakdown of COPCs. This reagent would be injected periodically within a series of injection wells (and existing monitoring wells) at the source area and site boundary to attain low oxygen and redox conditions. These conditions will facilitate the biodegradation of chlorinated hydrocarbons and TBP. Current biogeochemistry is a vital aspect of the success of implementing Alternative R-4 and manipulation of subsurface conditions is a complex process.

9.1.5 In-Situ Reductive Precipitation

In-situ reductive precipitation is targeted for the remediation of uranium. It is well-documented that under reducing conditions, such as those created by additional organic carbon source injection, mobile uranium will react with ferrous iron and sulfides produced during increased anaerobic bacteria to form insoluble oxides, hydroxides, and/or sulfides. This will be accomplished in the same manner as in-situ enhanced anaerobic bioremediation but focused on the uranium plume.

9.2 Rationale for Preference

Based on ARCADIS Geraghty & Miller's review of available data, our understanding of site conditions, RAOs, alternative evaluation, and pending the results of a natural attenuation evaluation, Alternative R-4 - Deed Restrictions, Fencing, Site Monitoring (of natural attenuation), In-Situ Enhanced Anaerobic Bioremediation, and In-Situ Reductive Precipitation, is the preferred alternative for groundwater remediation at the Site.

Alternative R-4 provides the highest degree of overall protectiveness to human health and the environment by providing reduction in risk through fencing, and direct, cost-effective containment/reduction of COPCs within site groundwater by in-situ degradation/precipitation, supported by the natural attenuation monitoring well network. Alternative R-4 complies with applicable regulations because: 1) enhanced biodegradation, reductive precipitation, and natural attenuation will reduce COPC concentrations below PRGs over a reasonable time frame; and 2) remedial actions will eliminate or reduce risk posed by potential exposure pathways. Alternative R-4 provides long-term effectiveness and permanence by removing COPC mass, stimulating in-situ biodegradational processes that reduce residual risk, and eliminating or reducing long-term management.

The equipment and controls needed for Alternative R-4 are mobile, reliable, easily operated, used commonly in other remedial activities, and require low O&M cost. The implementation time for Alternative R-4 is estimated to be less than 6 months. The time required to achieve RAOs is estimated to be 8 years, based on the effectiveness of enhanced bioremediation/precipitation treatments, and natural attenuation processes. Alternative R-4 is easily implementable, with vendors available, and any remedial upgrades or additions are easy to install. Approval from any regulatory agency is expected based on the degree of risk reduction provided by the remedial components; minimal permitting requirements; and cost effectiveness. Alternative R-4 provides a high level of effectiveness in a short period of time in achieving RAOs at the Site.

The advantages of using in-situ enhanced anaerobic bioremediation and reductive precipitation as technologies to remove COPC mass, and thus reduce clean-up time at the Site, include: 1) effective in-situ treatment of a COPC plume that has migrated offsite; 2) assured protection of potential receptors through COPC reduction; 4) a reasonable remedial time compared to other alternatives; and 5) ultimate enhancement of presently-occurring natural attenuation processes. Alternative R-4 is a phased approach intended to reduce COPC mass and concentrations to levels amenable to natural attenuation. In the long term, natural attenuation processes will become the primary remedial technology to achieve groundwater RAOs.

10.0 References

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Table 2-1. Summary of Occurrence Data in Monitoring Wells - Total Uranium and Volatile Organics

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 72 U233,234 (pCi/L)	Well 72 U234 (pCi/L)	Well 72 U235 (pCi/L)	Well 72 U238 (pCi/L)	Well 93 U233,234 (pCi/L)	Well 93 U234 (pCi/L)	Well 93 U235 (pCi/L)	Well 93 U238 (pCi/L)	Well 108A U233,234 (pCi/L)	Well 108A U234 (pCi/L)	Well 108A U235 (pCi/L)	Well 108A U238 (pCi/L)
Jun-95	—	—	—	—	—	—	—	—	—	—	—	—
Jul-95	—	—	—	—	—	—	—	—	—	—	—	—
Aug-95	—	—	—	—	—	—	—	—	—	—	—	—
Sep-95	—	—	—	—	—	—	—	—	—	—	—	—
Oct-95	—	—	—	—	—	—	—	—	—	—	—	—
Nov-95	137.7	—	6.31	53.46	—	—	—	—	—	—	—	—
Dec-95	—	—	—	—	—	—	—	—	—	—	—	—
Jan-97	—	—	—	—	—	—	—	—	—	—	—	—
Feb-97	—	—	—	—	—	—	—	—	648.545	—	26.269	300.047
Mar-97	—	—	—	—	—	—	—	—	—	—	—	—
Apr-97	—	—	—	—	—	—	—	—	—	—	—	—
May-97	—	—	—	—	—	—	—	—	816.409	—	37.202	383.936
Jun-97	—	—	—	—	—	—	—	—	—	—	—	—
Jul-97	—	—	—	—	—	—	—	—	—	—	—	—
Aug-97	—	—	—	—	—	—	—	—	—	—	—	—
Sep-97	—	—	—	—	—	—	—	—	—	837.835	51.213	372.232
Oct-97	—	—	—	—	—	—	—	—	—	—	—	—
Nov-97	—	—	—	—	—	—	—	—	—	—	—	—
Dec-97	—	—	—	—	—	—	—	—	—	835.924	44.05	350.039
Jan-98	—	—	—	—	—	—	—	—	—	—	—	—
Feb-98	—	—	—	—	—	—	—	—	—	—	—	—
Mar-98	—	—	—	—	—	75.172	3.901	11.718	—	661.576	31.274	317.471
Apr-98	—	—	—	—	—	—	—	—	—	828.775	50.867	380.116
May-98	—	—	—	—	—	—	—	—	—	—	—	—
Jun-98	—	—	—	—	—	—	—	—	—	—	—	—
Jul-98	—	—	—	—	—	—	—	—	—	—	—	—
Aug-98	—	—	—	—	—	—	—	—	—	—	—	—
Sep-98	—	—	—	—	—	—	—	—	246.317	—	12.41	108.304
Oct-98	—	—	—	—	—	—	—	—	—	—	—	—
Nov-98	—	—	—	—	—	—	—	—	—	—	—	—
Dec-98	—	—	—	—	—	—	—	—	622.473	—	39.631	237.783

pCi/L - picocuries per liter

— no data for this sampling period

Table 2-1. Summary of Occurrence Data in Monitoring Wells - Total Uranium and Volatile Organics

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 109A U233,234 (pCi/L)	Well 109A U234 (pCi/L)	Well 109A U235 (pCi/L)	Well 109A U238 (pCi/L)	Well 110A U233,234 (pCi/L)	Well 110A U234 (pCi/L)	Well 110A U235 (pCi/L)	Well 110A U238 (pCi/L)	Well 111A U233,234 (pCi/L)	Well 111A U234 (pCi/L)	Well 111A U235 (pCi/L)	Well 111A U238 (pCi/L)
Jun-95	—	—	—	—	—	—	—	—	—	—	—	—
Jul-95	—	—	—	—	—	—	—	—	—	—	—	—
Aug-95	—	—	—	—	—	—	—	—	—	—	—	—
Sep-95	—	—	—	—	—	—	—	—	—	—	—	—
Oct-95	—	—	—	—	—	—	—	—	—	—	—	—
Nov-95	—	—	—	—	—	—	—	—	—	—	—	—
Dec-95	—	—	—	—	—	—	—	—	—	—	—	—
Jan-97	—	—	—	—	—	—	—	—	—	—	—	—
Feb-97	282.711	—	22.535	555.178	10.22	—	.548 B	2.464	6.566	—	.101 B	0.303 UJ
Mar-97	—	—	—	—	—	—	—	—	—	—	—	—
Apr-97	—	—	—	—	—	—	—	—	—	—	—	—
May-97	174.078	—	9.178	277.791	7.279	—	0.531	2.957	10.084	—	.062 UJ	1.294
Jun-97	—	—	—	—	—	—	—	—	—	—	—	—
Jul-97	—	—	—	—	—	—	—	—	—	—	—	—
Aug-97	—	—	—	—	—	—	—	—	—	—	—	—
Sep-97	—	146.971	9.929	272.242	—	7.978	0.276	1.696	—	6.238	0.136	0.679
Oct-97	—	—	—	—	—	—	—	—	—	—	—	—
Nov-97	—	—	—	—	—	—	—	—	—	—	—	—
Dec-97	—	191.785	13.699	333.028	—	—	—	—	—	—	—	—
Jan-98	—	—	—	—	—	—	—	—	—	—	—	—
Feb-98	—	—	—	—	—	—	—	—	—	—	—	—
Mar-98	—	241.434	18.874	372.04	—	—	—	—	—	—	—	—
Apr-98	—	—	—	—	—	—	—	—	—	—	—	—
May-98	—	233.565	18.114	376.845	—	—	—	—	—	—	—	—
Jun-98	—	—	—	—	—	—	—	—	—	—	—	—
Jul-98	—	—	—	—	—	—	—	—	—	—	—	—
Aug-98	—	—	—	—	—	—	—	—	—	—	—	—
Sep-98	107.639	—	10.329	210.93	—	—	—	—	—	—	—	—
Oct-98	—	—	—	—	—	—	—	—	—	—	—	—
Nov-98	—	—	—	—	—	—	—	—	—	—	—	—
Dec-98	14.381	—	1.144	26.205	—	—	—	—	—	—	—	—

pCi/L - picocuries per liter

J - estimated value

U - value less than the minimal detectable concentration

— = no data for this sampling period

Table 2-1. Summary of Occurrence Data in Monitoring Wells - Total Uranium and Volatile Organics

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Date Measured	Well 112A U233,234 (pCi/L)	Well 112A U234 (pCi/L)	Well 112A U235 (pCi/L)	Well 112A U238 (pCi/L)	Well 113A U233,234 (pCi/L)	Well 113A U234 (pCi/L)	Well 113A U235 (pCi/L)	Well 113A U238 (pCi/L)	Well 114A U233,234 (pCi/L)	Well 114A U234 (pCi/L)	Well 114A U235 (pCi/L)	Well 114A U238 (pCi/L)
Jun-95	—	—	—	—	—	—	—	—	—	—	—	—
Jul-95	—	—	—	—	—	—	—	—	—	—	—	—
Aug-95	—	—	—	—	—	—	—		—	—	—	—
Sep-95	—	—	—	—	—	—	—		—	—	—	—
Oct-95	—	—	—	—	—	—	—		—	—	—	—
Nov-95	—	—	—	—	—	—	—		—	—	—	—
Dec-95	—	—	—	—	—	—	—		—	—	—	—
Jan-97	—	—	—	—	—	—	—		—	—	—	—
Feb-97	2.172	—	.207 B	0.103	1.158	—	0 B	0 UJ	0.579	—	.579 B	.29 UJ
Mar-97	—	—	—	—		—	—		—	—	—	—
Apr-97	—	—	—	—		—	—		—	—	—	—
May-97	0.26	—	0.065 UJ	0.065 UJ	0.394	—	0.056 UJ	.113 UJ	.647 UJ	—	.216 UJ	.647 UJ
Jun-97	—	—	—	—	—	—	—		—	—	—	—
Jul-97	—	—	—	—	—	—	—		—	—	—	—
Aug-97	—	—	—	—	—	—	—		—	—	—	—
Sep-97	—	0.873	0 UJ	0.0 UJ	—	0.282	.056 UJ	0.056	—	0.449	.013 UJ	0.053
Oct-97	—	0.35	0 UJ	0.0 UJ	—	0.0 UJ	.109 UJ	0.0 UJ	—	—	—	—
Nov-97	—	—	—	—	—	—	—		—	—	—	—
Dec-97	—	—	—	—	—	—	—		—	—	—	—
Jan-98	—	—	—	—	—	—	—		—	—	—	—
Feb-98	—	—	—	—	—	—	—		—	—	—	—
Mar-98	—	—	—	—	—	—	—		—	—	—	—
Apr-98	—	—	—	—	—	—	—		—	—	—	—
May-98	—	—	—	—	—	—	—		—	—	—	—
Jun-98	—	—	—	—	—	—	—		—	—	—	—
Jul-98	—	—	—	—	—	—	—		—	—	—	—
Aug-98	—	—	—	—	—	—	—		—	—	—	—
Sep-98	—	—	—	—	—	—	—		—	—	—	—
Oct-98	—	—	—	—	—	—	—		—	—	—	—
Nov-98	—	—	—	—	—	—	—		—	—	—	—
Dec-98	—	—	—	—	—	—	—		—	—	—	—

pCi/L - picocuries per liter

B - detected in the blank at similar concentrations or activities
J - estimated value
U - value less than the minimal detectable concentration

Table 2-1. Summary of Occurrence Data in Monitoring Wells - Total Uranium and Volatile Organics

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 114B U233,234 (pCi/L)	U234 (pCi/L)	U235 (pCi/L)	U238 (pCi/L)	Well 115A U233,234 (pCi/L)	U234 (pCi/L)	U235 (pCi/L)	U238 (pCi/L)
Jun-95	—	—	—	—	—	—	—	—
Jul-95	—	—	—	—	—	—	—	—
Aug-95	—	—	—	—	—	—	—	—
Sep-95	—	—	—	—	—	—	—	—
Oct-95	—	—	—	—	—	—	—	—
Nov-95	—	—	—	—	—	—	—	—
Dec-95	—	—	—	—	—	—	—	—
Jan-97	—	—	—	—	—	—	—	—
Feb-97	0.987	—	.37 B	0.123	0.241	—	0 B	0.483
Mar-97	—	—	—	—	—	—	—	—
Apr-97	—	—	—	—	—	—	—	—
May-97	.609 UJ	—	.203 UJ	0.102 UJ	.339 UJ	—	.226 UJ	0.0 UJ
Jun-97	—	—	—	—	—	—	—	—
Jul-97	—	—	—	—	—	—	—	—
Aug-97	—	—	—	—	—	—	—	—
Sep-97	—	0.299	.0176 UJ	.018 UJ	—	0.347	.0128 UJ	0.0 UJ
Oct-97	—	—	—	—	—	—	—	—
Nov-97	—	—	—	—	—	—	—	—
Dec-97	—	—	—	—	—	—	—	—
Jan-98	—	—	—	—	—	—	—	—
Feb-98	—	—	—	—	—	—	—	—
Mar-98	—	—	—	—	—	—	—	—
Apr-98	—	—	—	—	—	—	—	—
May-98	—	—	—	—	—	—	—	—
Jun-98	—	—	—	—	—	—	—	—
Jul-98	—	—	—	—	—	—	—	—
Aug-98	—	—	—	—	—	—	—	—
Sep-98								
Oct-98	—	—	—		—			
Nov-98	—	—	—	—	—	—	—	—
Dec-98	—	—	—	—	—	—	—	—

pCi/L - picocuries per liter

J - estimated value

U - value less than the minimal detectable concentration

— no data for this sampling period

Table 2-1. Summary of Uranium Occurrance in Monitoring Wells

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Date Measured	Well 92 PCE (mg/L)	Well 92 TCE (mg/L)	Well 92 1,2-DCE (mg/L)	Well 92 Vinyl chloride (mg/L)	Well 97A PCE (mg/L)	Well 97A TCE (mg/L)	Well 97A 1,2-DCE (mg/L)	Well 97A Vinyl chloride (mg/L)	Well 100A PCE (mg/L)	Well 100A TCE (mg/L)	Well 100A 1,2-DCE (mg/L)	Well 100A Vinyl chloride (mg/L)	Well 101A PCE (mg/L)	Well 101A TCE (mg/L)	Well 101A 1,2-DCE (mg/L)	Well 101A Vinyl chloride (mg/L)
Jan-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-95					---			---	0.005617	0.01221	0.010612	0.005	0.01519	0.00998	0.20924	0.00718
Apr-95	---			---	---	---		---	---	---	---	---	---	---	---	---
May-95	---	---	---	---	---	---	---	---	0.004035	0.0172	0.014991	0.005	0.01105	0.00827	0.21915	0.005
Jun-95	---	---	---	---	---	---	---	---	0.00103	0.01042	0.013263	0.005	0.00008	0.01807	0.30412	0.005
Jul-95	---	---	---	---	---	---	---	---	0.023791	0.01301	0.011439	0.005	0.0158	0.00038	0.19069	0.005
Aug-95	---	---	---	---	---	---	---	---	0.011249	0.01282	0.012284	0.005	0.01242	0.00788	0.1769	0.005
Sep-95	---	---	---	---	---	---	---	---	0.02874	0.0166	0.019722	0.005	0.04245	0.00532	0.15741	0.005
Oct-95		---	---	---	---	---	---	---	0.008635	0.00862	0.009849	0.005	0.01074	0.0098	0.14884	0.005
Nov-95		---	---	---	---	---	---	---	0.005759	0.01044	0.008413	0.005	0.02364	0.02216	0.20169	0.005
Dec-95	---	---	---	---	---	---	---	---	0.023889	0.00941	0.011477	0.005	0.05883	0.0722	0.48706	0.03136
Jan-96	---	---	---	---	---	---	---	---	0.026795	0.00795	0.012468	0.005	0.05244	0.04823	0.26064	0.08295
Feb-96	---	---	---	---	0.017	0.005	0.0082	0.01	0.012982	0.01531	0.019245	0.005	0.05341	0.06239	0.39124	0.08094
Mar-96	0.005	0.005	0.005	0.01	---	---	---	---	0.014945	0.01234	0.029431	0.005	0.00008	0.04529	0.22034	0.08028
Apr-96	---	---	---	---	---	---	---	---	0.024185	0.0098	0.017698	0.005	0.00008	0.00038	0.28871	0.005
May-96	---	---	---	---	---	---	---	---	0.022427	0.01394	0.028348	0.005	0.00008	0.02133	0.22578	0.02599
Jun-96	---	---	---	---	---	---	---	---	0.019449	0.01227	0.01692	0.005	0.08241	0.0858	0.23612	0.11461
Jul-96	---	---	---	---	---	---	---	---	0.014117	0.01349	0.012884	0.012115	0.00008	0.07976	0.20492	0.12016
Aug-96	---	---	---	---	---	---	---	---	0.010551	0.01044	0.009145	0.005	0.00008	0.00038	0.18875	0.005
Sep-96	---	---	---	---	---	---	---	---	0.012618	0.00981	0.009132	0.005	0.00008	0.05439	0.16095	0.06768
Oct-96	---	---	---	---	---	---	---	---	0.022979	0.00953	0.018264	0.005	0.94934	0.06029	0.04425	0.005
Nov-96	---	---	---	---	---	---	---	---	0.009405	0.00799	0.008	0.005	0.07315	0.0441	0.16562	0.006589
Dec-96	---	---	---	---	---	---	---	---	0.009935	0.0077	0.017732	0.005	0.07588	0.04803	0.23117	0.07044
Jan-97	---	---	---	---	---	---	---	---	0.017917	0.01202	0.013699	0.005	0.07753	0.05751	0.31037	0.0744
Feb-97	---	---	---	---	---	---	---	---	0.018585	0.00709	0.019523	0.005	0.0008	0.04926	0.24908	0.05
Mar-97		---	---	---	---	---	---	---	0.006943	0.00872	0.036184	0.005784	0.04514	0.03656	0.27236	0.06158
Apr-97								---	0.006048	0.02072	0.122319	0.007542	0.0008	0.02886	0.25749	0.06365
May-97	---	---			0.007148	0.00076	0.011146	0.01	0.016759	0.01696	0.078754	0.007799	0.02221	0.03196	0.23223	0.07201
Jun-97	---	---	---	---	---	---	---	---	0.013217	0.01167	0.058	0.007136	0.0008	0.0298	0.18017	0.06929
Jul-97	---	---	---	---	---	---	---	---	0.0212	0.0073	0.0275	0.005	0.022	0.029	0.171	0.069
Aug-97							---	---	0.0184	0.0067	0.012	0.005	0.001	0.028	0.145	0.068
Sep-97					0.0098	0.0035	0.0086	0.005	0.0183	0.0064	0.014	0.005	0.06	0.037	0.22	0.05
Oct-97	---		---	---	---	---	---	---	0.0155	0.006	0.0139	0.005	0.067	0.042	0.219	0.05
Nov-97	---	---	---	---	---	---	---	---	0.0157			0.005	0.0143	0.0057	0.013	0.005
Dec-97	---	---	---	---	0.0035	0.0004	0.0055	0.005	0.064	0.004	0.08	0.05		0.102	0.407	0.119
Jan-98	---	---	---	---	---	---	---	---	0.0111	0.0061	0.0115	0.005	0.0884	0.0843	0.3537	0.16
Feb-98	---	---	---	---	---	---	---	---	0.0108	0.0085	0.0099	0.005	0.0926	0.0838	0.3462	0.1786
Mar-98	---	---	---	---	0.0075	0.003	0.0111	0.005	0.0227	0.0179	0.0735	0.0097	0.0495	0.0375	0.2544	0.0836
Apr-98	---	---	---	---	---	---	---	---	0.0291	0.0224	0.1026	0.0099	0.0537	0.0428	0.2735	0.0849
May-98	---	---	---	---	0.006	0.0012	0.008	0.005	0.0111	0.0092	.0249 J	0.005	0.0518 J	0.0386	0.2106	0.05
Jun-98	---	---	---	---	---	---	---	---	0.0125	0.0103	0.0492	0.005	0.001	0.0123	0.2202	0.05
Jul-98	---	---	---	---	---	---	---	---	0.0076	0.0068	0.0164	0.005	0.001	0.004	0.1487	0.05
Aug-98	---	---	---	---	0.0113	0.004	0.008	0.005	0.0097	0.0076	0.0218	0.005	0.001	0.004	0.1513	0.05
Sep-98	---	---	---	---	---	---	---	---	0.0212	0.0067	0.0134	0.005	0.001	0.004	0.1821	0.05
Oct-98	---	---	---	---		---	---	---	0.0137	0.0056	0.01	0.005	0.001	0.004	0.1341	0.05
Nov-98	---	---	---	---	---	---	---	---	0.022	0.0058	0.0093	0.005	0.001	0.004	0.0998	0.05
Dec-98	---	---	---	---	0.005	0.0004	0.008	0.005	0.0166	0.0054	0.008	0.005	0.001	0.004	0.1139	0.05
Jan-99	---	---	---	---	0.0339	0.0039	0.008	0.005	0.0121	0.0076	0.0146	0.005	0.0525	0.0409	0.2564	0.05
Feb-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-99	---	---	---	---	---	---	---	---	---		---	---	---	---	---	---
Apr-99	---	---	---	---	---	---	---	---	---		---	---	---	---	---	---

mg/L - milligrams per liter

J - estimated value

--- = no data for this sampling period

Table 2-1. Summary of Uranium Occurrance in Monitoring Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 103A PCE (mg/L)	Well 103A TCE (mg/L)	Well 103A 1,2-DCE (mg/L)	Well 103A Vinyl chloride (mg/L)	Well 104A PCE (mg/L)	Well 104A TCE (mg/L)	Well 104A 1,2-DCE (mg/L)	Well 104A Vinyl chloride (mg/L)	Well 108A PCE (mg/L)	Well 108A TCE (mg/L)	Well 108A 1,2-DCE (mg/L)	Well 108A Vinyl chloride (mg/L)	Well 109A PCE (mg/L)	Well 109A TCE (mg/L)	Well 109A 1,2-DCE (mg/L)	Well 109A Vinyl chloride (mg/L)
Jan-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-95	5.6382	0.0381	0.3404	0.005	0.000841	0.00038	0.008	0.005	---	---	---	---	---	---	---	---
Apr-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May-95		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jun-95	12.2466	0.6021	0.8858	0.005	0.000467	0.00038	0.008	0.005			---	---	---			
Jul-95	6.20015	0.35115	0.5066	0.005	---	---		---	---	---	---	---	---	---	---	
Aug-95	4.88395	0.21565	0.32235	0.005	0.000467	0.00038	0.008	0.005	---	---	---	---	---	---	---	---
Sep-95	7.7009	0.4466	0.534	0.005	---	---	---	---	---	---	---	---	---	---	---	---
Oct-95	3.4849	0.1459	0.37205	0.005	0.00008	0.00038	0.008	0.005	---		---	---	---	---	---	
Nov-95	2.6172	0.13175	0.1784	0.005							---	---	---		---	
Dec-95	7.59325	0.34705	0.957	0.005								---				
Jan-96	4.93585	0.00038	0.43925	0.005		---	---	---	---		---	---	---		---	---
Feb-96	3.9708	0.32685	0.396	0.005	---	---	---	---	6.4	0.005	0.005	0.01	---			
Mar-96	0.28288	0.00038	0.008	0.005	0.004734	0.00038	0.008	0.005	---	---	---	---	0.34	0.077	0.22	0.03
Apr-96	5.71988	0.3102	0.4398	0.005	---	---	---	---	---	---	---	---	---	---	---	---
May-96	6.06	0.41775	0.4403	0.10355	0.00008	0.00038	0.008	0.005	---	---	---	---	---	---	---	---
Jun-96	6.6356	0.57665	0.5814	0.57195	---	---	---	---	---		---	---	---	---	---	
Jul-96	6.63245	0.56255	0.5626	0.5805	0.00008	0.00038	0.008	0.005	---		---	---	---	---	---	
Aug-96	2.03405	0.14608	0.12902	0.005	---	---	---	---	---	---	---	---	---	---	---	---
Sep-96	10.0387	0.6777	0.6917	0.005			---	---	---		---	---	---	---	---	
Oct-96	10.2666	0.6324	0.6254	0.005	---	---	---		---		---	---	---			
Nov-96	5.6846	0.37515	0.39555	0.005	0.00008	0.00038	0.008	0.005	---		---	---				
Dec-96	6.848	0.3905	0.37465	0.005	---	---	---	---	---	---	---	---	---		---	---
Jan-97	7.48045	0.41585	0.4676	0.25	---	---	---	---	---	---	---	---	---	---	---	
Feb-97	7.9096	0.4386	0.497	0.2	0.00008	0.00038	0.008	0.005	1.13665	0.125564	0.201606	0.070559	0.14094	0.025527	0.139001	0.034169
Mar-97	6.3194	0.29375	0.3932	0.25	---	---	---	---	---	---	---	---	---	---	---	---
Apr-97	1.8167	0.019	0.4	0.25	---	---	---	---	---	---	---	---	---	---	---	---
May-97	3.4936	0.2803	0.5913	0.5	0.00008	0.00038	0.008	0.005	8.717	0.3074	0.8	0.5	0.3692	0.5538	0.8	0.5
Jun-97	5.6148	0.2492	0.40375	0.25	---	---	---	---	---	---	---	---	---	---	---	---
Jul-97	5.585	0.255	0.455	0.25	---	---	---	---	---	---	---	---	---	---	---	---
Aug-97	5.195	0.24	0.4	0.25	0.0001	0.0004	0.008	0.005	---	---	---	---	---	---	---	---
Sep-97	3.665	0.235	0.53	0.25	---	---	---	---	14.61	0.4	1.02	0.5	0.111	0.039	0.139	0.05
Oct-97	5.84	0.275	0.6	0.25	0.006	0.0004	0.0084	0.005	---	---	---	---	---	---	---	---
Nov-97	4.315/3.186 J	0.25/0.198	0.495	0.25/.043 J		---	---	---	---	---	---	---	---	---		
Dec-97	4.1139	0.1765	0.3825	0.25		---	---	---	14.091	0.6205	1.204	0.625	0.0783	0.0273	0.084	0.05
Jan-98	1.8886	0.2783	0.4572	0.25	---	---			---		---	---	---	---	---	---
Feb-98	2.4039	0.2819	0.3488	0.25	0.0001	0.0004	0.008	0.005	---		---	---	---	---	---	---
Mar-98	4.4634	0.2094	0.435	0.25	---	---	---	---	12.5713	0.2779	0.6979	0.5	0.1546	0.0344	0.1191	0.05
Apr-98	5.7773	0.3076	0.2346	0.25	0.0001	0.0004	0.008	0.005	11.8002	0.4198	0.8	0.5	---	---	---	---
May-98	10.1597	0.5015	0.8	0.5	---	---	---	---	---	---	---	---	0.1368	0.0178	0.08	0.1034
Jun-98	1.8344 J	0.1846	0.4	0.25	---	---	---	---	---		---	---	---	---	---	---
Jul-98	9.5296	0.5631 B	0.8	0.5	---	---		---	---	---	---	---	---	---	---	---
Aug-98	5.2896	0.2682	0.4	0.25	0.0001	0.0004	0.008	0.005	---		---	---	---	---	---	
Sep-98	3.8781	0.02	0.2657	0.25	---	---	---	---	8.109	0.1	2	1.25	0.1377	0.0466	0.1753	0.05
Oct-98	5.8539 J	0.04	0.800 J	0.5	---	---	---	---	---	---	---	---	---	---	---	---
Nov-98	6.7459	0.04	0.8	0.5	0.0001	0.0004	0.008	0.005	---	---	---	---	---	---	---	
Dec-98	5.4053	0.2143	0.4	0.25	---	---	---	---	19.583	0.100 J	2.000 J	1.250 J	0.3438	0.0761	0.2134	0.05
Jan-99	6.6024	0.4277	0.8 J	.500 J	---	---	---	---	13.8945	0.100 J	2.000 J	1.250 J	---	---	---	---
Feb-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-99	---	---	---	---	---	---	---	---	---		---	---	---	---	---	---
Apr-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

mg/L - milligrams per liter
J - estimated value
--- = no data for this sampling period
B - detected in the blank at similar concentrations or activities

Table 2-1. Summary of Uranium Occurrance in Monitoring Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 111A PCE (mg/L)	Well 111A TCE (mg/L)	Well 111A 1,2-DCE (mg/L)	Well 111A Vinyl chloride (mg/L)	Well 113A PCE (mg/L)	Well 113A TCE (mg/L)	Well 113A 1,2-DCE (mg/L)	Well 113A Vinyl chloride (mg/L)	Well 114B PCE (mg/L)	Well 114B TCE (mg/L)	Well 114B 1,2-DCE (mg/L)	Well 114B Vinyl chloride (mg/L)	Well 116A PCE (mg/L)	Well 116A TCE (mg/L)	Well 116A 1,2-DCE (mg/L)	Well 116A Vinyl chloride (mg/L)
Jan-95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Feb-95	--	--	--	--		--	--	--	--	--	--	--	--	--	--	
Mar-95		--	--	--			--	--	--	--	--	--	--	--	--	--
Apr-95	--	--		--		--	--	--	--	--	--	--	--	--	--	
May-95	--			--			--	--	--		--	--	--	--	--	--
Jun-95	--		--		--	--	--	--	--		--	--	--	--	--	
Jul-95	--	--	--			--	--	--	--	--	--	--	--	--	--	--
Aug-95	--			--		--	--	--	--		--	--	--	--	--	
Sep-95	--	--	--	--	--	--	--	--	--		--	--	--	--	--	
Oct-95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nov-95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dec-95	--			--	--	--	--	--	--	--	--	--	--	--	--	
Jan-96			--										--			
Feb-96	8.4	0.005	0.6	0.01	0.063	0.005	0.005	0.01	--	--		--	--	--	--	
Mar-96	--	--	--	--	--	--	--	--	0.92	0.073	0.059	0.01	--	--	--	
Apr-96	--	--	--	--		--	--	--	--	--	--	--	--	--	--	
May-96		--		--		--	--	--	--	--	--	--	--	--	--	
Jun-96												--	--	--	--	
Jul-96	--		--	--		--	--					--	--	--		
Aug-96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Sep-96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Oct-96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nov-96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Dec-96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Jan-97	--	--	--	--	--	--	--	--	--	--	--	--	0.49	0.02	--	0.02
Feb-97	5.48415	0.39485	1.8117	0.25	0.51085	0.019	0.19895	0.25	1.2705	0.2457	0.184	0.25	--	--	--	--
Mar-97	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Apr-97	--	--		--		--	--	--	--		--	--	0.44045	0.03247	0.03118	0.05
May-97	10.4607	0.3241	1.4078	0.5	0.27855	0.019	0.4	0.25	1.1493	0.1722	0.4	0.25	--	--	--	--
Jun-97	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Jul-97	--	--	--	--	--	--	--	--	--	--	--	--	0.47785	0.02775	0.04386	0.025
Aug-97	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sep-97				--	0.229	0.004	0.08	0.05	2.41	0.1525	0.25	0.125	--	--		
Oct-97			--	--	0.2	0.004	0.084	0.05	--	--	--	--	0.599	0.03	--	0.004
Nov-97	2.915	0.26	0.93	0.25	--	--	--	--	--	--	--	--	--	--	--	--
Dec-97			--	--		--	--	--	2.8837	0.2132	0.268	0.125	--	--	--	
Jan-98	--			--		--	--	--	--	--	--	--	--	--	--	
Feb-98					--	--	--	--	--	--	--	--	--	--	--	
Mar-98	4.2260 HJ	0.3422 HJ	1.1847 HJ	0.250 HJ	0.1959	0.004	0.08	0.05	1.5004	0.081	0.129	0.0833	1.007	0.035	--	0.007
Apr-98	--	--	--	--	0.0643	0.0433	0.08	0.05	--	--	--	--	--	--	--	--
May-98	12.5405 J	0.2003 J	0.9011 J	0.500 J	--	--	--	--	--		--	--	0.04	0.004	--	0.004
Jun-98									1.6164	0.1989	0.4	0.25	--		--	
Jul-98												--				
Aug-98		--										--	--		--	
Sep-98	9.2133	0.4174	0.9238	0.5	0.0751	0.004	0.08	0.05	1.8631	0.1402	0.1412	0.125	0.971	0.03	--	0.008
Oct-98	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nov-98	4.0345 J	0.2043	0.431	0.25	0.1538 J	0.004	0.08	0.05	--	--	--	--	1.221 HJ	0.043	--	0.009
Dec-98	--	--	--	--	--	--	--	--	1.8506 J	0.1341	0.2	0.125	--	--	--	--
Jan-99	2.2130 J	0.2451	1.1292	0.25	--	--	--	--	--	--	--	--	--	--	--	--
Feb-99	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Mar-99	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Apr-99	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

mg/L - milligrams per liter
J - estimated value
-- = no data for this sampling period
H - sample exceeded holding time

Table 2-1. Summary of Uranium Occurrance in Monitoring Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 116B PCE (mg/L)	Well 116B TCE (mg/L)	Well 116B 1,2-DCE (mg/L)	Well 116B Vinyl chloride (mg/L)	Well 117A PCE (mg/L)	Well 117A TCE (mg/L)	Well 117A 1,2-DCE (mg/L)	Well 117A Vinyl chloride (mg/L)	Well 117B PCE (mg/L)	Well 117B TCE (mg/L)	Well 117B 1,2-DCE (mg/L)	Well 117B Vinyl chloride (mg/L)	Well 119A PCE (mg/L)	Well 119A TCE (mg/L)	Well 119A 1,2-DCE (mg/L)	Well 119A Vinyl chloride (mg/L)
Jan-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Apr-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jun-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jul-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Aug-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sep-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Oct-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Nov-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dec-95	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jan-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Apr-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jun-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jul-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Aug-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sep-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Oct-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Nov-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dec-96	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jan-97	2.4	.091 J	---	0.05	0.15	0.012	---	0.012	0.5	0.05	---	0.05	0.13	.011 J	---	0.002
Feb-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Apr-97	2.7858	0.14235	0.22125	0.125	0.14079	0.01557	0.01289	0.025	0.47335	0.04381	0.03837	0.05	0.081215	0.016645	0.011955	0.025
May-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jun-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jul-97	2.48697	0.10605	0.20122	0.0833	0.209895	0.018015	0.03025	0.025	---	---	---	---	0.1212	0.01892	0.02702 J	0.025
Aug-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sep-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Oct-97	1.823	0.066	---	0.017	0.227	0.012	---	0.004	0.384	0.023	---	0.004	.0144 J	0.016	---	0.004
Nov-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dec-97	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jan-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-98	2.789	0.097	---	0.019	0.161	0.007	---	0.004	0.519	0.025	---	0.004	0.004	0.004	---	0.004
Apr-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May-98	2.595 HJ	0.097	---	0.022	0.127	0.005	---	0.004	0.462	0.023	---	0.004	0.004	0.004	---	0.004
Jun-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jul-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Aug-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sep-98	2.992	0.096	---	0.026	0.253	0.01	---	0.004	0.53	0.022	---	0.004	0.099	0.007	---	0.004
Oct-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Nov-98	2.763	0.092	---	0.023	0.3	0.013	---	0.004	0.459	0.023	---	0.004	0.146	0.011	---	0.004
Dec-98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Jan-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Feb-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mar-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Apr-99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

mg/L - milligrams per liter
J - estimated value
- - - = no data for this sampling period
H - sample exceeded holding time

Table 2-1. Summary of Uranium Occurrance in Monitoring Wells
Nuclear Fuel Services, Inc. Erwin, Tennessee

Date Measured	Well 120A PCE (mg/L)	Well 120A TCE (mg/L)	Well 120A 1,2-DCE (mg/L)	Well 120A Vinyl chloride (mg/L)	Well 120B PCE (mg/L)	Well 120B TCE (mg/L)	Well 120B 1,2-DCE (mg/L)	Well 120B Vinyl chloride (mg/L)	Well 121A PCE (mg/L)	Well 121A TCE (mg/L)	Well 121A 1,2-DCE (mg/L)	Well 121A Vinyl chloride (mg/L)	Well 121B PCE (mg/L)	Well 121B TCE (mg/L)	Well 121B 1,2-DCE (mg/L)	Well 121B Vinyl chloride (mg/L)
Jan-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Feb-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apr-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jun-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jul-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sep-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oct-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nov-95					—					—	—	—	—	—	—	—
Dec-95	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—
Jan-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Feb-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apr-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jun-96	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—
Jul-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Sep-96		—	—	—	—	—			—	—	—	—	—	—		
Oct-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nov-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dec-96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jan-97	0.29	0.016	—	0.001	0.46	.018 J	—	0.001	0.062	0.005 J	—	0.001	0.097	.005 J	—	0.001
Feb-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apr-97	0.17489	0.02765	0.01858	0.05	0.29738	0.02575	0.022445	0.025	0.097752	0.006847	0.005431 UJ	0.005	0.091697	0.006752	0.004536 UJ	0.005
May-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jun-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jul-97	0.29965	0.02282	0.03237	0.025	0.25482	0.02176	0.03602	0.025	0.08803	0.01381	—	0.025	0.07986	0.01426	0.02676 J	0.025
Aug-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sep-97			—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oct-97	0.203	0.014	—	0.004	0.364	0.024	—	0.004	0.079	0.005	—	0.004	0.069	0.005	—	0.004
Nov-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dec-97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jan-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Feb-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar-98	0.284	0.018	—	0.004	.386 B	0.023	—	0.004	—	—	—	—	—	—	—	—
Apr-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May-98	0.279	0.015	—	0.004	0.309	0.019	—	0.004	—	—	—	—	—	—	—	—
Jun-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jul-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sep-98	0.229	0.013	—	0.004	0.2	0.012	—	0.004	—	—	—	—	—	—	—	—
Oct-98	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—
Nov-98	0.209	0.011	—	0.004	0.351	0.018	—	0.004	—	—	—	—	—	—	—	—
Dec-98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jan-99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Feb-99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar-99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apr-99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

mg/L - milligrams per liter
J - estimated value
--- = no data for this sampling period
H - sample exceeded holding time
B - detected in the blank at similar concentrations or activities
U - value less than the minimal detectable concentration

Table 2-2. Summary for Groundwater Biogeochemical Data

Nuclear Fuel Services, Inc. Erwin, Tennessee

	Monitoring Well					
	Well 107A (background)	Well 103A	Well 116A	Well 118A	Well 120A	Well 121A
Volatiles (mg/L)						
Tetrachloroethene	< 0.004	3.186	0.710	0.008	0.250	0.090
Trichloroethene	< 0.004	0.198	< 0.050	0.007	< 0.025	< 0.005
1,2 Dichloroethene (cis)	< 0.004	0.278	< 0.050	0.006	< 0.025	< 0.005
1,2 Dichloroethene (trans)	< 0.004	< 0.004	< 0.050	< 0.001	< 0.025	< 0.005
Vinyl Chloride	< 0.004	0.043	< 0.050	< 0.001	< 0.025	< 0.005
Benzene	< 0.004	< 0.004	< 0.050	< 0.001	< 0.025	< 0.005
Toluene	< 0.004	0.005	< 0.050	< 0.001	< 0.025	< 0.005
Ethylbenzene	< 0.004	< 0.004	< 0.050	< 0.001	< 0.025	< 0.005
Xylenes	< 0.004	< 0.004	< 0.050	< 0.001	< 0.025	< 0.005
1,1,1 Trichloroethane	< 0.004	1.004	< 0.050	< 0.001	< 0.025	< 0.005
1,1 Dichloroethene	< 0.004	2.004	< 0.050	< 0.001	< 0.025	< 0.005
Chloroethane	0.020	0.020	< 0.050	< 0.001	< 0.025	< 0.005
Miscellaneous (mg/L)						
Nitrate	3.65	0.347	3.55	4.63	9.18	5.93
Iron	< 0.10	0.930	< 0.10	0.275	0.212	< 0.10
Sulfate	2.0	16.6	52.0	68.4	17.3	15.2
Sulfide	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Methane	0.00856	no data	0.005006	0.003403	0.000376	0.000371
Chloride	10.5	42.6	11.9	21.9	8.94	8.16
Field Parameters						
Dissolved Oxygen	5.17	3.38	2.01	0.25	2.12	0.45
Temperature (°C)	17.91	15.91	16.09	16.8	15.09	13.86
pH	4.21	6.44	7.22	6.99	7.51	7.9
Specific Conductivity (mmho)	80	374	487	650	294	244

mg/L - milligrams per liter
°C - degrees centigrade
mmho - micro mhos

Table 2 - 3. Summarization of Potential Exposure Pathways

Population Potentially Exposed	Exposure Medium and Exposure Point	Complete Pathway	Reason for Selection or Exclusion	Exposure Concentration Data
Current Land Use				
Residents	Ingestion of groundwater from water supply wells. Dermal contact and inhalation of groundwater during home use.	No	Land zoned industrial. No domestic or other wells downgradient. Drinking water is provided municipal water system.	NA
Industrial Workers	Utilizing groundwater for drinking and general industrial purposes.	No	All local industries are presently using municipal water system.	NA
	Utilizing groundwater for process cooling water systems.	No	Groundwater is not used; system is closed - non contact.	NA
Recreational Users	Ingestion of water from swimming. Dermal exposure from water activities. Ingestion of contaminated fish.	Yes	Excluded because water analytical results are below the State of Tennessee Water Quality Standards (1995).	Surface water data
Future Land Use				
Residents	Ingestion of groundwater from water supply wells. Dermal contact and inhalation of groundwater during home use.	No	Land zoned industrial and anticipated to remain industrial. Municipal water system is available for new residents.	NA
Industrial Workers	Utilizing groundwater for drinking and general industrial purposes.	No	Municipal water system is used by industries and is anticipated to remain abundant and cost effective.	NA
	Utilizing groundwater for process cooling water systems.	No	Groundwater is not expected to be used; system is closed - non contact.	NA
Recreational Users	Ingestion of water from swimming. Dermal exposure from water activities. Ingestion of contaminated fish.	Yes	Excluded because water analytical results are below the State of Tennessee Water Quality Standards (1995).	Surface water data
Construction Workers	Dermal and inhalation exposure from construction activities below the groundwater surface (e.g. placement of footers).	Yes	Construction of buildings on-site and off-site in industrial park could occur in the future.	On-site and off-site monitoring well data

Table 2-4. Risk Assessment Constituents of Concern and Risk Assessment Remedial Goal Options

Nuclear Fuel Services, Inc. Erwin, Tennessee

Constituent of Concern	Arithmetic Mean Concentration (mg/L)		Remedial Goal Options						RCRA Action Level (mg/L)
			Carcinogen			Noncarcinogen			
	On-Site	Off-Site	1E-6	1E-5	1E-4	0.1	1	3	
Volatile Organics									
1,2-DCE (total)	0.405	NA	NA	NA	NA	0.32	3.2	9.6	0.07
1,2-DCE (cis)	NA	0.025	NA	NA	NA	3.67	36.7	106.7	0.07
1,2-DCE (trans)	NA	< 0.015	NA	NA	NA	7.11	71.1	231.4	0.1
PCE	1.72	0.508	2.37	23.7	237	3.14	31.4	94.4	0.005
TCE	0.062	0.025	3.89	38.9	389	0.21	2.1	6.3	0.005
Vinyl chloride	0.118	< 0.015	0.076	0.76	7.6	NA	NA	NA	0.002
Semivolatiles									
TBP	21.24	NA	NA	NA	NA	10.1	101	302.8	0.2

$$RGO = \frac{TR \times BW \times AT \times 365}{EF \times ED \times ET \times \{(SFi \times K \times IR) + (SFd \times SA \times PC \times CF)\}} \quad OR \quad \frac{TR \times BW \times AT \times 365}{EF \times ED \times ET \times \{(1/RfDi \times K \times IR) + 1/RfDd \times SA \times PC \times CF)\}}$$

TR = target risk (1E6-3)
BW = body weight (70 kg)
EF = exposure frequency (73 day/yr)
ED = exposure duration (1 yr)
ET = exposure time (0.76 hr/day)
K = volatilization factor (chemical specific)
IR = inhalation rate (2.5 m^3/hr)
SA = exposed surface area (3565 cm^2)
PC = permeability constant (chemical specific)
CF = conversion factor (1L/1000 cm^3)

Carcinogen
SFi = inhalation slope factor (chemical specific)
SFd = dermal slope factor (chemical specific)
AT = averaging time (70 yr)

Noncarcinogen
RfDi = inhalation reference dose (chemical specific)
RfDd - dermal reference dose (chemical specific)
AT = averaging time (1 yr)

NOTE: Groundwater exposure scenario only.
REFERENCE: Groundwater Risk Assessment, Nuclear Fuel Services, Inc., June 1997 (Table 6-1)

Table 3-1. Federal and State of Tennessee Applicable Requirements
NFS, Inc. Erwin, Tennessee

Chemical-Specific ARARs

Requirement	Requirement Synopsis	Consideration for the Site
Groundwater		
Safe Drinking Water Act (SDWA) - Maximum Contaminant Levels (MCLs) (40 Code of Federal Regulations (CFR) 141.11 - 141-.16)	MCLs have been promulgated for a number of common organic and inorganic contaminants. These are legally enforceable levels that regulate the concentration of contaminants in public drinking water supplies, but may also be considered relevant and appropriate for groundwater aquifers used for drinking water or potential sources of drinking water.	Bedrock aquifer may be a potential source of drinking water. MCLs should be used to assess the potential risks to human health due to consumption of groundwater. Contaminant concentrations should be compared to their respective MCLs, if available.
SDWA - Maximum Contaminant Level Goals (MCLGs) (40 CFR 141.50 - 141.52)	MCLGs are health-based criteria for a number of organic and inorganic contaminants in drinking water sources. MCLGs are used in cases in which multiple contaminants or pathways of exposure present extraordinary risks to human health.	The 1990 NCP states the non-zero MCLGs are to be used as goals. Contaminant concentrations in groundwater should be compared to their respective MCLGs, if available.
Tennessee State Drinking Water Rules - MCLs, Chapter 1200-5-1-.06, 12, 25	Tennessee state regulation that establishes primary and secondary drinking water standards.	See SDWA MCLs, same consideration.
Tennessee Hazardous Waste Management Act - Hazardous Waste Management Rules, Chapter 1200-1-11-.06(6)(a)	Establishes standards for management of hazardous waste.	Should any soil or groundwater be found to be characteristically hazardous, or a listed hazardous waste, those standards could apply during investigation and remediation (only to "RCRA-hazardous" waste streams).

Table 3-1. Federal and State of Tennessee Applicable Requirements
NFS, Inc. Erwin, Tennessee

Requirement	Requirement Synopsis	Consideration for the Site
	Chemical-Specific ARARs	
Groundwater (continued)		
National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 71)	Standards promulgated under the Clean Air Act (CAA) for significant sources of vinyl chloride, benzene, asbestos, wet dust particulates, etc. These standards are also for sources that have the potential to emit 10 tons/year of any single hazardous air pollutant or 25 tons of all pollutants/year.	Remedial actions (e.g., air stripping) may result in release of hazardous air pollutants.
National Pollutant Discharge Elimination System (NPDES) discharges to surface water	Standards for both on-site and off-site discharges to surface water of treated or untreated groundwater.	Applicable in developing remediation goals for groundwater discharged to surface water (i.e., streams).
	Action-Specific ARARs	
Requirement	**Requirement Synopsis**	**Consideration for the Site**
OSHA Requirements (29 CFR 1910, 1926, and 1904)	Regulations provide occupational safety and health requirements applicable to workers engaged in on-site field activities.	Required for site workers during construction and operation of remedial activities.
DOT Rules for Hazardous Materials Transport (49 CFR 107, 171.1-500)	Regulates the transport of hazardous waste materials including packaging, shipping, and placarding.	Remedial actions may include off-site treatment and disposal (e.g., off-site regeneration of activated carbon).

Table 3-1. Federal and State of Tennessee Applicable Requirements
NFS, Inc. Erwin, Tennessee

Requirement	Action-Specific ARARs Requirement Synopsis	Consideration for the Site
Underground Injection Control (UIC) Program (40 CFR 144, 146)	Regulations promulgated under the Safe Drinking Water Act, which ensure that operation of the underground injections will not endanger drinking water sources. Regulations include construction, operation, and maintenance requirements for injection wells. Typically, two types of wells apply to site remediation: Class I Well: Injection of wastes (or treated groundwater) beneath the lowermost formation containing an underground drinking water source. Class IV Well: Injection of wastes (or treated groundwater) into or above an underground drinking water source. Note that injections of untreated groundwater into a Class IV well is banned.	Effluent from treatment of on-site groundwater may be reinjected (Class IV well) into the same formation from which it was withdrawn.
Clean Air Act, as amended (42 U.S.C. 7401 et seq.) NESHAPs (40 CFR 61)	Provides a national frame work for controlling air pollution which regulates any activities that affect air quality.	Remedial actions (e.g., air stripping) may result in release of hazardous air pollutants.

Table 3-1. Federal and State of Tennessee Applicable Requirements
NFS, Inc. Erwin, Tennessee

Action-Specific ARARs

Requirement	Requirement Synopsis	Consideration for the Site
Solid Waste Disposal Act as amended by the RCRA (42 U.S.C. 6901 et seq.)	Establish the basic frame work for Federal regulation of solid waste.	
Treatment, Storage, and Disposal of Hazardous Waste (40 CFR 262-266)	Regulates the treatment, storage, and disposal of hazardous waste.	Hazardous waste generated by site remediation activities must meet RCRA generator and treatment, storage, or disposal requirements.
Land Disposal Restrictions (LDRs) (40 CFR 268)	Restricts certain listed or characteristic hazardous waste from placement or disposal on land (includes injections wells) without treatment. Provides treatment standards and Best Demonstrated Available Technology (BDAT).	Treated groundwater from site may be reinjected into a Class IV well. Wastes or treatment residuals such as spent activated carbon may require disposal in a landfill. Likewise, precipitated sludge may leach toxic metals at levels considered hazardous by characteristic.
RCRA Identification and Listing of Hazardous Waste (40 CFR 261)	Regulations concerning determination of whether or not a waste is hazardous based on characteristic or listing.	Impacted groundwater and soil could potentially be RCRA hazardous wastes by either containing a RCRA-listed waste or exhibiting any RCRA characteristics.
EPA Administered Permit Programs: The Hazardous Waste Permit Program (40 CFR 270)	Regulations cover basic RCRA permitting requirements, such as application requirements, standard permit conditions, and monitoring and reporting requirements. Subpart F includes the "Permits By Rule" criteria.	Effluent from treatment of site groundwater may be discharged to a sanitary sewer directed to the local Publicly Owned Treatment Works (POTW).

Table 3-1. Federal and State of Tennessee Applicable Requirements
NFS, Inc. Erwin, Tennessee

Action-Specific ARARs		
Requirement	**Requirement Synopsis**	**Consideration for the Site**
Safe Drinking Water Act (42 U.S.C. 300f et seq.) Underground Injection Control Program (40 CFR 144, 147)	Ensures that operations of the underground injections will not endanger drinking water sources by violating MCLs or by adversely affecting health. Injection of hazardous fluids into Class IV wells is banned.	Effluent from treatment of groundwater from site may be reinjected into the same formation (Class IV well) from which it was withdrawn.
Federal Water Pollution Control Act, as amended by the CWA of 1997 (33 U.S.C. 1251 et seq.)	Creates the basic national framework for water pollution control and water-quality management in the United States.	
National Pollutant Discharge Elimination System (NPDES) Requirements (40 CFR 122)	Requires permits for the discharge of pollutants from any point source into the waters of the United States.	Effluent from treatment of groundwater may be discharged to storm water or sewage collection systems, permitted outfalls such as GWTF.
General Pretreatment Regulations for Existing and New Sources of Pollutants (40 CFR 403)	Includes positions for effluent discharge to POTW. Discharge of pollutants that pass through or interfere with the POTW, contaminate sludge, or endanger health/safety of POTW workers is prohibited.	Effluent from treatment of groundwater from site may be discharged to a sanitary sewer directed to the local POTW.

Table 3-2. SWMU 20 Groundwater Preliminary Remediation Goals
Nuclear Fuel Services, Inc. Erwin, Tennessee

Constituent of Concern	MCL or MCLG (a) (mg/L)	Risk-Based Concentration (b) (mg/L)	Background Concentration (c) (mg/L)	Groundwater PRG (d) (mg/L)
Organics				
1,2-DCE (total)	0.07	3.2	NA	0.07
1,2-DCE (cis)	0.07	36.7	NA	0.07
1,2-DCE (trans)	0.1	71.1	NA	0.1
PCE	0.005	2.37	NA	0.005
TCE	0.005	3.89	NA	0.005
Vinyl chloride	0.002	0.076	NA	0.002
Tributyl phosphate	0.2	101	NA	0.2
Radionuclides				
Uranium (piC/L)	30 (e)	NA	unknown	30

MCL - Maximum Contaminant Level
MCLG - Maximum Contaminant Level Goals
NA - Not Applicable
PRG - Preliminary Remediation Goal
mg/L - milligrams per liter
piC/L - picocuries per liter

(a) MCLs and MCLGs are based on Drinking Water Regulations and Health Advisories (Office of Water. USEPA. October 1996)
(b) For carcinogens. the risk-based goal corresponds to a 10^{-6} incremental cancer risk for each constituent. For non-carcinogens. the risk-based goal corresponds to a Hazard Quotient of 1.0 for each constituent.
(c) Background concentrations for organic constituents is zero.
(d) Hierarchy for groundwater PRGs: If a primary MCL or MCLG is available. it is used as the PRG. If an MCL or MCLG is not available. the risk-based goal is used as the PRG.
(e) Proposed MCL

Table 3-3. Comparison of SWMU 20 Groundwater Data to Preliminary Remediation Goals

Nuclear Fuel Services, Inc. Erwin, Tennessee

Constituent of Concern	Groundwater PRG (mg/L)	Max Detected Concentration (a) (mg/L)	Monitoring Well with Maximum Detection Exceeding PRG
Organics			
1,2-DCE (total)	0.07	2	108A
1,2-DCE (cis)	0.07	2	108A
1,2-DCE (trans)	0.1	2	108A
PCE	0.005	13.89	108A
TCE	0.005	0.427	103A
Vinyl chloride	0.002	1.25	108A
Tribuytl phosphate	0.2	21.24 (b)	*Unknown*
Radionucleides			
Uranium (piC/L)	30 (c)	622.47	108A

PRG - Preliminary Remediation Goal
piC/L - pico curies per liter
mg/L - milligrams per liter
(a) Jan 99 Monitoring Data
(b) Groundwater Risk Assessment (NFS 1997)
(c) proposed MCL

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
No Action	None	None	Processes such as dilution, dispersion, biodegradation, radioactive decay, or volatilization may naturally reduce the concentrations of some contaminants in some media.	All contaminants	Retained	Remedial action objectives do not allow continued migration of plume off NFS. However, retained for baseline comparison
Minimal Action	Administrative Controls	Physical Barriers	Fences, signs, or other barriers are used to limit site access.	All contaminants	Retained	
		Covenants/ Deed Restrictions	Codes, deeds, or zoning are used to restricts certain land uses.	All contaminants	Retained	
		Industrial Requirements	Industrial policies and procedures (e.g., training, standard operating procedures, badges, guards) control employee access.	All contaminants	Retained	
	Maintenance and Monitoring	Surveillance and Maintenance	Inspections of facilities and performance of preventive or corrective measures to ensure proper operation of engineered controls.	All contaminants	Retained	
		Monitoring (including Monitored Natural Attenuation)	Sampling and characterization of groundwater before, during, and after remediation will verify the effectiveness of remedial actions.	All contaminants	Retained	
Containment	Physical Barrier	Subsurface/Vertical Barriers	Usually used in conjunction with groundwater extraction; requires subsurface construction of an impermeable (~10^{-8} cm/sec) barrier composed of bentonite slurry, grout, or sheet piling to direct groundwater flow patterns to a specific control point or points.	All contaminants	Eliminated	Not applicable for varying depths of competent bedrock, industrialized area, and site boundary restrictions.

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
Containment (continued)	Hydrodynamic Controls	Groundwater Extraction [pump and treat (P&T)]	A plume of impacted groundwater can be contained or manipulated by pumping and reinjection wells (horizontal or vertical). Similar to water-table adjustment, cones of depression or recharge in the water table are developed to modify prevailing hydraulic gradients. The movement and size of the plume can be manipulated by various pumping and recharge strategies. Recovered groundwater may be treated at the surface and reinjected as part of the plume-containment program.	All contaminants	Retained	
		Vacuum-Enhanced Recovery (VER) Process	A high vacuum (20-28 inches of Hg) drawn through a well installed below the water table that extracts volatile contaminants in groundwater via pumping while stripping VOCs from the saturated and unsaturated soils from the aqueous phase into the vapor phase. Extracted groundwater and vapor-phase treatment (e.g., granular activated carbon) or other treatment systems can be included aboveground.	VOCs in groundwater and soil. Effective in moderate to low permeability formations. Metals for recovery only.	Retained	
		Hydraulic Fracturing	Used in conjunction with another contaminant recovery technology (i.e., VER process) or in-situ technology (vapor extraction). Fracturing emplaces propped horizontal fractures on vertical spacings of approx. one meter. Fractures increase contaminant movement and/or can serve as conduits for delivery of pressurized hot air or steam.	VOCs in soil or water	Eliminated	Usually applied to soils and unconsolidated sediments. Not applicable to large industrialized area.

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
In-Situ Treatment	Physical/Chemical Treatment	Permeable Reaction Walls/ Reactive Gates	A trench filled with appropriate reactive or sorbant material (e.g., granular activated carbon, ion exchange resin, or iron filings) can remove contaminants from groundwater flowing through the barrier. Process option can include DNAPL sorbants in trench. Can also be combined with subsurface vertical barriers.	All contaminants (with appropriate material) in shallow subsurface water.	Eliminated	Site infrastructure makes implementation infeasible.
		Air Sparging	Injecting air into groundwater to enhance volatilization. Coupled with collection and treatment of gases and condensate.	VOCs in groundwater.	Eliminated	Number of wells required and capture of volatilized COCs within low permeability overburden soil and bedrock is infeasible.
		Vertical Circulation Systems (In-Well Stripping)	Wells with screens near the bottom and top of a single aquifer can be operated to circulate water vertically in the aquifer and treat water within the well, and promote aerobic conditions within the aquifer. Air-lift pumping and air stripping using a blower and/or submersible pump can draw water into the well, and strip VOCs from the water as air bubbles rise through the water column. Nutrients, oxygen, electron acceptors, and other soluble reagents can be added through the well to the groundwater within the aquifer to enhance bioremediation or other in-situ treatment. Filters, bioreactors, catalysts, or other devices can also be placed in the well for sorption or degradation of contaminants.	VOCs, nitrate, NAPLs, possibly other organic or inorganic contaminants in groundwater within the radius of influence of the circulation well.	Eliminated	Large number of wells required within area of concern, low permeability soils, dependency on desorption, long-term costs, and low effectiveness in bedrock render process option infeasible.

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
In-Situ Treatment (continued)	Physical/Chemical Treatment (continued)	Mobile Enhanced Multiphase Extraction (MEME)	Employment of high vacuum and flow rates to wells to simultaneously remove both aqueous and vapor-phase constituents. Treatments are periodic with a mobile treatment unit.	VOCs	Eliminated	Same as In-Well Stripping
		Oxidation	Introduction of an oxidant, such as hydrogen peroxide (H2O2), into the subsurface within impacted groundwater. Resulting hydroxl radicals (OH-), a strong chemical oxidizer, creates instantaneous oxidation of VOCs.	VOCs and certain SVOCs. Certain compounds can inhibit process.	Retained	
		Reductive Precipitation	Injection of organic or metal reagents to facilitate rapid and sequential reductive dechlorination and/or precipitation.	VOCs, metals	Retained	
	Biological	Phytoremediation	Continuous passive treatment by use of vegetation to act as a pump for groundwater extraction and biological treatment. Also limits recharge via surface infiltration.	VOCs and certain SVOCs. Certain compounds can inhibit process. Certain metals can be bioaccumulated.	Eliminated	Area of concern paved with high traffic; Groundwater extraction at maximum root depth is not effective.
		Enhanced Bioremediation (Aerobic and Anaerobic)	Bacteria/Algae (stimulation) are used for in-situ conversion of compounds and/or immobilize the contaminant either aerobically through addition of O2 through biosparging, oxygen release compound (ORC), or anaerobically through substrate addition to promote reductive dechlorination.	VOCs, metals	Retained (Anaerobic only)	Aerobic processes are ineffective on site chlorinated VOCs and metals.
Ex-Situ Treatment	Water Physical/Chemical Treatment (used in conjunction with P&T or VER)	Chemical Reduction/Oxidation	Contaminants are either destroyed or converted to more easily handled form by addition of oxidation agents (ex. Hydrogen peroxide, ozone, etc.), UV light, TiO2 catalyst, or reducing agents (ex. ferrous sulfate, sulfur dioxide).	VOCs, metals	Retained	

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
Ex-Situ Treatment (continued)	Water Physical/ Chemical Treatment (used in conjunction with P&T or VER) (continued)	Liquid Phase Adsorption	Water is pumped through a series of vessels containing sorbant to which contaminants are adsorbed. Potential adsorbents include granular activated carbon, Amersorb®, and sulfur impregnated carbon. Granular Activated Carbon (GAC) is a well established, regenerable sorbant for VOCs. Amersorb® is a regenerable adsorption system with synthetic adsorbent with 5 to 10 times capacity of granular activated carbon.	VOCs, low concentrations of metals in water.	Retained	
		Air Stripping	Counter-current mixing of large volumes of air with water to promote transfer of VOCs to air. VOC contaminated water could be removed and stripped in a diffuser/stripper or an on-site cooling tower.	VOCs (Henry's law constant >0.003)	Retained	
		Chemical Precipitation	Chemically converts dissolved metals and/or other inorganic ions into an insoluble form, or precipitate. Metal ions generally precipitate out as hydroxides, sulfides, or carbonates and are removed as solids through flocculation, clarification, and filtration.	Metals, inorganic ions	Retained	
	Water Biological	Aerobic Biological Treatment	Aerobic biological wastewater treatment processes employ microorganisms, principally bacteria, that can use wastewater contaminants as part of their metabolism. The contaminants are thereby removed from the wastewater or transformed into a benign form. The primary mechanism of removal is oxidation with molecular oxygen serving as the oxidant or electron acceptor. The contaminant compounds serve as the electron donor and are typically referred to as substrates. The microorganisms obtain energy from mediating these redox reactions and use this energy to maintain cells and synthesize new cells or biomass.	VOCs	Eliminated	Unsuitable for expected low flow recovery, the low concentration of contaminants, startup time, and required detention times

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
Ex-Situ Treatment (continued)	Water Biological (continued)	Anaerobic Biological Treatment	Anaerobic biological wastewater treatment processes employ microorganisms, principally bacteria, that can use wastewater contaminants as part of their metabolism. The contaminants are thereby removed from the wastewater or transformed into a benign form. The primary mechanism of removal is oxidation with methane as the carbon source to promote dechlorination.	VOCs	Eliminated	Unsuitable for expected low-flow recovery, the low concentration of contaminants, startup time, and required detention times
	Air Treatment (req'd for phase transfer treatment process options)	Biofiltration	Microorganisms grow on materials such as soil, compost, peat, heather, activated carbon, or polystyrene. VOC-laden air stream is transported to biofilter bed where the microorganisms oxidize them to carbon dioxide, water, and chlorides. Pretreatment (dedusting, cooling, and humidification) of the VOC air stream is usually required.	VOCs	Eliminated	Unsuitable for the expected low recovery rates, the concentration of contaminants, startup time, and required detention times.
		Vapor Phase Adsorption	Most common VOC abatement. Gaseous VOC molecules contact the granular activated carbon (GAC) or other adsorbent and bond via weak intermolecular forces. Sensitive to temperature changes therefore requiring moisture knockout systems and in-line heaters. Spent adsorbent must be periodically replaced or regenerated. Longevity of adsorption highly dependent on VOC influent concentrations.	VOCs	Retained	

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
Ex-Situ Treatment (continued)	Air Treatment (req'd for phase transfer treatment process options) (continued)	Thermal Oxidation	VOC-laden emissions are captured by a ventilation system, pre-heated, thoroughly mixed, and combusted at high temperature to form carbon dioxide and water. Low concentration VOC streams may not possess oxidation energy required to maintain the combustion temperature, and therefore, may require supplemental fuel or electrical energy. If exhaust streams contain high VOC concentrations, dilution air may be required to prevent explosion. Chlorinated VOCs may produce HCl fumes requiring scrubber removal prior to discharge.	VOCs	Retained	
		Catalytic Oxidation	Similar to thermal oxidation except a catalyst, either precious or base metal, will allow oxidation to occur at a lower temperature. Average catalyst lifetime is 2 to 5 years. Typically applied to low VOC concentration streams.	VOCs	Eliminated	Unsuitable due to potential presence of metals which may mask catalyst.
Disposal	On- and Off-Site Discharge	On-Site Direct or Indirect Discharge to GWTF	Recovered groundwater is treated at the on-site GWTF and discharged to the City of Erwin POTW. A treatability study may be required to meet treatment process efficiencies and effluent discharge requirements.	All contaminants	Retained	
		On-Site Reinjection	Discharge of treated or partially-treated groundwater via wells or infiltration gallery downgradient or cross gradient of the impacted area. Reinjection rates are restricted by hydraulic conductivity, aquifer thickness, and available hydraulic gradient.	All contaminants	Eliminated	Unsuitable due to low soil permeability, hydraulic conductivity and space constraints.

Table 5-1. Preliminary Screening of Remedial Technologies and Process Options
NFS, Inc. Erwin, Tennessee

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability for Groundwater	Retained/ Eliminated	Justification
Disposal (continued)	On- and Off-Site Discharge (continued)	On-Site Direct Spray Irrigation	Disposal of treated or partially-treated groundwater through sprinkling of the water over grasslands or similar ground cover. Major constraints on spray irrigation are climate, since water cannot be spread/sprinkled on a frozen or water-saturated ground, and the relatively large land area required (i.e., for a year-round application rate of 2-inches per week, approximately 130 irrigated acres are required.	VOCs	Eliminated	Unsuitable due to lack of available on-site irrigation area and climate limitations.
		Off-Site Stream	Off-site disposal to a tributary of Martin Creek under a National Pollutant Discharge Elimination System (NPDES) permit following high degree of treatment.	All contaminants	Eliminated	Site GWTF incorporate discharge to Martin Creek
		Off-Site POTW	Off-site disposal to City of Erwin POTW either directly or via the on-site GWTF. Requires NPDES permit and/or effluent requirements of POTW.	All contaminants	Retained	

COCs = Constituents of Concern
DNAPL = Dense Nonaqueous Phase Liquid
GAC = Granular Activated Carbon
GWTF = Groundwater Treatment Facility
Hg = Mercury
MEME = Mobile Enhanced Multiphase Extraction
NAPL = Nonaqueous Phase Liquid
NPDES = National Pollutant Discharge Eliminatio
ORC = Oxygen Release Compound
POTW = Publicly Owned Treatment Works
P&T = Pump and Treat
SVE = Soil Vapor Extraction
SVOCs = Semi-Volatile Organic Compounds
TCE = Trichloroethene
UV = Ultraviolet
VER = Vacuum Enhanced Recovery
VOCs = Volatile Organic Compounds

Table 6-1. SWMU 20 Representative Process Options

Nuclear Fuel Services, Inc. Erwin, Tennessee

General Response Action	Technology Type	Representative Process Option
No action	No action	No action
Minimal action	Administrative controls	Fencing (1) Deed restrictions (2)
	Monitoring	Surveillance and maintenance Site monitoring (GW COCs and natural attenuation)
Containment	Hydrodynamic controls	Groundwater extraction (pump and treat) VER process
Disposal	On-site (groundwater) discharge	Discharge to local POTW
In situ treatment	Physical	Reductive precipitation Oxidation
	Biological	Enhanced anearobic bioremediation
Ex situ water treatment	Physical/Chemical	Air stripping Liquid-phase adsorption Chemical precipitation
Ex situ air treatment	Physical/Chemical	Thermal oxidation

(1) Includes NFS security requirements.
(2) Includes groundwater restrictions, if required, and NFS industrial requirements.

GW COCs - groundwater constituents of concern
VER - vacuum enhanced recovery
POTW - Publicly-Owned Treatment Works

Table 6-2. Range of Alternative Types

Nuclear Fuel Services, Inc. Erwin, Tennessee

Alternative Type
1. No Action (Baseline)
2. Containment/Limited Action - No or Minimal Treatment
3. Treatment - Addresses the Principal Threats
4. Treatment/Disposal - Eliminates or Minimizes Long-Term Management

Table 6-3. SWMU 20 Range of Alternatives

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Alternative Number	Alternative Type	RPOs Combined Into Alternatives
Alternative 1	No action	None
Alternative 2	Containment/limited action - no or minimal treatment	Deed restrictions, fencing, site monitoring
Alternative 3	Treatment -addresses the principal threats	Deed restrictions, fencing, site monitoring, VER process, air-phase thermal oxidation, air stripping, liquid-phase adsorption, chemical precipitation, discharge to local POTW.
Alternative 4	Treatment / disposal-eliminates or minimizes long-term management	Deed restrictions, fencing, site monitoring, VER process, air-phase thermal oxidation, air stripping, liquid-phase adsorption, precipitation, discharge to local POTW, in-situ reductive precipitation, in-situ enhanced anaerobic bioremediation
Alternative 5	Treatment / disposal-eliminates or minimizes long-term management	Deed restrictions, fencing, site monitoring, VER process, in-situ reductive oxidation
Alternative 6	Treatment / disposal-eliminates or minimizes long-term management	Deed restrictions, fencing, site monitoring, in-situ reductive precipitation, in-situ enhanced anaerobic bioremediation

Table 6-4. SWMU 20 Alternatives for Detailed Analysis

Nuclear Fuel Services, Inc. Erwin, Tennessee

Site Specific Alternative (Alternative Number)	RPOs Combined Into Alternatives
R-1 (Alternative 1)	No action
R-2 (Alternative 4)	Deed restrictions, fencing, site monitoring, VER process, air-phase thermal oxidation, air-stripping, chemical precipitation liquid-phase adsorption, and discharge to local POTW.
R-3 (Alternative 5)	Deed restrictions, fencing, site monitoring, in-situ oxidation.
R-4 (Alternative 6)	Deed restrictions, fencing, site monitoring, in-situ reductive precipitation, in-situ enhanced anaerobic bioremediation.

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Table 7-1. Cost Estimate for Alternative R-2
Deed Restrictions, Fencing, Site Monitoring, VER Process, Air-Phase Thermal Oxidation, Air Stripping, Carbon Adsorption, Precipitation, and Discharge to POTW
NFS, Inc. Erwin, Tennessee

Items	No. of Units		Unit Price	Cost
Preliminary Engineering and Permitting				
Institutional Controls/Deed Restrictions				$1,500
Sampling and Analysis/O&M Plan				$20,000
Air Permitting				$1,000
			Subtotal:	**$22,500**
Pilot Testing				
Senior Project Staff 2	4 hours	@	$127 /hour	$500
Project Engineer 2	40 hours	@	$96 /hour	$3,800
Engineer/Technician	100 hours	@	$80 /hour	$8,000
Drafting	24 hours	@	$55 /hour	$1,300
Clerical	16 hours	@	$45 /hour	$700
Per Diem	3 days	@	$100 person	$300
VER Mobile Unit	1 event	@	$4,000 event	$4,000
Pilot Test Report	1 report	@	$5,000 report	$5,000
			Subtotal:	**$23,600**
Drill and Install - 4-inch Recovery Wells				
Mob/demob drilling rig and crew	1 LS	@	$5,000 /LS	$5,000
Drill and install alluvium wells	6 wells	@	$3,500 /well	$21,000
Drill and install bedrock wells [a]	3 wells	@	$7,000 /well	$21,000
			Subtotal:	**$47,000**
Construction Costs				
Piping from recovery wells to treatment system	500 feet	@	$25 /ft	$12,500
Submersible pump with controls (3 gpm/well)	9 pumps	@	$1,641 /pump	$14,800
Liquid-ring vacuum pump	1 pump	@	$8,000 /pump	$8,000
Guard posts	40 posts	@	$48 /post	$1,900
Water Treatment System [b]				
Treatment system building	3,000 sf	@	$10 /sf	$30,000
Air stripper with controls (50 gpm)				
Air stripper	1 ea	@	$14,904 /ea	$14,900
Electrical controls	1 ea	@	$5,159 /ea	$5,200
Installation	1 ea	@	$3,263 /ea	$3,300
Skid mount	1 ea	@	$732 /ea	$700
Chemical precipitation				
Coagulation/flocculation clarifier tank (45 gpm)	1 ea	@	$88,873 /ea	$88,900
Mixer with single propeller	1 ea	@	$1,387 /ea	$1,400
Carbon adsorption system (50 gpm)	1 ea	@	$6,426 /ea	$6,400
Piping from treatment system to POTW discharge point	100 ft	@	$25 /ft	$2,500
Air Treatment System				
Regenerative thermal oxidation unit (1,000 cfm)	1 ea	@	$85,682 /ea	$85,700
Remote monitoring unit	1 ea	@	$3,985 /ea	$4,000
			Subtotal:	**$280,200**
			On-Site Construction Management (15%)	$56,000
			Engineering Design (20%)	$74,700
			TOTAL CONSTRUCTION COSTS:	**$504,000**

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Table 7-1. Cost Estimate for Alternative R-2
Deed Restrictions, Fencing, Site Monitoring, VER Process, Air-Phase Thermal Oxidation,
Air Stripping, Carbon Adsorption, Precipitation, and Discharge to POTW
NFS, Inc. Erwin, Tennessee

Items	No. of Units		Unit Price	Cost
Annual Operating Costs [c]				
Existing fence inspection	1 year	@	$500 /year	$500
Maintenance of recovery wells and transport system	4 inspections	@	$500 /inspection	$2,000
Maintenance of treatment system				
Field technician	8 hr/wk	@	$50 /hr	$20,800
Electricity costs	50 Hp	@	$0.08 kw-hr per HP	$26,100
Chemicals/Additives				
Activated carbon removal, transport, and regeneration	4 ea	@	$1,000 /ea	$4,000
Lime addition [d]	80 tons	@	$95 /ton	$7,600
Disposal				
Disposal of sludge to landfill [e]	2,500 cy/yr	@	$94 /ton	$233,800
Semi-annual reporting				
Senior Project Staff 2	8 hours	@	$127 /hour	$1,000
Project Engineer 2	60 hours	@	$96 /hour	$5,800
Engineer/Technician	160 hours	@	$80 /hour	$12,800
Drafting	60 hours	@	$55 /hour	$3,300
Clerical	40 hours	@	$45 /hour	$1,800
			Subtotal:	**$319,500**
			O&M PRESENT WORTH:	**$2,430,100** [f]
Site Closure				
Well/Piping Abandonment	9 wells	@	$1,000 well	$9,000
System Dismantling	1 job	@	$5,000 job	$5,000
Senior Project Staff 2	4 hours	@	$127 /hour	$500
Project Engineer 2	40 hours	@	$96 /hour	$3,800
Engineer/Technician	120 hours	@	$80 /hour	$9,600
Clerical	24 hours	@	$45 /hour	$1,100
			Subtotal:	**$29,000**
			Contingency (30%):	**$888,900**
			TOTAL ALTERNATIVE COST:	**$3,852,000** [g]

Note: All costs rounded to the nearest $100
a - Depth of bedrock wells is 50 feet, twice the depth of alluvium wells
b - Water treatment system is designed for maximum extraction rate of 32 gallons per minute
c - Estimated remedial action timeframe is 15 years
d - Addition of lime is at 1 lb/100 gallons of influent groundwater
e - Sludge concentration is at 3 percent of influent groundwater
f - O&M Present Worth equals Total Annual Operating Costs x (P/A @ 10% for 15 years)
g - Total alternative cost accuracy (+50 percent to -30 percent)
(U.S. Environmental Protection Agency 1988a).

cfm - cubic feet per minute
cy - cubic yards
ft - feet
gpm - gallons per minute
lb - pound
O&M - operation and maintenance
POTW - publicly-owned treatment works
sf - square feet

Table 7-2. Cost Estimate for Alternative R-3
Deed Restrictions, Fencing, Site Monitoring,
and In Situ Oxidation
NFS, Inc. Erwin, Tennessee

Items/Staff	No. of Units		Unit Price	Cost
Preliminary Engineering and Permitting				
Institutional Controls/Deed Restrictions				$1,500
Sampling and Analysis/O&M Plan				$20,000
Groundwater Injection Permit				$1,000
			Subtotal:	**$22,500**
Pilot Testing				
Senior Project Staff 2	4 hours	@	$127 /hour	$500
Project Engineer 2	40 hours	@	$96 /hour	$3,800
Engineer/Technician	120 hours	@	$80 /hour	$9,600
Drafting	24 hours	@	$55 /hour	$1,300
Clerical	24 hours	@	$45 /hour	$1,100
Mob/demob drilling rig and crew	1 LS	@	$5,000 /LS	$5,000
Drill and install - 4-inch" Injection Well	35 ft	@	$130 ft	$4,600
Per Diem	10 days	@	$100 person	$1,000
Reagent Injection	2 events	@	$5,000 event	$10,000
Bench Scale Uranium Precip	1 event	@	$8,000 event	$8,000
Analytical	2 events	@	$3,000 event	$6,000
Pilot Test Report	1 report	@	$3,000 report	$3,000
			Subtotal:	**$53,900**
Drill and Install - 4-inch Injection Wells [a]				
Mob/demob drilling rig and crew	1 LS	@	$5,000 /LS	$5,000
Drill and install source area injection wells	3 wells	@	$6,000 /well	$18,000
Drill and install boundary injection wells	14 wells	@	$7,500 /well	$105,000
Guard posts	72 posts	@	$48 /post	$3,400
			Subtotal:	**$131,400**
Construction Cost for In Situ Oxidation System				
Reagent feed system	1 system	@	$5,000 /system	$5,000
Tank with mixer	1 tank	@	$3,482 /tank	$3,500
Piping from tank to boundary injection wells	350 ft	@	$50 /ft	$17,500
Valves for boundary wells	14 valves	@	$250 /valve	$3,500
Treatment system building	2,000 sf	@	$10 /sf	$20,000
Electrical controls for reagent feed system	1 system	@	$15,000 /system	$15,000
			Subtotal:	**$64,500**
			On-Site Construction Management (15%):	**$40,800**
			Engineering Design (20%):	**$54,500**
			TOTAL CONSTRUCTION COST:	$367,600

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Table 7-2. Cost Estimate for Alternative R-3
Deed Restrictions, Fencing, Site Monitoring,
and In Situ Oxidation
NFS, Inc. Erwin, Tennessee

Items/Staff	No. of Units		Unit Price	Cost
Annual Source Area Operations and Maintenance Costs [b]				
Monthly injections [c, d]	12 ea	@	$10.000 /ea	$120.000
			Subtotal:	**$120.000**
Annual Boundary Operations and Maintenance Costs [c]				
System maintenance by field technician	8 hr/wk	@	$50 /wk	$20.800
Reagent	5.000 gal	@	$4 /gal	$17.500
Electrical costs	10 HP	@	$0.08 kw-hr per HP	$5.200
			Subtotal:	**$43,500**
Annual Maintenance and Reporting Costs [c]				
Existing fence inspection				$500
Semi-annual reporting				
Senior Project Staff 2	8 hours	@	$127 /hour	$1.000
Project Engineer 2	60 hours	@	$96 /hour	$5.800
Engineer/Technician	160 hours	@	$80 /hour	$12.800
Drafting	60 hours	@	$55 /hour	$3.300
Clerical	40 hours	@	$45 /hour	$1.800
			Subtotal:	**$25,200**
			O&M PRESENT WORTH:	**$369,500** [f]
Site Closure				
Well/Piping Abandonment	18 wells	@	$1.000 well	$18.000
System Dismantling	1 job	@	$5.000 job	$5.000
Senior Project Staff 2	4 hours	@	$127 /hour	$500
Project Engineer 2	40 hours	@	$96 /hour	$3.800
Engineer/Technician	200 hours	@	$80 /hour	$16.000
Clerical	24 hours	@	$45 /hour	$1.100
			Subtotal:	**$44,400**
			PROJECT TOTAL PRESENT WORTH:	**$781,500**
			Contingencies (30%):	**$234,500**
			TOTAL ALTERNATIVE COST:	**$1.016.000** [g]

Note: All costs rounded to the nearest $100
a - Wells are installed to modeled depth of contamination (35 ft for source area; 45 ft for boundary)
b - Estimated source area O&M for 1 year
c - Portable equipment will be used for source area injections (e.g., tanker truck)
d - Representative reagent concentrations are 5 percent for source area and 0.5 percent for boundary
e - Estimated O&M of 5 years
f - O&M Present Worth equals Annual Source Area Operations and Maintenance Costs x (P/A @ 10 percent for 1 year)
+ Annual Boundary Operations and Maintenance Costs x (P/A @ 10 percent for 5 years)
+ Annual Maintenance and Reporting Costs x (P/A @ 10 percent for 5 years)
g - Total alternative cost accuracy (+50 percent to -30 percent) (U.S. Environmental Protection Agency 1988a).

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Table 7-3. Cost Estimate for Alternative R-4
Deed Restrictions. Fencing, Site Monitoring,
In-Situ Enhanced Anaerobic Bioremediation, In-Situ Reductive Precipitation
NFS. Inc. Erwin, Tennessee

Item/Staff	No. of Units		Unit Price	Estimated Cost
Preliminary Engineering and Permitting				
Institutional Controls/Deed Restrictions				$1.500
Sampling and Analysis/O&M Plan				$20.000
Groundwater Injection Permit				$200
			Subtotal:	**$21,700**
Pilot Testing				
Senior Project Staff 2	8 hours	@	$127 /hour	$1.000
Project Engineer 2	80 hours	@	$96 /hour	$7.700
Engineer/Technician	240 hours	@	$80 /hour	$19.200
Drafting	24 hours	@	$55 /hour	$1.300
Clerical	24 hours	@	$45 /hour	$1.100
Mob/demob drilling rig and crew	1 LS	@	$2.000 /LS	$2.000
Drill and install - 4-inch Injection Well	35 ft	@	$50 ft	$1.800
Per Diem	20 days	@	$100 person	$2.000
Reagent Injection	6 events	@	$400 event	$2.400
Analytical	5 events	@	$1.500 event	$7.500
Pilot Test Report	1 report	@	$5.000 report	$5.000
			Subtotal:	**$51,000**
Drill and Install - 4-inch Injection Wells [a]				
Mob/demob drilling rig and crew	1 LS	@	$5.000 /LS	$5.000
Drill and install source area injection wells	3 wells	@	$5.000 /well	$15.000
Drill and install boundary injection wells	10 wells	@	$3.500 /well	$35.000
Guard posts	56 posts	@	$48 /post	$2.700
			Subtotal:	**$57,700**
			On-Site Construction Management (15%):	**$19,600**
			Engineering Design (20%):	**$26,100**
			TOTAL CONSTRUCTION COST:	**$176,100**
Annual Short-Term Operations and Maintenance Costs [b]				
Monthly injections [c]	6 injections	@	$10.000 /injection	$60.000
Quarterly injections [c]	2 injections	@	$10.000 /injection	$20.000
			Subtotal:	**$80,000**
Annual Long-Term Operations and Maintenance Costs [d]				
Quarterly injections [c]	4 injections	@	$10.000 /injection	$40.000
			Subtotal:	**$40,000**
Annual Maintenance and Reporting Costs [e]				
Existing fence inspection				$500
Semi-annual reporting				
Senior Project Staff 2	8 hours	@	$127 /hour	$1.000
Project Engineer 2	60 hours	@	$96 /hour	$5.800
Engineer/Technician	160 hours	@	$80 /hour	$12.800
Drafting	60 hours	@	$55 /hour	$3.300
Clerical	40 hours	@	$45 /hour	$1.800
			Subtotal:	**$25,200**
			O&M PRESENT WORTH:	**$401,900** [f]

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Table 7-3. Cost Estimate for Alternative R-4
Deed Restrictions. Fencing, Site Monitoring,
In-Situ Enhanced Anaerobic Bioremediation, In-Situ Reductive Precipitation
NFS. Inc. Erwin, Tennessee

Item/Staff	No. of Units		Unit Price	Estimated Cost
Site Closure				
Well/Piping Abandonment	14 wells	@	$1.000 well	$14.000
Senior Project Staff 2	4 hours	@	$127 /hour	$500
Project Engineer 2	40 hours	@	$96 /hour	$3.800
Engineer/Technician	80 hours	@	$80 /hour	$6.400
Clerical	12 hours	@	$45 /hour	$500
			Subtotal:	**$25,200**
			PROJECT TOTAL PRESENT WORTH:	**$603,200**
			Contingency (30%):	**$181,000**
			TOTAL ALTERNATIVE COST:	**$784,200** [g]

Note: All costs rounded to the nearest $100
a - Wells are installed to modeled depth of contamination (35 ft for source area; 45 ft for boundary).
b - Estimated short-term O&M for 1 year.
c - Portable equipment will be used for injections (e.g., tanker truck).
d - Estimated long-term O&M for 7 years.
e - Estimated project length for 8 years.
f - O&M Present Worth equals Annual Short-Term Operations and Maintenance Costs x (P/A @ 10% for 1 year)
+ Annual Long-Term Operations and Maintenance Costs x (P/A @ 10% for 7 years)
+ Annual Maintenance and Reporting Costs x (P/A @ 10% for 8 years)
g - Total alternative cost accuracy (+50 percent to -30 percent) (U.S. Environmental Protection Agency 1988a).

Table 7-4. Summary of Individual Analyses of Alternatives for SWMU 20

NFS, Inc. Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air-Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reductive Precipitation
Overall Protection of Human Health and the Environment				
Does alternative protect current and future users?	No	Yes	Yes	Yes
Are environmental risks reduced by alternative?	No	Yes	Yes	Yes
Compliance with ARARs				
Compliance with chemical specific ARARs?	No	Yes	Yes	Yes
Compliance with action-specific ARARs?	Not Applicable	Yes	Yes	Yes
Compliance with location-specific ARARs?	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Compliance with other criteria?	Not Applicable	Yes	Yes	Yes
Long-Term Effectiveness and Permanence				
Does alternative reduce residual risk?	No	Yes	Yes	Yes
Does alternative provide adequate remedial controls?	Not Applicable	Yes	Yes	Yes
Need a 5-year review?	Required to ensure adequate protection is maintained and to ensure ARAR compliance.	Required to ensure adequate protection is maintained and to ensure ARAR compliance.	Required to ensure adequate protection is maintained and to ensure ARAR compliance.	Required to ensure adequate protection is maintained and to ensure ARAR compliance.

Table 7-4. Summary of Individual Analyses of Alternatives for SWMU 20

NFS, Inc. Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 **Deed Restrictions Fencing Site Monitoring VER Process Air-Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW**	Alternative R-3 **Deed Restrictions Fencing Site Monitoring In-Situ Oxidation**	Alternative R-4 **Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reductive Precipitation**
Need for long-term management	Not Applicable	Yes	No	No
O&M requirements	Not Applicable	High Intensity	Moderate Intensity	Low Intensity
Reduction of Toxicity, Mobility, and Volume through Treatment				
Treatment process used	None / Natural Attenuation	Stripping, Adsorption, Precipitation, and Natural Attenuation	Oxidation, Precipitation, and Natural Attenuation	Enhanced Bioremediation Precipitation, and Natural Attenuation
Reduction in toxicity, mobility, and volume?	Toxicity and volume by natural attenuation	Mobility by VER recovery; Toxicity and volume by ex situ treatments and natural attenuation	Toxicity and volume by oxidation and natural attenuation; mobility by precipitation	Toxicity and volume by reduction and natural attenuation; mobility by precipitation
Type and quantity of residuals remaining after treatment	Minor organic constituents remain after PRGs achieved.	Minor organic constituents remain after PRGs achieved.	Minor organic constituents remain after PRGs achieved.	Minor organic constituents remain after PRGs achieved
Short-Term Effectiveness				
Risks to the community during implementation remedial action	No risks	Moderate	Minimal	Minimal
Risks to workers during implementation of remedial action	No risks	Short-term risk during O&M and sampling	Short-term risk during oxidation treatments, O&M, and sampling.	Short-term risk during sampling.

Table 7-4. Summary of Individual Analyses of Alternatives for SWMU 20

NFS, Inc. Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air-Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reductive Precipitation
Environmental impacts?	Unmonitored potential migration	Potential VOC emissions; long-term storage of precipitate sludge	None	None
Time until remedial action objectives achieved	>30 years	<1 year	<1 year	<1 year
Implementability				
Constructable?	No Activity	Yes; but difficult	Yes; but difficult	Yes
Reliability of technology	No technology implemented	Reliable	Reliable	Reliable
Ease of undertaking additional remedial action, if necessary	Easily implemented	Some difficulty to remove wells and piping system.	Some difficulty to remove wells and piping system.	Easily implemented
Can you monitor effectiveness of remedy?	Not Applicable	Yes	Yes	Yes
Ability to coordinate with regulatory agency	"No Action" alternative may not be acceptable to the regulatory authority	Obtainable; air emissions and POTW permitting required	Obtainable; injection permit required	Obtainable; injection permit required
Availability of off-site disposal services	None required	Available	Available	Available
Availability of equipment and specialists	None required	Available	Limited	Limited
Availability of prospective technologies	None required	Available	Available	Available

Table 7-4. Summary of Individual Analyses of Alternatives for SWMU 20

NFS, Inc. Erwin, Tennessee

Criteria	Alternative R- 1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air-Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reductive Precipitation
Cost				
Installation Cost	$0	$504,000	$367,600	$176,100
Annual O&M Cost	$0	$319,500	$188,700	$145,200
O&M Present Worth Cost	$0	$2,430,100	$369,500	$401,900
Site Closure Cost	$0	$29,000	$44,400	$25,200
Contingency (30%)	$0	$888,900	$234,500	$181,000
Total Cost	$0	$3,852,000	$1,016,000	$784,200

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20
Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
THRESHOLD CRITERIA				
Overall Protection of Human Health and the Environment				
Human Health Protection	No reduction in risk.	Provides high level of protection. Deed restrictions, fencing, and monitoring well network reduce risk from all potential exposure pathways. VER process controls off-site migration.	Provides higher level of protection. Deed restrictions, fencing, and monitoring well network reduce risk from all potential exposure pathways. In-situ oxidation eliminates source and controls off-site migration.	Provides highest level of protection. Deed restrictions, fencing, and monitoring well network reduce risk from all potential exposure pathways. In-situ reductive precipitation enhanced bioremediation controls off-site migration and enhances downgradient remediation.
Environmental Protection	Allows potential environmental impacts from groundwater migration. However, natural attenuation reduces constituent concentrations over time.	Migration of groundwater is curtailed by VER treatment. Natural attenuation reduces constituent concentrations over time.	Source is eliminated through in-situ oxidation. Migration of groundwater is curtailed by in-situ treatment. Natural attenuation reduces constituent concentrations over time.	Migration of groundwater is controlled by in-situ treatments. Natural attenuation is enhanced and reduces constituent concentrations over time.
Compliance with ARARs				
Compliance with Chemical-Specific ARAR (i.e., MCLs, RBCs)	Does not meet ARARs.	Will meet ARARs at site boundary. Meets ARARs within plume area in estimated 15 years.	Will meet ARARs at site boundary. Meets ARARs within plume area in estimated 5 years.	Will meet ARARs at site boundary. Meets ARARs within plume area in estimated 8 years.

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20

Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Compliance with ARARs (cont)				
Compliance with Action-Specific ARARs (i.e., waste management restrictions)	Not applicable	Meets ARARs if proper PPE used during well installation, system construction, O&M, and sampling.	Meets ARARs if proper PPE used during well installation, system construction, O&M, and sampling.	Meets ARARs if proper PPE used during well installation, system construction, O&M, and sampling.
Compliance with Location-Specific ARARs (i.e., floodplains, wetlands)	No ARAR Identified	No ARAR Identified	No ARAR Identified	No ARAR Identified
BALANCING CRITERIA				
Long-Term Effectiveness and Permanence				
Reduction in Contaminant Residual Risk at Conclusion of Remedial Activities	Natural attenuation decreases risk. However, risk is significant for >30 years.	Provides moderate level of long-term residual risk reduction. Risk reduced both onsite and downgradient to acceptable levels in 15 years.	Provides high level of long-term residual risk reduction. Risk greatly reduced both onsite and downgradient by in-situ oxidation to acceptable levels in 5 years.	Provides highest level of long-term residual risk reduction. Risk greatly reduced both onsite and downgradient by in-situ treatments to acceptable levels in 8 years.
Long-Term Reliability of Controls (i.e., management, monitoring, O&M, degree of confidence)	Not applicable	Deed restrictions, fencing, monitoring network, VER, and ex situ treatments are reliable if maintained.	Deed restrictions, fencing, monitoring network, and in-situ treatments are reliable if maintained.	Deed restrictions, fencing, in-situ treatment, and monitoring network are reliable if maintained.
Need for 5-Year Review	Required	Required	Required	Required

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20
Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Long-Term Effectiveness and Permanence (cont)				
Prevention of Exposure to Contaminant Residuals	All constituents remain. Groundwater migration is not monitored or controlled.	On-site exposure to residuals is reduced by collection and ex-situ treatment of impacted water and enforced deed restrictions. Protection from residuals risk enforced by deed restrictions and fencing. Natural attenuation will ultimately destroy all residuals. Groundwater migration is monitored and controlled.	Protection from residuals risk enforced by deed restrictions and fencing. In-situ oxidation and natural attenuation will provide high degree of prevention of exposure and ultimately destroy all residuals. Groundwater migration is monitored and controlled.	Protection from residuals risk enforced by deed restrictions and fencing. In-situ treatments and enhanced natural attenuation will provide highest degree of prevention of exposure and ultimately destroy all residuals. Groundwater migration is monitored and controlled.
Potential Need for Replacement of Technical Components After Remedial Objectives are Achieved	Not Applicable	Deed restrictions and SAP require update, modifications, or renewal. VER pumps, blower, and ex-situ treatment equipment are expected to be reliable until RAOs are achieved. Minor monitoring well repair may be required.	Deed restrictions and SAP require update, modifications, or renewal. Minor monitoring and injection well repair may be required.	Deed restrictions and SAP require update, modifications, or renewal. Minor monitoring and injection well repair may be required.
Long-Term Management	Not applicable	Long-term management required.	Long-term management eliminated or reduced.	Long-term management eliminated or reduced.

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20

Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Reduction of Mobility Toxicity, or Volume through Treatment				
Amount of Contaminant Destroyed or Treated	Not quantifiable	Monitoring of COC concentrations, influent, and natural attenuation processes will determine mass destroyed.	Estimated oxidation of 75% of COC mass. Monitoring of COC concentrations and natural attenuation processes will determine mass destroyed.	Monitoring of COC concentrations and natural attenuation processes will determine mass destroyed.
Reduction in Mobility, Toxicity, or Volume of Contaminants	Toxicity and volume may be reduced through natural attenuation.	Mobility, toxicity, and volume will be reduced through recovery, ex situ treatments, and enhanced natural attenuation.	Mobility, toxicity, and volume reduced through in situ treatments and through enhanced natural attenuation.	Mobility, toxicity, and volume reduced through in situ treatments and through enhanced natural attenuation.
Irreversible Treatment of Contaminants	Natural attenuation is an irreversible process.	Recovery and natural attenuation are irreversible processes. COCs are transferred to air phase and remain in precipitate sludge.	In-situ oxidation and natural attenuation of PCE are irreversible processes. Uranium may become resoluble if biogeochemistry is not conducive.	In-situ treatment and natural attenuation processes of PCE are irreversible processes. Uranium may become resoluble if biogeochemistry is not conducive (i.e., ORP less than 0 mV).
Type and Quantity of Contaminant Residuals Remaining After Treatment	Moderate organic residuals are left from natural attenuation.	Moderate organic residuals are left from VER and natural attenuation.	Residuals destroyed in source area by oxidation. Minor organic residuals are left from natural attenuation.	Organic residuals are ultimately destroyed through in-situ treatments and natural attenuation.

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20
Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Short-Term Effectiveness				
Community Protection During Implementation	Not applicable	Moderate risk during VER well and ex situ treatment system installation. No risk with monitoring well network in place.	Moderate risk during injection well installation and oxidation treatments. No risk with monitoring well network in place.	No risk with injection well and monitoring well network in place.
Worker Protection During Implementation	Not applicable	Workers use PPE as required for dermal contact and inhalation during monitoring and O&M.	Workers use PPE if required for dermal contact and inhalation during monitoring and in-situ oxidation. Moderate risk from injections and degradation gases under facility.	Workers use PPE if required for dermal contact and inhalation during monitoring and in-situ treatments. Minimal risk from injections and degradation gases under facility.
Environmental Impacts During Implementation	Continued impact from existing conditions.	Environmental impact is minimized by VER and monitoring well detection network. Migration is controlled.	Environmental impact is minimized by in-situ treatment and monitoring well detection network. Source is eliminated and migration is controlled.	Environmental impact is minimized by in-situ treatment and monitoring well detection network; migration is controlled.
Construction Time	Not Applicable	Less than 6 months	Less than 3 months	Less than 3 months
Time Until Remedial Response Objectives are Achieved	Estimated at > 30 years.	Estimated at 15 years	Estimated at 5 years	Estimated at 8 years

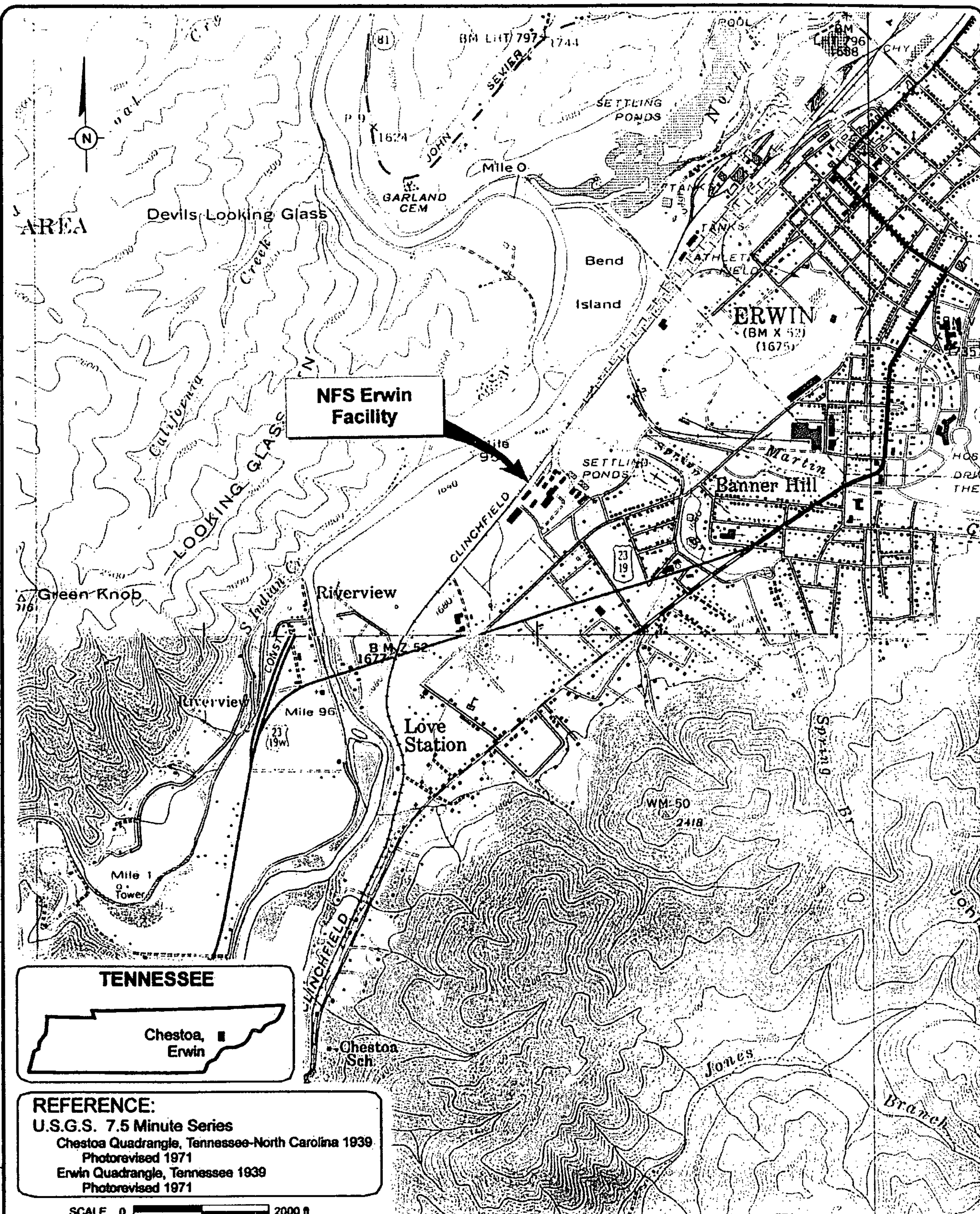
Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20

Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Implementability				
Ability to Construct and Operate the Technology	Not applicable	A number of vendors for VER/ex-situ treatment systems are available. Personnel available to perform natural attenuation monitoring.	Limited number of vendors for oxidation treatments. Personnel available to perform natural attenuation monitoring.	Specialty contractors available to perform in-situ enhanced anaerobic bioremediation and natural attenuation monitoring.
Reliability of Technology (i.e., technical problems associated with implementability that could lead to schedule delays)	Not applicable	Deed restrictions and fencing are reliable for restricting access immediately after implementation. Monitoring reliable upon sampling plan completion. VER and ex situ treatment reliable if maintained.	Deed restrictions and fencing are reliable for restricting access immediately after implementation. Monitoring reliable upon sampling plan completion. In-situ treatment reliable if maintained.	Deed restrictions and fencing are reliable for restricting access immediately after implementation. Monitoring reliable upon sampling plan completion. In-situ treatment reliable if maintained
Ease of Undertaking Additional Remedial Action, if Required	Easily implementable	Implementable	Implementable	Easily implementable
Ability to Monitor Effectiveness of Treatment	Not applicable	Monitoring gives notice of VER effectiveness and potential migration of constituents in groundwater.	Monitoring gives notice of failure before significant exposure occurs as well as monitor in-situ treatment and natural attenuation effectiveness.	Monitoring gives notice of failure before significant exposure occurs as well as monitor in-situ treatment and natural attenuation effectiveness.

Table 8.1 Summary of Comparative Analysis of Alternatives for SWMU 20
Nuclear Fuel Services, Inc. SWMU 20 Site Erwin, Tennessee

Criteria	Alternative R-1 No Action	Alternative R-2 Deed Restrictions Fencing Site Monitoring VER Process Air Phase Therm Ox Air Stripping Chemical Precipitation Liquid-Phase Adsorption Discharge to POTW	Alternative R-3 Deed Restrictions Fencing Site Monitoring In-Situ Oxidation	Alternative R-4 Deed Restrictions Fencing Site Monitoring In-Situ Enhanced Anaerobic Bioremediation In-Situ Reduction Precipitation
Implementability (cont)				
Permitting Requirements	Not applicable	Air and POTW permit required.	Injection permit required.	Injection permit required.
Coordination with Other Local or State Agencies	Not applicable	All approvals are obtainable.	Injection permit may be difficult.	All approvals are obtainable.
Availability of Services and Capabilities	Not applicable	Readily available; uranium sludge disposal may be difficult.	Available	Available
Availability of Equipment, Specialists, and Materials	Not applicable	Readily available	Available	Available
ESTIMATED COST				
Capital Costs	$0	$504,000	$367,600	$176,100
Annual O&M	$0	$319,500	$188,700	$145,200
O&M Present Worth	$0	$2,430,100	$369,500	$401,900
Site Closure	$0	$29,000	$44,400	$25,200
Contingency (30%)	$0	$888,900	$234,500	$181,000
Total Project Cost	$0	$3,852,000	$1,016,000	$784,200



DWG. DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.0001 | FILE NAME: REM ALT | DRAWING: D33377.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY

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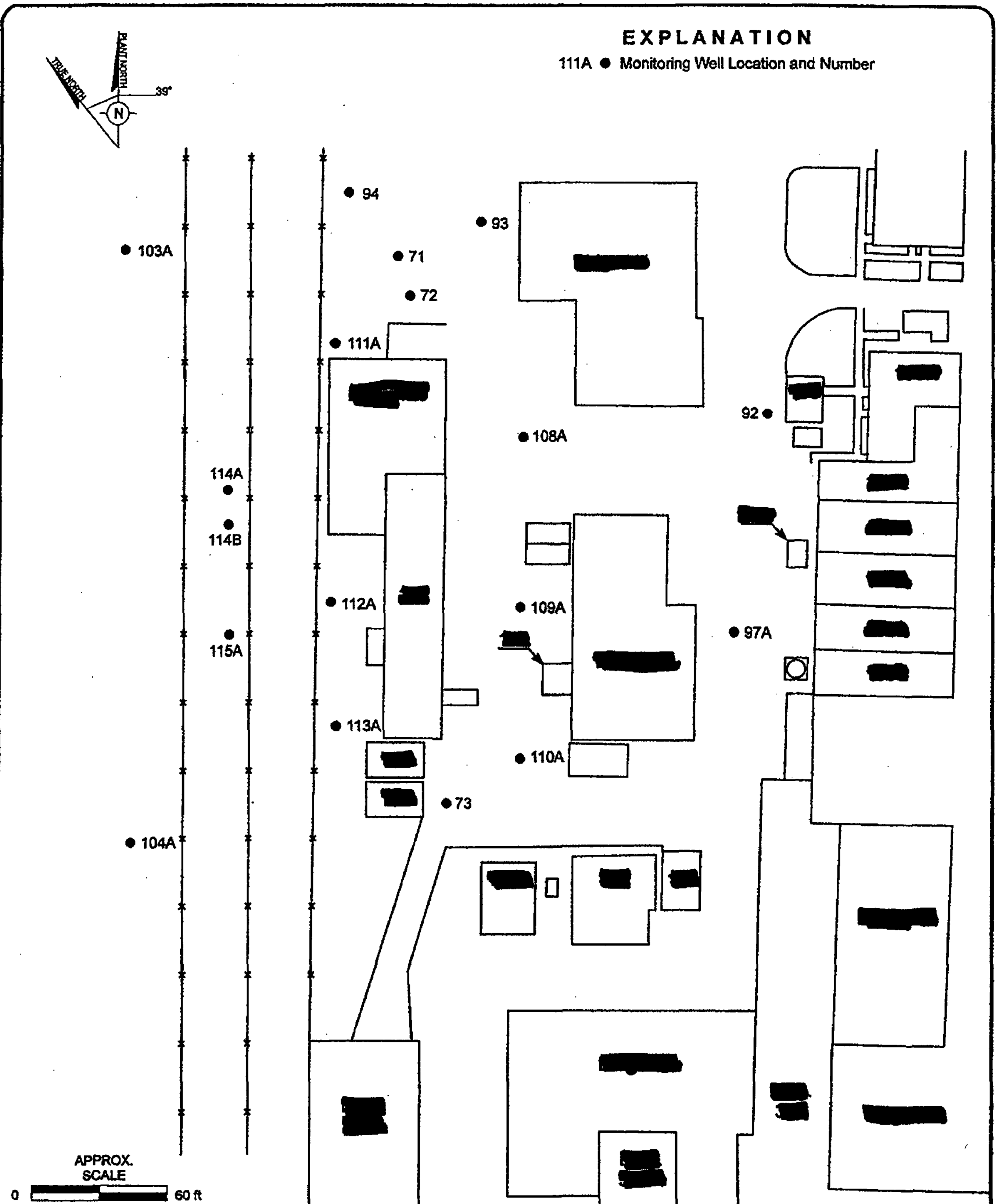
Regional Location Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-1



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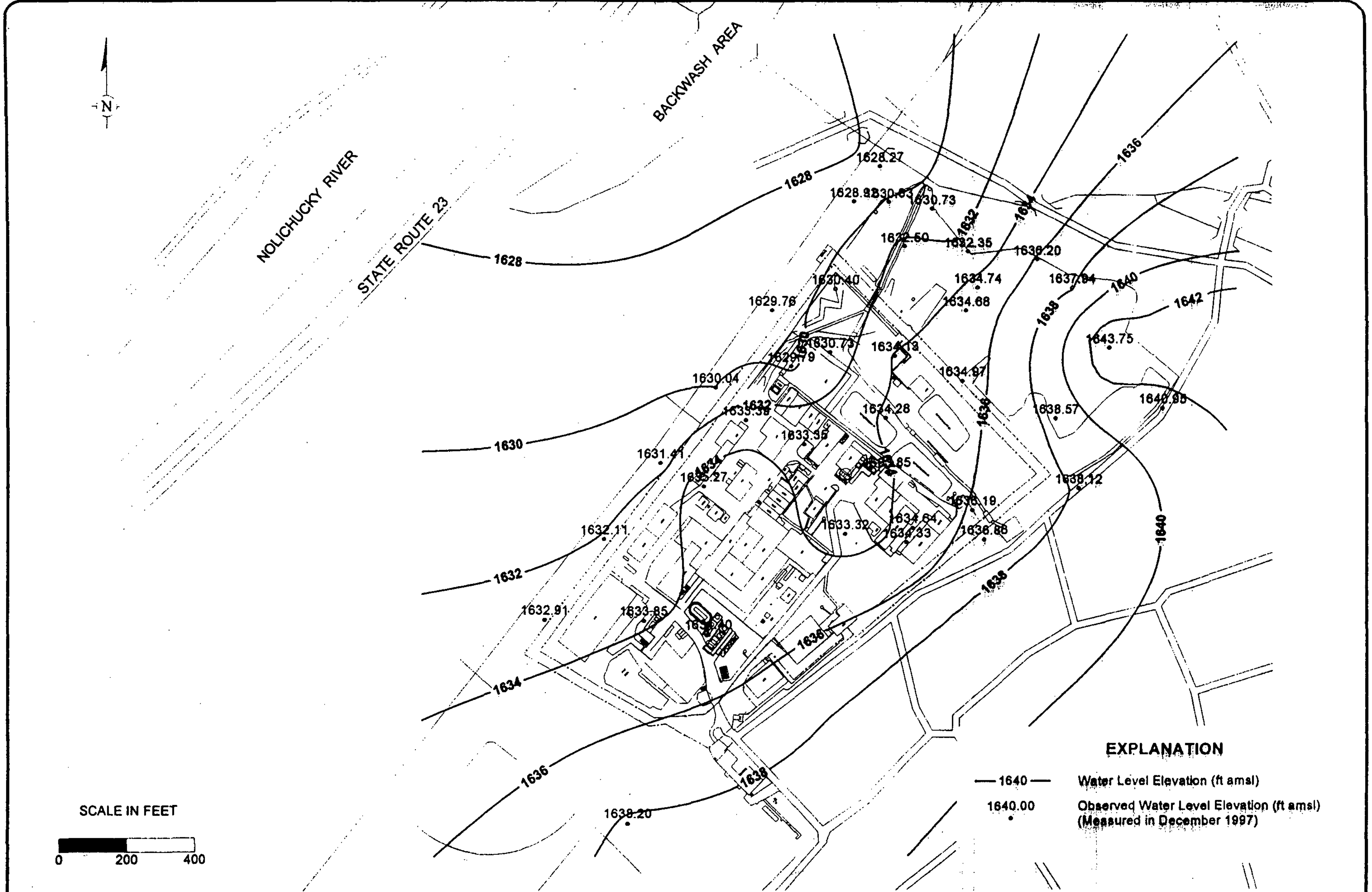
Site Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 2-2

DWG. DATE: 28MAY99	PROJ. NO.:TN000512.0001.00001	RPT NAME: REM. ALT.	DRAWING: 2-5A.SRF	PROJ. MANAGER: G.PAGE	PROJ. OFFICER: B. ILGNER	DRAFTER:MCHAPMAN



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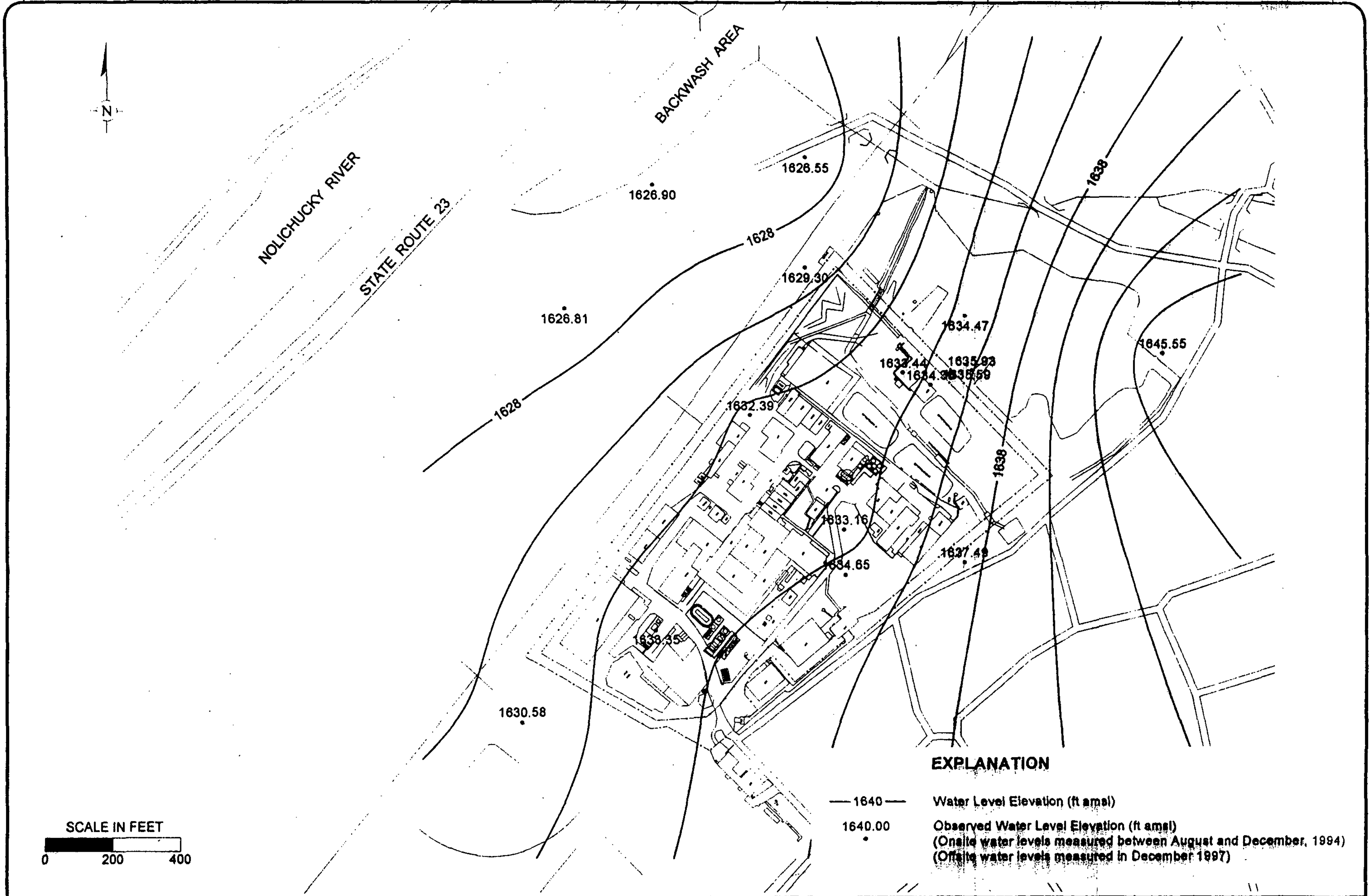
Water Table Contour Map - Alluvial Aquifer

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-3

DWG. DATE: 28MAY99 | PROJ. NO.: TN000512.0001.00001 | RPT NAME: REM. ALT. | DRAWING: 2-7A.SRF | PROJ. MANAGER: G.PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: MCHAPMAN



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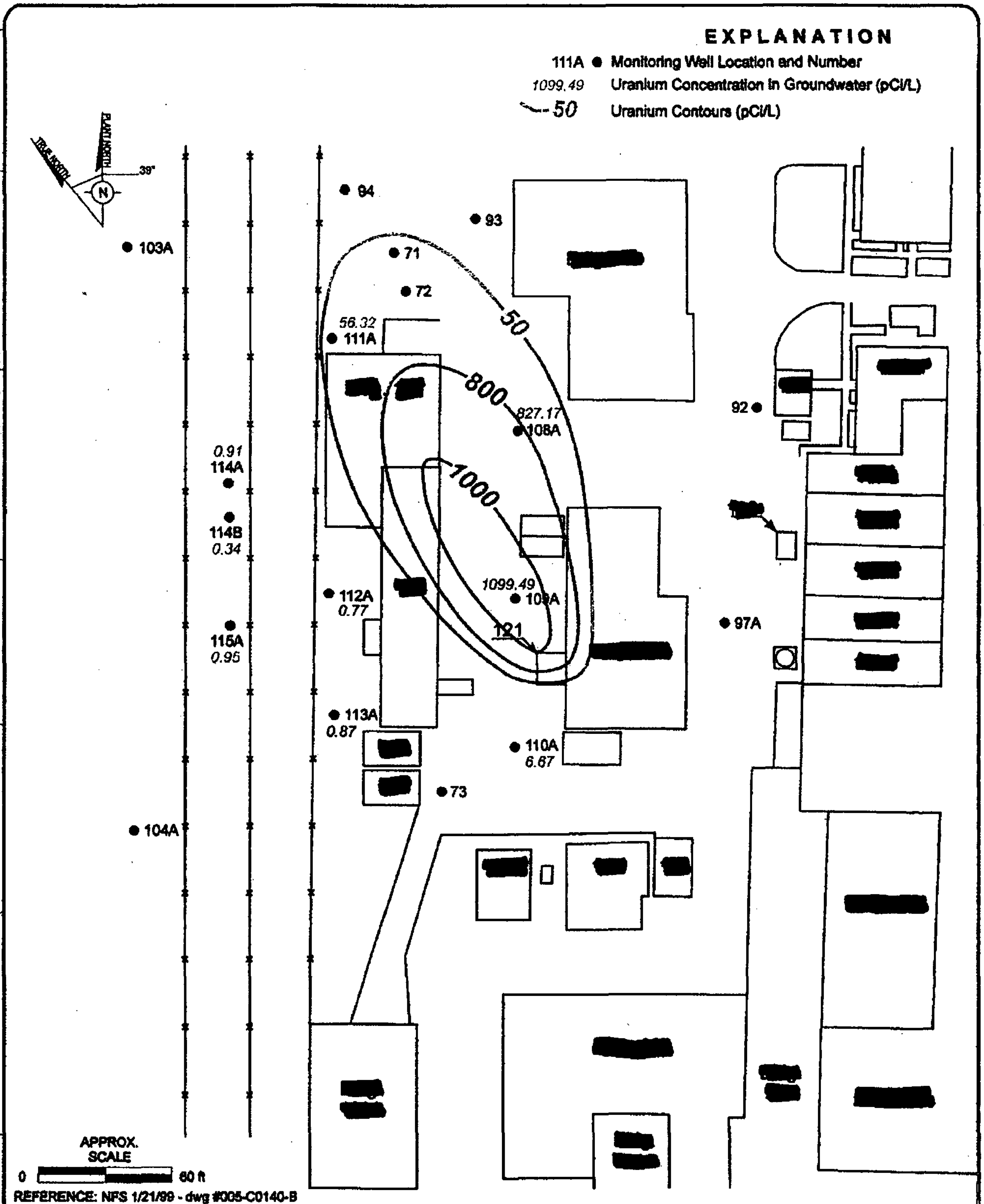
Potentiometric Surface Contour Map - Bedrock Aquifer

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-4



REFERENCE: NFS 1/21/99 - dwg #005-C0140-B

DWG. DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE NAME: REM ALT | DRAWING: D33378.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY

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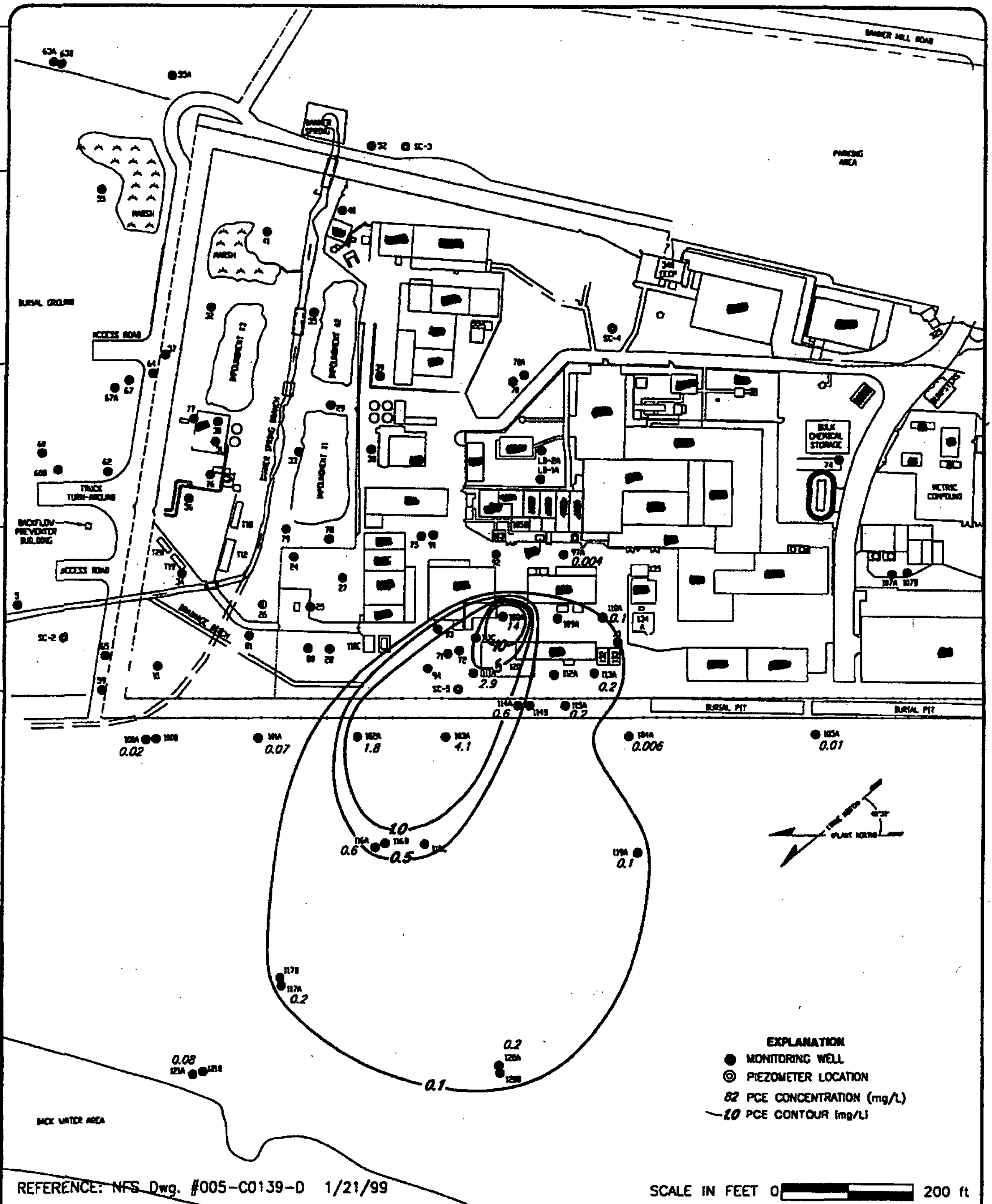
Horizontal Extent of Uranium in Groundwater, January 1999

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-5

DWG DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE: REM ALT ASSESS | DRAWING: D33379.DWG | PROJ. MGR.: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY

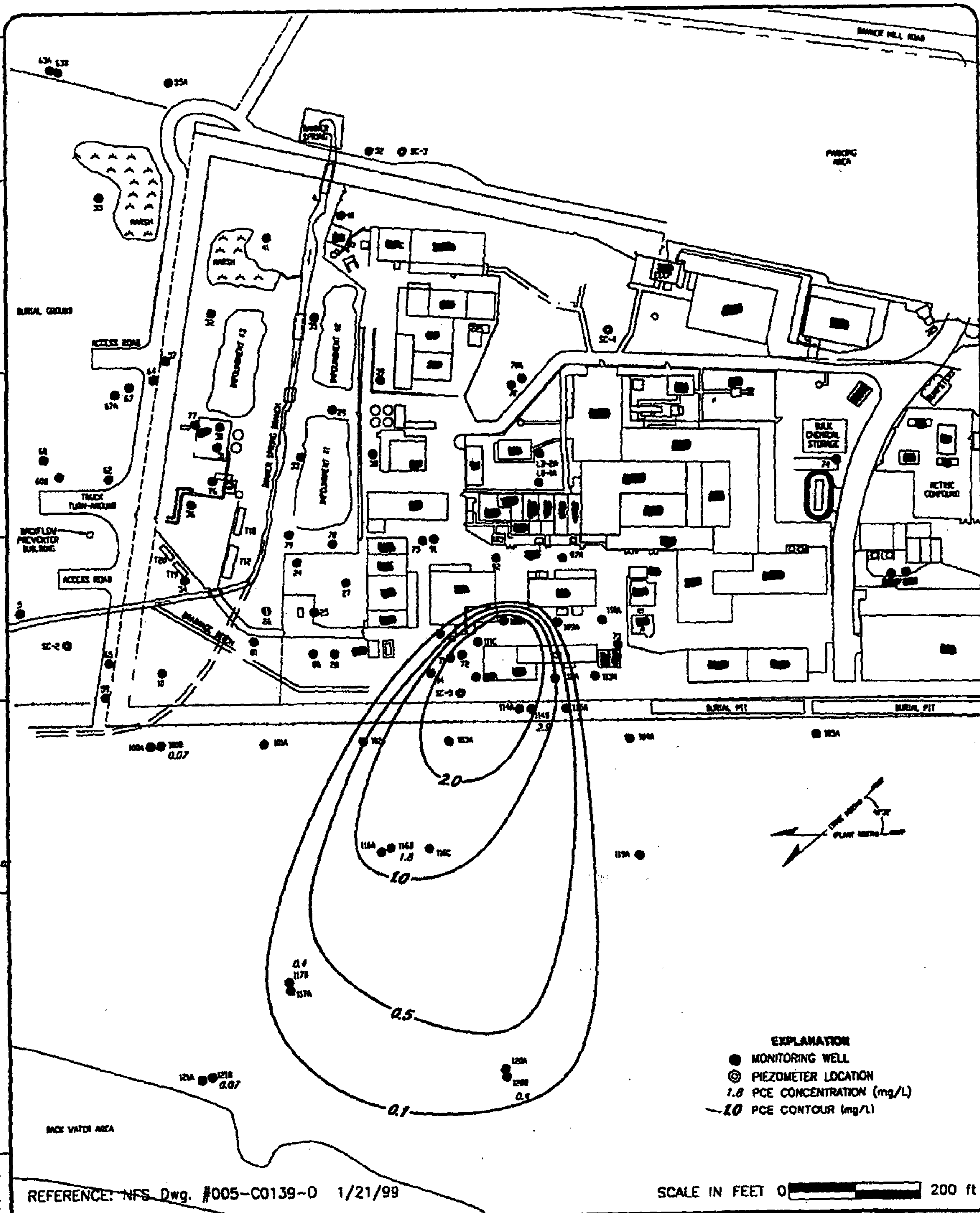


ARCADIS GERAGHTY & MILLER

Horizontal Extent of PCE in Groundwater Alluvial Aquifer - January 1999

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 2-6



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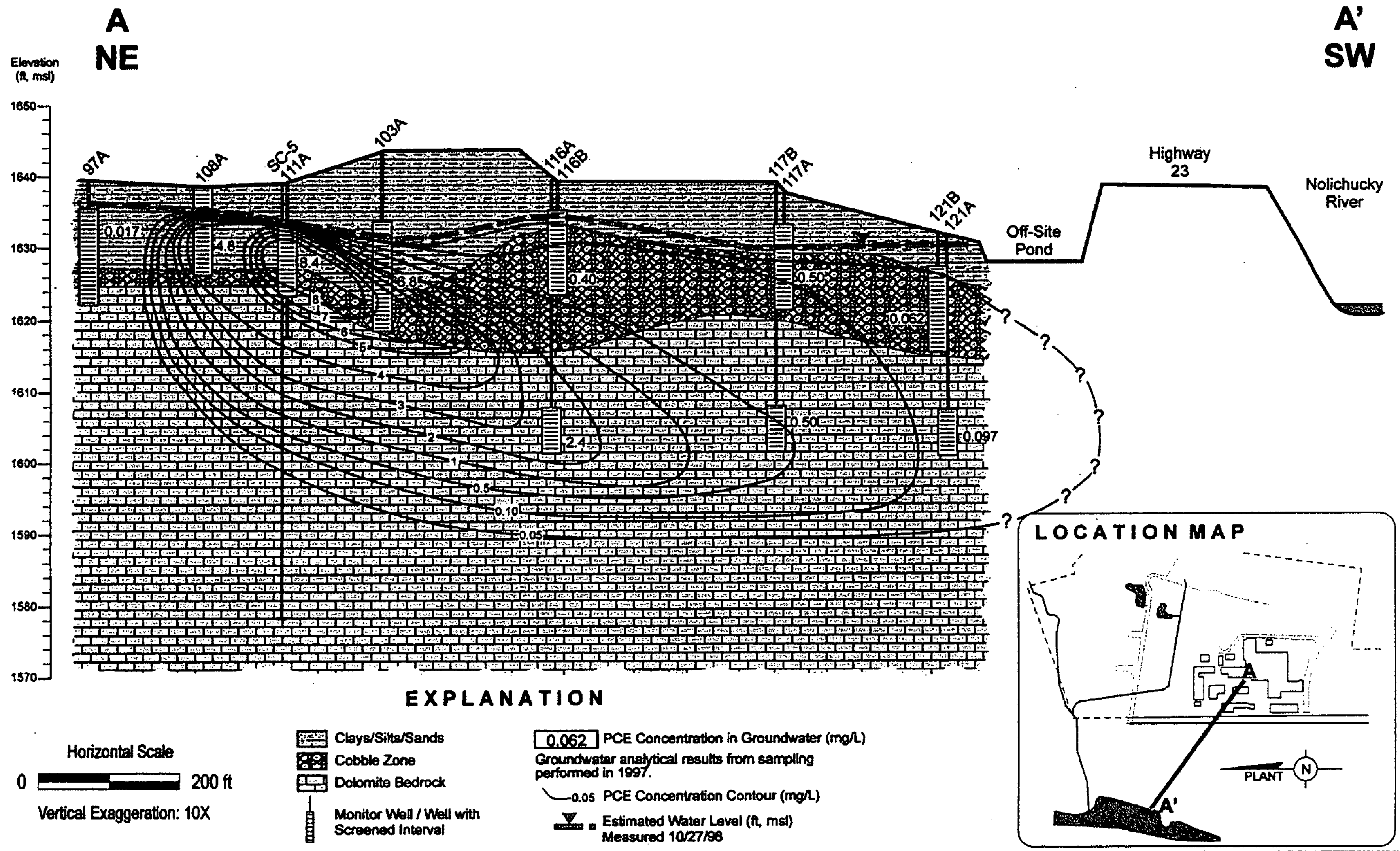
Horizontal Extent of PCE in Groundwater
Bedrock Aquifer - January 1999

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 2-7

DWG DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE: REM ALT ASSESS | DRAWING: D33379.DWG | PROJ. MGR.: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY

DWG. DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE NAME: REM ALT | DRAWING: D33380.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



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Site Geologic Cross Section

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 2-8

Figure 2 - 9. Conceptual Site Model

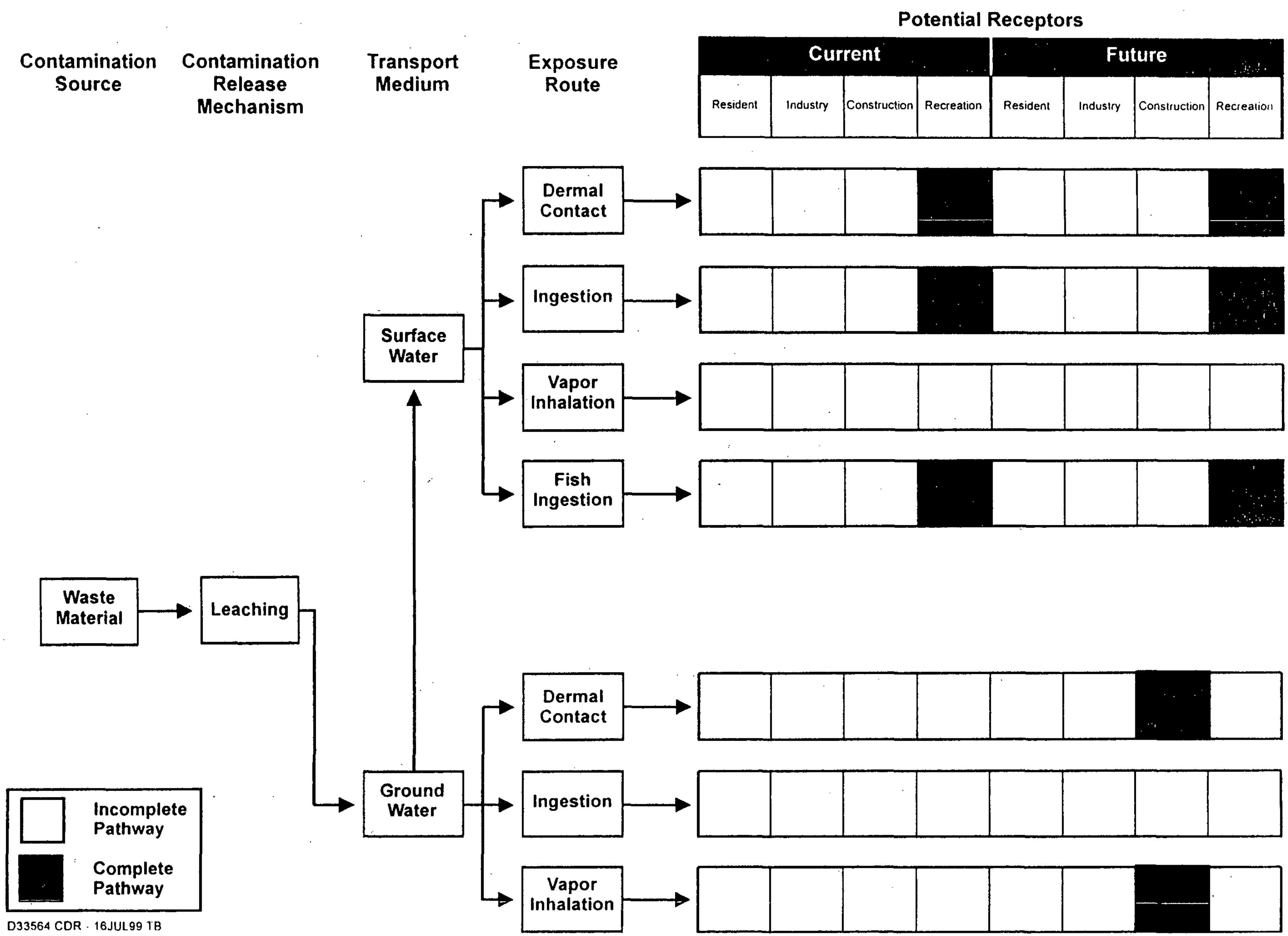

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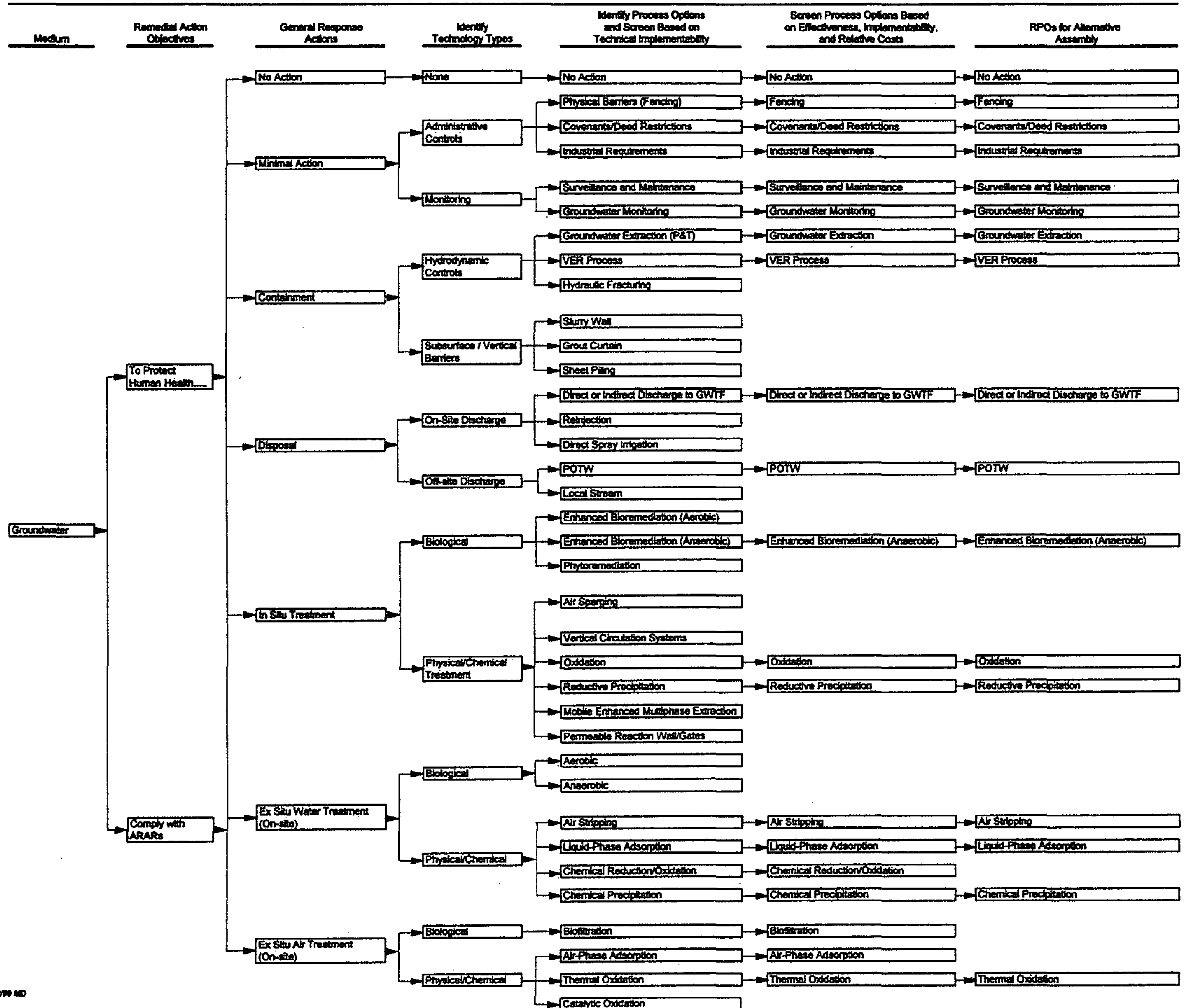
Figure 5-1. RPO Logic Diagram for Groundwater
Nuclear Fuel Services, Inc. Erwin, Tennessee



[ ] - Eliminated from Further Consideration Based on Screening/Evaluation

Threshold Criteria	
Overall Protection of Human Health and the Environment	**Compliance With Applicable Regulations**
• How Alternative Provides Human Health and Environmental Protection	• Compliance with Chemical-Specific Regulations • Compliance with Action-Specific Regulations • Compliance with Location-Specific Regulations

Balancing Criteria				
Long-Term Effectiveness and Permanence	**Reduction of Toxicity, Mobility, and Volume Through Treatment**	**Short-Term Effectiveness**	**Implementability**	**Cost**
• Magnitude of Residual Risk • Adequacy and Reliability of Controls	• Treatment Process Used and Materials Tested • Amount of Hazardous Materials Destroyed or Treated • Degree of Expected Reductions in Toxicity, Mobility, and Volume • Degree in Which Treatment is Irreversible • Type and Quality of Residuals Remaining After Treatment	• Protection of Community During Remedial Actions • Protection of Workers During Remedial Actions • Environmental Impacts • Time Until Remedial Action Objectives are Achieved	• Ability to Construct and Operate the Technology • Reliability of the Technology • Ease of Undertaking Additional Remedial Actions, if Necessary • Ability to Obtain Approvals from Other Agencies • Coordination with Other Agencies • Availability of Offsite Treatment, Storage, and Disposal Services and Capacity • Availability of Necessary Equipment, Materials, and Specialists • Ability of Prospective Technologies	• Capital Costs • Operating and Maintenance Costs • Present Worth Costs

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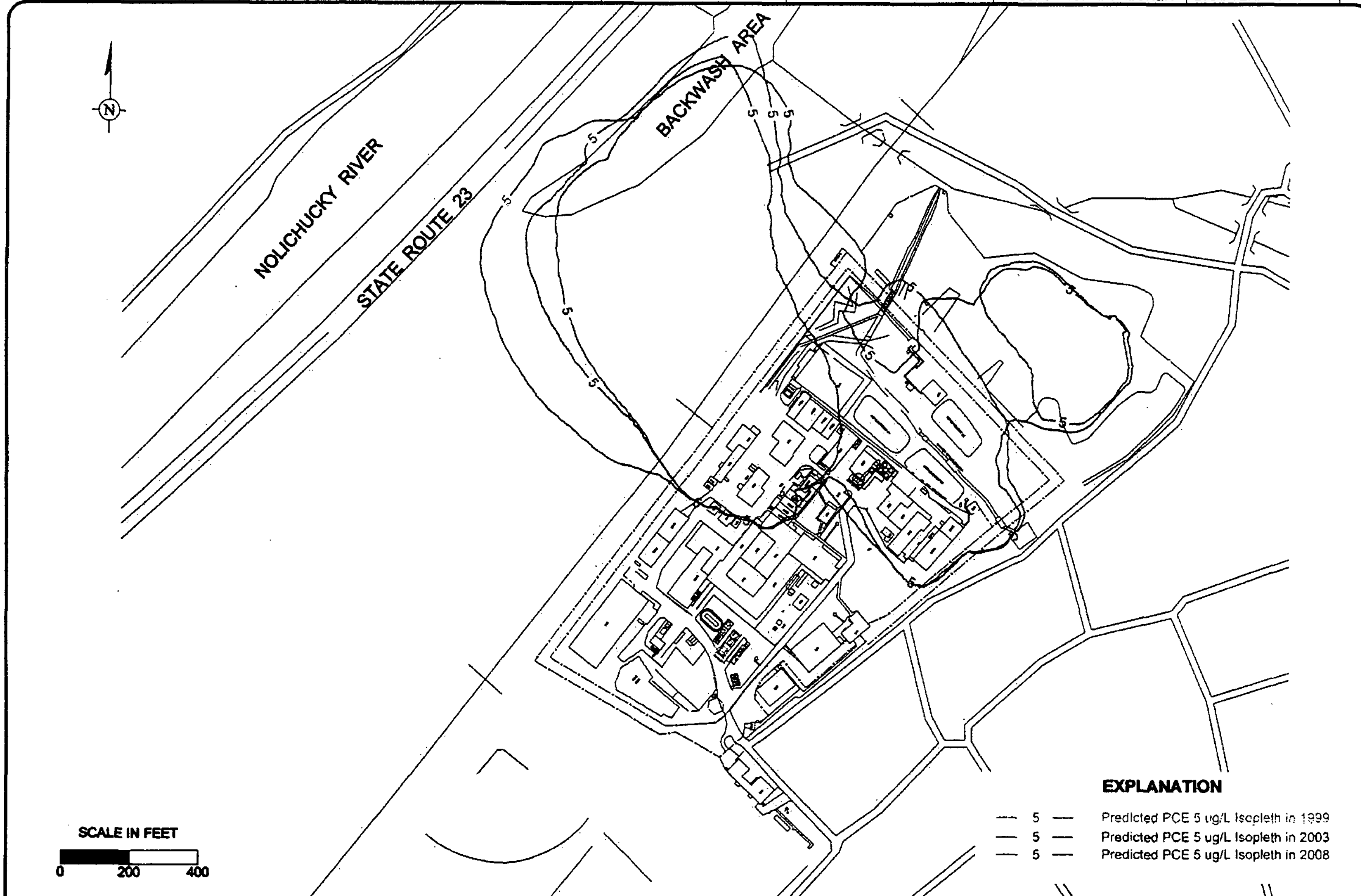
Criteria for Detailed Analysis of Alternatives

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-1

DWG. DATE: 28MAY99	PROJ. NO.:TN000512.0001.00001	RPT NAME: REM. ALT.	DRAWING: Rem7-2.SRF	PROJ. MANAGER: G.PAGE	PROJ. OFFICER: B. ILGNER	DRAFTER:CHAPMAN



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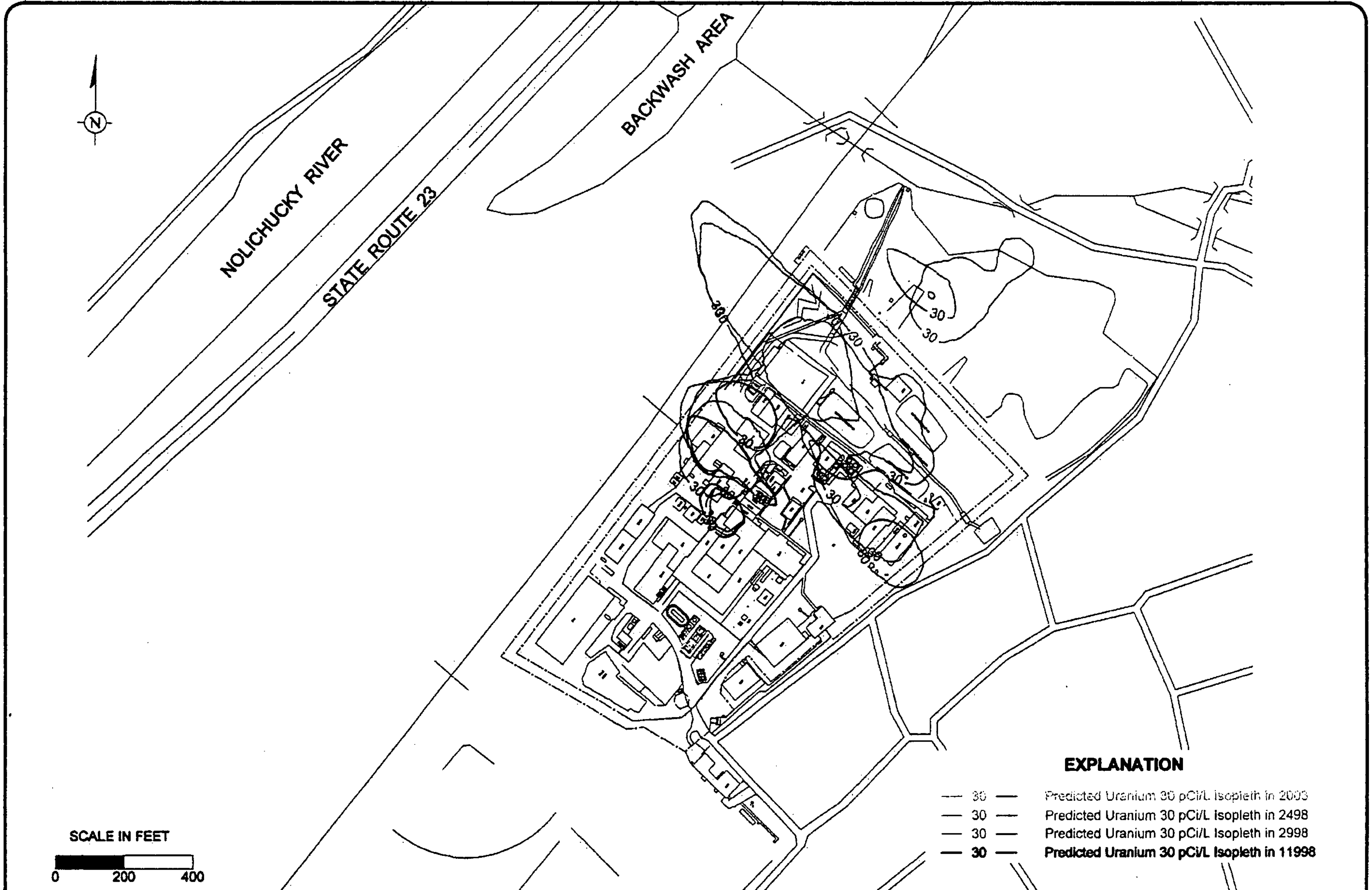
Predicted PCE Concentrations with Continuous Sources in 1999, 2003, and 2008 (Model Layer 2)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-2

DWG. DATE: 28MAY99 | PROJ. NO.: TN000512.0001.00001 | RPT NAME: REM. ALT. | DRAWING: Rem7-3.SRF | PROJ. MANAGER: IG.PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: .CHAPMAN



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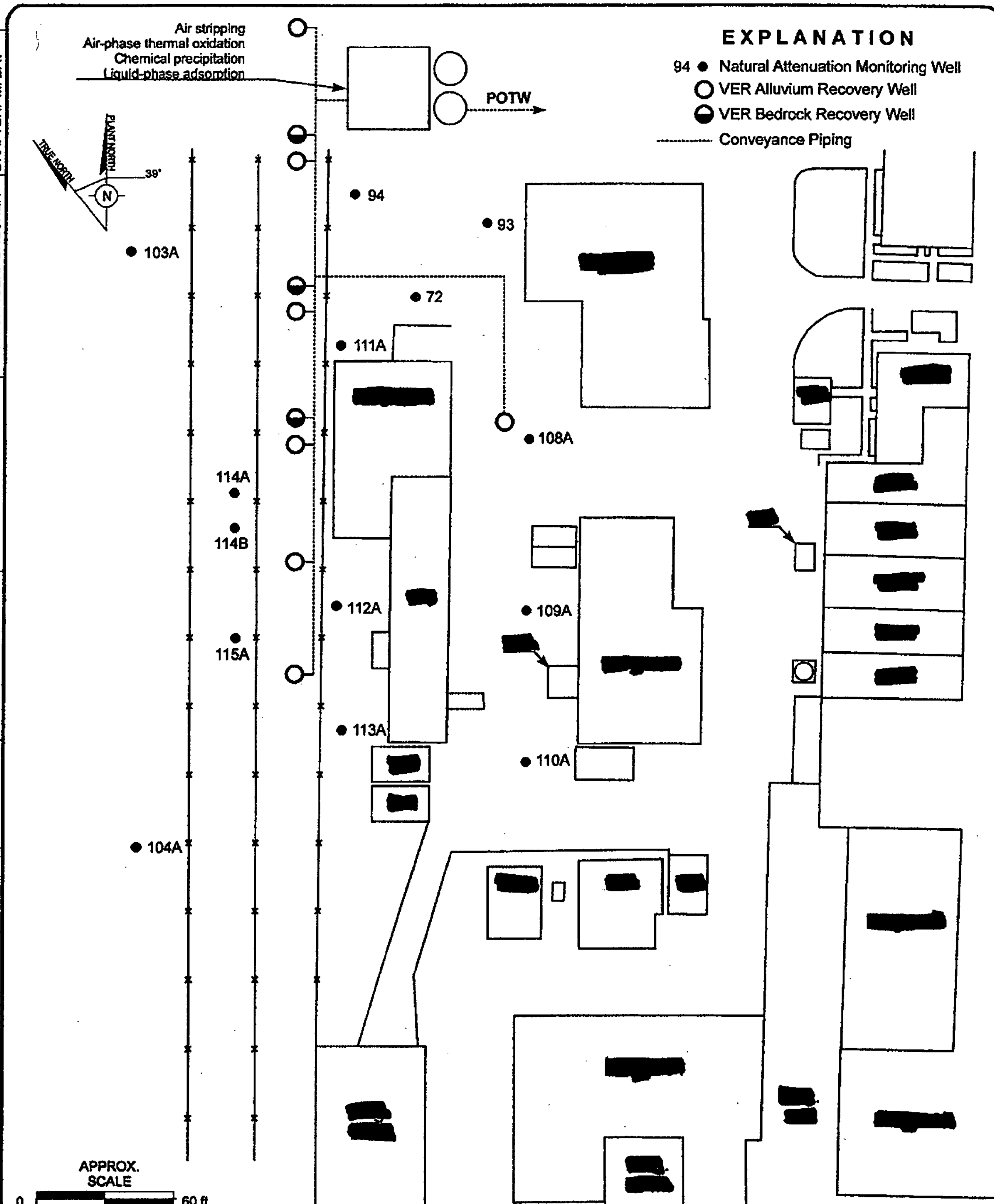
Predicted Uranium Concentrations with Continuous Sources in 2003, 2498, 2998, and 11998 (Model Layer 2)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-3



REFERENCE: NFS 1/21/99 - dwg #005-C0140-B

DWG. DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE NAME: REM ALT | DRAWING: D33378.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY

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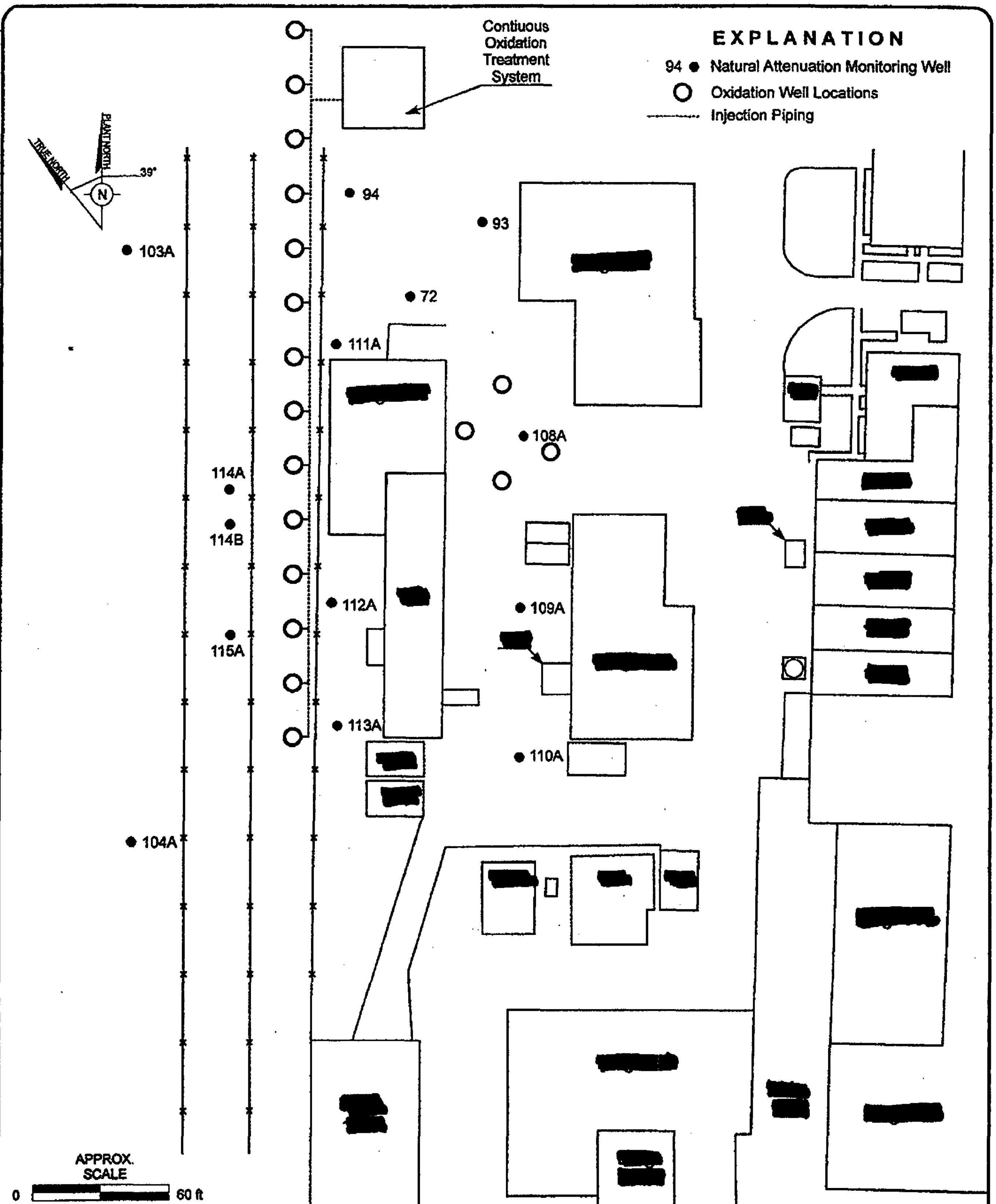
Alternative R-2: Natural Attenuation Monitoring Well Network, VER Recovery Wells, and Treatment Systems

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-4



REFERENCE: NFS 1/21/99 - dwg #005-C0140-B

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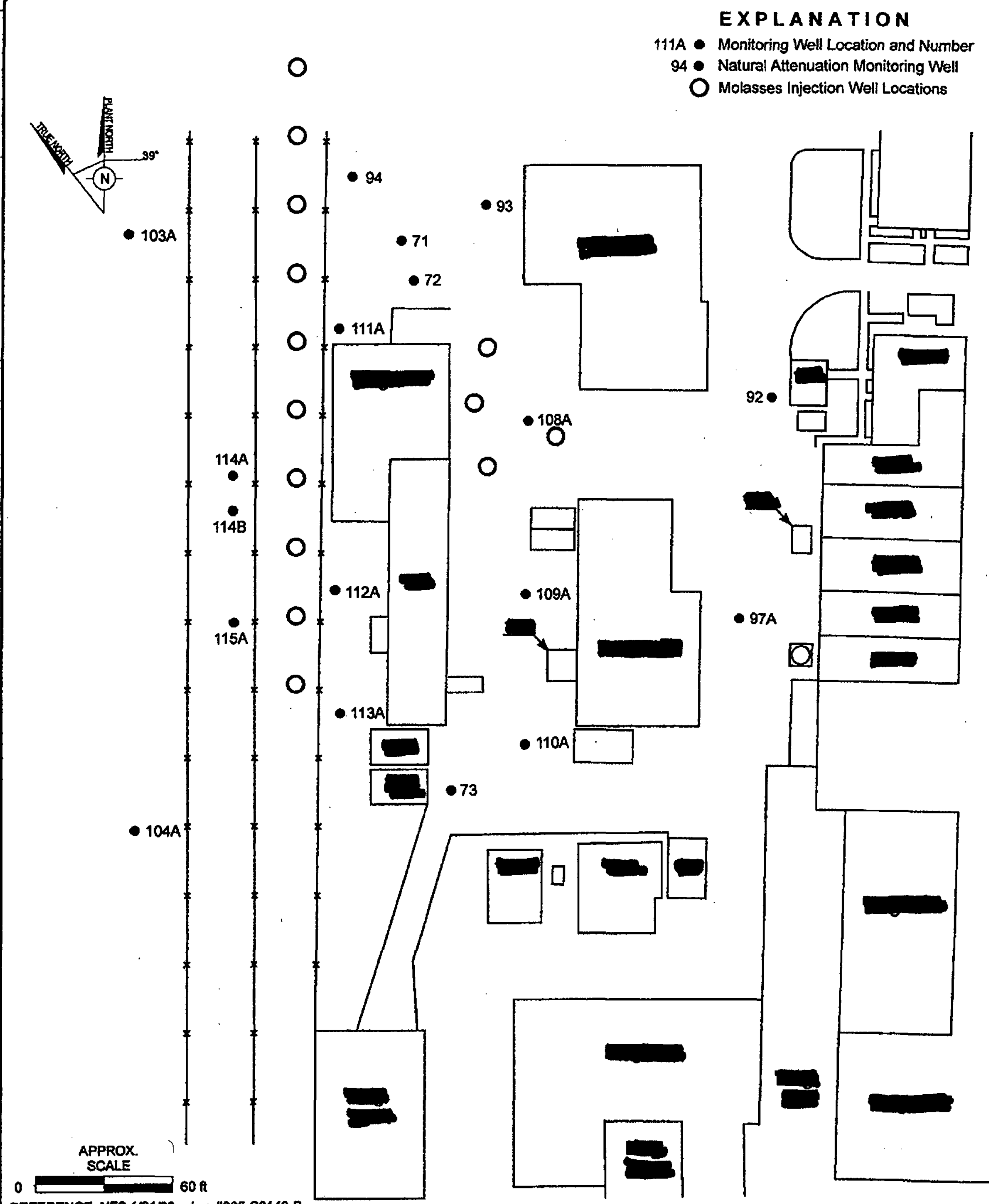
Alternative R-3: Natural Attenuation Monitoring Well Network and In-Situ Oxidation Treatment Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-5

DWG. DATE: 01JUN99 MD | PROJ. NO.: TN000512.0001.00001 | FILE NAME: REM ALT | DRAWING: D33378.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



REFERENCE: NFS 1/21/99 - dwg #005-C0140-B

DRAFTER: T. BARISH | PROJ. OFFICER: B. ILGNER | PROJ. MANAGER: G. PAGE | DRAWING: D33378.CDR | FILE NAME: REM ALT | PROJ. NO.: TN000512.0001.00001 | DWG. DATE: 05AUG99 TB

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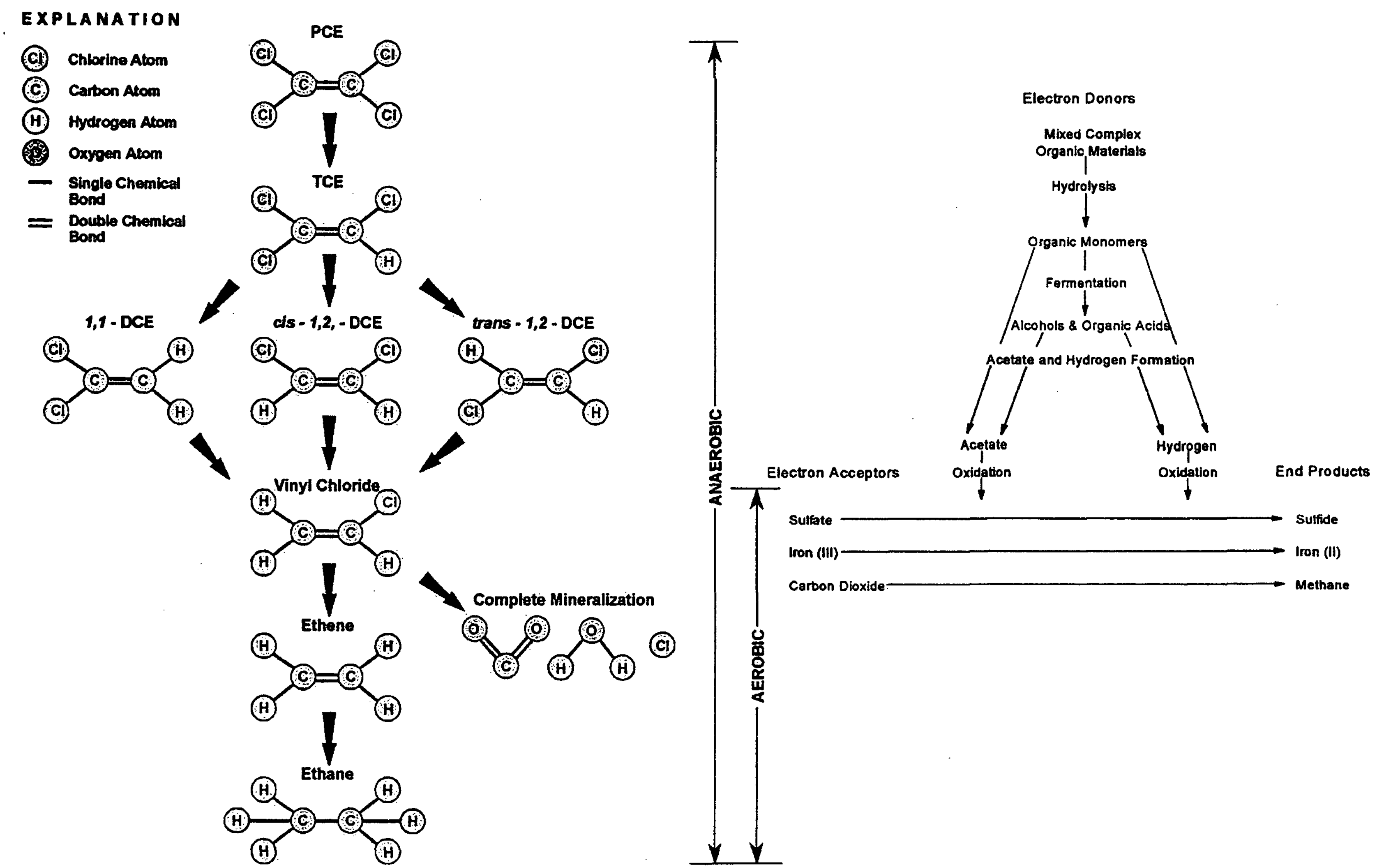
Alternative R-4: Natural Attenuation Monitoring Well Network, Enhanced Anaerobic Bioremediation, and Reductive Precipitation Treatment Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-6

DWG. DATE: 28JUL99 TB | PROJ. NO.: TN000512.0001.00001 | FILE NAME: REM ALT | DRAWING: D33383.CDR | PROJ. MANAGER: G. PAGE | PROJ. OFFICER: B. ILGNER | DRAFTER: T. BARISH



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Transformations of Chlorinated Aliphatic Hydrocarbons

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 7-7

RAI 7

Attachment 2

1st Semi-Annual 2009 Full Scale Data Package, February 23, 2010

ARCADIS
Infrastructure, environment, buildings

ARCADIS
114 Lovell Road, Suite 202
Knoxville, TN 37934
Tel 865.675.6700
Fax 865.675.6712
www.arcadis-us.com

ENVIRONMENT

Mr. Scott Morie
Nuclear Fuel Services, Inc.
1205 Banner Hill Road
Erwin, Tennessee 37650

Subject:
1st Semi-Annual 2009 Full Scale Data Package
SWMU 20/Maintenance Shop Area
Nuclear Fuel Services, Inc.
Erwin, Tennessee

Date:
February 23, 2010

Contact:
Paul Preston

Phone:
865.675.6700, ext. 3110

Email:
Paul.Preston@arcadis-us.com

Our ref:
TNNFS901.FS07

Dear Mr. Morie:

ARCADIS was retained by Nuclear Fuel Services, Inc. (NFS) to conduct full-scale in-situ reactive zone (IRZ®) groundwater treatment at the Solid Waste Management Unit (SWMU) 20/Maintenance Shop Area of the NFS plant located in Erwin, Tennessee. The objective of this effort is to remediate chlorinated solvents and uranium in groundwater in the SWMU 20 area utilizing the ARCADIS IRZ® technology of enhanced anaerobic reductive dechlorination/precipitation, and ultimately prevent off-site migration of impacted groundwater. Activities conducted since the last status report (ARCADIS U.S., Inc. 2008) have included continued in-situ remediation and performance monitoring (observation and injection well sampling including monitoring designed to determine stability conditions and test closure performance).

In-Situ Remediation Injections

Seven reagent injections (#83 through #89) were completed from January 2009 through June 2009. The reagent mixture ratio (potable water to molasses) for these injections was 80:1. Each injection ratio was designed according to observed field parameters and data/performance interpretations relative to IRZ® development and/or progress.

The volume of reagent solution injected per well for each event varied from approximately 18 gallons (IW-21, January 2009) to 5,728 gallons (IW-13, March 2009) (Table 1). The variation of injectate volume was based on hydrogeologic characteristics, constituent of interest distribution, well injectability, and the observed biogeochemical conditions at each well.

A total of 562,291 gallons of reagent solution (approximately 61,688 pounds of total organic carbon) has been injected during the 89 injection events since initiation of full-scale IRZ® remediation in September 2002 (Table 2).

Performance Monitoring

During January and February 2009, ARCADIS completed annual injection well sampling. Locations selected were based on the ability to collect data that would supplement data collected from the observation wells. Sample locations were selected from wells presented in the Annual Well Collection List as described in NFS Procedure NFS-DC-126, Revision 1 Attachment C (IW-1, IW-2, IW-3, IW-7, IW-8, IW-18, IW-20, IW-21, IW-22, IW-23, IW-24, and Well 72).

During the same January and February 2009 mobilization, ARCADIS also completed the 1st semi-annual observation well sampling and First Quarter closure monitoring events. Samples were collected from wells 92, 93, 94, 97A, 102A, 103A, 108A, 109A, 110A, 111A, 112A, 113A, 116A, IW-9, IW-10, and OW-1.

Throughout the January and February 2009 sampling event, water levels were collected from each well just prior to purging. Wells were purged and sampled in accordance with NFS-DC-126, Revision 1. Water samples were collected by low-flow sampling methods using a flow-through cell, and field parameters were recorded in order to determine well stabilization (Tables 3 and 4). Samples were collected using a peristaltic pump while utilizing the reverse flow method for volatile organic compound (VOC) sample collection. Sample aliquots were submitted to ALS Laboratory in Fort Collins, Colorado for non-radiological analysis and to the NFS on-site laboratory for radiological analysis. Data summaries are presented in Tables 5, 6, and 7.

During April 2009, ARCADIS completed the Second Quarter closure monitoring event. Samples were also collected from wells 97A, 109A, IW-5R, IW-6, IW-9, IW-10, and IW-17. A full round of water levels were collected from all observation wells listed in NFS-DC-126 Attachment C and were used to construct SWMU 20 area potentiometric contours (Figure 1). Samples were collected using a peristaltic pump while utilizing the reverse-flow method for VOC sample collection. Sample aliquots were submitted to ALS Laboratory in Fort Collins, Colorado for non-radiological analysis and to the NFS on-site laboratory for radiological analysis. Data summaries are presented in Tables 5, 6, and 7.

Concentration contour maps were created using data collected from the January and February 2009 sampling event (Figures 2, 3, 4, 5, 6, and 7). In the case where the Second Quarter closure monitoring result was less than the January/February 2009 result, the more recent of the two data points were used to refine the distributions and is footnoted as appropriate.

Conclusions

The concentrations of on-site chlorinated solvents have continued to reduce under the influence of the in-situ remediation program. The area of on-site tetrachloroethene impact has been reduced from approximately 2 acres at baseline to less than 0.18 acres during January and February 2009, indicating an approximate 91 percent reduction. In areas where injections have ceased in order to monitor the effectiveness of stabilization, April 2009 data indicated no rebound, and all VOC results were reported as non-detect.

Uranium concentrations in the SWMU 20/Maintenance Shop area continued to decrease as measured in the January/February and April 2009 events. The area of uranium impact has been reduced from approximately 0.75 acres at baseline to approximately 0.18 acres indicating a 76 percent reduction.

ARCADIS appreciates the opportunity to provide this package containing a summary of groundwater data collected in association with the full-scale IRZ® remediation activities requested by NFS. If we can be of any further assistance, please contact us at your convenience.

Sincerely,
ARCADIS

Paul M. Preston, PE
Project Engineer

Berny D. Ilgner, PG
Vice President

RM/bf
Attachments

REFERENCE:

ARCADIS U.S. Inc. 2008. Second Semi-Annual 2008 Full-Scale IRZ® Status Report. Prepared for Nuclear Fuel Services, Inc. May 2009.

ARCADIS

Table 1. Reagent Solution Injection Summary (January - June 2009)
Nuclear Fuel Services, Inc. Erwin, Tennessee

	Week	IW-1	IW-2	IW-3	IW-4R[1]	IW-5R[1]	IW-6	IW-7	IW-8	IW-9	IW-10	IW-11	IW-12	IW-13	IW-14	IW-15	IW-17	IW-18	IW-19	IW-20	IW-21	IW-22	IW-23	IW-24	72
Reagent Injection 83	1/9/2009																								
Reagent Solution Injected (gal)		230.0	845.4	657.9	NI	NI	NI	62.3	76.7	NI	NI	NI	NI	NI	NI	NI	NI	79.0	AW	524.3	18.3	625.3	512.7	841.5	47.9
Ratio (water:molasses)		80:1	80:1	80:1	NI	NI	NI	80:1	80:1	NI	NI	NI	NI	NI	NI	NI	NI	80:1	AW	80:1	80:1	80:1	80:1	80:1	80:1
Molasses Volume Injected (gal)		2.9	10.6	8.2	NI	NI	NI	0.8	1.0	NI	NI	NI	NI	NI	NI	NI	NI	1.0	AW	6.6	0.2	7.8	6.4	10.5	0.6
Organic Carbon Injected (lbs) [2]		10.1	37.1	28.9	NI	NI	NI	2.7	3.4	NI	NI	NI	NI	NI	NI	NI	NI	3.5	AW	23.0	0.8	27.4	22.5	36.9	2.1
Sodium Bicarbonate Added (lbs)		0.0	0.0	0.0	NI	NI	NI	0.0	0.0	NI	NI	NI	NI	NI	NI	NI	NI	0.0	AW	0.0	0.0	0.0	0.0	0.0	0.0
Ferrous Sulfate Added (lbs)		57.5	211.4	164.5	NI	NI	NI	15.6	19.2	NI	NI	NI	NI	NI	NI	NI	NI	9.9	AW	131.1	4.6	156.3	128.2	210.4	12.0
Reagent Injection 84	2/16/2009																								
Reagent Solution Injected (gal)		71.2	414.4	371.0	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	3639.9	NI	NI	61.7	AW	584.5	46.8	NI	NI	892.8	NI
Ratio (water:molasses)		80:1	80:1	80:1	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	80:1	NI	NI	80:1	AW	80:1	80:1	NI	NI	80:1	NI
Molasses Volume Injected (gal)		0.9	5.2	4.6	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	45.5	NI	NI	0.8	AW	7.3	0.6	NI	NI	11.2	NI
Organic Carbon Injected (lbs) [2]		3.1	18.2	16.3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	159.7	NI	NI	2.7	AW	25.6	2.1	NI	NI	39.2	NI
Sodium Bicarbonate Added (lbs)		0.0	0.0	0.0	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	NI	NI	0.0	AW	0.0	0.0	NI	NI	0.0	NI
Ferrous Sulfate Added (lbs)		17.8	103.6	92.8	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	NI	NI	15.4	AW	148.1	11.7	NI	NI	223.2	NI
Reagent Injection 85	3/9/2009																								
Reagent Solution Injected (gal)		34.1	642.5	373.2	NI	NI	NI	NI	163.1	NI	NI	NI	NI	5727.6	NI	NI	NI	NI	AW	NI	63.8	NI	109.8	608.3	26.4
Ratio (water:molasses)		80:1	80:1	80:1	NI	NI	NI	NI	80:1	NI	NI	NI	NI	80:1	NI	NI	NI	NI	AW	NI	80:1	NI	80:1	80:1	80:1
Molasses Volume Injected (gal)		0.4	8.0	4.7	NI	NI	NI	NI	2.0	NI	NI	NI	NI	71.6	NI	NI	NI	NI	AW	NI	0.8	NI	1.4	7.6	0.3
Organic Carbon Injected (lbs) [2]		1.5	28.2	16.4	NI	NI	NI	NI	7.2	NI	NI	NI	NI	251.3	NI	NI	NI	NI	AW	NI	2.8	NI	4.8	26.7	1.2
Sodium Bicarbonate Added (lbs)		0.0	0.0	0.0	NI	NI	NI	NI	0.0	NI	NI	NI	NI	0.0	NI	NI	NI	NI	AW	NI	0.0	NI	0.0	0.0	0.0
Ferrous Sulfate Added (lbs)		8.5	160.6	93.3	NI	NI	NI	NI	40.8	NI	NI	NI	NI	0.0	NI	NI	NI	NI	AW	NI	16.0	NI	27.4	152.1	6.6
Reagent Injection 86	4/6/2009																								
Reagent Solution Injected (gal)		NI	795.0	684.0	NI	NI	NI	NI	NI	NI	NI	NI	NI	3115.0	NI	1602.0	NI	73.0	AW	NI	NI	NI	NI	NI	NI
Ratio (water:molasses)		NI	80:1	80:1	NI	NI	NI	NI	NI	NI	NI	NI	NI	80:1	NI	80:1	NI	80:1	AW	NI	NI	NI	NI	NI	NI
Molasses Volume Injected (gal)		NI	9.9	8.7	NI	NI	NI	NI	NI	NI	NI	NI	NI	38.9	NI	20.0	NI	0.9	AW	NI	NI	NI	NI	NI	NI
Organic Carbon Injected (lbs) [2]		NI	34.9	30.4	NI	NI	NI	NI	NI	NI	NI	NI	NI	136.7	NI	70.3	NI	3.2	AW	NI	NI	NI	NI	NI	NI
Sodium Bicarbonate Added (lbs)		NI	0.0	0.0	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	NI	0.0	NI	0.0	AW	NI	NI	NI	NI	NI	NI
Ferrous Sulfate Added (lbs)		NI	198.8	173.5	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	NI	0.0	NI	18.3	AW	NI	NI	NI	NI	NI	NI
Reagent Injection 87	5/11/2009																								
Reagent Solution Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	4392.0	3793.0	NI	NI	AW	620.8	NI	NI	146.4	874.7	NI
Ratio (water:molasses)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	80:1	80:1	NI	NI	AW	80:1	NI	NI	80:1	80:1	NI
Molasses Volume Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	54.9	47.4	NI	NI	AW	7.8	NI	NI	1.8	10.9	NI
Organic Carbon Injected (lbs) [2]		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	192.7	166.4	NI	NI	AW	27.2	NI	NI	6.4	38.4	NI
Sodium Bicarbonate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	0.0	NI	NI	AW	0.0	NI	NI	0.0	0.0	NI
Ferrous Sulfate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	0.0	NI	NI	AW	155.2	NI	NI	36.6	218.7	NI
Reagent Injection 88	6/1/2009																								
Reagent Solution Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	966.7	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	209.4	NI
Ratio (water:molasses)		NI	NI	NI	NI	NI	NI	NI	NI	NI	80:1	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	80:1	NI
Molasses Volume Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	12.1	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	2.6	NI
Organic Carbon Injected (lbs) [2]		NI	NI	NI	NI	NI	NI	NI	NI	NI	42.4	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	9.2	NI
Sodium Bicarbonate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	0.0	NI
Ferrous Sulfate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	302.1	NI	NI	NI	NI	NI	NI	NI	AW	NI	NI	NI	NI	65.4	NI
Reagent Injection 89	6/8/2009																								
Reagent Solution Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	4139.0	2585.5	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Ratio (water:molasses)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	80:1	80:1	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Molasses Volume Injected (gal)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	51.7	32.3	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Organic Carbon Injected (lbs) 2		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	181.6	113.4	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Sodium Bicarbonate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	0.0	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Ferrous Sulfate Added (lbs)		NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	0.0	0.0	NI	NI	NI	AW	NI	NI	NI	NI	NI	NI
Total Organic Carbon Injected (lbs) [2]		**3442.7**	**2416.1**	**3856.1**	**768.8**	**1666.5**	**2500.6**	**1062.3**	**2326.3**	**3486.1**	**3611.1**	**2281.6**	**2702.7**	**6326.3**	**6667.2**	**6774.0**	**2013.9**	**1146.8**	**1392.8**	**2913.0**	**794.4**	**981.0**	**131.9**	**267.3**	**967.7**
Total Sodium Bicarbonate Added (lbs)		**696.7**	**556.3**	**637.5**	**223.5**	**632.7**	**561.3**	**240.3**	**369.5**	**587.5**	**612.5**	**612.5**	**662.5**	**662.5**	**675.0**	**696.7**	**461.5**	**137.5**	**134.2**	**231.3**	**105.8**	**97.4**	**0.0**	**0.0**	**87.0**
Total Ferrous Sulfate Added (lbs)		**3996.1**	**2052.7**	**5563.5**	**3.5**	**597.3**	**2321.5**	**16.6**	**122.5**	**2022.9**	**6645.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**941.0**	**1105.3**	**1099.4**	**2670.8**	**46.5**	**166.3**	**284.5**	**869.8**	**16.6**

1 - Replacement wells IW-4R and IW-5R were installed on 11/1/06. Injections prior to 11/1/06 were made into the original wells IW-4 and IW-5.

2 - Based on 30%(by weight) of organic carbon in molasses. Molasses density is 11.7 pounds/gallon.

gal - gallons

lbs - pounds

NI - no injection

AW- abandoned well

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Table 2. Project Summary of Reagent Injected
Nuclear Fuel Services, Inc. Erwin, Tennessee

Total Volume Injected (gal)	562,291
Total Molasses Volume Injected (gal)	17,574
Organic Carbon Injected (lbs) *	61,688
Total Sodium Bicarbonate (lbs)	10,118
Total Ferrous Sulfate (lbs)	31,302

* - organic carbon in molasses is 30% by weight / molasses density is 11.7 pounds per gallon
gal - gallons
lbs - pounds

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Table 3. Full-Scale Performance Field Data in Observation Wells (January-June 2009)
Nuclear Fuel Services, Inc. Erwin, Tennessee

Well ID	Date	Depth to Water (ft btoc)	Water-Table Elevation (ft msl)	pH (SU)	Spec Cond (mS/m)	Temp (°C)
92	2/11/2009	5.50	1633.48	6.50	0.818	13.86
	4/14/2009	4.97	1634.01	NM	NM	NM
93	2/10/2009	5.05	1633.34	6.33	2.855	14.44
	4/14/2009	4.45	1633.94	NM	NM	NM
94	1/29/2009	4.87	1635.73	6.27	0.529	7.21
	4/14/2009	6.15	1634.45	NM	NM	NM
97A	2/9/2009	4.38	1634.39	6.35	0.652	18.18
	4/16/2009	4.10	1634.67	6.35	1.118	19.98
102A	2/5/2009	12.32	1630.31	6.61	0.499	11.25
	4/14/2009	12.15	1630.48	NM	NM	NM
103A	2/5/2009	13.27	1630.10	6.56	0.697	13.40
	4/14/2009	12.55	1630.82	NM	NM	NM
108A	2/3/2009	3.36	1635.13	6.61	2.178	9.40
	4/14/2009	3.71	1634.78	NM	NM	NM
109A	1/28/2009	4.13	1634.46	6.07	1.667	13.39
	4/15/2009	3.80	1634.79	6.12	1.444	12.87
110A	1/27/2009	2.52	1635.83	6.28	1.730	11.60
	4/14/2009	3.09	1635.26	NM	NM	NM
111A	1/29/2009	6.42	1634.83	6.59	0.397	7.84
	4/14/2009	7.01	1634.24	NM	NM	NM
112A	2/2/2009	7.27	1633.85	6.42	0.190	9.54
	4/14/2009	6.62	1634.50	NM	NM	NM
113A	2/2/2009	7.24	1633.97	6.32	0.218	9.30
	4/14/2009	6.50	1634.71	NM	NM	NM
116A	1/22/2009	9.20	1629.75	6.71	0.969	13.16
	4/14/2009	9.27	1629.68	NM	NM	NM
OW-1	1/28/2009	5.00	1632.97	8.58	1.290	11.66
	4/14/2009	4.81	1633.16	NM	NM	NM

btoc - below top of casing
°C - degrees Celsius
ft - feet
msl - mean sea level
mS/m - millisiemens per meter

NM - not measured
Spec Cond - specific conductance
SU - standard units
Temp - temperature

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Table 4. Full-Scale Performance Field Data in Injection Wells (January-June 2009)
Nuclear Fuel Services, Inc. Erwin, Tennessee

Well ID	Date	Depth to Water (ft btoc)	Water-Table Elevation (ft msl)	pH (SU)	Spec Cond (mS/m)	Temp (°C)
IW-1	2/3/2009	5.40	1632.92	5.97	5.314	6.95
	4/14/2009	5.05	1633.27	NM	NM	NM
IW-2	1/26/2009	4.66	1633.78	5.12	6.080	13.15
	4/14/2009	4.20	1634.24	NM	NM	NM
IW-3	1/26/2009	4.23	1634.28	4.57	10.430	11.97
	4/14/2009	4.12	1634.39	NM	NM	NM
IW-4R	4/14/2009	4.31	1634.51	NM	NM	NM
IW-5R	4/16/2009	4.13	1634.67	6.51	3.735	18.74
IW-6	4/16/2009	4.36	1634.13	6.02	3.626	13.70
IW-7	2/3/2009	5.10	1633.10	4.39	7.385	10.64
	4/14/2009	5.01	1633.19	NM	NM	NM
IW-8	1/29/2009	4.95	1633.32	5.46	3.747	10.47
	4/14/2009	4.91	1633.36	NM	NM	NM
IW-9	1/27/2009	5.16	1633.44	6.17	3.406	11.92
	4/16/2009	4.63	1633.97	6.15	3.242	14.31
IW-10	1/27/2009	4.60	1634.26	6.09	2.578	13.50
	4/15/2009	3.59	1635.27	6.07	2.891	16.21
IW-17	4/16/2009	4.38	1634.62	6.24	2.626	18.25
IW-18	2/9/2009	4.72	1633.89	4.67	5.419	13.72
	4/14/2009	2.96	1635.65	NM	NM	NM
IW-20	2/4/2009	5.68	1633.05	5.53	4.503	11.39
	4/14/2009	5.21	1633.52	NM	NM	NM
IW-21	2/10/2009	4.25	1634.95	4.85	3.212	15.15
	4/14/2009	3.11	1636.09	NM	NM	NM
IW-22	2/11/2009	5.60	1632.89	4.32	9.180	16.19
	4/14/2009	5.28	1633.21	NM	NM	NM
IW-23	1/29/2009	4.96	NM	4.93	5.872	11.84
	4/14/2009	5.09	NM	NM	NM	NM
IW-24	2/10/2009	6.50	NM	6.52	2.091	16.24
	4/14/2009	6.42	NM	NM	NM	NM
72	2/10/2009	5.33	1633.21	4.92	6.000	11.13
	4/14/2009	4.53	1634.01	NM	NM	NM

btoc - below top of casing
°C - degrees Celsius
ft - feet
msl - mean sea level
mS/m - millisiemens per meter

NM - not measured
Spec Cond - specific conductance
SU - standard units
Temp - temperature

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Table 5. Full Scale Perfomance Non-Radiological Analytical Data in Observation and Injection Wells (January-June 2009)

Nuclear Fuel Services, Inc. **Erwin, Tennessee**

	Date	92	93	94	97A	102A	103A	108A	109A	110A	111A	112A	113A	116A	GW-1
Volatile Organic Compounds (mg/L)															
Tetrachloroethene	1st QTR/SA	0.005 U	0.005 U	0.0042 J	0.005 U	0.005 U	0.012	0.005 U	0.005 U	0.005 U	0.24	0.005 U	0.005 U	0.019	0.013
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	0.005 U						
Trichloroethene	1st QTR/SA	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.0052	0.005 U	0.005 U	0.005 U	0.016	0.005 U	0.005 U	0.005 U	0.0057
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	0.005 U						
cis-1,2-Dichloroethene	1st QTR/SA	0.005 U	0.0056	0.005 U	0.005 U	0.005 U	0.11	0.0023 J	0.0026 J	0.0065	0.036	0.005 U	0.005 U	0.0042 J	0.13
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	0.005 U						
trans-1,2-Dichloroethene	1st QTR/SA	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.012 U	0.005 U	0.005 U	0.005 U	0.01 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	0.005 U						
Vinyl Chloride	1st QTR/SA	0.005 U	0.0021 J	0.005 U	0.005 U	0.005 U	0.016	0.0033 J	0.002	0.0066	0.012 U	0.005 U	0.005 U	0.005 U	0.041
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS
Semi-Volatile Organic Compounds (mg/L)															
Tributyl Phosphate	1st QTR/SA	0.0044 J	34 J	0.00097 U	0.0011 U	0.0011 U	0.001 U	11 J	0.007 J	0.018 J	0.00097 U	0.00098 U	0.00097 U	0.00094 U	0.47 J
	2nd QTR	NS	NS	NS	0.00098 U	NS	NS	NS	0.0036	NS	NS	NS	NS	NS	NS
Biogeochemical Analytes (mg/L)															
Total Organic Carbon	1st QTR/SA	2.6	49	1.1	1.8	1.9	13	14	10	13	1.3	1 U	1 U	1.9	4.4
	2nd QTR	NS	NS	NS	1.6	NS	NS	NS	8.3						
Nitrate/Nitrite Nitrogen	1st QTR/SA	0.2	0.01	3.3	0.044	0.01	1	0.1	0.01	0.1	3	3.5	2.8	0.63	0.01
	2nd QTR	NS	NS	NS	0.033	NS	NS	NS	0.01	NS	NS	NS	NS	NS	NS
Ammonia Nitrogen	1st QTR/SA	8.6	8.8	0.1 U	0.14	0.1 U	0.1 U	1.2 J	0.88 HJ	0.32	0.1 U	0.1 U	0.1 U	0.1 U	2.8 HJ
	2nd QTR	NS	NS	NS	0.18	NS	NS	NS	0.81	NS	NS	NS	NS	NS	NS
Iron (total)	1st QTR/SA	4.5 J	39 J	0.15 J	1.4 J	3.2 J	7.1 J	20 J	120 J	85 J	0.1 U	8.7 J	0.011 J	0.0091 J	3.6 J
	2nd QTR	NS	NS	NS	1.4	NS	NS	NS	100	NS	NS	NS	NS	NS	NS
Iron (dissolved)	1st QTR/SA	6 J	40 J	0.1 U	2.1 J	3.5 J	7.9 J	15 J	110 J	90 J	0.1 U	0.35 J	0.018 J	0.0095 J	0.13 J
	2nd QTR	NS	NS	NS	1.3	NS	NS	NS	87	NS	NS	NS	NS	NS	NS
Manganese (total)	1st QTR/SA	1	1.1	0.0088 U	0.43	0.67	0.099	0.61	3	4.4	0.0017 U	0.042	0.048	2.2	0.048
	2nd QTR	NS	NS	NS	0.43	NS	NS	NS	2.5	NS	NS	NS	NS	NS	NS
Manganese (dissolved)	1st QTR/SA	1	1.1	0.0083	0.5	0.67	0.13	0.61	2.9	4.3	0.00014	0.025	0.047	1.5	0.034
	2nd QTR	NS	NS	NS	0.46	NS	NS	NS	2.4	NS	NS	NS	NS	NS	NS
Sulfate	1st QTR/SA	3.9	57	27	39	51	11	2.5	8 J	16	22	15	26	38	36
	2nd QTR	NS	NS	NS	30	NS	NS	NS	4.2	NS	NS	NS	NS	NS	NS
Chloride	1st QTR/SA	140	590	33	63	14	120	210	81	61	18	6.1	9.2	13	29
	2nd QTR	NS	NS	NS	73	NS	NS	NS	100	NS	NS	NS	NS	NS	NS
Dissolved Gases/Light Hydrocarbons (mg/L)															
Carbon Dioxide (free)	1st QTR/SA	72	350	18	81	59	100	220 HJ	350	480	17	14	31	64	1.5
	2nd QTR	NS	NS	NS	78	NS	NS	NS	360	NS	NS	NS	NS	NS	NS
Methane	1st QTR/SA	260	13	0.0026	3	1.5	1.8	9.9	6.8	7	0.0014	0.0014	0.0019	0.64	4.2
	2nd QTR	NS	NS	NS	0.009	NS	NS	NS	5.5	NS	NS	NS	NS	NS	NS
Ethene	1st QTR/SA	1 U	0.014	0.001 U	0.001 U	0.001 U	0.0051	0.16	0.001 U	0.0012	0.001 U	0.001 U	0.001 U	0.001 U	0.014
	2nd QTR	NS	NS	NS	0.001 U	NS	NS	NS	0.001 U	NS	NS	NS	NS	NS	NS
Ethane	1st QTR/SA	2 U	0.047	0.002 U	0.002 U	0.002 U	0.007	0.26	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.064
	2nd QTR	NS	NS	NS	0.002 U	NS	NS	NS	0.002 U	NS	NS	NS	NS	NS	NS

mg/L - milligrams per liter
NS - not sampled
QTR - Quarterly Sampling Event
SA - Semi-Annual Sampling Event

Data Qualifiers:
H - exceeded hold time
J - estimated
U - undetected
UJ - estimated, non-detect

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Table 6. Full Scale Perfomance Non-Radiological Analytical Data in Observation and Injection Wells (January-June 2009)
Nuclear Fuel Services, Inc. Erwin, Tennessee

	Date	IW-1	IW-2	IW-3	IW-4	IW-5R	IW-6	IW-7	IW-8	IW-9	IW-10	IW-11	IW-12	IW-13
		Well ID												
Volatile Organic Compounds (mg/L)														
Tetrachloroethene	1st QTR/SA	0.22 J	0.005 U	0.005 U	NS	NS	NS	0.005 U	0.012	0.005 U	0.005 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.005 U	0.005 U	NS	NS	0.005 U	0.005 U	NS	NS	NS
Trichloroethene	1st QTR/SA	0.25 U	0.005 U	0.005 U	NS	NS	NS	0.005 U	0.012	0.005 U	0.005 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.005 U	0.005 U	NS	NS	0.005 U	0.005 U	NS	NS	NS
cis-1,2-Dichloroethene	1st QTR/SA	2.3	0.005 U	0.005 U	NS	NS	NS	0.0018 J	0.29 J	0.005 U	0.005 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.005 U	0.005 U	NS	NS	0.005 U	0.005 U	NS	NS	NS
trans-1,2-Dichloroethene	1st QTR/SA	0.25 U	0.005 U	0.005 U	NS	NS	NS	0.005 U	0.012 U	0.005 U	0.005 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.005 U	0.005 U	NS	NS	0.005 U	0.005 U	NS	NS	NS
Vinyl Chloride	1st QTR/SA	0.45	0.005 U	0.0024 J	NS	NS	NS	0.005 U	0.02 J	0.005 U	0.005 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.005 U	0.005 U	NS	NS	0.005 U	0.005 U	NS	NS	NS
Semi-Volatile Organic Compounds (mg/L)														
Tributyl Phosphate	1st QTR/SA	0.24	0.00098 U	0.0095 U	NS	NS	NS	0.0057	7	0.0057	0.007	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.0007 J	NA*	NS	NS	0.0052	0.025	NS	NS	NS
Biogeochemical Analytes (mg/L)														
Total Organic Carbon	1st QTR/SA	660	930	2400	NS	NS	NS	2000	1100	220	130	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	220	580	NS	NS	120	46	NS	NS	NS
Nitrate/Nitrite Nitrogen	1st QTR/SA	1 U	0.1 U	0.1 U	NS	NS	NS	1 U	0.1 U	0.1 U	0.01 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.05 U	0.014	NS	NS	0.072	0.01 U	NS	NS	NS
Ammonia Nitrogen	1st QTR/SA	0.95 J	0.51 J	1.3 J	NS	NS	NS	4.2 J	1.7 J	0.59 J	0.65 J	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	29	18	NS	NS	7.3	3.2	NS	NS	NS
Iron (total)	1st QTR/SA	1500	1300	3000	NS	NS	NS	3300	2000	270	260	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	240	430	NS	NS	220	210	NS	NS	NS
Iron (dissolved)	1st QTR/SA	1400	1300	3100	NS	NS	NS	3200	1900	270	250	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	230	430	NS	NS	230	200	NS	NS	NS
Manganese (total)	1st QTR/SA	17	9.3	21	NS	NS	NS	21	12	4.4	3.8	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	1.7	5.8	NS	NS	3.4	3.7	NS	NS	NS
Manganese (dissolved)	1st QTR/SA	16	9.4	22	NS	NS	NS	21	12	4.5	3.8	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	1.8	5.7	NS	NS	3.3	3.8	NS	NS	NS
Sulfate	1st QTR/SA	1900	2100	4500	NS	NS	NS	5500	3100	2 U	2 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	2 U	2 U	NS	NS	0.5 J	2 U	NS	NS	NS
Chloride	1st QTR/SA	220	72	140	NS	NS	NS	120	110	180	140	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	140	160	NS	NS	180	290	NS	NS	NS
Dissolved Gases/Light Hydrocarbons (mg/L)														
Carbon Dioxide (free)	1st QTR/SA	1600 HJ	8000 J	27000 J	NS	NS	NS	410 J	6000 J	960 HJ	810 HJ	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	640	1300	NS	NS	820	970	NS	NS	NS
Methane	1st QTR/SA	4.1 J	4.5 J	3.4 J	NS	NS	NS	7.8	7 J	4.7 J	4.1 J	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	10	7.3	NS	NS	6.5	7.8	NS	NS	NS
Ethene	1st QTR/SA	0.22 J	0.001 U	0.001 U	NS	NS	NS	0.001 U	0.0066 J	0.001 U	0.001 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.001 U	0.001 U	NS	NS	0.001 U	0.001 U	NS	NS	NS
Ethane	1st QTR/SA	0.02 J	0.002 J	0.002 U	NS	NS	NS	0.002 U	0.0068 J	0.002 U	0.002 U	NS	NS	NS
	2nd QTR	NS	NS	NS	NS	0.002 U	0.002 U	NS	NS	0.002 U	0.002 U	NS	NS	NS

mg/L - milligrams per liter
NA* - sampled but bottles were broken upon lab receipt
NS - not sampled
QTR - quarterly sampling event
SA - semi-annual sampling event

Data Qualifiers:
H - exceeded hold time
J - estimated
U - undetected
UJ - estimated, non-detect

ARCADIS

Table 6. Full Scale Perfomance Non-Radiological Analytical Data in Observation and Injection Wells (January -June 2009)
Nuclear Fuel Services, Inc. Erwin, Tennessee

		Well ID											
	Date	IW-14	IW-15	IW-16	IW-17	IW-18	IW-19	IW-20	IW-21	IW-22	IW-23	IW-24	72
Volatile Organic Compounds (mg/L)													
Tetrachloroethene	1st QTR/SA	NS	NS	NS	NS	0.005 U	NS	0.005 U	0.005 U	0.005 U	0.005 J	0.005 U	0.005 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS	NS	NS
Trichloroethene	1st QTR/SA	NS	NS	NS	NS	0.005 U	NS	0.005 U	0.005 U	0.005 U	0.0036 J	0.005 U	0.005 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS	NS	NS
cis-1,2-Dichloroethene	1st QTR/SA	NS	NS	NS	NS	0.005 U	NS	0.005 U	0.0061	0.005 U	0.12 J	0.005 U	0.005 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS	NS	NS
trans-1,2-Dichloroethene	1st QTR/SA	NS	NS	NS	NS	0.005 U	NS	0.005 U	0.005 U	0.005 U	0.01 U	0.005 U	0.005 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS	NS	NS
Vinyl Chloride	1st QTR/SA	NS	NS	NS	NS	0.005 U	NS	0.005 U	0.0024 J	0.005 U	0.043 J	0.005 U	0.005 U
	2nd QTR	NS	NS	NS	0.005 U	NS	NS	NS	NS	NS	NS	NS	NS
Semi-Volatile Organic Compounds (mg/L)													
Tributyl Phosphate	1st QTR/SA	NS	NS	NS	NS	0.0011 U	NS	0.0071	1.7	0.0021 U	0.32	0.11	0.031
	2nd QTR*	NS	NS	NS	0.00099 U	NS	NS	NS	NS	NS	NS	NS	NS
Biogeochemical Analytes (mg/L)													
Total Organic Carbon	1st QTR/SA	NS	NS	NS	NS	2600	NS	580	470	2800 J	1900	38	850
	2nd QTR	NS	NS	NS	140	NS	NS	NS	NS	NS	NS	NS	NS
Nitrate/Nitrite Nitrogen	1st QTR/SA	NS	NS	NS	NS	1	NS	1 U	0.01 U	1 UJ	0.1 U	0.01 U	1 U
	2nd QTR	NS	NS	NS	0.05 U	NS	NS	NS	NS	NS	NS	NS	NS
Ammonia Nitrogen	1st QTR/SA	NS	NS	NS	NS	0.98 J	NS	0.86 J	1.6	2.1 J	2.5 J	1.7 J	6.4 J
	2nd QTR	NS	NS	NS	16	NS	NS	NS	NS	NS	NS	NS	NS
Iron (total)	1st QTR/SA	NS	NS	NS	NS	4900	NS	1700	980	3600	4100	300	2000
	2nd QTR	NS	NS	NS	130	NS	NS	NS	NS	NS	NS	NS	NS
Iron (dissolved)	1st QTR/SA	NS	NS	NS	NS	5100	NS	960	1000	3500	4400	300	2000
	2nd QTR	NS	NS	NS	120	NS	NS	NS	NS	NS	NS	NS	NS
Manganese (total)	1st QTR/SA	NS	NS	NS	NS	35	NS	11	6.4	23	22	4.5	14
	2nd QTR	NS	NS	NS	2.9	NS	NS	NS	NS	NS	NS	NS	NS
Manganese (dissolved)	1st QTR/SA	NS	NS	NS	NS	36	NS	7.5	6.6	22	23	4.5	14
	2nd QTR	NS	NS	NS	2.8	NS	NS	NS	NS	NS	NS	NS	NS
Sulfate	1st QTR/SA	NS	NS	NS	NS	6600	NS	2400	1500	6000	5200	280	3400
	2nd QTR	NS	NS	NS	0.77 J	NS	NS	NS	NS	NS	NS	NS	NS
Chloride	1st QTR/SA	NS	NS	NS	NS	100	NS	120	26	110	92	69	77
	2nd QTR	NS	NS	NS	100	NS	NS	NS	NS	NS	NS	NS	NS
Dissolved Gases/Light Hydrocarbons (mg/L)													
Carbon Dioxide (free)	1st QTR/SA	NS	NS	NS	NS	41000 J	NS	3300 J	8600 J	720 J	20000 J	520 J	11000 J
	2nd QTR	NS	NS	NS	630	NS	NS	NS	NS	NS	NS	NS	NS
Methane	1st QTR/SA	NS	NS	NS	NS	0.012 J	NS	4.1 J	8.6 J	6200 J	8.1 J	13	11
	2nd QTR	NS	NS	NS	8	NS	NS	NS	NS	NS	NS	NS	NS
Ethene	1st QTR/SA	NS	NS	NS	NS	0.001 U	NS	0.001 U	0.0011	1 U	0.22 J	0.001 U	0.001 U
	2nd QTR	NS	NS	NS	0.001 U	NS	NS	NS	NS	NS	NS	NS	NS
Ethane	1st QTR/SA	NS	NS	NS	NS	0.002 U	NS	0.002 U	0.002 U	2 U	0.018 J	0.012	0.002 U
	2nd QTR	NS	NS	NS	0.002 U	NS	NS	NS	NS	NS	NS	NS	NS

mg/L - milligrams per liter
NS - not sampled
QTR - Quarterly Sampling Event
SA - Semi-Annual Sampling Event

Data Qualifiers:
H - exceeded hold time
J - estimated
U - undetected
UJ - estimated, non-detect

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Table 7. Full Scale Perfomance Radiological Analytical Data in Observation and Injection Wells (January -June 2009)

Nuclear Fuel Services, Inc. Erwin, Tennessee

		U233/234				U235/236				U238				U Mass Activity		U Mass Concentration [a]	
Well ID	Sample Date	Dissolved (pCi/L)	Total (pCi/L)	Dissolved (µg/L)	Total (µg/L)	Dissolved (pCi/L)	Total (pCi/L)	Dissolved (µg/L)	Total (µg/L)	Dissolved (pCi/L)	Total (pCi/L)	Dissolved (µg/L)	Total (µg/L)	Dissolved (pCi/L)	Total (pCi/L)	Dissolved (mg/L)	Total (mg/L)
92	2/11/2009	0.3517	1.306	0.000	0.000	0.6198	0.1860	0.287	0.086	0.000	0.000	0.000	0.000	0.97	1.49	0.000	0.000
93	2/10/2009	1.427	4.849	0.000	0.001	0.7893	1.059	0.365	0.490	0.3431	0.7544	1.021	2.245	2.56	6.66	0.001	0.003
94	1/29/2009	20.10	17.10	0.003	0.003	3.664	3.206	1.696	1.484	3.352	3.313	9.976	9.860	27.12	23.62	0.012	0.011
97A	2/9/2009	14.69	15.03	0.002	0.002	2.106	2.802	0.975	1.297	1.185	1.299	3.527	3.866	17.98	19.13	0.005	0.005
	4/16/2009	10.09	11.65	0.002	0.002	1.257	1.060	0.582	0.491	0.9134	0.6417	2.718	1.910	12.26	13.35	0.003	0.002
102A	2/5/2009	1.702	0.8745	0.000	0.000	0.3599	0.2538	0.167	0.118	0.5326	1.127	1.585	3.354	2.59	2.26	0.002	0.003
103A	2/5/2009	2.996	3.397	0.000	0.001	0.6159	0.254	0.285	0.118	2.635	3.024	7.842	9.000	6.25	6.68	0.008	0.009
108A	2/3/2009	4.816	13.97	0.001	0.002	0.6601	2.388	0.306	1.106	2.664	2.397	7.929	7.134	8.14	18.76	0.008	0.008
109A	1/28/2009	8.428	7.823	0.001	0.001	1.181	1.214	0.547	0.562	4.196	8.151	12.488	24.259	13.81	17.19	0.013	0.025
	4/15/2009	3.459	4.242	0.001	0.001	0.7005	0.5413	0.324	0.251	3.804	3.641	11.321	10.836	7.96	8.42	0.012	0.011
110A	1/27/2009	2.950	4.311	0.000	0.001	1.078	0.5064	0.499	0.234	1.577	1.686	4.693	5.018	5.61	6.50	0.005	0.005
111A	1/29/2009	43.70	42.67	0.007	0.007	7.747	80.89	3.587	37.449	4.690	6.108	13.958	18.179	56.14	129.67	0.018	**0.056**
112A	2/2/2009	1.659	15.98	0.000	0.003	0.1806	3.614	0.084	1.673	0.2915	2.917	0.868	8.682	2.13	22.51	0.001	0.010
113A	2/2/2009	4.099	5.462	0.001	0.001	0.4994	0.5415	0.231	0.251	1.260	1.165	3.750	3.467	5.86	7.17	0.004	0.004
116A	1/22/2009	0.4419	0.7429	0.000	0.000	-0.1817[b]	0.2618	0.000	0.121	0.09778	0.3170	0.291	0.943	0.54	1.32	0.000	0.001
OW-1	1/28/2009	80.79	91.52	0.013	0.015	16.56	17.24	7.667	7.981	37.03	37.57	110.208	111.815	134.38	146.33	**0.118**	**0.120**
IW-1	2/3/2009	8.421	7.398	0.001	0.001	2.297	2.042	1.063	0.945	4.757	3.297	14.158	9.813	15.48	12.74	0.015	0.011
IW-2	1/26/2009	49.80	55.46	0.008	0.009	9.049	12.55	4.189	5.810	18.07	17.39	53.780	51.756	76.92	85.40	**0.058**	**0.058**
IW-3	1/26/2009	6.257	7.119	0.001	0.001	1.481	1.533	0.686	0.710	4.531	4.725	13.485	14.063	12.27	13.38	0.014	0.015
IW-5R	4/16/2009	3.203	6.438	0.001	0.001	0.439	0.9423	0.203	0.436	1.367	1.630	4.068	4.851	5.01	9.01	0.004	0.005
IW-6	4/16/2009	0.7054	0.7843	0.000	0.000	0.3108	0.5806	0.144	0.269	1.555	1.510	4.628	4.494	2.57	2.87	0.005	0.005
IW-7	2/3/2009	3.788	3.219	0.001	0.001	0.3595	1.184	0.166	0.548	1.064	1.012	3.167	3.012	5.21	5.42	0.003	0.004
IW-8	1/29/2009	5.739	7.458	0.001	0.001	0.7585	1.892	0.351	0.876	1.837	3.265	5.467	9.717	8.33	12.62	0.006	0.011
IW-9	1/27/2009	3.577	6.654	0.001	0.001	2.206	2.897	1.021	1.341	1.781	1.169	5.301	3.479	7.56	10.72	0.006	0.005
	4/16/2009	0.6959	2.135	0.000	0.000	0.1226	0.7429	0.057	0.344	0.09899	0.6541	0.295	1.947	0.92	3.53	0.000	0.002
IW-10	1/27/2009	0.9949	3.368	0.000	0.001	0.7364	0.5539	0.341	0.256	0.1981	0.4471	0.590	1.331	1.93	4.37	0.001	0.002
	4/15/2009	0.4621	1.554	0.000	0.000	0.2534	0.7189	0.117	0.333	0.1023	0.2901	0.304	0.863	0.82	2.56	0.000	0.001
IW-17	4/16/2009	0.7009	0.6856	0.000	0.000	0.1235	0.2603	0.057	0.121	0.2493	0.105	0.742	0.313	1.07	1.05	0.001	0.000
IW-18	2/9/2009	404.6	444.9	0.065	0.072	55.88	27.60	25.870	12.778	13.59	15.23	40.446	45.327	474.07	487.73	**0.066**	**0.058**
IW-20	2/4/2009	0.4631	45.41	0.000	0.007	0.3174	14.94	0.147	6.917	0.2049	0.000	0.610	0.000	0.99	60.35	0.001	0.007
IW-21	2/10/2009	81.24	158.1	0.013	0.025	13.83	19.45	6.403	9.005	22.33	43.74	66.458	130.179	117.40	221.29	**0.073**	**0.139**
IW-22	2/11/2009	3.446	6.250	0.001	0.001	0.7086	0.9402	0.328	0.435	1.258	1.366	3.744	4.065	5.41	8.56	0.004	0.005
IW-23	1/29/2009	252.6	280.6	0.041	0.045	46.90	48.34	21.713	22.380	34.73	39.69	103.363	118.125	334.23	368.63	**0.125**	**0.141**
IW-24	2/10/2009	0.9719	0.7318	0.000	0.000	0.4196	0.3611	0.194	0.167	0.1452	-0.04858[b]	0.432	0.000	1.54	1.09	0.001	0.000
72	2/10/2009	10.92	12.75	0.002	0.002	3.305	2.294	1.530	1.062	4.309	6.349	12.824	18.896	18.53	21.39	0.014	0.020

Notes:

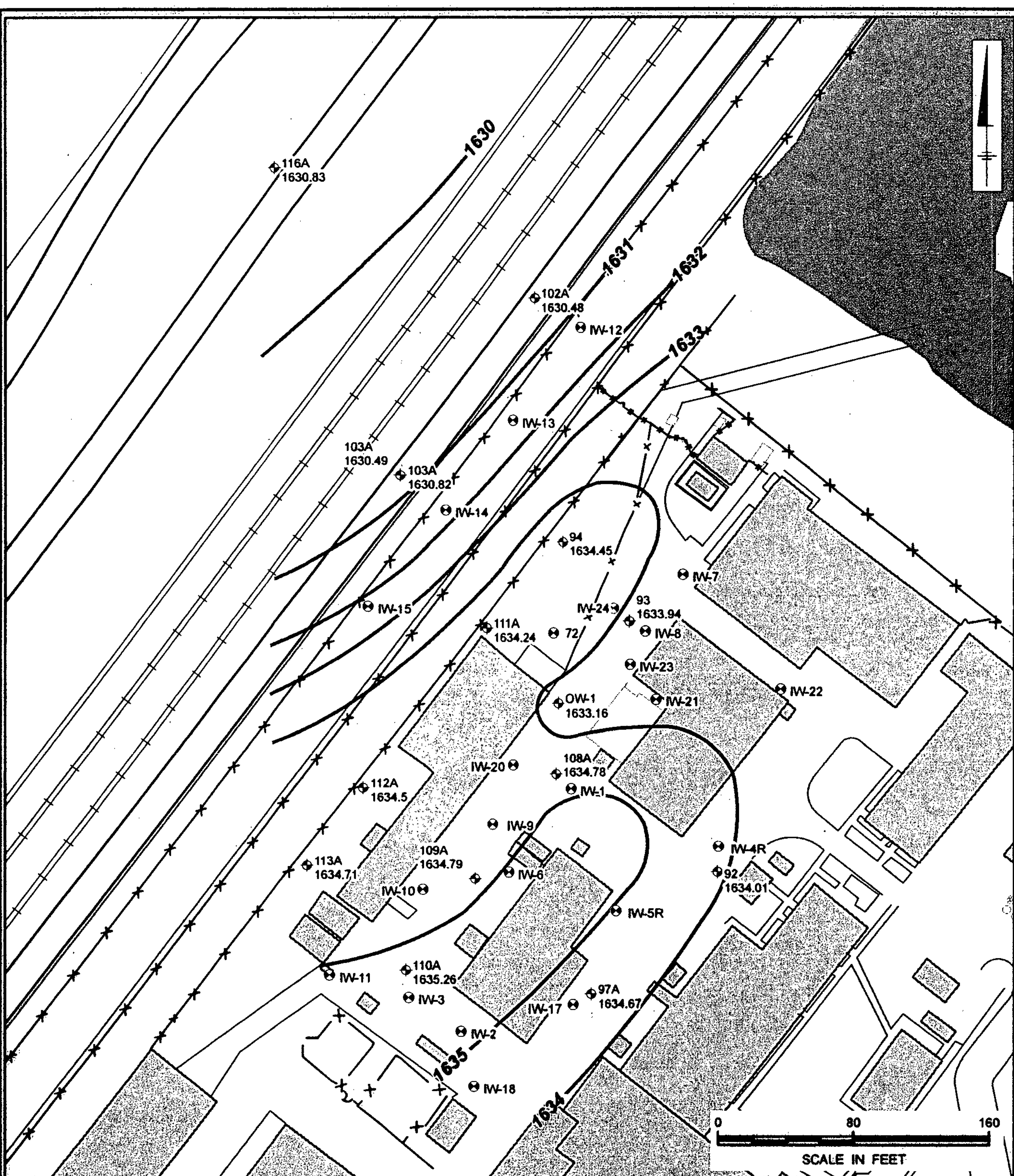
Conversion from pCi/L to µg/L carried to 1000ths (0.000). Activity reported to 4 significant digits.

[a] - Mass concentration calculated using specific activity of each isotope and summing concentrations.

[b] - Negative activity in pCi/L is not used in the calculation of the conversion to concentration (µg/L or mg/L).

µg/L - micrograms per liter
mg/L - milligrams per liter
pCi/L - picocuries per liter
U - uranium

Bold - indicates concentration above new Maximum Contaminant Level for uranium of 0.030 mg/L as of 12/8/03 (USEPA 2002)



LEGEND:

- Building
- Monitor Well/Groundwater Elevation
- Injection Well
- Potentiometric Contour (ft-amsl)

NOTES:
a) Groundwater depth to water collected on April 14, 2009 and was subtracted from NFS reference elevations.
b) Injection wells were not measured during this sampling event.

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

FIRST SEMI-ANNUAL
2009 FULL-SCALE IRZ STATUS REPORT

Potentiometric Contours, April 2009

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FIGURE **1**

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(B.BAILEY)
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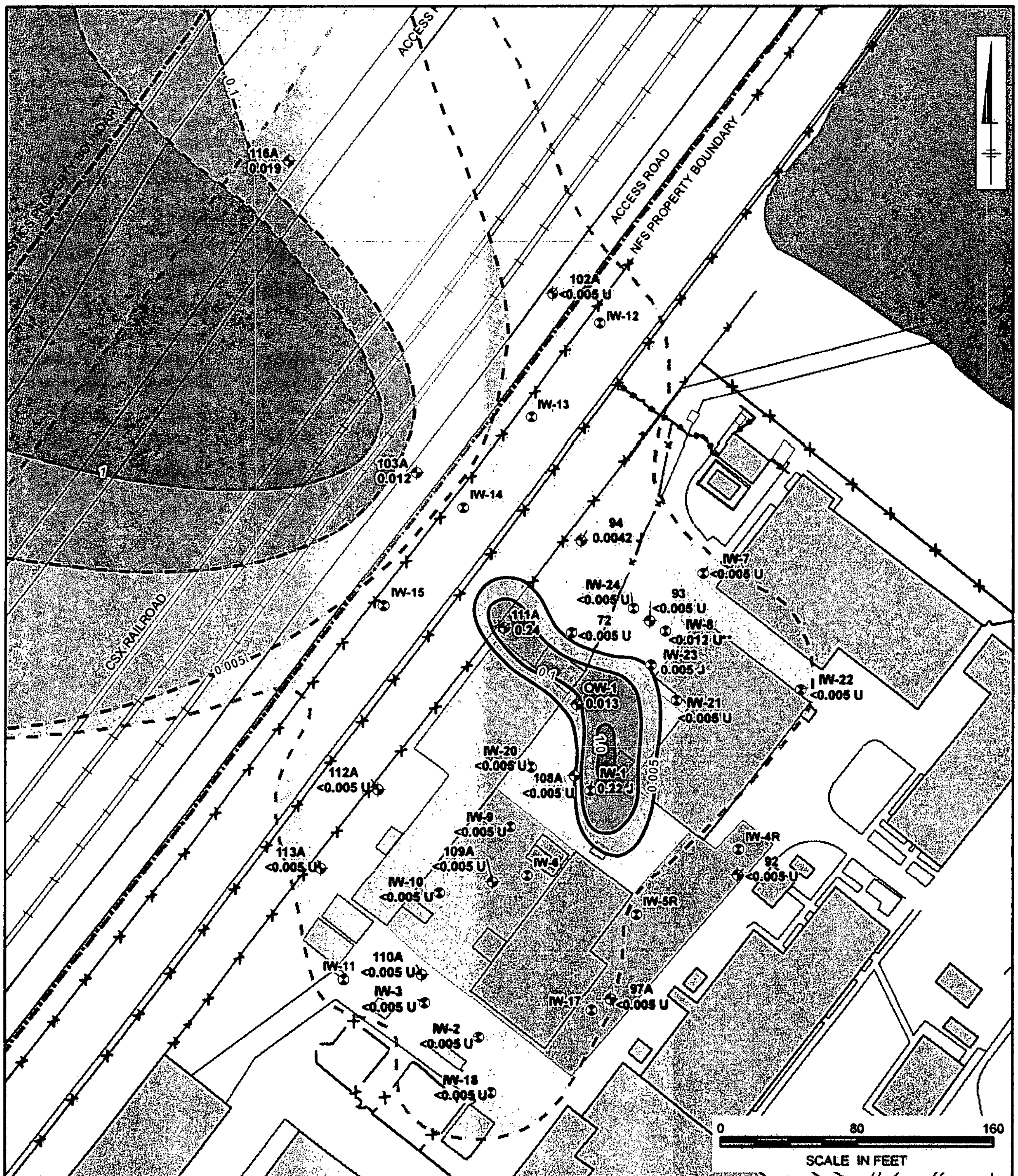

LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building
- Closure Monitoring Zone

PCE Isopleth (mg/L)

- >1.0 mg/L
- >0.1 mg/L
- >0.005 mg/L
- Baseline >0.005 mg/L
- Approximate Isopleth
- Inferred Isopleth

NOTES:
mg/L - milligrams per liter
PCE - Tetrachloroethene
U - Non-Detect
J - Estimated
** - Not used in contouring

NUCLEAR FUEL SERVICES; ERWIN, TENNESSEE

FIRST SEMI-ANNUAL 2009 FULL-SCALE IRZ STATUS REPORT

PCE Concentrations, February 2009

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FIGURE **2**

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(R.MCKINNEY)
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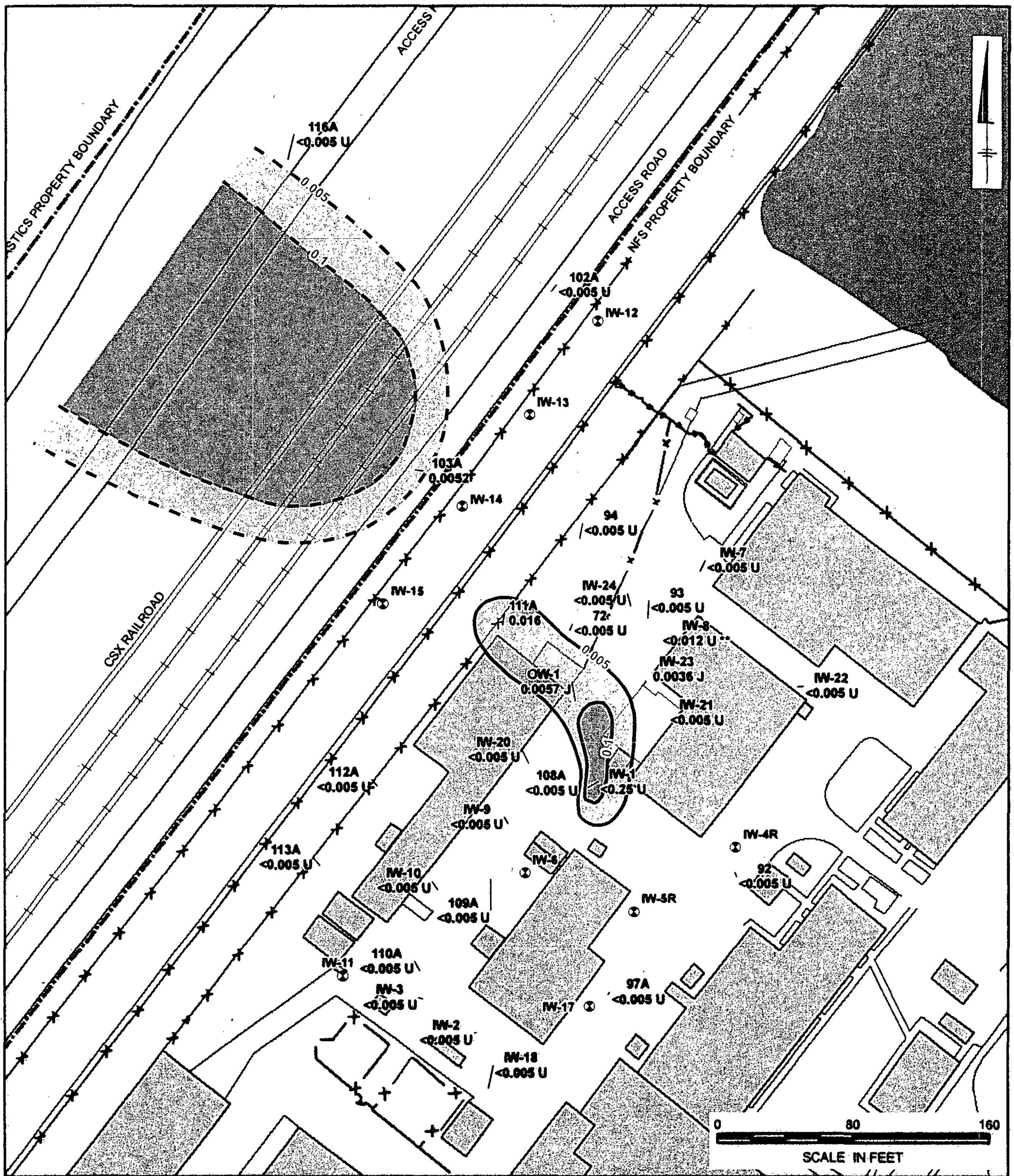


LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building

TCE Isopleth (mg/L)

- >1.0 mg/L
- >0.1 mg/L
- >0.005 mg/L
- Approximate Isopleth
- Inferred Isopleth

NOTES:
mg/L - milligrams per liter
TCE - Trichloroethene
U - Non-Detect
J - Estimated
** - Not used in contouring

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

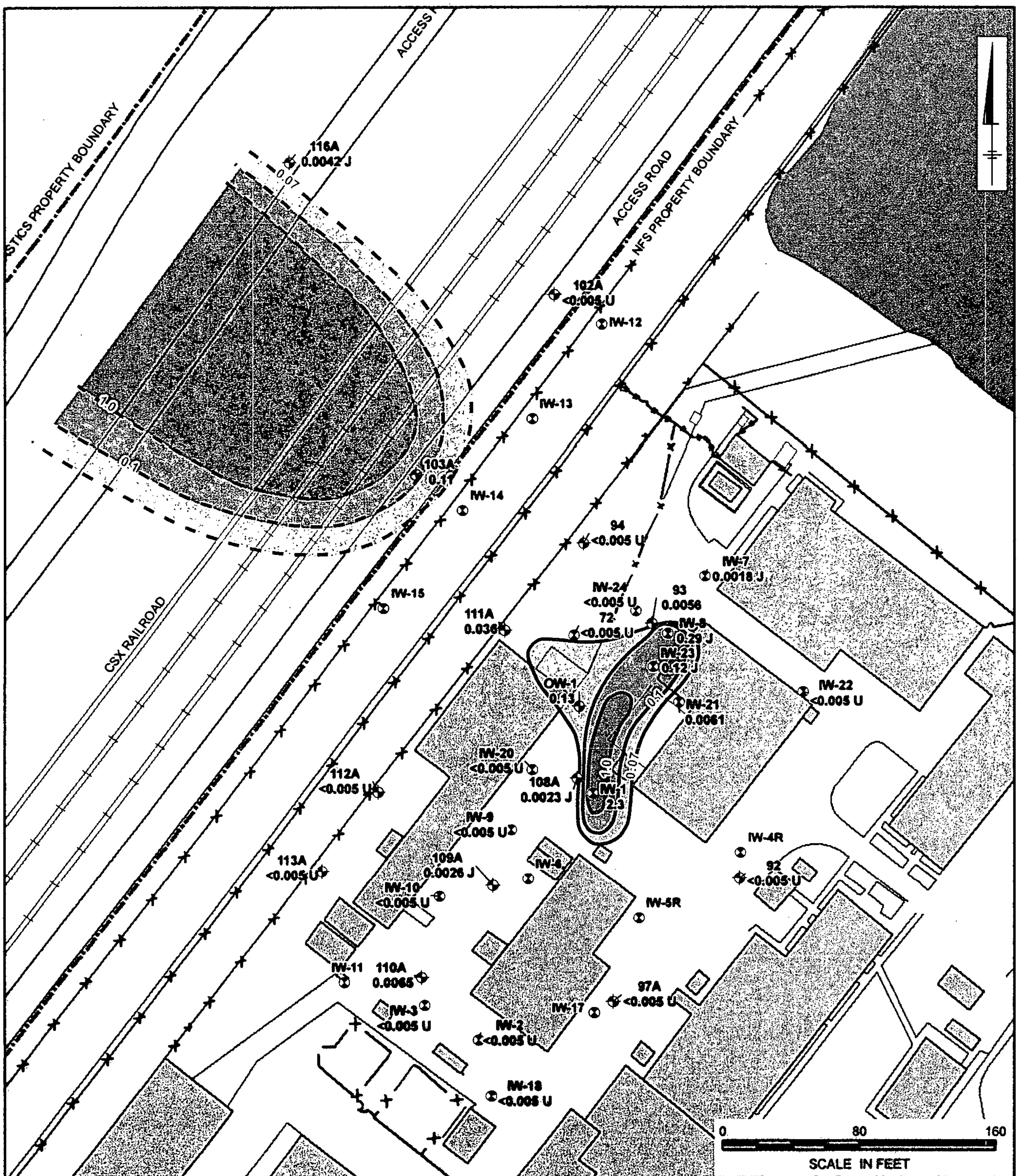
FIRST SEMI-ANNUAL 2009 FULL-SCALE IRZ STATUS REPORT

TCE Concentrations, February 2009

ARCADIS

FIGURE 3

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(R.MCKINNEY)
PROJECT: TNNFS801.FS08.00004 PATH: G:\ENV\TNNFS_Erwin\GIS\MapDocuments\2008\2008 2nd SA - PCE.mxd SAVED: 8MAY2009



LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building

Cis-1,2 DCE Isopleth (mg/L)

- >1.0 mg/L
- >0.1 mg/L
- >0.07 mg/L
- Approximate Isopleth
- Inferred Isopleth

NOTES:

mg/L - milligrams per liter
Cis-1,2-DCE - Cis-1,2-Dichloroethene
U - Non-Detect
J - Estimated

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

FIRST SEMI-ANNUAL 2009 FULL-SCALE IRZ STATUS REPORT

Cis-1,2-DCE Concentrations, February 2009

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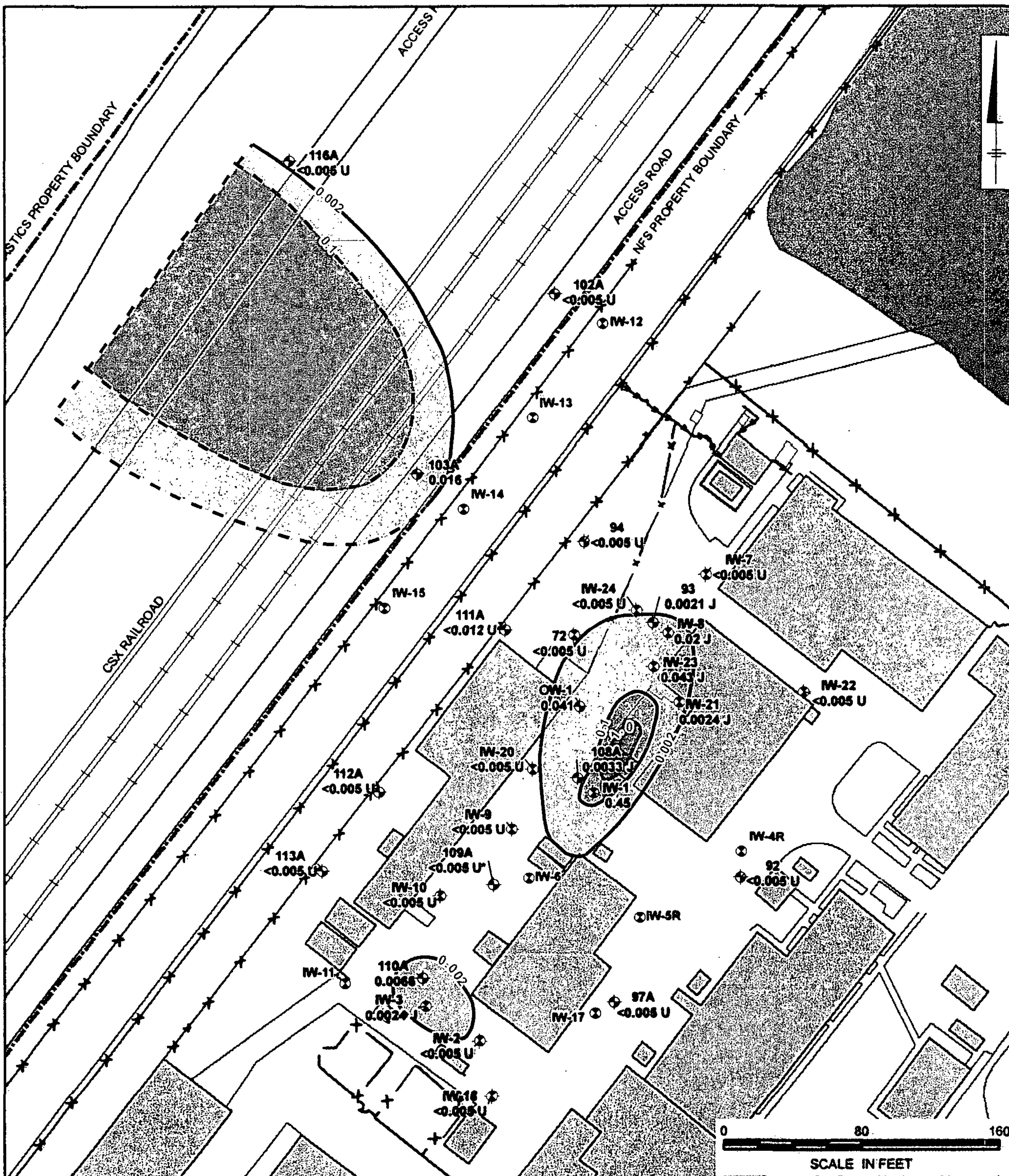
FIGURE 4

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(R.MCKINNEY)
PROJECT: TNNFS801.FS06.00004 PATH: G:\ENV\TNNFS_Erwin\GISMapDocuments\2008\2008 2nd SA - PCE.mxd SAVED: 8MAY2009



LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building

Vinyl Chloride Isopleth (mg/L)

- >1.0 mg/L
- >0.1 mg/L
- >0.002 mg/L
- Approximate Isopleth
- Inferred Isopleth

NOTES:
mg/L - milligrams per liter
U - Non-Detect
J - Estimated
* - April 2009 data indicated a lower concentration and has been used in construction of the concentration contour.

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

FIRST SEMI-ANNUAL 2009 FULL-SCALE IRZ STATUS REPORT

Vinyl Chloride Concentrations, February 2009

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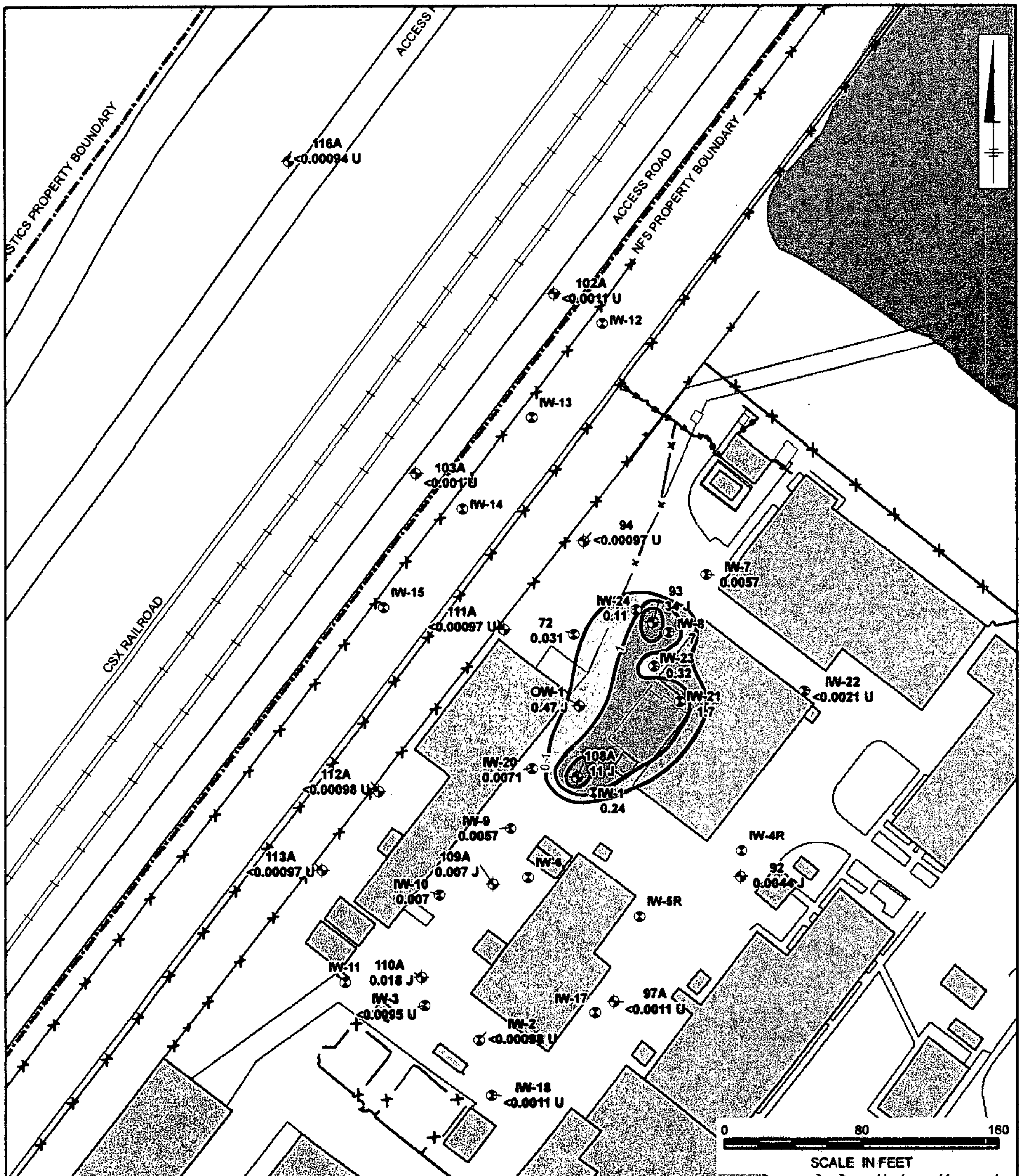
FIGURE 5

CITY: (KNOXVILLE) DIV/GROUP: (ENV) DB: (B.ALTOM) LD: (R.MCKINNEY) PIC: (B.ILGNER) PM: (P.PRESTON) TM: (R.MCKINNEY)
PROJECT: TNNFS801.FS06.00004 PATH: G:\ENV\TNNFS_Erwin\GIS\MapDocuments\2008\2008 2nd SA - PCE.mxd SAVED: 8MAY2009



LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building

TBP Isopleth (mg/L)

- >10 mg/L
- >1.0 mg/L
- >0.1 mg/L
- Approximate Isopleth
- Inferred Isopleth

NOTES:
mg/L - milligrams per liter
TBP - Tributyl phosphate
U - Non-Detect
J - Estimated

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

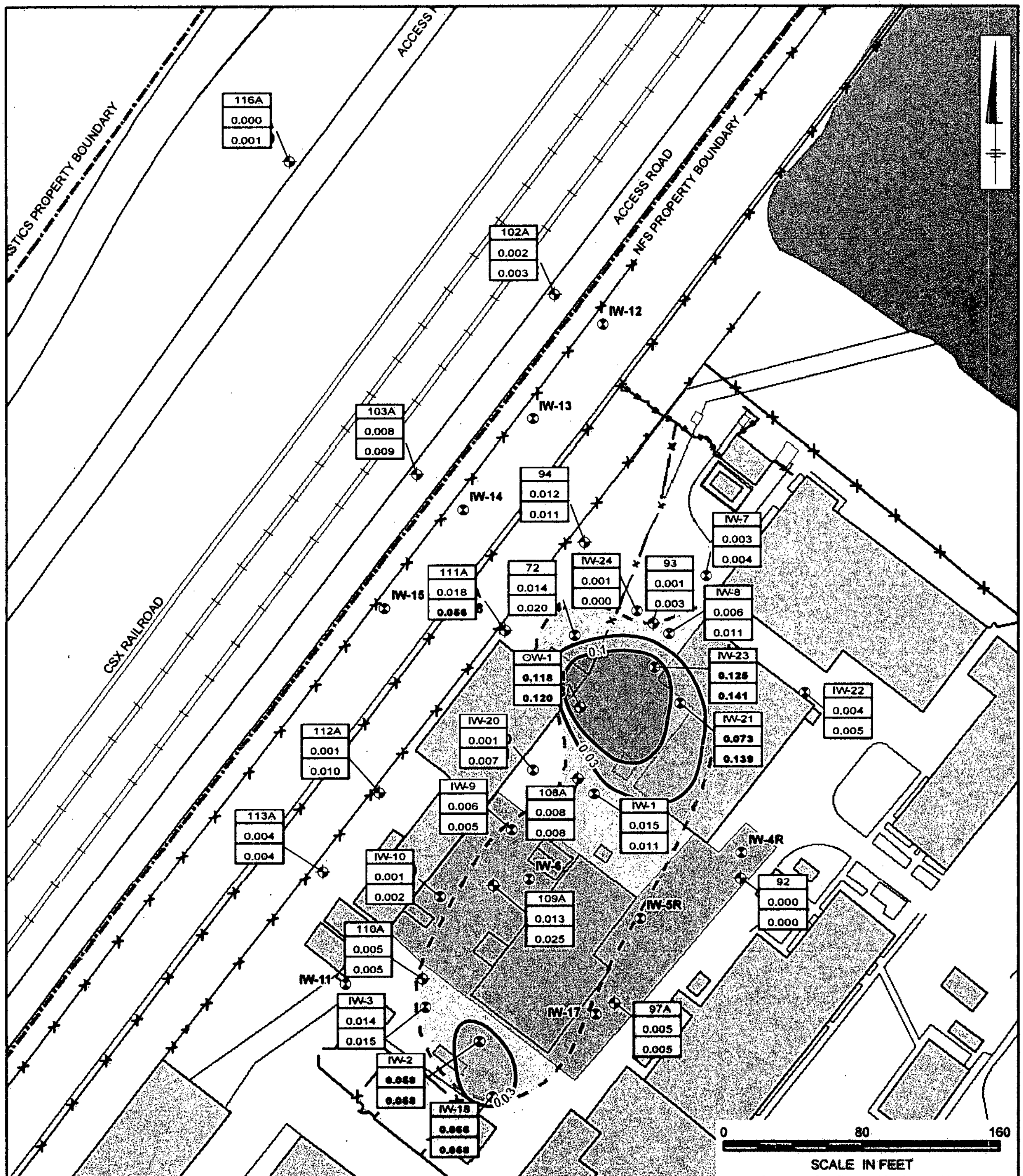
FIRST SEMI-ANNUAL
2009 FULL-SCALE IRZ STATUS REPORT

TBP Concentrations, February 2009

ARCADIS

FIGURE
6

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(R.MCKINNEY)
PROJECT: TNNFS801.FS06.0004 PATH: G:\ENVT\NNFS_Erwin\GIS\MapDocuments\2008\2008 2nd SA - PCE.mxd SAVED: 8MAY2009



LEGEND:

- Injection Well
- Groundwater Monitoring Well
- Building
- Injections Suspended
- Approximate Isopleth
- Inferred Isopleth

Dissolved Uranium Isopleth (mg/L)

- >0.1 mg/L
- >0.03 mg/L

Dissolved Uranium Baseline

- >0.03 mg/L

Well ID
Dissolved (mg/L)
Total (mg/L)

NOTES:
mg/L - milligrams per liter
BOLD - exceeds 0.030 mg/L maximum contaminant level.

NUCLEAR FUEL SERVICES, ERWIN, TENNESSEE

FIRST SEMI-ANNUAL 2009 FULL-SCALE IRZ STATUS REPORT

Total and Dissolved Uranium Concentrations, February 2009

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FIGURE **7**

RAI 7

Attachment 3

BOS 100 Injection Services, March 30, 2007

44N-07-0002
DCM-17-03-08

ARCADIS

Infrastructure, environment, facilities

ARCADIS U.S., Inc.
114 Lovell Road
Suite 202
Knoxville
Tennessee 37934
Tel 865.675.6700
Fax 865.675.6712
www.arcadis-us.com

Mr. Scott Morie
Nuclear Fuel Services, Inc.
1205 Banner Hill Road
Erwin, Tennessee 37650

Subject:
BOS 100® Injection Services
Industrial Park Facility
Nuclear Fuel Services, Inc.
Erwin, Tennessee

ENVIRONMENT

Date:
30 March 2007

Contact:
Paul Preston
Berny Ilgner

Phone:
Paul – ext. 3110
Berny – ext. 3112

Email:
paul.preston@arcadis-us.com
berny.ilgner@arcadis-us.com

Our ref:
TNNFS606.BOSS

Dear Mr. Morie:

ARCADIS has prepared this letter report to document the implementation of the in-situ remediation activities conducted at the above-referenced location. The adjacent property is located to the west of the Nuclear Fuel Services, Inc. (NFS) Industrial Park Facility (Exhibit 1). The objective of the application of BOS 100® is to treat chlorinated solvent contaminated groundwater with an in-situ technique such that migration to surface water will not result in concentrations exceeding standards. The field work for remediation activities was conducted by ARCADIS and its subcontractor, M&W Drilling, Inc. Field activities began on February 12, 2007, and were successfully completed on March 1, 2007.

A total of 250 injection points were spaced triangularly in five rows (Rows A, B, C, D, and E) on 5-feet (ft) centers in an area approximate 250 ft long and 20 ft wide (Exhibit 2). The reagent application was applied using the top down method; that is, the injections began at the top at 8 ft below ground surface (bgs) and were continued down to 20 ft bgs, or refusal, at each of the 250 locations (Appendix A). The DPT rig 2-inch outer rod and 1-inch inner rod were first inserted to a depth of 8 ft bgs, then the rods were withdrawn 2 ft and the inner rod was removed. A hose connector was then attached to the 2-inch rod, then connected to the injection system. Rods were decontaminated between each borehole with a pressure washer.

Attempts were made to inject at least 10 to 15 gallons of reagent at each vertical injection point, and a total of approximately 5 pounds of BOS 100® per vertical injection; however, if the reagent was noted surfacing to the ground at various intervals, the injection was immediately stopped and extended to the next interval unless rod refusal occurred. Tables 1 through 5 provide a summary of each borehole, including the total depth/refusal of each borehole, total gallons injected at each borehole, and the estimated pounds of BOS 100® in each borehole (Appendix B).

All borehole locations were grouted with bentonite chips upon completion of each injection. The injections resulted in a total of approximately 8,929 pounds of BOS 100® injected over the 250 borehole locations across the site. On March 8, 2007, the application, storage, and decontamination areas were re-seeded, fertilized, and covered with straw, and the forty-two 55-gallon drums that formerly contained BOS 100® material were decontaminated and disposed of at a metal recycler (Appendix C).

ARCADIS appreciates the opportunity to provide services to NFS and looks forward to continuing work in the future. Should you have any questions or need additional information, please contact on of the undersigned.

Sincerely,

ARCADIS U.S., Inc.

Paul M. Preston, PE
Project Engineer

Berny D. Ilgner, PG
Vice President

WMB/bf

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Table 1. BOS 100® Summary Table - Row A
Nuclear Fuel Services, Inc. Impact Plastic Facility Erwin, Tennessee

Injection Location	Total Borehole Depth (feet)	Total Gallons Reagent Injected	Estimated Total Pounds BOS 100® Injected
A-1	18	100	46
A-2	17	100	46
A-3	17	100	46
A-4	16	100	46
A-5	18	100	46
A-6	19	75	35
A-7	11	45	21
A-8	11	100	46
A-9	11	75	35
A-10	11	25	12
A-11	12	65	30
A-12	12	70	32
A-13	11	70	32
A-14	11	45	21
A-15	12	70	32
A-16	20	101	46
A-17	15	65	30
A-18	20	105	48
A-19	12	59	27
A-20	14	90	41
A-21	20	105	48
A-21A	20	100	46
A-22	15	120	55
A-23	20	90	41
A-23A	20	105	48
A-24	20	100	46
A-25	13	70	32
A-26	12	65	30
A-27	13	90	41
A-28	12	70	32
A-29	11	60	28
A-30	11	65	30
A-31	12	65	30
A-32	11	65	30
A-33	11	65	30
A-34	11	30	14
A-35	11	45	21
A-36	14	38	17
A-37	11	40	18
A-38	11	90	41
A-39	11	90	41
A-40	11	80	37
A-41	12	80	37
A-42	11	80	37
A-43	12	60	28
A-44	12	50	23
A-45	12	80	37
A-46	15	110	51
A-47	12	90	41
A-48	12	80	37
A-49	12	70	32
A-50	12	40	18
		Estimated Total Pounds Injected:	1816

ft - feet
lbs/gal - pounds per gallon

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Table 2. BOS 100® Summary Table - Row B
Nuclear Fuel Services, Inc. Impact Plastic Facility Erwin, Tennessee

Injection Location	Total Borehole Depth (feet)	Total Gallons Reagent Injected	Estimated Total Pounds BOS 100® Injected (0.46 lbs/gal)
B-1	15	53	24
B-2	19	100	46
B-3	12	54	25
B-4	13	80	37
B-5	11	31	14
B-6	11	65	30
B-7	13	55	25
B-8	11	55	25
B-9	12	65	30
B-10	18	100	46
B-11	18	105	48
B-12	15	110	51
B-13	9	10	5
B-14	18	100	46
B-15	20	85	39
B-16	18	100	46
B-17	12	70	32
B-18	14	70	32
B-19	14	80	37
B-20	19	90	41
B-21	20	110	51
B-22	20	95	44
B-23	13	70	32
B-24	20	100	46
B-25	20	100	46
B-26	15	105	48
B-27	12	65	30
B-28	20	90	41
B-29	12	45	21
B-30	13	30	14
B-31	12	75	35
B-32	12	55	25
B-33	12	60	28
B-34	12	75	35
B-35	11	50	23
B-36	11	70	32
B-37	11	75	35
B-38	11	50	23
B-39	11	31	14
B-40	11	70	32
B-41	12	80	37
B-42	14	80	37
B-43	12	80	37
B-44	12	80	37
B-45	12	80	37
B-46	11	80	37
B-47	12	80	37
B-48	11	90	41
B-49	12	70	32
		Estimated Total Pounds Injected:	1665

ft - feet
lbs/gal - pounds per gallon

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Table 3. BOS 100® Summary Table - Row C
Nuclear Fuel Services, Inc. Impact Plastic Facility Erwin, Tennessee

Injection Location	Total Borehole Depth (feet)	Total Gallons Reagent Injected	Estimated Total Pounds BOS 100® Injected (0.46 lbs/gal)
C-1	19	90	41
C-2	11	51	23
C-3	20	100	46
C-4	11	70	32
C-5	18	85	39
C-6	11	31	14
C-7	15	75	35
C-8	12	65	30
C-9	11	70	32
C-10	20	100	46
C-11	15	90	41
C-12	20	100	46
C-13	20	100	46
C-14	16	105	48
C-15	19	100	46
C-16	14	85	39
C-17	13	70	32
C-18	11	70	32
C-19	18	120	55
C-20	20	90	41
C-21	13	80	37
C-22	20	105	48
C-23	16	85	39
C-24	13	65	30
C-25	14	60	28
C-26	11	35	16
C-27	14	70	32
C-28	13	38	17
C-29	15	85	39
C-30	11	70	32
C-31	13	42	19
C-32	11	40	18
C-33	11	40	18
C-34	12	70	32
C-35	11	30	14
C-36	11	65	30
C-37	12	110	51
C-38	12	80	37
C-39	12	80	37
C-40	12	80	37
C-41	12	80	37
C-42	11	70	32
C-43	13	80	37
C-44	12	80	37
C-45	12	80	37
C-46	13	80	37
C-47	15	100	46
C-48	12	90	41
C-49	15	110	51
		Estimated Total Pounds Injected:	1733

ft - feet
lbs/gal - pounds per gallon

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Table 4. BOS 100® Summary Table - Row D

Nuclear Fuel Services, Inc. ***Impact Plastic Facility*** ***Erwin, Tennessee***

Injection Location	Total Borehole Depth (feet)	Total Gallons Reagent Injected	Estimated Total Pounds BOS 100® Injected (0.46 lbs/gal)
D-1	17	100	46
D-2	17	100	46
D-3	20	100	46
D-4	18	110	51
D-5	20	100	46
D-6	11	31	14
D-7	11	70	32
D-8	11	68	31
D-9	20	100	46
D-10	18	105	48
D-11	13	60	28
D-12	13	40	18
D-13	20	100	46
D-14	12	70	32
D-15	18	100	46
D-16	11	70	32
D-17	12	70	32
D-18	14	75	35
D-19	16	105	48
D-20	12	66	30
D-21	12	45	21
D-22	13	95	44
D-23	12	36	17
D-23A	13	65	30
D-24	20	100	46
D-25	13	65	30
D-26	12	75	35
D-27	12	45	21
D-28	13	70	32
D-29	12	75	35
D-30	12	50	23
D-31	18	100	46
D-32	12	26	12
D-33	12	70	32
D-34	13	80	37
D-35	12	65	30
D-36	16	120	55
D-37	12	90	41
D-38	11	60	28
D-39	11	80	37
D-40	12	80	37
D-41	12	80	37
D-42	11	80	37
D-43	12	80	37
D-44	13	80	37
D-45	11	80	37
D-46	15	110	51
D-47	16	110	51
D-48	13	80	37
D-49	13	90	41
		Estimated Total Pounds Injected:	1804

ft - feet
lbs/gal - pounds per gallon

Table 5. BOS 100® Summary Table - Row E
Nuclear Fuel Services, Inc. Impact Plastic Facility Erwin, Tennessee

Injection Location	Total Borehole Depth (feet)	Total Gallons Reagent Injected	Estimated Total Pounds BOS 100® Injected (0.46 lbs/gal)
E-1	20	90	41
E-2	13	65	30
E-3	11	80	37
E-4	11	77	35
E-5	11	60	28
E-6	11	35	16
E-7	13	80	37
E-8	16	110	51
E-9	20	115	53
E-10	11	95	44
E-11	19	110	51
E-12	12	70	32
E-13	12	70	32
E-14	20	105	48
E-15	19	100	46
E-16	10	30	14
E-17	12	70	32
E-18	20	100	46
E-19	20	90	41
E-20	20	90	41
E-21	20	132	61
E-22	11	95	44
E-23	12	65	30
E-24	13	80	37
E-25	13	75	35
E-26	12	75	35
E-27	13	65	30
E-28	15	51	23
E-29	15	70	32
E-30	18	110	51
E-31	11	50	23
E-32	12	80	37
E-33	11	65	30
E-34	11	70	32
E-35	12	100	46
E-36	12	100	46
E-37	11	90	41
E-38	12	80	37
E-39	39	110	51
E-40	12	80	37
E-41	13	80	37
E-42	11	80	37
E-43	15	110	51
E-44	12	80	37
E-45	12	80	37
E-46	12	80	37
E-47	12	90	41
E-48	13	90	41
E-49	16	90	41
E-50	12	90	41
		Estimated Total Pounds Injected:	1911

ft - feet
lbs/gal - pounds per gallon

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Appendix A

Site Photographs

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Appendix B

Field Notes

2-12-07

NFS BOSS 100 Injection

930 Leave for NFS.

1145 Arrive @ NFS IPF Building.

1200 Driller on site. Unload equipment. Meet with Scott Morie. Walk on site

1220 Go to Impact Plastics to meet with site contact Rick Turner

1300 Get keys from S. Morie for IPF. Talk with Erwin Utilities about water usage from fire hydrant and site visit to confirm proposed boring locations. G. Hensley City of Erwin

1400 Meet with Rick Turner (Impact Plastics) to confirm location of drain culvert and wire for out side parking lights.

Charles McNabb, Erwin Utilities stops by and we discuss the use of hydrant for water. Will need back flow preventer and meter before we can connect also inspected before we can use.

NFS 2-12-07

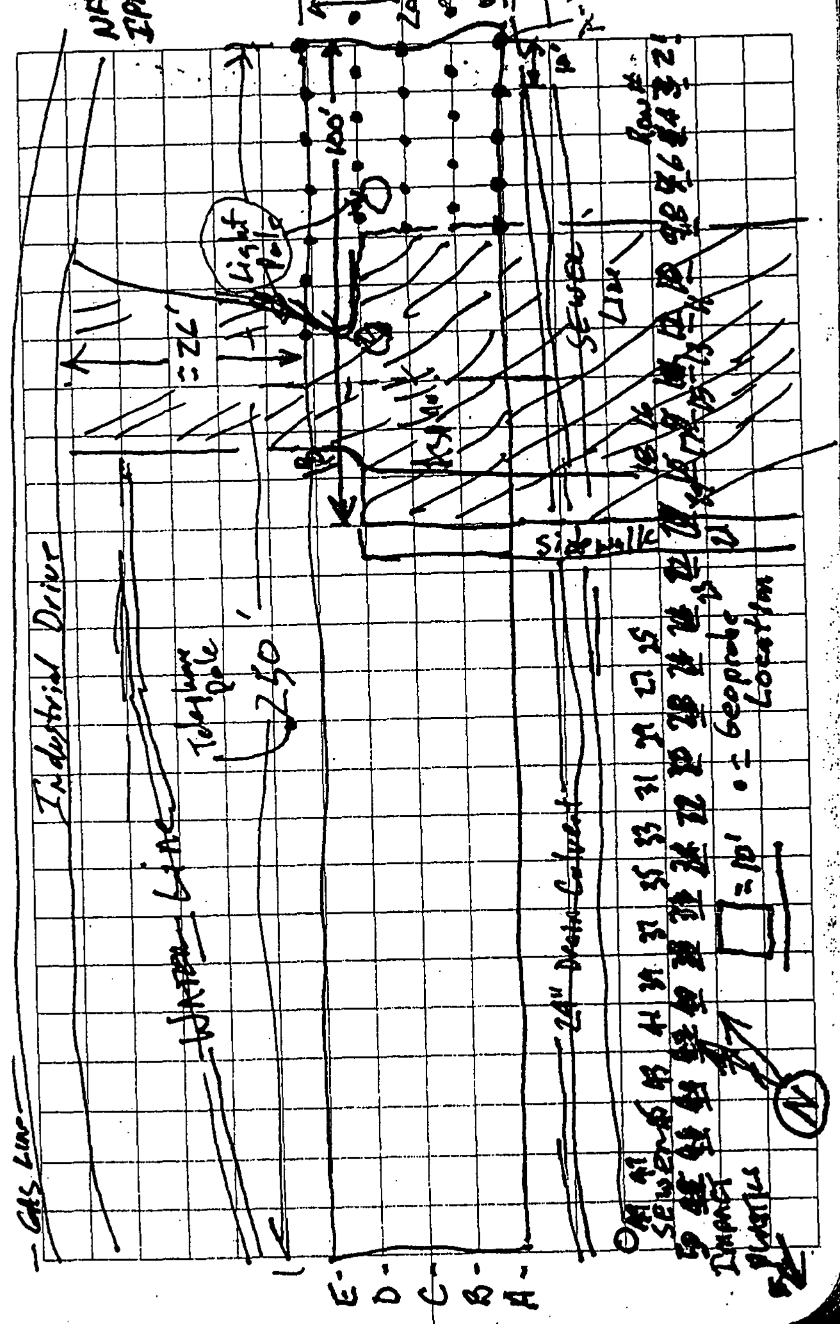
Conduct H&S meeting with M&W crew while waiting on fork lift and waiting to confirm utility locations. Based on discussion with Erwin Utilities, Rich Turner (Impact Plastics) and Scott Moore, it looks like proposed boring locations are clear of utilities and other underground structures.

1500 Work on marking first phase of boring locations on the east end (near the NFS IPF building. Mark the entire grid outline to review utility locations. Confirm overhead location vs geoprobe distance with M&W crew. Distance safe according to M&W.

1600 Mark locations, work on map, take photos (page 3).

1700 Leave site. Drive to local hospital to confirm location.

Bill Barley 2-12-07



NES - IPP · 2-13-07

700 Meet with M & W and conduct H & S meeting. Arrive @ site and check inside of trailer with O_2 meter. 20.9% oxygen inside trailer.

745 M & W meets with City of Erwin Utility Dept to get backflow meter inspected for use

835 Return to site.

845 Open drum #1, start adding water ~~[illegible]~~ to drum through bung in top of drum.

850 Start boring on A-1. Pump approx 4 gallons, then pucker off.

928 ~~[illegible]~~ Reagent noted coming out of ground approx 2.0 ft. from boring location @ 10-12.

950 Complete A-1. Put bentonite chips in hole.

1000 Move to A-4 to allow bentonite to set-up.

	ID #	Boss Batch AMT LBS	Injection Interval	Gallons Reagent Injected	System PSI	Drum #	
(1)	A-1	(2-Buckets	6-8	6.0	400	#1	Refusal @ 18'
		5 gallon)	8-10	10.0	0		
		each	10-12	10.0	50		
		See	12-14	10.0	40		
		Tables	14-16	10.0	50		
		↓	16-18	54.0	125		
				100.0			
(2)	A-4	(2-Buckets	6-8	2.0	300	#1	Refusal @ 16'
		5-gallon each)	8-10	10.0	50		
		See	10-12	10.0	90		
		Tables	12-14	10.0	60		
		↓	14-16	~~46.0~~ 78.0	100		
				100.0			

ONE BUCKET = ≈ 35-40 lbs

50's - Sunny to cloudy 2-13-07

1035 Complete A-4.
1040 Move to A-8
1110 Move to A-2, Talk with P. Preston. The 6-8 interval is packing off, stopping up injection pipe. OK to start injections @ 8 ft.
1200 Complete A-2. Go for more water to fill injection tank.
1245 Start @ A-3 (page 8). M&W decons rods between holes. Check storm drain for signs of reagent from injections, none noted in any drain.
1320 Move to A-5.
1420 Complete A-5. Move to A-6.
1530 Complete A-6. Move to A-7.
1550 Move to B-1.
1620 Move to C-1.
1700 Complete C-1.

2-13-07

	ID #	BOSS Lbs	Inj Interval	Gallons Injected	System PSI	Drum #	
(3)	A-8	2-Buckets (5-gallon) See Table	6-8	4.0	300	1	Refusal @ 11.0 ft
			8-10	10.0	40		
			10-11	86.0	100		
				100.0			
(4)	A-2	2-Buckets (5-gallon) See Table	8-10	15.0	60	1	Refusal @ 17.0 ft
			10-12	15.0	70		
			12-14	15.0	80		
			14-16	15.0	200		
			16-17	40.0	150		
				100.0			

[illegible signature]

2-13-07

⑧

ID #	Boss Lbs	IWS Interval	Gallons Injected	System PSI	Drum #	
⑤ A-3	2-Bucket	8-10	15.0	60	1	Refusal @ 17.0 ft
	5-gallon	10-12	15.0	60		
	See	12-14	15.0	80		
	Tables	14-16	15.0	50		
		16-~~18~~ 17	40.0	NA		
			100			
⑥ A-5	2-Buckets	8-10	10.0	300	1 & 2	Refusal @ 18.0 ft
	5-gals	10-12	15.0	80		
	See	12-14	15.0	80		
	Table	14-16	15.0	100		
	↓	16-18	45.0	100		
			100			

2-13-07

⑨

ID #	Boss Lbs	IWS Interval	Gallons Injected	System PSI	Drum #	
⑦ A-6	(2-Bucket)	8-10	15.0	60	#2	Refusal @ 19.0 ft
	5-gals)	10-12	15.0	50		
	See	12-14	15.0	70		
	Tables	14-16	15.0	300		
	↓	16-18	15.0	40		
		18-19	~~25.0~~ 0	300		
			75.0			
⑧ A-7	1-Bucket	8-10	15.0	100	#2	Refusal @ 11.0 ft
	5-gallons	10-11	30	90		
	See table		45.0			

B. Bailey

2-13-07

ID #	Base LBS.	Injection Interval	Gallons Injected	System PSI	Observ #	
(9) B-1	2-buckets	8-10	15.0	75	2	Refusal @ 15.0 ft
	(5-gallon each)	10-12	15.0	60		
	see Table	12-14	15.0	70		
		14-15	8.0	300		
			53			
(10) C-1	2-Buckets	8-10	15.0	60	2	Refusal @ 19.0 ft
	See Table	10-12	15.0	100		
		12-14	15.0	70		
		14-16	15.0	40		
		16-18	0	0		
		18-19	30	0		
			90			

2-14-07

700 Conduct H&S meeting with M&W. Cold, blowing snow. M&W works on getting equipment ready, putting line jack on injection/grout plant.

750 Start on D-1. M&W goes to fill water tank. ~~Set tools~~ rod in D-2 while waiting for injection/grout plant to return. drop ½ D2

900 Move back to D-1.

945 Complete D-1. Move E-1.

1050 Move to E-2. Grout holes after injection.

1120 Move to B-2.

1210 Move to B-3. Go to fill water tank and get something to eat.

1400 At B-3 hit refusal @ 12.0 ft. While pumping into B-3 @ 12.0 ft noted fluids coming out of B-2. Stopped pumping @ 24 gallons.

1405 Move to C-3. ~~Complete C-3~~ 1435

1445 Move to C-2.

1500 Move to D-3.

1530 Move to E-3.

(12)

ID	Buss LBS	Inj Interval	Gallons Injected	Injection PSI	Drum #/ Refusal
D-2 (11)	(2- 5 gallon	8-10	15.0	NA	#2
	Buckets)	10-12	15.0	NA	
	See	12-14	15.0	70	
	Tables	14-16	15.0	80	
	↓	16-17	40.0	60	17.0'
			100.0		
D-1 (12)	2-5-gallon	8-10	15.0	70	#2
	Buckets	10-12	15.0	80	
		12-14	15.0	80	
		14-16	15.0	80	
	↓	16-17	40.0	80	17.0'
			100.0		
E-1 (13)	2-Buckets	8-10	15.0	60	#3
		10-12	15.0	80	
		12-14	15.0	70	
		14-16	15.0	50	
		16-18	15.0	50	
	↓	18-20	15.0	0	
			90.0		
E-2 (14)	2-Buckets	8-10	15.0	60	#3
	See	10-12	15.0	60	
	Tables	~~12-13~~			
	↓	12-13	50.0	60	13.0'
			65.0		

(13)

ID	Buss Amt	Inj Interval	Gals Inj	PSI	Drum #/ Refusal
B-2 (15)	~~8-10~~	8-10	15.0	NA	#3
	2-Buckets	10-12	15.0		
	See	12-14	15.0		
	Tables	14-16	15.0		
		16-18	15.0		
	↓	18-19	25.0	↓	19.0'
			100.0		
B-3 (16)	2-Buckets	8-10	15.0	NA	#3
	See	10-12	15.0	↓	12.0'
	Tables	10-12	24 32 (Add 32 gallons)		
			62 54		
C-3 (17)	2-Buckets	8-10	15.0	70	#3
	See	10-12	15.0	50	
	Tables	12-14	15.0	40	
		14-16	15.0	150	
		16-18	15.0	40	
	↓	18-20	25.0	NA	
			100.0		

NA - not available; malfunction

I.D.	Boss Vol.	Inj. Interval	Gallons Injected	System PSI	Drum # Refusal
C-2 (18)	2-Buckets	8-10	15	NA	#3
	See Tables	10-11	36	100	11.0 ft
			51.0		
D-3 (19)	2-Buckets	8-10	15.0	80	
	See	10-12	15.0	80	
	Tables	12-14	15.0	70	
	↓	14-16	15.0	NA	
		16-18	15.0	NA	
		18-20	25.0	40	
			100.0		
E-3 (20)	↓	8-10	15.0	70	#3
		10-11	65.0	70	11.0'
~~D-4 (21)~~			80.0		
D-4 (21)	↓	8-10	15.0	80	#3
		10-12	15.0	80	
		12-14	15.0	90	
		14-16	15.0	80	
		16-18	50.0	70	18.0'
			110.0		

2-14-07

1600 Call to S. Marie, confirm its ok to use TPF to store trailer overnight. S. Marie gives approval.

1605 Refusal of E-3 @ 11.0 ft.

1615 Move to D-4. Light snow, windy, very cold 20's.

1650 Complete D-4. Start shutting down and M&W starts draining water from equipment.

Total Footage To date 339 ft

Total Gallons Injected 1823 gals

Total LBS BOSS (3x240) 720 lbs
(3 drums @ 240)

~~720 lbs / 339 ft = 2.1 lbs per ft~~ 2 lbs

- TYPICALLY Add 30 gallons water to each drum to "cook".
- 1 bucket per ~~40~~ 50 gallons of water
- 1 drum of boss = 225 lbs dry.

Cloudy, ≈10°F 2-15-07

700 Meet with M&W and have H&S Meeting and sign safety forms and Elegant Plastics site access form. M&W crew getting equipment ready. Very cold. Work on putting back together. Go for water. Geoprobe sig trucks frozen from water on trucks.

845 M&W injection trailer with water return to site. Geoprobe sets rods in B-4 and B-5 while waiting on injection trailer.

920 Get hoses and equipment thawed out. Start injection at B-5.

927 Stop injection on B-5, Reagent noted coming out of ground near B-6 location.

1015 Move to D-5. Grout hole as finished

1110 Move to E-4.

1130 Move to E-5.

ID	Boss Buckets	Injection Interval	Gals. Inj	System PSI	Drums/ Refusal
B-5 (22)	See Table	8-10	15.0	50	#4
		10-11	16.	70	11.0 ft refusal
			31.0		
B-4 (23)		8-10	15.0	80	#4
		10-12	15.0	70	
		12-13	50.0	70	13.0 ft refusal
			80.0		
C-4 (24)		8-10	15.0	70	#4
		10-11	55.0	80	11.0 ft refusal
			70.0		
D-5 (25)		8-10	15.0	80	#4
		10-12	15.0	70	
		12-14	15.0	80	
		14-16	15.0	60	
		16-18	15.0	50	
		18-20	25.0	50	
			100.0		
E-4 (26)		8-10	12.0	300	~~#4~~ #4
		10-11	65.0	80	11.0 refusal
			77.0		
E-5 (27)		8-10	15.0	70	#4
		10-11	45.0	80	11.0 refusal
			60.0		

2-15-07

1145 Move to D-6

1200 Note reagent coming out of ground from D-6 injection between D-7 and C-6.

1205 Move to C-5.

1245 Complete C-5. Go for food + M&W filling water tank.

1345 Set rods in B-6. M&W cleaning rods while waiting on water tank.

1430 Move to B-7.

1455 Move to B-8.

1510 Move to C-6.

1520 Stop injection on C-6, note reagent coming out of ground between C-6 and B-6.

1525 Move to C-7

1600 Move to C-8

1615 Move to D-7

1634 Move to E-6

1645 Reagent noted coming to surface, ~~stop~~ stop pumping on E-6.

1650 Move to E-7

1730 Store inject plant in IPF. Off-site.

Bill Bailey 2-15-07

2-15-07

IDH	Boss Vol	Injection Interval	Gallons Inj	System PSI	[illegible]/ Refusal
D-6 (28)	See Tables	8-10	15.0	80	#4
	↓	10-11	16.0	80	11.0 Refusal
			31.0		
C-5 (29)	↓	8-10	15.0	70	#4
		10-12	15.0	70	
		12-14	15.0	80	
		14-16	15.0	70	
		16-18	25.0	80	18.0 Refusal
			85.0		
B-6 (30)	↓	8-10	15.0	80	#5
		10-11	40.0	100	11.0 Refusal
			65.0		
B-7 (31)	↓	8-10	15.0	80	#5
		10-12	15.0	80	
		12-13	25.0	80	13.0 Refusal
			55.0		
B-8 (32)	↓	8-10	15.0	70	#5
		10-11	40.0	80	11.0 Refusal
			55.0		
C-6 (33)	↓	8-10	15.0	70	#5
		10-11	16.0	70	11.0 Refusal
			31.0		

2-15-07

ID #	Boss Amt	Inj. Interval	Gallons Injected	System PSI	Drum #/ Refusal
C-7 (34)	See Table	8-10	15.0	70	#5
	↓	10-12	15.0	90	
	↓	12-14	15.0	100	
	↓	14-15	30.0	90	15.0 ft
			75.0		
C-8 (35)	↓	8-10	15.0	70	#5
	↓	10-12	15.0	70	
	↓	12-12	35.0	70	12.0 ft
			65.0		
D-7 (36)	↓	8-10	15.0	70	#5
	↓	10-11	55.0	70	11.0 ft
			70.0		
E-6 (37) *	↓	8-10	15.0	70	#5
	↓	10-11	20.0	70	11.0'
			35.0		
E-7 (38)	↓	8-10	15.0	70	#5
	↓	10-12	15.0	70	
	↓	12-13	50.0	70	13.0'
			80.0		

* Change water to 40 gallons of water to one bucket of Boss 100.

Bill Bailey 2-15-07

2-16-07

700 Conduct H&S meeting with M&W. Very cold = 10°F
720 Get access to IDF and hook-up and pull out injection/grout plant. M&W goes for load of water. Start moving geoprobe to next injection location.
750 Set up on D-8.
815 Stop injection @ D-8. Reagent surfacing on north side of E-8.
820 Move to E-8. Grout holes as we finish
855 Move to E-9.
930 Move to E-10.
950 Move to E-11
1030 Move to C-18, across asphalt drive. Will do injection points in asphalt drive next week when warmer so we can seal holes in asphalt. M&W goes for second load of water.
1125 Move to B-19.
1130 Stop injection on B-19, reagent coming to ground surface.

2-16-07

ID #	Boss Amt	Inj Interval	Gallons Inj	System PSI	Drawn#/Refusal
D-8 (39)	See Table	8-10	8.0	300	#5
		10-11	60.0	60	11.0 ft
			68.0		
E-8 (40)	↓	8-10	15.0	50	~~#5~~ #6
		10-12	15.0	60	
		12-14	15.0	60	
		14-16	15.0	70	
		16-16	50.0	60	16.0 ft
			110.0		
E-9 (41)	↓	8-10	15.0	70	#6
		10-12	15.0	40	
		12-14	15.0	60	
		14-16	15.0	50	
		16-18	15.0	NA	
		18-20	40.0	70	
			115.0		
E-10 (42)	↓	8-10	15.0	70	#6
		10-11	80.0	70	11.0 ft
			95.0		
E-11 (43)	↓	8-10	15.0	70	#6
		10-12	15.0	80	
		12-14	15.0	100	
		14-16	15.0	100	
		16-18	15.0	100	

ID #	Boss Amt	Inj Interval	Gallons Inj	System PSI	Drawn#/Refusal
E-11 (43)	See Table	18-19	35	100	
			110		
C-18 (44) 18	↓	8-10	15	90	#7
		10-12	35	100	Refusal
			70		
B-19 (45)	↓	8-10	15.0	70	
		10-12	15.0	100	
		12-14	50.0	100	14.0 ft refusal
			80.0		
C-19 (46)	↓	8-10	15.0	70	#7
		10-12	15.0	100	
		12-14	15.0	100	
		14-16	15.0	100	
		16-18	60.0	80	18.0 ft refusal
			120.0		
A-23 (47)	↓	8-10	15.0	70	#7
		10-12	15.0	100	
		12-14	15.0	~~60~~ 70	
		14-16	15.0	60	
		16-18	15.0	100	
		18-20	15.0	80	
			90.0		

[initials]

2-16-07

1130 Move to C-19
1215 Go to get food and warm ~~up~~ up. Go to get more water (1/2 tank)
1330 Set-up on ~~B-23~~ A-23
1410 Set-up on B-20
1440 Set-up on B-21.
1510 Go to Impact Plastic and meet with Rich Turner and let him know that we are leaving and will return Monday. Also, we will touch up rough spots upon project completion.
1540 Call Jamie Green and let her know we have completed work for week.
1600 Leave site.

Bill Bailey 2-16-07

ID #	Boss Amt	Inj Interval	Gallons Injected	System PSI	Drum #/ Refusal
B-20 (48)	See Table	8-10	15.0	70	#7
		10-12	15.0	70	
		12-14	15.0	80	
		14-16	15.0	90	
		16-18	15.0	80	
		18-19	15.0	80	19.0 Refusal
			90.0		
B-21 (49)		8-10	15.0	70	#7
		10-12	15.0	80	
		12-14	16.0	70	
		14-16	15.0	70	
		16-18	15.0	60	
		18-20	25.0	70	
			110.0		

Bill Bailey 2-16-07

2-19-07

700 Arrive @ office. Complete limited expenses and copy field notes. Switch out vehicle.
800 Leave for Erwin.
1010 Arrive at site. M&W goes for water.
1045 Conduct H&S Meeting with M&W.
1055 Set-up on E-20 [over 18]. Try different injection rod with holes in side of ~~rod~~ rod. Had been injection through the bottom of rod. New method does not work, go back to old method.
1140 Move to E-19 [over 18]. Grout up hole after injec.
1215 Move to D-19.
1240 M&W goes for water (1/2 tank).
1305 Move to D-20. Stopped up @ 8.0 - 10.0 ft.
1335 Move C-20.
1405 Move to D-21. Reagent coming to ground surface near injection location.
1420 Move to ~~[illegible]~~ D-22.
1440 Move to E-21.
1530 Set-up on E-22

ID	[illegible]	Injection Interval	Gallons Injected	System PSI	Dosage/Refusal
E-20 [over 19] (50)	See Table	8-10	15.0	70	#8
		10-12	15.0	60	
		12-14	15.0	80	
		14-16	15.0	70	
		16-18	15.0	80	
		18-20	15.0	80	
			90.0		
E-19 [over 18] (51)		8-10	15.0	80	#8
		10-12	15.0	80	
		12-14	15.0	100	
		14-16	15.0	100	
		16-18	15.0	110	
		18-20	15.0	110	
			90.0		
D-19 (52)		8-10	15.0	100	#8
		10-12	15.0	120	
		12-14	15.0	120	
		14-16	6.0	120	
			10.5		
D-20 (53)		8-10	4.0	300	#8
		10-12	~~15.0~~		
		10-12	62.0	120	12.0 Refusal
			66.0		

ID#	Boss Amt	Inj Interval	Gallons Inj	System PSI	Drum #/Refusal
C-20 (58)	See Tables	8-10	~~18~~ 15.0	110	#8/9
		10-12	15.0	110	
		12-14	15.0	110	
		14-16	15.0	110	
		16-18	15.0	~~120~~ 100	
		18-20	15.0	100	
			90.0		
D-21 (58)		8-10	15.0	100	#9
		10-12	15.0	120	
		10-12	15.0	100	12.0'
			45.0		
D-~~22~~ 21 / 22 (58)		8-10	15.0	100	#9
		10-12	15.0	100	
		12-13	65.0	110	13.0
			95.0		
E-21 (59)		8-10	15.0	100	#9
		10-12	15.0	100	
		12-14	15.0	110	
		14-16	15.0	110	
		16-18	12.0	300	
		18-20	60.0		
			132.0		

ID#	Boss Amt	Inj Interval	Gallons Injected	System PSI	Drum #/Refusal
E-22 (58)	See Tables	8-10	15.0	110	#9
		10-11	80.0	100	11.0' refusal
			95.0		
D-23 (60) (59)		8-10	6.0	300	#9
		10-12	30.0	110	12.0' refusal
			36.0		
C-21 (60)		8-10	15.0	110	#10
		10-12	15.0	110	
		12-13	~~80~~ 50.0	110	13.0' refusal
			80		
A-21 (62)		8-10	15.0	110	#10
		10-12	15.0	110	
		12-14	15.0	130	
		14-16	15.0	120	
		16-18	15.0	120	
		18-20	30.0	120	
			105.0		
A-22 (62)		8-10	10.0	300	#10
		10-12	15.0	NA	
		12-14	15.0	110	15.0' refusal
		14-15	80.0	120	
			120.0		

2-19-07

1550 Move to D-23. Stopped up @ 8-10 ft interval. Reagent flowing to surface at 120 ft interval.

1610 Move to C-21. Reagent noted coming to surface. Stop injection @ 13.0 ft, also refusal.

1630 Set-up at A-21.

1705 Set up on A-22.

1730 Set up on A-23

ID#	Boas Amt	Injection Interval	Gallons Inj	System PSI	Drawn/Refusal
* A-23-A (63)	See Table	8-10	15.0	120	#10
	↓	10-12	15.0	120	
		12-14	15.0	110	
		14-16	15.0	100	
		16-18	15.0	110	
		18-20	30.0	100	
			105.0		

* A-23-A Accidently marked two locations.

1850 Leave site for the day.

11.5 hrs — Bill Barley 2-19-07

2-20-07

0700 Conduct H&S Meeting. Get trailer out of BPF. M&W goes for water. Fuel up geoprobe.

0740 Set up on B-22. Problem with clogged hose.

0850 Set up on B-23.

0905 Set up on B-24.

0940 Set up on A-24.

1010 Set up on B-25.

1040 M&W goes for load of water (2nd tank).

1100 Set up on A-25.

1115 Set up on B-26

1142 Set up on A-26. Reagent noted coming to surface @ 12.0 injection interval, stopped injection.

1155 Set-up on B-27. Seeping out of ground.

1210 Set up on A-27. Stop injection, seeping to ground surface from 13.0 ft interval

1230 Set-up on B-28.

1315 M&W goes for more water (Tank #3)

1400 Set up on C-22.

1440 Set up on C-23.

ID #	Boss Amt	Inj Interval	Gallons Inj	System PSI	Drum #/ Refusal
B-22 (64)	See Tables	8-10	15.0	NA	#10
	↓	10-12	15.0	NA	
		12-14	15.0	140	
		14-16	15.0	100	
		16-18	15.0	80	
		18-20	20.0	110	
			~~[illegible]~~ 95.0		
B-23 (65)	↓	8-10	15.0	100	#11
		10-12	15.0	110	
		12-13	40.0	110	13.0'
			70.0		
B-24 (66)	↓	8-10	15.0	100	#11
		10-12	15.0	110	
		12-14	15.0	110	
		14-16	15.0	90	
		16-18	15.0	100	
		18-20	25.0	110	
			100.0		
A-24 (67)	↓	8-10	15.0	90	#11
		10-12	15.0	100	
		12-14	15.0	90	
		14-16	15.0	80	
		16-18	15.0	90	
		18-20	25.0	100	
			100.0		

ID #	Boss Amt	Inj Interval	Gallons Inj	System PSI	Drum/ Refusal
B-25 (68)	See Tables	8-10	15.0	100	#11
	↓	10-12	15.0	100	
		12-14	15.0	90	
		14-16	15.0	120	
		16-18	15.0	110	
		18-20	25.0	90	
			100.0		
A-25 (69)	↓	8-10	15.0	100	#12
		10-12	15.0	100	
		12-13	40.0	110	13.0' Refusal
			70		
B-26 (70)	↓	8-10	15.0	110	
		10-12	15.0	110	
		12-14	15.0	NA	
		14-15	60.0	120	15.0' refusal
			105.0		
A-26 (71)	↓	8-10	15.0	90	#12
		10-12	50.0	110	120' refusal
			65.0		
B-27 (72)	↓	8-10	15.0	90	#12
		10-12	40.0	110	12.0' refusal
			65.0		

IP #	[illegible] Point	Inj. Interval	Gallons Inj.	System PSI	[illegible] Refusal
A-27	See table	8-10	15.0	90	#12
(73)	↓	10-12	15.0	100	
		12-13	60.0	110	13.0'
			90.0		
B-28	↓	8-10	15.0	100	#12
(74)		10-12	15.0	100	
		12-14	15.0	110	
		14-16	15.0	150	
		16-18	15.0	140	
		18-20	15.0	130	
			90.0		
C-22	↓	8-10	15.0	100	#13
(75)		10-12	15.0	100	
		12-14	15.0	130	
		14-16	15.0	130	
		16-18	15.0	110	
		18-20	30.0	120	
			105.0		
C-23	↓	8-10	15.0	100	#13
(76)		10-12	15.0	110	
		12-14	15.0	110	
		14-16	40.0	110	16.0'
			85.0		

2-20-07

1500 At C-23 reagent noted coming to top.
1505 Set-up on D-23
1520 Set up on E-23
1535 Set up on D-24
1610 Set up on E-24
1630 M & W goes for more water (Tank # 4).
1650 Set up on C-24. Reagent noted seeping out of ground at refusal.
1700 Set-up on D-25.
1720 Set up on E-25.
1800 Leave site for the day.

Bill Bailey
2-20-07

ID#	Boss Ant	Inj Interval	Gals Injected	System PSI	DRwasty Refusal
D-23 (77)	See Table	8-10	15.0	100	#13
		10-12	15.0	100	
		12-13	35.0	110	13.0'
			65.0		
E-23 (78)	↓	8-10	15.0	100	#13
		10-12	50.0	100	12.0'
			65.0		
D-24 (79)	↓	8-10	15.0	100	#13
		10-12	15.0	100	
		12-14	15.0	110	
		14-16	15.0	90	
		16-18	15.0	110	
		18-20	25.0	120	
			100.0		
E-24 (80)	↓	8-10	0	300	#13
		10-12	15.0	NA	
		12-13	65.0	110	13.0'
			80.0		
C-24 (81)	↓	8-10	15.0	110	#13
		10-12	15	110	
		12-13	35	110	13.0'
			65		
D-25 (82)	↓	8-10	10.0	300	#13
		10-12	15.0	110	
		12-13	40.0	110	13.0'
			65.0		

2-20-07

ID#	Boss Ant	Inj Interval	Gals Inj	System PSI	DRwasty Refusal
E-25 (83)	See Table	8-10	15.0	110	#13
		10-12	15.0	120	
		12-13	45.0	120	13.0
			75.0		

2-20-07 Bill Bailey

2-21-07

0700 Conduct H&S Meeting with M&W.

0740 Set up on D-9. West side of light pole in parking lot.

0805 Set up on D-10.

0820 NFS Staff comes by to pick-up decon tank water ≈ 750 gallons.

0840 Move to C-10.

0905 M&W goes for load of water (Tank #1).

0910 Move to C-9.

0940 Move to C-11

1005 Move to D-11. Refusal at 13.0 ft, water seeping to ground surface, stop injection @ 13.0 ft.

1025 Move to D-12. Starts seeping out of ground, stop injections.

1045 Move to B-9.

1100 Move to B-10.

1135. Move to B-11.

1205 M&W goes for load of water (Tank #2).

1210 Set-up on B-12.

1320 Set-up on A-13.

2-21-07

TD #	Boss Ant	INJ Interval	Gals INJ	System PSI	Drum/Refill
D-9 (84)	See Table	8-10	15.0	100	#13
		10-12	15.0	120	
		12-14	15.0	100	
		14-16	15.0	100	
		16-18	15.0	100	
		18-20	25.0	110	
			100.0		
D-10 (85)		8-10	15.0	100	#14
		10-12	15.0	110	
		12-14	15.0	110	
		14-16	15.0	110	
		16-18	45.0	120	18.0'
			105		
C-10 (86)		8-10	25.0	100	#14
		10-12	15.0	100	
		12-14	15.0	100	
		14-16	15.0	100	
		16-18	15.0	110	
		18-20	25.0	120	
			100.0		

[signature] 2-21-07

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2-21-07

ID#	Boss Amt	Inj Interval	Gals Inj	System PSI	Drum # Refusal
C-9 (87)	See Table	8-10	15.0	110	#14
	↓	10-11	55.0	120	11.0'
			70.0		
C-11 (88)	↓	8-10	15.0	100	#14
		10-12	15.0	180	
		12-14	15.0	100	
		14-15	45.0	120	15.0'
			90.0		
D-11 (89)	↓	8-10	15.0	100	#14
		10-12	15.0	120	
		12-13	30.0	120	13.0'
			60.0		
D-12 (90)	↓	8-10	15.0	110	#14
		10-12	15.0	120	
		12-13	10.0	80	13.0'
			40.0		
B-9 (91)	↓	8-10	15.0	100	#14/15
		10-12	50.0	100	12.0'
			65.0		
B-10 (92)	↓	8-10	15.0	100	#15
		10-12	15.0	120	
		12-14	15.0	110	
		14-16	15.0	110	
		16-18	0	360	

2-21-07

ID#	Boss Amt	Inj Interval	Gals Inj	Sys PSI	Drum #/ Refusal
B-10 Cont.	See Table	18-18	40	120	18.0 refusal
			100.0		
B-11 (93)	↓	8-10	15.0	120	#15
		10-12	15.0	100	
		12-14	15.0	100	
		14-16	15.0	110	
		16-18	45.0	110	18.0' refusal
			105.0		
B-12 (94)	↓	8-10	15.0	100	#15
		10-12	15.0	110	
		12-14	15.0	150	
		12-15	65.0	120	15.0' refusal
			110.0		
A-13 (95)	↓	8-10	15.0	100	#15
		10-11	55.0	110	11.0' refusal
			70.0		
A-12 (96)	↓	8-10	15.0	120	#15/16
		10-12	55.0	120	12.0' refusal
			70.0		
A-11 (97)	↓	8-10	15.0	100	#16
		10-12	40.0	80	12.0' refusal
			65.0		

[signature] 2-21-07

2-21-07

1835 Set up on A-12.
1250 Set up on A-11. Refusal @ 12.0 ft, seeping out from 12.0 ft injection.
1410 Set up on A-10. Refusal @ 11.0 ft, injection @ 11.0 ft resulted in reagent seeping out of ground within injection point 15 ft away. Stopped injection.
1425 Set up on A-9.
1445 Set up on B-13. Refusal at 9.0 ft. Back of rod while injecting, taken 10.0 gallons of water & reagent.
1455 Set-up on C-12.
1530 Set-up on D-13. Mix w/ goes for water (Tank # 3).
1615 Set-up on C-13
1645 Set up on B-14
1510 Set up on A-14. Refusal at 11.0 ft, while injecting at 11.0 ft, noted reagent seeping out of ground.
1525 Set up on B-15.
1800 Start shutting down for the day.
1830 Arrive @ motel.

(1.5)

2-21-07

ID #	Boss Amt	Inj Interval	Inj Gallons	Inj PSI	Drum # / Refusal
A-10	See Table	8-10	15.0	100	#16
(98)	↓	10-11	10.0	80	11.0' Refusal
			25.0		
A-9	↓	8-10	15.0	100	#16
(99)	↓	10-11	60.0	60	11.0' refusal
			75.0		
B-13	↓	8-9	10.0	300	#16
(100)	↓		10.0		9.0' refusal
C-12	↓	8-10	15.0	80	#16
(101)	↓	10-12	15.0	100	
	↓	12-14	15.0	100	
	↓	14-16	15.0	100	
	↓	16-18	15.0	110	
	↓	18-20	25.0	120	
			100.0		
D-13	↓	8-10	15.0	120	#16/17
(102)	↓	10-12	15.0	120	
	↓	12-14	15.0	100	
	↓	14-16	15.0	100	
	↓	16-18	15.0	100	
	↓	18-20	25.0	100	
			100.0		

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ID#	Boss/Vent	Inj Interval	Gallons Inj	Sys PSI	DR/Hole/Refusal
C-13 (103)	See Tables	8-10	15.0	100	#17
		10-12	15.0	NA	
		12-14	15.0	110	
		14-16	15.0	NA	
		16-18	15.0	NA	
		18-20	25.0	NA	
			100		
B-14 (104)		8-10	15.0	NA	#17
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	
		16-18	40.0	NA	18.0'
			100.0		
A-14 (105)		8-10	15.0	NA	#17
		10-11	30.0	NA	11.0'
			45.0		
B-15 (106)		8-10	15.0	NA	#18
		10-12	15.0	NA	
		12-14	15.0	NA	
		16-18	15.0	NA	
		18-20	25.0	NA	
			85.0		

* Mix approx 40 lbs per 100 gallons
NA = Not avaible, guege gone bad.

[signature] 2-21-07

2-22-07

0700 Health & Safety Meeting.
0715 Arrive @ site. M&W goes for water.
0745 Set up on E-12. M&W works on filling hole in asphalt while waiting on getting new batch mixed up.
0810 Move to E-13.
0825 Move to D-14.
0840 Set up on C-14.
0910 Set up on E-14.
0945 Set up on D-15.
1015 M&W goes for load of tank (Tank #2)
1020 Set up on ~~A-20~~ ~~A-20~~ A-21. [initials] 2-22-07
1110 Set up on A-20
1130 Set up on A-19. Refusal @ 12.0 ft, Seeping @ 12.0 ft, stop injection.
1150 Set up on A-18.
1226 Set up on A-17.
1400 Set up on E-17, M&W goes for water (Tank #3).
1435 Move to E-18.

Roger Donvan (TEC) on site 0930-1400

ID#	Boss Part	Inj Interval	Calc Inj	Sys PSI	Drum#/ Return
~~[illegible]~~ E-12 (107)	See Table	8-10	15.0	110	#18
	↓	10-12	55.0	130	12.0'
			70.0		
E-13 (108)	↓	8-10	15.0	130	#18
		10-12	55.0	140	12.0'
			70.0		
D-14 (109)	↓	8-10	15.0	NA	#18
		10-12	55.0	NA	12.0'
			70.0		
C-14 (110)	↓	8-10	15.0	NA	#19
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	60.0	NA	16.0'
			105.0		
E-14 (111)	↓	8-10	10.0	NA	#19
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	
		16-18	15.0	NA	
		18-20	35.0	NA	
			105.0		
D-15 (112)	↓	8-10	15.0	NA	#19
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	

ID#	Bass Part	Inj Interval	Calc Inj	Sys PSI	DRUM#	Return
D-15 (112)	See table	16-18	15.0	NA	#20	18.0'
			100.0			
~~A-~~ A-21-A* (113)	↓	8-10	15.0	NA	#20	
		10-12	15.0	NA		
		12-14	15.0	NA		
		14-16	15.0	NA		
		16-18	15.0	NA		
		18-20	15.0	NA		
			100			
A-20 (114)	↓	8-10	15.0	NA	#20	
		10-12	15.0	NA		
		12-14	60.0	NA		18.0'
			90.0			
A-19 (115)	↓	8-10	15.0	NA	#20	
		10-12	44.0	NA		12.0'
			59.0			
A-18 (116)	↓	8-10	15.0	NA	#20	
		10-12	15.0	NA		
		12-14	15.0	NA		
		14-16	15.0	NA		
		16-18	15.0	NA		
		18-20	30.0	NA		
			105.0			

*A-21-A - Second [Accidental] location in area (page 29).

ID #	Bgss Amt	Inj Interval	Gallons Inj	System PSI	DRUM Refusal
A-17 (117)	See Tables	8-10	10.0	NA	#20
		10-12	0	NA	
		12-14	15.0	NA	
	↓	14-15	40.0	NA	15.0'
			65.0		
E-17 (118)	↓	8-10	15.0	NA	#21
	↓	10-12	55.0	NA	12.0'
			70.0		
E-18 (119)	↓	8-10	15.0	NA	#21
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	
		16-18	15.0	NA	
	↓	18-20	25.0	NA	
			100.0		
E-16 (120)	↓	8-10	30.0	NA	#21
			30.0		10.0'
E-15 (121)	↓	8-10	15.0	NA	#21
		10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	
		16-18	15.0	NA	
	↓	18-19	25.0		19.0'
			100.0		

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1515 Set up on ~~E-18~~ E-16. Refusal at 10.0 ft. Start injecting and note reagent coming to ground surface. Stop injection.

1520 Set up on E-15.

1555 Set up on D-16.

1610 Set up on D-17.

1625 Set up on D-18. M&W gone for water (#4)

1720 Set up on C-17.

1730 Set up on B-17.

1740 Set up on B-18. Refusal @ 14.0 ft, start injections and stop after 40 gallons due to seepage to ground surface.

1800 Set up on C-16.

1815 Complete C-16, refusal @ 15.0 ft. Site clean-up, secure site. Off-site

ID #	Bass Amt	Inj Interval	Gals Inj	System PSI	Drum #/ Refusal
D-16	See Tables	8-10	15.0	NA	#21
(122)	↓	10-11	55.0	NA	11.0'
			70.0		
D-17	↓	8-10	15.0	NA	#21
(123)		10-12	55.0	NA	12.0'
			70.0		
D-18	↓	8-10	10.0	NA	#21
(124)		10-12	15.0	NA	
		12-14	50.0	NA	14.0'
			75.0		
C-17	↓	8-10	15.0	NA	#22
(125)		10-12	15.0	NA	
		12-13	40.0	NA	13.0'
			70.0 80.0		
B-17	↓	8-10	15.0	NA	#22
(126)		10-12	55.0	NA	12.0'
			70.0		
B-18	↓	8-10	15.0	NA	#22
(127)		10-12	15.0	NA	
		12-14	40.0	NA	14.0'
			70.0		
C-16	↓	8-10	15.0	NA	#22
(128)		10-12	15.0	NA	
		12-14	15.0	NA	

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ID #	Bass Amt	Inj Interval	Gals Inj	Sys PSI	Drum #/ Refusal
C-16	See tables	14-15	40.0	NA	15.0'
(128)			85.0		

Bill Bailey
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2-23-07

0700 Conduct H&S meeting.
0715 Arrive at site. M&W getting equipment ready. Pull trailer out of IPF.
0730 Set up on A-16. M&W get water (1/2 tank).
0820 Move to A-15.
0845 Move to B-16.
0915 Move to C-~~16~~
0945 Move to C-25. Refusal at 14.0 ft, noted seeping out of ground, injection stopped.
1000 Move to D-26.
1015 M&W gone for water (Tank 2)
1030 Move to C-26. Seeping out.
1050 Move to D-27. Seeping out.
1100 Move to E-26.
1110 Move to E-27.
1130 Move to D-28
1145 Move to C-27.
1205 Move to A-28.
1220 Set up on B-29. Refusal @ 12.0 ft, stopped injection, seeping from ground.

ID#	Boss Amt	Inj Interval	Gals Injected	Sys PSI	Drum #/ Refusal
A-16	See Table	8-10	~~15.0~~ 8.0	NA	#22
(129)	↓	10-12	15.0	NA	
		12-14	15.0	NA	
		14-16	15.0	NA	
		16-18	6.0	NA	
		18-20	42.0	NA	
			101		
A-15	↓	8-10	15.0	NA	# 23
(130)		10-12	55.0	NA	12.0'
			70.0		
B-16	↓	8-10	15.0	NA	# 23
(131)		10-12	15.0		
		12-14	15.0		
		14-16	15.0		
		16-18	40.0		18.0'
			100.0		
C-15 ~~C-18~~	↓	8-10	15.0	NA	# 23
(132)		10-12	15.0		
		12-14	15.0		
		14-16	15.0		
		16-18	15.0		
		18-19	25.0		19.0'
			100.0		

ID#	Boss Amt	Interval	Gallons	PSI	Drive/Refusal
C-25	See Tables	8-10	15.0	NA	#23
(133)	↓	10-12	15.0	NA	
		12-14	30.0	NA	14.0'
			60.0		
D-26	↓	8-10	15.0	NA	#23
(134)		10-12	60.0	NA	
			75.0		
C-26	↓	8-10	15.0	NA	#23
(135)		10-11	20.0	NA	11.0'
			35.0		
D-27	↓	8-10	15.0	NA	#23
(136)		10-12	30.0	NA	12.0'
			45.0		
E-26	↓	8-10	15.0	NA	#23
(137)		10-12	60.0		12.0'
			75.0		
E-27	↓	8-10	6.0	NA	#24
(138)		10-12	15.0	NA	
		12-13	50.0	NA	13.0'
			65.0		
D-28	↓	8-10	15.0	NA	#24
(139)		10-12	0	NA	~~13.0~~
		12-13	55.0	NA	13.0'
			70.0		

ID#	Boss Amt	Inj Interval	Gals Inj	Stus PSI	Drive/Refusal
C-27	See Tables	8-10	15.0	NA	#24
(140)	↓	10-12	15.0	NA	
		12-14	40.0	NA	14.0'
			70.0		
A-28	↓	8-10	15.0	NA	#24
(141)		10-12	55.0	NA	12.0'
			70.0		
B-29	↓	8-10	15.0	NA	#24
(142)		10-12	30.0	NA	12.0'
			45.0		
A-29	↓	8-10	15.0	NA	#24
(143)		10-11	45.0		11.0'
			60.0		
B-30	↓	8-10	15.0	NA	#24
(144)		10-12	15.0	NA	
		12-13	0.0		13.0'
			30.0		
C-28	↓	8-10	15.0	NA	#24
(145)		10-12	15.0	NA	
		12-13	8.0	NA	13.0'
			38.0		
A-30	↓	8-10	15.0	NA	#24
(146)		10-11	50.0	NA	
			65.0		

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1240 Move to A-29.
1250 Move to B-30. Reagent surfacing to ground at borehole approx 15.0 ft away. Stop injection.
1310 Move to C-28, Refusal @ 13.0 ft, during injection at 13.0 ft, reagent noted coming to top of surface.
1340 Move to A-30.
1350 Move to A-31.
1410 Move to B-31.
1430 Move to C-30.
1445 Move to C-29, Refusal at 15.0 ft, stop injection from 15.0 ft because reagent noted coming to surface.
1510 Move to D-29
1530 check out @ Dupont Plastics, call J. Green. Clean up site, secure ~~clean~~ site.
1600 Leave Erwin.
1815 Arrive @ Office.

Bill Bailey 2-23-07

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ID#	Bags Amt	Inj Interval	Gals Inj	845 PSI	Drum #/ Refusal
A-31	See Table	8-10	15.0	NA	#25
(147)	↓	10-12	50.0		12.0'
			65.0		
B-31		8-10	15.0	NA	#25
(148)	↓	10-12	60.0	NA	12.0'
			75.0		
C-30		8-10	15.0	NA	#25
(149)	↓	10-11	55.0	NA	11.0'
			70.0		
C-29		8-10	15.0	NA	#25
(150)		10-12	15.0	NA	
		12-14	15.0	NA	
	↓	14-15	40.0	NA	15.0'
			85.0		
D-29		8-10	15.0	NA	#25
(151)	↓	10-12	60.0	NA	12.0'
			75.0		

Bill Bailey 2-23-07

2-26-07

0630 Leave Oak Ridge for Erwin.
0900 Arrive in Erwin. M&W getting equipment ready for site work.
Conduct H&S Meeting.
0940 Set up on E-28. Seeping
1000 Set up on D-30. Seeping
1020 Set up on B-32. Seeping
1030 Set up on A 32. Seeping
1050 Set up on C-31. Seeping
1105 Set up on B 33.
1120 Set up on C-32. Seeping
Change water/hoss to 30 gallon to one bucket.
1130 Set up on D-31. Seeping out of ground from 16.0-18.0 ft.
1200 Set up on D-32. Seeping.
1210 Set up on C-33.
1230 M&W goes for water (Tank #2)
1300 Set up on B-34. Stop injection, seeping.
1315 Set up on D-33. Seeping.
1330 Set up on E-32.
1345 Set up on E-30. Seeping.

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ID#	[illegible]	Inj. Interval	Gals Inj.	Sys PSI	Drawing #/Refusal
E-28	[illegible]	8-10	15.0	NA	#26
(152)	↓	10-12	15.0	↓	
		12-14	15.0		
		14-15	~~51.0~~ 6.0		15.0'
			~~96.0~~ 51.0		
D-30	↓	8-10	15.0	↓	#26
(153)		10-12	35.0		12.0'
			50.0		
B-32	↓	8-10	15.0	↓	#26
(154)		10-12	40.0		12.0'
			55.0		
A-32	↓	8-10	15.0	↓	#26
(155)		10-11	50.0		11.0'
			65.0		
C-31					
(156)	↓	8-10	15.0	↓	#26
		10-12	15.0		
		12-13	12.0		13.0'
			42.0		
B-33	↓	8-10	20.0	↓	#26
(157)		10-12	40.0		12.0'
			60.0		

NA: Not Available

ID#	Boss Amt	Inj Interval	Gals Inj	PSI	Drum#/Refusal
C-32	See Table	8-10	20.0	NA	#27
(158)	↓	10-11	20.0	↓	11.0'
			40.0		
D-31		8-10	20.0		#27
(159)		10-12	20.0		
		12-14	20.0		
		14-16	20.0		
	↓	16-18	20.0	↓	18.0'
			100.0		
D-32		8-10	16.0		#27
(160)	↓	10-12	10.0	↓	12.0'
			26.0		
C-33		8-10	20.0		#27
(161)	↓	10-11	20.0	↓	11.0
			40.0		
B-34		8-10	20.0		#27
(162)	↓	10-12	55.0	↓	12.0'
			75.0		
D-33		8-10	20.0		#27
(163)	↓	10-12	50.0	↓	12.0'
			70.0		
E-32		8-10	20.0		#28
(164)	↓	10-12	60.0	↓	12.0
			80.0		

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ID#	Boss Amt	Inj Interval	Gals Inject	PSI	Drum#/Refusal
E-30	See Table	8-10	20.0	NA	#28
(165)		10-12	20.0		
		12-14	20.0		
		14-16	20.0		
	↓	16-18	30.0	↓	18.0'
			110.0		
A-33		8-10	20.0		#28
(166)		10-11	45.0	↓	11.0'
			65.0		
D-34		8-10	20.0		#28
(167)		10-12	20.0		
	↓	12-13	40.0	↓	13.0'
			80.0		
E-33		8-10	20.0		#28
(168)	↓	10-11	45.0	↓	11.0'
			65.0		
E-34		8-10	20.0		#28
(169)	↓	10-11	50.0	↓	11.0'
			70.0		
E-29		8-10	20.0		#29
(170)		10-12	20.0		
		12-14	20.0		
	↓	14-15	10.0	↓	15.0'
			70.0		

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1415 Set up on A-33. Seeping.
1430 Set up on D-34. Seeping.
1445 Set up on E-33. Seeping
1500 Set up on E-34. M&W goes for water.
1535 Set up on E-29. Seeping
1600 Set up on D-35. Seeping
1610 Set up on A-34. Seeping
1620 Set up on B-35. Seeping
1640 Set up on C-34.
1655 Set up on C-35. Seeping
1700 Set up on B-36.
Use all of drum #29. Start shut down of site activities for the day, temps expected to be below 32°F on Tuesday.
1745 Arrive @ motel. Update tables.

Bill Bailey
2-26-07

11.0

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ID#	Bore Unit	Inj Interval	Gals Inj	Sys PSI	Drum#/Refusal
D-35	See table	8-10	20.0	NA	#29
(171)	↓	10-12	45.0	↓	12.0'
			65.0		Seep
A-34		8-10	20.0		#29
(172)	↓	10-11	10.0	↓	11.0'
			30.0		Seep
B-35		8-10	20.0		#29
(173)	↓	10-11	30.0	↓	11.0'
			50.0		Seep
C-34		8-10	20.0		#29
(174)	↓	10-12	50.0	↓	12.0'
			70.0		
C-35		8-10	20.0		#29
(175)	↓	10-11	30.0	↓	11.0'
			50.0		Seep
B-36		8-10	20.0		#29
(176)	↓	10-11	50.0		11.0'
			70.0		

Bill Bailey
2-26-07

2-27-07

0700 Health & Safety Meeting.
M&W removed trailer from IPE and gone for water.
Fuel up geoprobe unit.
Call to R. Austin on refusal depth to the west of the site. Of the 25 boreholes yesterday, 19 hit refusal of 12.0 ft or less.
0750 Set up on E-31. Seeping
0820 Set up on A-35. Seeping
0830 Set up on C-36.
0845 Set up on B-37. Seeping
0900 Set up on E-35.
0910 Set up on D-36
0930 Set up on A-36. Seeping
1000 Set up on A-37. Seeping
1010 Set up on B-38. M&W gone for load of water (Tank #2). Seeping.
1045 Set up on A-37.
1100 Set up on C-37.
1115 Set up on D-37.
1130 Set up on E-36.

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ID #	Boss Amt	Inj Interval	Gals Inj	Drum #	Refusal/Comments
E-31	See table	8-10	20.0	#30	
(177)	↓	10-11	30.0		11.0'
			50.0		seep
A-35	↓	8-10	20.0	#30	
(178)		10-11	25.0		11.0'
			45.0		Seep
C-36	↓	8-10	20.0	#30	
(179)		10-11	45.0		11.0'
			65.0		
B-37	↓	8-10	20.0	#30	
(180)		10-11	55.0		11.0'
			75.0		Seep
E-35	↓	8-10	20.0	#30	
(181)		10-12	80.0		12.0'
			100.0		
D-36	↓	8-10	20.0	#30	
(182)		10-12	20.0		
		12-14	20.0	#31	
		14-16	60.0		16.0'
			120.0		
A-36	↓	8-10	~~8.0~~ ~~20.0~~	#31	
(183)		10-12	20.0		
		12-14	10.0		14.0'
			38.0		Seep

✓

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ID#	Boxes Amt	Inj Interval	Gals Inj	Drum #	Refusal
A-37	See table	8-10	20.0	#31	
(184)	↓	10-11	20.0		11.0'
			40.0		Seep
B-38	↓	8-10	30.0	#31	
(185)		10-11	20.0		11.0'
			50.0		Seep
A-38	↓	8-10	20.0	#31	
(186)		10-11	70.0		11.0'
			90.0		
C-37	↓	8-10	20.0	#31	
(187)		10-12	90.0		12.0'
			110.0		
D-37	↓	8-10	20.0	#32	
(188)		10-12	70.0		12.0'
			90.0		
E-36	↓	8-10	20.0	#32	
(189)		10-12	80.0		12.0'
			100.0		
E-37	↓	8-10	20.0	#32	
(190)		10-11	70.0		11.0'
			90.0		
D-38	↓	8-10	20.0	#32	
(191)		10-11	40.0		11.0
			60.0		

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ID #	Boxes Amt	Inj Interval	Gals Inj	Drum #	Refusal
B-39	See Table	8-10	20.0	#33	
(192)		10-12	12.0		11.0'
			32.0		Seep
A-39		8-10	20.0	#33	
(193)		10-11	70.0		11.0
			90.0		
B-40		8-10	20.0	#33	
(194)		10-11	50.0		11.0'
			70.0		
A-40		8-10	20.0	#33	
(195)		10-11	60.0		11.0'
			80.0		Seep
C-38		8-10	20.0	#34	
(196)		10-12	60.0		12.0'
			80.0		Seep
C-39		8-10	20.0	#34	
(197)		10-12	60.0		12.0'
			80.0		
D-39		8-10	20.0	#34	
(198)		10-11	60.0		11.0'
			80.0		
E-38		8-10	0	#34	~~8.0'~~
(199)		10-12	80.0		12.0'
			80.0		

2-27-07

1145 Set up on E-37.
1200 Set up on D-38.
1210 Set up on B-39. M&W goes for water. B-39 seeping @ 11.0 ft (refusal)
1325 Set up on A-39. Seeping.
1335 Set up on B-40.
1350 Set up on A-40. Seeping
1405 Set up on C-38.
1420 Set up on C-39.
1431 Set up on D-39.
1500 Set up on E-39. M&W goes for water (Tank #3).
1535 Set up on E-40
1545 ~~THE~~ State off Rem. Site visitor, stopped by, did not get out of car, sat a few minutes then drove off.
1550 Set up on D-40.
1605 Set up on C-40.
1615 Set up on B-41.
1635 Set up on A-41.
1650 Set up on ~~D-41~~ C-46
1715 M&W goes for water for Wednesday, prep for Wednesday work.
1745 Off-site.

Bill Bailey 2-27-07

110

2-27-07

ID#	[illegible]	Time Interval	Gals Pump	Drum #	Refusal
E-39		8-10	20.0	#34	
(200)		10-12	20.0		
		12-13	70.0		13.0'
			110.0		
E-40		8-10	20.0	#34	
(201)		10-12	60.0		12.0'
			80.0		
D-40		8-10	20.0	#34	
(202)		10-12	60.0		12.0'
			80.0		
C-40		8-10	20.0	#34	
(203)		10-12	60.0		12.0'
			80.0		
B-41		8-10	10.0 ~~20.0~~	#35	
(204)		10-12	70.0		12.0'
			80.0		
A-41		8-10	20.0	#35	
(205)		10-12	60.0		12.0'
			80.0		
C-41 ~~D-41~~		8-10	20.0	#35	
(206)		10-12	60.0		12.0'
			80.0		

Bill Bailey 2-27-07

2-28-07

0700 Conduct H&S meeting. Get equip going.
0740 Set up on D-41.
0755 Set up on D-42.
0810 Set up on E-41.
0825 Set up on E-42.
0845 Set up on B-42.
0905 Set up on A-42.
0915 Set up on B-43.
0930 Set up on C-42.
0945 Set up on D-43. M&W goes for water (#2, already loaded up yesterday).
1020 Set up on E-43.
1040 Set up on D-44.
1055 Set up on C-43
1115 Set up on B-44.
1125 Set up on A-43. Seeping
1135 Set up on C-44.
1150 Set up on D-45. M&W goes for water.
1300 Set up on E-44.
1315 Set up on A-44. Seeping.
1330 Set up on B-45.

ID#	Bore Unit	Inj. Interval	Gals Injected	Drum #	Refusal
D-41	See Table	8-10	20.0	#35	
(207)		10-12	60.0		12.0'
			80.0		
D-42	↓	8-10	20.0	#35	
(208)		10-11	60.0		11.0'
			80.0		
E-41	↓	8-10	15.0	#35	
(209)		10-12	20.0		
		12-13	45.0		13.0'
			80.0		
E-42	↓	8-10	20.0	#35	
(210)		10-11	60.0		11.0'
			80.0		
B-42	↓	8-10	15.0	#35	
(211)		10-12	20.0		
		12-14	45.0		14.0'
			80.0		
A-42	↓	8-10	20.0	#36	
(212)		10-11	60.0		11.0'
			80.0		
B-43	↓	8-10	20.0	#36	
(213)		10-12	60.0		12.0'
			80.0		

B Bailey
2-28-07

2-28-07

ID #	Boss Amt	INJ Interval	Gals Injected	DRUM #	Refusal
C-42	see Tables	8-10	20.0	#36	
(214)		10-11	50.0		11.0'
			70.0		
D-43		8-10	20.0	#36	
(215)		10-12	60.0		12.0'
			80.0		
E-43		8-10	20.0	#36	
(216)		10-12	20.0		
		12-14	20.0		
		14-15	50.0		15.0'
			110.0		
D-44		8-10	20.0	#36	
(217)		10-12	20.0		
		12-13	40.0		13.0'
			80.0		
C-43		8-10	20.0	#36	
(218)		10-12	20.0		
		12-13	40.0		13.0'
			80.0		
B-44		8-10	20.0	#37	
(219)		10-12	60.0		12.0'
			80.0		

Bh 2-28-07

2-28-07

ID #	Boss Amt	INJ Interval	Gals Inj	DRUM #	Refusal
A-43		8-10	20.0	#37	
(220)		10-12	40.0		12.0'
			60.0		Seep
C-44		8-10	20.0	#37	
(221)		10-12	60.0		12.0'
			80.0		
D-45		8-10	20.0	#37	
(222)		10-11	60.0		11.0'
			80.0		
E-44		8-10	20.0	#37	
(223)		10-12	60.0		12.0'
			80.0		
A-44		8-10	0.0	#37	
(224)		10-12	50.0		12.0'
			50.0		Seep
B-45		8-10	20.0	#37	
(225)		10-12	60.0		12.0'
			80.0		
√ C-45		8-10	20.0	#38	
(226)		10-12	60.0		12.0'
			80.0		
A-45		8-10	20.0	#38	
(227)		10-12	60.0		12.0'
			80.0		

2-28-07

1340 Set up on C-45.
1355 Set up on A-45.
1410 Set up on B-46.
1420 Set up on C-46.
1440 Set up on D-46. M&W goes for water.
1515 Set up on E-45
1535 Set up on D-47
1600 Set up on E-46
1610 Set up on A-46
1640 Set up on B-47
1706 Set up on C-47
1720 Set up on D-48
1740 Start shutting down for the day. M&W goes for load of water. Work on deconning rods.

Bill Bailey
2-28-07

2-28-07

ID#	Base Amt	Inj Interval	Gals Inj	Drum #	Refusal
B-46 (228)	See table	8-10	20.0	#38	
		10-11	60.0		11.0'
			80.0		
C-46 (229)	↓	8-10	20.0	#38	
		10-12	20.0		
		12-13	40.0		13.0'
			80.0		
D-46 (230)	↓	8-10	20.0	#38	
		10-12	20.0		
		12-14	20.0		
		14-15	50.0		15.0'
			110.0		
E-45 (231)	↓	8-10	20.0	#38	
		10-12	60.0		12.0'
			80.0		
D-~~47~~ (~~232~~) (232)	↓	8-10	20.0	#38	
		10-12	20.0		
		12-14	20.0		
		14-16	50.0		16.0'
			110.0		

go to page 76

BB 2-28-07

2-28-07

ID#	Boss Ang	INJ Interval	Gals Injected	DRUM #	Refusal
E-46	See Table	8-10	20.0	#39	
(233)		10-12	60.0		12.0'
			80.0		
A-46		8-10	20.0	#39	
~~(233)~~ (234)		10-12	20.0		
		12-14	20.0		
		14-15	40.0		15.0'
			110.0		
B-47		8-10	20.0	#39	
(235)		10-12	60.0		12.0'
			80.0		
C-47		8-10	20.0	#39	
(236)		10-12	20.0		
		12-14	20.0		
		14-15	40.0		15.0'
			100.0		
D-48		8-10	20.0	#39	
(237)		10-12	20.0		
		12-13	40.0		13.0'
			80.0		

Bill Bailey
2-28-07

3-1-07

0700 Conduct H2S Meeting.
0730 Set up on E-47.
0750 Set up on D-49.
0800 Set up on E-48.
0820 Set up on E-49.
0840 Set up on E-50.
0855 Set up on A-47. M&W goes for water. ~~Do~~ Do B-48
0915 Set up on C-48.
1000 Set up on B-49, Seeping
1010 Set up on A-48.
1020 Set up on A-50 Seeping
1035 Set up on A-49, Seeping
1045 Set up on C-49, hole # 250
1115 Complete injection activities. M&W starts decon activities.
1130 Return sign-in sheets and meet with Rick Turner, contact for Dupont Plastics.
1300 Leave site.
1530 Arrive in Knoxville

Bill Bailey
3-1-07

ID #	Boss Amt	Inj Int	Gals Inj	Down #	Refusal
E-47		8-10	20.0	#40	
(238)		10-12	70.0		12.0'
			90.0		
D-49		8-10	20.0	#40	
(239)		10-12	20.0		
		12-13	50.0		13.0'
			90.0		
E-48		8-10	20.0	#40	
(240)		10-12	20.0		
		12-13	50.0		13.0'
			90.0		
E-49		8-10	20.0	#40	
(241)		10-12	20.0		
		12-14	20.0		
		14-16	30.0		16.0'
			90.0		
E-50		8-10	20.0	#41	
(242)		10-12	70.0		12.0'
			90.0		
A-47		8-10	20.0	#41	
(243)		10-12	70.0		
~~B-48~~			90.0		
~~(244)~~					

B Bailey

3-1-07

ID #	Boss Amt	Inj Int	Gals Inj	Down #	Refusal
B-42		8-10	10.0	#41	
(244)		10-11	80.0		11.0'
			90.0		
C-48		8-10	20.0	#41	
(245)		10-12	70.0		12.0'
			90.0		
B-49		8-10	10.0	#42	
(246)		10-12	60.0		12.0'
			70.0		Seep
A-48		8-10	10.0	#42	
(247)		10-12	70.0		12.0'
~~A-50~~		/	80.0		
A-50		8-10	20.0	#42	
(248)		10-12	20.0		12.0'
			40.0		Seep
A-49		8-10	20.0	#42	
(249)		10-12	50.0		12.0'
			70.0		Seep
C-49		8-10	20.0	#42	
250		10-12	20.0		
		12-14	20.0		
		14-15	50.0		15.0
			110.0		

ARCADIS

Appendix C

Non-Hazardous Material Disposal Manifest

SEI
Environmental, Inc.
11054 Terrapin Station Lane
Knoxville, TN 37932

NON-HAZARDOUS MATERIAL DISPOSAL MANIFEST

Manifest Number: **070803**

GENERATOR INFORMATION

Nuclear Fuel Services
1080 S Industrial Dr
Erwin, TN 37650

Contact Person: Bill Baily
Contact Phone: (865)675-6700ext3138

CERTIFICATION: This is to certify the below named waste materials are properly marked, labeled, classified, packaged and described and in the proper condition for transportation in accordance with the applicable regulations of the Department of Transportation.

Bill Bailey for NFS
Generator or Authorized Agent for Generator

3-8-07
Date

NON-HAZARDOUS MATERIAL INFORMATION

Description	Quantity
empty drums	**42**

TRANSPORTER INFORMATION

SEI Environmental
11054 Terrapin Station Lane
Knoxville, Tennessee

Contact Person: Fred Dixon
Contact Phone: (865)765-3130

CERTIFICATION: This is to certify that the above named waste materials were picked-up from the above named Generator and the transportation portion of this manifest is correctly filled out to the best of my knowledge.

Driver Signature ______

Date of Pickup: 3-8-07

DISPOSER INFORMATION

Cash Metals
7826 Old Rutledge Pk.
Knoxville, TN 37924

Contact Person:
Contact Phone: 865-932-1112

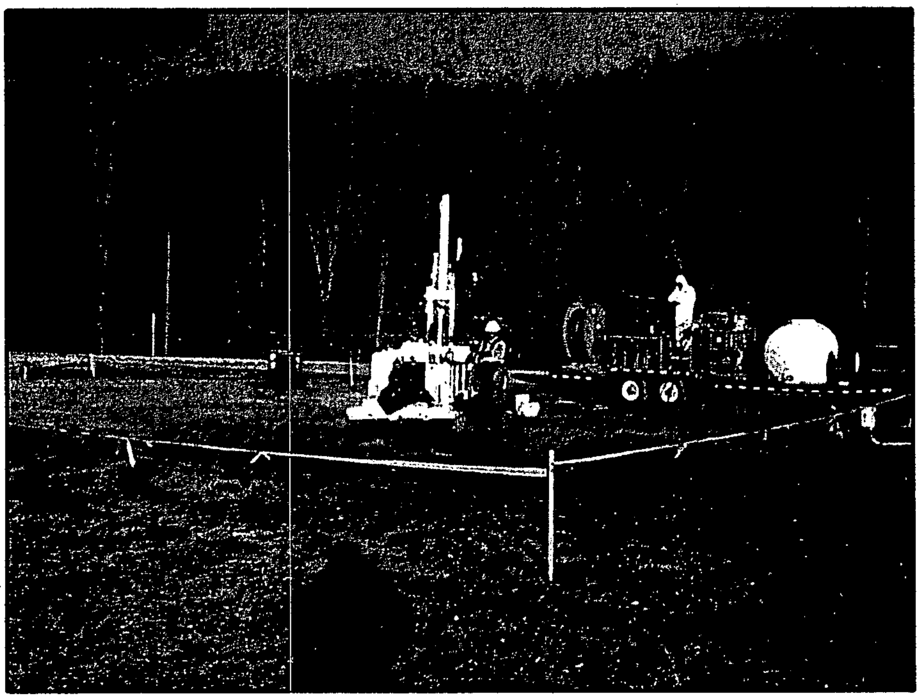
CERTIFICATION: This is to certify that the above named waste material has been received and accepted for disposal in a manner pursuant to all Federal, State and County or Municipal regulations and guidelines to the best of my knowledge.

______
Authorized Agent for Disposer

3/8/07
Date

ARCADIS

Appendix A
Site Photographs
Nuclear Fuel Services, Inc.
Erwin, Tennessee
TNNFS606.BOSS.00002

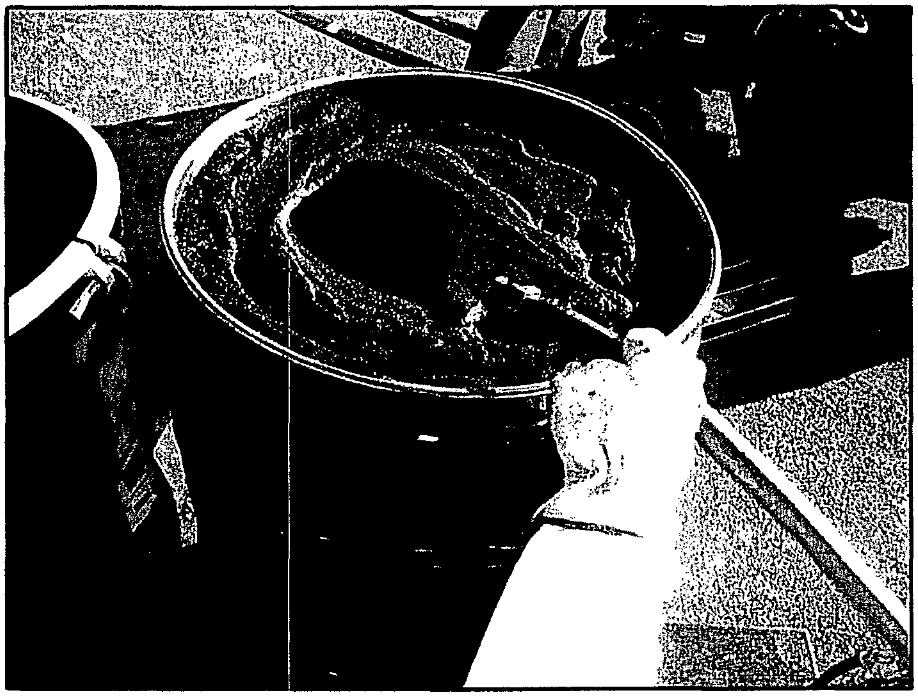


Photograph A-1.
BOS 100® Application –
Injection system and DPT rig.
Photographed February 2007.

Photograph A-2.
BOS 100® Application –
Injection of BOS 100®.
Photographed February 2007.

ARCADIS

Appendix A
Site Photographs
Nuclear Fuel Services, Inc.
Erwin, Tennessee
TNNFS606.BOSS.00002



Photograph A-3.
BOS 100® Application –
55-gallon drum of BOS 100®.
Photographed February 2007.

Photograph A-4.
BOS 100® Application –
Mixing tank.
Photographed February 2007.

ARCADIS

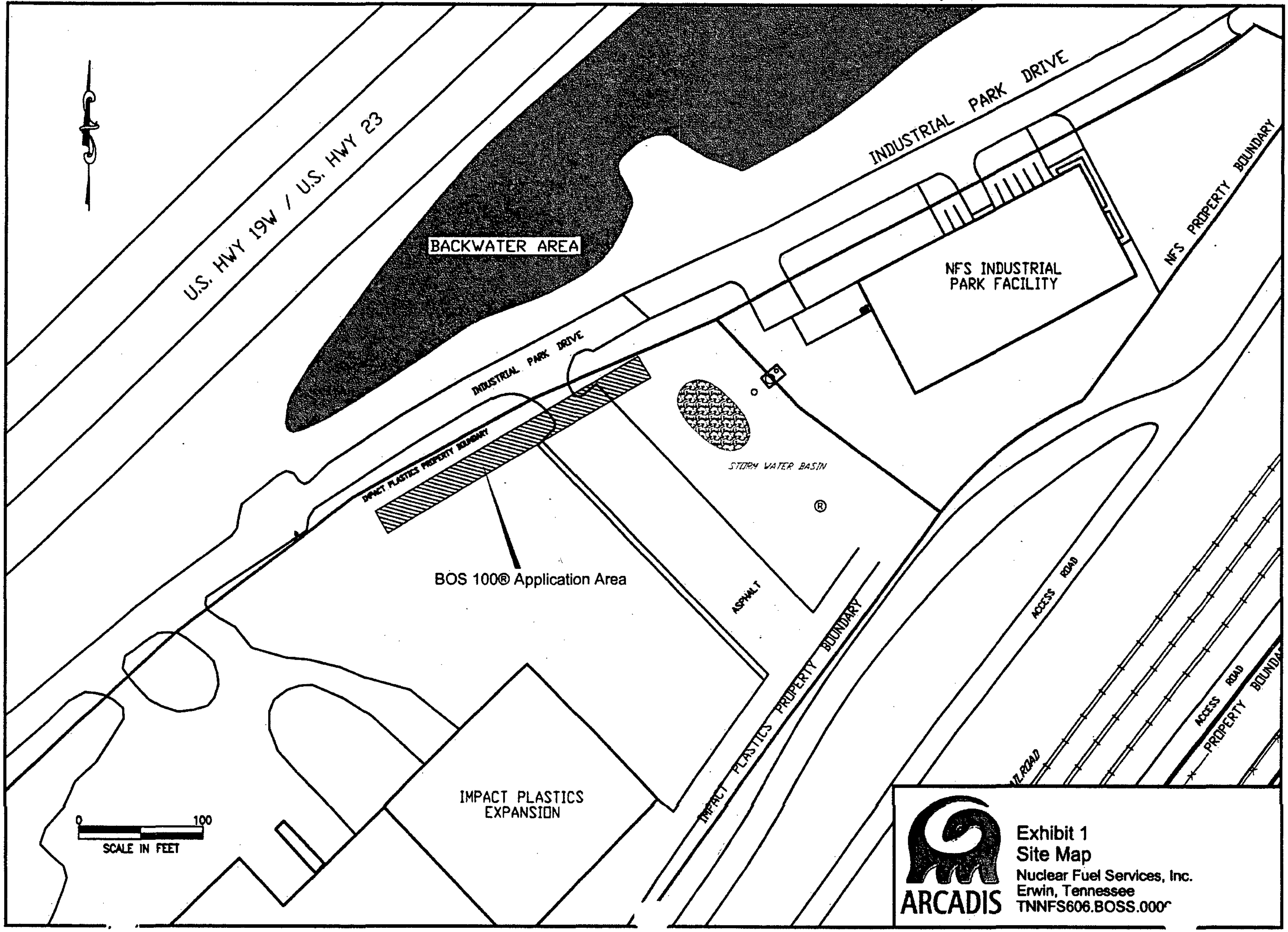
Photograph A-5.
BOS 100® Application –
Grouting of borehole after injection.
Photographed February 2007.

Acad Version : R17.0s (LMS Tech)
User Name : balfom

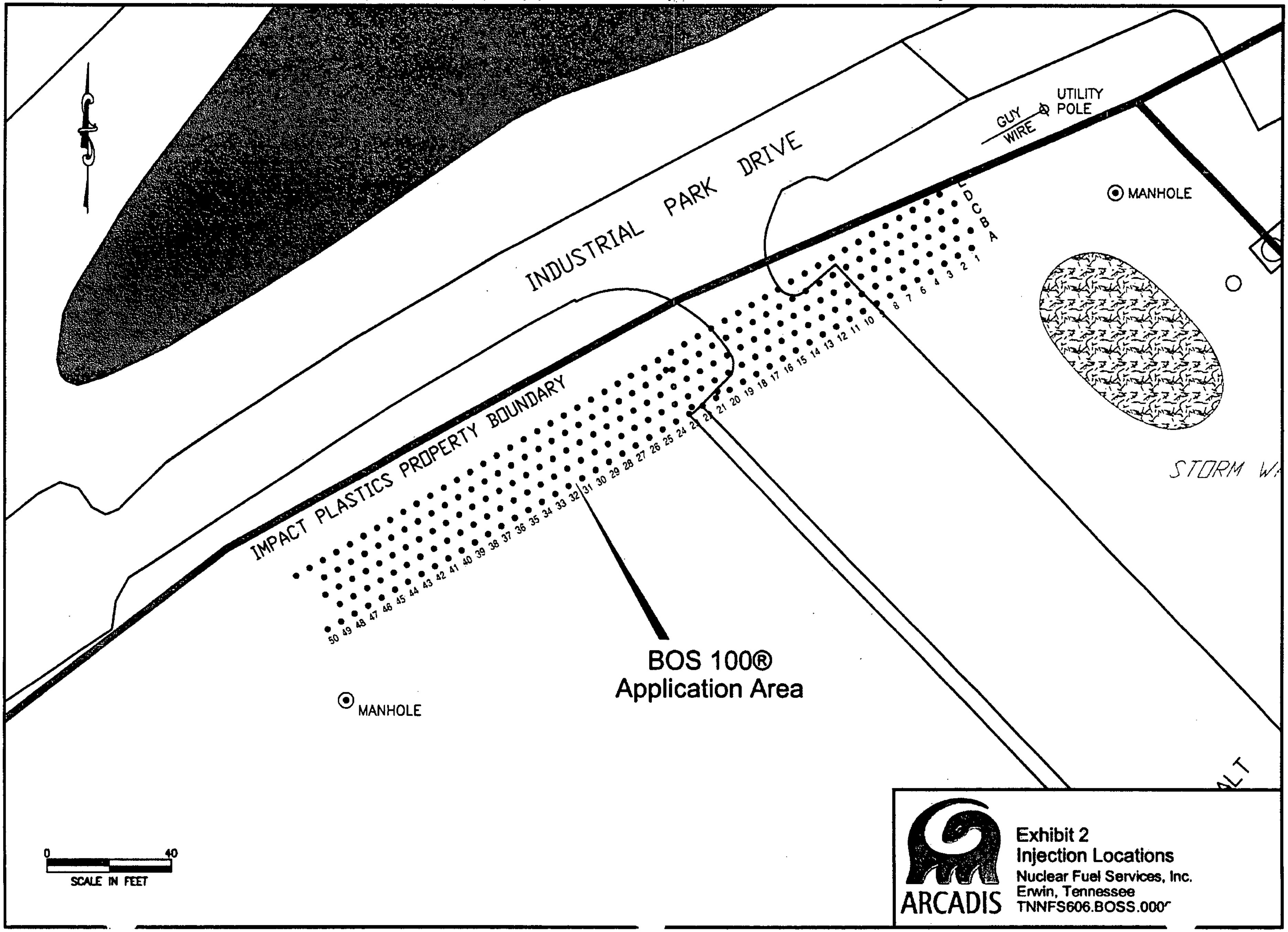
Date\Time : Fri, 30 Mar 2007 - 11:11am
Path\Name : G:\ENV\NFS_Erwin\TNNFS606.BOSS\DLV\0703 BOS 100 Application\BOS100_site.dwg

Current Plotstyle : ByColor
Layout Tab: SITE

Drawing Date: 30MAR2007 Ba



Acad Version : R17.0s (LMS Tech) Date\Time : Fri, 30 Mar 2007 - 11:10am Current Plotstyle : ByColor
User Name : bollom Path\Name : G:\ENV\NFS_Erwin\TNNFS606.BOSS\DLV\0703 BOS 100 Application\BOS100_inj.dwg Layout Tab: SITE Drawing Date: 30MAR2007 Bo



ARCADIS

Exhibit 2
Injection Locations
Nuclear Fuel Services, Inc.
Erwin, Tennessee
TNNFS606.BOSS.000

RAI 7

Attachment 4

2010 Facility Action Plan, January 2010

ORIE

NUCLEAR FUEL SERVICES, INC.
a subsidiary of The Babcock & Wilcox Company

▪ 1205 banner hill road ▪ erwin, tn 37650 ▪ phone 423.743.9141
▪ www.nuclearfuelservices.com

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

21G-10-0008
GOV-05-01-03
ACF-10-0015

January 28, 2010

Mr. Mike Apple
Director, Division of Solid Waste Management
Tennessee Department of Environment & Conservation
Fifth Floor, L&C Tower
401 Church Street
Nashville, Tennessee 37243-1535

References:
1) Permit, Nuclear Fuel Services, Inc., Erwin, Tennessee, EPA ID: TND 00 309 5635, TN Permit No.: TN HW-108, September 30, 2002
2) Letter, Jamie Burroughs to Marie Moore, dated January 10, 2003
3) NFS letter, B.M. Moore to Mr. Mike Apple, TDEC, dated January 16, 2009 (21G-09-0007)

Subject: **FACILITY ACTION PLAN, REVISION 7**

Dear Mr. Apple:

Enclosed is the Nuclear Fuel Services, Inc. (NFS) Facility Action Plan (FAP), Revision 7, as required in References 1 and 2 above. This is the update to the FAP submitted in Reference 3 above. The plan was updated to reflect discussions during the FAP meetings held on June 11, 2009, and December 17, 2009.

If you or your staff have any questions, require additional information, or wish to discuss this, please contact me, or Scott Morie, Decommissioning Environmental Manager at (423) 735-5616. Please reference our unique document identification number (21G-10-0008) in any correspondence concerning this letter.

Sincerely,

NUCLEAR FUEL SERVICES, INC.

B M Moore

B. Marie Moore
Safety & Regulatory

Enclosure
CSM/pj

FACILITY ACTION PLAN

Revision 7

for

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

Prepared for:

Tennessee Department of Environment & Conservation

Prepared by:

Nuclear Fuel Services, Inc.
Erwin, Tennessee

January 2010

Section	Description of Changes
Cover Page	Changed "Revision 6" to "Revision 7."
Cover Page	Changed "2009" to "2010."
Entire Document	Reformatted for consistency.
Table of Contents	Modified Table of Contents to reflect correct pages and dates of this document.
List of Tables	Modified List of Tables and page numbers to reflect this document.
1.3	Added sentence at the end of section stating "Note: Beginning in 2010 the biannual FAP meeting will become an annual FAP meeting as directed by TDEC."
2.2	Changed the groundwater elevation levels to reflect 2009 data.
2.3.1.1.2 2.3.1.2.2 2.3.1.6.2 2.3.3.2	Modified section to reflect activities that occurred in 2009.
3.0	Modified section to reflect planned activities for 2010.

TABLE OF CONTENTS

APPENDIX A

LIST OF TABLES

FACILITY ACTION PLAN

1.0 INTRODUCTION

Nuclear Fuel Services, Inc. (NFS) is a participant in the Facility Action Plan (FAP) process by the Division of Solid Waste Management (DSWM) of the Tennessee Department of Environment and Conservation (TDEC) in order to accelerate corrective action at Resource Conservation and Recovery Act (RCRA) Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs). The FAP is a requirement of this process.

1.1 Purpose

The purpose of this FAP is to meet requirements of condition VI.J.6 of TNHW-108, provide background information on SWMUs and AOCs, provide the status of SWMUs and AOCs, and to outline the planned work.

1.2 Scope

The scope of this FAP is to describe the SWMUs and AOCs identified in TNHW-108. The FAP will be updated annually. Any newly identified SWMUs and/or AOCs will be added to the FAP, and their regulatory requirements and plan of action will be identified and described.

1.3 Objective

The objectives of this FAP are as follows:

1) describe each SWMU and AOC;
2) describe the regulatory requirement;
3) describe the planned activity associated with them;
4) Incorporate comments and agreed upon plan of action resulting from NFS discussions with TDEC during the biannual FAP meeting. Note: Beginning in 2010 the biannual FAP meeting will become an annual FAP meeting as directed by TDEC.

2.0 SITE DESCRIPTION

2.1 Facility Background

The NFS Facility is located in northeast Tennessee within the city limits of the Town of Erwin in Unicoi County. The property consists of approximately 70 acres of land. The site is bordered on the south and east by Banner Hill road and private residences. The CSX Railroad right-of-way parallels the site boundary on the northwest. An industrial park is located northwest of the railroad in which property is owned by NFS (NFS IPF), CSX Railroad, and Impact Plastics, Inc. Martin Creek bounds the site to the northeast, with privately owned and vacant low density residential land on the opposite side of the creek.

No water supply wells are located between NFS and the Nolichucky River. The closest municipal well to the NFS site is the Erwin Utility Railroad Well. Groundwater withdrawn from the Railroad Well does not originate beneath or downgradient from the NFS site (Geraghty and Miller 1996).

2.2 Site Hydrogeology

The NFS site is located in the alluvial valley of the Nolichucky River. The site is underlain by 0 to 30 feet of unconsolidated alluvium consisting of silts and clays, clayey sand, and sand with varying amounts of gravel and cobble. The alluvium coarsens with depth into cobbles and boulders. This cobble/boulder zone overlies weathered, fractured, bedrock consisting of steeply dipping beds of shale or shale interbedded with dolomite and siltstone (EcoTek 1994).

Both the alluvium and shallow bedrock contain groundwater under unconfined conditions. No laterally continuous physical separation exists between the two lithologies. Recharge to the alluvium and shallow bedrock is predominantly from downward infiltration of rainwater through the vadose zone. Some upward component of flow is evident within the deeper bedrock (50+ feet), which is probably the result of higher elevation recharge through fracture systems in the mountains to the southeast. Measured heads in the bedrock wells are consistent with and indicative of a nonfractured dominated flow regime. The thinly bedded, poorly competent nature of the bedrock may contribute to flow patterns more analogous to the porous media model than the fracture flow model. Limited evidence, such as high well yields, exists for structure or fracture controlled movement of groundwater in the deeper zone (EcoTek 1994).

Groundwater flow is generally towards the north-northwest. Groundwater elevations ranged from approximately 1618 to 1636 feet above mean sea level during 2009.

A more detailed description of the site hydrogeology can be found in the "Revised Groundwater Flow and Solute-Transport Modeling Report," February 1999 (ARCADIS 1999).

2.3 SWMUs and AOCs/Requirements

The twenty-four (24) SWMUs and seven (7) AOCs are described in Table A-1 (Appendix A). The SWMU and AOC requirements consist of interim measures, institutional controls, groundwater remediation under AOC groundwater, and no further action required. The SWMUs and AOCs have been grouped according to their applicable requirements for discussion purposes.

2.3.1 SWMUs and AOCs Requiring Interim Measures

2.3.1.1 SWMU 1 – Impoundments 1, 2, and 3

2.3.1.1.1 Site Description –

SWMU 1 is located northeast of plant production facilities and consists of Impoundments 1, 2, and 3. The impoundments were constructed between 1957 and 1963 to retain process wastewater generated from operations associated with the production of nuclear materials. The unlined impoundments were excavated to depths of approximately four feet and enclosed by low earthen berms. The impoundments were used from the beginning of plant operations in 1957 through 1978. In 1978, use of the impoundments ceased concurrent with the start-up of the NFS wastewater treatment plant.

The three impoundments contained approximately 91,000 cubic feet of waste material. Predominant radiological contaminants in waste were isotopes of uranium and thorium. RCRA hazardous constituents detected in waste samples prepared by the Toxicity Characteristic Leaching Procedure (TCLP) included tetrachloroethylene, trichloroethylene, barium, cadmium, chromium, and lead. Waste from Pond 2 was characteristically hazardous for tetrachloroethylene and cadmium. The potentially affected media include air, soil, surface water, and groundwater.

Waste removal and processing began in August 1991 at Pond 3. Wastes were removed as a slurry by dredge, pumped to mixing tanks, treated for hazardous constituents and dewatered using a filter press. The filter cake was disposed of as low-level radioactive waste at a licensed burial facility. Waste removal from Ponds 1, 2, and 3 was completed in September 1993, August 1994, and May 1994, respectively.

2.3.1.1.2 Proposed Plan –

Soil removal is complete for this SWMU. Effectiveness sampling is complete for this SWMU. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis for this SWMU. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A. Results show that all samples are below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil.

2.3.1.2 SWMU 2 – Pond 4

2.3.1.2.1 Site Description –

SWMU 2 (i.e. "Pond 4") was used for waste storage and disposal from approximately 1957 to 1966. Waste materials consisting of press cake, incinerator ash, sludges, drums, buckets, conduit, pipes, old equipment and general trash were placed in the area and covered with soil. Building 410 was constructed over this area and the waste debris has been removed. The potentially affected media include soil, surface water, and groundwater. Excavation of the Pond 4 debris began in August 1994 and was completed in December 1996. The remaining contaminated soil will be excavated.

2.3.1.2.2 Proposed Plan –

Soil removal and effectiveness sampling is complete for a portion of the SWMU. Additional soil removal and effectiveness sampling is planned. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A. Results show that one area requires additional removal and effectiveness sampling to get below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil.

2.3.1.3 SWMU 3 – Building 110 Complex Underground Storage Tank (UST)

2.3.1.3.1 Site Description –

SWMU 3 is the Underground Storage Tank (UST) at the Building 110 Complex. Building 110C was used as a wet chemistry support laboratory. The underground storage tank (UST), a 55-gallon stainless steel drum (2 feet diameter), was located approximately eight feet north of Building 110C and 18 inches below ground level. According to site personnel, the UST was used in the 1960s for managing laboratory waste, including effluent from glove box drains. The potentially affected media in this area include soil and groundwater.

2.3.1.3.2 Proposed Plan –

SWMU 3 is located within the Building 410 area (SWMU 2). Therefore, the proposed plan for SWMU 3 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.4 SWMU 4 – Yard Incinerator

2.3.1.4.1 Site Description –

SWMU 4 is an incinerator, which was located within the boundaries of SWMU 2. The incinerator was used to incinerate office waste from 1970 to 1990. The potentially affected media in this area include air, soil, and surface water.

2.3.1.4.2 Proposed Plan –

SWMU 4 is located in the Building 410 area (SWMU 2). Therefore, the proposed plan for SWMU 4 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.5 SWMU 6 – Abandoned Banner Spring Branch (BSB) Stream Channel

2.3.1.5.1 Site Description –

SWMU 6, the abandoned channel of Banner Spring Branch, is located within the boundaries of SWMU 2. SWMU 6 received supernate from three surface impoundments (SWMU 1) from approximately 1957 to 1968. The potentially affected media in this area include soil and groundwater.

2.3.1.5.2 Proposed Plan –

SWMU 6 is located within the boundaries of SWMU 2. Therefore, the proposed plan for SWMU 6 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.6 SWMU 7 – Soil Stockpile

2.3.1.6.1 Site Description –

SWMU 7 was a mound of soil contaminated with low levels of uranium, thorium and plutonium. From 1957 to 1977, process wastes containing low-level concentrations of uranium and thorium were discharged to three NFS surface impoundments. Banner Spring Branch received supernatant from these impoundments resulting in contamination of stream sediments. In 1967, the channel of Banner Spring Branch was relocated to divert stream flow into Martin Creek approximately 200 feet upstream from its previous confluence. Contaminated soils from the former streambed were excavated between 1980 and 1984 and stored in the location, which is SMWU 7. Potentially affected media include soil and surface water.

The soil stockpile has been removed and contaminated soils were disposed of at a licensed radioactive burial facility.

2.3.1.6.2 Proposed Plan –

The soil pile has been removed. Soil removal and effectiveness sampling is complete. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A. Preliminary results indicate all samples are below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil.

2.3.1.7 SWMU 9 – Radiological Burial Ground (RBG) Trenches

2.3.1.7.1 Site Description –

SWMU 9 is the Radiological Burial Ground. Between 1966 and 1977, NFS disposed of low-level radioactive waste by on-site shallow land burial in accordance with NRC regulations (10 CFR 20.304). Waste materials predominantly consisted of contaminated equipment, construction debris, laboratory waste, and process waste (e.g., filter "press cake"). Radionuclides contained in the waste primarily consisted of low-level thorium and uranium, with enrichments ranging from depleted to 97 percent; however, records indicate small amounts of Plutonium-239 and Uranium-233 in trench 69-6. The total radioactive inventory from all of the burial trenches within SWMU 9 is estimated as slightly greater than 800 mCi. Radionuclides of importance are Thorium-232 (892 kg), Uranium-238 (275 kg), and Uranium-235 (11.5 kg). Liquid wastes and small amounts of waste mercury were also buried in several of the trenches. Potentially affected media include soil and groundwater.

2.3.1.7.2 Proposed Plan –

Soil removal has been completed and effectiveness sampling is planned. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.8 AOC 5 – BSB Stream Channel

2.3.1.8.1 Site Description –

AOC 5 is located northeast of plant production facilities. The channel of Banner Spring Branch from approximately 1967 to 2003 is designated as AOC 5. In September 2003 the channel of Banner Spring Branch was relocated by burying it in a culvert from its source to Martin Creek. Banner Spring Branch has no known unregulated releases; however, it was a potential receptor of pond overflow because of its location between the surface impoundments. Potentially affected media consist of surface water.

2.3.1.8.2 Proposed Plan –

Relocation of Banner Spring Branch was completed in September 2003. A portion of the excavation of the channel and a portion of the effectiveness sampling is complete. More excavation and effectiveness sampling is planned. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.2 SWMUs and AOCs Requiring Institutional Controls

2.3.2.1 SWMU 13 – Building 111 Bulk Chemical Storage Area

2.3.2.1.1 Site Description –

The Bulk Chemical Storage Area at Building 111 (SWMU 13) was used to store process chemical products from initial operations in 1957 until March 1992. In 1992, tanks were relocated to the Bulk Chemical Storage Area at the southwest portion of the plant's protected area. The storage tank and dike have been removed. Potentially affected media in this area include soil, surface water, and groundwater.

2.3.2.1.2 Proposed Plan –

Institutional controls consisting of concrete to cover the soil in the area have been implemented. Inspection of concrete occurs annually to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.2 SWMU 15 – Waste Water Treatment Facility (WWTF)

2.3.2.2.1 Site Description –

SWMU 15 is the WWTF. It has been in operation since 1975. There is no potentially affected media for this area.

2.3.2.2.2 Proposed Plan –

Institutional controls consisting of concrete (building floor) to cover the soil in the area are required. Inspection of the concrete floor occurs annually to ensure its integrity. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.3 SWMU 16 – Radiological Incinerator

2.3.2.3.1 Site Description –

SWMU 16 is the Radiological Incinerator at Building 302. The incinerator was operated from 1975 to April 1996 under an approved State of Tennessee Air Pollution Control Operating Permit.

The main purpose of the incinerator was to facilitate recovery of uranium from combustible materials. After incineration, ash was transferred to NFS' High Enriched Uranium Recovery Facility for uranium recovery. The incinerator was also used to reduce the volume of low-level combustible materials prior to disposal at a licensed radioactive waste disposal facility. Potentially affected media include air and soil.

2.3.2.3.2 Proposed Plan –

Institutional controls consisting of controlled access and concrete (building floor) to contain any potential contamination is in place. The concrete floor is inspected annually to ensure the integrity of the concrete floor. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.4 SWMU 20 – Building 130 Scale Pit

2.3.2.4.1 Site Description –

SWMU 20 is the Building 130 Scale Pit. The scale pit was constructed in the late 1950s. This structure was one of the first on site and was probably constructed concurrently with Building 130. The scales were used primarily for weighing cylinders containing uranium hexaflouride.

The exact dates of operation of the scale could not be determined since records of its use are not available; however, it is believed to have been utilized in the 1960s. The affected media include soil and groundwater.

2.3.2.4.2 Proposed Plan –

Institutional controls consisting of concrete to cover the soil in the area have been implemented. Inspection of concrete occurs annually to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.5 SWMU 21 - 30,000 Gallon Diesel Above Ground Storage Tank (AST)

2.3.2.5.1 Site Description –

SWMU 21 is the 30,000-gallon above ground storage tank. SWMU 21 is located in the western portion of the NFS site. SWMU 21 was used for diesel fuel (No. 2 fuel oil) storage from the mid 1970's to 1998. The fuel in the tank was used for heating purposes during winter months. The tank was last used in 1998 and at that time the contents were pumped out of the tank and into appropriate storage containers. There have not been any documented releases from the tank. The tank was removed in October 2001. Potentially affected media include soil and groundwater.

2.3.2.5.2 Proposed Plan –

Institutional controls consisting of gravel to cover the soil in the area have been implemented. Inspection of gravel occurs quarterly to ensure no soil is exposed. The area has been built up with approximately 4 feet of gravel and a new building has been constructed at this location. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.6 SWMU 25 - Underground Pipe on the West Side of Building 111

2.3.2.6.1 Site Description –

SWMU 25 is the underground pipe on the west side of Building 111. The pipe was installed in 1959, concurrently with the construction of Building 111, the first structure built on the site. The ten inch pipe was used primarily for plant drainage and its use was discontinued in 1984 when the new plant drainage was installed. In October 2007, NFS was performing excavation activities immediately west of Building 111 to enhance the institutional control requirement for SWMU 13 from gravel to concrete. During this excavation, a ten inch drainage pipe was located within this area on the west side of Building 111. The pipe was located approximately 21 feet from Building 111 and was approximately 3 feet deep. The pipe within the excavated area was removed along with the excavated soil. Potentially affected media include soil and groundwater.

2.3.2.6.2 Proposed Plan –

Institutional controls consisting of gravel, asphalt, and concrete to cover the soil in the area have been implemented. Inspection of the area occurs quarterly to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. NFS plans to conduct further characterization to determine the extent of PCB contamination in soil and to determine the source of contamination to soil and groundwater. Once characterization is complete, follow-up actions will be proposed and implemented. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.7 AOC 2 – Building 111 Boiler Blowdown and Backwash Water

2.3.2.7.1 Site Description –

AOC 2 is the location previously occupied by three boilers, which provided heat and heat tracing for the NFS facility from 1958 until 1991. Boilers #1 and #2, located in the east corner of Building 111, were installed in 1958 and 1962, respectively. The third boiler located in the southeast end of Building 111 was installed in 1977. In July 1991, boilers #1 and #2 were shut down and removed from the plant; boiler #3 was relocated to Building 130. AOC 2, the "unit," as it refers to AOC 2, is blowdown from the three boilers, and backwash (and regeneration water) from the water purification system deionizers and softeners. Potentially affected media includes soil.

2.3.2.7.2 Proposed Plan –

Institutional controls consisting of pavement to cover the soil in the area and posting of signs stating that the area is potentially contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. Soil removal and effectiveness sampling is planned at the end of plant life.

2.3.2.8 AOC 3 – Building 130 Cooling Tower

2.3.2.8.1 Site Description –

AOC 3 is the Cooling Water Tower at Building 130. The purpose of the Cooling Water Tower was to provide a means of storing, cooling, and recirculating non-contact plant process water. The Cooling Water Tower supported operations conducted in numerous buildings at NFS from 1957 to 1992. Its use during that time was continuous, with demand increasing or decreasing depending upon the type of work NFS had under contract. From 1958 until 1968, the Cooling

Water Tower reservoir also served as a heat exchanger for a submerged recirculating coil containing tetrachloroethylene, which was used in vacuum furnace operations in the 130 Building. Potentially affected media include soil and surface water.

2.3.2.8.2 Proposed Plan –

Institutional controls consisting of pavement to cover the soil in the area have been implemented. Inspection of pavement occurs annually to ensure no soil is exposed. Soil removal and effectiveness sampling is planned at the end of plant life.

2.3.2.9 AOC 4 – Storm Drainage System

2.3.2.9.1 Site Description –

AOC 4, the storm drainage system, has been operating in various capacities since the plant was built in 1957. The system, which was developed to provide directed flow of storm water throughout the plant, was expanded in 1984 with minor modifications subsequent to that time. Potentially affected media include soil, surface water, and groundwater.

2.3.2.9.2 Proposed Plan –

Institutional controls consisting of pavement to cover the soil in the area and posting of signs stating that the area is potentially contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal action and effectiveness sampling are planned at the end of plant life.

2.3.2.10 AOC 6 – Building 220 Mercury Contaminated Soil

2.3.2.10.1 Site Description –

AOC 6 is an area of mercury-contaminated soil located immediately northeast of Building 220. It is an area approximately 55 by 27 feet covered with soil and gravel. A concrete slab is present in some areas of the site at a depth of approximately 0.5 feet beneath the soil. AOC 6 is surrounded by asphalt pavement to the northeast, southeast, and northwest, and Building 220 to the southwest. Potentially affected media includes soil.

2.3.2.10.2 Proposed Plan -

Institutional controls consisting of gravel to cover the soil in the area and posting of signs stating that the area is potentially mercury contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. The gravel has been upgraded to pavement as an enhancement in this area. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.3 AOC GW

2.3.3.1 Site Description –

AOC GW is site wide groundwater. AOC GW is a combination of SWMUs and AOCs that require corrective measures for groundwater. AOC GW is a consolidation of SWMUs 1, 2, 3, 6, 9, 10, 14, 18, 20, and 21 and AOCs 4, 5, and 6.

2.3.3.2 Proposed Plan –

Groundwater will be sampled routinely for tetrachloroethylene, trichloroethylene, dichloroethylene, and vinyl chloride, gross alpha and gross beta activity. If the gross alpha activity exceeds 15 picoCuries per Liter (pCi/L), then at a minimum, isotopic analysis for uranium will be performed. If gross beta activity exceeds 50 pCi/L, then analysis for technetium-99 will be performed.

Groundwater remediation is in progress at the Maintenance Shop area and is planned to continue through 2010. The automated injection system was completed in 2009 for injecting a higher volume of reagent in the area between the fences.

Groundwater monitoring will continue at the plant site after source term removal. Results from groundwater monitoring will be used to determine appropriate remedial actions.

Off site Well 122A (TDOT Well) was sampled on a semi-annual basis. The most recent results for Well 122A showed PCE detections below the drinking water MCL.

The Nolichucky River Backwater Area was sampled at three locations on a semi-annual basis. The most recent results show that two of the three locations are above the maximum contaminant level (MCL). These two areas are posted with a sign indicating that the water is not a potable drinking water source in accordance with the TDEC Environmental Indicator Memorandum (TDEC, 2004).

In February 2007, NFS implemented the BOS 100 technology on a one time injection at approximately 250 locations just upgradient of the backwater area using direct-push technology. BOS 100 is a reagent that consists of nanoscale iron coated with carbon that can be injected into the subsurface using direct-push technology and a variety of pumping systems to create a reactive curtain to treat chlorinated solvent contaminated groundwater via reductive dechlorination.

2.3.4 SWMUs and AOCs Requiring No Further Action at this Time

2.3.4.1 SWMU 8 – CSX Soil Excavation Site

2.3.4.1.1 Site Description –

SWMU 8 is located along the northwestern boundary of the NFS plant site. SWMU 8, the soil excavation site on CSX property, designates a portion of the former channel of Banner Spring Branch. The former streambed was contaminated with isotopes of uranium and thorium classified as Low Specific Activity material. Contamination resulted from the discharge of supernate to Banner Spring Branch from three surface impoundments (SWMU 1). SWMU 8 was active from approximately 1957 to 1967. In 1967, the stream was rerouted to its present location. Contaminated soils comprising the area were excavated and stockpiled on NFS property during the early 1980s (SWMU 7). The excavated area was released by the NRC for unrestricted use in July 1987. Potentially affected media was groundwater.

2.3.4.1.2 Proposed Plan –

TDEC and the EPA have closed out this SWMU in a letter dated January 19, 1994. No further action is required.

2.3.4.2 SWMU 10 – Demolition Landfill

2.3.4.2.1 Site Description –

SWMU 10 is the former Demolition Landfill. Between 1981 and 1984, NFS disposed of nonradioactive and nonhazardous waste by on-site shallow land burial into the Demolition Landfill. No disposal records exist for SWMU 10; however, plant personnel and previous investigations have identified that the landfill was primarily used for disposal of construction debris. Potentially affected media include soil and groundwater.

2.3.4.2.2 Proposed Plan –

TDEC approved No Further Action (NFA) for SWMU 10 in August 2004, therefore, no additional measures are required.

2.3.4.3 SWMU 11 – CSX Burial Trenches

2.3.4.3.1 Site Description –

SWMU 11, the CSX burial trenches were located along the northwestern boundary of the NFS plant site. SWMU 11 was located on land leased from CSX and consists of two trenches located within 50 feet west of, and roughly parallel to, NFS buildings 300 and 310. Each trench measured about 18 feet wide by 275 feet long, with less than ten feet separation between the two trenches. Maximum trench depth was approximately 10 feet in predominantly alluvial materials. Burial trench contents consisted of low-level uranium and thorium contaminated scrap metals and equipment. Excavation of the trenches was completed in June 2000. Potentially affected media includes groundwater.

2.3.4.3.2 Proposed Plan –

TDEC and the EPA have closed out this SWMU in a letter dated January 19, 1994. No further action is required.

2.3.4.4 SWMU 12 – Permitted Hazardous Waste Management Storage Area

2.3.4.4.1 Site Description –

SWMU 12 is a permitted hazardous waste management storage area (HW Unit) located in the 310 Warehouse (Permit Number TN HW-066). It is a RCRA storage unit for liquid and non-liquid wastes. It has been in operation since 1989. It is covered, enclosed, and is an access controlled space. There is no potentially affected media.

2.3.4.4.2 Proposed Plan –

No further action is required.

2.3.4.5 SWMU 14 – Light Non-Aqueous Phase Liquid (LNAPL)

2.3.4.5.1 Site Description –

SWMU 14, the LNAPL, is located in the northwestern part of the NFS plant site, northwest of Building 111, and northeast of Building 120. Potentially affected media is groundwater.

2.3.4.5.2 Proposed Plan –

The remediation of this groundwater will occur as part of AOC GW. No further action is required.

2.3.4.6 SWMU 17 – Scrap-Recovery Incinerator

2.3.4.6.1 Site Description –

SWMU 17 was a scrap-recovery incinerator. It was removed as part of Decommissioning activities in Building 200. There is no potentially affected media.

2.3.4.6.2 Proposed Plan –

No further action is required.

2.3.4.7 SWMU 18 – Building 105 UST

2.3.4.7.1 Site Description –

SWMU 18 was a 1,000 gallon UST located at Building 105. It was in operation from the late 1960s until the mid 1970s. The tank was removed in May 1991. Potentially affected media include soil and groundwater.

2.3.4.7.2 Proposed Plan –

No further action is required.

2.3.4.8 SWMU 19 – Building 100 UST

2.3.4.8.1 Site Description –

SWMU 19 was a 1,000 gallon number 2 fuel oil UST located at Building 100. It was in operation from the late 1960s until the mid 1970s. The tank was removed in November 1991. Potentially affected media include soil and groundwater.

2.3.4.8.2 Proposed Plan –

No further action is required.

2.3.4.9 SWMUs 22, 23, and 24 – Building 304 Hazardous Waste Unit

2.3.4.9.1 Site Description –

SWMUs 22, 23, and 24 are permitted Hazardous Waste units at the west end of Building 304 (Permit Number TN HW-108). Although permitted, they are not currently in use. SWMU 22 is the RCRA storage unit for mercury mixed wastes. SWMU 23 is the RCRA treatment unit for mercury mixed wastes. SWMU 24 is the RCRA miscellaneous unit (shredder) unit for mercury mixed wastes. There are no potentially affected media from these units.

2.3.4.9.2 Proposed Plan –

No further action is required. NFS began removing this equipment in accordance with permit on November 22, 2004 and the closure report was submitted to TDEC on April 7, 2005.

2.3.4.10 AOC 1 – Plant Scrubbers

2.3.4.10.1 Site Description –

AOC 1 consists of high-efficiency venturi demisting plant scrubbers that are currently in use. There is no potentially affected media in these areas.

2.3.4.10.2 Proposed Plan –

No further action is required.

3.0 PROPOSED SCHEDULE FOR 2010

Activities planned for 2010 consist of:

1) Soil removal and effectiveness sampling for SWMUs 2, 6, 9, and AOC 5 may occur.
2) Quarterly inspections of SWMUs 13, 21, and AOCs 2, 4, and 6;
3) Annual inspections of SWMUs 15, 16, 20, 25, and AOC 3; and
4) Continuation of the full-scale in-situ reactive zone (IRZ®) technology for groundwater remediation near the maintenance shop area.
5) Continue with the full-scale Ferrous Sulfate injections in the groundwater remediation area.
6) Continue sampling surface water in the backwater area at 3 locations and continue sampling Well 122A as part of the semi-annual off site sampling program.
7) Continue with groundwater monitoring on and off site.
8) Continue using the automated zone.
9) Conduct further characterization activities for SWMU 25.

4.0 REFERENCES

ARCADIS Geraghty & Miller, Inc., 1999. Revised Groundwater Flow and Solute-Transport Modeling Report. Nuclear Fuel Services, Inc./Erwin, Tennessee. February 1999.

Ecotek, Inc., 1994. 1992/1993 Nuclear Fuel Services Hydrogeologic Investigation and Monitoring Well Installation Program. June 1994.

Geraghty & Miller, Inc., 1996. Railroad well Capture Zone Analysis near the Nuclear Fuel Services Facility. Erwin, Tennessee. June 14, 1996.

Tennessee Department of Environment and Conservation (TDEC), Division of Solid Waste Management, Environmental Indicator Evaluation Memorandum Letter, Roger Donovan to B. Marie Moore. November 19, 2004.

Table A-1. Table of SWMUs and AOCs

SWMU /AOC	Description	Status
SWMU 1	Impoundments 1, 2, and 3	Interim Measures
SWMU 2	Pond 4	Interim Measures
SWMU 3	Building 110 Complex Underground Storage Tank	Interim Measures
SWMU 4	Yard Incinerator	Interim Measures
SWMU 6	Abandoned Banner Spring Branch Stream Channel	Interim Measures
SWMU 7	Soil Stock Pile	Interim Measures
SWMU 8	CSX Soil Excavation Site	No Further Action
SWMU 9	Radiological Burial Ground Trenches	Interim Measures
SWMU 10	Demolition Landfill	No Further Action
SWMU 11	CSX Burial Trenches	No Further Action
SWMU 12	Permitted Hazardous Waste Management Area	No Further Action
SWMU 13	Building 111 Bulk Chemical Storage Area	Institutional Controls
SWMU 14	Light Non-Aqueous Phase Liquid	No Further Action
SWMU 15	Waste Water Treatment Facility	Institutional Controls
SWMU 16	Radiological Incinerator	Institutional Controls
SWMU 17	Scrap Recovery Incinerator	No Further Action
SWMU 18	Building 105 Underground Storage Tank	No Further Action
SWMU 19	Building 100 Underground Storage Tank	No Further Action
SWMU 20	Building 130 Scale Pit	Institutional Controls
SWMU 21	30,000 gallon Diesel Above Ground Storage Tank	Institutional Controls
SWMU 22	Building 304 Hazardous Waste Unit	No Further Action
SWMU 23	Building 304 Hazardous Waste Unit	No Further Action
SWMU 24	Building 304 Hazardous Waste Unit	No Further Action
SWMU 25	Underground Pipe on the West Side of Building 111	Institutional Controls
AOC 1	Plant Scrubbers	No Further Action
AOC 2	Building 111 1,000 Gallon Tank	Institutional Controls
AOC 3	Building 130 Cooling Tower	Institutional Controls
AOC 4	Storm Drainage System	Institutional Controls
AOC 5	Banner Spring Branch Channel	Interim Measures
AOC 6	Building 220 Mercury Contaminated Soil	Institutional Controls
AOC Groundwater	Site Wide Groundwater	Groundwater Remediation under AOC GW

Table A-2. Regional Screening Levels for Chemical Contaminants at Superfund Sites

Contaminant	Residential Soil (mg/kg)	Industrial Soil (mg/kg)
Arochlor-1254	0.22	0.74
Arsenic*	22	22
Benzene	1.1	5.6
Benz (a) anthracene	0.15	2.1
Benzo (a) pyrene	0.015	0.21
Benzo (b) fluoranthene	0.15	2.1
Benzo (k) fluoranthene	1.5	2.1
Beryllium	160	2000
Bis (2-ethylhexyl) phthalate (DEHP)	35	120
Carbon tetrachloride	0.25	1.3
Chromium VI	230	1400
Dibenz (ah) anthracene	0.015	0.21
Indeno (1,2,3-cd) pyrene	0.15	2.1
Mercury	23	310
Tetrachloroethylene (PCE)	0.57	2.7
Trichloroethylene (TCE)	2.8	140
Vinyl chloride (VC)	0.060	1.7

* - Negotiated level with TDEC during FAP workshop meeting on March 18, 2003 and follow up letter April 23, 2003 (21G-03-0109)

RAI 7

Attachment 5

2009 Facility Action Plan, January 2009

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	CEA	

Nuclear Fuel Services, Inc.

1205 Banner Hill Road
Erwin, TN 37650
(423) 743-9141

CERTIFIED MAIL
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21G-09-0007
GOV-05-01-03
ACF-09-0006

January 16, 2009

Mr. Mike Apple
Director, Division of Solid Waste Management
Tennessee Department of Environment & Conservation
Fifth Floor, L&C Tower
401 Church Street
Nashville, Tennessee 37243-1535

References:
1) Permit, Nuclear Fuel Services, Inc., Erwin, Tennessee, EPA ID: TND 00 309 5635, TN Permit No.: TN HW-108, September 30, 2002
2) Letter, Jamie Burroughs to Marie Moore, dated January 10, 2003
3) NFS letter, B.M. Moore to Mr. Mike Apple, TDEC, dated February 9, 2007 (21G-07-0004)

Subject: **FACILITY ACTION PLAN, REVISION 6**

Dear Mr. Apple:

Enclosed is the Nuclear Fuel Services, Inc. (NFS) Facility Action Plan (FAP), Revision 6, as required in References 1 and 2 above. This is the update to the FAP submitted in Reference 3 above. The plan was updated to reflect discussions during the FAP meetings held on July 10, 2008 and December 11, 2008.

If you or your staff have any questions, require additional information, or wish to discuss this, please contact me, or Scott Morie, Decommissioning Environmental Manager at (423) 735-5616. Please reference our unique document identification number (21G-09-0007) in any correspondence concerning this letter.

Sincerely,

NUCLEAR FUEL SERVICES, INC.

B. Marie Moore
Director of Safety & Regulatory

Enclosure

FACILITY ACTION PLAN

Revision 6

for

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

Prepared for:

Tennessee Department of Environment & Conservation

Prepared by:

Nuclear Fuel Services, Inc.
Erwin, Tennessee

January 2009

Section	Description of Changes
Cover Page	Changed "Revision 5" to "Revision 6."
Cover Page	Changed "2008" to "2009."
Table of Contents	Modified Table of Contents to reflect correct pages and dates of this document.
List of Tables	Modified List of Tables and page numbers to reflect this document.
2.3	Modified the number of SWMUs to make it up to date.
2.3.1.1.2	Modified section to reflect activities that occurred in 2008. Changed confirmatory to effectiveness.
2.3.1.2.2	Modified section to reflect activities that occurred in 2008 and that are planned for 2009. Changed confirmatory to effectiveness.
2.3.1.3.2, 2.3.1.4.2, 2.3.1.5.2	Changed confirmatory to effectiveness.
2.3.1.6.2	Modified section to reflect activities that occurred in 2008 and that are planned for 2009. Changed confirmatory to effectiveness.
2.3.1.7.2, 2.3.1.8.2	Changed confirmatory to effectiveness.
2.3.2.1.2	Modified section to reflect activities that occurred in 2008.
2.3.2.2.2, 2.3.2.3.2, 2.3.2.4.2, 2.3.2.5.2	Changed confirmatory to effectiveness.
2.3.2.6.2	Added section for SWMU 25.
2.3.2.7.2, 2.3.2.8.2, 2.3.2.9.2, 2.3.2.10.2	Changed confirmatory to effectiveness.
2.3.3.2	Modified section to reflect activities that occurred in 2008.
3.0	Modified section to reflect planned activities for 2009.
Table A-1	Added SWMU 25.
Table A-2	Incorporated new regional screening levels for chemical contaminants at superfund sites.

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APPENDIX A

LIST OF TABLES

FACILITY ACTION PLAN

1.0 INTRODUCTION

Nuclear Fuel Services, Inc. (NFS) is a participant in the Facility Action Plan (FAP) process by the Division of Solid Waste Management (DSWM) of the Tennessee Department of Environment and Conservation (TDEC) in order to accelerate corrective action at Resource Conservation and Recovery Act (RCRA) Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs). The FAP is a requirement of this process.

1.1 Purpose

The purpose of this FAP is to meet requirements of condition VI.J.6 of TNHW-108, provide background information on SWMUs and AOCs, provide the status of SWMUs and AOCs, and to outline the planned work.

1.2 Scope

The scope of this FAP is to describe the SWMUs and AOCs identified in TNHW-108. The FAP will be updated annually. Any newly identified SWMUs and/or AOCs will be added to the FAP, and their regulatory requirements and plan of action will be identified and described.

1.3 Objective

The objectives of this FAP are as follows:

1) describe each SWMU and AOC;
2) describe the regulatory requirement;
3) describe the planned activity associated with them;
4) Incorporate comments and agreed upon plan of action resulting from NFS discussions with TDEC during the biannual FAP meeting.

2.0 SITE DESCRIPTION

2.1 Facility Background

The NFS Facility is located in northeast Tennessee within the city limits of the Town of Erwin in Unicoi County. The property consists of approximately 70 acres of land. The site is bordered on the south and east by Banner Hill road and private residences. The CSX Railroad right-of-way parallels the site boundary on the northwest. An industrial park is located northwest of the railroad in which property is owned by NFS (NFS IPF), CSX Railroad, and Impact Plastics, Inc. Martin Creek bounds the site to the northeast, with privately owned, and vacant low density residential land on the opposite side of the creek.

No water supply wells are located between NFS and the Nolichucky River. The closest municipal well to the NFS site is the Erwin Utility Railroad Well. Groundwater withdrawn from the Railroad Well does not originate beneath or downgradient from the NFS site (Geraghty and Miller 1996).

2.2 Site Hydrogeology

The NFS site is located in the alluvial valley of the Nolichucky River. The site is underlain by 0 to 30 feet of unconsolidated alluvium consisting of silts and clays, clayey sand, and sand with varying amounts of gravel and cobble. The alluvium coarsens with depth into cobbles and boulders. This cobble/boulder zone overlies weathered, fractured, bedrock consisting of steeply dipping beds of shale or shale interbedded with dolomite and siltstone (EcoTek 1994).

Both the alluvium and shallow bedrock contain groundwater under unconfined conditions. No laterally continuous physical separation exists between the two lithologies. Recharge to the alluvium and shallow bedrock is predominantly from downward infiltration of rainwater through the vadose zone. Some upward component of flow is evident within the deeper bedrock (50+ feet), which is probably the result of higher elevation recharge through fracture systems in the mountains to the southeast. Measured heads in the bedrock wells are consistent with and indicative of a nonfractured dominated flow regime. The thinly bedded, poorly competent nature of the bedrock may contribute to flow patterns more analogous to the porous media model than the fracture flow model. Limited evidence, such as high well yields, exists for structure or fracture controlled movement of groundwater in the deeper zone (EcoTek 1994).

Groundwater flow is generally towards the north-northwest. Groundwater elevations range from approximately 1626 to 1644 feet above mean sea level.

A more detailed description of the site hydrogeology can be found in the "Revised Groundwater Flow and Solute-Transport Modeling Report", February 1999 (ARCADIS 1999).

2.3 SWMUs and AOCs/Requirements

The twenty-four (24) SWMUs and seven (7) AOCs are described in Table A-1 (Appendix A). The SWMU and AOC requirements consist of interim measures, institutional controls, groundwater remediation under AOC groundwater, and no further action required. The SWMUs and AOCs have been grouped according to their applicable requirements for discussion purposes.

2.3.1 SWMUs and AOCs Requiring Interim Measures

2.3.1.1 SWMU 1 – Impoundments 1, 2, and 3

2.3.1.1.1 Site Description – SWMU 1 is located northeast of plant production facilities and consists of Impoundments 1, 2, and 3. The impoundments were constructed between 1957 and 1963 to retain process wastewater generated from operations associated with the production of nuclear materials. The unlined impoundments were excavated to depths of approximately four feet and enclosed by low earthen berms. The impoundments were used from the beginning of plant operations in 1957 through 1978. In 1978, use of the impoundments ceased concurrent with the start-up of the NFS wastewater treatment plant.

The three impoundments contained approximately 91,000 cubic feet of waste material. Predominant radiological contaminants in waste were isotopes of uranium and thorium. RCRA hazardous constituents detected in waste samples prepared by the Toxicity Characteristic Leaching Procedure (TCLP) included tetrachloroethylene, trichloroethylene, barium, cadmium, chromium, and lead. Waste from Pond 2 was characteristically hazardous for tetrachloroethylene and cadmium. The potentially affected media include air, soil, surface water, and groundwater.

Waste removal and processing began in August 1991 at Pond 3. Wastes were removed as a slurry by dredge, pumped to mixing tanks, treated for hazardous constituents and dewatered using a filter press. The filter cake was disposed of as low-level radioactive waste at a licensed burial facility. Waste removal from Ponds 1, 2, and 3 was completed in September 1993, August 1994, and May 1994, respectively.

2.3.1.1.2 **Proposed Plan** - Soil removal is complete for this SWMU. Effectiveness sampling is complete for this SWMU. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis for this SWMU. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A. Preliminary results indicate all samples are below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil.

2.3.1.2 SWMU 2 – Pond 4

2.3.1.2.1 **Site Description** - SWMU 2 (i.e. "Pond 4") was used for waste storage and disposal from approximately 1957 to 1966. Waste materials consisting of press cake, incinerator ash, sludges, drums, buckets, conduit, pipes, old equipment and general trash were placed in the area and covered with soil. Building 410 was constructed over this area and the waste debris has been removed. The potentially affected media include soil, surface water, and groundwater. Excavation of the Pond 4 debris began in August 1994 and was completed in December 1996. The remaining contaminated soil will be excavated.

2.3.1.2.2 **Proposed Plan** - Soil removal and effectiveness sampling is complete for a portion of the SWMU. Additional soil removal and effectiveness sampling is planned. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A. Preliminary results indicate that one area requires additional removal and effectiveness sampling to get below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil.

2.3.1.3 SWMU 3 – Building 110 Complex Underground Storage Tank (UST)

2.3.1.3.1 **Site Description** – SWMU 3 is the Underground Storage Tank (UST) at the Building 110 Complex. Building 110C was used as a wet chemistry support laboratory. The underground storage tank (UST), a 55-gallon stainless steel drum (2 feet diameter), was located approximately eight feet north of Building 110C and 18 inches below ground level. According to site personnel, the UST was used in the 1960s for managing laboratory waste, including effluent from glove box drains. The potentially affected media in this area include soil and groundwater.

2.3.1.3.2 **Proposed Plan** – SWMU 3 is located within the Building 410 area (SWMU 2). Therefore, the proposed plan for SWMU 3 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.4 SWMU 4 – Yard Incinerator

2.3.1.4.1 **Site Description** - SWMU 4 is an incinerator, which was located within the boundaries of SWMU 2. The incinerator was used to incinerate office waste from 1970 to 1990. The potentially affected media in this area include air, soil, and surface water.

2.3.1.4.2 **Proposed Plan** – SWMU 4 is located in the Building 410 area (SWMU 2). Therefore, the proposed plan for SWMU 4 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.5 SWMU 6 – Abandoned Banner Spring Branch (BSB) Stream Channel

2.3.1.5.1 **Site Description** - SWMU 6, the abandoned channel of Banner Spring Branch, is located within the boundaries of SWMU 2. SWMU 6 received supernate from three surface impoundments (SWMU 1) from approximately 1957 to 1968. The potentially affected media in this area include soil and groundwater.

2.3.1.5.2 **Proposed Plan** - SWMU 6 is located within the boundaries of SWMU 2. Therefore, the proposed plan for SWMU 6 is identical to SWMU 2. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.6 SWMU 7 – Soil Stockpile

2.3.1.6.1 **Site Description** – SWMU 7 was a mound of soil contaminated with low levels of uranium, thorium and plutonium. From 1957 to 1977, process wastes containing low-level concentrations of uranium and thorium were discharged to three NFS surface impoundments. Banner Spring Branch received supernatant from these impoundments resulting in contamination of stream sediments. In 1967, the channel of Banner Spring Branch was relocated to divert stream flow into Martin Creek approximately 200 feet upstream from its previous confluence. Contaminated soils from the former streambed were excavated between 1980 and 1984 and stored in the location, which is SMWU 7. Potentially affected media include soil and surface water.

The soil stockpile has been removed and contaminated soils were disposed of at a licensed radioactive burial facility.

2.3.1.6.2 **Proposed Plan** – The soil pile has been removed. Soil removal and effectiveness sampling is complete. Ten percent (10%) of the radiological effectiveness sample locations were sampled for RCRA constituents on a random basis. RCRA effectiveness sampling consisted of analyzing for the parameters shown in Table A-2 of Appendix A. Preliminary results indicate all samples are below the Regional Screening Levels for Chemical Contaminants at Superfund Sites for Industrial soil. NFS plans to perform additional soil removal at this SWMU to get below the residential soil levels.

2.3.1.7 SWMU 9 – Radiological Burial Ground (RBG) Trenches

2.3.1.7.1 **Site Description** – SWMU 9 is the Radiological Burial Ground. Between 1966 and 1977, NFS disposed of low-level radioactive waste by on-site shallow land burial in accordance with NRC regulations (10 CFR 20.304). Waste materials predominantly consisted of contaminated equipment, construction debris, laboratory waste, and process waste (e.g., filter "press cake"). Radionuclides contained in the waste primarily consisted of low-level thorium and uranium, with enrichments ranging from depleted to 97 percent; however, records indicate small amounts of Plutonium-239 and Uranium-233 in trench 69-6. The total radioactive inventory from all of the burial trenches within SWMU 9 is estimated as slightly greater than 800 mCi. Radionuclides of importance are Thorium-232 (892 kg), Uranium-238 (275 kg), and Uranium-235 (11.5 kg). Liquid wastes and small amounts of waste mercury were also buried in several of the trenches. Potentially affected media include soil and groundwater.

2.3.1.7.2 **Proposed Plan** - Soil removal has been completed and effectiveness sampling is planned. The groundwater portion of the potentially affected media has been converted to AOC GW. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.1.8 AOC 5 – BSB Stream Channel

2.3.1.8.1 **Site Description** – AOC 5 is located northeast of plant production facilities. The channel of Banner Spring Branch from approximately 1967 to 2003 is designated as AOC 5. In September 2003 the channel of Banner Spring Branch was relocated by burying it in a culvert from its source to Martin Creek. Banner Spring Branch has no known unregulated releases; however, it was a potential receptor of pond overflow because of its location between the surface impoundments. Potentially affected media consist of surface water.

2.3.1.8.2 **Proposed Plan** - Relocation of Banner Spring Branch was completed in September 2003. A portion of the excavation of the channel and a portion of the effectiveness sampling is complete. More excavation and effectiveness sampling is planned. Ten percent (10%) of the radiological effectiveness sample locations will be sampled for RCRA constituents on a random basis. RCRA effectiveness sampling will consist of analyzing for the parameters shown in Table A-2 of Appendix A.

2.3.2 SWMUs and AOCs Requiring Institutional Controls

2.3.2.1 SWMU 13 – Building 111 Bulk Chemical Storage Area

2.3.2.1.1 **Site Description** – The Bulk Chemical Storage Area at Building 111 (SWMU 13) was used to store process chemical products from initial operations in 1957 until March 1992. In 1992, tanks were relocated to the Bulk Chemical Storage Area at the southwest portion of the plant's protected area. The storage tank and dike have been removed. Potentially affected media in this area include soil, surface water, and groundwater.

2.3.2.1.2 **Proposed Plan** - Institutional controls consisting of concrete to cover the soil in the area have been implemented. Inspection of concrete occurs annually to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.2 SWMU 15 – Waste Water Treatment Facility (WWTF)

2.3.2.2.1 **Site Description** - SWMU 15 is the WWTF. It has been in operation since 1975. There is no potentially affected media for this area.

2.3.2.2.2 **Proposed Plan** - Institutional controls consisting of concrete (building floor) to cover the soil in the area are required. Inspection of the concrete floor occurs annually to ensure its integrity. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.3 SWMU 16 – Radiological Incinerator

2.3.2.3.1 **Site Description** – SWMU 16 is the Radiological Incinerator at Building 302. The incinerator was operated from 1975 to April 1996 under an approved State of Tennessee Air Pollution Control Operating Permit.

The main purpose of the incinerator was to facilitate recovery of uranium from combustible materials. After incineration, ash was transferred to NFS' High Enriched Uranium Recovery Facility for uranium recovery. The incinerator was also used to reduce the volume of low-level combustible materials prior to disposal at a licensed radioactive waste disposal facility. Potentially affected media include air and soil.

2.3.2.3.2 **Proposed Plan** - Institutional controls consisting of controlled access and concrete (building floor) to contain any potential contamination is in place. The concrete floor is inspected annually to ensure the integrity of the concrete floor. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.4 SWMU 20 – Building 130 Scale Pit

2.3.2.4.1 **Site Description** – SWMU 20 is the Building 130 Scale Pit. The scale pit was constructed in the late 1950s. This structure was one of the first on site and was probably constructed concurrently with Building 130. The scales were used primarily for weighing cylinders containing uranium hexaflouride. The exact dates of operation of the scale could not be determined since records of its use are not available; however, it is believed to have been utilized in the 1960s. The affected media include soil and groundwater.

2.3.2.4.2 **Proposed Plan** - Institutional controls consisting of concrete to cover the soil in the area have been implemented. Inspection of concrete occurs annually to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.5 SWMU 21 - 30,000 Gallon Diesel Above Ground Storage Tank (AST)

2.3.2.5.1 **Site Description** – SWMU 21 is the 30,000-gallon above ground storage tank. SWMU 21 is located in the western portion of the NFS site. SWMU 21 was used for diesel fuel (No. 2 fuel oil) storage from the mid 1970's to 1998. The fuel in the tank was used for heating purposes during winter months. The tank was last used in 1998 and at that time the contents were pumped out of the tank and into appropriate storage containers. There have not been any documented releases from the tank. The tank was removed in October 2001. Potentially affected media include soil and groundwater.

2.3.2.5.2 **Proposed Plan** - Institutional controls consisting of gravel to cover the soil in the area have been implemented. Inspection of gravel occurs quarterly to ensure no soil is exposed. The area has been built up with approximately 4 feet of gravel and a new building has been constructed at this location. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.6 SWMU 25 - Underground Pipe on the West Side of Building 111

2.3.2.6.1 **Site Description** – SWMU 25 is the underground pipe on the west side of Building 111. The pipe was installed in 1959, concurrently with the construction of Building 111, the first structure built on the site. The ten inch pipe was used primarily for plant drainage and its use was discontinued in 1984 when the new plant drainage was installed. In October 2007, NFS was performing excavation activities immediately west of Building 111 to enhance the institutional control requirement for SWMU 13 from gravel to concrete. During this excavation, a ten inch drainage pipe was located within this area on the west side of Building 111. The pipe was located approximately 21 feet from Building 111 and was approximately 3 feet deep. The pipe within the excavated area was removed along with the excavated soil. Potentially affected media include soil and groundwater.

2.3.2.6.2 **Proposed Plan** - Institutional controls consisting of gravel, asphalt, and concrete to cover the soil in the area have been implemented. Inspection of the area occurs quarterly to ensure no soil is exposed. The groundwater portion of the potentially affected media has been converted to AOC GW. NFS plans to conduct further characterization to determine the extent of PCB contamination in soil and to determine the source of contamination to soil and groundwater. Once characterization is complete, follow-up actions will be proposed and implemented. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.2.7 AOC 2 – Building 111 Boiler Blowdown and Backwash Water

2.3.2.7.1 **Site Description** - AOC 2 is the location previously occupied by three boilers, which provided heat and heat tracing for the NFS facility from 1958 until 1991. Boilers #1 and #2, located in the east corner of Building 111, were installed in 1958 and 1962, respectively. The third boiler located in the southeast end of Building 111 was installed in 1977. In July 1991, boilers #1 and #2 were shut down and removed from the plant; boiler #3 was relocated to Building 130. AOC 2, the "unit", as it refers to AOC 2, is blowdown from the three boilers, and backwash (and regeneration water) from the water purification system deionizers and softeners. Potentially affected media includes soil.

2.3.2.7.2 **Proposed Plan** - Institutional controls consisting of pavement to cover the soil in the area and posting of signs stating that the area is potentially contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. Soil removal and effectiveness sampling is planned at the end of plant life.

2.3.2.8 AOC 3 – Building 130 Cooling Tower

2.3.2.8.1 **Site Description** – AOC 3 is the Cooling Water Tower at Building 130. The purpose of the Cooling Water Tower was to provide a means of storing, cooling, and recirculating non-contact plant process water. The Cooling Water Tower supported operations conducted in numerous buildings at NFS from 1957 to 1992. Its use during that time was continuous, with demand increasing or decreasing depending upon the type of work NFS had under contract. From 1958 until 1968, the Cooling Water Tower reservoir also served as a heat exchanger for a submerged recirculating coil containing tetrachloroethylene, which was used in vacuum furnace operations in the 130 Building. Potentially affected media include soil and surface water.

2.3.2.8.2 **Proposed Plan** - Institutional controls consisting of pavement to cover the soil in the area have been implemented. Inspection of pavement occurs annually to ensure no soil is exposed. Soil removal and effectiveness sampling is planned at the end of plant life.

2.3.2.9 AOC 4 – Storm Drainage System

2.3.2.9.1 **Site Description** – AOC 4, the storm drainage system, has been operating in various capacities since the plant was built in 1957. The system, which was developed to provide directed flow of storm water throughout the plant, was expanded in 1984 with minor modifications subsequent to that time. Potentially affected media include soil, surface water, and groundwater.

2.3.2.9.2 **Proposed Plan** - Institutional controls consisting of pavement to cover the soil in the area and posting of signs stating that the area is potentially contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. The groundwater portion of the potentially affected media has been converted to AOC GW. Soil removal action and effectiveness sampling are planned at the end of plant life.

2.3.2.10 AOC 6 – Building 220 Mercury Contaminated Soil

2.3.2.10.1 **Site Description** - AOC 6 is an area of mercury-contaminated soil located immediately northeast of Building 220. It is an area approximately 55 by 27 feet covered with soil and gravel. A concrete slab is present in some areas of the site at a depth of approximately 0.5 feet beneath the soil. AOC 6 is surrounded by asphalt pavement to the northeast, southeast, and northwest, and Building 220 to the southwest. Potentially affected media includes soil.

2.3.2.10.2 **Proposed Plan** - Institutional controls consisting of gravel to cover the soil in the area and posting of signs stating that the area is potentially mercury contaminated have been implemented. Notification is required before digging. Inspection of the signs occurs quarterly to ensure that the signs are present and legible. The gravel has been upgraded to pavement as an enhancement in this area. Soil removal and effectiveness sampling are planned at the end of plant life.

2.3.3 AOC GW

2.3.3.1 Site Description - AOC GW is site wide groundwater. AOC GW is a combination of SWMUs and AOCs that require corrective measures for groundwater. AOC GW is a consolidation of SWMUs 1, 2, 3, 6, 9, 10, 14, 18, 20, and 21 and AOCs 4, 5, and 6.

2.3.3.2 Proposed Plan - Groundwater will be sampled routinely for tetrachloroethylene, trichloroethylene, dichloroethylene, and vinyl chloride, gross alpha and gross beta activity. If the gross alpha activity exceeds 15 picoCuries per Liter (pCi/L), then at a minimum, isotopic analysis for uranium will be performed. If gross beta activity exceeds 50 pCi/L, then analysis for technetium-99 will be performed.

Groundwater remediation is in progress at the Maintenance Shop area and is planned to continue through 2009. The automated injection system is nearing completion for injecting a higher volume of reagent in the area between the fences. The automated zone is projected to be utilized beginning first quarter 2009.

Groundwater monitoring will continue at the plant site after source term removal. Results from groundwater monitoring will be used to determine appropriate remedial actions.

Off site Well 122A (TDOT Well) was sampled on a semi-annual basis. The most recent results for Well 122A showed PCE detections slightly above the drinking water MCL.

The Nolichucky River Backwater Area was sampled at three locations on a semi-annual basis. The most recent results show that all locations are below the maximum contaminant level (MCL). However, in 2008 the backwater area had PCE detections slightly above the drinking water MCL. This area remains posted with a sign indicating that the water is not a potable drinking water source in accordance with the TDEC Environmental Indicator Memorandum (TDEC, 2004).

In February 2007, NFS implemented the BOS 100 technology on a one time injection at approximately 250 locations just upgradient of the backwater area using direct-push technology. BOS 100 is a reagent that consists of nanoscale iron coated with carbon that can be injected into the subsurface using direct-push technology and a variety of pumping systems to create a reactive curtain to treat chlorinated solvent contaminated groundwater via reductive dechlorination.

2.3.4 SWMUs and AOCs Requiring No Further Action at this Time

2.3.4.1 SWMU 8 – CSX Soil Excavation Site

2.3.4.1.1 **Site Description** - SWMU 8 is located along the northwestern boundary of the NFS plant site. SWMU 8, the soil excavation site on CSX property, designates a portion of the former channel of Banner Spring Branch. The former streambed was contaminated with isotopes of uranium and thorium classified as Low Specific Activity material. Contamination resulted from the discharge of supernate to Banner Spring Branch from three surface impoundments (SWMU 1). SWMU 8 was active from approximately 1957 to 1967. In 1967, the stream was rerouted to its present location. Contaminated soils comprising the area were excavated and stockpiled on NFS property during the early 1980s (SWMU 7). The excavated area was released by the NRC for unrestricted use in July 1987. Potentially affected media was groundwater.

2.3.4.1.2 **Proposed Plan** - TDEC and the EPA have closed out this SWMU in a letter dated January 19, 1994. No further action is required.

2.3.4.2 SWMU 10 –Demolition Landfill

2.3.4.2.1 **Site Description** – SWMU 10 is the former Demolition Landfill. Between 1981 and 1984, NFS disposed of nonradioactive and nonhazardous waste by on-site shallow land burial into the Demolition Landfill. No disposal records exist for SWMU 10; however, plant personnel and previous investigations have identified that the landfill was primarily used for disposal of construction debris. Potentially affected media include soil and groundwater.

2.3.4.2.2 **Proposed Plan** –TDEC approved No Further Action (NFA) for SWMU 10 in August 2004, therefore, no additional measures are required.

2.3.4.3 SWMU 11 – CSX Burial Trenches

2.3.4.3.1 **Site Description** - SWMU 11, the CSX burial trenches were located along the northwestern boundary of the NFS plant site. SWMU 11 was located on land leased from CSX and consists of two trenches located within 50 feet west of, and roughly parallel to, NFS buildings 300 and 310. Each trench measured about 18 feet wide by 275 feet long, with less than ten feet separation between the two trenches. Maximum trench depth was approximately 10 feet in predominantly alluvial materials. Burial trench contents consisted of low-level uranium and thorium contaminated scrap metals and equipment. Excavation of the trenches was completed in June 2000. Potentially affected media includes groundwater.

2.3.4.3.2 **Proposed Plan** - TDEC and the EPA have closed out this SWMU in a letter dated January 19, 1994. No further action is required.

2.3.4.4 SWMU 12 – Permitted Hazardous Waste Management Storage Area

2.3.4.4.1 **Site Description** - SWMU 12 is a permitted hazardous waste management storage area (HW Unit) located in the 310 Warehouse (Permit Number TN HW-066). It is a RCRA storage unit for liquid and non-liquid wastes. It has been in operation since 1989. It is covered, enclosed, and is an access controlled space. There is no potentially affected media.

2.3.4.4.2 **Proposed Plan** - No further action is required.

2.3.4.5 SWMU 14 – Light Non-Aqueous Phase Liquid (LNAPL)

2.3.4.5.1 **Site Description** – SWMU 14, the LNAPL, is located in the northwestern part of the NFS plant site, northwest of Building 111, and northeast of Building 120. Potentially affected media is groundwater.

2.3.4.5.2 **Proposed Plan** - The remediation of this groundwater will occur as part of AOC GW. No further action is required.

2.3.4.6 SWMU 17 – Scrap-Recovery Incinerator

2.3.4.6.1 **Site Description** - SWMU 17 was a scrap-recovery incinerator. It was removed as part of Decommissioning activities in Building 200. There is no potentially affected media.

2.3.4.6.2 **Proposed Plan** - No further action is required.

2.3.4.7 SWMU 18 – Building 105 UST

2.3.4.7.1 **Site Description** - SWMU 18 was a 1,000 gallon UST located at Building 105. It was in operation from the late 1960s until the mid 1970s. The tank was removed in May 1991. Potentially affected media include soil and groundwater.

2.3.4.7.2 **Proposed Plan** - No further action is required.

2.3.4.8 SWMU 19 – Building 100 UST

2.3.4.8.1 **Site Description** - SWMU 19 was a 1,000 gallon number 2 fuel oil UST located at Building 100. It was in operation from the late 1960s until the mid 1970s. The tank was removed in November 1991. Potentially affected media include soil and groundwater.

2.3.4.8.2 **Proposed Plan** - No further action is required.

2.3.4.9 SWMUs 22, 23, and 24 – Building 304 Hazardous Waste Unit

2.3.4.9.1 **Site Description** - SWMUs 22, 23, and 24 are permitted Hazardous Waste units at the west end of Building 304 (Permit Number TN HW-108). Although permitted, they are not currently in use. SWMU 22 is the RCRA storage unit for mercury mixed wastes. SWMU 23 is the RCRA treatment unit for mercury mixed wastes. SWMU 24 is the RCRA miscellaneous unit (shredder) unit for mercury mixed wastes. There are no potentially affected media from these units.

2.3.4.9.2 **Proposed Plan** - No further action is required. NFS began removing this equipment in accordance with permit on November 22, 2004 and the closure report was submitted to TDEC on April 7, 2005.

2.3.4.10 AOC 1 – Plant Scrubbers

2.3.4.10.1 **Site Description** - AOC 1 consists of high-efficiency venturi demisting plant scrubbers that are currently in use. There is no potentially affected media in these areas.

2.3.4.10.2 **Proposed Plan** - No further action is required.

3.0 PROPOSED SCHEDULE FOR 2009

Activities planned for 2009 consist of:

1) Soil removal and effectiveness sampling for SWMUs 1, 2, 3, 4, 6, 9, and AOC 5.
2) Quarterly inspections of SWMUs 13, 21, and AOCs 2, 4, and 6;
3) Annual inspections of SWMUs 15, 16, 20, 25, and AOC 3; and
4) Continuation of the full-scale in-situ reactive zone (IRZ®) technology for groundwater remediation near the maintenance shop area.
5) Continue with the full-scale Ferrous Sulfate injections in the groundwater remediation area.
6) Continue sampling surface water in the backwater area at 3 locations and continue sampling Well 122A as part of the semi-annual off site sampling program.
7) Continue with groundwater monitoring on and off site.
8) Finalize the automated zone system and begin utilizing.

4.0 REFERENCES

ARCADIS Geraghty & Miller, Inc., 1999. Revised Groundwater Flow and Solute-Transport Modeling Report. Nuclear Fuel Services, Inc./Erwin, Tennessee. February 1999.

Ecotek, Inc., 1994. 1992/1993 Nuclear Fuel Services Hydrogeologic Investigation and Monitoring Well Installation Program. June 1994.

Geraghty & Miller, Inc., 1996. Railroad well Capture Zone Analysis near the Nuclear Fuel Services Facility. Erwin, Tennessee. June 14, 1996.

Tennessee Department of Environment and Conservation (TDEC), Division of Solid Waste Management, Environmental Indicator Evaluation Memorandum Letter, Roger Donovan to B. Marie Moore. November 19, 2004.

Table A-1. Table of SWMUs and AOCs

SWMU /AOC	Description	Status
SWMU 1	Impoundments 1, 2, and 3	Interim Measures
SWMU 2	Pond 4	Interim Measures
SWMU 3	Building 110 Complex Underground Storage Tank	Interim Measures
SWMU 4	Yard Incinerator	Interim Measures
SWMU 6	Abandoned Banner Spring Branch Stream Channel	Interim Measures
SWMU 7	Soil Stock Pile	Interim Measures
SWMU 8	CSX Soil Excavation Site	No Further Action
SWMU 9	Radiological Burial Ground Trenches	Interim Measures
SWMU 10	Demolition Landfill	No Further Action
SWMU 11	CSX Burial Trenches	No Further Action
SWMU 12	Permitted Hazardous Waste Management Area	No Further Action
SWMU 13	Building 111 Bulk Chemical Storage Area	Institutional Controls
SWMU 14	Light Non-Aqueous Phase Liquid	No Further Action
SWMU 15	Waste Water Treatment Facility	Institutional Controls
SWMU 16	Radiological Incinerator	Institutional Controls
SWMU 17	Scrap Recovery Incinerator	No Further Action
SWMU 18	Building 105 Underground Storage Tank	No Further Action
SWMU 19	Building 100 Underground Storage Tank	No Further Action
SWMU 20	Building 130 Scale Pit	Institutional Controls
SWMU 21	30,000 gallon Diesel Above Ground Storage Tank	Institutional Controls
SWMU 22	Building 304 Hazardous Waste Unit	No Further Action
SWMU 23	Building 304 Hazardous Waste Unit	No Further Action
SWMU 24	Building 304 Hazardous Waste Unit	No Further Action
SWMU 25	Underground Pipe on the West Side of Building 111	Institutional Controls
AOC 1	Plant Scrubbers	No Further Action
AOC 2	Building 111 1,000 Gallon Tank	Institutional Controls
AOC 3	Building 130 Cooling Tower	Institutional Controls
AOC 4	Storm Drainage System	Institutional Controls
AOC 5	Banner Spring Branch Channel	Interim Measures
AOC 6	Building 220 Mercury Contaminated Soil	Institutional Controls
AOC Groundwater	Site Wide Groundwater	Groundwater Remediation under AOC GW

Table A-2. Regional Screening Levels for Chemical Contaminants at Superfund Sites

Contaminant	Residential Soil (mg/kg)	Industrial Soil (mg/kg)
Arochlor-1254	0.22	0.74
Arsenic*	22	22
Benzene	1.1	5.6
Benz (a) anthracene	0.15	2.1
Benzo (a) pyrene	0.015	0.21
Benzo (b) fluoranthene	0.15	2.1
Benzo (k) fluoranthene	1.5	2.1
Beryllium	160	2000
Bis (2-ethylhexyl) phthalate (DEHP)	35	120
Carbon tetrachloride	0.25	1.3
Chromium VI	230	1400
Dibenz (ah) anthracene	0.015	0.21
Indeno (1,2,3-cd) pyrene	0.15	2.1
Mercury	23	310
Tetrachloroethylene (PCE)	0.57	2.7
Trichloroethylene (TCE)	2.8	140
Vinyl chloride (VC)	0.060	1.7

* - Negotiated level with TDEC during FAP workshop meeting on March 18, 2003 and follow up letter April 23, 2003 (21G-03-0109)

RAI 7

Attachment 6

Railroad Well Capture Zone Analysis

44N-96-204
DCM-027-14-07

CLIENT PRIVILEGED

RAILROAD WELL CAPTURE ZONE ANALYSIS NEAR THE NUCLEAR FUEL SERVICES FACILITY ERWIN, TENNESSEE

June 14, 1996

Prepared for

NUCLEAR FUEL SERVICES, INC.
Erwin, Tennessee

Prepared by

GERAGHTY & MILLER, INC.
Environment and Infrastructure
97 Midway Lane
Oak Ridge, Tennessee 37830
(423) 481-3000

Client Privileged

RAILROAD WELL CAPTURE ZONE ANALYSIS NEAR THE NUCLEAR FUEL SERVICES FACILITY ERWIN, TENNESSEE

June 14, 1996

Prepared by GERAGHTY & MILLER, INC.

Michael P. Kladias
Senior Hydrogeologist

Bill R. Moore
Project Manager

Berny D. Ilgner
Associate

CONTENTS

TABLE

FIGURES

1.0 INTRODUCTION

Geraghty & Miller, Inc. (Geraghty & Miller) was retained by Nuclear Fuel Services (NFS) to develop a groundwater flow and constituent transport model at the NFS facility in Erwin, Tennessee (Geraghty & Miller, Inc. 1996). This report documents the use of that numerical groundwater flow model to conduct a capture zone analysis for a public water-supply well (Railroad Well) located approximately 3,500 feet (ft) northeast of the plant. The purpose of this simulation is to determine if expected increases in the groundwater withdrawal rate at the Railroad Well results in a capture zone that extends to the NFS facility. Additionally, this report presents a description of the model, discussions of model assumptions and limitations, and summary of findings and conclusions.

2.0 SITE LOCATION AND HISTORY

NFS is a nuclear fuel fabrication and uranium recovery facility that has been operational since the late 1950s. The NFS facility, approximately 64 acres in size, is located in the mountainous region of east Tennessee, east of the Nolichucky River and adjacent to the CSX Railroad (Figure 2-1). As shown in Figure 2-1, the NFS Erwin site, located in Unicoi County, is within the city limits of Erwin and is immediately west of the community of Banner Hill. Situated in a narrow valley surrounded by rugged mountains, the site occupies a relatively level area approximately 20 to 30 ft above the elevation of the Nolichucky River. To the west, east, and south, the mountains rise to elevations of 3,500 to 5,000 ft within a few miles of the site.

3.0 BRIEF MODEL DESCRIPTION

The groundwater flow model used for determination of the Railroad Well capture zone was developed according to the following tasks:

- Review and organize available data describing past and present groundwater flow conditions at the NFS Site.

- Develop a conceptual hydrogeologic model for the NFS Site. The components of this conceptual model include a summary of the geologic framework, hydraulic properties, groundwater and surface-water interaction, hydrologic sources and sinks, water-level distributions, contaminant distributions, and groundwater flow directions and rates.

- Develop a three-dimensional numerical groundwater flow model for the NFS Site suitable for evaluating past, present, and future groundwater conditions. The conceptual model formed the basis for the construction of the numerical model. Calibration of the numerical flow model was accomplished by matching water levels simulated by the model to water levels measured in monitoring wells. The model predicts the distribution of hydraulic heads (water levels) and groundwater velocities at the Site.

- Develop a solute transport model for uranium and PCE concentrations at the Site. The solute transport model was calibrated by matching observed uranium and PCE groundwater concentrations.

- Develop predictive simulations to estimate the migration extent and concentration of uranium and PCE in the Site area.

- Prepare and submit a final report to NFS documenting the entire modeling study at the Site.

Geraghty & Miller addressed these objectives through several phases of work which are thoroughly documented in a report submitted to NFS. That report is entitled "Final Project Report Groundwater Flow and Constituent Transport Modeling at the Nuclear Fuel Services Facility Erwin, Tennessee" (Geraghty & Miller, Inc. 1996).

This regional groundwater flow model provides a quantitative tool for predicting the distribution of hydraulic heads (water levels) and groundwater velocities at the site. The model also provides regional-scale estimates of the volume and direction of groundwater flow within the alluvium and bedrock and the recharge/discharge relationships of groundwater flow.

The groundwater flow model was constructed and calibrated covering nearly 38 square miles for the purpose of simulating groundwater flow on a regional scale in the two principal water-bearing units beneath the site: surficial saturated unconsolidated materials and the bedrock aquifer. The three-dimensional model grid developed for the NFS groundwater flow model extends over an area covering approximately 38 square miles. The grid boundaries were specified to coincide with natural boundaries, when possible, and to minimize the influence of model boundaries on simulation results at the site. The model domain extends approximately 6.6 miles from the east to west boundaries and 5.7 miles from the north to south boundaries. The finite-difference grid consists of 128 columns and 100 rows with five layers for a total of 64,000 grid cells or nodes. The model grid uses a uniform 50-ft areal grid spacing in the vicinity of the site to provide increased computational detail in the area of interest and grades to larger grid spacing at greater distances from the site. The groundwater flow model was also oriented such that a principal axis of the model grid conforms to regional groundwater flow directions (north/northwest). The strike of the bedrock units is also roughly perpendicular to the average groundwater flow direction. Conveniently, the model has two axes along the column and row directions that correspond to the directions of permeability anisotropy and groundwater flow directions (NW/SE). Shallow groundwater flow directions are typically from upland areas towards major rivers and streams such as the Nolichucky River, South Indian Creek, and smaller tributaries including Martin Creek.

Even though the site is underlain by the Rome Formation, the model domain was large enough such that the Honaker Dolomite, Shady Dolomite, Erwin, Hampton, Unicoi, and Snowbird formations were simulated. Model Layer 1 incorporates the alluvium found directly beneath the NFS Site, with the bottom of this layer coinciding with the variable elevation of the top of the cobble/boulder zone. Model Layer 2 represents the cobble/boulder zone generally found just above the bedrock beneath the site. The bottom of Model Layer 2 conforms to the top of bedrock in the vicinity of the site. In areas where the alluvium pinches out, Model Layers 1 and 2 represent the first encountered bedrock unit. The lower model layers represent only the bedrock lithologies in the model domain. Multiple bedrock layers allow for accurate simulation of vertical gradients in the bedrock and for more accurate representation of the steeply dipping bedrock units. The base of the model is defined by the low permeability regions within the bedrock units as determined mainly from municipal well yield information in the area and through numerical simulations.

The simulated hydraulic heads in the model generally show regional water levels declining from all areas surrounding the NFS Site toward the Nolichucky River and Indian Creeks. The water table gradient significantly flattens in the higher permeability units, specifically the alluvial and cobble zones and in the Rome Formation along the Nolichucky and Indian Creeks. Groundwater flow directions in the vicinity of the site are northwest towards the Nolichucky River. Slight inflections are noticed in the water table due to influences from the drainage ditch, Banner Spring, and the ponds. Beneath the ponds, slight downward gradients are produced from Model Layer 1 to Model Layer 2, but these gradients reverse closer to the river. Generally, there is a downward hydraulic gradient in the highland areas, while gradients tend to be upward near discharge points such as springs and the Nolichucky River. Across the site, gradients are predominately horizontal with increasing upward vertical flow components in the vicinity of the Nolichucky River.

4.0 CAPTURE ZONE ANALYSIS FOR THE RAILROAD WELL

During the calibration of the groundwater flow model, the capture zone of the railroad well was evaluated with the MODFLOW groundwater flow model and was described in the modeling report (Geraghty & Miller, Inc. 1996). For this evaluation, the model was run with the pumping rate for the Railroad Well being increased to 1,000 gallons per minute to determine if, under this pumping condition, the capture zone would extend to the NFS facility. The capture zone was delineated from the MODFLOW results for both studies by using a particle-tracking (pathline) analysis. The MODPATH code (Pollock 1989) was used in conjunction with MODFLOW to perform the pathline analysis. Pathline analysis is a simple, cost-effective form of contaminant transport analysis which ignores the effects of dispersion, retardation and chemical reactions. In effect, the particles represent the motion of groundwater in the model. The MODPATH code uses the flow terms and velocities computed by MODFLOW for use in the calculations. Figure 4-1 depicts the simulated capture zone for the Railroad Well pumping at 270.4 gpm in the previous analysis (Geraghty & Miller, Inc. 1996). Figure 4-2 depicts the simulated capture zone for the Railroad Well at a rate of 1,000 gpm. Actual particle tracks or pathlines were not shown in these figures, but the shaded area depicting the capture zone was drawn by outlining particle tracks that enter the well. In addition to the simulated capture zone analysis, the groundwater flow directions in the vicinity of NFS were shown on Figure 4-2 by a generalized flow arrow. This flow direction was delineated using a pathline analysis to track groundwater flow beneath the NFS Site.

The capture zone analysis for both pumping rates indicate that the Railroad Well receives practically all of its water from the Rome Formation. Groundwater flows along strike in the Rome Formation from the eastern portion of the model domain to the Railroad Well. Groundwater flow directions and rates at the NFS facility are generally unaffected by the operation of the Railroad Well. Table 4-1 indicates the model grid location and average rate for each of the wells included in the model for the new capture zone analysis. All other model parameters were held constant between the two simulations.

The increase in the pumping rate of the Railroad Well from 270.4 gpm to 1,000 gpm resulted in a significant enlargement of the capture zone. The capture zone is about 3.7 times the area of the original analysis. Even at 1,000 gpm, the Railroad Well demand for groundwater is easily satisfied by groundwater flowing from the upgradient direction in the Rome Formation and by recharge. It is unlikely that, given our current understanding of site conditions, minor increases above the 1,000 gpm Railroad Well withdrawal rate will result in a capture zone which would encompass the NFS Site. It should be recognized that the model simulations do not account for potential future water withdrawals in the direct vicinity of NFS. For example, if the utility company has plans for future additional water-supply wells in the direct vicinity of the site, this capture zone analysis should be re-evaluated.

The increased groundwater withdrawal from the Railroad Well in the Rome Formation generally results in regionally depressed groundwater levels in the Rome Formation. Even though the capture zone of the Railroad Well does not extend to the NFS facility, the influence of the well is observed at the site by slightly decreased water levels. At the higher Railroad Well pumping rate (1,000 gpm), water levels at the NFS Site are about 0.3 to 0.8 ft lower than at the previous rate modeled for the Railroad Well (270.4 gpm). Even though the simulated water levels are slightly lower, they are not significant enough to produce a noticeable difference in the simulated flow directions and hydraulic gradients.

5.0 DISCUSSION OF MODEL ASSUMPTIONS AND LIMITATIONS

A thorough discussion of the assumptions and limitations of the groundwater flow model and the associated capture zone analysis was presented in the modeling report (Geraghty & Miller, Inc. 1996). The increase in the rate of the Railroad Well does not change the assumptions and limitations or degree of uncertainty in the model from previous analyses.

6.0 SUMMARY AND CONCLUSIONS

- A capture zone analysis performed at the Railroad Well for an increased rate of 1,000 gpm indicated that its area of capture does not include the NFS Site.

- As a result of running the model at an increased pumping rate for the Railroad Well (1,000 gpm), a larger capture zone was defined in comparison to the earlier model rate (270.4 gpm). The capture zone at 1,000 gpm was approximately 3.7 times larger in areal extent than the 270.4 gpm withdrawal rate.

- The increased groundwater withdrawal rate from the Railroad Well (1,000 gpm) results in regionally depressed groundwater levels within the Rome Formation. These lower levels are reflected at the NFS Site with a lowering of approximately 0.3 to 0.8 ft compared to the previous modeled rate (270.4 gpm). However, even with this modeled lowering of water levels at the Site, groundwater flow directions and rates are generally unaffected by the increased withdrawal rate at the Railroad Well.

- The capture zone analysis at the increased rate (1,000 gpm), based on our current understanding of conditions and model limitations, indicates that the Railroad Well receives all of its water from an upgradient area within the Rome Formation and from direct recharge.

- The limitations and assumptions and/or model uncertainty in this recent capture zone analysis is essentially unchanged from the previous analysis.

7.0 REFERENCES

Geraghty & Miller, Inc. 1996. Final Project Report Groundwater Flow And Constituent Transport Modeling At The Nuclear Fuel Services Facility Erwin, Tennessee. April 25, 1996.

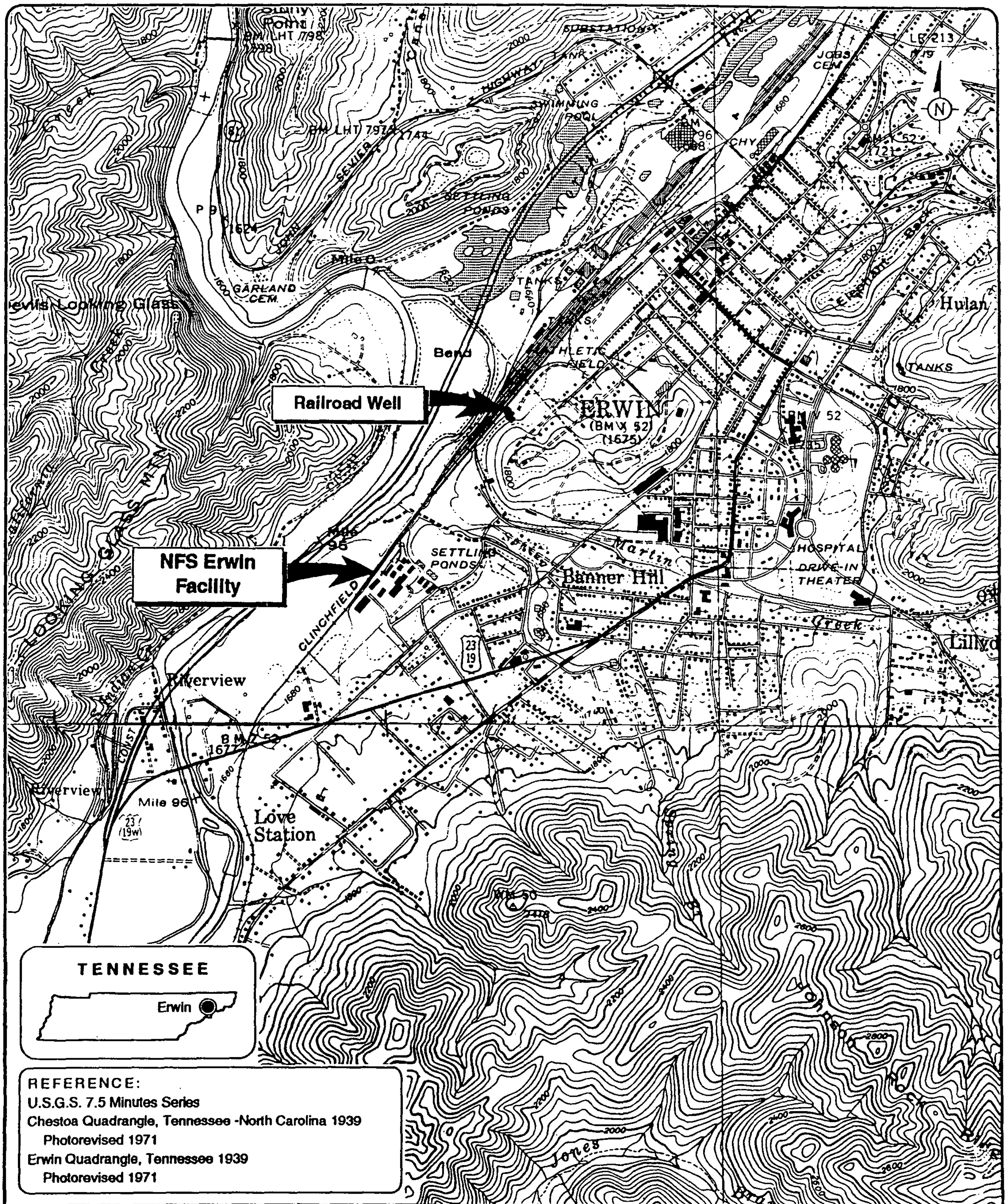
McDonald, M. G., and A. W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Techniques of Water-Resources Investigations, Book 6, Chapter A1, U. S. Geological Survey, Reston, Virginia.

Pollock, D., 1989. Documentation of Computer Programs to Compute and Display Pathlines Using Results for the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Open File Report 89-381, Reston, Virginia.

Table 4-1. Summary of Withdrawal Wells
Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Layer	Row	Column	Rate (gpm)
Railroad Well	3,4,5	40	116	1000.0
Birchfield Well	3,4,5	12	122	552.7
O'Brien Well	3	7	123	241.5
PW-1	1	55	92	0.6
PW-2	1	54	92	0.6
PW-3	1	53	91	0.6
PW-4	1	52	90	0.6
PW-5	1	53	89	0.6
PW-6	1	53	88	0.6
PW-7	1	54	89	0.6
PW-8	1	55	89	0.6
PW-9	1	56	90	0.6
PW-10	1	56	91	0.6

gpm - gallons per minute



REFERENCE:
U.S.G.S. 7.5 Minutes Series
Chestoa Quadrangle, Tennessee -North Carolina 1939
Photorevised 1971
Erwin Quadrangle, Tennessee 1939
Photorevised 1971

GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

0 — 2,000 ft

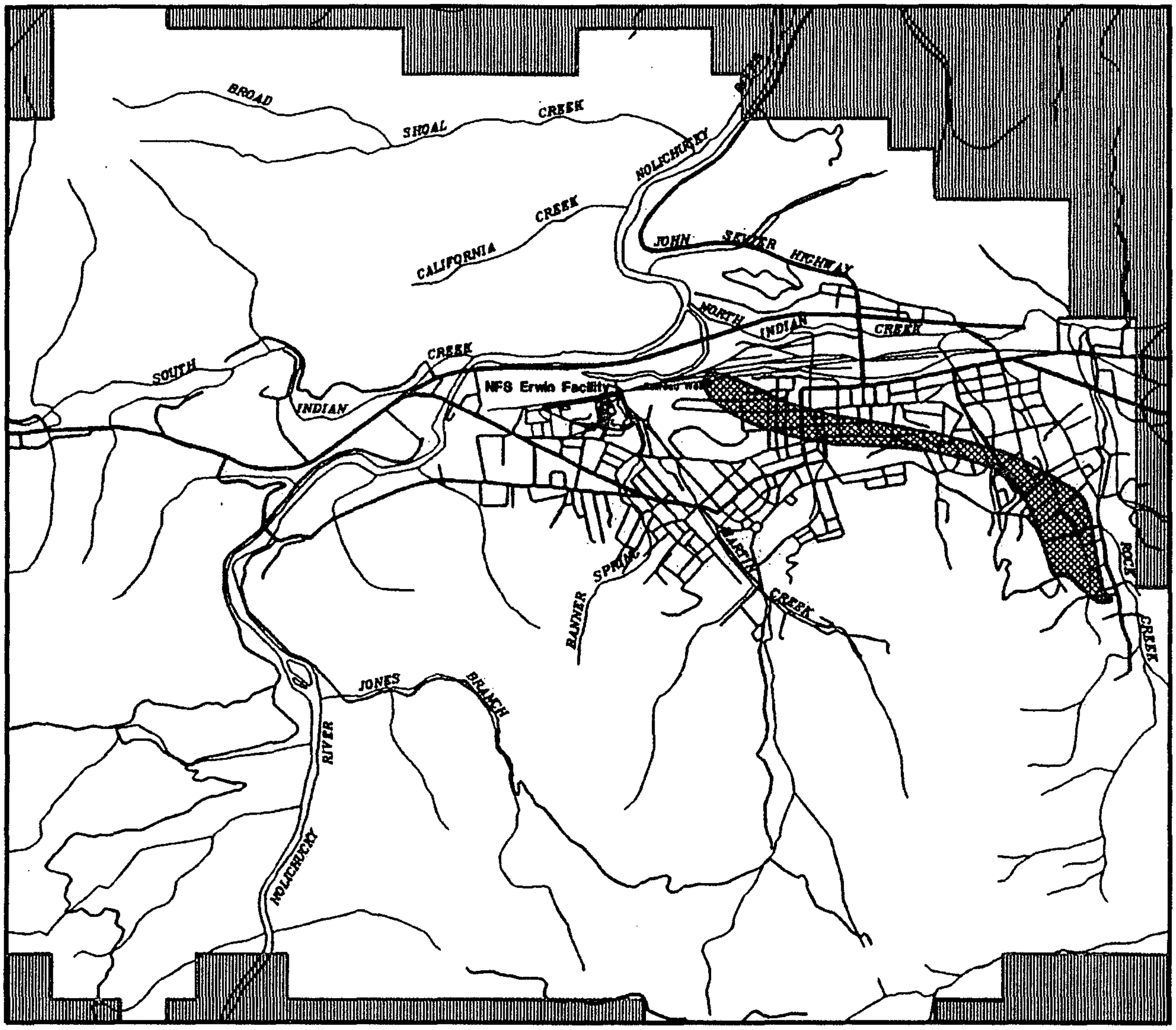
Regional Location Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-1

DRAWING NO.: 0295-30413 / DRAWING DATE: 29MAY96 MD / FILE NAME: RR WELL MODEL / PROJECT NO.: TN0368.001 / PROJECT MANAGER: B. MOORE / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /

DWG DATE: 29MAY96 MD | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30411.DWG | PROJ. MGR.: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: S. BAKER



LEGEND

Outside Model Domain

Capture Zone Extent

0 5000

SCALE IN FEET

PLOT: 1:1

N

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

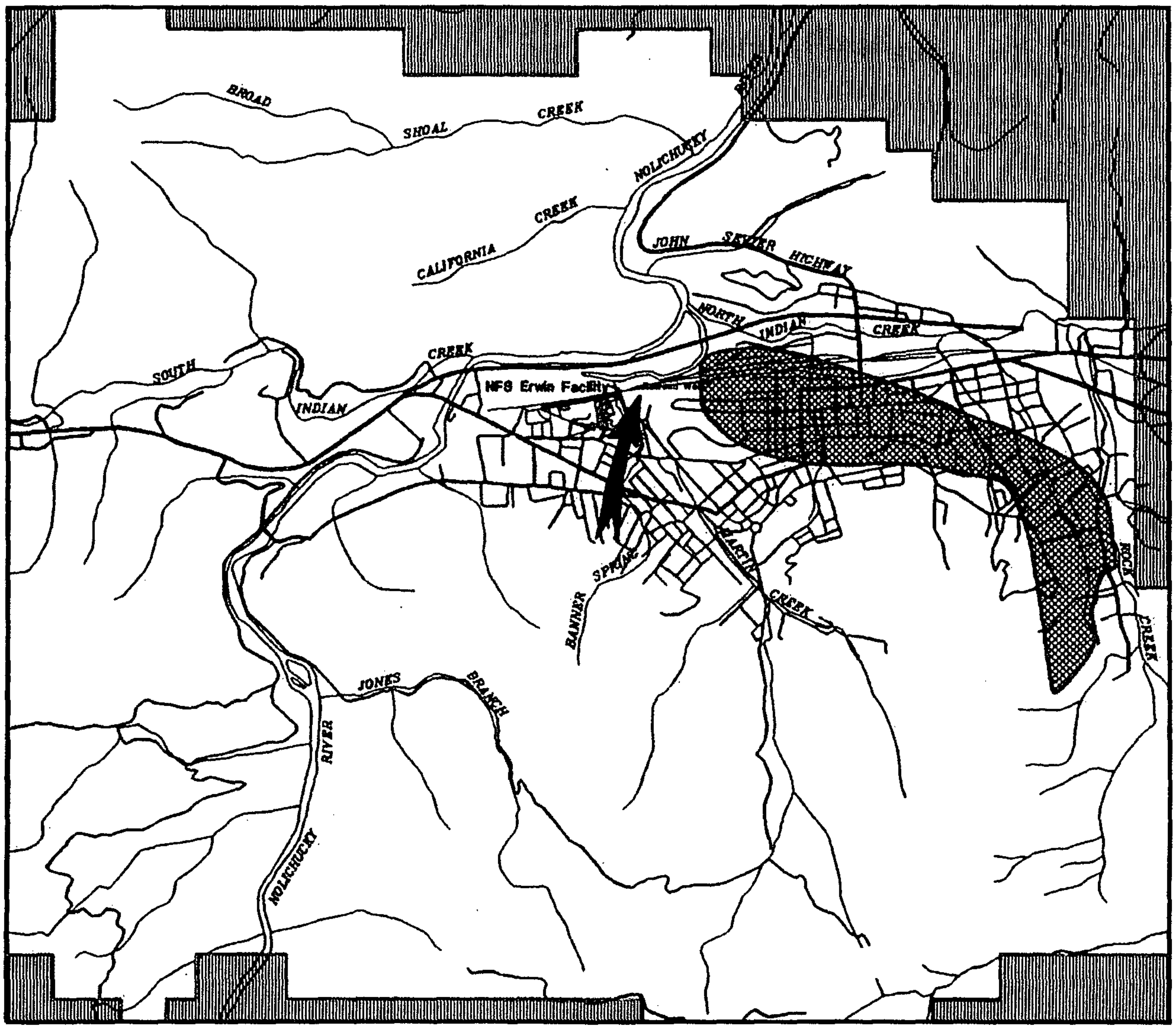
Simulated Capture Zone
Railroad Well - 270.4 GPM

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE

4-1

DWG DATE: 31MAR96 Ba | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30407.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: S. BAKER



LEGEND

Outside Model Domain

Capture Zone Extent

Direction of Groundwater Flow

0 5000

SCALE IN FEET

PLOT: 1:1

N

GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated Capture Zone
Railroad Well - 1,000 GPM

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE **4-2**