Five-Year Review for

Naval Reactors Facility

Operable Unit 8-05/06 Inactive Landfill Areas

and

Operable Unit 8-08 Remedial Action Sites

December 2006

Prepared for the
U. S. Department of Energy
Pittsburgh Naval Reactors Office
Idaho Branch Office
P. O. Box 2469
Idaho Falls, Idaho 83403-2469

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

December 21, 2006

Reply to
Attn Of: ECL-117

Ms. Wendy Dixon
United States Department of Energy
Pittsburgh Naval Reactors Office
Idaho Branch Office
P.O. Box 2469
Idaho Falls, Idaho 83403

Re: EPA Concurrence with the Five-Year Review for the Naval Reactors Facility, Operable Unit 8-05/6 Inactive Landfill Areas and Operable Unit 8-08 Remedial Action Sites

Dear Ms. Dixon:

EPA has reviewed the December 2006 Five-Year Review for the Naval Reactors Facility at the Idaho National Laboratory (INL) Federal Facility. EPA is encouraged by the progress INL has made in implementing the recommendations set forth in the previous Five-Year Review and acknowledges the efforts of the Federal Facility Agreement/Consent Order (FFA/CO) project team.

EPA reviewed the document for technical adequacy, accuracy, and consistency with EPA guidance. The document provides a clear summary of the status of the Naval Reactors Facility. It also identifies a number of actions to be taken that affect the protectiveness of the remedies and documents a schedule for completion of the recommended actions.

EPA looks forward to working with INL-Pittsburgh Naval Reactors Office and the Idaho Department of Environmental Quality on implementing the recommended actions in the five-year review report.

If you have questions concerning this letter, please call me at (206) 553-1271, or contact EPA's site manager for this review, Diane Thangamani, at (206) 553-8513.

Sincerely,

Daniel D. Opalski, Director
Office of Environmental Cleanup

cc: Daryl Koch, Idaho Department of Environmental Quality, HQ
Nick Ceto, EPA, Hanford Operations Office

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List of Acronyms

A1W	Large Ship Reactor Prototype (1st Aircraft Carrier design by Westinghouse)
ARAR	Applicable or Relevant and Appropriate Requirements
BBI	Bechtel Bettis, Inc.
bls	below land surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facility Area
CFR	Code of Federal Regulations
COC	Contaminant of Concern
CQA	Construction Quality Assurance
DOE	Department of Energy
ECF	Expended Core Facility
EPA	Environmental Protection Agency
FFA/CO	Federal Facility Agreement and Consent Order
FS	Feasibility Study
IDEQ	Idaho Department of Environmental Quality
IC	Institutional Control
ICMR	Institutional Control Monitoring Report
INL	Idaho National Laboratory
IWD	Industrial Waste Ditch
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
NFA	No Further Action
NNPP	Naval Nuclear Propulsion Program
NR/IBO	Naval Reactors/Idaho Branch Office
NRF	Naval Reactors Facility
O&M	Operations and Maintenance
OU	Operable Unit
RA	Remedial Action
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act.
RD/RA	Remedial Design/Remedial Action
ROD	Record of Decision
RI/FS	Remedial Investigation and Feasibility Study
RWMC	Radioactive Waste Management Complex
S1W	Submarine Thermal Reactor Prototype (1st Submarine design by Westinghouse)
S5G	Submarine Reactor Plant Prototype (5th Submarine design by General Electric)
SRPA	Snake River Plain Aquifer
SSC	Soft Sided Container
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOX	Total Organic Halogens
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WAG	Waste Area Group
WEC	Westinghouse Electric Company

List of Units

°F	Degrees Fahrenheit
μ	Micro (a prefix denoting a one-millionth part or 10^{-6})
mg	Milligrams
mi^2	Square Miles
NTU	Nepholametric Turbidity Unit
pCi	Picocurie; one trillionth (10^{-12}) of a curie, a measure of the amount of radioactivity
pCi/g	Picocuries per Gram
pCi/L	Picocuries per Liter
ppb	Parts per Billion
ppbv	Parts per Billion by Volume
μ g/m^3	Micrograms per Cubic Meter
μ S/cm	Microsiemens per Centimeter

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Executive Summary

The Idaho National Laboratory (INL), located in southeastern Idaho, is a government-owned reservation managed by the U.S. Department of Energy (DOE). It was listed on the National Priorities List of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in November 1989. In accordance with the requirements of CERCLA, the Environmental Protection Agency (EPA), the State of Idaho, and DOE negotiated a Federal Facility Agreement and Consent Order (FFA/CO). That agreement described the methods by which DOE, EPA, and the State of Idaho would implement CERCLA activities at INL.

To aid in the management of this project, INL was divided into Waste Area Groups (WAGs), and the WAGs were further divided into Operable Units (OUs). The FFA/CO and the associated Action Plan identified the appropriate level of investigation for each OU. Naval Reactors Facility (NRF) was designated as WAG 8; DOE-Naval Reactors/Idaho Branch Office (NR/IBO) is the signatory DOE agency responsible for NRF (WAG 8). Under direction of the Action Plan, OUs 8-05 and 8-06 (Inactive Landfill Sites) at NRF were investigated as “Track 2” sites. The investigation resulted in the identification of three former (inactive) landfill areas that required remedial actions to ensure continued protection of human health and the environment. A Record of Decision (ROD) was signed in 1994, which implemented the presumptive remedy for municipal type landfills at NRF. As part of the presumptive remedy, engineered soil covers were constructed over the inactive landfill areas, and monitoring of soil-gas and groundwater was implemented.

In 1997, a Comprehensive Remedial Investigation/Feasibility Study (RI/FS) was performed, which identified twelve OU 8-08 No Further Action (NFA) sites (areas with a source or potential source present, but for which an exposure pathway is not available) and nine OU 8-08 Remedial Action (RA) sites. A ROD was signed the following year. The ROD identified selected remedies for the various sites including Institutional Controls at the NFA Sites and removal of contaminated soil, concrete, and pipe; off-site disposal of debris; consolidation on-site of soils above remediation goals; and construction of engineered earthen covers at the RA Sites. All on-site remedial actions were complete by the end of 2004.

Bechtel Bettis, Inc., on behalf of the signatories of the FFA/CO, has conducted a Five-Year Review that combines reviews of the OU 8-05/06 and 8-08 sites. Since contamination remains at these sites above levels that would support unrestricted release, CERCLA requires a Five-Year Review to evaluate the continued effectiveness of the selected remedies. The INL recently completed a site-wide Five-Year Review for all WAGs except WAG 8 (NRF). WAG 8 is addressed separately since it is under the jurisdiction of the Naval Nuclear Propulsion Program (NNPP) rather than the U.S. Department of Energy Idaho Operations Office, and cleanup is overseen and funded solely by the NNPP.

This Five-Year Review concludes that the selected remedies remain protective of human health and the environment.

The next NRF Five-Year Review is scheduled for five years from the issuance of this document (2011).

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Five-Year Review Summary Form

SITE IDENTIFICATION

Site name *(from WasteLAN)*: Idaho National Laboratory (USDOE), Naval Reactors Facility

EPA ID *(from WasteLAN)*: ID4890008952

Region: 10 | **State:** ID | **City/County:** Idaho Falls/ Butte Co.

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify)

Remediation status (choose all that apply): ☐ Under Construction ☐ Operating ☒ Complete

Multiple OUs?* ☒ YES ☐ NO | **Construction completion date:** 2004

Has site been put into reuse? ☐ YES ☒ NO

REVIEW STATUS

Lead agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency ____________________

Author name: Naval Reactors Facility

Author title: N/A | **Author affiliation:** Naval Nuclear Propulsion Program/ DOE

Review period:** February 2001 to February 2006

Date(s) of site inspection: Annual Inspections Associated with the Institutional Control Plan

Type of review:

☒ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion

Review number: ☐ 1 (first) ☒ 2 (second) ☐ 3 (third) ☐ Other (specify) __________

Triggering action:

☐ Actual RA Onsite Construction at OU #____ ☐ Actual RA Start at OU#____
☐ Construction Completion ☒ Previous Five-Year Review Report
☐ Other (specify)

Triggering action date *(from WasteLAN)*: February 2001

Due date *(five years after triggering action date)*: February 2006

Issues:

- Sparse vegetation
- Ant hills and animal burrows
- Elevated metal results from well NRF-13
- Siltation in NRF-6
- Plugged Probes
- Standing water in some probes in the Spring
- Low water production in NRF-13 and NRF-7

* [“OU” refers to operable unit.]

Five-Year Review Summary Form, cont'd.

Recommendations and Follow-up Actions:

- Sparse vegetation: reseeded covers in 2004
- Ant hills and animal burrows: continue to inspect sites to check if the number of holes increase and/or the holes compromise cover integrity. Remove pest if necessary and make any necessary repairs.
- Elevated metal results from well NRF-13: Pull hardware from well and inspect both hardware and well borehole for problems. Hold follow-up meeting between NRF and regulatory agencies to determine best course of action.
- Siltation in NRF-6: Monitor well for signs of sediments in samples and recondition well if necessary.
- Plugged probes: replaced probes in 2003.
- Standing water in some probes during the spring season: Look for negative effects on probe efficiency. Consider sample scheduling adjustments if probe efficiency is affected.
- Low water production in NRF-13 and NRF-7: Continue to monitor results from wells.
- Constituents collected: discontinue collection of TOX beginning in 2007.
- Sampling frequency: begin collecting groundwater and soil gas samples semi-annually beginning in 2007, and collecting soil gas data annually beginning in 2010 if supported by data.

Protectiveness Statement(s):

OU 8-05/06 Landfill Covers: The remedy at OU 8-05/06 Landfill Covers is protective of human health and the environment. The analytical data shows that the covers are effective at containing contaminants. The covers and direct contact with contaminated soils and landfill wastes are being controlled by institutional controls.

OU 8-08 NFA Sites: The remedy at OU 8-08 No Further Action Sites is protective of human health and the environment because the remedy has been effective in limiting unauthorized access and excavation. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the No Further Action designation of the sites.

OU 8-08 Remediated Radiological Sites: The remedy at OU 8-08 Remediated Radiological Sites is protective of human health and the environment. The OU 8-08 Remedial Action (RA) report indicates that pipe removal and consolidation of contaminated soil has been successful in achieving remedial action objectives (RAOs). The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statement for the sites.

OU 8-08 Engineered Cover Sites: The remedy at OU 8-08 Engineered Cover Sites is protective of human health and the environment. The OU 8-08 RA report indicates that the construction of an engineered earthen cover has been successful in achieving RAOs. Exposure pathways that could result in unacceptable risks are being controlled by institutional controls. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statements for the sites.

In summary, because the individual remedies at each site are protective of human health and the environment, collectively the selected remedies for the NRF remediated CERCLA sites are protective.

1.0 Introduction

Bechtel Bettis, Inc. (BBI) operates the Naval Reactors Facility (NRF) for the U. S. Department of Energy (DOE), Office of Naval Reactors (NR). In 1991, DOE signed a Federal Facilities Agreement and Consent Order (FFA/CO) with the Idaho Department of Health and Welfare and the U. S. Environment Protection Agency (EPA) Region 10, which initiated NRF's participation in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at the Idaho National Laboratory (INL).

A Five-Year Review is required if the selected remedial actions result in any hazardous substances, pollutants, or contaminants remaining at the site at levels that would preclude unlimited use and unrestricted release of the site. This Five-Year Review is intended to determine whether the selected remedies remain protective of human health and the environment. In addition, the review reassesses the monitoring programs to ensure the correct constituents are being monitored.

BBI, on behalf of the signatories of the FFA/CO, has conducted a Five-Year Review of the remedial actions implemented at NRF for three Operable Unit (OU) 8-05/06 Inactive Landfill Areas, twelve OU 8-08 No Further Action (NFA) Sites, and nine OU 8-08 Remedial Action (RA) Sites (also referred to as Remediated Radiological Sites and OU 8-08 Engineered Cover Sites). This Five-Year Review was initiated in October 2005 and the draft document was submitted to EPA and Idaho Department of Environmental Quality (IDEQ) in February 2006. The INL recently completed a site-wide Five-Year Review for all Waste Area Groups (WAGs) except WAG 8 (NRF). WAG 8 is addressed separately since it is under the jurisdiction of the Naval Nuclear Propulsion Program (NNPP) rather than the U.S. Department of Energy Idaho Operations Office, and cleanup is overseen and funded solely by the NNPP.

In 2001, a Five-Year Review was performed for the three OU 8-05/06 Inactive Landfill Areas (two OU 8-05 and one OU 8-06 landfill areas) identified as NRF-1, NRF-51, and NRF-53. In 2004, a Five-Year Review was performed for the OU 8-08 NFA and RA Sites. This document combines the required subsequent reviews for all three operable units into a single Five-Year Review for NRF (i.e., addressing OU 8-08 earlier than required to support efficient future reviews). The review includes the three Inactive Landfill Areas identified above and twelve NFA Sites designated as NRF-2, NRF-16, NRF-18A, NRF-22, NRF-23, NRF-42, NRF-43, NRF-61, NRF-66, NRF-81, NRF-82, and NRF-83. This review also includes the OU 8-08 RA Sites designated as NRF-11, NRF-12A, NRF-12B, NRF-14, NRF-17, NRF-19, NRF-21A, NRF-21B, and NRF-80. Figure 1-1 shows the location of the Inactive Landfill Areas. Figure 1-2 shows the location of the NFA Sites. Figure 1-3 shows the location of the eight Remediated Radiological Sites (that subset of the nine OU 8-08 RA Sites that required remediation independent of cover placement). Figure 1-4 shows the locations of the OU 8-08 Engineered Covers (OU 8-08 RA Sites where covers were constructed). The required date for this review is five years after the issuance of the first Five-Year Review for the Inactive Landfill Areas, which was February 22, 2001.

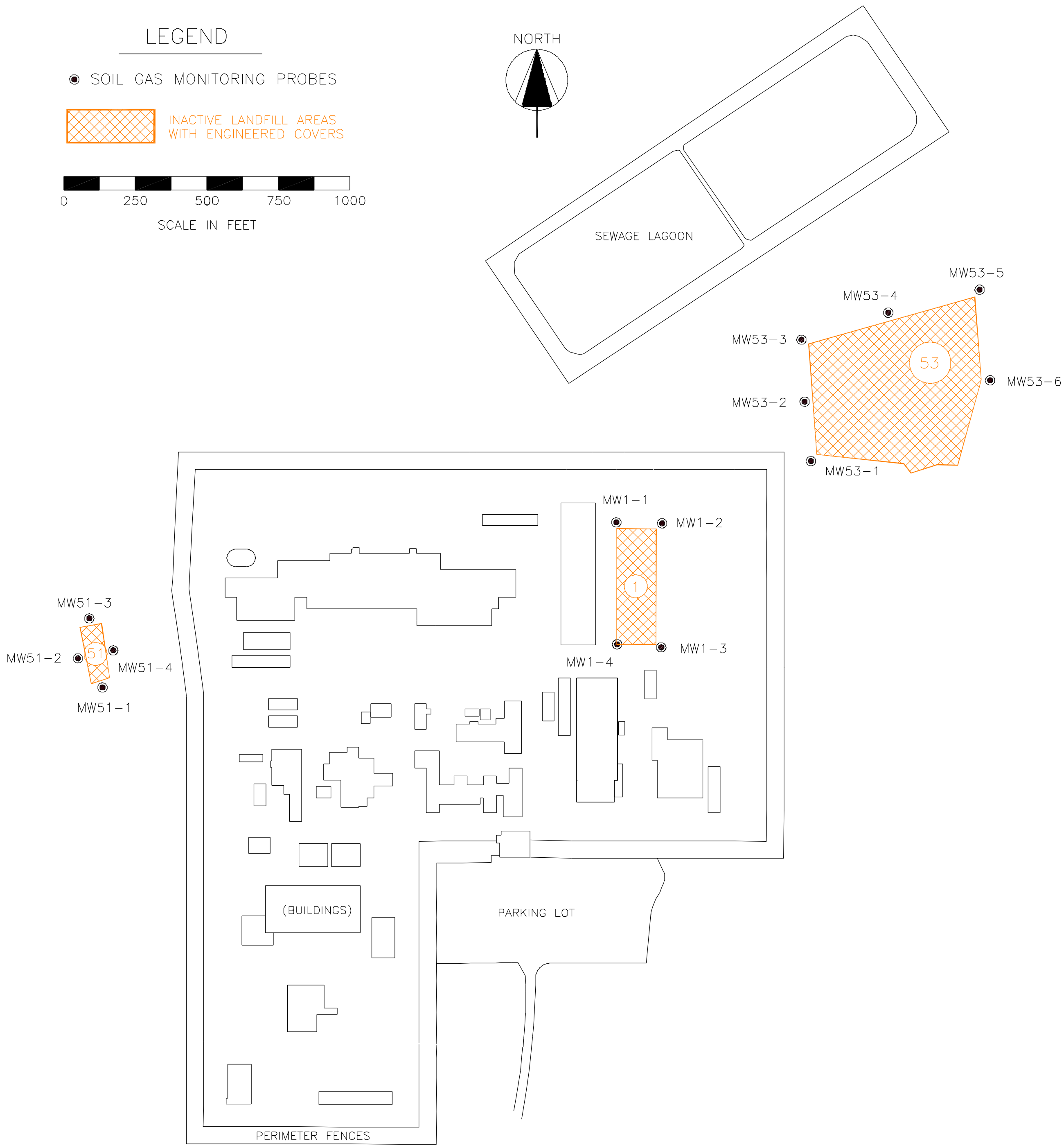

Figure 1-1 Location of NRF OU 8-05/6 Inactive Landfill Areas

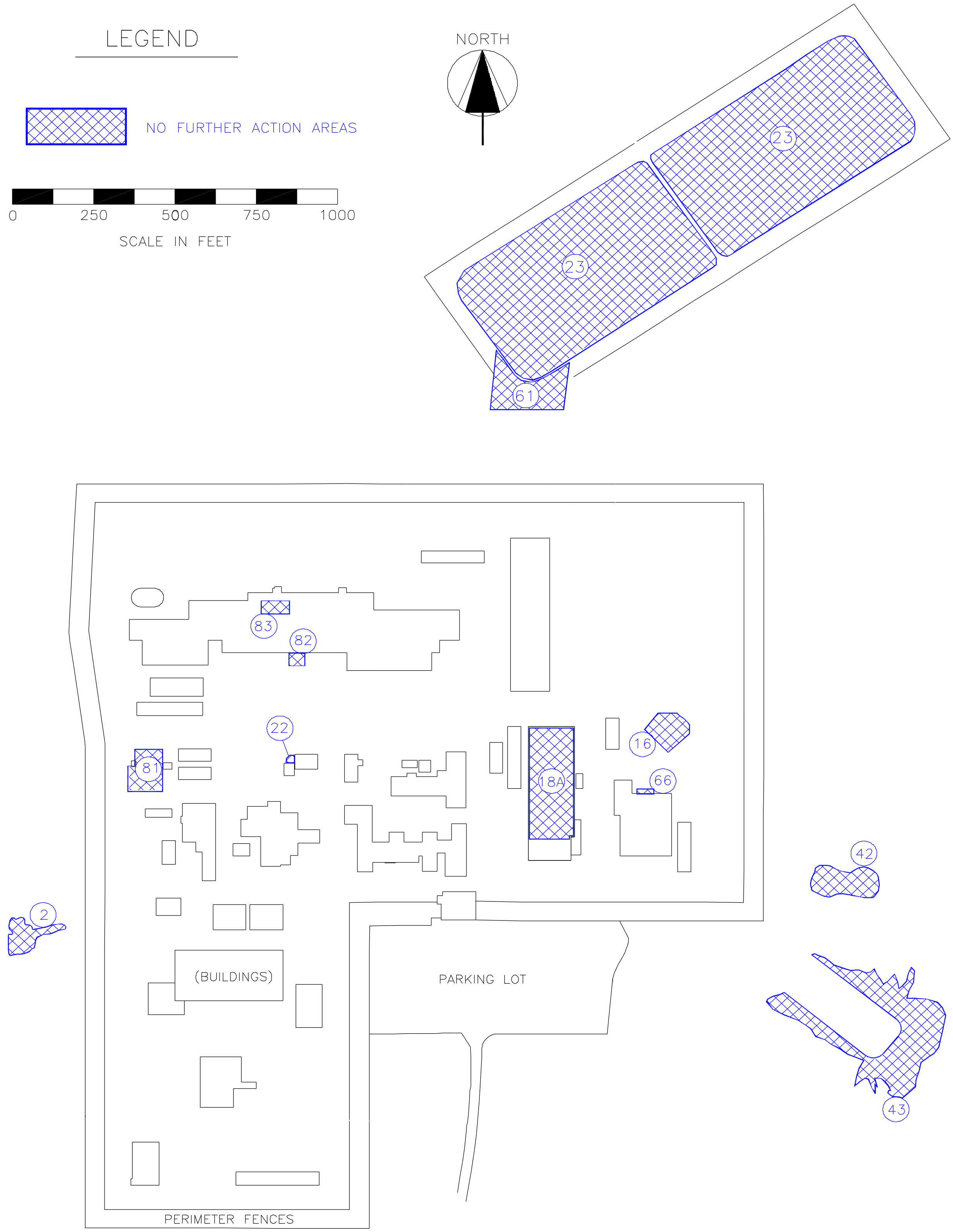

Figure 1-2 Location of OU 8-08 No Further Action Sites

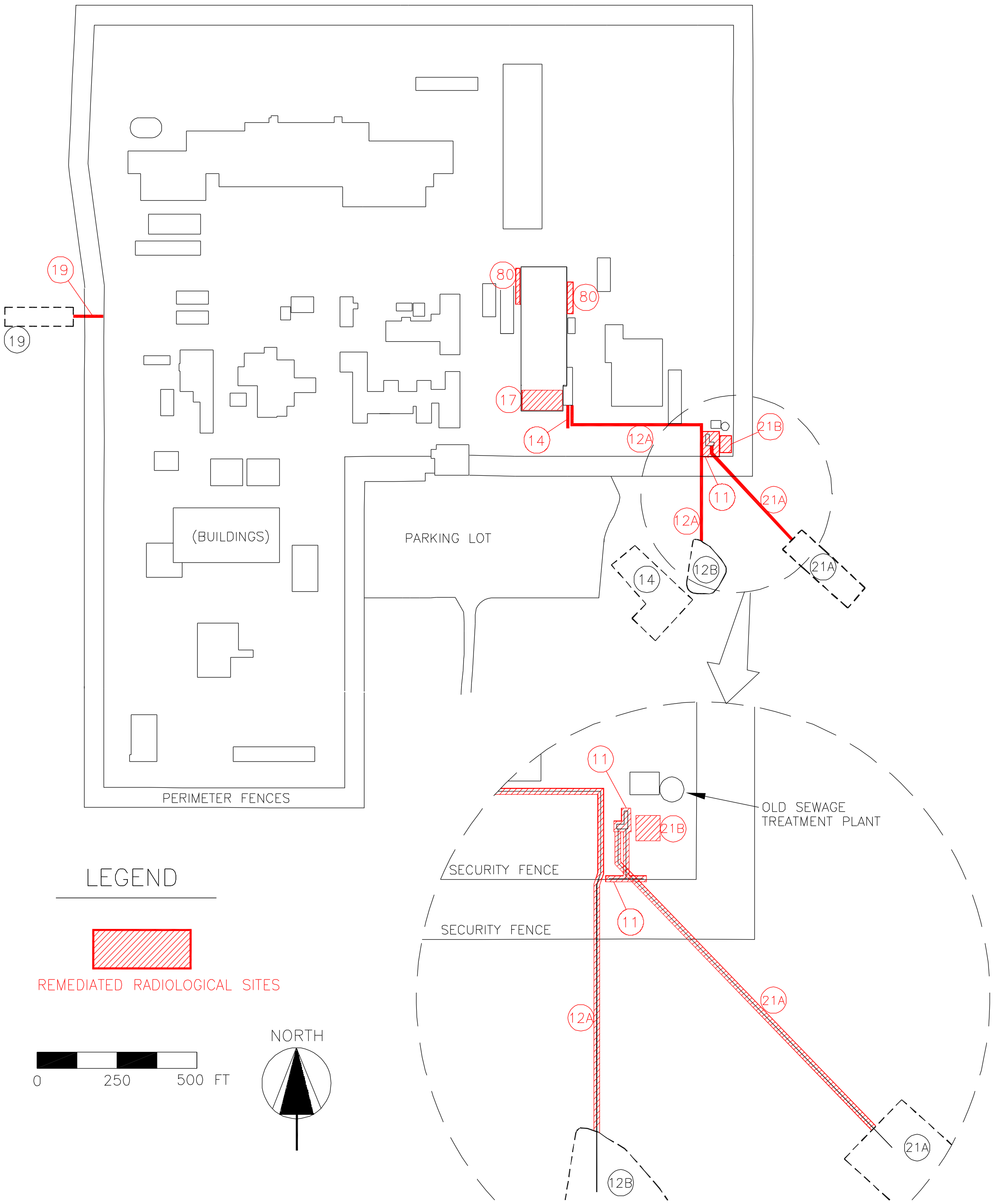

Figure 1-3 Location of OU 8-08 Remediated Radiological Sites

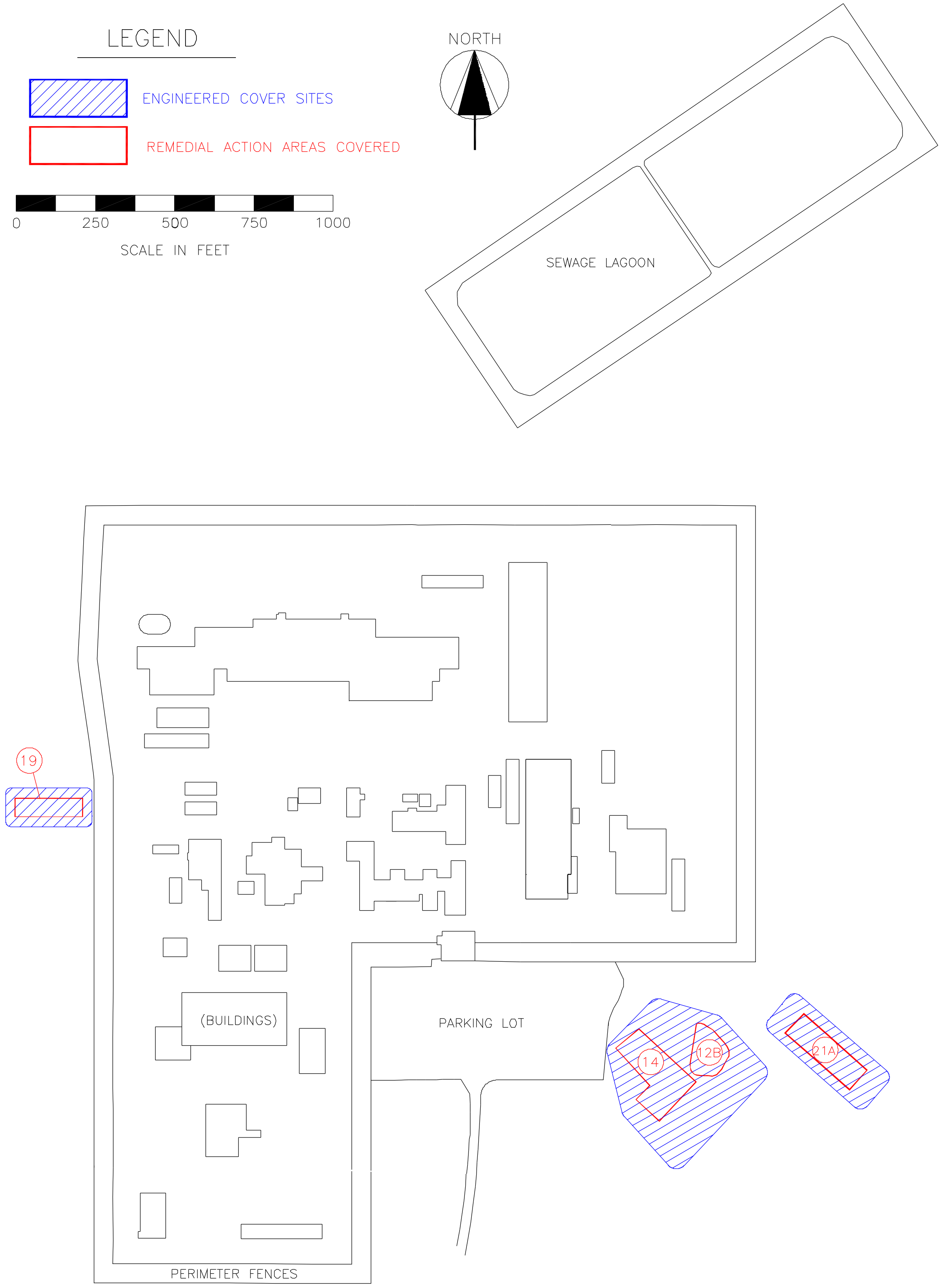

Figure 1-4 Location of OU 8-08 Engineered Covers

2.0 Site Chronology

Table 2-1 summarizes the chronology of significant events for the NRF OU 8-05/06 Inactive Landfill Areas (including groundwater monitoring wells and soil gas probes). Table 2-2 summarizes the chronology of significant events for the NRF OU 8-08 sites. These lists include key construction and regulatory dates.

Table 2 1 Chronology of NRF Inactive Landfills Areas

Date	Event
1960	Estimated initial closure of landfill site NRF-1
1963	Estimated initial closure of landfill site NRF-51
1970	Estimated initial closure of landfill site NRF-53
Circa 1987	Initial post closure discovery of landfill problem
November 1989	INL added to National Priorities List
November 1993	1st Track 2 Investigation completed (NRF-1 and NRF-51)
April 1994	2nd Track 2 Investigation completed (NRF-53)
September 1994	Record of Decision signed
October 1994	Remedial design began
May 1995	Groundwater monitoring wells construction began
August 1995	Remedial design completed
September 1995	Groundwater monitoring wells construction completed
February 1996	Landfill covers construction began
February 1996	Soil gas monitoring probes construction began
June 1996	Soil gas monitoring probes construction completed
September 1996	Landfill covers construction completed
September 1996	Final Inspection of landfill covers completed
February 2001	First Five-Year Review Report for OU 8-05/06 issued
November 2003	Replaced Soil Gas Probes MW1-1 and MW1-2

Table 2 2 Chronology of OU 8 08 Areas

Date	Event
November 1989	INL added to National Priorities List
September 1997	Completion of Remedial Investigation/Feasibility Study (RI/FS)
September 1998	Record of Decision signed
June 1999	Work at NRF-14 commenced
September 1999	Phase I Remedial Design/Remedial Action (RD/RA) Work Plan issued (remediation)
July 2002	Explanation of Significant Difference (to the Record of Decision) to add a third engineered cover was signed
August 2002	Phase II RD/RA Work Plan issued (cover construction)
June 2003	Phase I work completed
April 2004	Construction of OU 8-08 Engineered Covers began
June 2004	First Five-Year Review Report for OU 8-08 issued
October 2004	Phase II OU 8-08 Engineered Cover construction completed
October 2005	Final Inspection of OU 8-08 Engineered Covers completed

3.0 Background

3.1 Site Location and Demography

3.1.1 INL

INL is a government facility managed by the DOE. It is located 32 miles west of Idaho Falls, Idaho, and occupies 894 square miles (mi^2) of the northeastern portion of the Eastern Snake River Plain. Facilities at INL are primarily dedicated to environmental research, nuclear research and development, and waste management.

3.1.2 NRF

NRF is located on the west central side of INL, as shown in Figure 3-1, approximately 50 miles west of Idaho Falls, Idaho. NRF was established in 1949 as a testing site for the Naval Nuclear Propulsion Program. The Westinghouse Electric Company (WEC) operated NRF for DOE, Office of Naval Reactors from 1949 through the fall of 1998, at which time site operations were turned over to BBI. NRF covers seven mi^2, of which 80 acres are developed. At various times, up to 3,300 people occupied the site. Approximately 965 Bechtel employees and 200 long-term subcontractor and DOE employees are currently working at NRF. The nearest public roads to NRF are approximately seven miles west, ten miles north, and ten miles south.

3.1.3 Ecological Characteristics

The INL lies within the sagebrush steppe region of North America. The natural vegetation at the INL typically consists of a predominant shrub canopy with an underlayment of perennial grasses and forbs. The predominant shrub is Wyoming big sagebrush. Other important shrubs include Basin big sagebrush, winterfat, and green rabbit brush. Common native grasses include thick-spiked wheatgrass, bottlebrush squirreltail, Indian ricegrass, and needle-and-thread. Less common grasses are bluebunch wheatgrass (common at higher elevations on alluvial fans) and Great Basin wildrye (occurs in areas with deep soils between lava ridges, in sandy soils, and in disturbed sites). In comparison to the rest of the sagebrush steppe region, the INL supports a high diversity of forbs. Some of the common native forbs are globe-mallow, Hood’s phlox, various milkvetches, paintbrushes, and mustards (Anderson 2003).

The variety of habitats on the INL supports numerous species of reptiles, birds, and mammals. Several bird species warrant special concern because of their threatened status or sensitivity to disturbance. All birds of prey that exist on the INL are protected species. Of these birds, owls, hawks, and falcons are known to exist or have been spotted at NRF. There are no known endangered or threatened species that dwell within the NRF property boundary; however, the bald eagle (currently listed as a threatened species but is likely to be de-listed in the near future) has been spotted on occasion. Other animals that can be found near NRF include: antelope, mule deer, elk, moose, mountain lions, cottontail rabbits, ground squirrels, mice, badgers, beavers, bobcats, raccoons, coyotes, jackrabbits, starlings, weasels, bats, frogs, lizards, salamanders, snakes, swans, and a variety of small birds.

3.2 Site Physical Characteristics

The INL is located on the northeastern portion of the Eastern Snake River Plain, a volcanic plateau that is composed primarily of volcanic rocks and relatively minor amounts of sediments. Underlying INL is a series of basaltic flows containing sedimentary interbeds. The Snake River

Plain Aquifer (SRPA) is the largest potable aquifer in Idaho, and underlies the Eastern Snake River Plain and INL.

3.2.1 Climate Summary

The INL is located in a temperate climate, with warm summers and cold winters. Average daily temperatures range from 7 °F during the winter to 70 °F during the summer. Temperature extremes range from -47 °F to 105 °F. NRF receives approximately 8.3 inches of precipitation per year based on data collected at a weather reporting station located five miles south of the facility.

Since 1972, southeast Idaho has experienced three droughts. Each drought has been successively more severe than the previous drought. As shown in Figure 3-2, the first drought occurred between 1975 and 1980, the second between 1988 and 1993, and the latest between late 1999 and late 2004. Figure 3-3 compares precipitation received at Central Facility Area (CFA) located five miles south of NRF to the water table elevation in well USGS-12, which is located approximately three miles north of NRF. Note that changes in water level lag behind changes in average precipitation by approximately two to three years.

Figure 3-3 also indicates that precipitation to the Snake River Plain near NRF appears to be trending downward. During three dry periods, the trough that formed in the graph represented successively lower yearly precipitation. Between January 1972 and January 1989, CFA received a total of 149 inches of precipitation. In comparison, between January 1989 and the present, a period representing the same amount of time, CFA received a total of 136 inches of precipitation. Furthermore, the regional decline in SRPA water levels follows an identical pattern which indicates that these water levels may be as much influenced by declining long-term precipitation totals as by increased water usage from the SRPA.

This analysis suggests that in the future NRF may be adversely affected by cyclical droughts in two ways. First, declining water levels, over time, may require NRF to lower pump intake levels in the wells. Second, vegetation located on the earthen covers that may be suitable for temperate climates may become severely stressed (where some of the less drought tolerant plant species may not survive) under drier conditions than those that occurred between May 2003 and April 2004, when the INL received 3.71 inches of precipitation.

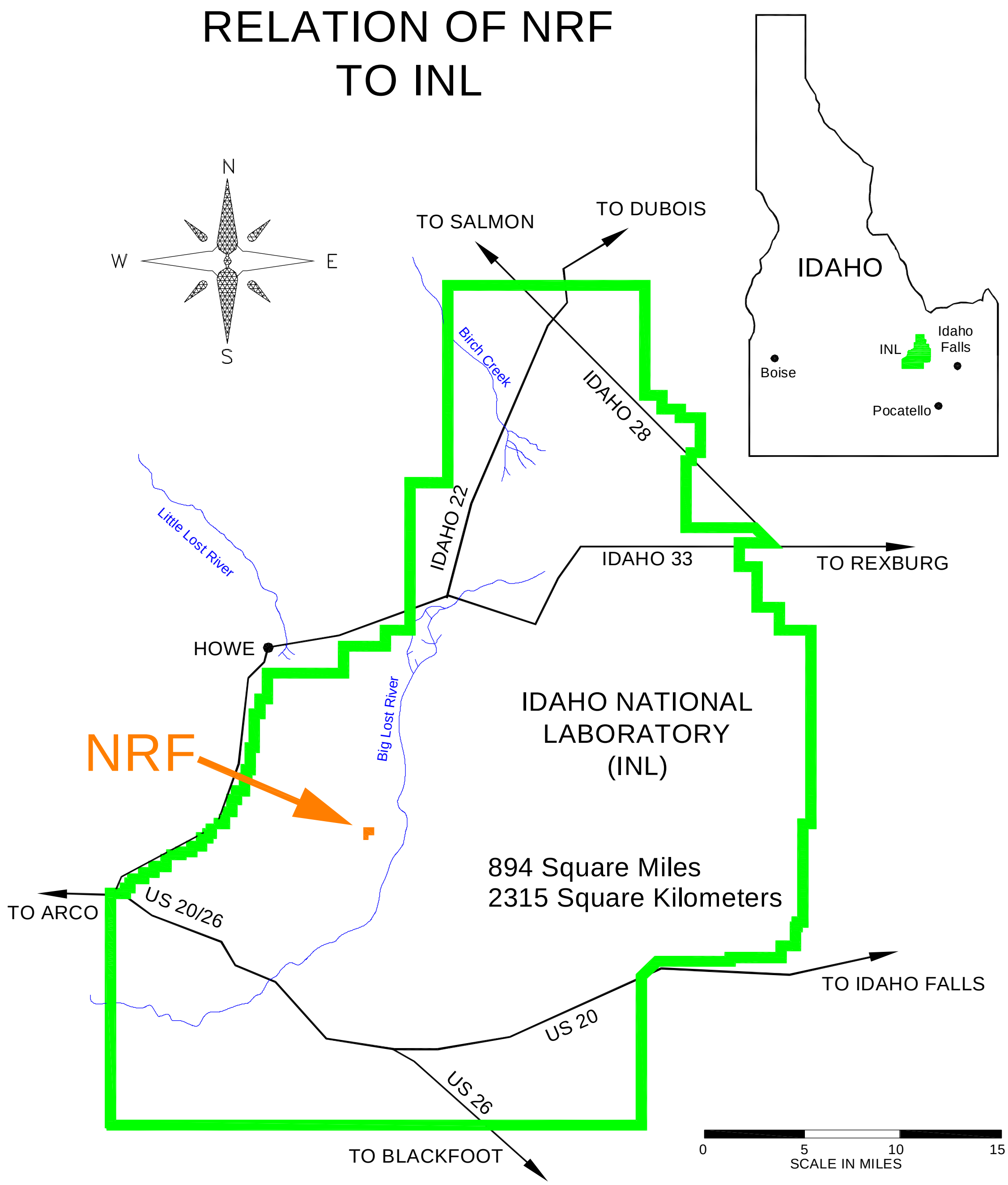

Figure 3-1 Location of the Naval Reactors Facility (Waste Area Group 8)

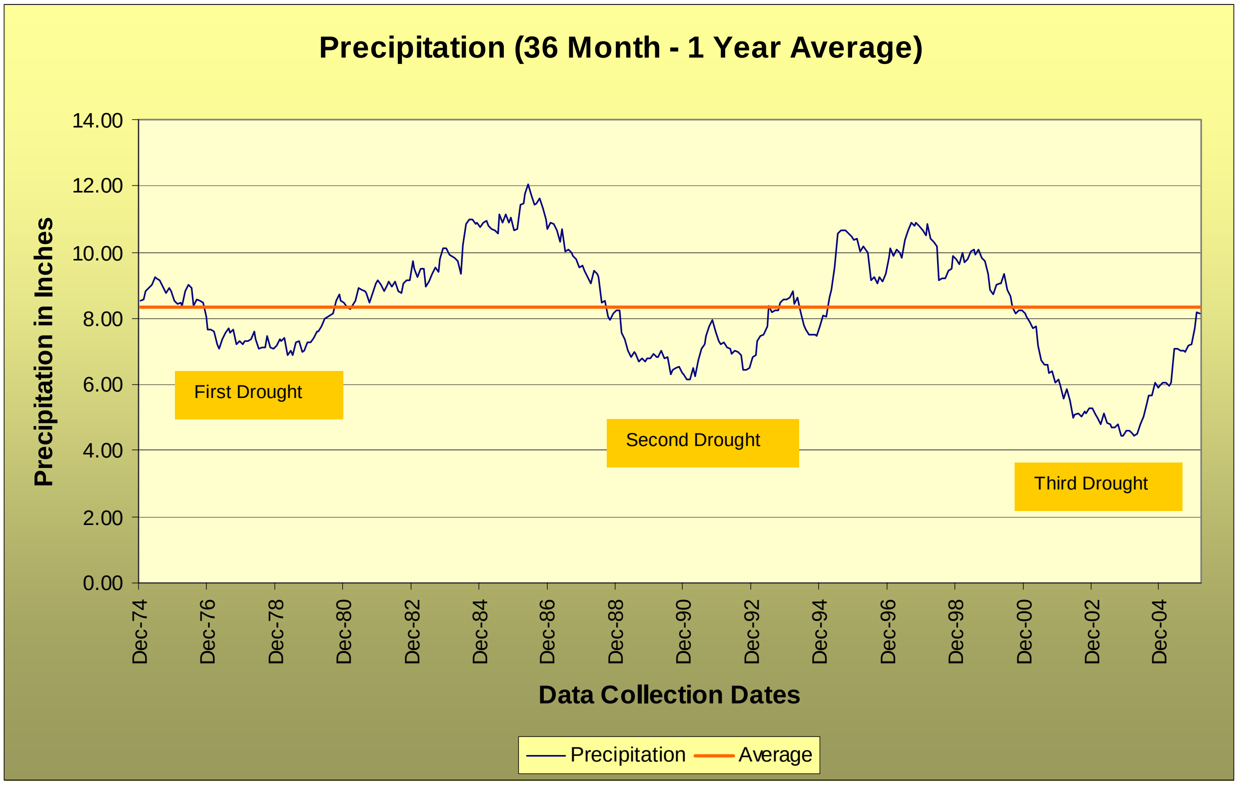

Figure 3-2 36 Month Running Average Precipitation Normalized over 1 Year

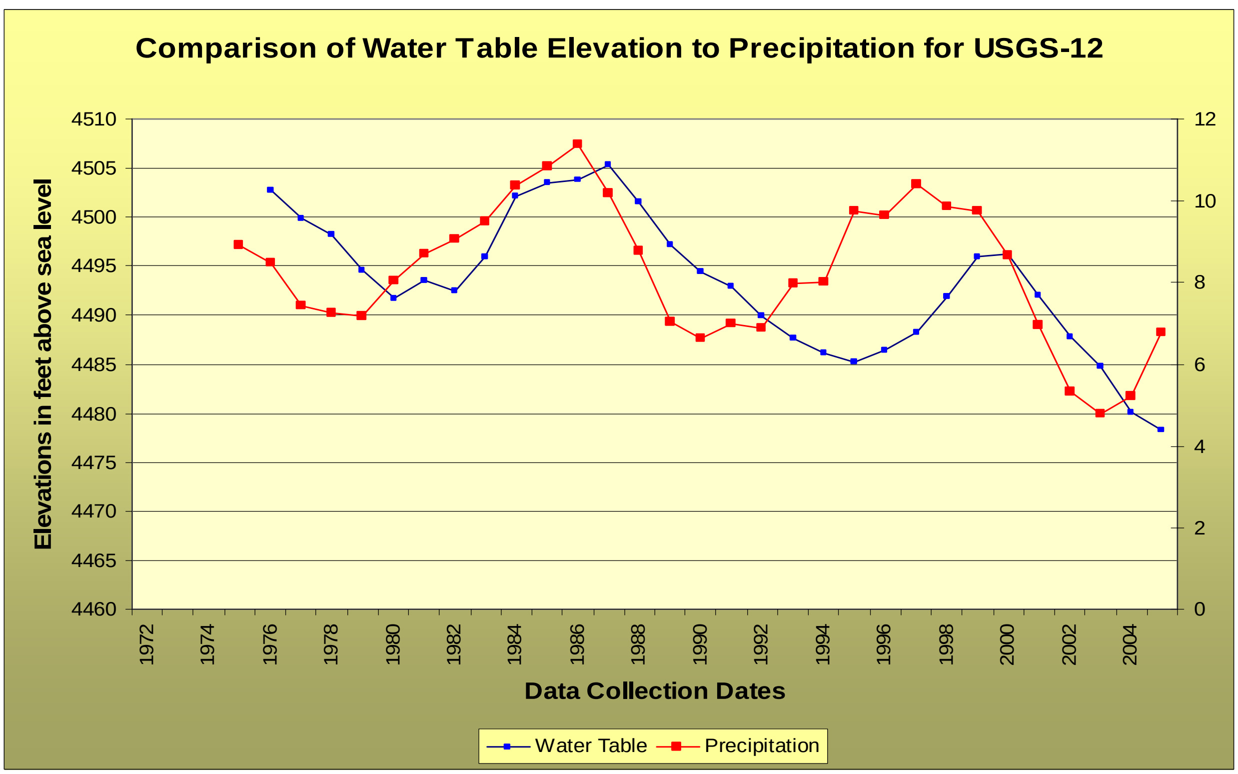

Figure 3-3 Precipitation and Water Table Elevation

3.2.2 Site Hydrogeology

3.2.2.1 SRPA

The SRPA is the largest source of potable water in Idaho, and underlies the Eastern Snake River Plain and the INL. The aquifer is approximately 200 miles long and 50 miles wide, and covers an area of approximately 9,600 mi^2. The depth to the SRPA at the INL varies from approximately 200 feet in the northeastern corner to approximately 900 feet in the southeastern corner. The distance between these extremes is 42 miles.

The EPA designated the SRPA as a sole-source aquifer under the Safe Drinking Water Act on October 7, 1991. On a grand scale, the SRPA is highly permeable because of the presence of fractures in the basalt; however, permeability on a local scale may vary greatly due to the high variability in the physical properties of the aquifer. Groundwater flow in the SRPA is to the south-southwest at rates between 1.5 to 20 feet per day. Near NRF, natural recharge to the SRPA occurs by infiltration of water (from precipitation runoff) from the Big Lost River, Little Lost River and Birch Creek, and to a lesser extent by direct infiltration of water (due to precipitation) into the soil over a wide area. Man made recharge sources to the aquifer at NRF include the Industrial Waste Ditch (IWD) and the sewage lagoon.

The SRPA occurs approximately 375 feet below NRF, and consists of a series of water saturated basalt flows and interlayered volcanic and sedimentary material. Drinking water for employees at NRF comes from several production wells located in the central portion of the facility. Figure 3-4 is a map showing the top of the aquifer near NRF during March 2006 based on water table elevation data collected from NRF wells. Currently water flows beneath NRF from the northeast to the southwest.

3.2.2.2 Industrial Waste Ditch

The NRF Industrial Waste Ditch is located at the northwest corner of NRF and extends approximately 3.2 miles to the northeast. In 1992, the volume of discharge to the IWD reached a maximum of approximately 171 million gallons per year. After the shutdown of the S5G and A1W prototype plants in the mid-1990s, the volume of discharge to the IWD declined rapidly (Figure 3-5). Since 2000, IWD effluent discharge has averaged six million gallons per year. At its maximum, water flowed in the IWD to a distance of approximately 1.8 miles. Currently water reaches a distance of approximately 150 yards.

3.2.2.3 Sewage Lagoons

The NRF sewage lagoons are two open rectangular ponds that measure 425 feet by 725 feet each. Only the northeast lagoon currently contains water. The lagoons were designed as facultative evaporation ponds; however, a portion of the effluent released to the lagoons infiltrates into the subsurface based on evidence gathered from nearby shallow wells and groundwater data. Some of the infiltrating water forms a shallow perched water zone beneath the wet lagoon. From 1990 to 2005, NRF released an estimated annual average of 17 million gallons of effluent to the sewage lagoons.

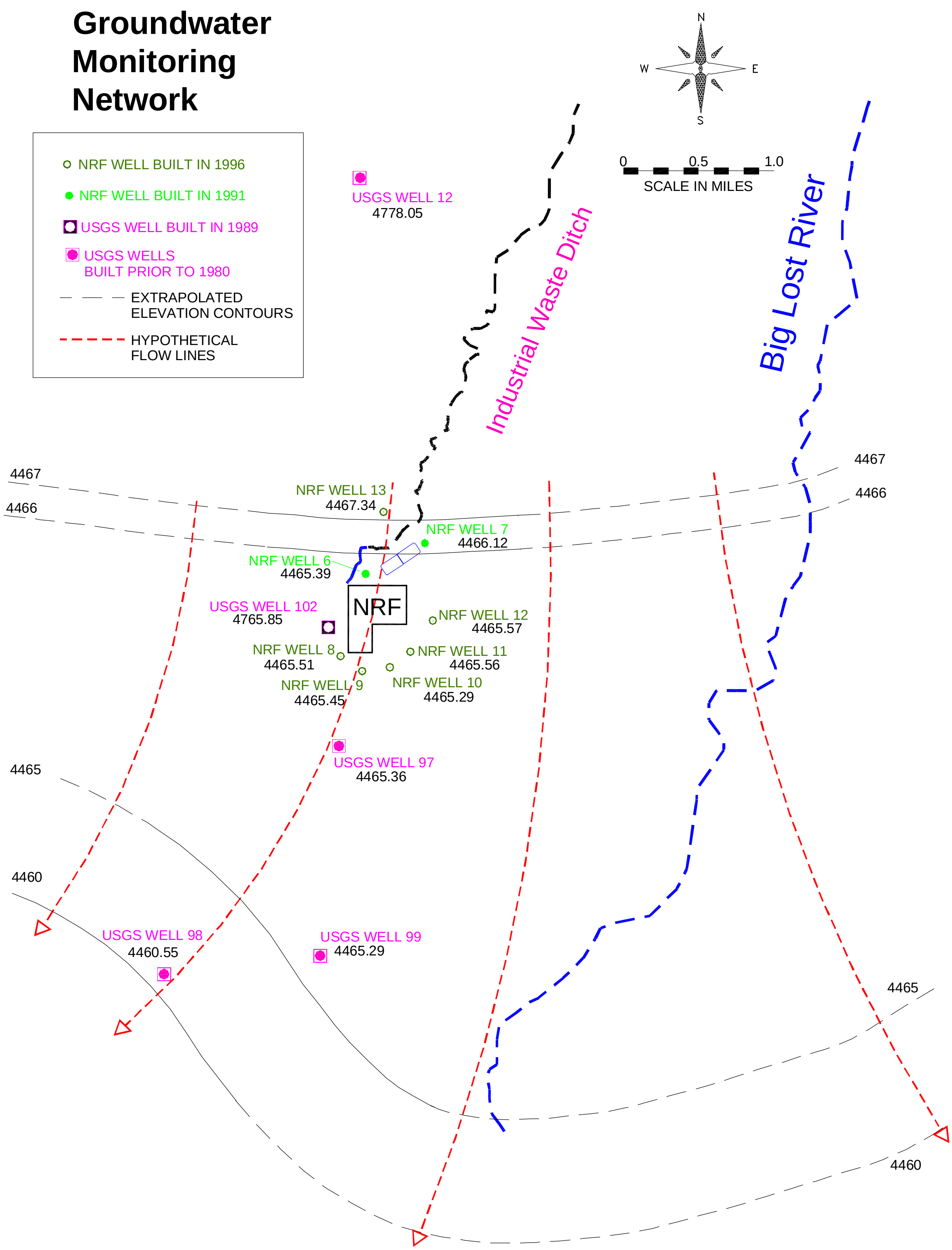

Figure 3-4 Top of Aquifer March 2006

3.2.2.4 Perched Water

Perched water, which lies above the regional water table between 20 and approximately 100 feet below land surface, occurs in several locations at NRF including beneath the IWD, the sewage lagoons, and historically the leaching beds/pits. In general, perched water forms at any location where a substantial surface recharge source is present. The most significant perched water at NRF is located beneath the outfall of the NRF IWD. Figure 3-6 provides a historical perspective to perched water located at NRF. This figure shows the estimated current extent of perched water (from the most current water level measurements) along the IWD and at the sewage lagoons versus its extent in 1993. Figure 3-6 also shows the locations and extent of historical perched water zones at the A1W and S1W Leaching Beds and an area located approximately 1000 ft north of the sewage lagoons.

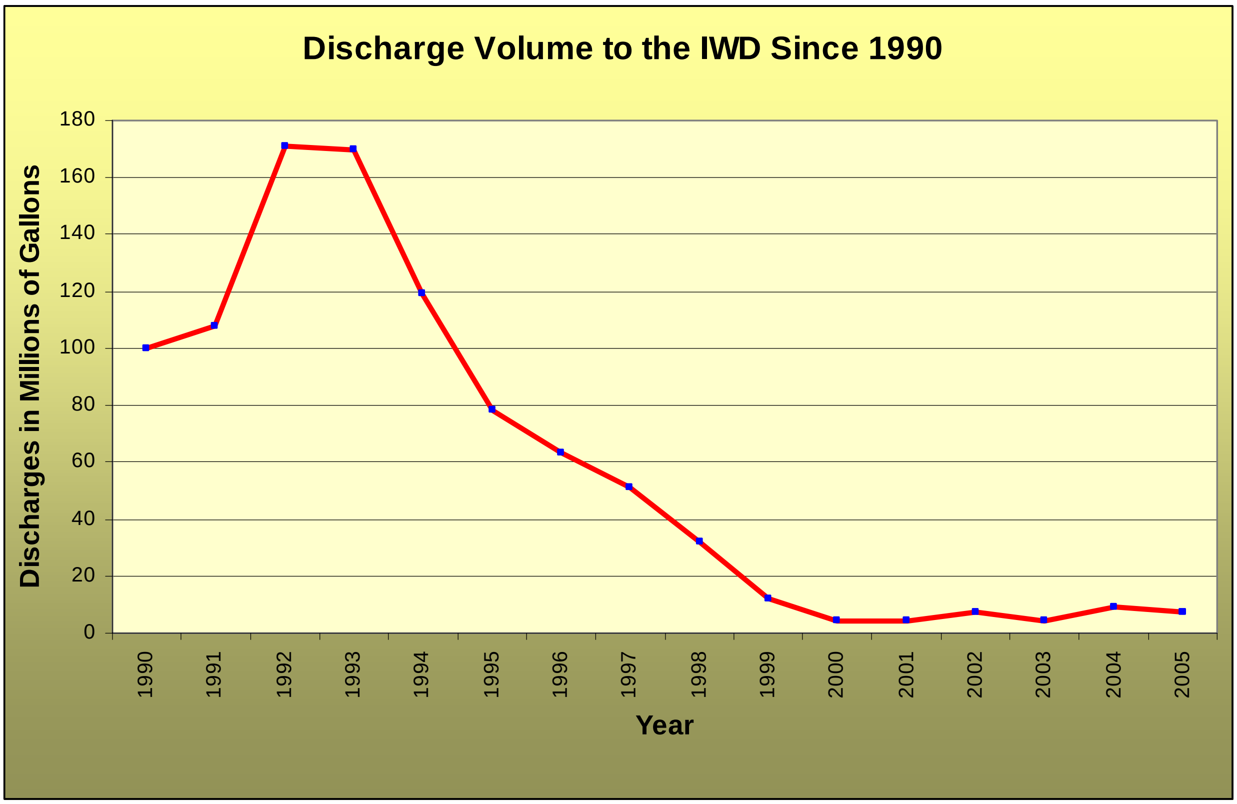

Figure 3-5 Volume of Water Discharged to the NRF IWD

Because of reduced discharge volume to the IWD, the perched water observed at PS-6 (located approximately 1000 ft northeast of well NRF-6) in 1993 is now gone. Similarly, the perched water zone located at the outfall of the IWD has been reduced in areal extent by approximately 20 percent of what it was in 1993. The Sewage Lagoon (SL) perched water zone is estimated to be approximately the same size as in 1993.

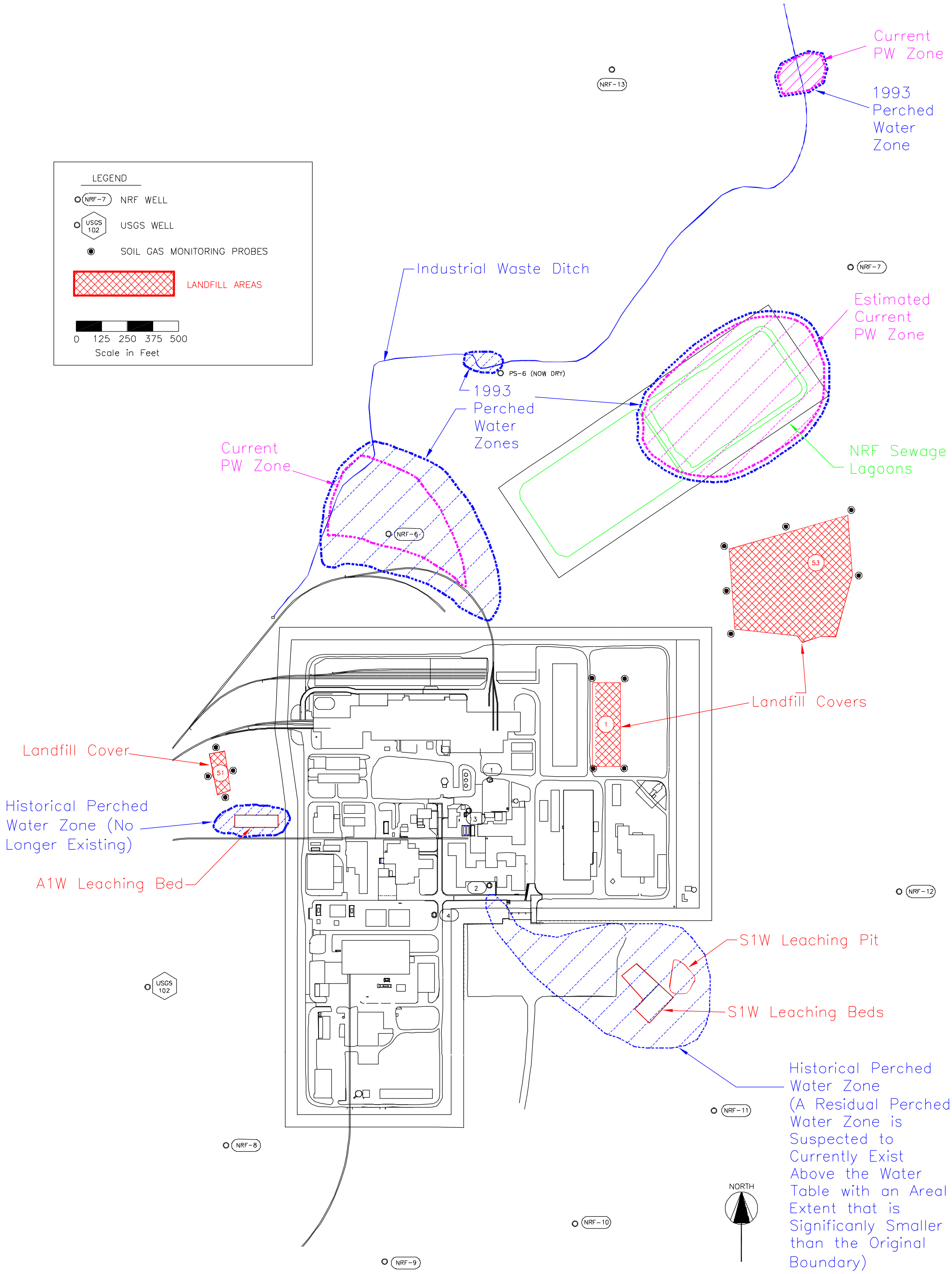

Figure 3-6 Current and Historical Perched Water at NRF

3.2.2.5 Groundwater Monitoring

NRF has been routinely collecting groundwater monitoring data since 1989. The NRF Groundwater Monitoring Network consists of 13 wells strategically located to monitor upgradient and downgradient water quality. Figure 3-7 shows the location of the NRF groundwater monitoring wells.

The 13 wells are grouped into categories that indicate the portion of the aquifer being monitored. These categories are identified as Regional Upgradient, Regional Downgradient, Local Downgradient, and Effluent System. Table 3-1 lists the wells with the associated well category or group.

Table 3 1 Well Groups

Well Group	Well
Regional Upgradient	USGS-12, NRF-7*
Regional Downgradient	USGS-97, USGS-98, USGS-99
Effluent System	NRF-6, NRF-13**
Local Downgradient	USGS-102, NRF-8, NRF-9, NRF-10, NRF-11, NRF-12

* NRF-7 was originally constructed as an Effluent System well, but well sample characteristics more closely represent background water quality.

** NRF-13 was originally constructed as a Regional Upgradient well, but well sample characteristics do not represent upgradient water quality. It has been included in the Effluent System well group; however, as noted in Appendix A, the well's ability to monitor the effluent system has been questioned.

3.2.2.6 Water Table Elevations

The water table in the SRPA has been declining for the past several decades. A direct consequence of this decline is that many domestic and agricultural wells in eastern Idaho had to be deepened to prevent them from going dry. The wells at NRF have been similarly affected. In 2005, well USGS-98 was deepened because the pump intake level was approximately one foot below the water level. Hydrographs for wells USGS-12, NRF-6, and USGS-98 (from north to south) have been plotted and are shown in Figure 3-8, Figure 3-9, and Figure 3-10, respectively. These wells are typical of the aquifer conditions near NRF.

These graphs display the same horizontal and vertical scales for ease of comparison and show both cyclical and long-term trends in water table elevation. The graph for USGS-12 best exemplifies the stair-step pattern of decline in water table elevation. In this well, the water level has declined about 15 feet since 1980 (valley to valley on the graph). The water level in NRF-6 has declined almost 10 feet since 1994. The most important information from these graphs is that water levels can drop rapidly; therefore, NRF must continually track water level changes to ensure ample time is available to deepen wells, if needed. Table 3-2 shows the physical characteristics of the NRF wells. This table indicates that all NRF wells have ample water above the well intake with the exception of USGS-97 (8.28 feet) and USGS-99 (15.59 feet). Presently, NRF does not anticipate the need to deepen the wells for possibly five to ten years if current trends continue.

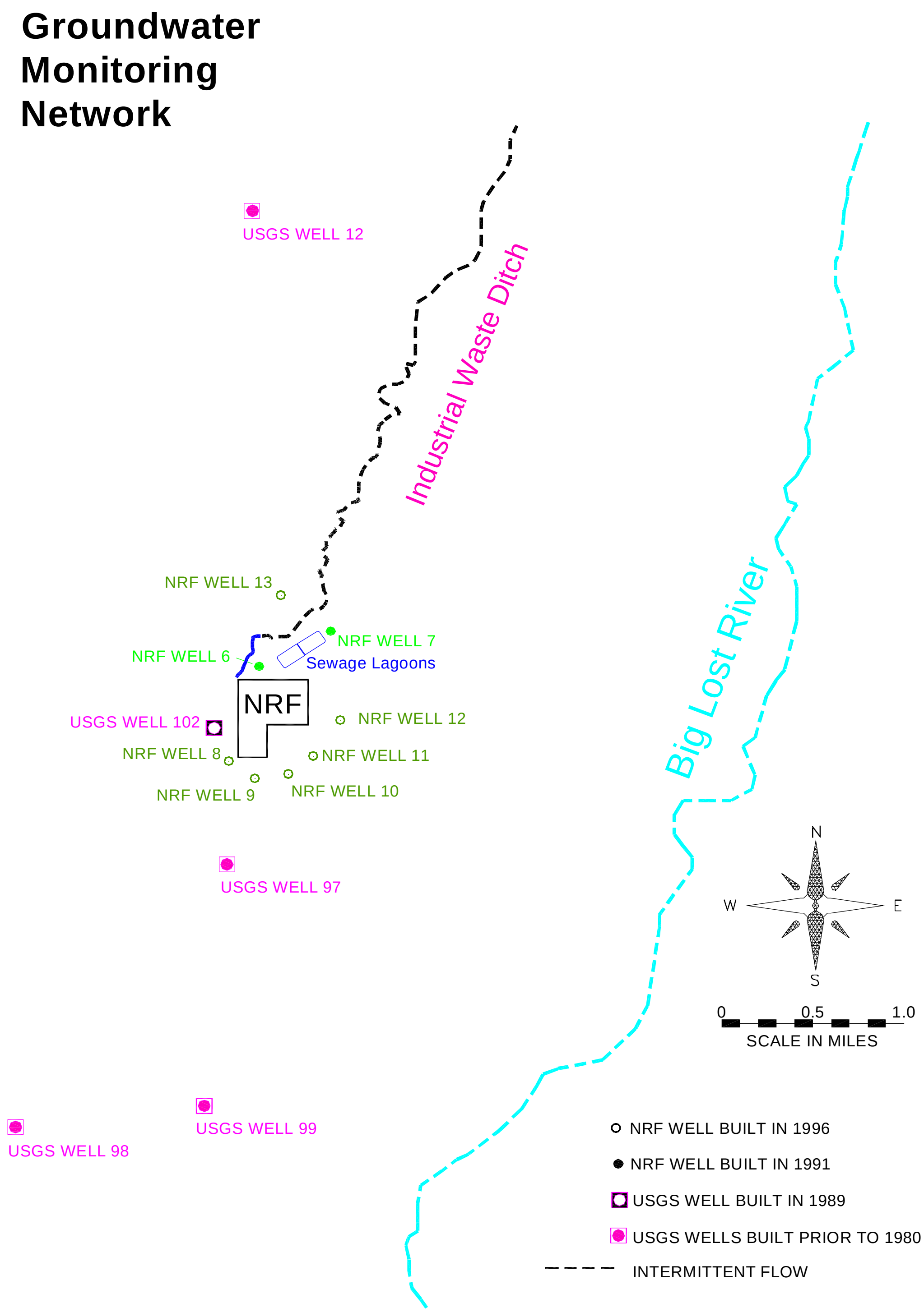

Figure 3-7 Location of NRF Groundwater Monitoring Wells

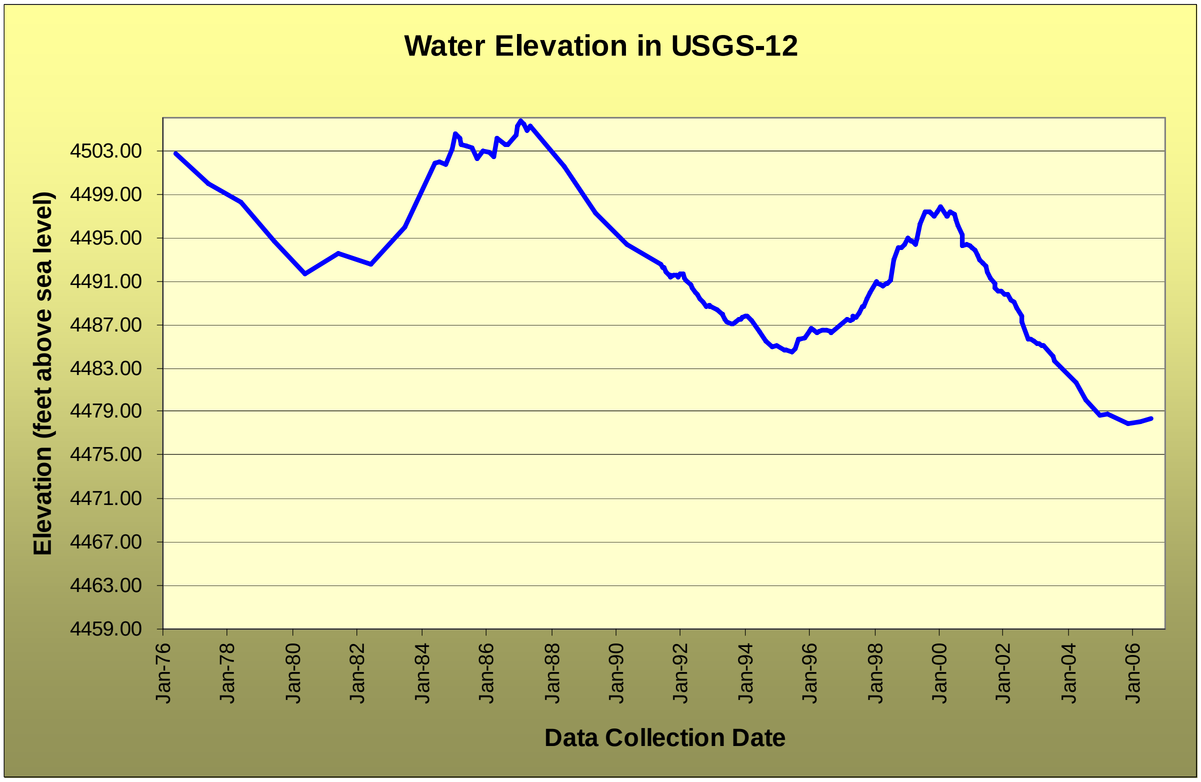

Figure 3-8 Water Table Elevation at USGS-12

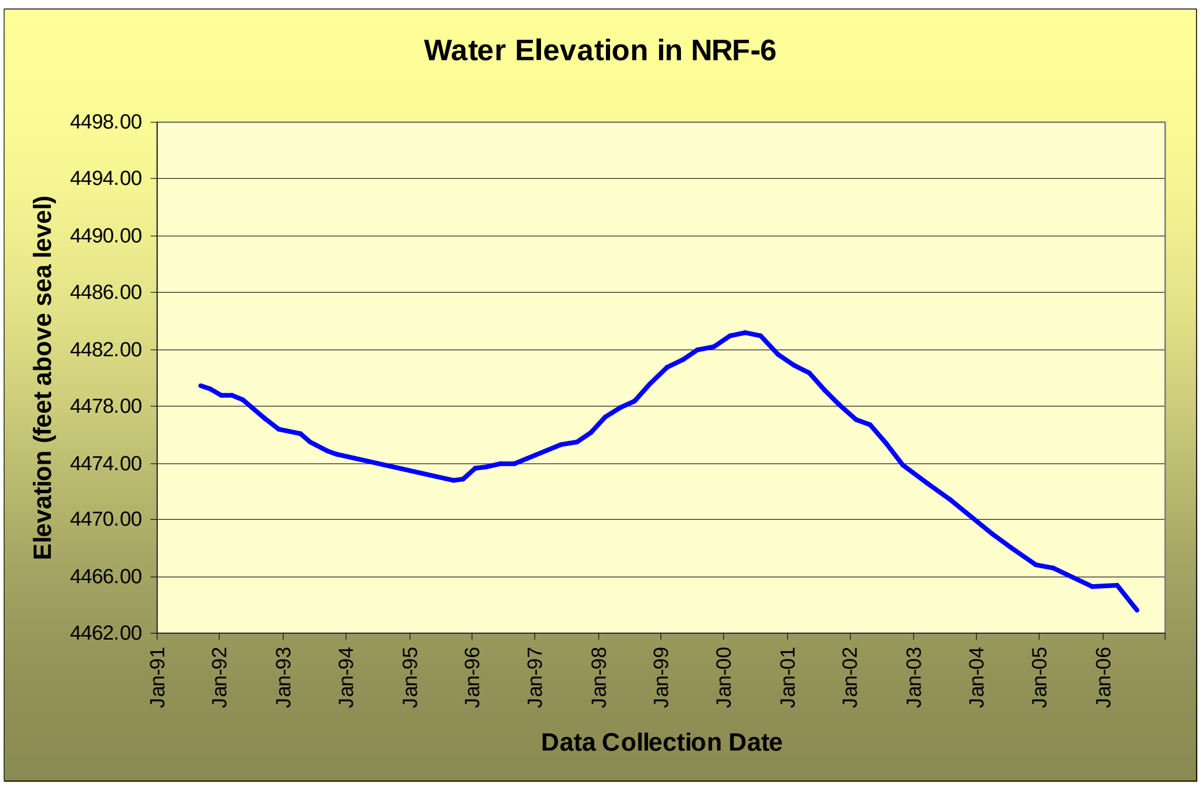

Figure 3-9 Water Table Elevation at NRF-6

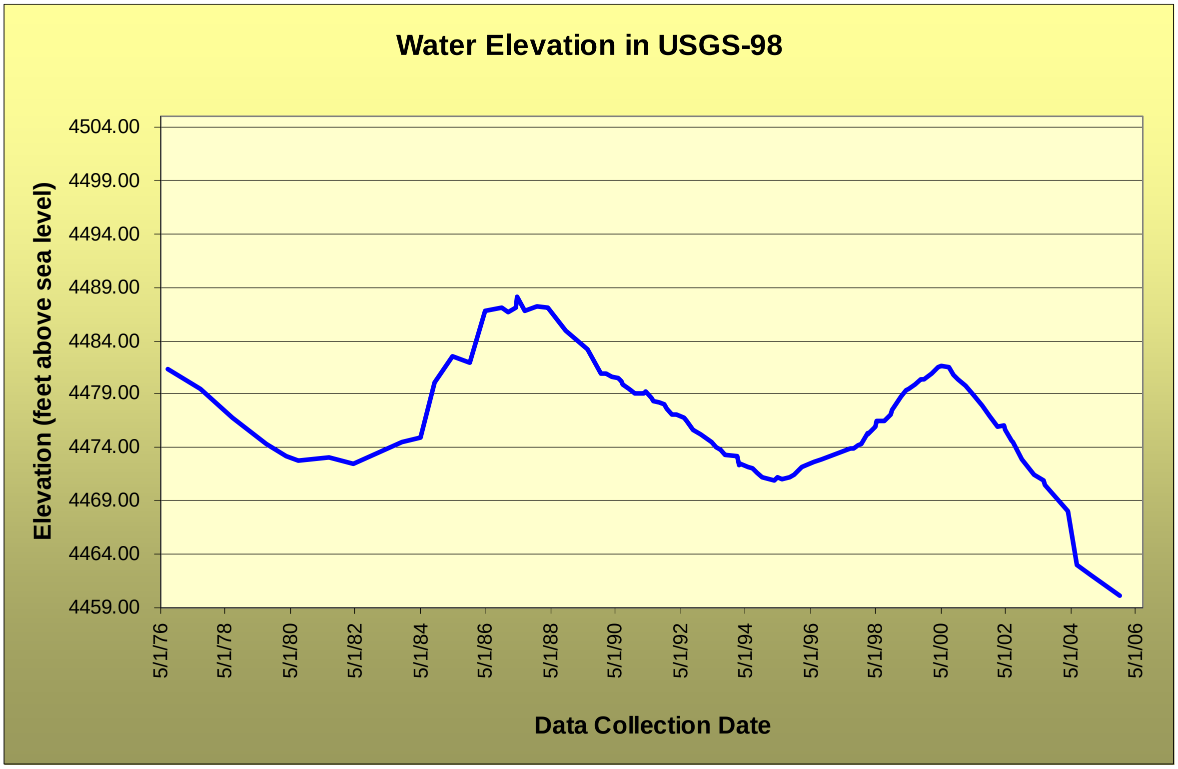

Figure 3-10 Water Table Elevation at USGS-98

3.2.2.7 Flood Potential

NRF is located in the central portion of the INL. The land surface at NRF is relatively flat, with elevations ranging from 4,840 feet near the wetted end of the NRF IWD, which is located approximately 150 yards north of NRF, to 4,870 feet at the south side of NRF. Flooding at NRF is not likely, since the facility is not located within the current 100-year flood plain. A flood of the Big Lost River with a recurrence interval in excess of 10,000 years is capable of inundating NRF (Ostenaa 1998, 1999). Recurrence interval refers to how often a flood of a given magnitude is likely to occur. This number assumes that the diversion dam located approximately 8 miles southwest of NRF is intact. Without the diversion dam, the flood recurrence interval capable of inundating NRF shrinks to something considerably less.

3.3 Site Geology

3.3.1 Overview

The INL is located on the northeastern portion of the Eastern Snake River Plain, a volcanic plateau that is composed primarily of volcanic rocks and relatively minor amounts of sediments. Underlying the INL is a series of basaltic flows containing some sedimentary layers (called interbeds).

NRF is located on the Big Lost River alluvial plain and is approximately 1.5 miles from the closest portion of the Big Lost River. The thickness of alluvial sediment near NRF ranges from several inches to in excess of 60 feet north of NRF. Near surface sediments at NRF consist of alluvial deposits of the Big Lost River and are composed of loosely compacted river deposits of

Table 3 2 Physical Characteristic of the NRF Groundwater Monitoring Wells

Well Name	Well Elevation at Surface	Well Elevation at Completion Depth	Elevation of Pump Intake	Most Recent Water Table Elevation	Date Measurement Taken	Water Above Pump Intake in feet	Screened Interval Closest to Pump
NRF 6	4846.62	4429.62	4444.00	4465.75	11/2/05	21.75	Stainless Steel; 4430 - 4488 feet
NRF 7	4843.09	4428.09	4433.00	4465.80	11/1/05	32.80	Stainless Steel; 4428 - 4478 feet
NRF 8	4852.33	4427.33	4437.33	4464.64	11/2/05	27.31	Stainless Steel; 4429 - 4479 feet
NRF 9	4853.47	4428.47	4441.47	4465.40	10/31/05	23.93	Stainless Steel; 4431 - 4481 feet
NRF 10	4853.10	4426.10	4438.10	4465.22	11/2/05	27.12	Stainless Steel; 4426 - 4476 feet
NRF 11	4850.73	4433.73	4441.73	4465.50	11/1/05	23.77	Stainless Steel; 4434 - 4484 feet
NRF 12	4850.83	4429.83	4436.83	4465.52	11/1/05	28.69	Stainless Steel; 4430 - 4480 feet
NRF 13	4843.59	4418.59	4438.59	4468.55	11/1/05	29.96	Stainless Steel; 4419 - 4469 feet
USGS 12	4819.58	4127.58	4461.58	4477.86	11/1/05	16.28	Open Hole; 4128 - 4235 feet
USGS 97	4858.95	4348.95	4456.95	4465.24	10/31/05	8.28	Open Hole; 4348 - 4471 feet
USGS 98	4883.29	4378.29	4440.29	4460.15	11/3/05	19.86	Perforated carbon steel; 4462 - 4482 feet
USGS 99	4872.36	4422.36	4449.36	4464.95	11/3/05	15.59	Perforated carbon steel; 4423 - 4569 feet
USGS 102	4850.81	4406.21	4429.81	4465.78	11/2/05	35.97	Open Hole; 4407 - 4491 feet

All elevations are in feet above sea level.

silt, sand, and pebble-sized gravel. Most of the soil near NRF is described as sandy loam or loess. The loess is an accumulation of wind deposited silt-sized particles probably of glacial origin.

A complex sequence of basalt flows and sedimentary layers underlie NRF. The sedimentary interbeds vary in thickness and lateral extent and separate the basalt flows that underlie the surface sediments. Samples from basalt flows have been correlated into approximately 23 flow groups that erupted from related source areas. Known eruption vents occur to the southwest of NRF, along what is referred to as the Arco volcanic rift zone, to the southeast along the axial volcanic zone, and to the north at Atomic Energy Commission Butte. The uneven alluvial thickness and undulating basalt surface at NRF are typical of basalt flow morphology.

3.3.2 Geology of the Snake River Plain

The Snake River Plain (SRP) can be described as a bow shaped plain that stretches from Ashton, Idaho at its northeastern edge to Ontario, Oregon at its western edge. Elevation of the plain varies from approximately 6500 feet near Ashton to approximately 2100 feet west of Boise, Idaho. Rocks of basaltic composition are prominent at the surface over the entire SRP, thus it is often mistakenly considered to be one region or unit possessing a common structure and origin. From a geological perspective, the SRP can be separated into two or three distinctive regions.

Some researchers (Mabey, 1982), divide the SRP into a western segment, a central segment, and an eastern segment based on the geophysical characteristics of the plain. Other researchers (Leeman, 1982, Alt and Hyndman, 1989) note that the SRP can be divided into two segments based on its physical characteristics. In either case, NRF is located in the eastern portion of the SRP. The eastern and central SRP are not fault bounded. The eastern and central SRP are best described geologically as a thin veneer of basalt overlying a very thick sequence of rhyolite (the fine-grained equivalent of granite). Both the basalt and rhyolite sequences are occasionally interlayered with sedimentary deposits. A study of the rocks encountered in INEL-1 deep borehole located approximately two miles south of NRF shows that 2200 feet of interbedded basalt and sediments overlie at least 8200 feet of rocks composed of compacted volcanic fragments and ash or their derivatives. This log is typical of the central and eastern SRP (Mann, 1986).

3.3.3 Geomorphology

NRF is located on a fluvial plain, the origin of which is attributed to historical deposition of sediments associated with the Big Lost River. Sediments deposited by the Big Lost River consist of interbedded sand, gravel, silt, and clay that in places are in excess of sixty feet thick. The sand, gravel, and silt of the alluvial plain were deposited historically during a period of time that possessed a climate that was considerably wetter than the climate of today. At present, the plain is experiencing a period of reduced-deposition. The fluvial plain surrounding NRF is oriented generally north-south, and is bounded on the east by basalt outcrops. These outcrops rise to a maximum height of approximately 30 feet above the adjacent fluvial plain. Northwest of NRF, an arcuate-shaped ridge is present at the surface. Best seen on aerial photographs, this feature is reported to be a series of extinct eruption vents (EG&G, 1988). These vents begin several miles west of NRF, but are not visible at the surface at NRF. Low lying, highly or moderately weathered basalt flows rising between 10 and 30 feet above the fluvial plain are located approximately 1/2 mile west of NRF. Beyond these low lying hills is the Lost River Mountain Range. These mountains rise to an elevation in excess of 9000 feet.

Aerial photographs taken of the area surrounding NRF show a mosaic of abandoned or dry meandering channels. Several prominent features are evident in these photographs, including a number of point bar deposits and abandoned oxbows. A major abandoned meander channel is located approximately 600 feet due west of the IWD. This channel is 12 feet across and 6 to 8 feet deep. At the surface, abandoned meander channels are present in varying states of erosion. The regional surface surrounding NRF gently dips to the north, and ranges in elevation from 4870 feet south of NRF to 4830 feet north of NRF. The elevation within the NRF security fence ranges from 4848 feet to 4852 feet above sea level. Several man-made irrigation canals cross the desert terrain near NRF. The most prominent of these canals lies approximately 1/4-mile north-northwest of NRF. This canal is 20 feet wide and 15 feet deep. It rises above the desert floor 8 to 10 feet. Water no longer flows in these channels and canals, and they do not appreciably influence the hydrogeology of the IWD. These features would affect the hydrology of NRF only during an extreme flood event (like the 10,000 year flood) associated with the Big Lost River.

3.3.4 Structural Geology

The eastern SRP lies within the Basin and Range physiographic province, but within itself exhibits few characteristics typical of the basin and range spreading. The general appearance of the plain suggests that it was formed from rifting oriented along a northeast/southwest trending axis. This would result in the apparent lateral separation of the northwest-southeast trending mountains, which are located on either side of the SRP. In actuality, rifting is occurring, but the orientation is along a northwest-southeast trending axis. Several prominent rift features embedded in the Snake River Plain are observable on high altitude reconnaissance maps of the eastern SRP. These features are believed to be extensions of the normal faults that bound the ranges located to the north and south of the plain.

A combination of the North American continent moving westward, and a rifting center located near the eastern edge of the Great Basin, has caused a stretching of the crust. This stretching is exhibited in the form of down dropped valleys and raised mountains in most of the Great Basin. In the SRP, this stretching is accommodated by plastic flow and infilling with basalt (Alt and Hyndman, 1989; Mabey, 1982; Leeman, 1982).

3.3.5 Lithostratigraphy

The following four sections discuss the important rock and sediment layers present beneath NRF. The four layers include the near surface alluvium, the boundary between the near surface alluvium and the basalt, interbeds contained within the basalt, and the basalt itself. Much of what is known about the physical characteristics of the rocks and sediments is derived from the numerous boreholes and wells that have been drilled at NRF over the past 50 years.

3.3.5.1 Near Surface Alluvium

There are two types of surface sedimentary deposits typically found at NRF. The topsoils are primarily loess deposits believed to be of wind-blown origin. Analysis of the loess shows that its primary constituent is the clay montmorillonite combined with lesser amounts of the clay illite, quartz, feldspar, and various carbonate minerals (Chen-Northern Report, 1991). Montmorillonite is a water-absorbing (swelling) clay and possesses an affinity for adsorbing positively charged ions (Deer et. al, 1978, p. 250). The thickness of the loess near NRF varies from several inches to over ten feet (EG&G Report, 1988, Phase I Closure Plan and Sample Collection Report, WEC, 1988). In some isolated locations near NRF, the removal of fine dirt by the wind has caused fine grain sand dune deposits to form. In most places near NRF, the loess and sand deposits overlie river deposited gravels and sands.

NRF is located near the western edge of a river (meander) plain. This plain is several miles wide and consists of well rounded to sub-angular, moderately to poorly sorted sand and gravel interbedded with silt and clay. Much of the sand and gravel is stratified, which is evidence of its river origin. The gravels consist of a wide variety of rock types, the source of which are the mountains located north and west of NRF, and include material of sedimentary, metamorphic, or igneous (plutonic) origin. Individual pebbles range in size from three quarters of an inch to two inches in diameter. Some of the pebbles are composed of basalt derived from the basalt flows that surround the river plain. The shape of individual gravel pebbles is indicative of distance of transport and resistance to abrasion. Clay and fine silt interbeds are found sporadically throughout the river sediments, but are commonly found at the basalt/sediment interface. These clay interbeds usually possess lower permeability than the surrounding sand and gravel. Past geologic investigations have demonstrated that the formation of perched water is facilitated by infilling of fractures in the top of the basalt with clay (Cecil et. al, 1991).

The gravels of the Big Lost River either directly overlie a thin soil/clay layer immediately overlying the basalt or a widespread clay and silt deposit interpreted to be of fluvial (river) or lacustrine (lake) origin (F/L deposit). The contact between the alluvium and clay and silt deposit has been described as abrupt to gradational. In areas where alluvium was observed to overlay basalt, the contact was often marked by an increase in the percentage of basalt pieces imbedded within a one to two foot layer of soil located directly above the basalt bedrock. These soils ranged from white to light brown in color and are interpreted to be a buried soil horizon that developed prior to the deposition of the fluvium. The F/L deposit is coarser grained and darker in color than the soil covering the bedrock. The F/L deposit was determined to be present wherever the elevation of the top of the basalt was below approximately 4825 feet above sea level (asl).

The F/L deposit is characterized by light brown silty clay interbedded with fine sand and occasional gravels. These layers occur as repetitive fining upward sequences that range in thickness from four inches to one foot. Near the contact with the underlying basalt, these fining units are occasionally interlayered with basaltic gravels. Percolating water that originates from surface discharge sources or precipitation appears to be inhibited by the clay content of this unit. A large portion of the IWD is underlain by the F/L deposit. Borehole data indicates that the surface of this deposit slopes to the southeast.

3.3.5.2 Top of Basalt

Over the past 35 years, a number of boreholes have been drilled near NRF that have penetrated to the top of the basalt. These data were used to construct a map of the top of the basalt. It is important to understand how the surface of the basalt changes laterally because of evidence that shows that this surface can potentially impede the downward migration of water thus promoting the formation of perched water at this interface. If the surface that causes the perched water to form is sloped perched water will flow down slope. Any contaminants that may be present in the water will be carried along with the water to locations that may be some distance from their origin. This phenomenon has the potential of creating phantom contamination. That is, the occurrence of contamination for which no apparent source exists.

3.3.5.3 Interbeds - Occurrence and Distribution

Sedimentary interbeds separate many of the basalt flows that occur beneath NRF. These interbeds vary in composition, thickness, and areal extent. Four major interbeds have been identified in the subsurface. The first important interbed is brick red to red-orange in color and occurs at a depth that varies from 70 to 120 feet. This interbed is widespread and ranges in thickness from less than six inches to over 14 feet. This interbed is composed of poorly sorted mixtures of angular to subangular sand sized grains. The term lithic wacke was used to describe the sediments in these interbeds and refers to immature sandstones with high clay content and a large number of rock fragments other than quartz and chert (Chen-Northern, 1991, and Blatt et. al., Origin of Sedimentary Rocks). Dominant grain fragments are composed of basalt and quartz, with the finer constituents consisting of silt and clay. The sediments of this interbed appear to be loosely consolidated in the subsurface. Perched water has been associated with this interbed, although it is not positively known whether the interbed itself, or a tight basalt located immediately beneath, is the perching layer. Because of its wide-ranging occurrence, and physical properties, this interbed can inhibit potential contaminant migration.

Other important interbeds occurring at 200 feet, 270 feet, and 370 feet have been identified from geophysical logs from many wells near NRF. Several minor interbeds are also present. These interbeds are generally limited in areal extent.

3.3.5.4 Basalt

Underlying the alluvium is approximately 1500 to 2000 feet of transitional olivine to alkaline olivine basalts. Minerals present in this section include magnesium olivine, clinopyroxene, calcic-plagioclase, spinel, and magnetite (Chen-Northern, 1991). Depth from the surface to the top of the basalt surface ranges from zero to 60 feet, but is typically 30 feet. The basalt consists of individual flows ranging in thickness from 5 feet to over 70 feet. Basalt that is void of interconnected vesicles and fractures is nearly impermeable. The hydraulic conductivity (an approximation of a material's ability to pass water) measurements from basalt cores collected from a borehole located just north of the NRF site are generally in the range of 1×10^{-8} cm/sec (Chen-Northern, 1991). However, local fracturing greatly increases effective conductivity values. Extremely variable transmissivity (hydraulic conductivity times the aquifer thickness) values are common at NRF as is evidenced by values from NRF-2 and NRF-7, which are located approximately 1200 feet apart. Measured transmissivity in these wells were 3.1 ft^2/day in well NRF-7 and 576,000 ft^2/day in NRF-2. A well with a transmissivity value of 3.1 ft^2/day can produce approximately 3000 gallons of water per day while a well with a transmissivity of 576,000 ft^2/day can produce in excess of 3,000,000 gallons of water per day.

Based on evidence observed from cores collected at NRF, it appears that most of the fractures in the basalt are probably the result of the cooling process. If this is so, these fractures will be confined to one flow, and will not transect other flows. These fractures appear to be randomly distributed in the horizontal plane, but are concentrated at the top of individual flows in the vertical plane. Some flows are completely fracture free, while other flows are fractured from top to bottom. No evidence exists to substantiate the conclusion that one set of fractures is continuous from the surface to the aquifer (i.e., providing an uninterrupted pathway for potential contaminants to follow). There is evidence that indicates that some portions of the basalt, perhaps occurring in quasi-linear trends, are more highly fractured than the surrounding basalt. An increase in the frequency of fractures in the basalt would expedite surface water infiltration into the aquifer. It would be improper to assume that these "fracture zones" act as conduits, allowing surface water to flow unimpeded from the surface directly to the aquifer. Water that may infiltrate along these hypothetical trends would interact with surface soils, clay-lined fractures, and the soils contained in interbeds. In areas where these trends are present, however, travel time through the basalt would tend to decrease.

3.4 Land Use and Resources

3.4.1 Past and Current Land Use

INL was established in 1949 as the National Reactor Testing Station by the United States Atomic Energy Commission as a site for building, testing, and operating nuclear reactors, fuel processing plants, and support facilities with maximum safety and isolation. In 1974, the area was designated as the Idaho National Engineering Laboratory to reflect the broad scope of engineering activities conducted there. The name was changed to Idaho National Engineering and Environmental Laboratory in 1997 to reflect the redirection of its mission to include environmental research. In 2005, the name was changed to INL to emphasize its role as one of the United States' leading national laboratories.

The Bureau of Land Management manages the areas surrounding INL for multipurpose use. Communities nearest to INL are Atomic City (south), Arco (west), Butte City (west), Howe (northwest), Mud Lake (northeast), and Terreton (northeast). In the counties surrounding INL, approximately 45% is agricultural land, 45% is open land, and 10% is urban. Fences and security personnel strictly control public access to facilities at INL. A total of 90 miles of paved highways pass through INL and are used by the public.

NRF consists of three former Naval nuclear reactor prototype plants, the Expended Core Facility (ECF), and miscellaneous support buildings. Construction of the Submarine Thermal Reactor Prototype (S1W) at NRF began in 1951. The prototype completed operation in 1989. The Large Ship Reactor Prototype (A1W) was constructed in 1958 and completed operation in January 1994. The Submarine Reactor Plant Prototype (S5G) was constructed in 1965 and completed operation in May 1995. The prototypes were used to train sailors for the nuclear Navy and were used for research and development purposes. ECF, which receives, inspects, and conducts research on Naval nuclear fuel, was constructed in 1958 and is still in operation. The Dry Storage Overpack Facility was completed in 2001 to store expended Naval nuclear fuel in a non-aqueous environment.

3.4.2 Projected Land Uses

NRF is projected to continue operations until at least 2035. Operations will continue to include receiving, inspecting, and conducting research on Naval nuclear fuel, as well as the temporary dry storage of Naval nuclear fuel until a permanent national repository is available. Other NRF operations will include the decontamination and disposition actions associated with retired buildings and facilities.

3.4.3 Groundwater Use

The SRPA is the largest aquifer in Idaho and the principal source of drinking water for thousands of Idaho residents. For the majority of the past century, water withdrawal from the SRPA was limited to its periphery at relatively small quantities. In the past forty years, demand for both potable water and water for agricultural uses has increased in response to an increasing population base in eastern Idaho. Increased water demand coupled with several extended droughts has caused a decline in the SRPA water table. Demand for water in eastern Idaho is expected to increase in the future, which will result in a continued decline of the water table.

3.4.3.1 Past Uses at NRF

NRF has been in operation since the early 1950s. Up through the mid-1990s, the site was primarily used for training Navy personnel to operate nuclear propulsion plants aboard Naval vessels. Well NRF-1, drilled in 1950, supplied early demand for water at NRF. Water from this well was used for drinking, irrigation, sewerage, and cooling the S1W prototype plant. As the number of plants increased so did the number of Navy students and full time employees. The demand for water also increased. Additional water wells were constructed in 1951 (NRF-2), 1956 (NRF-3), and 1964 (NRF-4). During its peak period in the mid-1980s, NRF had three operating prototypes (S1W, S5G, and A1W), ECF, and approximately 3,300 full-time, part-time, and Naval personnel. At that time, peak water demand was approximately 300,000,000 gallons per year. Most groundwater used at NRF was eventually returned to the environment in one of several ways. NRF water was discharged to the IWD or to the Sewage Lagoons where it was evaporated, used by vegetation, or infiltrated into the subsurface. The balance of the water was used to irrigate lawns or was supplied to cooling towers for indirectly cooling operating reactors (evaporative losses).

3.4.3.2 Present Use at NRF

Current water usage at NRF is approximately 33,000,000 gallons per year. This use is primarily limited to domestic consumption, irrigation, and ECF operation. The environmental fate for groundwater is the same as described above except that cooling tower evaporation is no longer occurring. Approximately 965 BBI employees and 200 long-term subcontractor and DOE employees are currently working at NRF.

3.4.3.3 Future Use at NRF

In the near future, water usage at NRF is expected to remain stable or rise slightly, due to increased personnel.

3.5 History and Description of Sites

3.5.1 Landfill Sites

NRF operations over the time period when the landfills were active consisted of Naval ship reactor prototype facilities and support operations (i.e., cooling systems operations; water treatment operations; laboratory operations; production support operations from paint, electrical, machine, and equipment maintenance shops; and subcontractor construction support operations). The characteristics of the refuse disposed of in the three landfills were influenced by the NRF facilities and the various support operations. The typical waste disposal practice at the sites was to dispose of refuse in trenches, incinerate the combustible refuse, and then bury the residual material. When these sites were abandoned, the remains were left in place and covered with soil from the surrounding area.

The resulting primary contaminant source at all three landfill areas is refuse material and refuse degradation products buried at the sites. From records kept since 1971 of wastes sent from NRF to the Central Facilities Area landfill, it is estimated that almost two-thirds of the waste would have consisted of office trash. Less than one percent of the waste would have consisted of solid and liquid chemicals, waste oil, and solvents (WEC 1994a).

In addition, during the operational period of these landfills, major construction activities were carried out. These activities included the construction of two prototype plants and other support buildings (i.e., training facilities, storage buildings, etc.). These construction activities would have contributed a considerable amount of construction debris to these landfills, therefore decreasing the estimated hazard (i.e., reduced percentage of chemicals). Figure 1-1 shows the location of the landfills.

Since contaminated soil remains at these sites with concentrations of contaminants of concern above risk-based concentrations that prevent unrestricted use of the area, Institutional Controls (ICs) have been implemented. ICs used at NRF preserve the underlying assumptions of the RI/FSs developed for WAG 8 that will protect human health and the environment. Section 7.2.1 discusses site ICs in more detail.

3.5.1.1 NRF-1 Field Area North of S1W

Use of NRF-1 started in approximately 1951 and continued until 1960. The locations of the primary disposal areas within NRF-1 were identified from old drawings, photographs, verbal testimony, and records. NRF-1 covers an area of 192,500 square feet (350 feet wide and 550 feet long). Within this area, there was a previously utilized trench containing buried waste and a mounded area consisting of surface debris and soil. The buried waste disposal trench is located on the west side of the site. The depth of this trench ranges from approximately four feet on the north end to 25 feet on the south end relative to the surrounding grade. The dimensions of this trench are 120 feet wide and 375 feet long. From historical records, photographs, and drawings, the bulk of the waste was disposed of at the southern half of the site where the trench dimensions were greater. The north end of the trench was covered when Spray Pond #2 was constructed around 1954 (WEC 1995), thus limiting the amount of wastes that were disposed of at the north end of the trench.

3.5.1.2 NRF-51 West Refuse Pit

NRF-51 started operating in about 1957 and continued until 1963. Previous investigations indicated the shape of this unit was irregular with curved boundaries. The overall size of the site was originally estimated to be approximately 450 feet long, varying in width from 100 to 175 feet. Based on photographs and a magnetometer survey of the location, only one disposal trench was identified. The trench was originally estimated to be approximately 250 feet in length, 15 to 20 feet wide, and 10 to 15 feet deep (WEC 1993). The length and width of the trench were further refined by a magnetometer survey which determined it to be 175 feet long and 40 feet wide (WEC 1995). Analysis of photographs indicated the materials disposed of at NRF-51 tended to be construction debris rather than the types of wastes found in the other two units. In addition, it was noted that there were no drums in the trench at the time the photographs were taken. It is believed that a portion of this site was previously used as a construction staging area.

3.5.1.3 NRF-53 East Refuse Pit and Trenching Area

NRF-53 was used as a disposal area from about 1956 to 1970. The various types of waste that may have been disposed of in this area include waste petroleum products, small quantities of waste paints and solvents, construction debris, scrap metal, and cafeteria waste. Geophysical data indicated that there were at least five pits or trenches at NRF-53. Based on the geophysical data and verbal testimony, the trenches were estimated to have been up to 90 feet wide by seven to ten feet deep and up to 350 feet long. The area of site NRF-53 that included both surface debris and the trenches was approximately 400,000 square feet.

3.5.2 No Further Action Sites

The NFA designation was created by the FFA/CO signatory agencies for those sites with a source or potential source present, but for which an exposure route was not available. The following sections discuss each of the NFA Sites. Figure 1-2 shows the location of the NFA Sites.

Since contaminated soil remains at these sites with concentrations of contaminants of concern above risk-based concentrations that prevent unrestricted use of the area, ICs have been implemented. ICs used at NRF preserve the underlying assumptions of the RI/FSs developed for WAG 8 that will protect human health and the environment. Section 7.2.1 discusses site ICs in more detail.

3.5.2.1 NRF-2 Old Ditch Surge Pond

This site was originally a gravel or soil pit. In 1959 the pit was connected to the NRF interior waste ditch system and a pond area formed. The pond and connecting ditch were used from approximately 1959 to 1985. Low-levels of radioactivity and slightly elevated levels of metals were detected in the pond. The pond became contaminated with very low levels of radioactivity when water with trace amounts of cobalt-60 and cesium-137 was released to the ditch in the late 1960s. Accumulation of radioactivity in the upper several feet of ditch sediments produced slightly elevated activity levels that are below remediation goals established in the ROD (WEC 1998).

3.5.2.2 NRF-16 Radiography Building Collection Tanks

This building was originally a decontamination building used for cleaning radioactive equipment. The decontamination solutions were sent to two underground tanks. These tanks were used from 1954 to 1960. Adjacent to the building was a concrete pad that was used for outdoor storage of radioactive material. The concrete pad was removed in 1979. The tanks were removed in 1993 with no indication of leakage. Sampling results showed arsenic (which was found at depth adjacent to the underground tanks), cesium-137, cobalt-60, and uranium-235 above risk-based screening levels; however, the risk assessment performed for this site was very conservative and a risk management decision was made that the actual risks are acceptable.

3.5.2.3 NRF-18A S1W Spray Pond #1

The S1W Spray Pond #1 is a large concrete structure that contained cooling water for plant operations. At one time, a chromium based corrosion inhibitor was used in the water. Leakage and overspray from the pond caused an elevated chromium concentration in the surrounding soil. A risk assessment showed a low risk for this site assuming the Spray Pond remains in place, thus limiting exposure to the soil below the basins in the event that any contamination is present.

3.5.2.4 NRF-22 A1W Painting Locker French Drain

This site is the location of a former French drain that may have received paints, solvents, and possibly mercury. A removal action was performed in 1994 after receiving public comment on the proposed action. Sampling performed after the removal action showed elevated levels of lead and mercury remained. The excavated hole was 12 feet deep and was grouted to the surface eliminating all exposure pathways. A risk assessment of the site after the removal action estimated the risk to be low. Although no exposure route is present, a source remains at the site.

3.5.2.5 NRF-23 Sewage Lagoons

This site is the current sewage lagoons. The lagoons are two open rectangular ponds that measure 425 feet by 725 feet each. The northeast lagoon is currently active, while the southwest lagoon is typically dry and receives overflow from the active lagoon on occasion. Both lagoons are lined with clay. The sewage lagoons were built in 1960 and expanded to their current length in 1972. The lagoons were designed to be evaporative ponds; however, subsurface seepage of liquid effluent from the active lagoon has created a shallow perched water zone beneath the pond. This water contains non-hazardous chemicals (salts). Sampling of the sediment has shown the presence of slightly elevated levels of metals and radionuclides and only trace amounts of organic compounds in the upper 12 inches of soil. Most contaminants are believed to be contained within the lagoon sludge or lagoon clay lining. The risk assessment for the site was very conservative and a risk management decision was made that the actual risks are acceptable.

3.5.2.6 NRF-42 Old Sewage Effluent Ponds

This site is the location of a former temporary sewage pond used in the 1950s. There is no direct evidence that a hazardous source exists at the site; however, process knowledge gained from sampling of the current sewage lagoons suggests that elevated amounts of metals, semi-volatile organics, and low-level radionuclide contaminants may be present. The site is currently covered with a ten-foot layer of soil. Based on current conditions (i.e., ten foot soil cover), the risk associated with this site was estimated to be low.

3.5.2.7 NRF-43 Seepage Basin Pumpout Area

This site is an area that physically surrounds NRF-21A and was formed when the contents of NRF-21A (Old Sewage Basin) were pumped out into the surrounding area in 1958. The effluent to NRF-21A had been cross-contaminated with radioactivity in 1956. Characterization sampling performed in 1996 showed arsenic, cesium-137, carbon-14 and plutonium-239 above risk-based screening levels; however, the risk assessment performed for this site was very conservative and a risk management decision was made that the actual risks are acceptable.

During the spring and summer of 2002, in conjunction with remediation of NRF-21A, the amount of contaminated soil and the size of NRF-21A were found to be larger than anticipated. A portion of NRF-21A extended into the previously identified NRF-43 area. NRF and the regulatory agencies decided that the NRF-21A basin area, including the portion that extended into NRF-43, would be capped with an engineered cover similar in design to those intended for NRF-12/14 and NRF-19. This decision was documented in an Explanation of Significant Difference (ESD) issued in 2002. Construction of the cover was completed in 2004.

3.5.2.8 NRF-61 Old Radioactive Materials Storage and Laydown Area

This site is the historic location of a radioactive material storage and laydown area that was used from 1954 to 1960. Soil sampling showed detectable amounts of cesium-137 that were well below remediation levels. The risk associated with this site was determined to be low.

3.5.2.9 NRF-66 Hot Storage Pit

This site is an area where a tanker truck collected radioactive liquid waste for transportation to other INL facilities for processing. Spills reportedly occurred in this area. Contaminated soil was removed from the area in 1980. Sampling during the remedial investigation showed slightly elevated amounts of cesium-137 that were well below remediation levels.

3.5.2.10 NRF-81 A1W Processing Building Area Soil

This site is the area around a radioactive materials processing building where known spills have occurred in the past. Typically, these spills were cleaned up to the maximum extent possible at the time. Cesium-137 and cobalt-60 were the only radionuclides detected during past sampling, and all results were below remediation levels.

3.5.2.11 NRF-82 Evaporator Bottoms Tank Release

This site consists of the soil above an underground storage tank vault. One spill was known to have occurred at the area in 1972. The spill was cleaned up to the standards at the time, but slightly elevated amounts of radioactivity were reported after the cleanup. Additional cleanup was performed in 1977. The remaining radioactivity is below remediation levels.

3.5.2.12 NRF-83 ECF Hot Cells Release Area

NRF-83 is located within an operational building (ECF). Radioactive liquid was released in 1972 from a pipe to a concrete trench. The soil below and adjacent to the trench also became contaminated. Cleanup actions taken in 1972 did not include the soil below the trench. The contaminated soil was discovered in 1997 when a concrete pad adjacent to the concrete trench was removed during ECF upgrade work. Elevated amounts of cobalt-60 and cesium-137 are present in the soil. All accessible contaminated soil was removed and replaced with clean soil during the construction project. Thirty-seven cubic yards of contaminated soil are estimated to remain under the trench to preserve the integrity of the trench. A new concrete pad was poured at the location of the old concrete pad excavation. The contaminated soil below the trench is not presently accessible and no exposure route is available.

3.5.3 OU 8-08 Remedial Action Sites

Nine sites were determined in the NRF Comprehensive RI/FS (WEC, 1997b) to have unacceptable or potentially unacceptable risks that must be addressed. The primary radionuclides of concern were cesium-137 and strontium-90, both of which have a 30-year half-life. During remedial activities, contaminated soil was removed from eight sites (three of which were associated with sites that were later capped) and consolidated in the S1W Leaching Beds area. These eight sites are referred to as Remediated Radiological Sites. Figure 1-3 shows the location of the Remediated Radiological Sites. Four sites are topped with three engineered covers (two sites are under one cover). These sites are referred to as OU 8-08 Engineered Cover Sites. Figure 1-4 shows the location of the Engineered Cover Sites.

The following sections discuss each of the nine OU 8-08 RA Sites. Since contaminated soil remains at these sites with concentrations of contaminants of concern above risk-based concentrations that prevent unrestricted use of the area, ICs have been implemented. ICs used at NRF preserve the underlying assumptions of the RI/FSs developed for WAG 8 that will protect human health and the environment. Section 7.2.1 discusses site ICs in more detail.

3.5.3.1 Remediated Radiological Sites

3.5.3.1.1 NRF-11 S1W Tile Drainfield and L-Shaped Sump

This site consisted of a below-surface concrete L-shaped sump and four underground perforated drainfield pipes of various lengths downstream of the sump. The drainfield was likely used between 1953 and 1955 for sewage and radioactive liquid discharges. The drainfield area was approximately 36 feet wide by 150 feet long and consisted of four perforated pipes buried parallel to each other approximately 11 feet deep. Each outside leg of the drainfield extended about 150 feet, while both inner legs were 50 feet long. The drainfield was connected to the sump, which was an L-shaped concrete structure. Each leg of the sump was 11 feet long and three feet wide with a maximum depth of approximately 12 feet. The sump was isolated from the drainfield in 1955 but was used until 1960 as part of the sewage system.

3.5.3.1.2 NRF-12A Underground Piping to Leaching Pit

This site consisted of an underground pipe (465 feet in length) that ran from the S1W Retention Basins (NRF-17) to a subsurface concrete manhole. This pipe is known to have leaked on occasion. From the manhole, a perforated pipe used for draining and leaching purposes ran approximately 400 feet to the S1W Leaching Pit (NRF-12B) at a depth of approximately eight to ten feet. This site was used from 1955 through 1961 for radioactive liquid discharges.

3.5.3.1.3 NRF-14 Underground Piping to Leaching Bed

This site included the underground pipe (approximately 530 feet) leading to the leaching beds from the S1W Retention Basins (NRF-17). The pipe was laid in 1960 and delivered radioactive effluence from the S1W, S5G, and A1W prototype plants to the leaching bed.

3.5.3.1.4 NRF-17 S1W Retention Basins

This site consisted of two concrete basins partially below grade that collected radioactive water from various facilities. This was a storage area prior to releasing the water to NRF-11, NRF-12A/12B, and NRF-14. The basins were constructed in 1951. The basins comprised two adjacent concrete structures, each 140 feet long by 34 feet wide. One of the basins was known to have leaked approximately 33,000 gallons in 1971. The leak was directly below the basins.

3.5.3.1.5 NRF-19 Underground Piping to A1W Leaching Bed

This site consisted of two underground pipes leading to the A1W Leaching Bed (NRF-19). The pipes were placed in service in 1957 and delivered radioactive effluent from A1W to the leaching bed. One pipe was six inches in diameter and was referred to as the dilution pipe. This pipe was used to transfer radioactive effluent from a dilution tank to the leaching bed. Another pipe was two inches in diameter and was referred to as the bilge pipe. This pipe was used to transfer liquid collected in the prototype plant bilges to the leaching bed.

3.5.3.1.6 NRF-21A Underground Piping to Old Sewage Basin

This site consisted of a ten-inch concrete pipe, constructed in a bell and spigot configuration that led to the Old Sewage Basin from the L-shaped sump (part of NRF-11). Each section of concrete pipe was three feet long and each joint appeared to be grouted to prevent leakage. The concrete pipe leading to the sewage basin was approximately 435 feet long and ranged from seven feet deep near the L-shaped sump to 11 feet deep at the sewage basin. Leakage along the joints caused the surrounding soil to be contaminated.

NRF-21A also includes the Old Sewage Basin itself. During the spring and summer of 2002, in conjunction with remediation of NRF-21A, the amount of contaminated soil and the size of the NRF-21A basin area were found to be larger than anticipated. A portion of NRF-21A extended into the previously identified NRF-43 area. NRF and the regulatory agencies decided that the NRF-21A basin area, including the portion that extended into NRF-43, would be capped with an engineered cover similar in design to those intended for NRF-12/14 and NRF-19, rather than continuing with excavation of the NRF-21A basin area.

3.5.3.1.7 NRF-21B Sludge Drying Bed

This site consisted of a concrete bed that received sludge from the sewage system. It was cross-contaminated from a radiological system. The bed was constructed in 1951 as part of the sewage system at NRF. The bed was a concrete slab that was 28 feet long by 29 feet wide and was approximately five feet below grade.

3.5.3.1.8 NRF-80 A1W/S1W Radioactive Line near BB19

This area consisted of an underground pipe that was known to have leaked near the west side of the S1W Spray Pond. This pipe carried radioactive water for eventual discharge to the S1W Leaching Beds (NRF-14). This pipe was buried approximately six feet below the surface. During decontamination and disposition work at NRF in 1995, portions of the pipe were removed and contamination was detected in the soil. NRF-80 also includes an area on the east side of the S1W spray pond where remedial actions were not necessary but residual contamination exists.

3.5.3.2 OU 8-08 Engineered Cover Sites

3.5.3.2.1 NRF-12B S1W Leaching Pit

This site consisted of a former pit area that was used for radioactive discharges. The pit was constructed at the end of the drainfield piping (NRF-12A) in 1957 and was used until 1961. The pit was filled with soil, and in 1978, an asphalt cap was placed over the pit. The asphalt cap was removed during the summer of 2003. A single cover addresses both NRF-12B and NRF-14.

3.5.3.2.2 NRF-14 S1W Leaching Beds

This site consisted of two leaching beds, one constructed in 1960, and the other in 1963. These beds were open ponds that collected radioactive water and allowed the water to leach into the subsurface or evaporate. Each bed was about 75 feet by 125 feet at the water line and was 13 to 15 feet deep. The ponds were used until 1979. Large cobblestones were placed in the leaching beds in 1972. Earthen ramps were constructed to allow sampling equipment into the beds in 1992. A single cover addresses both NRF-12B and NRF-14.

3.5.3.2.3 NRF-19 A1W Leaching Bed

This site consisted of an underground leaching bed. Perforated pipes ran through an engineered leaching bed that consisted of various layers of gravel and sand. The bed was constructed west of NRF in 1957, and was used continually from 1958 to 1964 and sporadically between 1964 and 1972. The bed was 200 feet long and 50 feet wide.

3.5.3.2.4 NRF-21A Old Sewage Basin

This site consisted of an open pond used for non-radiological discharges that was cross-contaminated from a radiological system. An unknown amount of radioactive effluent was sent to the sewage basin. The sewage basin was constructed in 1956 and measured 72 feet by 72 feet by 11 feet deep. The basin was enlarged in 1957 in the southeast direction and was used until 1960. The basin was then filled in with soil. This cover was selected after the ROD due to the unexpected extent of contamination, and was documented via an ESD to the ROD.

3.6 Summary of Contaminants of Concern at NRF

3.6.1 Landfill Sites

Evaluation of historical sample data and records indicated that three waste types of specific interest were placed into the landfill areas: waste oil, solvents, and chemicals. As a result of the evaluation of data for the three designated landfill areas, several Contaminants of Concern (COCs) were identified as shown in Table 3-3.

Table 3 3 Contaminants of Concern in the Landfill Areas		
Site	Metals	Volatile Organics
NRF 1 NRF 51 NRF 53	Chromium, mercury, and silver	1,1,1-trichloroethane, tetrachloroethylene, trichlorofluoromethane (Freon 11), Dichlorodifluoromethane (Freon 12) (1), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), chloroform, and trichloroethylene

(1) Freon 12 was detected in soil gas samples collected at NRF-1 after remedial actions were completed.

3.6.2 No Further Action Sites

Table 3-4 summarizes COCs for the NFA Sites.

Table 3 4 Contaminants of Concern at No Further Action Sites	
Site	Contaminants of Concern
NRF 2	Cesium-137
NRF 16	Cesium-137, Uranium-235
NRF 18A	Chromium
NRF 22	Lead, Mercury
NRF 23	Cesium-137
NRF 42	Cesium-137
NRF 43	Cesium-137
NRF 61	Cesium-137
NRF 66	Cesium-137
NRF 81	Cesium-137, Uranium-235
NRF 82	Cesium-137
NRF 83	Cesium-137, Cobalt-60

3.6.3 Remedial Action Sites

Table 3-5 summarizes COCs for the RA Sites. This table shows the COCs prior to remediation and the COCs remaining after remedial actions.

3.6.4 Groundwater Contaminants

Groundwater at NRF contains both natural and anthropogenic constituents. Naturally occurring groundwater constituents are determined by the chemical properties of the rocks located in the source area and along the groundwater flow path. Examples of naturally occurring groundwater constituents near NRF are calcium, potassium, and magnesium.

Through the course of NRF's operation, some chemicals and radionuclides have been released to the environment, either accidentally or intentionally in accordance with practices acceptable at the time. Many of the same constituents are detectable in the groundwater. The IWD RI/FS Work Plan and the NRF Comprehensive RI/FS provided lists of potential contaminants released at NRF. Not all of the constituents have been observed in the groundwater. Several reasons for this include limited source, low migration potential, dilution, or degradation through various natural processes, and very conservative estimates of the quantities of the constituents released. The following constituents have been consistently observed in groundwater at NRF (Effluent System and Local Downgradient well groups) in concentrations (greater than three standard deviations) above local background levels: aluminum, nickel, iron, chromium, calcium, potassium, magnesium, sodium, chloride, and sulfate. Small quantities of chloroform and tetrachloroethylene have also been detected. The natural background concentration for these organic compounds is zero. Tritium in groundwater also exceeds (greater than three standard deviations) local background concentrations. All organic and radionuclide data are significantly below their respective Federal or State regulatory level (e.g., EPA drinking water standards).

Water upgradient to NRF could theoretically contain man-caused contamination that is unrelated to the Naval Reactors Program. The Big and Little Lost River systems are the primary source of recharge to the SRPA north (or upgradient) of NRF. No contaminants are known to exist in groundwater sampled by the Regional Upgradient wells.

Table 3 5 Contaminants of Concern at Remedial Action Sites

Site	COC Prior to Remedial Actions(1)	COC After Remedial Actions(2)
NRF 11	Cesium-137, Plutonium-244	Cesium-137
NRF 12A	Cesium-137, Nickel-63, Plutonium-244, Strontium-90	Cesium-137, Strontium-90
NRF 12B	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Lead, Plutonium-238, Strontium-90	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Lead, Plutonium-238, Strontium-90
NRF 14 (Cover Area)	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Lead, Plutonium-238, Strontium-90	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Plutonium-238, Plutonium-244(3), Strontium-90, Uranium-235(3), Lead
NRF 14 (Pipe area)	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Plutonium-238, Strontium-90	Aroclor-1242(4), Cesium-137
NRF 17	Americium-241, Cesium-137, Nickel-63, Neptunium-237, Plutonium-238, Plutonium-244, Strontium-90, Uranium-235	Cesium-137, Strontium-90
NRF 19 (Cover Area)	Americium-241, Cesium-137, Nickel-63, Plutonium-238, Strontium-90	Americium-241, Cesium-137, Nickel-63, Plutonium-238, Strontium-90
NRF 19 (Pipe Area)	Americium-241, Cesium-137, Nickel-63, Plutonium-238, Strontium-90	Cesium-137, Strontium-90
NRF 21A (Cover Area)	Cesium-137	Cesium-137, Strontium-90
NRF 21A (Pipe Area)	Cesium-137	Cesium-137
NRF 21B	Cesium-137, Uranium-235	Cesium-137
NRF 80	Cesium-137	Cesium-137, Cobalt-60(5)

(1) COCs were identified in the NRF Comprehensive RI/FS (based on the 100-year future residential scenario)

(2) COCs were based on confirmatory sampling performed during Remedial Actions and the potential unrestricted release of the area (present day residential)

(3) These are identified as COCs because this area was used to consolidate soil from other sites where these were identified as COCs.

(4) Aroclor-1242 was detected (below a ten foot depth) at levels greater than residential unrestricted release values but less than occupational values.

(5) Cobalt-60 (Co-60) was not a COC as determined in the ROD. However, this was based on the assumption of 100 years of controls and the resulting radioactive decay of Co-60. Co-60 is a COC when considering the potential for present-day unrestricted release of an area

4.0 Remedial Actions

4.1 Remedy Selection

4.1.1 Remedy Selection for Landfill Sites (OU 8-05/06)

A Feasibility Study (FS) was performed for the landfill areas (WEC, 1994c). The FS was a comprehensive evaluation of potential remedial action alternatives for OUs 8-05 and 8-06 landfills that represent NRF-1, NRF-51, and NRF-53. The presumptive remedy for CERCLA municipal landfills as given in the EPA directive 9355.0-049FS, "Presumptive Remedy for CERCLA Municipal Landfill Sites," was used for these landfill units, since they were similar in nature and content to municipal landfills and the EPA directive expects the presumptive remedy to be used at all appropriate sites. Using the presumptive remedy eliminated the need for the initial identification and screening of alternatives during the FS.

The Remedial Action Objectives (RAOs) for the landfill areas were developed in accordance with the RI/FS CERCLA Landfill Guidance (EPA, 1991). The RAOs specified the contaminants and media of interest, exposure pathways, and preliminary remediation goals, to support development of a range of source containment alternatives. The attainability of the RAOs to protect human health and the environment was addressed through the detailed evaluation of each remedial action alternative. Compliance with potential chemical-specific applicable or relevant and appropriate requirements (ARARs) was one method used to evaluate the extent to which each remedial action alternative would meet the RAOs.

The RAOs for the environmental media of groundwater, soil, and surface water for the landfills were identified as follows:

Human Health:

- Ensure that the SRPA downgradient of NRF has no contaminant levels above Maximum Contaminant Levels (MCLs) due to migration of contaminants from the landfills.
- Minimize infiltration and resulting contaminant leaching to the SRPA.
- Restrict intrusion into the landfill contents. (Since the landfill contents were not sampled and characterized, it was not possible to accurately assess the risk for future receptors).
- Prevent direct contact with the landfill contents.
- Control surface water runoff and erosion of the landfill covers.
- Meet all ARARs.

Environmental Protection:

- Meet all ARARs.

4.1.2 Remedy Selection for No Further Actions Sites (OU 8-08)

A NFA decision was made by DOE, IDEQ, and EPA for those sites with a source or potential source present, but for which an exposure pathway is not available under current conditions. The NFA decision means the site is included in a CERCLA review performed at least every five years to ensure that site conditions used to evaluate the site have not changed and to verify the effectiveness of the NFA decision. This remedy selection did not require any additional remedial action other than ICs such as signs and fencing, administrative controls on excavation, and inspections.

4.1.3 Remedy Selection for Remedial Action Sites (OU 8-08)

The ROD-selected remedy for the RA Sites was "Limited Excavation, Disposal, and Containment." This remedy was divided into two phases to expedite the remedial action process. The Phase I RD/RA Work Plan activities included excavation of contaminated soil above cleanup levels, consolidation of contaminated soil from other RA Sites to NRF-14, removal and characterization of piping and concrete fixtures for disposal off-site (away from NRF), and backfilling with clean soil. The Phase II RD/RA Work Plan activities originally included construction of engineered covers over the filled S1W Leaching Pit/Bed area (NRF-12B/14) and A1W Leaching Bed (NRF-19). In 2002, the selected remedy for site NRF-21A was modified per an Explanation of Significant Difference (ESD) to the ROD to include construction of the same type of engineered cover over NRF-21A. To prevent unauthorized intrusion and excavation and to control land use and transfer, ICs were included as part of the selected remedy for the RA Sites. These actions address human health risk posed by the RA Sites and also address ecological risk. In addition to engineered earthen covers, the selected remedy at NRF-12B/14, NRF-19, and NRF-21A also included installation of soil moisture probes.

To protect human health and the environment, RAOs for the RA Sites were developed and documented in the ROD. These RAOs are discussed below:

Human Health:

- Prevent external gamma radiation exposure from all radionuclides of concern that exceed a total exposure pathway excess cancer risk of 1 in 10,000 for the future 100-year residential receptor.

- Prevent ingestion of soil and food crops contaminated with radionuclides of concern that exceed a total pathway excess cancer risk of 1 in 10,000 for the future 100-year residential receptor.

- Prevent exposure to soil contaminated with lead that exceeds the EPA recommended screening level of 400 parts per million (ppm) for lead cleanup.

Environmental:

- Prevent erosion or intrusion by resident plant or animal species in contaminated soils that could cause the release of contaminated soils.

- Prevent exposure to COCs that may cause adverse effects on populations of resident species.

4.2 Remedy Implementation and Maintenance

Remedy implementation included the remedial design, remedial actions, and subsequent operations and maintenance (O&M). Details of remedy implementation are summarized below. A more detailed account of remedy implementation for the inactive landfills can be found in the RA Report for the Inactive Landfills (WEC, 1997a). A detailed description of remedial actions associated with the OU 8-08 Sites, including construction of the OU 8-08 Engineered Covers is located in the OU 8-08 RA Report.

4.2.1 Landfill Covers

The regulatory requirements regarding final closure of landfills (WEC, 1995) provide for the placement of a final cover designed and constructed to:

- Have a permeability (where permeability is expressed as hydraulic conductivity with units of centimeters per second (cm/sec)) less than or equal to the natural subsoils of the surrounding area,
- Function with minimal maintenance,
- Promote drainage and minimize erosion,
- Accommodate settling and subsidence to maintain integrity of the cover, and
- Minimize the migration of liquids.

The design criteria for the landfill covers included the selection of appropriate soils that minimize erosion with properties (i.e., permeability) that will also limit infiltration. The cover design incorporated an appropriate slope that provides adequate surface runoff. To further minimize erosion and the migration of liquids through the landfill, the landfill cover included a top vegetative layer. To minimize settling and subsidence, the surfaces of the landfill areas were preloaded with fill material, compacted, and leveled to the same elevation as the surrounding natural surfaces, which provided a stable base for the cover. The landfill cover was then placed over the top of each of the landfill areas, moderately compacted (except the upper foot of topsoil), completed with a proper surface slope, and seeded. To minimize maintenance of the vegetative cover, indigenous plants were used.

4.2.1.1 Cover Construction

Landfill cover construction operations are summarized below. The construction activities included: (1) site clearing, (2) landfill unit base layer fill and grading, (3) subsurface soil cover construction, (4) topsoil cover construction, and (5) vegetative cover.

Site Clearing

Site clearing activities removed vegetation greater than three inches in diameter and surface debris, and provided scarification of the landfill base to facilitate blending of newly placed soil layers. Cleared soils that were sufficiently free of debris were stockpiled adjacent to each landfill for use as the top soil cover, since these soils contained organic matter beneficial to re-establishing the vegetative cover.

Base Layer

A motor grader, bulldozers, water truck, and smooth drum roller and/or sheep's foot roller were used to knock down, process, and compact the fill material into place for the landfill cover base at each of the landfill areas. Each of the three landfill units was filled, compacted, and graded as necessary to achieve a three to five percent gradient.

Subsurface Soil Cover

Each of the three landfill units was filled and graded using appropriate soil for the subsurface cover layer to achieve a minimum three foot cover at NRF-1 and a minimum two foot cover at NRF-51 and NRF-53 with a three to five percent gradient.

Top Layer

Each of the three landfill units was filled and graded to achieve a minimum one foot final topsoil cover with a three to five percent gradient. Soil for the topsoil cover was loosely placed with minimum compaction, to ensure the establishment of adequate vegetation. The final topsoil cover thickness at NRF-51 and NRF-53 was one foot. The final topsoil cover thickness at NRF-1 averaged 1.5 feet.

Vegetative Cover

The vegetative cover consisted of indigenous vegetation with the characteristics specified in the RD/RA Work Plan (WEC 1995). The specific plant mixtures described in the Work Plan were also recommended for use as appropriate vegetative cover for erosion control based on studies at other INL sites.

Mulching, seeding, and fertilization were performed in accordance with the RD/RA Work Plan. Mulch was applied after placement of the top layer in early summer to minimize erosion. Prior to application of the mulch, the soil surface was scarified using a spring-tooth harrow to loosen the soil and permit anchoring of the mulch. Straw mulch was applied and then anchored in the soil using a crimping disk. Fertilization and seeding were done in late summer to provide a greater chance for plant growth in the spring.

4.2.2 Groundwater Monitoring Network

4.2.2.1 Network Design (Location and Number of Wells)

Groundwater monitoring was part of the remedy selected for the Landfill Areas. The NRF Groundwater Monitoring Network consists of individual wells designed and built over a period of approximately 50 years. In 1995, NRF built six new groundwater monitoring wells (NRF-8 through 13). These wells were administratively included into a network with existing wells that were located upgradient (USGS-12 and NRF-7) and downgradient (USGS-97, -98, -99, and -102) of NRF. Two wells (NRF-6 and NRF-13) are currently a part of the Effluent System Monitoring Group. However, as discussed in Appendix A, the ability of NRF-13 to monitor NRF effluent has been questioned.

The locations of five newly constructed wells (NRF-8 through 12) were optimized with the aid of a computer program called Monitoring Efficiency Model (MEMO). These wells, along with USGS-102, were placed along a semi-circular arc just south of NRF. These became what NRF called the Local Downgradient well group. The purpose of these wells was to be the first line of detection for constituents that may have been released from NRF.

The configuration of the NRF Groundwater Monitoring Network allows NRF to collect samples for comparison to assess what impacts, if any, operations at NRF have on the aquifer.

4.2.2.2 Constituent Analysis Design

The identification of analytes to be monitored at NRF focuses on those that had been identified from the following: compounds that had been identified in process waste streams, potential degradation products, those addressed in 40 CFR 141 considered as relevant and appropriate, and detection of the constituents in samples taken from monitoring wells and other site investigation sampling activities (i.e., soil and soil gas sampling). Selection of target compounds for analysis was based on whether a compound is characteristic of the waste, easily and reliably detected analytically, and/or addressed by an applicable regulation to be monitored. The constituents for which analyses are performed are presented in Table 4-1.

4.2.2.3 Well Construction

The wells constructed specifically for the NRF groundwater network were designed to similar specifications. The goal was to create wells that were cost effective, met or exceeded State and Federal guidelines, and provided the data needed by NRF. The typical NRF well has a surface casing ranging from 12 to 22 inches in diameter. This surface casing terminates at the top of the first basalt encountered and is grouted in place. Most NRF wells are constructed with ten-inch diameter carbon steel casing from the surface to approximately 50 feet above the aquifer. In some wells, this casing is 12 inches in diameter. This casing is also grouted in place in such a manner as to prevent the grout from bridging and separating from the borehole wall. The casing in the NRF wells then telescopes down to a stainless steel six-inch casing isolated from the carbon steel casing with dielectric insulating material. The bottom 50 feet of the casing consists of stainless steel screen. Either welds or internal threads join all casings. Each well is fitted with a submersible pump connected to a three-phase five-horsepower motor. Water is pushed to the surface through a 1½-inch stainless steel pipe. Figure 4-1 shows the major design elements of the NRF groundwater monitoring wells.

4.2.3 Soil Gas Monitoring Probes

4.2.3.1 Design Criteria

Soil gas monitoring was part of the remedy selected for the Landfill Areas. To assess the effectiveness of the three landfill covers in limiting water infiltration and soil gas emissions, soil gas monitoring (utilizing a soil gas emissions survey) was implemented at the cover and probe locations shown in Figure 1-1.

Soil gas monitoring was initiated and conducted periodically after the landfill cover had been placed at each location. The monitoring included a soil gas emissions survey over the landfill cover and the placement of permanent soil gas monitoring probes around the perimeter of the landfill areas for the collection and analysis of subsurface soil gas samples. The soil gas emissions survey was utilized to assess the effectiveness of the landfill cover. The soil gas monitoring probes were used to detect any potential gaseous contaminant migration. The soil gas probes were designed with a screened section at the top of the basalt or at the top of the fluvial/lacustrine layer, as applicable. A top removable sampling assembly is attached to the probe opening for access during sampling evolutions (WEC, 1997a).

4.2.3.2 Soil Gas Probe Construction

Soil gas monitor probes were installed after the placement of the final topsoil layer at each landfill. The drill rig used a four-inch hollow stem auger that produced a six-inch diameter hole. Monitoring locations were selected and staked prior to drilling. Fourteen monitor probes were installed with a PVC casing size of 1.05-inch outer diameter (0.75 inch inner diameter), a surface protective casing size of six inches, a bentonite seal of three feet, and use of 8-12 silica sand to form the sand pack around the probes. Figure 4-2 depicts the typical soil gas monitor probe construction. Borings were advanced to depths as determined by the presence of fluvial/lacustrine deposits or the presence of basalt. Monitor probe depths ranged from 12.5 to 26.5 feet (WEC, 1997a). Protection of the monitor probes was achieved through the installation of six-inch steel casings with lockable caps.

Table 4 1 Groundwater Monitoring Constituents

Constituent	Analytical Method	MCL (mg/L)	MCLG** (mg/L)
Aluminum	6010A ICP	0.2***	*
Antimony	6020 ICP/MS	0.006	0.006
Arsenic	6020 ICP/MS	0.01	0.01
Barium	6020 ICP/MS	2	2
Beryllium	6020 ICP/MS	0.004	0.004
Cadmium	6020 ICP/MS	0.005	0.005
Calcium	6010 ICP	*	*
Chromium	6020 ICP/MS	0.1	0.1
Copper	6020 ICP/MS	1.3	1.3
Iron	6010A ICP	0.3***	*
Lead	6020 ICP/MS	0.015****	0
Magnesium	6010A ICP	*	*
Manganese	6020 ICP/MS	0.05***	*
Mercury	7476A	0.002	0.002
Nickel	6020 ICP/MS	*	*
Potassium	6010 ICP	*	*
Selenium	6020 ICP/MS	0.05	0.05
Silver	6020 ICP/MS	0.1***	*
Sodium	6010A ICP	*	*
Thallium	6020 ICP/MS	0.002	0.0005
Zinc	6020 ICP/MS	5***	*
Sulfate	300	250***	*
Chloride	300	250***	*
Nitrate as Nitrogen	353.2	10	10
Nitrite as Nitrogen	354.1	1	1
Total Organic Halogens (TOX)	9020B	*	*

Table 4 1 Groundwater Monitoring Constituents (Continued)			
Constituent	Analytical Method	MCL (mg/L)	MCLG (mg/L)
Ni 63	DOE STL-RC-0055	4 mrem/year	*
Sr 90	EPA 905	8 pCi/L	*
Tritium	R-1173-76	20,000 pCi/L	*
Quantitative Isotopic Gamma	EPA 901.1	*	*
Benzene	524.2	0.005	0
Carbon Tetrachloride	524.2	0.005	0
1,1 Dichloroethane	524.2	*	*
1,2 Dichloroethane	524.2	0.005	0
1,1 Dichloroethylene	524.2	0.007	0.007
Cis 1,2 Dichloroethylene	524.2	0.07	0.07
Trans 1,2 Dichloroethylene	524.2	0.1	0.1
Ethylbenzene	524.2	0.7	0.7
Methylene Chloride	524.2	0.005	0
1,1,2,2 Tetrachloroethane	524.2	*	*
Tetrachloroethylene	524.2	0.005	0
Toluene	524.2	1	1
1,1,1 Trichloroethane	524.2	0.2	0.2
Trichloroethylene	524.2	0.005	0
Trichlorofluoromethane	524.2	*	*
Vinyl Chloride	524.2	0.002	0
Xylenes (total o+p+m)	524.2	10	10
Benzo(b)fluoranthene	525.1	*	*
Benzo(a)pyrene	525.1	0.0002	0
Di n butylphthalate	525.1	*	*
Di(2 ethylhexyl)phthalate	525.1	0.006	0
Di n octylphthalate	525.1	*	*
Isophorone	525.1	*	*
Naphthalene	525.1	*	*
Phenanthrene	525.1	*	*
Pyrene	525.1	*	*

* Not Applicable
**MCLG – Maximum Contaminant Limit Goal
***Secondary Maximum Contaminant Limit
****Treatment Technique – A required process intended to reduce the level of a contaminant in drinking water - Action Level

4.2.4 No Further Action Sites

The primary remedial action implemented at the NFA Sites is ICs. NFA Sites have been posted with signs that indicate site identification, site hazard, access restrictions, and a point of contact. Sites NRF-16, NRF-23, NRF-61, NRF-66, and NRF-81 are enclosed within fences. The remaining sites are either outside the NRF site fence (thus away from the general NRF population) or are beneath structures (resulting in limited access). All sites are inspected at least annually followed by the issuance of an Institutional Control Monitoring Report (ICMR) containing the results of the inspections.

4.2.5 Remedial Action Sites

Remediation work associated with the OU 8-08 RA Sites was divided into two major tasks called Phase I and Phase II Remedial Design/Remedial Action (RD/RA). The Phase I and Phase II RD/RA Work Plans for OU 8-08 provided the design criteria for the selected remedies.

Phase I remedial actions began in 1999 and were completed in June 2003, and involved excavation at eight of the nine sites (all except NRF-12B, which did not require excavation) with potentially elevated risk levels. These remedial actions resulted in the removal of contaminated soil above remediation goals as stated in the ROD from the surface to at least ten feet below ground surface.

Phase II work, which included construction of the earthen covers (at NRF-12B/14, NRF-19, and NRF-21A) and installation of soil moisture probes, began in April 2004, and was completed in October 2004.

4.2.5.1 Phase I Remedial Actions

The remedial actions for Phase I included three major work projects that facilitated the overall work effort. The work projects for Phase I were defined as follows: (1) excavation activities, (2) debris characterization and disposal, and (3) soil consolidation.

4.2.5.1.1 Excavation Activities

The excavation project involved the following work elements:

- Soil excavation;
- Demolition (often reversed with soil excavation, as appropriate);
- Confirmatory sampling; and,
- Site Restoration (backfill to grade, repave, etc.).

Soil Excavation

Most soil excavation was performed using a backhoe, trackhoe, or remotely operated demolition robot (primarily used for soil removal at NRF-17). Removed pieces of asphalt paving or concrete and grubbing wastes (sagebrush, grasses, etc.) were segregated as much as practical from contaminated soils. In some cases, such as near obstructions, at areas with high contamination levels (radiological controls discussed below), or for small quantity soil removal, hand shoveling was performed.

Excavation occurred in eight of the nine RA Sites (the exception being NRF-12B). Soil with cesium-137 greater than 16.7 picocuries per gram (pCi/g) was excavated to a minimum depth of ten feet (strontium-90 and lead were not identified above cleanup levels in any of the excavation sites). Concrete structures that extended below the ten foot depth at NRF-11 and NRF-12A were also removed. Additional soil below ten feet was excavated at several locations, to support potential unrestricted release of such areas within the 100-year future land use period (i.e., following sufficient radioactive decay). Table 4-2 summarizes remedial activities associated with Phase I work.

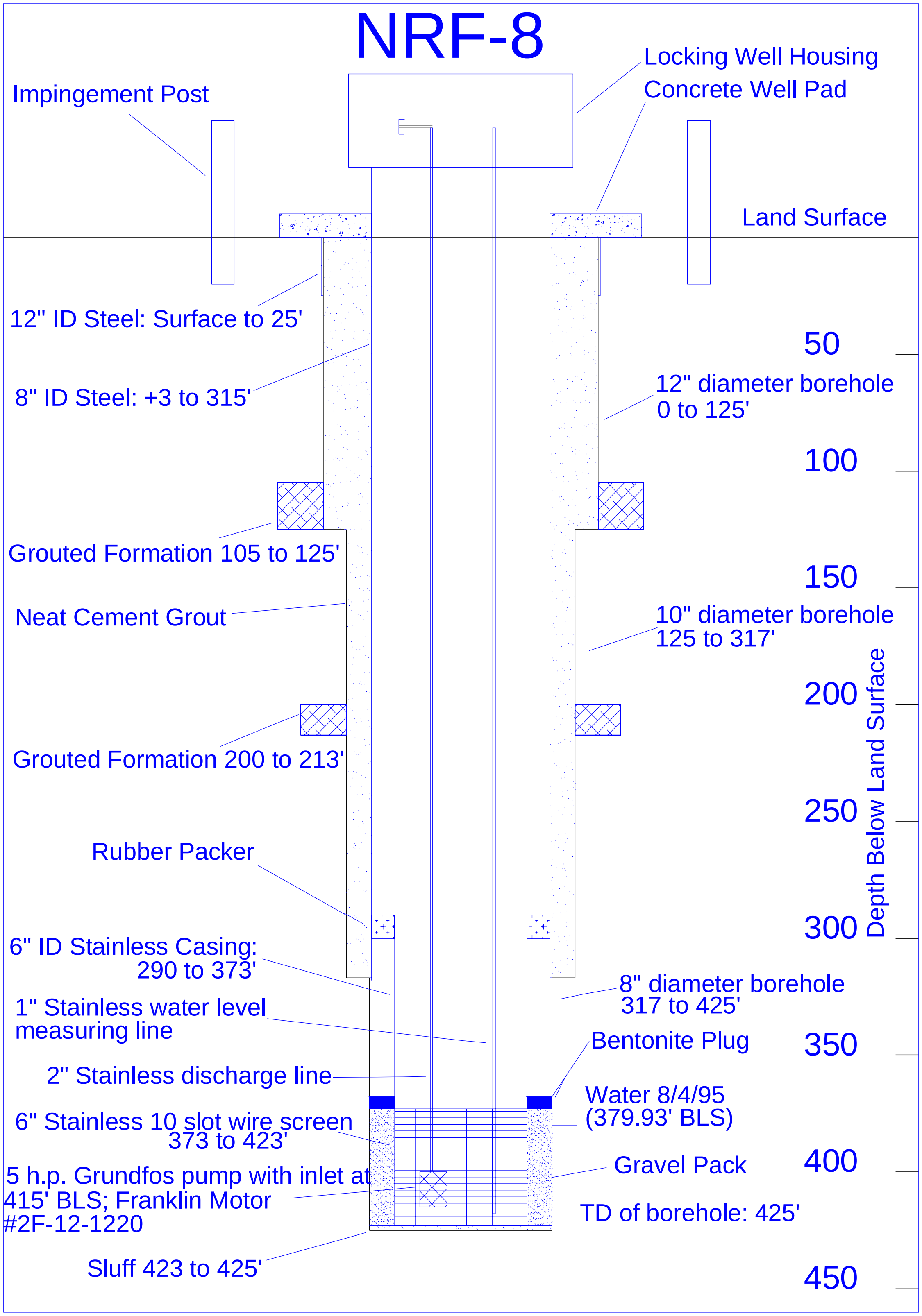

Figure 4-1 Typical Groundwater Well Construction Diagram

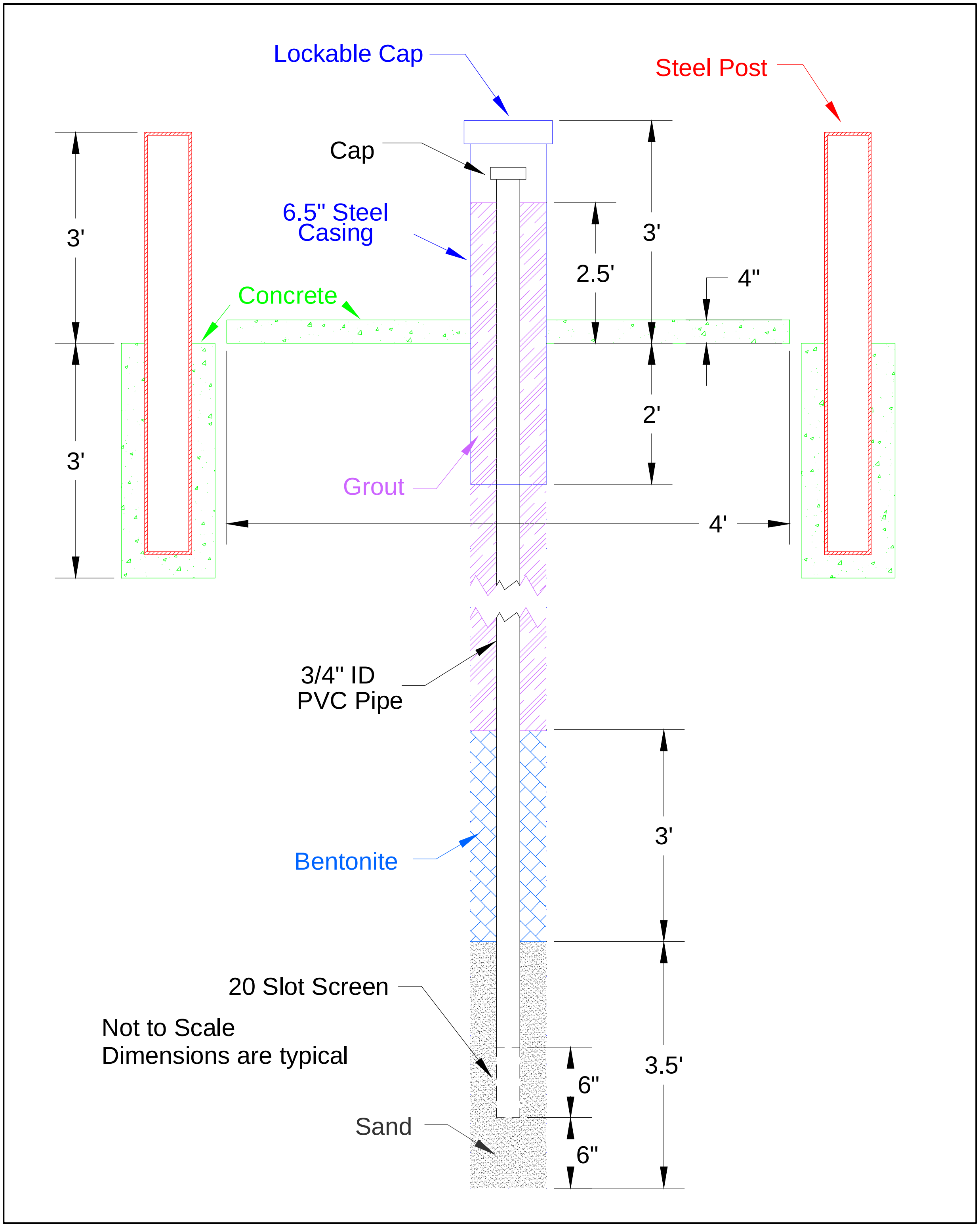

Figure 4-2 Typical Soil Gas Probe Construction Diagram

Table 4 2 Summary Data for Selected OU 8 08 5 Year Review Report			
Site	Feet of Pipe Removed	Volume of Soil Removed	Volume of Concrete Removed
NRF-11 (Including L-Shaped Sump)	488' 6"	120 yd^3	21 yd^3
NRF-12A (Including Concrete Manhole)	824' 8"	5505 yd^3	2.6 yd^3
NRF-12B/14	N/A	N/A	N/A[(a)]
NRF-14 (supply line)	530'	165 yd^3	N/A
NRF-17	N/A	1120 yd^3	1,875 yd^3
NRF-19	200'	86 yd^3	N/A
NRF-21A	435'	890 yd^3	N/A
NRF-21B (Sludge Drying Bed)	N/A	60 yd^3	19 yd^3
NRF-80	93'	4 yd^3	N/A
TOTALS	**2571' 2"**	**7,950 yd^3**	**1,917.6 yd^3**

(a) No concrete was removed, but 400 yd^3 of asphalt was removed

Demolition

Several sites required demolition of concrete structures or removal of piping. The demolition of most structures simply required reducing the structure to a size needed for disposition actions. The debris was characterized prior to disposal. Excavated metallic pipe was size-reduced for disposal. Cement or ceramic type piping was removed in sections at the bell and spigot connections. The pipe was properly characterized and packaged for disposal at the Radioactive Waste Management Complex (RWMC) on INL.

Confirmatory Sampling

Soil samples were collected periodically during remediation work and analyzed by NRF Chemistry for total and isotopic gamma activity. Radiation surveys were performed on the excavated soil and periodically in the excavated hole. Samples were also collected during and after the excavation and demolition work. After achieving satisfactory preliminary results from NRF data indicating completion of remedial actions, follow-up samples were taken for off-site independent analyses to provide the actual confirmation data needed. The off-site analyses verified that the preliminary NRF data was accurate, and confirmed that remediation goals were met. Hence, the confirmatory sampling ensured soil above cleanup levels was removed and provided information on the contaminant levels, if any, that remained in the soil.

Site Restoration

Fill material was taken locally from the NRF gravel pit located southwest of the NRF site and from excavation activities associated with construction actions at ECF. All excavated holes were filled to grade with clean soil and compacted.

All excavated areas were generally returned to preexisting conditions (e.g., to historic pre-NRF site grade) as much as possible. Compaction of the soil was 90% or better and, in roadways, 95% or better. Where required, sites were repaved with asphalt after soil removal. The S1W Retention Basins (NRF-17) area is presently being used as a laydown area for a construction project adjacent to the former location of the basins. After the construction project is complete, the area will be returned to a lawn or other productive use. The construction project does not impact this site.

4.2.5.1.2 Debris Characterization and Disposal

The characterization and disposal of debris (e.g., concrete and piping) from the RA Sites was conducted in accordance with a Waste Management Plan (BBI, 1999). Most of the debris was radioactive and was packaged in accordance with the INL Reusable Property, Recyclable Materials, and Waste Acceptance Criteria and disposed of at the RWMC. None of the debris generated during the remedial actions was hazardous according to the Resource Conservation and Recovery Act (RCRA); therefore, disposal at a RCRA licensed facility or in accordance with the INL Site Treatment Plan was not required.

4.2.5.1.3 Soil Consolidation

Excavated soil containing radioactivity above cleanup levels or above 30 pCi/g total gamma activity was consolidated into the S1W Leaching Beds (NRF-14). The soil was placed into Soft Sided Containers (SSCs), temporarily stored, transported to, and placed in the leaching beds area (still in the containers). A temporary road leading to the S1W Leaching Beds was constructed to support the heavy equipment used to move the SSCs.

4.2.5.2 Phase II Remedial Actions

The OU 8-08 Phase II remedial actions entailed the construction of engineered covers over three designated areas, NRF-12B/14, NRF-19, and NRF-21A. The controlling elements in the design of the engineered covers included providing a barrier to prevent exposure to and direct contact with contaminated soil, limiting biotic intrusion, limiting infiltration, and providing erosion control. Therefore, the engineered covers were constructed incorporating the following design considerations: (1) the use of appropriate soil material and vegetation that minimize erosion; (2) features that limit infiltration (use of soil with an appropriate hydraulic conductivity, soil layer of a sufficient thickness for adequate water storage, and vegetation for evapotranspiration); (3) appropriate material and thickness to provide a barrier that will prevent exposure to and direct contact with the contaminated soil by any individual and also inhibit biotic intrusion; and (4) appropriate slope to provide adequate drainage. The engineered cover design consists of three components: a top soil layer for the vegetative cover, a subsurface soil layer, and a biobarrier layer. The engineered cover layers, beginning with the biobarrier layer, were placed on top of a base support layer. In turn, the base support layer was only applied after a stable subgrade was established, to minimize subsidence. Neutron access tubes for soil moisture monitoring were also installed during this project.

The engineered cover installation project entailed the following work elements:

- Pre-construction testing at the individual sites for hydraulic conductivity determination of the soil beneath the contamination layer;
- Site preparation and mobilization;
- Construction of engineered covers over the designated areas, including geotechnical testing of the soil material;
- Completion work activities.

A summary of these tasks is provided below.

4.2.5.2.1 Pre-construction Testing

Pre-construction testing activities consisted of drilling a total of nine soil borings (three around the perimeter of each planned cover area) for obtaining samples of the soil layer beneath the contamination layer. This was to verify that the hydraulic conductivity of the underlying soil layer was greater than or equal to the proposed hydraulic conductivity of the engineered cover. These data were needed to ensure that the cover would adequately minimize infiltration and prevent leachate from accumulating under the contamination layer (this phenomenon is known as the bathtub effect). The hydraulic conductivity for all of the samples was greater than the required hydraulic conductivity for the engineered covers ($1X10^{-5}$ cm/sec). Results of the geotechnical investigation indicated that conditions were suitable to construct the engineered covers as designed.

4.2.5.2.2 Site Preparation and Mobilization

The site preparation phase included site clearing and other preliminary steps, the sampling of borrow and in-place soils, and site surveying activities. Mobilization included establishing the project trailer, grading, and preparation of an equipment yard, and the transport of equipment and equipment services to the site.

Areas with preexisting natural soil cover were cleared of vegetation within the cover area, followed by filling and compaction of any areas that contained pits, cavities, or any other type of depressions that might be an indication of subsidence. The asphalt cover over NRF-12B was broken up and removed. Existing fencing at NRF-12B/14 and at NRF-19 was removed. Site preparations at NRF-21A included leveling the remaining three to five foot mounded area to the surrounding grade.

To ensure the areas were suitable for the placement of engineered covers, clean fill material was placed over all three cover locations. This fill material was placed as a stable subgrade. The thickness of this subgrade was at least one foot. The fill material used for this subgrade was obtained from the NRF gravel pit. Inspections prior to commencing construction determined that there were no soft spots or any other defects at any of the three areas to be covered.

4.2.5.2.2.1 Borrow Soil Testing and Source Management

Four types of soil materials were used as engineered cover material (or pre-cover material) including pit-run gravel for the base support layer, crushed gravel and cobble for the biobarrier layer, clay-rich native soil for the subsurface layer, and native soil with some gravel for the top layer. Geotechnical testing of the soil borrow material, which included the collection of soil samples, was performed to assess the suitability of soil for use as cover material. Suitable material was excavated (using a bulldozer) and processed (e.g., pit-run gravel was crushed and sorted) as required, and loaded into transport trucks. The cobble was obtained from an off-site commercial vendor.

4.2.5.2.2.2 Site Surveying

Site surveying activities commenced during mobilization and continued through the cover installation process. Site surveys were performed after the placement of each cover layer. The survey data were used to develop the as-built drawings, including cross-sections, and to provide a verification of the actual quantities of material used.

4.2.5.2.3 OU 8-08 Engineered Cover Construction

The engineered covers constructed at the three designated areas, NRF-12B/14, NRF-19, and NRF-21A, all employed the same construction methods. The cover construction activities included: (1) base support layer fill and grading, (2) biobarrier cover construction, (3) subsurface soil cover construction, and (4) topsoil cover construction. Gravel material was used to form the base support layer for the engineered cover to provide stability by minimizing or eliminating subsidence. This subgrade consisted of a compacted layer of pit-run gravel with a minimum thickness of one foot. The base support layer serves as a base/foundation that provides additional stability (sufficient load bearing capacity) for the upper three soil layers of the engineered cover, thereby minimizing subsidence problems with the cover. The biobarrier layer was constructed by placing cobble between two layers of crushed gravel. The purpose of the biobarrier layer is to inhibit biotic intrusion. The subsurface cover layer was constructed for minimizing water infiltration. The cover side slopes (where the cover edges will meet with the surrounding natural surfaces) were constructed as to achieve a maximum three horizontal to one vertical (3H:1V) ratio. Water was added during construction to aid compaction and prevent desiccation cracking. The soil was placed in five, ten-inch lifts (four feet minimum total thickness) at all cover locations.

A six to twelve inch topsoil cover layer was also constructed with soil material designed to support native vegetation, inhibit erosion, and promote drainage by placement of a three to five percent top slope. Soil material for the topsoil layer was loosely placed, with minimum compaction resulting from grading the material to the final surface grade. Construction Quality Assurance (CQA) practices were implemented to ensure construction quality. All CQA test results were within the acceptable limits (BBI, 2006).

The general cross-section of the engineered covers is shown in Figure 4-3. The engineered cover top view with finished grade for each of the three areas is shown in Figure 4-4 and Figure 4-5.

4.2.5.2.4 Completion Work Activities

The project completion phase included the installation of neutron access tubes for soil moisture monitoring, final surveying of the engineered covers, area seeding including the placement of mulch, pre-final and final inspections by regulators, and the preparation of the OU 8-08 RA Report. A summary of the installation of neutron access tubes for soil moisture monitoring and area seeding/mulching are described in the following sections.

4.2.5.2.4.1 Soil Moisture Neutron Access Tube Installation

Six neutron access tubes were installed. The access tubes were placed about a foot deep into the base support layer (i.e., they are located in the central portion of the covers where the base support layer is thickest). Tubes consisted of two-inch nominal size steel pipe, approximately seven feet in length. Two monitoring locations were selected per site. A bentonite seal was placed at the surface around each access tube, and then soil was placed on top of the bentonite seal and mounded to shed precipitation away from the access tube. Figure 4-6 depicts the typical access tube construction.

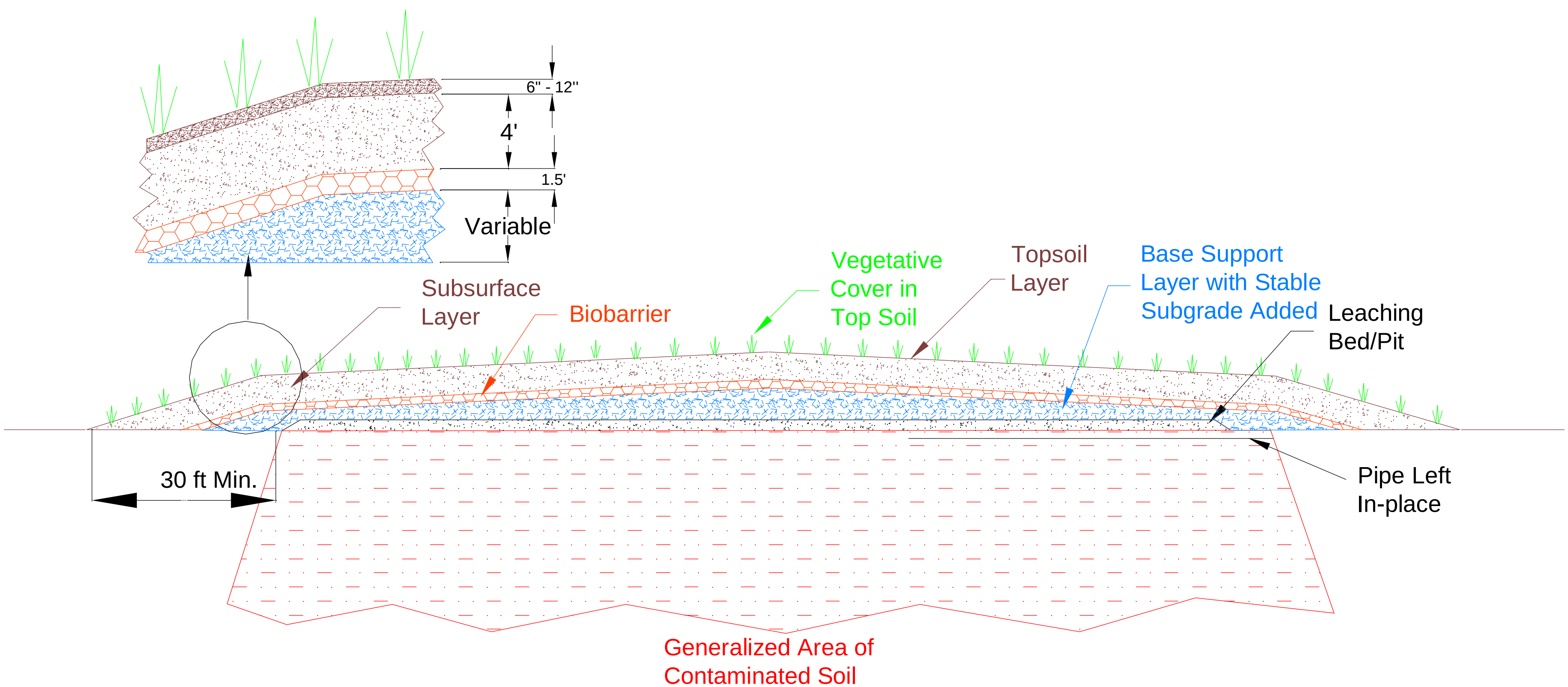

Figure 4-3 General Cross-section of OU 8-08 Engineered Cover

Figure 4-4 NRF-12B/14, NRF-21A, and NRF-19 OU 8-08 Engineered Cover Areas

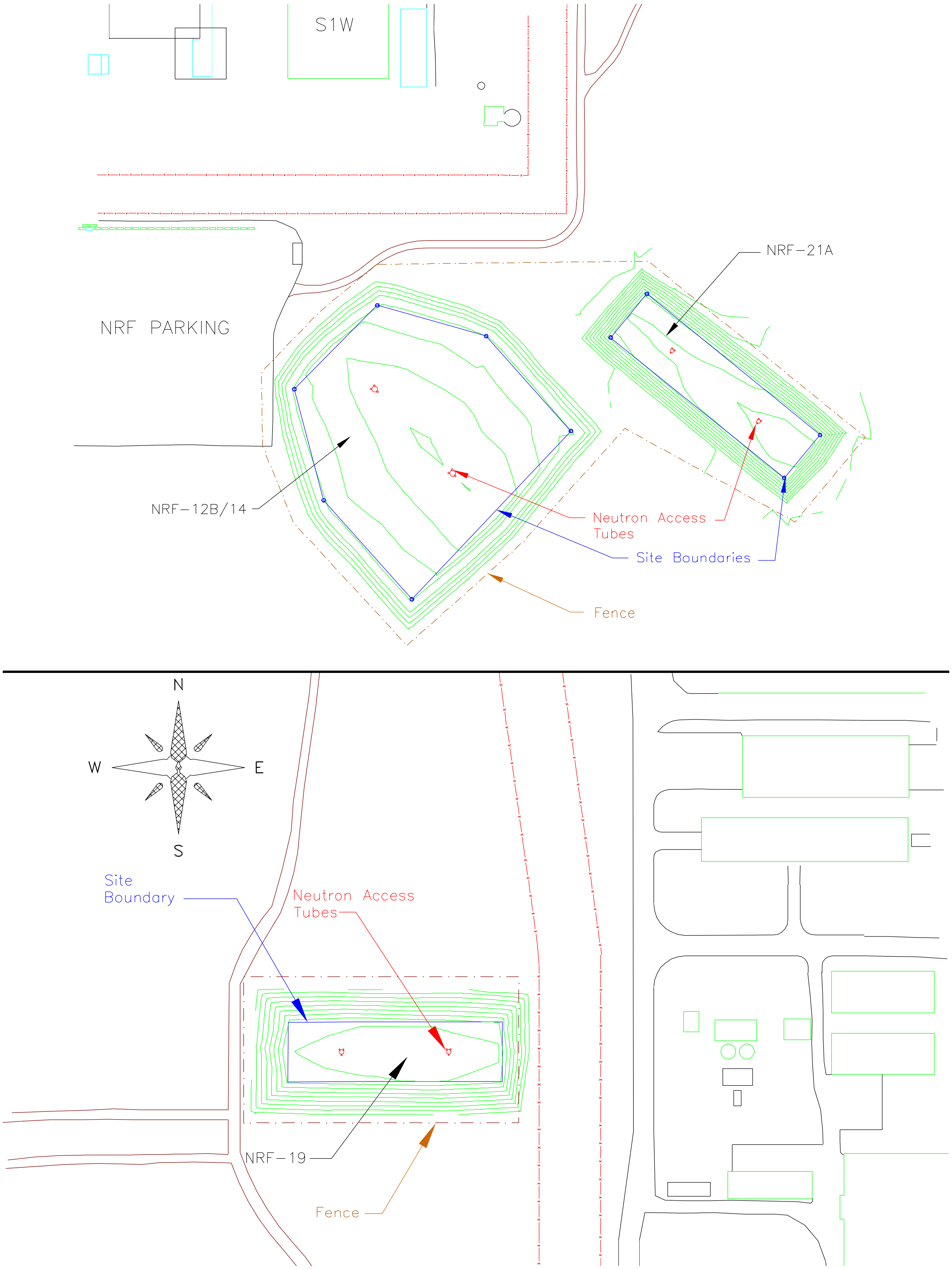

Figure 4-5 NRF-12B/14, NRF-21A, and NRF-19 Engineered Cover Areas

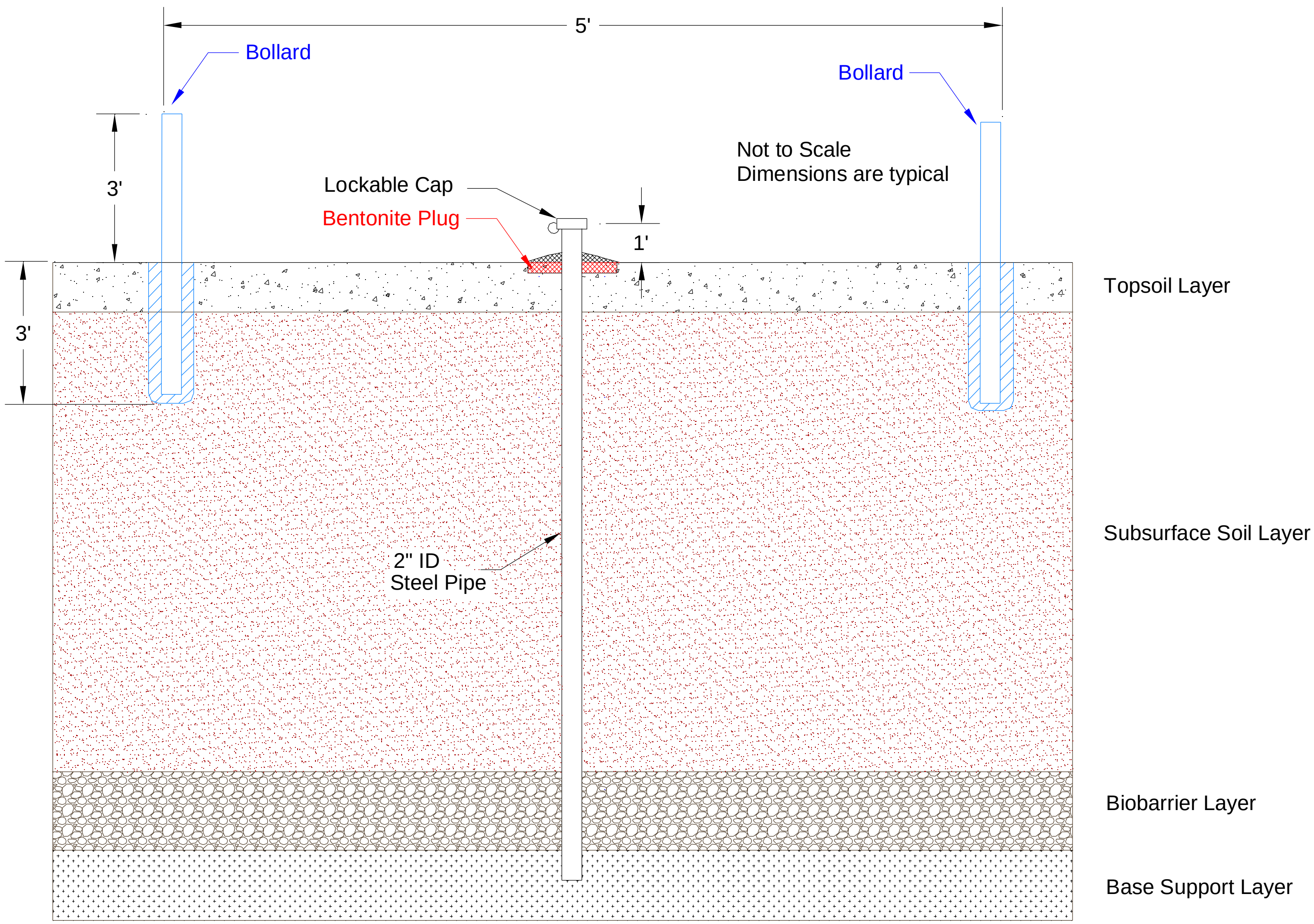

Figure 4-6 Typical Soil Moisture Neutron Access Tube Construction

4.2.5.2.4.2 Fertilization, Seeding, and Mulching

Fertilization, seeding, and mulching were performed after cover construction. Prior to seeding, fertilizer was applied at all three cover areas. Following fertilization, the soil surface was tilled two to three inches deep. Seeding was performed at all three cover areas with native plant species including sagebrush. The covers were mulched immediately after the fertilization and seeding were completed. Supplemental irrigation was temporarily applied at each location to promote plant growth.

5.0 Progress Since Last Review

5.1 2001 Review of Inactive Landfill Areas

5.1.1 Protectiveness Statement

Protectiveness statements were originally presented in the 2001 Five-Year Review for the NRF Inactive Landfill Areas. These protectiveness statements confirmed that the landfill covers were effective at containing contaminants by inhibiting infiltration of precipitation and by preventing direct contact with contaminated soils and landfill wastes. Furthermore, the landfill covers appeared to limit the migration of volatile organic compounds (VOCs) away from the landfill areas; therefore, it was concluded that the landfill covers were working as designed and thus they were protective of human health and the environment.

5.1.2 Recommendations

In the 2001 NRF Inactive Landfill Areas Five-Year Review, DOE NR/IBO provided recommendations pertaining to the landfill covers, the groundwater monitoring network, and the soil gas monitoring probes.

The 2001 review discussed problems with sparse vegetation areas and weeds and raised the possibility of re-seeding some of the landfill. It was recommended that if little or no improvement was noted, NRF would make plans to re-seed any bare spots. Plans were also identified to post the landfills with warning signs.

DOE NR/IBO did not propose any major changes to the NRF Groundwater Monitoring Network or sampling methodology. However, some minor changes were proposed. These changes included discontinuing analysis for gross alpha and beta, total kjeldahl nitrogen (TKN), total organic carbon (TOC), and phosphorus, as well as changing sample collection frequency from four times per year to three times per year.

The 2001 review identified additional issues related to the NRF Groundwater Monitoring Network. The first issue was that the upgradient groundwater quality relative to NRF was not well defined. USGS-12 is an older well (constructed in 1950) located at a distance that is not ideally suited to be an upgradient well, and NRF-7 is not physically upgradient to NRF.

The second issue related to the Groundwater Monitoring Network concerned well screens. NRF was concerned that a 50 foot screened interval design may inadvertently underestimate the impact that NRF operations have on the aquifer, since potential contaminants released to the aquifer will stay close to the surface of the aquifer. However, the 2001 review concluded that since the detectable results are all far below risk-based levels of concern, well data appeared to remain useful and applicable to assessing NRF's impact on the aquifer.

The third Groundwater Monitoring Network issue was that water samples from two wells, NRF-10 and NRF-13, consistently contained higher than desired levels of suspended solids, which were believed to be responsible for elevated metal concentrations in water samples. The 2001 review indicated the sources of the suspended solids are sedimentary interbeds that intersect the screened interval of the wells. The suspended solids in the wells contained metals that in turn raise the level of these metals in the water analyses. Groundwater sample results that are biased high for metal content in downgradient wells could exaggerate any conclusion that activities at NRF have adversely affected groundwater quality. This condition prompted NRF to state that DOE NR/IBO, EPA, and IDEQ will develop a list of criteria for re-evaluating groundwater chromium and for considering possible responses in the event that apparent trends in chromium concentrations observed in NRF-13 continue, and Federal MCLs exceeded for an average of four quarters.

Finally, the 2001 review noted as a deficiency that the scarcity of wells within the NRF fenced area increased the chance of near-site undetected releases. No actions were recommended, and subsequent downgradient sample results continued to show that ongoing operations at NRF did not adversely affect the quality of aquifer water.

The 2001 review also identified two issues with the soil gas probes. The first issue was that two of the probes, MW1-1 and MW1-2, were plugged and not working correctly. NRF indicated that an attempt to unplug the wells would be made. If unsuccessful, two options were to be considered: 1) seek regulatory agreement that no action was needed; or 2) construct new monitoring probes to replace the plugged probes. The second issue was that some of the probes periodically contained water. No corrective actions were recommended in the 2001 review for moisture in the probes since the moisture did not impede sample collection.

5.1.3 Follow-up Actions

Based on recommendations from the 2001 NRF Inactive Landfill Areas Five-Year Review, the following actions were performed.

Although the annual inspections of the landfill covers at NRF-1 and NRF-51 from 2001 to 2004 revealed new vegetation growth occurring in the sparse areas at the southwest corner of NRF-1 and areas along the east perimeter of NRF-53, it was occurring slowly and re-seeding was necessary in these areas. Due to drought conditions that persisted in eastern Idaho, re-seeding was delayed until precipitation increased to near normal amounts. Re-seeding was performed during the late fall of 2004 just prior to several significant snow events. Additionally, warning signs were posted at the landfill cover sites in 2003.

Beginning in 2003, proposed NRF Groundwater Monitoring Network changes were implemented. Specifically, the analyses for gross alpha and beta, TKN, TOC, and phosphorus were discontinued. Additionally, with regulatory agency agreement, sample collection frequency was changed from four times per year to three times per year.

On two occasions (December 2004 and July 2006) since the 2001 Five-Year Review, the concentration of chromium in NRF-13 exceeded the federal MCLs. NRF performed an evaluation of this well and the results are presented in Appendix A and summarized in Section 6.0.

The malfunctioning of two soil gas probes (MW1-1 and MW1-2) due to plugging was also addressed. Between 2001 and 2003, NRF inspected the interior of the plugged soil gas probes and attempted to clear the obstructions by mechanical means. These attempts were unsuccessful; therefore, NRF replaced the two probes in 2003. The new soil gas probes were constructed using a slightly modified version of the specifications used to build the original soil gas monitoring probes. This was done to maintain overall consistency while addressing issues that contributed to the problems encountered in the old probes. The modifications included adding more sand pack material below and above the slotted pipe section, to ensure that the bentonite would not migrate into the slotted pipe section. The existing probes adjacent to the new probes were abandoned by cutting off the surface pipe even with the existing pad and pouring grout down the pipe, up to the surface of the pad. The new probes were initially tested immediately after construction to ensure they were functioning correctly. Additional discussion of replacement of these probes is provided in Section 6.2.1.6.1.

5.1.4 Current Status

The 2005 inspection of the landfill covers at NRF-1 and NRF-51 revealed that the re-seeding that was performed in the late fall of 2004 had resulted in the growth of some new seedlings, particularly at the NRF-1 southwest corner and the NRF-51 sparse area.

The proposed NRF Groundwater Monitoring Network changes (as noted in Section 5.1.3) have been fully implemented. NRF has performed an evaluation of NRF-13 which concludes that the elevated chromium results are related to sedimentation. Details of this evaluation are included in Appendix A.

The new soil gas probes have operated correctly and provided useable data since their reconstruction. Additionally, although some of the soil gas probes continue to periodically contain some water (as noted in Section 6.2.1.6), subsequent sample results have confirmed that these probes provide adequate useable data.

5.2 2004 Review of OU 8-08 Sites

5.2.1 Protectiveness Statement

Protectiveness statements were originally presented in the 2004 Five-Year Review for the Naval Reactors Facility OU 8-08 Sites. These protectiveness statements confirmed that visual inspections, soil gas data, and groundwater data indicated that the selected remedies for the NFA sites appeared to be effective at limiting unauthorized access and excavation. Based on this assessment it was concluded that the selected remedies remain protective of human health and the environment.

The 2004 review also stated that it was expected that all evidence presented in the upcoming Remedial Action (RA) Report (issued in its final form in March 2006) would indicate that the selected remedies, i.e., soil, concrete and pipe removal, and consolidation of contaminated soil at NRF-12B/14, would be protective of human health and the environment by achieving Remedial Action Objectives.

Section 6.4 of the RA Report (BBI, 2006) stated that based on all available information, NR/IBO certified that the remedial actions intended to be performed at the OU 8-08 sites as described in the Record of Decision were fully performed and that the Performance Standards were attained;

therefore, NRF concluded that all nine OU 8-08 remedial action sites were in a state that protects human health and the environment.

5.2.2 Status from 2004 Review of OU 8-08 Sites

Remedial actions associated the OU 8-08 Sites, including issuing the Remedial Action Report, were not complete when the 2004 Five-Year Review was issued; therefore, no recommendations were presented at that time. An evaluation of data collected in association with the remediation of OU 8-08 Remedial Action Sites confirm that RAOs have been achieved.

6.0 Data Review and Evaluation for Five-Year Review Process

6.1 Summary of Five-Year Review Process

This Five-Year Review is intended to determine whether the selected remedies remain protective of human health and the environment. In addition, the review reassesses the monitoring programs to ensure the correct constituents are being monitored, and to ensure the frequency of sampling and the number of wells are correct. BBI personnel have reviewed past site information, including sampling data (groundwater, soil gas, and soil moisture), ICMRs, work plans, ARARs, and RODs, and were responsible for drafting this Five-Year Review. NR/IBO, EPA, and IDEQ personnel have also reviewed this information and approved this report. This document is available at the INL Information Repository. Public notification of the Five-Year Review and its availability will be given in local newspapers.

6.2 Site Inspections

6.2.1 Overview of Site Inspection Activities

Annual inspections of the various CERCLA sites are required per the O&M plans and results are reported annually in the ICMR. Additional inspections were performed as part of the final inspection certification of the OU 8-08 Engineered Cover Sites. In addition, routine surveillances are conducted as a matter of good practice. The following sections discuss results of inspections at the various sites.

6.2.1.1 Inspections of Inactive Landfill Areas

Annual inspections of the landfill covers are required. Annual inspections revealed mostly minor problems (e.g., anthills, rodent holes). The following is a summary of the more important observations (e.g., sparse vegetation, vehicle intrusion) associated with the inspections.

The initial NRF Inactive Landfill Areas Five-Year Review (February 2001) discussed problems with sparse vegetation areas and weeds. The inspections of NRF-1 and NRF-51 from 2001 to 2004 indicated improvement with some new growth occurring in the sparse areas at the southwest corner and areas along the east perimeter. Even though the natural re-vegetation process had increased the vegetation density, it was occurring slowly and re-seeding was necessary in these areas. Due to drought conditions that persisted in eastern Idaho, re-seeding was delayed until precipitation increased to near normal amounts. Re-seeding was performed during the late fall of 2004 just prior to several significant snow events. The 2005 inspection revealed that the re-seeding had resulted in the growth of some new seedlings, particularly at the NRF-1 southwest corner and the NRF-51 sparse area. All areas will continue to be closely monitored during future inspections.

The 2003 annual inspection revealed evidence that vehicles had driven on the extreme west side of NRF-1. Only minor damage to some vegetation and to the surface of the cover was observed. This intrusion occurred prior to the placement of additional signs with larger lettering that could be seen from a distance. Site personnel were retrained and monitoring of the area was increased until a temporary fence was placed to enclose the area. NRF posted the landfill areas with new signs easily seen from a distance to warn employees, subcontractors, or potential trespassers of no unauthorized entry into these sites. Permanent fences have since been constructed around each of the Inactive Landfill Areas.

6.2.1.2 Inspections of No Further Action Sites

NRF issued an Initial ICMR in 2001 and annual ICMRs between 2002 and 2005. Each ICMR included site inspections of the NFA Sites. No significant deficiencies were noted during site inspections. Minor deficiencies (e.g., sagging fences) were addressed when they were noted, as soon as circumstances allowed (e.g., weather conditions).

6.2.1.3 Inspections of Remediated Radiological Sites

Formal inspections of the Remediated Radiological Sites will begin in 2006 since the RA Report was finalized earlier in 2006. However, these sites have been inspected as part of routine surveillances. Most sites have been restored to near pre-work conditions. NRF-17 is presently being used as a staging area for a construction project and will be restored to surrounding lawn conditions or put to other productive use after project completion. Signs for the sites have been received and installed.

6.2.1.4 Inspection of OU 8-08 Engineered Covers

Several inspections were conducted at the three OU 8-08 engineered cover areas in preparation for the pre-final and final inspections by the regulatory agencies. These inspections were conducted shortly after the covers were constructed and after seeding had been performed. The inspections occurred during the summer and fall of 2004 and during the spring, summer, and fall of 2005. The inspections included, but were not limited to, the following items: 1) whether erosion had occurred after significant rainfall events (0.75 inches or greater of rainfall in one day (Sagendorf, 1996)), 2) the occurrence of any subsidence, and 3) whether sufficient vegetation was growing on the covers. Only minor evidence of erosion was observed during 2004. More significant evidence of erosion was observed during 2005 at NRF-12B/14 and NRF-19 but was limited to small areas on the side slopes. These areas were repaired and re-seeded during the fall of 2005.

During the fall of 2004, representatives of the IDEQ and EPA visited the OU 8-08 Engineered Cover Sites and performed a pre-final inspection. The following is a summary of the deficiencies noted: 1) gates had not been secured with locks; 2) warning signs had not been installed; 3) minor subsidence and desiccation cracking observed around neutron access tubes were noted and required repair by mounding and compacting additional soil around the tubes and sloping the mounds such that precipitation is shed radially; and 4) vegetation had not been established on some side slopes and perimeter areas. The first three deficiencies were corrected by NRF as soon as conditions permitted. The deficiency associated with vegetation was self correcting as spring and summer plant growth occurred.

During fall of 2005, IDEQ and EPA personnel performed final inspections of the OU 8-08 Engineered Cover Sites to ensure that deficiencies noted during the pre-final inspections had been corrected. Both agencies agreed this had occurred.

6.2.1.5 Inspections of Groundwater Monitoring Wells

The United States Geological Survey (USGS), the organization assisting in the collection of NRF groundwater samples, inspects wells during the sampling process. Any problems with the wells are reported to NRF personnel. Maintenance or repairs are handled through the USGS under the cognizance of NRF personnel. NRF personnel also periodically inspect well locations. Since the last Five-Year Review, inspections of the wells have revealed only minor problems (e.g., cracked paint, cracked concrete pad, etc.) which were corrected shortly thereafter. Other more serious problems were discovered during scheduled sampling events (or as the case with USGS-98, during in-house analysis of groundwater elevation data). These problems are discussed below.

6.2.1.5.1 Refurbishment of Well NRF-12

In February 2002, while collecting first quarter groundwater data, the USGS reported that well NRF-12 would not produce water. The pump, motor, riser pipe, and measuring-line were pulled and examined. It was determined that the motor had failed. The motor and pump were replaced and the electrical wiring was upgraded. The well has functioned as designed since 2002.

6.2.1.5.2 Refurbishment of Well NRF-6

While collecting samples from well NRF-6 in November 2003, the USGS noted in their logbook that the generator used to power the pump motor cutout repeatedly during well purging. The purge water was dark red for almost one minute after turning the pump on. The sample was eventually collected and analyzed. Several of the constituent results were significantly elevated above their historical averages. Table 6-1 shows the results for constituents that were elevated. The historical averages for these constituents are included for reference.

Table 6 1 Comparison of Turbidity and Metal Results from NRF 6

	Turbidity	Chromium	Copper	Iron	Manganese	Nickel
November 2003	52	460	23	39,000	350	100
Historical Average	5	39	7	749	7	15

Metal results in ppb
Turbidity in Nephelolometric Turbidity Units (NTU)

Prior to the collection of samples in March 2004, the USGS tested the well and determined either the pump or pump motor had failed. These components were pulled from the well and examined. The motor had overheated and seized, apparently due to silt that had accumulated around the motor. Further examination revealed that corrosion of the pump, motor, measuring-line, and riser pipe had occurred. The pump and motor and other affected parts were replaced with new parts (the wiring was also upgraded). A videolog of the well showed that while extensive precipitation/sedimentation had occurred and thickly deposited on the well screen, no corrosion of the screen itself was evident. The pump and motor assembly was placed five feet above its original position when reinserted in the well. Subsequent testing of the well showed that the well functioned properly and subsequent sample results have returned to historical levels with some constituents dropping below historical levels.

Section 5.2 of Appendix A discusses data trends in this well, and also compares the groundwater data to sample turbidity. Turbidity is an indicator of the presence of suspended solids in the water sample. Suspended solids, whether from sediments or corrosion products, will likely contain metal constituents. Samples containing these solids can produce results with elevated metal concentrations. Analysis in Appendix A indicates that, the elevated metal results in NRF-6 for November 2003 were a result of high suspended solids in the well. The high suspended solids were likely derived from well sediments, corrosion products, or both.

6.2.1.5.3 Refurbishment of Well NRF-7

Beginning in November 2002 and continuing into 2004, the analysis results for aluminum, chromium, iron, manganese, and nickel from well NRF-7 were abnormally elevated compared to historical results. As part of an investigation of the cause for the anomalous data, USGS pulled the pump, pump motor, measuring-line, and riser pipe from the well during the fall of 2004. Examination of the well components showed that they were still in acceptable condition; however, since the pump and motor were nearly 15 years old, they were both replaced along with the pump motor wiring. A videolog of the well showed that the screen was in excellent condition. Table 6-2 is a summary of data collected before, during, and after the period in question. These data show that the anomalous results occurred in association with high suspended solids (turbidity). Section 3.4.2 of Appendix A discusses these results in more detail and suggests that they are the result of sediment in the well. Subsequent sample results from this well returned to near historical levels.

Table 6 2 Comparison of Turbidity and Metal Results from NRF 7

	Turbidity	Aluminum	Chromium	Iron	Manganese	Nickel
Before 11/2002	9.4	177	11	365	8.8	9.4
During Anomaly*	104	3,234	23	3,700	95	22
After 3/2004	5.5	70	14	302	7.3	10.3

Metal results in ppb
Turbidity in NTU
*November 2002 to March 2004

6.2.1.5.4 Refurbishment of Well USGS-98

During 2004, an evaluation of water table elevation in the NRF wells determined that the water table elevation in well USGS-98 was very near the pump intake level, which would result in the well becoming inoperative. Maintenance of the well was scheduled for late February or early March of 2005 in order to accommodate the first trimester sampling of the well in late March. The maintenance crew had intended to pull the pump and motor, inspect the condition of pump, motor, and well casing, and then reinstall the pump and motor approximately 20 feet deeper in the well. During the extraction process, the well casing was pulled up out of the well along with the pump and motor. It was later determined that the pump, motor, and probably the riser pipe had rusted to the casing.

In order to restore the well, a drill rig was used to remove silt that had accumulated in the bottom of the well. A new pump and motor, riser pipe, measuring-line, casing, and screen were installed in the well. The pump intake was placed 20 feet deeper than before. The well has functioned properly since its refurbishment.

6.2.1.6 Inspections of Soil Gas Monitoring Probes

The initial Five-Year Review (February 2001) for the Inactive Landfill Areas stated that MW1-1 and MW1-2 (soil gas monitoring probes at NRF-1) were not functioning properly because of a plugging problem with both probes. The plugging problem may have been due to defective construction. That Five-Year Review stated that attempts would be made to clear the probes, and if unsuccessful, two options would be considered: 1) seek regulatory agreement that the plugged probes are in a non-critical area and no further action is required; or 2) construct new monitoring probes to replace the problem probes.

Follow-up annual inspections indicated that MW1-1 and MW1-2 soil gas monitoring probes remained partially plugged even after attempts were made to unplug the probes. Since the mechanism causing the plugging problem was unknown, NRF initiated plans to replace these probes during 2003. A third probe (MW1-4) was found to contain standing water while collecting samples. This has been an intermittent problem that appears to be related to precipitation events and standing water that accumulates in puddles next to the engineered cover, leading to the formation of a small perched water zone.

No problems were encountered with any of the soil gas monitoring probes during subsequent inspections after the construction of the replacement probes. Replacement probe construction is discussed below.

6.2.1.6.1 Probe Reconstruction

An inspection of MW1-1 and MW1-2 was performed using a small diameter down-hole video camera. The video camera used for inspecting the probes identified standing water, which may have been from condensation inside the pipe, and obstructions about an inch below the water level, in both probes. The obstruction in MW1-2 was encountered at about two feet above the top of the slotted section (see Figure 4-2). The obstruction in MW1-1 was encountered at approximately the top of the slotted section of pipe.

Attempts to clear the restrictions by mechanical means were conducted without success; therefore, NRF replaced the two original probes in 2003. The new monitoring probes were placed as close to the original probes as physically possible. The new probes were checked for proper completion and functionality immediately after their construction by: 1) running a depth-measuring device down the pipe to ensure proper depth, and 2) attaching the sampling equipment to the probes and verifying that sufficient airflow could be drawn to collect samples.

The new soil gas probes were constructed using a slightly modified version of the specifications used to build the original soil gas monitoring probes. This was done to maintain overall consistency while addressing issues that contributed to the problems encountered in the old probes. The modifications included adding more sand pack material below and above the slotted pipe section, to ensure that the bentonite would not migrate into the slotted pipe section. The existing probes adjacent to the new probes were abandoned by cutting off the surface pipe even with the existing pad and pouring grout down the pipe, up to the surface of the pad.

6.2.1.7 Inspections of Soil Moisture Neutron Access Tubes

Inspection of the soil moisture neutron access tubes was performed by NR/IBO, IDEQ, and EPA during a pre-final inspection of the OU 8-08 Engineered Cover Areas in 2004 and a final inspection in 2005. The pre-final inspection noted that the access tubes needed to be mounded with soil so that water would be shed radially away from the access tubes, followed by seeding the soil mound. The soil mounding was performed during the latter part of 2004. The seeding of the mounds was performed in 2005. During the final inspection, IDEQ and EPA noted the deficiencies were corrected.

6.3 Data Review

6.3.1 Monitoring Program Overview

NRF collects various types of data including groundwater, soil gas, surface soil gas emissions, and soil moisture. These data are used to assess the effectiveness of remedies that have been implemented and to determine if operations at NRF are having an adverse effect on the environment. Surface soil gas emissions data for the three inactive landfill cover areas are acquired during an annual survey using a portable meter. No VOCs have been detected from these surveys. The following sections discuss the results of the other monitoring performed at NRF. A summary of yearly monitoring results is included in the annual NRF Environmental Monitoring Report (BBI, 2001 to 2005).

6.3.2 Groundwater

6.3.2.1 Analysis of Groundwater Monitoring Data

Groundwater monitoring data collected from monitoring wells located around NRF were analyzed. This analysis covers the period from the well's construction or initial inclusion into the monitoring network through March 2006.

NRF collects groundwater data from 13 groundwater wells located around the site as shown in Figure 3-4. These data were placed into the following groups; upgradient background (Regional Upgradient Group), downgradient (Local Downgradient and Regional Downgradient Groups), and Effluent System water quality.

As noted in Section 7.3 of the 2001 Five-Year Review, upgradient water quality relative to NRF is not well defined. NRF-7 was originally placed to monitor water released from the IWD. Based on water quality characteristics, the data collected from NRF-7 were included with USGS-12 to become the Regional Upgradient Group. The basis for doing this was provided in the 2001 5-Year Review.

NRF-6 and NRF-13 have been placed in the Effluent System well group. NRF-6 is known to monitor effluent from the IWD. Although NRF-13 was originally constructed as an upgradient well, it was included as an Effluent System well because its results do not reflect upgradient quality water. For the following analysis, NRF-13 data has been included with the Effluent System Group since during the period of this Five-Year Review (2001-2006) it has been part of the Effluent System Group. However, as noted in Appendix A, the wells' ability to monitor the effluent system has been questioned.

6.3.2.2 Inorganic Data Review

Analysis of inorganic data included a comparison of upgradient background water quality to downgradient (including Effluent System) water quality and evaluating monitoring results for trends. Because organic constituents were seldom detected in the groundwater, they are discussed separately in Section 6.3.2.3.

For purposes of this groundwater analysis, several key constituents were considered. Key constituents included in the assessment were based on the following criteria:

- Contaminants of concern (COCs) as described in the RODs for the OUs 8-05/06 and 8-08 sites that are routinely measured due to potential for detection. These include cesium-137 and organic compounds.
- Constituents detected in the soil during confirmation sample analysis that were also consistently detected in groundwater samples and were known to have been released at NRF in the past. These constituents include chromium.
- Constituents that are good geochemical indicators. This group includes calcium, chloride, sodium, and tritium. These constituents generally do not interact with the aquifer, and therefore reflect important aquifer properties such as dispersion and groundwater flow paths.
- Constituents that are consistently present in NRF groundwater samples and act as geochemical indicators. This group includes aluminum, iron, manganese, and nickel. These constituents may interact with the aquifer.

This analysis compared long-term monitoring results to two benchmarks. These benchmarks were Federal drinking water guidelines and local background concentrations. The purpose of comparing to Federal drinking water guidelines was to determine compliance with Federal regulations. Comparison of NRF groundwater quality to local background concentrations was intended to assess the relative impact that NRF operations have had on the aquifer. The results of these comparisons were used to assess whether the selected remedies are functioning correctly and that the remedies are effective.

Local background concentrations were estimated using data from Regional Upgradient wells NRF-7 and USGS-12. For this report, data from NRF-7 were averaged with data from USGS-12 for all constituents except the statistical outliers. These outliers included data listed at a high method detection limit (MDL) if the constituent concentration were known to be significantly less than that MDL. For example, data listed at the MDL of 10 ppb for antimony were considered outliers since other data from the wells showed antimony at a much lower concentration or at a lower MDL. This would indicate that the higher MDL of 10 ppb would bias the calculated background concentration. Similar outliers were found with arsenic, beryllium, cadmium, copper, lead, manganese, nickel, silver, and thallium. In addition, NRF-7 data collected from November 2002 to March 2004 were considered outliers for aluminum, chromium, iron, manganese, calcium, potassium, and magnesium due to sediments in the samples as indicated by elevated turbidity measurements (see Section 5.2 of Appendix A for additional discussion of this event). Table 6-3 shows the most current estimate of regional background concentrations. These background concentrations, which are synonymous with the regional upgradient concentrations, are also listed in Table 6-4.

Table 6 3 Estimated NRF Background Groundwater Concentrations

Constituent	pH	Spec. Cond.	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium
Units		µS/cm	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MCL	6.5 to 8.5 (a)	(b)	200 (a)	6	10	2000	4	5	100
Mean	8.0	403	<[c] 100	<<[c] 0.74	<[c] 3	< 100	<<[c] 0.9	<<[c] 0.5	9
Std. Dev	0.3	154	107	0.93	1	33	0.7	0.3	4
Max	8.9	610	560	<< 5.10	6	160	2.0	<< 1.0	27
Min	7.4	202	< 10	0.04	1	49	< 0.2	0.0	1

Constituent	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Thallium
Units	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MCL	1000 (a)	300 (a)	15	50 (a)	2	100	50	100 (a)	2
Mean	<<[c] 4	319	<[c] 1.7	< 6	<<[c] 0.1	<[c] 4.9	< 4	<<[c] 0.8	<<[c] 0.2
Std. Dev	8	679	1.0	6	0.1	3.9	2	0.3	0.2
Max	67	4800	5.6	24	0.2	14.0	6	2.8	<< 0.5
Min	1	< 10	0.3	1	0.0	0.5	1	0.2	0.0

Constituent	Zinc	Calcium	Potassium	Magnesium	Sodium	Chloride	Sulfate	NO_2	$NO_2 + NO_3$
Units	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MCL	5000 (a)	(b)	(b)	(b)	(b)	250000 (a)	250000 (a)	1000	10000
Mean	<<[c] 14	45159	2482	15005	11456	17135	22655	<< 8	1102
Std. Dev	17	18649	566	5505	3060	13300	8976	4	659
Max	120	77000	3700	24000	17700	42000	38000	20	2500
Min	3	16000	1500	8300	4500	4000	13000	1	360

Constituent	TKN	TOX	P as P	TOC	Strontium-90	Cesium-137	Gross Alpha	Gross Beta	Tritium
Units	ppb	ppb	ppb	ppb	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
MCL	(b)	(b)	(b)	(b)	8 (d)	200 (d)	15.0	(d)	20000 (d)
Mean	<< 460	<< 19	49	< 686	0.1	0.1	2.0	4.1	29
Std. Dev	297	13	65	500	0.1	0.7	1.0	1.5	31
Max	2200	55	400	3600	0.7	1.7	5.4	7.6	131
Min	78	3	5	100	-0.3	-4.6	0.2	0.7	-29

< A significant portion of the data used to create this value are at or below the MDL

<< Most of the data used to create this value are at or below the MDL

(a) Secondary MCL

(b) MCL not determined

(c) Two or more MDLs were used in the creation of this number

(d) Individual nuclides have a pCi/L MCL for drinking water which will give a dose of 4 mrem/yr

The mean concentrations for all NRF inorganic groundwater constituents were compared to background concentrations and Maximum Contaminant Levels (MCL; 40 CFR 141, 143) in Table 6-4. With the exception of aluminum in two wells, iron in six wells, and chloride in one well, none of the mean concentrations exceeded secondary Federal MCLs.

Table 6-4 shows that most elevated constituents are associated with wells NRF-6 and NRF-13. NRF-6 is located immediately downgradient of the IWD; therefore, sample results from this well reflect contributions from the IWD effluent. These include calcium, chromium, iron, potassium, magnesium, sodium, chloride, and sulfate. Salts (i.e., calcium, potassium, magnesium, sodium, chloride, and sulfate) discharged to the IWD are from NRF water conditioning operations. Section 6.3.2.4 discusses trends in NRF-6 for selected constituents.

NRF-13 is located upgradient from the IWD. Sample results from NRF-13 typically contain elevated metal concentrations. Appendix A contains a comprehensive analysis of geochemical, geological, and hydrological data associated with this well. This analysis includes comparisons to individual wells NRF-6, NRF-7, USGS-12, and regional background data (consisting of combined data from NRF-7 and USGS-12). Appendix A concludes that the occurrence of elevated metals in this well is due to high suspended solids present in water samples. The high suspended solids are most likely from natural sediments in the well, with the possibility of a small contribution from corrosion of well hardware. NRF-13 is scheduled for maintenance after collection of the 2006 third trimester groundwater samples. Section 6.3.2.4 discusses trends in NRF-13 for selected constituents.

Downgradient wells USGS-97, -98, and -99 contain zinc concentrations that are elevated compared to background but are significantly below the MCL. Zinc levels in these wells are probably associated with well construction issues rather than groundwater issues. This is supported by the observation that the mean zinc concentration in USGS-98 was approximately 150 ppb prior to the replacement of the pump, motor, and well screen in this well early in 2005 compared to a mean of approximately 12 ppb after the refurbishment. Well components and construction history for USGS-97 and USGS-99 are similar to that of USGS-98.

The levels of tritium in NRF-10 and NRF-11 were elevated with respect to background, although significantly lower than the MCL. These wells are located downgradient of the S1W Leaching Beds/Pit (NRF-14 and NRF-12B). It is believed that residual contamination from historical releases to this site is responsible for the elevated tritium.

Table 6 4 Comparison of MCL, Background, Individual Wells, and Well Groups

Constituent / Units	pH	Spec. Cond. µS/cm	Aluminum ppb	Antimony ppb	Arsenic ppb	Barium ppb	Beryllium ppb	Cadmium ppb	Chromium ppb
MCL	6.5 to 8.5 (a)	(b)	200 (a)	6	10	2000	4	5	100
Background	8.0 ± 0.3	403 ± 154	100 ± 107	0.74 ± 0.93	3 ± 1	100 ± 33	0.9 ± 0.7	0.5 ± 0.3	9 ± 4
NRF 6	7.8 ± 0.1	1419 ± 188	32 ± 21	0.81 ± 1.22	4 ± 1	94 ± 35	1.0 ± 0.7	0.5 ± 0.3	32 ± 7
NRF 7	8.3 ± 0.2	246 ± 12	150 ± 133	0.72 ± 0.91	3 ± 2	67 ± 21	1.0 ± 0.7	0.5 ± 0.3	12 ± 3
NRF 8	7.9 ± 0.1	573 ± 22	178 ± 626	0.63 ± 0.98	4 ± 1	124 ± 12	0.9 ± 0.7	0.4 ± 0.3	8 ± 2
NRF 9	7.9 ± 0.2	618 ± 24	38 ± 17	0.68 ± 1.19	3 ± 1	133 ± 13	1.0 ± 0.7	0.4 ± 0.3	11 ± 3
NRF 10	7.9 ± 0.2	580 ± 29	308 ± 404	0.84 ± 1.59	4 ± 2	132 ± 13	1.0 ± 0.7	0.4 ± 0.3	14 ± 3
NRF 11	7.9 ± 0.1	600 ± 37	86 ± 78	0.90 ± 1.75	4 ± 2	136 ± 15	0.9 ± 0.7	0.5 ± 0.3	18 ± 4
NRF 12	7.9 ± 0.1	644 ± 50	37 ± 18	0.97 ± 1.65	4 ± 1	149 ± 20	0.9 ± 0.7	0.4 ± 0.3	19 ± 5
NRF 13	8.0 ± 0.2	563 ± 54	2882 ± 3889	0.84 ± 1.50	4 ± 1	104 ± 21	0.9 ± 0.7	0.4 ± 0.3	72 ± 54
USGS 12	7.8 ± 0.1	543 ± 51	32 ± 38	1.00 ± 1.61	3 ± 1	127 ± 21	0.9 ± 0.7	0.6 ± 0.3	7 ± 1
USGS 97	7.9 ± 0.1	585 ± 25	60 ± 145	0.89 ± 1.56	3 ± 1	129 ± 23	0.9 ± 0.7	0.6 ± 0.3	6 ± 1
USGS 98	7.9 ± 0.2	417 ± 34	32 ± 22	0.72 ± 1.13	3 ± 2	54 ± 6	1.0 ± 0.7	0.5 ± 0.3	6 ± 1
USGS 99	7.9 ± 0.1	524 ± 20	48 ± 98	0.73 ± 1.13	3 ± 2	107 ± 15	1.0 ± 0.7	0.9 ± 1.8	6 ± 2
USGS 102	7.9 ± 0.1	572 ± 20	30 ± 18	0.73 ± 1.22	3 ± 1	116 ± 17	0.9 ± 0.7	0.6 ± 0.4	7 ± 1
Regional Upgradient	8.0 ± 0.3	403 ± 154	100 ± 107	0.74 ± 0.93	3 ± 1	100 ± 33	0.9 ± 0.7	0.5 ± 0.3	9 ± 4
System Effluent	7.9 ± 0.2	1070 ± 449	1775 ± 3321	0.82 ± 1.35	4 ± 1	99 ± 29	0.9 ± 0.7	0.5 ± 0.3	50 ± 41
Local Downgradient	7.9 ± 0.1	595 ± 40	129 ± 335	0.79 ± 1.40	4 ± 2	131 ± 18	0.9 ± 0.7	0.5 ± 0.3	12 ± 6
Regional Downgradient	7.9 ± 0.1	509 ± 75	46 ± 99	0.78 ± 1.28	3 ± 2	101 ± 34	1.0 ± 0.7	0.7 ± 1.1	6 ± 1

Constituent / Units	Copper ppb	Iron ppb	Lead ppb	Manganese ppb	Mercury ppb	Nickel ppb	Selenium ppb	Silver ppb	Thallium ppb
MCL	1000 (a)	300 (a)	15	50 (a)	2	100	50	100 (a)	2
Background	4 ± 8	319 ± 679	1.7 ± 1.0	6 ± 6	0.1 ± 0.1	4.9 ± 3.9	4 ± 2	0.8 ± 0.3	0.2 ± 0.2
NRF 6	3 ± 2	749 ± 917	1.6 ± 0.9	7 ± 7	0.1 ± 0.1	15.4 ± 11.2	4 ± 1	0.8 ± 0.4	0.5 ± 1.6
NRF 7	6 ± 12	514 ± 867	1.8 ± 1.1	10 ± 7	0.1 ± 0.1	8.4 ± 3.1	4 ± 2	0.8 ± 0.4	0.2 ± 0.2
NRF 8	4 ± 3	239 ± 533	2.0 ± 1.0	4 ± 8	0.1 ± 0.1	2.9 ± 2.0	4 ± 1	0.7 ± 0.5	0.2 ± 0.2
NRF 9	4 ± 3	149 ± 161	1.9 ± 0.9	2 ± 2	0.1 ± 0.1	2.3 ± 1.5	4 ± 1	0.7 ± 0.5	0.2 ± 0.2
NRF 10	4 ± 6	450 ± 581	2.0 ± 0.9	11 ± 13	0.1 ± 0.1	14.6 ± 8.4	4 ± 1	0.7 ± 0.5	0.1 ± 0.2
NRF 11	5 ± 6	193 ± 276	1.9 ± 0.9	5 ± 4	0.2 ± 0.3	8.0 ± 4.1	4 ± 1	0.8 ± 0.7	0.4 ± 1.0
NRF 12	4 ± 3	165 ± 319	1.9 ± 0.9	2 ± 2	0.1 ± 0.1	13.2 ± 12.3	4 ± 1	0.8 ± 0.6	0.1 ± 0.2
NRF 13	7 ± 7	3500 ± 4302	2.3 ± 1.3	58 ± 64	0.1 ± 0.1	28.9 ± 18.7	4 ± 2	0.9 ± 0.7	0.1 ± 0.2
USGS 12	2 ± 2	161 ± 420	1.5 ± 0.8	3 ± 5	0.1 ± 0.1	1.7 ± 1.4	4 ± 2	0.9 ± 0.4	0.2 ± 0.2
USGS 97	6 ± 17	235 ± 575	2.6 ± 1.6	3 ± 6	0.1 ± 0.1	1.7 ± 1.4	4 ± 1	0.9 ± 0.4	0.2 ± 0.3
USGS 98	12 ± 51	215 ± 378	4.5 ± 3.0	3 ± 4	0.1 ± 0.1	1.3 ± 0.6	3 ± 2	0.9 ± 0.4	0.3 ± 0.6
USGS 99	3 ± 3	310 ± 724	2.2 ± 1.0	5 ± 8	0.1 ± 0.1	1.6 ± 0.9	3 ± 2	0.8 ± 0.3	0.2 ± 0.2
USGS 102	3 ± 3	417 ± 1539	1.6 ± 0.8	3 ± 4	0.1 ± 0.1	1.6 ± 0.8	4 ± 1	0.8 ± 0.4	0.4 ± 1.1
Regional Upgradient	4 ± 8	319 ± 679	1.7 ± 1.0	6 ± 6	0.1 ± 0.1	4.9 ± 3.9	4 ± 2	0.8 ± 0.3	0.2 ± 0.2
System Effluent	5 ± 5	1924 ± 3160	1.9 ± 1.1	35 ± 54	0.1 ± 0.1	21.1 ± 16.2	4 ± 1	0.8 ± 0.5	0.4 ± 1.2
Local Downgradient	4 ± 4	283 ± 853	1.8 ± 0.9	5 ± 8	0.1 ± 0.1	7.9 ± 8.8	4 ± 1	0.8 ± 0.5	0.2 ± 0.7
Regional Downgradient	7 ± 32	254 ± 577	3.1 ± 2.3	4 ± 6	0.1 ± 0.1	1.6 ± 1.0	3 ± 2	0.9 ± 0.4	0.3 ± 0.4

(a) Secondary MCL
(b) MCL not determined

Between 1 and 2 std. dev. greater than background
Between 2 and 3 std. dev. greater than background
Greater than 3 std. dev. from background

Group Configuration –

Regional Upgradient Group	USGS-12 and NRF-7
Effluent System Group	NRF-6 and NRF-13 (As noted in Appendix A, the ability of NRF-13 to monitor the Effluent System has been questioned.)
Local Downgradient Group	NRF-8 through 12 and USGS-102
Regional Downgradient Group	USGS-97, -98, and -99

Note: Table constituents are arranged by metals, salts, and then nutrients.
Averages are for the period 1989 to present for wells USGS-12, 97, 98, 99, and 102; 1991 to present for NRF-6 and 7; and 1996 to present for NRF-8, 9, 10, 11, 12, and 13.

Table 6 4 Comparison of MCL, Background, Individual Wells, and Well Groups (Cont.)

Constituent	Zinc	Calcium	Potassium	Magnesium	Sodium	Chloride	Sulfate	NO_2	$NO_2 + NO_3$
Units	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MCL	5000 (a)	(b)	(b)	(b)	(b)	250000 (a)	250000 (a)	1000	10000
Background	14 ± 17	45159 ± 18649	2482 ± 566	15005 ± 5505	11456 ± 3060	17135 ± 13300	22655 ± 8976	8 ± 4	1102 ± 659
NRF 6	10 ± 7	124130 ± 23825	4860 ± 748	33437 ± 5000	110209 ± 36901	264963 ± 100118	156146 ± 65434	6 ± 4	1782 ± 246
NRF 7	17 ± 18	25912 ± 3721	3016 ± 398	9266 ± 802	8833 ± 1007	5065 ± 479	14412 ± 3001	6 ± 4	518 ± 279
NRF 8	9 ± 6	68724 ± 4123	2253 ± 217	22305 ± 1306	15041 ± 948	33111 ± 3690	33662 ± 2114	6 ± 4	1911 ± 222
NRF 9	9 ± 5	72543 ± 4373	2441 ± 263	22722 ± 1347	17668 ± 1306	43757 ± 3764	42814 ± 4057	6 ± 4	2216 ± 472
NRF 10	10 ± 8	68575 ± 5440	2465 ± 391	22189 ± 1571	15244 ± 1165	41075 ± 3649	39422 ± 3492	6 ± 4	1783 ± 176
NRF 11	10 ± 6	69089 ± 4627	2506 ± 224	22062 ± 1437	18254 ± 1151	42108 ± 3595	41016 ± 4365	7 ± 4	1997 ± 462
NRF 12	9 ± 5	71603 ± 6248	2595 ± 312	22597 ± 2038	20786 ± 2543	50536 ± 9103	48081 ± 8826	7 ± 4	1903 ± 242
NRF 13	16 ± 13	71943 ± 8786	4089 ± 573	21766 ± 2692	12582 ± 8422	63944 ± 6297	74190 ± 8377	8 ± 10	861 ± 139
USGS 12	10 ± 5	61938 ± 5643	2017 ± 226	19862 ± 1894	13838 ± 2230	27671 ± 9656	30113 ± 5326	8 ± 4	1630 ± 414
USGS 97	113 ± 35	69208 ± 5912	2179 ± 317	22626 ± 1351	14989 ± 1691	33273 ± 3798	34181 ± 2620	8 ± 3	1962 ± 291
USGS 98	144 ± 44	49913 ± 7580	2074 ± 260	19197 ± 3216	9537 ± 1109	14898 ± 2077	21838 ± 3171	8 ± 3	1171 ± 267
USGS 99	113 ± 28	61782 ± 2958	1817 ± 212	21850 ± 782	13579 ± 1614	21878 ± 3036	26822 ± 3119	8 ± 7	1662 ± 144
USGS 102	12 ± 8	68182 ± 4789	2227 ± 539	21971 ± 1485	14055 ± 1792	32431 ± 3846	33553 ± 3168	7 ± 4	1879 ± 291
Regional Upgradient	14 ± 17	45159 ± 18649	2482 ± 566	15005 ± 5505	11456 ± 3060	17135 ± 13300	22655 ± 8976	8 ± 4	1102 ± 659
System Effluent	13 ± 11	97474 ± 31339	4455 ± 757	27469 ± 7019	68628 ± 55461	180535 ± 123233	123276 ± 64861	7 ± 8	1399 ± 500
Local Downgradient	10 ± 7	69776 ± 5193	2413 ± 366	22305 ± 1553	16547 ± 2822	39636 ± 8030	39092 ± 6942	6 ± 4	1942 ± 350
Regional Downgradient	123 ± 39	60301 ± 9840	2024 ± 305	21242 ± 2507	12736 ± 2745	23486 ± 8168	27675 ± 5876	8 ± 4	1605 ± 405

Constituent	TKN	TOX	P as P	TOC	Strontium-90	Cesium-137	Gross Alpha	Gross Beta	Tritium
Units	ppb	ppb	ppb	ppb	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
MCL	(b)	(b)	(b)	(b)	8 (c)	200 (c)	15	(c)	20000 (c)
Background	460 ± 297	19 ± 13	49 ± 65	686 ± 500	0.1 ± 0.1	0.1 ± 0.7	2.0 ± 1.0	4.1 ± 1.5	29 ± 31
NRF 6	543 ± 347	14 ± 11	87 ± 59	1023 ± 841	0.1 ± 0.2	0.2 ± 0.9	3.1 ± 1.8	7.2 ± 3.0	69 ± 22
NRF 7	491 ± 397	7 ± 3	62 ± 87	684 ± 641	0.1 ± 0.2	0.1 ± 0.5	1.5 ± 0.8	4.4 ± 1.4	3 ± 9
NRF 8	428 ± 151	7 ± 4	55 ± 42	1053 ± 1117	0.1 ± 0.2	0.3 ± 0.6	2.4 ± 1.1	4.6 ± 2.2	49 ± 12
NRF 9	456 ± 154	14 ± 19	51 ± 39	754 ± 335	0.1 ± 0.2	0.1 ± 0.5	3.1 ± 0.9	4.7 ± 1.8	92 ± 26
NRF 10	433 ± 145	12 ± 15	67 ± 56	830 ± 331	0.1 ± 0.1	0.2 ± 0.4	2.6 ± 0.9	4.8 ± 1.8	122 ± 29
NRF 11	429 ± 144	12 ± 14	53 ± 51	1010 ± 752	0.1 ± 0.1	0.2 ± 0.5	3.0 ± 1.1	5.0 ± 1.8	171 ± 77
NRF 12	417 ± 153	13 ± 13	50 ± 47	894 ± 494	0.1 ± 0.4	0.2 ± 0.7	2.6 ± 1.1	5.0 ± 1.9	56 ± 12
NRF 13	443 ± 119	11 ± 6	153 ± 179	827 ± 349	0.0 ± 0.1	0.1 ± 0.8	2.9 ± 1.3	6.8 ± 3.6	35 ± 9
USGS 12	413 ± 164	14 ± 16	58 ± 115	754 ± 585	0.1 ± 0.1	0.2 ± 0.3	2.5 ± 1.0	3.7 ± 1.6	55 ± 14
USGS 97	431 ± 139	12 ± 17	44 ± 35	686 ± 522	0.1 ± 0.2	0.2 ± 0.8	2.8 ± 1.2	4.1 ± 1.8	51 ± 16
USGS 98	433 ± 140	14 ± 22	42 ± 33	782 ± 1898	0.1 ± 0.1	0.1 ± 0.7	1.9 ± 0.7	3.4 ± 1.5	17 ± 7
USGS 99	433 ± 132	9 ± 5	40 ± 25	746 ± 645	0.1 ± 0.1	0.1 ± 1.3	2.5 ± 1.2	3.7 ± 2.0	29 ± 7
USGS 102	423 ± 193	8 ± 5	47 ± 48	799 ± 940	0.1 ± 0.1	0.4 ± 0.7	2.9 ± 1.2	4.4 ± 2.0	50 ± 14
Regional Upgradient	460 ± 297	19 ± 13	49 ± 65	686 ± 610	0.1 ± 0.1	0.1 ± 0.7	2.0 ± 1.0	4.1 ± 1.5	29 ± 31
System Effluent	493 ± 261	12 ± 9	118 ± 133	946 ± 500	0.1 ± 0.1	0.1 ± 0.8	3.0 ± 1.6	7.1 ± 3.2	53 ± 24
Local Downgradient	431 ± 156	11 ± 12	54 ± 47	878 ± 758	0.1 ± 0.2	0.2 ± 0.6	2.8 ± 1.1	4.7 ± 1.9	89 ± 58
Regional Downgradient	432 ± 135	12 ± 16	42 ± 31	738 ± 1180	0.1 ± 0.1	0.1 ± 1.0	2.4 ± 1.1	3.7 ± 1.8	33 ± 18

(a) Secondary MCL
(b) MCL not determined
(c) Individual nuclides have a pCi/L MCL for drinking water which will give a dose of 4 mrem/yr

Between 1 and 2 std. dev. greater than background
Between 2 and 3 std. dev. greater than background
Greater than 3 std. dev. from background

Group Configuration –

Regional Upgradient Group	USGS-12 and NRF-7
Effluent System Group	NRF-6 and NRF-13 (As noted in Appendix A, the ability of NRF-13 to monitor the Effluent System has been questioned.)
Local Downgradient Group	NRF-8 through 12 and USGS-102
Regional Downgradient Group	USGS-97, -98, and -99

Note: Table constituents are arranged by metals, salts, and then nutrients.
Averages are for the period 1989 to present for wells USGS-12, 97, 98, 99, and 102; 1991 to present for NRF-6 and 7; and 1996 to present for NRF-8, 9, 10, 11, 12, and 13.

6.3.2.3 Organic Data Review

NRF groundwater samples are analyzed for selected volatile and semi-volatile compounds once each year (refer to Table 4-1). Most of these organic compounds are not detected in NRF water samples. Those that were detected occurred at very low concentrations and were likely due to some form of cross-contamination (e.g., laboratory contaminants, exhaust fumes, or from plastic tubing used during sampling) or were detected below laboratory reporting limits (uncertain detection). Of the compounds analyzed, two compounds, chloroform and tetrachloroethylene, were consistently present in NRF-6 from 1997 to 2001 and 1997 to 2004, respectively. Chloroform is a potential degradation product of carbon tetrachloride, which was used in the past at NRF. Tetrachloroethylene is a solvent used in industry. The reason for their presence in NRF-6 is unknown, but they may have been inadvertently disposed of in drains connected to the IWD. The concentrations of these two compounds were well below any Federal drinking water standards. Neither compound was detected in 2005. There is no evidence of a pattern of consistent or wide-spread contamination of the aquifer associated with organic compounds. Table 6-5 shows the occurrence and concentration of various organic compounds in NRF-6.

Table 6 5 Occurrence of Organic Compounds Detected in NRF 6 from 1997 to Present

	MDL	NRF-6 (Concentrations in ppb)						
		1997	1998	1999	2000	2001	2003	2004
Acetic Acid[1]	NA							2.3
Bromocil[1]	0.1		0.3		0.2			
Chloroform	0.1	0.27	0.3	0.2	0.1	0.18		
Methylene Chloride	0.2					0.23		
Tetrachloroethene	0.2	0.47	0.5	0.3		0.22	0.23	0.23
1,1,1 Trichloroethane	0.2		0.1					
Di(2 ethylhexyl)phthalate	0.6					2.4		
(yellow)	Condition occurred above MDL							
(light blue)	Condition occurred at MDL							

1 - Found in laboratory library search. These constituents are not included in the standard analytical method list.

Table 6-6 Comparison of MCLs and Well Group Averages

Constituent		Aluminum	Calcium	Chromium	Iron	Manganese	Nickel	Sodium	Chloride	Cesium-137
Units		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	pCi/L
MCL		200 (a)	(b)	100	300 (a)	50 (a)	100	(b)	250000 (a)	200 (c)
2001 to 2005	Regional Upgradient	78 ± 102	43909 ± 18256	9 ± 4	151 ± 262	4 ± 4	8.5 ± 4.6	11156 ± 2441	13700 ± 9227	0.1 ± 0.3
	System Effluent	1137 ± 1112	100224 ± 36220	54 ± 32	1380 ± 1194	22 ± 23	21.9 ± 16.9	72203 ± 71819	206032 ± 175008	0.0 ± 0.4
	Local Downgradient	96 ± 145	66768 ± 3402	13 ± 6	195 ± 284	4 ± 5	6.8 ± 5.3	16786 ± 1937	36822 ± 5780	0.1 ± 0.4
	Regional Downgradient	59 ± 122	59014 ± 8668	6 ± 1	140 ± 254	3 ± 3	1.7 ± 0.5	13794 ± 2860	23024 ± 6873	0.1 ± 0.3
1996 to 2000	Regional Upgradient	119 ± 126	44468 ± 18698	9 ± 3	240 ± 341	8 ± 6	5.9 ± 3.4	11853 ± 3325	15090 ± 12598	0.2 ± 0.4
	System Effluent	2562 ± 4465	95138 ± 26759	51 ± 53	2925 ± 4376	47 ± 70	21.0 ± 16.4	57025 ± 45865	142978 ± 82240	0.3 ± 1.1
	Local Downgradient	171 ± 464	72348 ± 5044	12 ± 6	239 ± 453	6 ± 10	10.7 ± 11.0	17203 ± 2949	43526 ± 8226	0.3 ± 0.7
	Regional Downgradient	48 ± 96	61810 ± 10576	6 ± 2	207 ± 666	4 ± 6	1.8 ± 1.2	13226 ± 2756	23902 ± 9117	0.2 ± 1.4

(a) Secondary MCL
(b) MCL not determined
(c) Individual nuclides have a pCi/L MCL for drinking water which will give a dose of 4 mrem/yr

Group Configuration -

Regional Upgradient Group	USGS-12 and NRF-7
Effluent System Group	NRF-6 and NRF-13 (As noted in Appendix A, the ability of NRF-13 to monitor the Effluent System has been questioned.)
Local Downgradient Group	NRF-8 through 12 and USGS-102
Regional Downgradient Group	USGS-97, -98, and -99

6.3.2.4 Data Trends

Table 6-6 compares water quality averages for the four well groups for ten key constituents (a total of 40 comparisons) for the period 1996 through 2000 and 2001 through 2005. This table shows that mean concentrations for many constituents have dropped since 2000. In total, the mean concentrations for 24 comparisons have declined, eight have increased, and eight have remained unchanged. Where increases occurred they were relatively small with the exception of chromium in the Effluent System well group. The increase is due primarily to increased chromium levels in NRF-13 (as noted in Appendix A, this is likely due to sedimentation). In the Regional Downgradient Group, all selected constituent mean concentrations were statistically equivalent (chromium, cesium-137, and sodium) or declined. Overall, this table shows that the relative magnitude of mean constituent concentrations is nearly the same as those described in the 2001 Five-Year Review.

Data for ten selected key constituents (discussed above) were evaluated for all NRF groundwater monitoring wells for individual trends. A majority of the key constituents are stable or trending downward in the individual NRF groundwater monitoring wells. Sodium, calcium, chromium, and chloride appear to be trending upward in some NRF wells. Sodium, calcium, and chloride are major ions originating from site water softening and deionization activities. Of the few NRF wells where chromium appears to be trending upward, the most noticeable is in NRF-13. The issues associated with well NRF-13, are discussed in Appendix A.

A more in-depth trend analysis was performed for chromium, chloride, and tritium. These three constituents were chosen because they exemplify various aspects of NRF operations and are thus considered to be key constituents. Chromium, a contaminant that is known to have been released in wastewater prior to 1980, is consistently detected in both soil and groundwater and is the main constituent of concern in NRF-13. Chloride was also released in quantity at NRF in the past (primarily at the IWD in the form of the ionic salt sodium chloride). Tritium was released at NRF in the past at the S1W Leaching Bed/Pits and its flow path is different than for chloride (different source location). Chloride and tritium generally do not interact with the aquifer and therefore are suitable indicators of dispersion and groundwater flow paths.

Figure 6-1 shows the time versus concentration graphs for chromium in the NRF wells. Appendix B provides plots for each individual well along with trending lines. Chromium is a naturally occurring constituent in both groundwater and soil. Past hydrogeological investigations demonstrate that sediments beneath the IWD associated with historic discharges are the primary source for the limited chromium detected in some downgradient monitoring wells at levels above background but significantly below the MCL. The amounts of chromium currently detected in the IWD effluent are comparable to the background level. Chromium concentration is trending upward in three of thirteen wells; refer to Appendix B for graphs of these trends. Wells that have increasing trends include NRF-10; NRF-7, and NRF-13. For comparison, the chromium concentration has been decreasing in NRF-6 and in NRF-12. The concentration in the regional wells (USGS-12, 97, 98, and 99) remained relatively flat. The trends in the remaining wells represent small changes in chromium concentrations and are probably more reflective of changes in local flow directions than changes in the amount of chromium being released to the aquifer.

The highest chromium levels are found in wells NRF-6 and NRF-13. NRF-6 is located immediately downgradient of the IWD. The downward trend observed in this well likely reflects decreased discharge to the IWD. Since leaching of chromium is a limited process due to solubility, the amount of chromium entering the aquifer is sensitive to net infiltration. NRF-13 has historically contained elevated metal concentrations primarily due to sedimentation in the well and not necessarily from the IWD. For an in-depth discussion of chromium and its presence in NRF-13, see Appendix A.

Concentration data that were considered to be extreme outliers both with respect to the overall trend of the well and in comparison with trends in other wells were excluded from Figure 6-1. Outliers were considered to be values that are significantly different from the remainder of the data set. Specifically, values greater than three times the well average were removed (with the exception of NRF-13 that considered the outliers with values above the MCL).

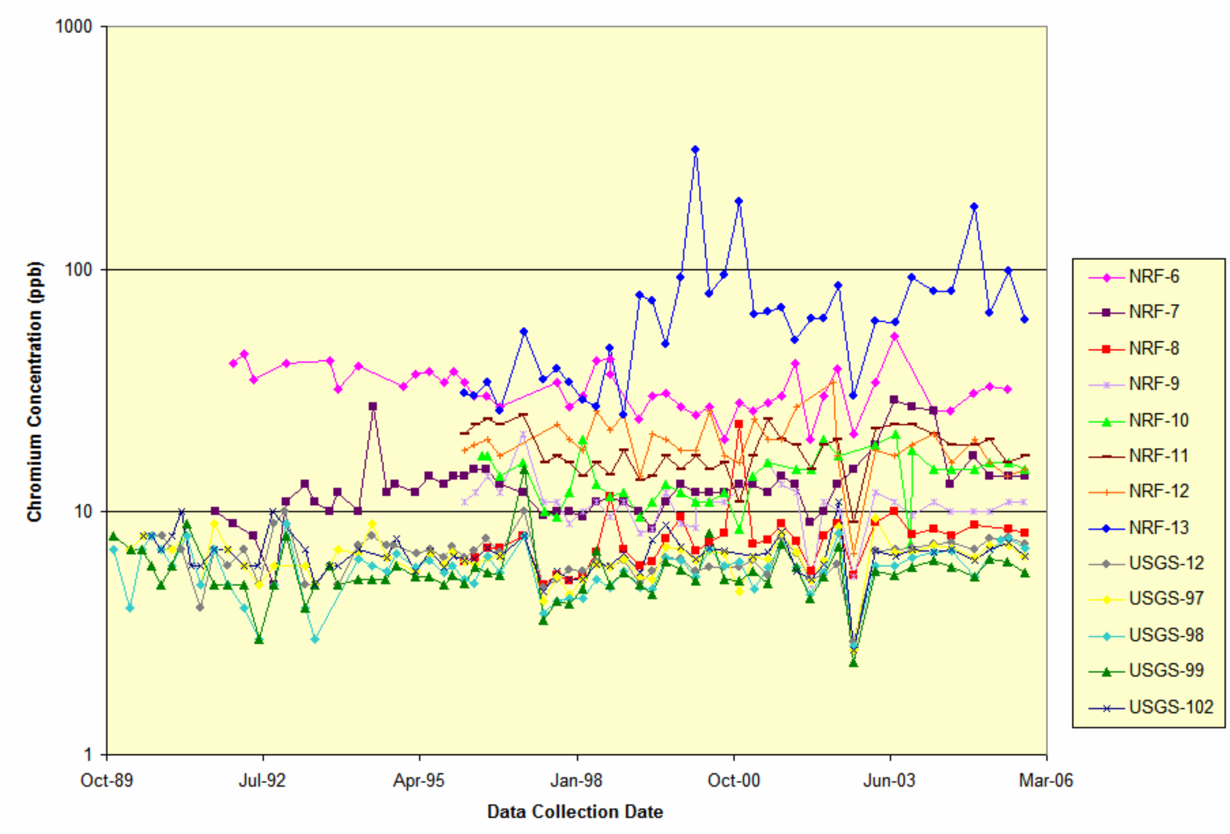

Figure 6-1 Chromium Concentration in NRF Wells

Concentration versus time graphs for chloride are shown for the NRF wells in Figure 6-2. Appendix B provides plots for each individual wells along with the trending line. Chloride, which is also a naturally occurring constituent in groundwater, is a good tracer because it is relatively unaffected by common retardation mechanisms associated with the aquifer system, thus allowing flow path and contaminant distribution analyses to be performed. Chloride concentrations are trending downward in all but two NRF wells. NRF-6 is generally higher in chloride concentration than the other NRF wells due to the influence of the IWD as discussed in Appendix A. The largest decreasing trends are in NRF-12 and USGS-12 falling 46% each. Trends in NRF-9, NRF-13, USGS-97, 98, and 99 were generally small.

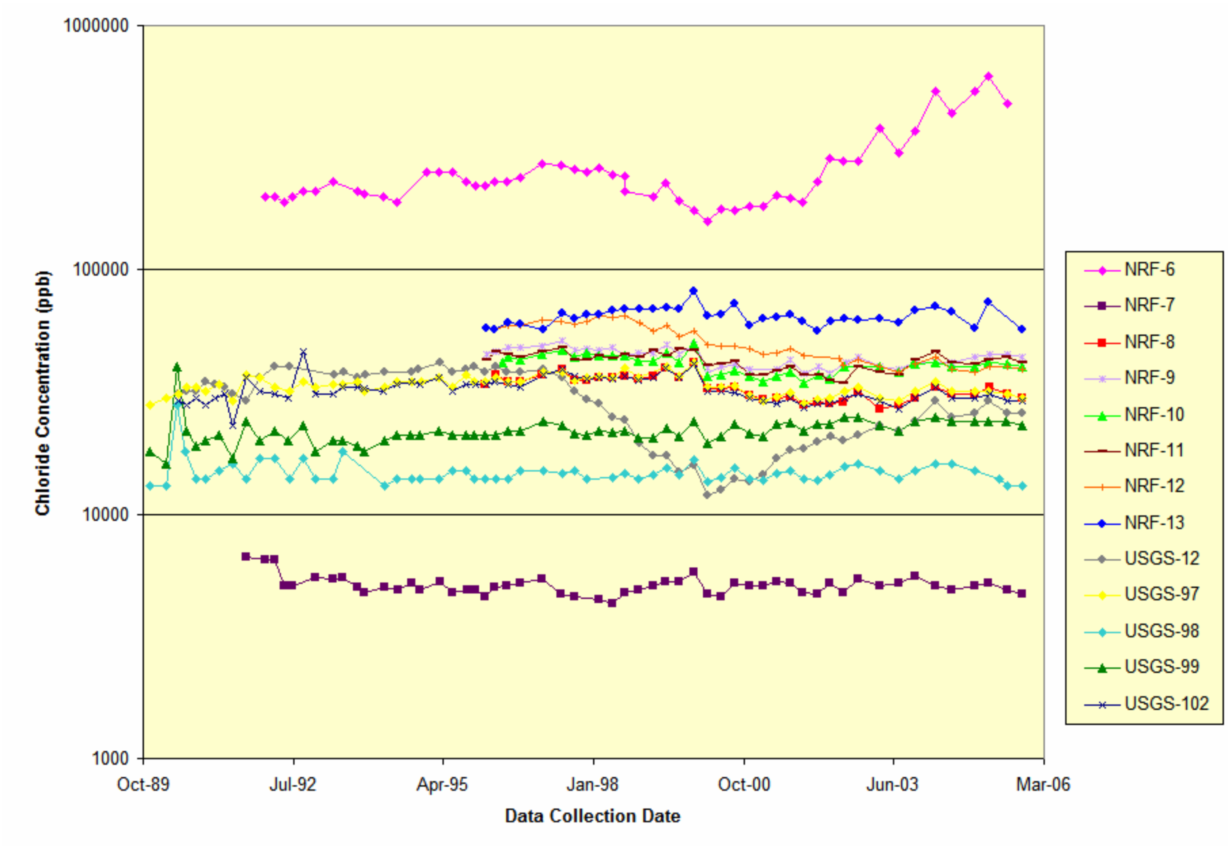

Figure 6-2 Chloride Concentrations in NRF Wells

Figure 6-3 shows the tritium concentration vs. time plots for the NRF wells. In most NRF wells, the tritium concentration is trending downward, while the tritium concentration has stabilized in the remaining wells. The tritium levels in NRF-10 and NRF-11, although decreasing significantly, are elevated with respect to background concentrations, though the concentrations in these wells are still significantly lower than MCLs. These wells are located downgradient of the S1W Leaching Beds/Pit. It is therefore likely that residual contamination from historical tritium releases to this site is responsible for these elevated concentrations, as water with trace amounts of tritium has not been released from NRF since 1978. A residual perched water zone, which is releasing small quantities of water to the aquifer, is suspected as the mechanism causing the current elevated tritium activities. The current downward trends in tritium activities are expected given normal decay.

Extreme outliers that were more than three times as large as well averages were excluded for wells NRF-13 and USGS-98. In addition, tritium concentrations measured for the third sample date in 1998 were excluded for wells NRF-6, NRF-7, NRF-8, NRF-9, NRF-10, NRF-12, NRF-13, USGS-12, USGS-98, and USGS-102, as most of these values were approximately twice the well average. The tritium concentrations were significantly greater than the well average in the cases of USGS-98 (nearly ten times the well average) and NRF-7 (nearly 19 times the well average).

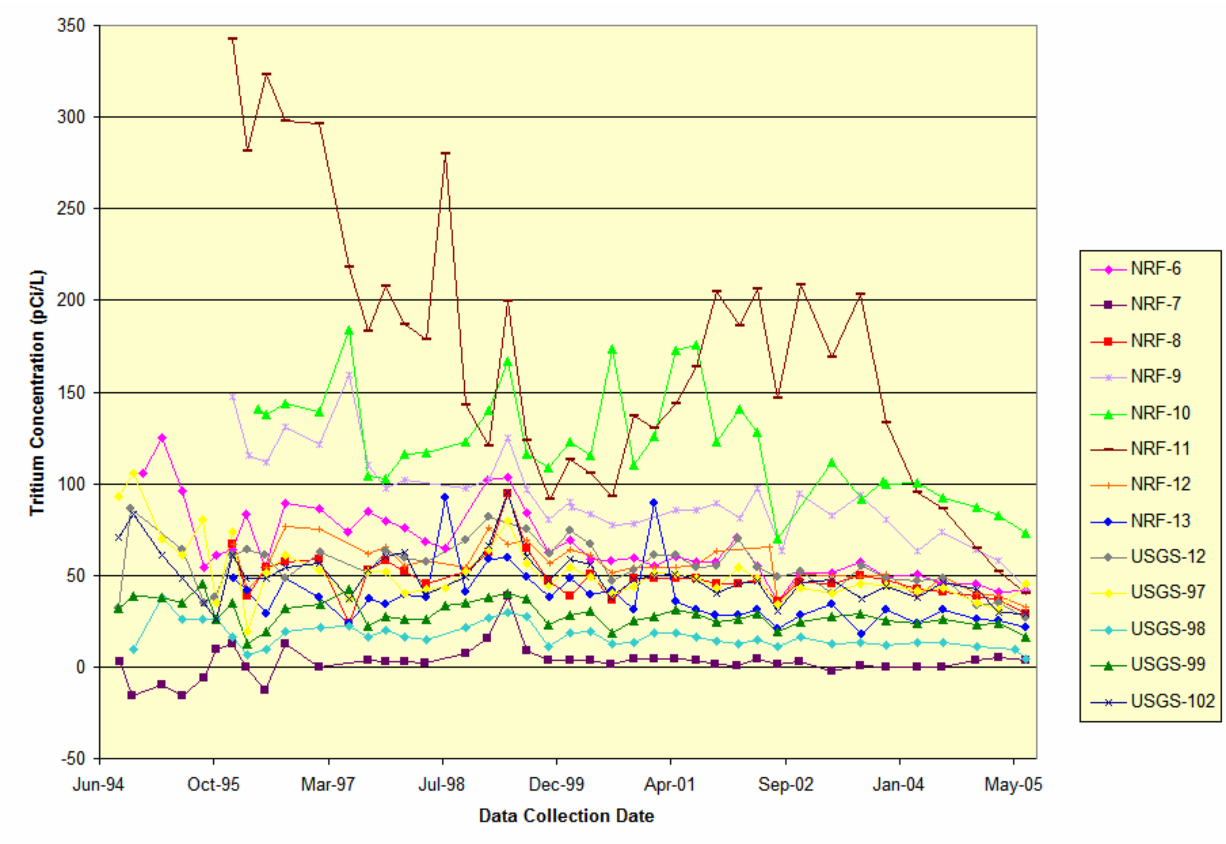

Figure 6-3 Tritium Concentrations in NRF Wells

Most chromium, chloride, and tritium concentrations are stable or trending downward, but each for different reasons. Chromium concentration decreases are probably related to two causes; decreased wastewater discharges to the IWD (result in less potential migration of historical chromium in sediments) and localized changes in flow patterns. The few wells showing increasing chromium concentrations are likely from a natural source, since chromium is no longer discharged to the IWD in significant amounts. The overall current chloride concentration decreases may be attributed to two possibilities: 1) the lower chloride concentration in the regional upgradient groundwater (as seen in USGS-12) that flows past NRF and/or 2) much less effluent to IWD thus less total chloride discharged. As previously mentioned, the current downward trends in tritium activities are expected given normal decay.

Overall, past and present activities at NRF have had no significant impact on water quality. Most measured contaminants are trending downward. Samples representing regional upgradient and regional downgradient water quality are statistically similar, thus, indicating no significant impact to groundwater quality from NRF operations. Although some individual chromium results from NRF-13 have exceeded the Federal MCL, these results were shown to be anomalous (i.e., not reflective of actual groundwater quality). As mentioned previously, Appendix A provides a more in-depth discussion of issues related to NRF-13.

6.3.3 Soil Gas

6.3.3.1 Analysis of Soil Gas Data

Soil gas monitoring data collected from monitoring probes around the perimeter of the three NRF Inactive Landfill Areas were analyzed by an off-site laboratory. The following are the VOCs that were consistently detected above the reporting limit during 1997 through 2005: dichlorodifluoromethane (Freon 12); trichlorofluoromethane (Freon 11); 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113); 1,1,1-trichloroethane; chloroform; trichloroethylene; and tetrachloroethylene. Freon 11 and tetrachloroethylene were the two most frequently detected constituents at all of the sites. The initial Five-Year Review presented data for the period from 1997 through 1999. This Five-Year Review includes additional data obtained through 2005.

The statistical review presented in this section centers on comparison of monitoring results to two different benchmarks. These benchmarks are the baseline concentrations obtained from the October 1996 initial sampling event (baseline data for each individual probe) and the overall maximum concentrations obtained during the Track 2 Investigations for these three landfill areas (the overall maximum data occurring at NRF-53). Such a comparison also presents a relative risk picture associated with NRF landfills. Ultimately, the results of these comparisons are used to re-evaluate risk associated with the selected remedies and to determine the overall effectiveness of the remedies. In addition, comparisons between the data collected from 1997 through 1999 during the initial Five-Year Review and subsequent data collected through 2005 will also be made where appropriate. A summary of data collected from 1997 through 2005 and baseline data are presented in Table 6-7, Table 6-8, and Table 6-9.

6.3.3.2 Statistical Review

6.3.3.2.1 Dichlorodifluoromethane (Freon 12)

Freon 12 was detected at only one site (NRF-1), and was consistently above the reporting limit at only one sample location (MW1-4), at a maximum concentration of 43 parts per billion on a volumetric basis (ppbv) or 212.2 micrograms per cubic meter ($\mu g/m^3$). This maximum concentration, detected in June 2001, exceeds the baseline concentration of 5.3 ppbv (26.2 $\mu g/m^3$); however, the levels detected since June 2001 are less than the maximum level. Freon 12 was detected only twice above the reporting limit at MW1-3, at a maximum concentration of 5.1 ppbv (25.2 $\mu g/m^3$), in December 2001. Freon 12 was not detected at any of the three landfill areas during the Track 2 Investigations. However, the concentrations observed recently are relatively low in comparison with other halogenated organic compounds detected at these three landfill areas.

6.3.3.2.2 Trichlorofluoromethane (Freon 11)

Freon 11 was detected at all three sites. Freon 11 was detected fairly consistently above the reporting limit at NRF-1 at sample locations MW1-3, MW1-4, and at both replacement probe locations (MW1-1, MW1-2). During the 1997-2005 sampling period, the overall maximum concentration detected at NRF-1 was 7.1 ppbv (39.8 $\mu g/m^3$) at sample location MW1-3 in 2000. This level is less than the baseline concentration of 8.5 ppbv (47.7 $\mu g/m^3$).

Freon 11 was detected at all four sample locations at NRF-51 fairly consistently above the reporting limit. During the 1997-2005 sampling period, Freon 11 was detected at NRF-51 at an overall maximum concentration of 15 ppbv (84 $\mu g/m^3$) at sample location MW51-2 in 1997.

However, the overall maximum Freon-11 concentration for the 2000-2005 sampling period was 12 ppbv (67.3 μg/m^3) detected in 2000. Both of these concentrations are less than the baseline concentration of 16 ppbv (89.7 μg/m^3).

At NRF-53, Freon 11 has been detected occasionally above the reporting limit only at locations MW53-2 and MW53-4. During the 2000-2005 sampling period, Freon-11 was detected below the reporting limit but above the method detection limit at the remaining NRF-53 locations. At NRF-53, the maximum concentration detected was 3.5 ppbv (19.6 μg/m^3) at MW53-2, which is less than the baseline concentration of 6.7 ppbv (37.6 μg/m^3).

The overall maximum concentration detected at all three sites during the 2000-2005 sampling period was 12 ppbv (67.3 μg/m^3), which is just above the maximum concentration of 10 ppbv (56.1 μg/m^3) detected during the Track 2 Investigation but below the baseline concentration of 16 ppbv (89.7 μg/m^3). These concentrations are low in comparison with other halogenated organic compounds detected at the three landfill areas.

6.3.3.2.3 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)

Freon 113 was only detected at NRF-1 and at only one sample location, MW1-4. The overall maximum concentration of 3.9 ppbv (29.8 μg/m^3) was detected in 1999. The overall maximum Freon 113 concentration for the 2000-2005 sampling period was 3.5 ppbv (26.8 μg/m^3) detected in 2000. Both of these levels were greater than the baseline concentration of 2.2 ppbv (16.8 μg/m^3), but less than the maximum concentration of 5.3 ppbv (40.5 μg/m^3) detected during the Track 2 Investigation. For the 2002-2005 period, most of the levels detected were below the reporting limit.

6.3.3.2.4 Chloroform

Chloroform was consistently detected at NRF-1 and NRF-51. Chloroform was not detected at NRF-53 above the reporting limit. During the 1997 through 2005 sampling period, chloroform was mainly detected at sample locations MW1-1 (replacement probe location) and MW1-3 at NRF-1. Chloroform was detected at maximum concentrations of 7.6 ppbv (37.0 μg/m^3) at the replacement probe location MW1-1 (from data available after construction in 2003) and 5.3 ppbv (25.8 μg/m^3) at MW1-3. During the 1997 through 2005 sampling period, chloroform was only detected seven times above the reporting limit at MW1-4 at a maximum concentration of 4.7 ppbv (22.9 μg/m^3).

Chloroform was detected above the reporting limit at NRF-51 at three out of four sample locations. Chloroform was detected above the reporting limit only four times at both MW51-1 and MW51-4 during the 1997-2005 sampling period. During the other sampling quarters, chloroform was typically detected at levels below the reporting limit but above the method detection limit. Chloroform was detected fairly consistently at sample location MW51-2 above the reporting limit during 1997-2002. From 2003-2005 most of the levels detected were below the reporting limit. The overall maximum concentration detected at NRF-51 was 2.9 ppbv (14.1 μg/m^3) at sample location MW51-2 in 1997. This level was slightly greater than the baseline concentration of 2.3 ppbv (11.2 μg/m^3) for this location.

The overall maximum chloroform concentration detected for all sites during this sampling period was 7.6 ppbv (37.0 μg/m^3), which is less than the overall maximum concentration of 19 ppbv (92.6 μg/m^3) detected during the Track 2 Investigation.

Table 6-7 Soil Gas Data Summary for Site NRF-1

Site	Sample Location	Statistical Parameter	Freon 12		Freon 11		Freon 113		Chloroform		1,1,1 Trichloroethane		Tetrachloroethylene		Trichloroethylene	
			(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3
Overall Maximum Track 2 Data			ND	ND	10.0	56.1	5.3	40.5	19.0	92.6	83.0	452.0	1400.0	9477.1	16.0	85.8
NRF 1	MW1 1	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Mean	ND	ND	<2.2	<12.1	ND	ND	5.7	27.8	ND	ND	7.0	47.4	202.2	1084.6
		Std Dev.	ND	ND	0.4	2.0	ND	ND	1.1	5.4	ND	ND	5.7	38.7	44.7	239.5
		Maximum	ND	ND	2.6	14.6	ND	ND	7.6	37.0	ND	ND	20.0	135.4	250.0	1340.8
		Minimum	ND	ND	1.5**	8.4**	ND	ND	4.3	21.0	ND	ND	ND	ND	130.0	697.2
		Confidence	ND	ND	0.2	1.1	ND	ND	0.6	2.9	ND	ND	3.1	21.1	24.3	130.2
NRF 1	MW1 2	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Mean	ND	ND	2.9	16.1	ND	ND	ND	ND	ND	ND	5.2	35.0	ND	ND
		Std Dev.	ND	ND	0.3	1.5	ND	ND	ND	ND	ND	ND	2.5	16.8	ND	ND
		Maximum	ND	ND	3.4	19.1	ND	ND	ND	ND	ND	ND	11.0	74.5	ND	ND
		Minimum	ND	ND	2.4	13.5	ND	ND	ND	ND	ND	ND	2.1	14.2	ND	ND
		Confidence	ND	ND	0.1	0.8	ND	ND	ND	ND	ND	ND	1.4	9.1	ND	ND
NRF 1	MW1 3	Baseline	ND	ND	8.5	47.7	ND	ND	4	19.5	ND	ND	580	3926.2	29	155.5
		Mean	<<	<<	<3.8	<21.6	ND	ND	<2.6	<12.6	<2.2	<12.1	376.4	2547.7	20.8	111.3
		Std Dev.	<<	<<	1.8	9.9	ND	ND	1.1	5.6	1.0	5.3	117.1	792.9	4.8	25.7
		Maximum	5.1	25.2	7.1*	39.8*	ND	ND	5.3	25.8	4.0	21.8	616.0	4169.9	30.0	160.9
		Minimum	ND	ND	1.4**	7.9**	ND	ND	0.9**	4.4**	ND	ND	120	812.3	9.2	49.3
		Confidence	<<	<<	1	5.4	ND	ND	0.6	3.0	0.5	2.9	63.7	431.0	2.6	14.0
NRF 1	MW1 4	Baseline	**5.3**	**26.2**	1.7**	9.5**	**2.2**	**16.8**	ND	ND	ND	ND	**120**	**812.3**	**2.9**	**15.6**
		Mean	13.0	64.3	<2.1	<11.6	<1.9**	<14.3**	<<	<<	ND	ND	213.4	1444.5	<4.2	<22.3
		Std Dev.	10.0	49.5	0.9	5.1	1.1	8.2	<<	<<	ND	ND	80.8	546.9	1.3	6.8
		Maximum	43.0	212.2	4.3	24.1	3.9	29.8	4.7	22.9	ND	ND	360.0	2437.0	7.5	40.2
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	72.0	487.4	1.9**	10.2**
		Confidence	5.5	26.9	0.5	2.8	0.6	4.4	<<	<<	ND	ND	43.9	297.3	0.7	3.7

** = Estimated quantities, * = Excludes Baseline Data, ND = Not Detected at or above the reporting limit
< = Mean includes estimated values below the Reporting Limit, << = Most values below Reporting Limit thus no calculations were performed

Table 6-8 Soil Gas Data Summary for Site NRF-51

Site	Sample Location	Statistical Parameter	Freon 12		Freon 11		Freon 113		Chloroform		1,1,1 Trichloroethane		Tetrachloroethylene		Trichloroethylene	
			(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3
Overall Maximum Track 2 Data			ND	ND	10.0	56.1	5.3	40.5	19.0	92.6	83.0	452.0	1400.0	9477.1	16.0	85.8
NRF 51	MW51 1	Baseline	ND	ND	15	84.1	ND	ND	2.7	13.2	6.3	34.3	22	148.9	ND	ND
		Mean	ND	ND	7.5	42.0	ND	ND	<1.3**	<6.1**	<3.3	<17.8	14.6	98.7	ND	ND
		Std Dev.	ND	ND	3.4	19.1	ND	ND	0.7	3.6	1.5	8.4	5.6	37.8	ND	ND
		Maximum	ND	ND	14*	78.5*	ND	ND	2.7	13.2	7.8	42.5	29.0	196.3	ND	ND
		Minimum	ND	ND	2.8	15.7	ND	ND	ND	ND	1.0**	5.4**	6.8	46.0	ND	ND
		Confidence	ND	ND	1.9	10.4	ND	ND	0.4	1.94	0.8	4.5	3.0	20.6	ND	ND
NRF 51	MW51 2	Baseline	ND	ND	16	89.7	ND	ND	2.3	11.2	6.6	35.9	23	155.7	ND	ND
		Mean	ND	ND	<7.8	<43.5	ND	ND	<1.8**	<9.0**	<3.8	<20.9	14.9	100.8	<<	<<
		Std Dev.	ND	ND	3.5	19.7	ND	ND	0.7	3.3	1.6	8.9	4.7	31.8	<<	<<
		Maximum	ND	ND	15*	84.1*	ND	ND	2.9	14.1	8.4	45.7	23.0	155.7	10	53.6
		Minimum	ND	ND	1.7**	9.5**	ND	ND	ND	ND	1.0**	5.4**	3.2	21.7	ND	ND
		Confidence	ND	ND	1.9	10.7	ND	ND	0.4	1.80	0.9	4.9	2.6	17.3	<<	<<
NRF 51	MW51 3	Baseline	ND	ND	13	72.9	ND	ND	ND	ND	4.8	26.1	19	128.6	ND	ND
		Mean	ND	ND	4.7	26.1	ND	ND	ND	ND	<2.0	<11.0	<9.9	<66.7	<<	<<
		Std Dev.	ND	ND	2.9	16.2	ND	ND	ND	ND	1.2	6.7	4.5	30.7	<<	<<
		Maximum	ND	ND	11*	61.7*	ND	ND	ND	ND	5.7	31.0	21	142.2	4	21.5
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Confidence	ND	ND	1.6	8.8	ND	ND	ND	ND	0.7	3.7	2.5	16.7	<<	<<
NRF 51	MW51 4	Baseline	ND	ND	16	89.7	ND	ND	2.6	12.7	6	32.7	26	176.0	ND	ND
		Mean	ND	ND	<6.3	<35.1	ND	ND	<1.2**	<5.8**	<2.8	<15.0	13.5	91.4	<<	<<
		Std Dev.	ND	ND	3.4	18.9	ND	ND	0.7	3.5	1.5	8.4	5.4	36.4	<<	<<
		Maximum	ND	ND	14*	78.5*	ND	ND	2.6	12.7	7.0	38.1	24*	162.5*	94	504.1
		Minimum	ND	ND	1.3**	7.3**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Confidence	ND	ND	1.8	10.3	ND	ND	0.4	1.91	0.8	4.6	2.9	19.8	<<	<<

** = Estimated quantities, * = Excludes Baseline Data, ND = Not Detected at or above the reporting limit
< = Mean includes estimated values below the Reporting Limit, << = Most values below Reporting Limit thus no calculations were performed

Table 6-9 Soil Gas Data Summary for Site NRF-53

Site	Sample Location	Statistical Parameter	Freon 12		Freon 11		Freon 113		Chloroform		1,1,1 Trichloroethane		Tetrachloroethylene		Trichloroethylene	
			(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3
Overall Maximum Track 2 Data			ND	ND	10.0	56.1	5.3	40.5	19.0	92.6	83.0	452.0	1400.0	9477.1	16.0	85.8
NRF 53	MW53 1	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**5.2**	**35.2**	ND	ND
		Mean	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	<2.0	<13.7	<<	<<
		Std Dev.	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	0.8	5.6	<<	<<
		Maximum	ND	ND	ND	ND	ND	ND	ND	ND	2.6	14.2	4.4*	29.8*	3.5	18.8
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5**	3.4**	ND	ND
		Confidence	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	0.5	3.1	<<	<<
NRF 53	MW53 2	Baseline	ND	ND	**6.7**	**37. 6**	ND	ND	ND	ND	ND	ND	**24**	**162.5**	ND	ND
		Mean	ND	ND	<1.9**	<10.8**	ND	ND	ND	ND	<<	<<	<17.1	<115.8	<<	<<
		Std Dev.	ND	ND	1.0	5.9	ND	ND	ND	ND	<<	<<	5.2	35.1	<<	<<
		Maximum	ND	ND	3.5*	19.6*	ND	ND	ND	ND	2.1	11.4	27.0	182.8	2.3	12.3
		Minimum	ND	ND	0.8**	4.5**	ND	ND	ND	ND	ND	ND	1.1**	7.4**	ND	ND
		Confidence	ND	ND	0.6	3.2	ND	ND	ND	ND	<<	<<	2.8	19.1	<<	<<
NRF 53	MW53 3	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std Dev.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Confidence	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NRF 53	MW53 4	Baseline	ND	ND	**2.1**	**11.8**	ND	ND	ND	ND	ND	ND	**3.6**	**24.4**	ND	ND
		Mean	ND	ND	<<	<<	ND	ND	ND	ND	<<	<<	<2.4	<15.9	<<	<<
		Std Dev.	ND	ND	<<	<<	ND	ND	ND	ND	<<	<<	1.1	7.4	<<	<<
		Maximum	ND	ND	2.2	12.3	ND	ND	ND	ND	4.6	25.1	5.1	34.5	6.5	34.9
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7**	4.7**	ND	ND
		Confidence	ND	ND	<<	<<	ND	ND	ND	ND	<<	<<	0.6	4	<<	<<

** = Estimated quantities, ND = Not Detected at or above the reporting limit
* = Excludes Baseline Data
< = Mean includes estimated values below the Reporting Limit
<< = Most values below Reporting Limit thus no calculations were performed

Table 6-9 Soil Gas Data Summary for Site NRF-53 (Continued)

Site	Sample Location	Statistical Parameter	Freon 12		Freon 11		Freon 113		Chloroform		1,1,1 Trichloroethane		Tetrachloroethylene		Trichloroethylene	
			(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3	(ppbv)	g/m3
Overall Maximum Track 2 Data			ND	ND	10.0	56.1	5.3	40.5	19.0	92.6	83.0	452.0	1400.0	9477.1	16.0	85.8
NRF 53	MW53 5	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**6**	**40.6**	ND	ND
		Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<2.7	<18.0	<<	<<
		Std Dev.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	8.5	<<	<<
		Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.9*	39.9*	7.2	38.6
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0**	6.8**	ND	ND
		Confidence	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7	4.6	<<	<<
NRF 53	MW53 6	Baseline	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**9.9**	**67.0**	ND	ND
		Mean	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	<5.4	<36.3	<<	<<
		Std Dev.	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	2.2	15.0	<<	<<
		Maximum	ND	ND	ND	ND	ND	ND	ND	ND	29	157.9	11.0	74.5	45	241.4
		Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9**	12.9**	ND	ND
		Confidence	ND	ND	ND	ND	ND	ND	ND	ND	<<	<<	1.2	8.1	<<	<<

** = Estimated quantities
ND = Not Detected at or above the reporting limit
* = Excludes Baseline Data
< = Mean includes estimated values below the Reporting Limit
<< = Most values below Reporting Limit thus no calculations were performed

6.3.3.2.5 1,1,1-Trichloroethane

1,1,1-Trichloroethane was consistently detected at NRF-1 at only one sample location, MW1-3. The maximum concentration for MW1-3 was 4.0 ppbv (21.8 μg/m^3) in 2000. During 2002-2005 most of the levels detected were below the reporting limit. 1,1,1,-trichloroethane was not detected during the baseline sampling evolution.

1,1,1-Trichloroethane was consistently detected at NRF-51 at all sample locations. The maximum concentration for this site was 8.4 ppbv (45.7 μg/m^3) detected at MW51-2 in 1997. This level is greater than the baseline concentration of 6.6 ppbv (35.9 μg/m^3). However, the maximum 1,1,1-trichloroethane concentration for the 2000-2005 sampling period was 5.7 ppbv (30 μg/m^3) detected at MW51-2 in 2000.

1,1,1-Trichloroethane was detected only four times above the reporting limit at NRF-53, at sample locations MW53-1, MW53-2, MW53-4, and MW53-6. The overall maximum concentration for this chemical was 29 ppbv (157.9 μg/m^3), detected at NRF-53 at sample location MW53-6 in 2001. However, this was the only occurrence at this location above the reporting limit. Also, since this was the only occurrence at this location, this value can be considered an outlier.

The highest maximum concentration (not including the 29 ppbv outlier in MW53-6) for all three sites was 8.4 ppbv. This concentration is less than the overall maximum concentration of 83 ppbv (452.0 μg/m^3) detected during the Track 2 Investigation.

6.3.3.2.6 Tetrachloroethylene

Tetrachloroethylene was the most commonly detected constituent above the reporting limit at all three sites. Tetrachloroethylene was also detected at the highest concentration (excluding the outliers identified in other sections) at all three sites. The overall maximum concentration detected during the 1997-2005 sampling period was 616 ppbv (4170 μg/m^3), which occurred at NRF-1 at sample location MW1-3 in 1998. This level was slightly greater than the baseline concentration of 580 ppbv (3926 μg/m^3) detected at MW1-3. However, the overall maximum tetrachloroethylene concentration for the 2000-2005 sampling period was 560 ppbv (3790.9 μg/m^3) in 2001, which is less than the baseline concentration. Regarding the rest of NRF-1, at sample location MW1-4 tetrachloroethylene was detected at a maximum concentration of 360 ppbv (2437 μg/m^3) in 2004. At sample location MW1-1, tetrachloroethylene was detected at a maximum concentration of 20 ppbv (135.4 μg/m^3) in 1999. However, at the replacement probe location for MW1-1 during the 2003-2005 sampling period, the maximum concentration detected was 8.8 ppbv (59.6 μg/m^3). At the other replacement probe location MW1-2, tetrachloroethylene was detected at a maximum concentration of 11 ppbv (74.5 μg/m^3) during the 2003-2005 sampling period.

Tetrachloroethylene was consistently detected above the reporting limit at all four sample locations at NRF-51, and was at roughly consistent levels at all probe locations. The overall maximum concentration was detected in 1997 at 29 ppbv (196.3 μg/m^3) at sample location MW51-1, followed by a concentration of 25 ppbv (169.2 μg/m^3) in 2000 and 2001 also at MW51-1. These values are slightly greater than the baseline concentration of 22 ppbv (148.9 μg/m^3). The maximum concentration detected at sample location MW51-2 was 23 ppbv (155.7 μg/m^3). The maximum concentration detected at sample location MW51-3 was 21 ppbv (142.2 μg/m^3), and at sample location MW51-4 it was 24 ppbv (162.5 μg/m^3).

Tetrachloroethylene was fairly consistently detected above the reporting limit at NRF-53 at five out of six sample locations. The overall maximum concentration detected at NRF-53 during this sampling period was 27 ppbv (182.8 μg/m^3) at sample location MW53-2 in 2002. This level was only slightly greater than the baseline concentration of 24 ppbv (162.5 μg/m^3) for this sample location. About half of the sample results at sample location MW53-1 were above the reporting limit, with a maximum concentration of 4.4 ppbv (29.8 μg/m^3) in 2003. Over half of the sample results for sample location MW53-4 were above the reporting limit, where the maximum concentration was 5.1 ppbv (34.5 μg/m^3). The maximum concentration detected at sample location MW53-5 was 5.9 ppbv (39.9 μg/m^3). The maximum concentration detected at sample location MW53-6 was 11 ppbv (74.5 μg/m^3).

The overall maximum tetrachloroethylene concentration detected during this sampling period was 616 ppbv (4170 μg/m^3), which is less than the overall maximum concentration of 1400 ppbv (9477 μg/m^3) detected during the Track 2 Investigation.

6.3.3.2.7 Trichloroethylene

Trichloroethylene was detected predominately at NRF-1 and only occasionally at NRF-51 and NRF-53. Trichloroethylene was detected at an overall maximum concentration of 250 ppbv (1341 μg/m^3) at the replacement sample probe location MW1-1 at NRF-1 in 2004 and again in 2005 (probe replaced in 2003). Trichloroethylene was also detected at sample location MW1-3 at a maximum concentration of 30 ppbv (160.9 μg/m^3) and at sample location MW1-4 at a maximum concentration of 7.5 ppbv (40.2 μg/m^3).

At NRF-51, trichloroethylene was detected only twice at sample probe location MW51-4 and once at sample probe locations MW51-2 and MW51-3 at or above the reporting limit. The maximum concentration detected at NRF-51 was 94.0 ppbv (504.1 μg/m^3) at sample location MW51-4. Since the concentration of 94.0 ppbv (504.1 μg/m^3) detected at MW51-4 is significantly greater than the concentration of 2 ppbv (10.7 μg/m^3) detected for the other occurrence, the higher value appears to be an outlier.

At NRF-53, trichloroethylene was detected only once at all sample probe locations at or above the reporting limit with the exception of MW53-3 where trichloroethylene was not detected. The maximum concentration detected at NRF-53 was 45.0 ppbv (241.4 μg/m^3) at sample location MW53-6. Since the concentration of 45.0 ppbv (241.4 μg/m^3) detected at MW53-6 is only a single occurrence and significantly greater than the levels detected at the other locations, the concentration of 45.0 ppbv (241.4 μg/m^3) appears to be an outlier.

Trichloroethylene is a natural degradation product of tetrachloroethylene. The overall maximum trichloroethylene concentration detected during this sampling period was 250 ppbv (1341 μg/m^3), which is greater than the overall maximum concentration of 16 ppbv (86 μg/m^3) detected during the Track 2 Investigation. However, the concentrations of trichloroethylene are considered low in comparison with tetrachloroethylene detected at all three landfill areas.

6.3.3.3 Trend Analysis

The baseline and 1997-2005 analytical data were plotted as concentration versus sample collection date to evaluate any specific patterns, trends, or anomalies. The graphical representation of the data is included in Appendix C. Trends were established by analyzing the concentration of constituents over the entire sample collection period (1997-2005). The analysis of the trends was a qualitative assessment used to identify acceptable trends (stable or decreasing) or future potential problems (increasing).

With reference to specific patterns in the graphical representation of the soil gas data, coincident peaks or dips may be attributed to one or more of the following factors: seasonal events (i.e., changes in precipitation or increased infiltration of water from snowmelt), effects of water infiltration within the periphery of the cover on contaminant migration, significant variations in barometric pressure, chemical-specific characteristics affecting migration patterns, or attainment of a new equilibrium within the contaminant/containment system. In order to explain the dissimilarity in trends between NRF-1 soil gas data and data from the other two sites, some of the factors that will be explored in this section, specific to NRF-1, are the attainment of a new equilibrium, infiltration of water within the periphery of the cover, and contaminant migration.

With reference to the graphical representation of the data for NRF-1, the data for sample location MW1-3 exhibit a fairly steady decreasing trend during the 1997 through 2005 sampling period for all constituents in general. Sample location MW1-4 exhibited an increasing trend for tetrachloroethylene and to a lesser extent trichloroethylene. For this location, Freon 12 initially exhibited an increasing trend from 1997 through 2002 but now appears to be stabilizing. However, Freon 11 and Freon 113 exhibited a decreasing trend (these two constituents exhibited an increasing trend in the previous Five-Year Review). The limited data for trichloroethene, Freon 11, and chloroform from December 2003 through December 2005 for the new replacement soil gas probe MW1-1 (replaced in 2003) appear to exhibit a generally flat to a decreasing trend. The combined tetrachloroethylene data for the original and replacement soil gas probe MW1-1 appear to exhibit an overall decreasing trend. The limited data available for replacement soil gas probe MW1-2 (replaced in 2003) appear to exhibit an increasing trend for tetrachloroethylene and a slight decreasing trend for Freon 11. NRF-1 is the only site that experienced an overall increasing trend for tetrachloroethylene and trichloroethylene at some locations during the 1997 through 2005 sampling period.

At NRF-1, a perched water zone that appeared briefly in the region of sample location MW1-4 may have had an impact on the data. The perched water was a result of standing water (see Section 5.2.1.6) adjacent to the cover (not related to the cover itself). The last observation of such an occurrence was in 2002. Percolating water may have laterally entered the waste layer from the periphery of the cover. Percolating water from natural precipitation may acquire soluble organic components that have been immobilized by adsorption in the soil or that are contained by the waste by processes of desorption and/or dissolution. These organic compounds can be transported a certain distance away from the original source and then become immobilized again (Everett, 1984); the organic compounds can then evaporate and become a new source for soil gases or supplement an existing source.

The depth to the top of the basalt in the general area of NRF-1 appears to increase from northeast to southwest along the southern portion of NRF-1. Thus, contaminants within the waste layer, if mobilized, could migrate toward MW1-4. From historical reviews of documents, photos, and old drawings, the bulk of the waste is located on the southern half of NRF-1 (just to the northwest of MW1-3, which is the closest of the probes to the waste). Because of the location of the bulk of the waste and the subsurface features, it is possible for some migration to occur in the direction of MW1-4. The above discussion would explain the increasing trends in tetrachloroethylene and trichloroethylene at this location. However, the combined chart for tetrachloroethylene for NRF-1 in Appendix C indicates that the tetrachloroethylene concentrations at MW1-3 (where a decreasing trend is exhibited) and MW1-4 (where an increasing trend is exhibited) have been essentially equal over the past two years (possibly having attained equilibrium). With regard to trichloroethylene, the concentration at MW1-4 is significantly lower than at sample locations MW1-1 and MW1-3.

The graphical representation of the data in Appendix C for all the constituents detected at NRF-51, in general, exhibit similar patterns amongst the probes. The similarities are in the general shape of the curves and the occurrences of the peaks and valleys for each constituent at each sample location. For the 1997 through 2005 sampling period at NRF-51, the data for all constituents detected exhibit a decreasing trend in concentration over time.

The graphical representation of the data in Appendix C for the two constituents detected (Freon 11 and tetrachloroethylene) at NRF-53 exhibit a pattern of change in concentration over time for each of the individual soil gas locations similar to that observed at NRF-51. At NRF-53, the data exhibit an overall decreasing trend with the exception of MW53-4, where the data exhibit a flat to slight increasing trend (refer to the graphical representation of the data in Appendix C).

In summary, NRF-51 and NRF-53 appear to exhibit either stable or decreasing trends (both indicating that the covers are functioning as designed). On occasion, slightly increasing trends at NRF-1 (indicating possible limited contaminant migration) were observed. This will be tracked by the ongoing monitoring program.

6.3.3.4 Comparison to Groundwater Data

Of the VOCs detected under the current soil gas and groundwater monitoring programs, only chloroform and tetrachloroethylene were detected under both monitoring programs. Organic compounds detected in groundwater samples at some of the monitoring well locations occurred at only trace levels, indicating that organic compounds are not significantly migrating from the landfill sites at this time.

6.3.4 Soil Moisture Monitoring

6.3.4.1 Soil Moisture Monitoring Results

Soil moisture measurements were initiated in 2005. A discussion of the soil moisture data from measurements obtained from neutron access tubes located at the OU 8-08 Engineered Cover Sites is presented below.

6.3.4.2 Analysis of Soil Moisture Data

Soil moisture content within the engineered cover at each site is estimated by obtaining measurements from a neutron probe via access tubes that were installed on the three engineered cover areas during their construction in 2004. The soil moisture data is used to assess the effectiveness of the covers in mitigating water infiltration to the contaminant zone. This is accomplished by evaluating the covers' water storage capacity; specifically, by monitoring the depth of the wetting front attributed to percolating water from precipitation. The soil moisture measurement data raw counts, obtained from the neutron probe instrumentation, have been converted to volumetric water content in percent.

For 2005, soil moisture measurements were taken in June through October. The soil moisture data obtained during this period are presented in graphs in Figure 6-4. May 2005 was the wettest month of the year; therefore, the soil moisture measurements taken in June should reflect the effects of precipitation that occurred in May and earlier (provided all of the moisture within each cover is due to precipitation and not residual moisture from the cover construction process). Little to no precipitation fell during July and August. Therefore, the soil moisture measurements in September reflect the effects of this dry period (indicated by a decrease in moisture content within the cover). Slightly above normal precipitation occurred during

September and October. Soil moisture measurements taken in October show the effects of entering into a wet period, after most of the vegetation on the covers had dried out. The graphs show that soil moisture content (measured in percent) decreased from June to September and increased slightly in October for all monitoring probes. The graphs also show that percolating water from precipitation did not migrate beyond the subsurface layer (as evidenced by low moisture content below 1.4 meters or 4.5 feet), and therefore did not migrate into the contaminant layer.

Data in future years will further refine any trends regarding moisture penetration.

6.4 Review of ARARs

The selected remedies for the OU 8-05/06 and 8-08 Sites were designed to meet substantive aspects of the Applicable or Relevant and Appropriate Requirements (ARARs) identified in the ROD. The following are the pertinent ARARs that were defined for the selected remedies, and which were reviewed for changes that could affect protectiveness:

- 40 CFR 61.92, NESHAPS for Emissions of Radionuclides Other than Radon, (Applicable)
- IDAPA 58.01.01.585 & .586, Toxic Air Pollutants, Non-Carcinogenic and Carcinogenic, (Applicable to work where potential release of these substances exists)
- IDAPA 58.01.11.200.01(a), Idaho Groundwater Quality Standards, (Relevant and Appropriate)
- IDAPA 58.01.05.006.01(40 CFR 262.1), Standards Applicable to Generators of Hazardous Waste, (Applicable to work generating hazardous waste)
- IDAPA 58.01.05.005 (40 CFR 261), Identification and Listing of Hazardous Waste, (Applicable to work generating hazardous waste)
- IDAPA 58.01.05.011 (40 CFR 268.7, .9, .40, .45, .48) Land Disposal Restrictions, (Applicable to work generating hazardous waste)
- IDAPA 58.01.01.651, Rules for Control of Fugitive Dust, (Applicable)
- IDAPA 58.01.05.008 (40 CFR 264.309(a), 40 CFR 264.310(a)(1)(2)(3)(4)(5), and .310.(b)(1)(4)(5)(6)), Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities (Surveying, Closure, and Post Closure Care for Landfills), Relevant and Appropriate
- 40 CFR 300.440, Procedures for Planning and Implementing Off-site Response Actions (Applicable to work that involves off-site transfer of CERCLA waste)
- 16 USC 470, National Historic Preservation, (Applicable to any site where cultural, historical artifacts are found)

These ARARs have not become more stringent since the signing of the ROD.

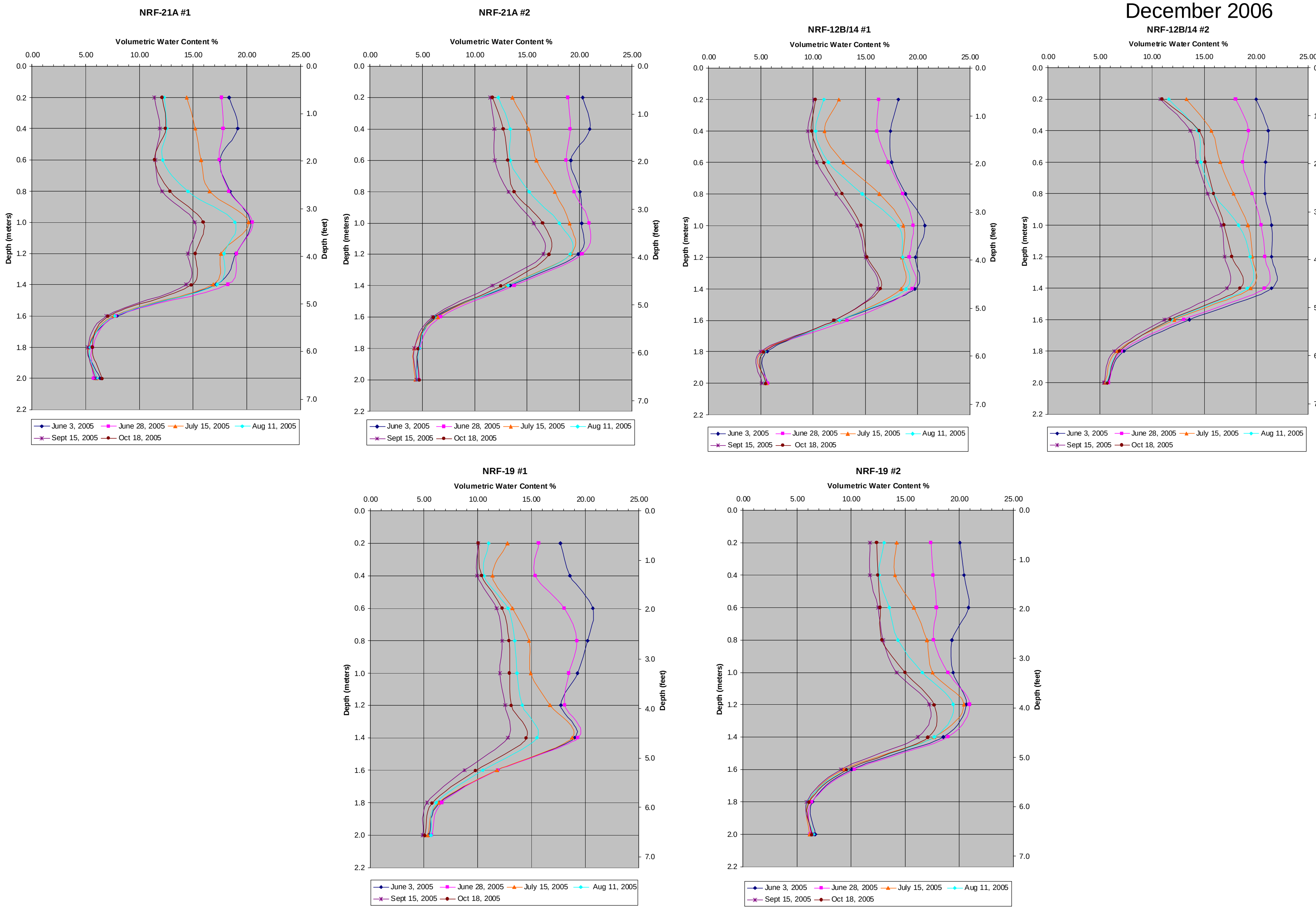

Figure 6-4 Soil Moisture Curves for OU 8-08 Engineered Cover Sites

6.5 Risk Information Review

Based on the EPA five-year review guidance, risk parameters (toxicity values) used in the risk assessment at the time of the remedy selection should be reviewed for changes to determine whether the selected remedy is still protective. Therefore, an evaluation of the toxicity data was conducted to see whether any changes had occurred and whether the changes were significant to affect the remedy selection.

Toxicity values (slope factors and reference doses) were reviewed for any updated values that may have been published since the time the remedy selection was implemented. The original toxicity values were compared to the newest values available from approved sources (e.g., Integrated Risk Information System, the Health Effects Assessment Summary Table).

For this review, the toxicity data for all of the contaminants of concern were evaluated. There were significant changes in toxicity data for some of the contaminants of concern. However, only the contaminants of concern that were the primary risk drivers for remedial actions are discussed since the other contaminants of concern (e.g., plutonium-238, uranium-235, etc.) were found in insignificant quantities or not detected during site cleanup operations. These primary contaminants included cesium-137 and strontium-90, the primary radionuclides of concern for OU 8-08 sites, and tetrachloroethylene (found in much greater concentrations and in more locations than other contaminants) for the inactive landfill areas.

For strontium-90, there is currently a published external exposure slope factor that was not available for the original risk assessment. However, strontium-90 was remediated above the 10-foot depth where contaminated soil was excavated and was placed at a site where an engineered containment structure was constructed preventing external exposure to strontium-90. For cesium-137, the latest inhalation and external exposure slope factors decreased compared to the slope factors used in the original risk calculations; however, the soil ingestion slope factor increased slightly compared to the one used in the original risk calculations (from 3.16E-11 to 4.33E-11 Risk/pCi). The risk-based soil concentration for the soil ingestion pathway was 24,860 pCi/g (WEC, 1998). The slight increase in the slope factor would not substantially reduce the soil ingestion risk-based concentration and, since soil was remediated to below 16.7 pCi/g (within the upper 10 feet of soil) due to the external exposure pathway, this would have no impact on remedy protection. For tetrachloroethylene, latest oral and inhalation slope factors increased by about one order of magnitude compared to the ones used in the original risk calculations. However, the sources of tetrachloroethylene reside under three engineered containment structures constructed over the three inactive landfill areas, which prevents potential exposure to this contaminant. Therefore, these changes to the toxicity values would not significantly impact the protectiveness of the remedy.

7.0 Data Assessment

7.1 Conditions External to the Remedy

Certain conditions external to a selected remedy can have a far-reaching influence on the applicability and the ultimate success of a chosen remedy. These conditions are discussed below.

7.1.1 Changes in Land Use or Projected Land Use

NRF does not anticipate that the land area within WAG 8 will be subject to leasing or property transfer through at least the year 2095 (100 years from initial risk assessments performed at NRF).

ICs are required as long as land use or access restrictions are necessary to maintain protection of human health and the environment. The adequacy of, and need for, the continued use of ICs for each controlled area will be evaluated during the annual inspections and the Five-Year Review process. ICs will not be changed or terminated unless NR/IBO, IDEQ, and EPA have concurred.

7.1.2 New Contaminants, Sources, or Pathway

New contaminants have not been observed in groundwater since the 2001 Five-Year Review.

Climatic changes (e.g., more or less precipitation) and changes in local discharge contribute to changing groundwater flow paths beneath NRF. For example, reduced flow to the IWD may be contributing to a reduction in elevation of a local groundwater high east of NRF, which was identified in past hydrogeological investigations. These changes could potentially impact groundwater flow paths; however, if any of these changes lead to new contaminant pathways, the current groundwater monitoring network should be capable of detecting them.

7.2 Remedy Implementation and System Operations

7.2.1 Access and Institutional Controls

Access to NRF remedial action areas is restricted from the general public as enforced by the INL security program (e.g., badges required for site access). Furthermore, NRF security personnel monitor access within the NRF fence and monitor actions in nearby areas outside the fence. A number of the NRF CERCLA sites, which are located both inside and outside the NRF fenced compound, are contained within specific fenced areas with locked gates. Other sites are marked by warning signs. Excavation controls are enforced by use of formal excavation permits which are required before any excavation at NRF may begin. These permits require the review and formal approval of Environmental Personnel prior to performing the excavation.

ICs used at NRF preserve the underlying assumptions of RI/FSs developed for WAG 8 that will protect human health and the environment. The ICs are selected remedies for the NFA Sites, and are part of the selected remedies for the NRF Inactive Landfill Areas and the RA Sites. ICs are reviewed annually and the results of the reviews are documented in the ICMR. Table 7-1 summarizes ICs applicable to the NRF CERCLA sites. Institutional Controls are discussed in more detail in Attachment E to the NRF OU 8-08 Remedial Action Report.

Table 7-1 Summary of Institutional Controls at NRF

Site	Description	Objectives	Exposure Threat	Land Restrictions	Controls
CERCLA Sites					
Group 1 (Inactive Landfill Areas)					
NRF 1	Field Area North of S1W	Prevent unauthorized access and excavation	VOC, metal leacheate	• Industrial • Lease Restriction • Transfer Restrictions	• Fencing • Excavation Controls • Signs • Inspections
NRF 51	West Refuge Pit #4	Prevent unauthorized access and excavation	VOC, metal leacheate	• Industrial • Lease Restriction • Transfer Restrictions	• Fencing • Excavation Controls • Signs • Inspections
NRF 53	East Refuge Pit and Trenching Area	Prevent unauthorized access and excavation	VOC, metal leacheate	• Industrial • Lease Restriction • Transfer Restrictions	• Fencing • Excavation Controls • Signs • Inspections
Group 2 (No Further Action Sites)					
NRF 2	Old Ditch Surge Pond	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Excavation Controls • Signs • Inspections
NRF 16	Radiography Building Collection Tank Area	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Existing fence also within NRF Fenced Area • Excavation Controls • Inspections
NRF 18A	S1W Spray Pond #1 and Portions of the Fire Protection System	Prevent unauthorized excavation	Elevated chromium	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Signs • Excavation Controls • Inspections
NRF 22	A1W Painting Locker French Drain	Prevent unauthorized excavation	Lead, mercury	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area also Beneath Existing Structure • Excavation Controls • Inspections
NRF 23	Sewage Lagoons	Prevent unauthorized excavation	VOC, metals, low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Existing Fencing • Signs • Excavation Controls

Table 7-1 Summary of Institutional Controls at NRF

CERCLA Sites					
Site	Description	Objectives	Exposure Threat	Land Restrictions	Controls
					• Inspections
Group 2 (No Further Action Sites) - Continued					
NRF 42	Old Sewage Effluent Ponds	Prevent unauthorized excavation	VOC, metals, low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Excavation Controls • Signs • Inspections
NRF 43	Seepage Basin Pumpout Area	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Excavation Controls • Signs • Inspections
NRF 61	Old Radioactive Materials Storage and Laydown Area	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Excavation Controls • Signs • Inspections
NRF 66	Hot Storage Pit	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Signs • Excavation Controls • Inspections
NRF 81	A1W Processing Building Area Soil	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 82	Evaporator Bottoms Tank Release	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 83	ECF Hot Cells Release Area	Prevent unauthorized excavation	Radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Inspections
Group 3 (Remediated Radiological Sites)					
NRF 11	S1W Tile Drainfield and L Shaped Sump	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 12A	Underground Piping to Leaching Pit	Prevent unauthorized	Low-level radioactivity	• Industrial • Lease Restriction	• Portion within NRF Fenced Area • Excavation Controls

Table 7-1 Summary of Institutional Controls at NRF

Site	Description	Objectives	Exposure Threat	Land Restrictions	Controls
CERCLA Sites					
		excavation		• Transfer Restrictions	• Signs • Inspections
Group 3 (Remediated Radiological Sites) – Continued					
NRF 14	Underground Piping to Leaching Bed	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 17	S1W Retention Basin	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 19	Underground piping to A1W Leaching Bed	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 21A	Underground piping to Old Sewage Basin	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Portions within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 21B	Sludge Drying Bed	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections
NRF 80	A1W/S1W Radioactive Line near Butler Building 19	Prevent unauthorized excavation	Low-level radioactivity	• Industrial • Lease Restriction • Transfer Restrictions	• Within NRF Fenced Area • Excavation Controls • Signs • Inspections

Table 7-1. Summary of Institutional Controls at NRF (continued)

Site	Description	Objectives	Exposure Threat	Land Restrictions	Controls
CERCLA Sites					
Group 4 (8-08 Engineered Cover Sites)					
NRF 12B	S1W Leaching Pit	Prevent unauthorized access and excavation	Radioactivity, lead	• Industrial • Lease Restriction • Transfer Restrictions • Radiologically Controlled Area	• Fencing • Excavation Controls • Engineered Cover • Signs • Inspections
NRF 14	S1W Leaching Beds	Prevent unauthorized access and excavation	Radioactivity	• Industrial • Lease Restriction • Transfer Restrictions • Radiologically Controlled Area	• Fencing • Excavation Controls • Engineered Cover • Signs • Inspections
NRF 19	A1W Leaching Bed	Prevent unauthorized access and excavation	Radioactivity	• Industrial • Lease Restriction • Transfer Restrictions • Radiologically Controlled Area	• Fencing • Excavation Controls • Engineered Cover • Signs • Inspections
NRF 21A	Old Sewage Basin	Prevent unauthorized access and excavation	Radioactivity	• Industrial • Lease Restriction • Transfer Restrictions • Radiologically Controlled Area	• Fencing • Excavation Controls • Engineered Cover • Signs • Inspections

7.2.2 Remedy Performance

7.2.2.1 Landfill Covers

The performance of the landfill covers was indirectly measured in several ways. First, visual inspections confirmed the physical integrity of the covers. These inspections were intended to identify the following problems: occurrence of soil erosion, establishment of adequate and appropriate vegetative cover, penetration of the cover by various burrowing animals, or formation of cracks in the cover due to temperature extremes, drought, or subsidence. The results of past inspections showed that the integrity of the landfills was maintained, thus indicating that the covers were performing as designed. Minor deficiencies are occasionally noted, as identified in ICMRs, such as inadequate vegetative cover at NRF-1, and rodent holes and/or anthills at all three sites. Deficiencies related to the landfill covers are addressed in more detail in Section 8.2.

The second measure of performance was gauged by results of surface soil gas monitoring. If the landfill covers are working as designed, then little or no organic vapors will be detected at the surface of the landfill covers. A number of soil gas surface emissions surveys have been performed since the construction of the landfill covers. No VOCs have been detected, thereby indicating the landfill covers are performing as designed.

Finally, several other indirect indicators were used to assess the performance of landfill covers. The soil gas monitoring probes measure the concentration of soil gas at the bedrock interface adjacent to the covers. The concentrations of soil gas constituents are essentially stable in all soil gas monitoring probes. To date, no unusual levels of organic compounds have been detected in soil gas probes, and no appreciable concentrations of organic compounds have been detected in groundwater samples. Based on survey, soil gas and groundwater monitoring results contained in the annual ICMRs, this Review concludes that the landfill covers are functioning as designed.

7.2.2.2 Groundwater Monitoring System

Four aspects of the groundwater monitoring system are assessed to determine its overall performance. These aspects include fitness of the wells, monitoring network fitness, constituents monitored, and sampling frequency. The data collected by the NRF groundwater monitoring program are used to assess remedy performance of all remedial actions at NRF and insure that these remedies remain protective of human health and the environment.

7.2.2.2.1 Well Fitness

NRF has 13 wells in its groundwater monitoring network. Nine of these wells have been constructed within the past 20 years. Installation of these newer wells incorporated modern drilling and construction techniques. They were built with environmentally inert materials and were designed to target the upper 50 feet of the aquifer. The other four wells are older (i.e., constructed between 1950 and 1980) and still provide usable data; however, they are not optimally constructed for specifically monitoring the upper 50 feet of the aquifer (wells USGS-12, -97, -98, and -99). Additionally, problems such as inadequate grouting and carbon steel in contact with aquifer water may be encountered. As previously discussed, well USGS-98 was refurbished in 2005, which addressed some of these problems.

Water samples from one well, NRF-13, contain higher than expected concentrations of chromium (and other metal constituents, e.g., aluminum, iron, and nickel). The causes for this are discussed in Appendix A.

Wells NRF-7 and NRF-13 can only sustain pumping rates of less than two gallons per minute, which is substantially less than other NRF wells which produce approximately 30 gallons per minute. Conditions present in wells NRF-7 and NRF-13 while collecting samples may promote entrainment of sediments, which may create anomalous results.

Well NRF-6 was refurbished in 2004. As noted previously, the problem with the well's motor appears to have been related to silting around the pump/motor assembly. As a result, this assembly was raised by five feet in the well when it was replaced. Although there currently is ample water over the pump intake, with falling water levels in the SRPA, care must be taken so that this well does not go dry in the future. Furthermore, additional care must be taken to ensure that any signs of future silting around the pump/motor assembly are noted and responded to as needed. Signs may include muddy purge water, over-amperage indications at the generator while running the motor, or abnormal or erratic sample results.

USGS-12 is located approximately three miles north of NRF (i.e., not ideally located in proximity to NRF), was constructed in 1950, and is cased with carbon steel to a depth of 563 feet. The total depth of the USGS-12 borehole was recorded at 692 feet; however geophysical logging information is only recorded to 564 feet. It is not clear whether the borehole was partially or completely back-filled 130 feet, or if logging was prematurely terminated. Information that was gathered during an INL site-wide well fitness survey indicated that the well was open from 585 to 692 feet or over a 107 foot interval. The submersible pump is located at 358 feet below land surface (bls). Hydrographs from the well indicate water level has varied from approximately 313 feet to 326 feet bls.

NRF routinely inspects the NRF wells and performs required maintenance. Since 2001, NRF has refurbished four wells. Currently, NRF plans to inspect and refurbish wells on a routine basis. This includes pulling well hardware from the well and observing its condition, and generally using a video camera to observe the condition of the well casing and screen. Refurbishment may include replacing worn or inoperative parts (e.g., riser pipe, pump, motor, etc.), pulling and cleaning well screens, adjusting pump intake depth, or deepening the well. The regulatory agencies will notified whenever significant modifications appear appropriate, such as deepening wells or changing the intake depth.

7.2.2.2.2 Network Fitness

The locations of the Local Downgradient wells, NRF-8, -9, -10, -11, and -12, exclusive of USGS-102 (in place prior to construction of other wells), which are the core of the NRF groundwater monitoring network, were designed using computer based modeling. Groundwater results as well as hydrogeologic evidence collected over the past several years indicate these wells adequately and effectively monitor for potential groundwater contaminants. For example, these wells have detected contamination (below MCLs) in locations where it is logical to do so (e.g., low levels of tritium in NRF-10 and -11, which are downstream of OU 8-08 sites). Also, the results from the Regional Downgradient wells (USGS-97, -98, and -99) substantiate the results from the Local Downgradient wells (NRF-8, -9, -10, -11, -12, and USGS-102).

The upgradient groundwater quality relative to NRF is not well defined. This condition is unchanged since the ROD for the OU 8-08 sites. At NRF, upgradient water samples are collected primarily from USGS-12, with additional data coming from NRF-7, a well not physically upgradient of the facility (although it has a geochemical signature consistent with upgradient (background) water). Water samples from USGS-12 may be collected from depths that are not reflective of background conditions at NRF. The mean concentrations for many constituents in NRF-7 are lower than those found in USGS-12. NRF has averaged NRF-7 data with the data collected from USGS-12, and has referred to this data as “Regional Upgradient” in the NRF Environmental Monitoring Report. Using the NRF-7 data (which is generally lower than USGS-12 data) is more conservative than using only the USGS-12 data since the mean concentration for “Regional Upgradient” data is lower. The likely effect of not having adequate upgradient groundwater information is to potentially overstate the impact that NRF operations may have had on the aquifer.

7.2.2.2.3 Adequacy of Monitored Constituents

The NRF groundwater monitoring system is designed to search for constituents that potentially could be released to the environment because of operations at NRF. This monitoring network also searches for constituents that are characteristic groundwater indicators (e.g., calcium and chloride) or provide valuable predictive data (e.g., tritium). All constituents that are believed to be potential contaminants to the environment or provide valuable predictive or characteristic data are currently monitored by NRF.

Based on groundwater monitoring results over the past five years, it is evident that the occurrence of organic compounds in the groundwater is a relatively rare occurrence. Total Organic Halogens (TOX) is an analytical method that detects gross halogenated substances in a sample. At NRF, it is used as a screening tool for the presence of organic compounds in the groundwater. Over the past five years, TOX results have been near the method detection limit in all wells, thus future collection of TOX may not be warranted.

7.2.2.2.4 Adequacy of Sampling Frequency

The current trimester sampling frequency meets and appears to exceed the level of groundwater monitoring required at NRF. All individual programmatic goals of accounting for short-term fluctuations in groundwater flow direction, short-term variations in local recharge, and longer-term trends due to known or unknown factors have likewise been met or exceeded. Furthermore, the current trimester sampling frequency is more than adequate in providing near-term data that can be used for assessing the effectiveness of the remedial actions completed in 2004 at the OU 8-08 RA Sites. Based on these observations, the current sampling frequency appears to exceed the NRF groundwater monitoring needs at this time. A decrease in sampling frequency from triannual to biannual would meet future monitoring needs.

7.2.2.3 Soil Gas Monitoring System

The current list of analytes and analytical methods used for the soil gas monitoring program includes all of the potential organic chemicals of concern, with adequate minimum detection levels.

7.2.2.4 No Further Action Sites

The primary remedy selected for the OU 8-08 NFA Sites is ICs. These controls are intended to prevent unauthorized intrusion and excavation and to control land use and transfer. Annual inspections are performed to ensure that conditions at the sites remain the same and to ensure that ICs are effective. As discussed in Section 5.2, inspections provide evidence that the remedy is performing as intended.

7.2.2.5 Remedial Action Sites

The selected remedies (e.g., removal actions, construction of the covers) for the OU 8-08 RA Sites have only recently been completed and appear to be functioning as expected. Formal annual inspections have not yet been performed; however, pre-final and final inspections by the agencies were performed in 2004 and 2005. Based on analysis of the data presented in the OU 8-08 RA Report, inspections of the various sites, and groundwater monitoring results, the selected remedies for the RA Sites appear to meet performance standards.

Specific requirements to maintain cover integrity against erosion, and to monitor for the potential release of contaminants from the sites, are identified in the Operations and Maintenance (O&M) Plan, the current revision of which is a part of the RA Report. The current revision of the Institutional Control Plan, which discusses ICs for limiting land use and access, is also part of the RA Report.

7.2.2.6 Operation and Maintenance Costs

7.2.2.6.1 Groundwater Monitoring Costs

Since the signing of both Record of Decisions for the NRF inactive landfill areas and the OU 8-08 sites, the groundwater monitoring system has consisted of thirteen wells, each sampled by the USGS four times per year between 1996 and 2002, then changed to three times per year in 2003. During each sampling period, one blank sample and one duplicate sample are collected and analyzed with the routine samples. Samples are analyzed by the contracted laboratories. Once received by NRF, sample results are sent to an independent contractor for data validation. At NRF, a representative coordinates the collection, analysis, validation, and interpretation of all groundwater samples. The breakdown of the actual costs from 2001 through 2005 associated with the groundwater monitor portion of the selected remedies for the inactive landfills and the OU 8-08 sites are summarized in Table 7-2. The total cost is higher ($549,150) than the expected cost ($521,000), which was based on the previous Five-Year review. This is due to the higher cost for the maintenance of three wells (about $20,000 higher due to more extensive work and parts replacement) and a slight increase in the analytical costs (about $8,000 higher due to the renegotiation of costs for contract renewal).

Table 7 2 Yearly Operational Costs for Groundwater Monitoring Network

Time Period	Analysis Costs	Validation Costs	Maintenance	Yearly Total
2001	$105,000	$7,900	0	$112,900[1]
2002	$110,000	$7,900	$8,800	$126,700[1]
2003	$94,500	$6,150	$8,800	$109,450[2]
2004	$92,500	$6,150	$8,800	$107,450[2]
2005	$86,500	$6,150	0	$92,650[2]
Subtotal	$488,500	$34,250	$26,400	
			Five Year Total	$549,150

1-Based on a quarterly sampling schedule
2-Based on a trimesterly sampling schedule

7.2.2.6.2 Soil Gas Monitoring Costs

The specific O&M activities associated with soil gas monitoring of the three inactive landfill cover areas includes sampling a total of fourteen soil gas monitoring probes (13 probes prior to November 2003), analytical costs, data validation, and any maintenance costs. The soil gas monitoring probe locations are sampled on a quarterly basis. This includes samples from all of the soil gas monitoring probes, one duplicate, one field air blank, and one field equipment blank. The samples are sent off-site and analyzed by the contract laboratory. The analytical results are then submitted for data validation. After the results are validated, NRF evaluates the data for any problems and for trends. The breakdown of the costs from 2001 through 2005 associated with the soil gas monitoring tasks is tabulated in Table 7-3. The total cost ($146,900) is higher than the expected cost ($112,900), which was based on the previous Five-Year review. This is due to the replacement costs (listed under maintenance costs) for two soil gas monitoring probes in 2003 and a slight increase in data validation costs.

Table 7 3 Yearly Operational Costs for Soil Gas Monitoring

Time Period	Analysis Costs	Validation Costs	Maintenance	Yearly Total
2001	$21,000	$2,400	$0	$23,400
2002	$21,000	$2,400	$0	$23,400
2003	$21,000	$2,400	$29,900	$53,300
2004	$21,000	$2,400	$0	$23,400
2005	$21,000	$2,400	$0	$23,400
Subtotals	$105,000	$12,000	$29,900	
			Five Year Total	**$146,900**

7.2.2.6.3 Soil Moisture Monitoring Costs

The specific O&M activities associated with soil moisture monitoring of the three OU 8-08 engineered cover areas includes obtaining soil moisture measurements from a total of six access tubes and any maintenance costs. Soil moisture measurements are obtained by subcontractor personnel (currently S. M. Stoller Corp.) with coordination and observation by NRF personnel. The soil moisture measurements from these access tube locations are obtained up to 12 times per year from early spring through the fall. NRF personnel evaluate the data for any problems (e.g., water infiltrating below the engineered cover). 2005 was the first year soil moisture measurements have been obtained at an annual cost of $4800. This cost is expected to remain the same over the next four years and may change after that when the contract is renegotiated.

7.2.2.7 Assessment Summary

In the EPA guidance for Five-Year Reviews, the EPA provided three questions to aid in assessing remedy performance. These questions and their answers are summarized in Table 7-4 below.

Table 7-4 Answers to Guidance Questions

Questions:	Location	Answer	Location	Answer	Location	Answer	Location	Answers:
	Inactive Landfill Areas		No Further Action Sites		Remediated Radiological Sites		OU 8-08 Engineered Cover Sites	
A: Is the remedy functioning as intended by the decision documents?	NRF-1 NRF-51 NRF-53	Yes	NRF-2 NRF-16 NRF-18A NRF-22 NRF-23 NRF-42 NRF-43 NRF-61 NRF-66 NRF-81 NRF-82 NRF-83	Data reviews and site inspections indicate that the remedies are functioning as intended.	NRF-11 NRF-12A NRF-14 NRF-17 NRF-19 NRF-21A NRF-21B NRF-80	These remedies were performed in accordance with the Phase **I** Work Plan. Relevant data, ARARs presented in the OU 8-08 ROD, and site inspections (pre-final and final by the agencies) indicate that the remedies are functioning as intended, and thus protective of human health and the environment.	NRF-12B NRF-14 NRF-19 NRF-21A	These remedies were performed in accordance with the Phase **II** Work Plan. A review of the relevant data and ARARs presented in the OU 8-08 ROD, and site inspections (pre-final and final by the agencies) indicate that the remedies were constructed in accordance with the requirements of the Remedial Design, and that the remedies are protective of human health and the environment.
B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy still valid?		Yes		Yes		Yes		Yes
C: Has any other information come to light that could call into question the protectiveness of the remedy?		No		No		No		No

8.0 Deficiencies

8.1 Overview

A review of prior site inspection results and data presented in the preceding sections shows only minor deficiencies associated with the NRF Inactive Landfills, NFA Sites, Remediated Radiological Sites, or OU 8-08 Engineered Cover Sites. The following sections summarize the identified deficiencies in greater detail.

8.2 Landfill Covers

The only deficiencies identified in the annual inspections included problems with sparse vegetation areas (including the presence of some weeds) and animal intrusion (anthills and holes caused by small rodents such as mice and voles). These deficiencies are considered minor. Areas that showed evidence of sparse vegetation were re-seeded in 2004, and are showing evidence of new growth. Animal intrusion is limited to the upper clean layers of the covers where a gravel layer is present for the purpose of preventing further intrusion into the covers. Therefore, these intrusions were not deep enough to expose buried contaminants. These deficiencies did not affect the integrity of the landfill covers.

8.3 Groundwater Monitoring Network

Over the past five years, several deficiencies were identified with the Groundwater Monitoring Network and wells. Most of the deficiencies were corrected shortly after their identification. The following list discusses current deficiencies.

1) The results for selected metal constituents from NRF-13 show an upward trend and periodically have been above Federal MCLs. Potential causes for these anomalies are being investigated.

2) Both NRF-13 and NRF-7 are low producing wells, which may promote poor and possibly unrepresentative sample quality.

3) The NRF-6 well has shown signs of active siltation as shown in March 2004 when the pump/motor was replaced.

8.4 Soil Gas Monitoring Probes

As discussed in Section 6.2.1.6, MW1-1 and MW1-2 were replaced in 2003. No further problems were encountered with these two probes. No problems were encountered with any of the other soil gas monitoring probes, with the exception of MW-1-4 in which water has been found on occasion. Data collection from this location has been unaffected by the water. The source of the water is believed to be related to seasonal precipitation. The NRF storm water system is being upgraded to allow for adequate drainage of storm water away from this probe location.

8.5 Soil Moisture Monitoring Probes

IDEQ and EPA performed a pre-final inspection of the OU 8-08 Engineered Cover Areas in 2004 and a final inspection in 2005. The pre-final inspection noted that the access tubes needed to be mounded with soil so that water would be shed radially away from the access tubes, followed by seeding the soil mound. The soil mounding was performed during the latter part of 2004. The seeding of the mounds was performed in 2005. During the final inspection, IDEQ and EPA noted the deficiencies were corrected.

8.6 Deficiencies Summary

Table 8-1 includes a summary of deficiencies observed during this Five-Year Review and whether they affect current and/or future protectiveness.

Table 8 1 Summary of Deficiencies

	Deficiency	Does this Deficiency Currently Affect Remedy Protectiveness?	Will this Deficiency Affect the Future Protectiveness of the Remedy?
Landfill Covers	Sparse vegetation at NRF-1	No	No
	Ant hills and evidence of small burrowing animals at all covers. Localized to near surface layers.	No	No, reseeding in 2004 appears successful
Groundwater Monitoring Network	Results from well NRF-13 are trending upward and have periodically tested above the Federal MCL	No, the elevated chromium is believed to be due to high levels of suspended sediments in water samples	No, evidence collected in the future is expected to continue to show that trends are due to non-anthropogenic sources
	NRF-13 and NRF-7 are low producing wells and may produce unrepresentative results	No	No, these wells do not appear to be impacted by the IWD (see Appendix A) and do not monitor sites that require remedies.
Groundwater Monitoring Network	Signs of active siltation are present in NRF-6	No	No, maintenance work has corrected the immediate problem. NRF will closely watch this well, NRF-6 does not monitor sites requiring remedies
	Upgradient water quality is not well defined at NRF	No, the conservative nature of the upgradient water quality currently used by NRF, leads to decisions that tend to be over protective	No, the upgradient monitoring data does not impact remedy effectiveness. Monitoring data is expected to continue to be conservative.
Soil Gas Monitoring Probes	Two probes were plugged and thus not operating correctly	No, these probes were replaced and are now working correctly	No, the soil gas probes are expected to function as designed in the future

9.0 Recommendations and Required Actions

9.1 Overview

The purpose of this section of the Five-Year Review is to evaluate the overall performance of the remedies, including the deficiencies discussed in Section 8.0, and make recommendations regarding what actions, if any, may be appropriate to correct a deficiency or to improve the overall effectiveness of remedies.

9.2 Landfill Covers

With regard to the OU 8-05/06 landfill covers, no immediate actions are recommended. The sparse growth areas at NRF-1 and the minor sparse area at NRF-51 were re-seeded and will continue to be monitored to ensure the new growth observed in the last inspection continues to flourish and fill in these areas. In addition, if adverse weather conditions interfere with natural germination and propagation of the vegetative cover at any of the landfill areas, NRF will take action as appropriate in accordance with the O&M Plan.

9.3 Groundwater Monitoring Network

Based on data presented in this review, specifically the relatively infrequent occurrence of organic compounds in the NRF Groundwater Monitoring Network, the collection of TOX no longer appears necessary. This Review proposes that analysis for TOX be discontinued at the beginning of 2007. Details supporting this proposed change will be incorporated as part of the 2006 ICMR.

Beginning in 2007, NRF will reduce the sampling frequency of all wells from three times per year to twice per year. Reducing sampling frequency should not affect NRF’s ability to monitor potential changes to aquifer water quality. NRF will assess the effectiveness of the recently completed OU 8-08 remedial actions and propose future recommendations to the agencies as appropriate.

The analysis presented in Appendix A indicates that the probable cause for elevated metal constituents in NRF-13 is suspended solids; evidence does not preclude an impact by corrosion of well components. This impact, if present, is expected to be minor. Although DOE NR/IBO believes the probable cause of elevated metals in NRF-13 has been identified, NRF will continue to assess the elevated chromium in NRF-13 by taking the following specific actions:

1) NRF will continue to collect filtered and unfiltered samples from NRF-13 until a decision is made to discontinue.
2) The pump, motor, riser pipe, and measuring line will be pulled from NRF-13 and inspected for signs of corrosion or malfunction. This work has been scheduled with the USGS for November 2006.
3) The internal condition of the well will be inspected for signs of corrosion and chemical precipitation using a borehole video camera (Included in the work scheduled with the USGS for November 2006).
4) The depth to bottom of the borehole will be determined. This depth will be compared to well construction information to determine if siltation has occurred. (Included in the work scheduled with the USGS for November 2006)
5) A meeting with the regulatory agencies will be held to determine the best course of action and potential future actions after items 2 through 4 are performed.

The adequacy of USGS-12 to continue to be used as an upgradient well, and whether a new upgradient well needs to be constructed will be discussed with IDEQ and EPA pending the outcome of the field inspection and assessment of NRF-13 discussed above.

Finally, NRF will continue to monitor NRF-6 for signs of silting, and if this condition persists, the well may be reconditioned.

9.4 Soil Gas Monitoring Probes

No problems exist concerning the soil gas monitoring probes (regarding functionality and physical defects). Even though water is sometimes present in one probe, this problem does not affect functionality. The concentrations of soil gas constituents are essentially stable in all soil gas monitoring probes, with overall decreasing trends at most sample locations. The main exception is one location at NRF-1, where two constituents exhibit increasing trends. However, the concentrations of these two constituents are still below the levels detected in the Track 2 Investigation. Soil gas monitoring on a quarterly basis no longer appears to be necessary because of the lack of variability exhibited by the data and the generally low concentrations found to date; therefore, the sampling frequency will be reduced to semiannual beginning in 2007. NRF will reduce sampling frequency to annual after three years of additional sample collection provided the data supports this change.

9.5 Soil Moisture Monitoring Probes

No recommendations or required actions are necessary at this time, since only one year's worth of data has been obtained with no anomalies observed.

9.6 Recommendations Summary

Table 9-1 includes a summary of recommendations that have been identified for this Five-Year Review along with any follow-up actions necessary. Table 9-1 also identify the responsible party for implementation of the recommendations, the agency with oversight authority, the milestone date for implementation and completion, and the impact, if any, on protectiveness.

Table 9 1 Summary of Recommendations and Follow up Actions

Deficiency Issue	Recommendation/ Follow up Actions	Responsible Party	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
Sparse vegetation	Re-seed covers	NRF	IDEQ/EPA	Complete in 2004	NO	NO
Animal burrows	Continue to inspect sites to see if the number of holes increase from the occasional hole observed and/or the holes compromise cover integrity; remove pest if necessary and make necessary repairs	NRF	IDEQ/EPA	As necessary	NO	NO
Ant hills	Inspect covers to ensure that hills do not compromise cover integrity	NRF	IDEQ/EPA	Periodic Inspections	NO	NO
Monitoring constituents	Discontinue the collection of TOX if data continue to support this action	NRF	IDEQ/EPA	Tentatively in 2007	NO	NO
Reduce monitoring frequency	Reduce monitoring frequency to biannual for groundwater	NRF	IDEQ/EPA	Begin in 2007	NO	NO
Elevated metal results from NRF 13	Collect filtered and unfiltered samples from the well	NRF/USGS	IDEQ/EPA	Began in March 2006	NO	NO
	Pull hardware from well and inspect both hardware and well borehole for problems	NRF	IDEQ/EPA	November 2006	NO	NO
	Hold follow-up meeting between NRF and regulatory agencies to determine best course of action.	NRF	IDEQ/EPA	Prior to March 2007	NO	NO
Siltation in NRF 6	Watch wells for signs of sediments in samples. Recondition well if necessary	NRF	IDEQ/EPA	As necessary	NO	NO
Reduce monitoring frequency	Reduce monitoring frequency to biannual for soil gas	NRF	IDEQ/EPA	Begin in 2007	NO	NO
Reduce monitoring frequency	Reduce monitoring frequency to annual for soil gas beginning in 2010 if supported by data	NRF	IDEQ/EPA	Begin in 2010	NO	NO
Plugged Probes	Replace probes	NRF	IDEQ/EPA	Complete in 2004	NO	NO
Water in some probes	Watch for negative effects on probe efficiency	NRF	IDEQ/EPA	During quarterly sampling	NO	NO
Low production in NRF 13 and NRF 7	Continue to monitor results from wells	NRF	IDEQ/EPA	As necessary	NO	NO

10.0 Protectiveness Statements

The protectiveness of the remedies selected for the areas discussed in this NRF Five-Year Review for the OU 8-05/06 Inactive Landfill Areas and OU 8-08 Remedial Action Sites are summarized in Table 10-1.

Table 10 1 Summary of Protectiveness Statements for NRF CERCLA Sites

Area	Protectiveness Determination	Protectiveness Statement
OU 8 05/06 Landfill Covers	Protective	The remedy at OU 8-05/06 Landfill Covers is protective of human health and the environment. The analytical data shows that the covers are effective at containing contaminants. The covers and direct contact with contaminated soils and landfill wastes are being controlled by institutional controls.
OU 8 08 "No Further Action" Sites	Protective	The remedy at OU 8-08 No Further Action Sites is protective of human health and the environment because the remedy has been effective in limiting unauthorized access and excavation. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the No Further Action designation of the sites.
OU 8 08 Remediated Radiological Sites	Protective	The remedy at OU 8-08 Remediated Radiological Sites is protective of human health and the environment. The OU 8-08 Remedial Action (RA) report indicates that pipe removal and consolidation of contaminated soil has been successful in achieving remedial action objectives (RAOs). The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statement for the sites.
OU 8 08 Engineered Cover Sites	Protective	The remedy at OU 8-08 Engineered Cover Sites is protective of human health and the environment. The OU 8-08 RA report indicates that the construction of an engineered earthen cover has been successful in achieving RAOs. Exposure pathways that could result in unacceptable risks are being controlled by institutional controls. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statements for the sites.

10.1 Summary

In summary, because the individual remedies at each site are protective of human health and the environment, collectively the selected remedies for the NRF remediated CERCLA sites are protective.

11.0 Next Review

NRF is a statutory site that requires ongoing Five-Year Reviews. The next review will be conducted within five years of this Five-Year Review, and is therefore scheduled for 2011. All subsequent NRF Five-Year Reviews will continue to address both the OU 8-05/06 Inactive Landfill Areas and the OU 8-08 Remedial Action Site.

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Appendix A

A Discussion of Causes

For the

Presence of Elevated Chromium

Concentrations

In Groundwater Well NRF-13

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List of Acronyms and Units

A1W	Large Ship Reactor Prototype (1st Aircraft Carrier design by Westinghouse)
Al	Aluminum
BBI	Bechtel Bettis, Inc.
bls	Below Land Surface
Ca	Calcium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cr	Chromium
DOE	Department of Energy
Eh	Reduction-Oxidation Potential
EPA	Environmental Protection Agency
Fe	Iron
F/L	Fluvial/Lacustrine
IDEQ	Idaho Department of Environmental Quality
INL	Idaho National Laboratory
IWD	Industrial Waste Ditch
Li	Lithium
Mn	Manganese
MCL	Maximum Contaminant Level
Mg	Magnesium
Na	Sodium
NRF	Naval Reactors Facility
NTU	Nephelometric Turbidity Units
OU	Operable Unit
pH	Potential of Hydrogen (-Log of the Hydronium Ion [H_3O^+] Concentration)
ppb	Parts per Billion
PS	Piezometer Shallow
PW	Perched Water
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RL	Reporting Limit
S1W	Submarine Thermal Reactor Prototype (1st Submarine design by Westinghouse)
S5G	Submarine Reactor Plant Prototype (5th Submarine design by General Electric)
SO_4	Sulfate
SRPA	Snake River Plain Aquifer
TD	Total Depth
TDS	Total Dissolved Solids
USGS	United States Geological Survey
WEC	Westinghouse Electric Company

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Executive Summary

Results from analysis of groundwater samples collected from NRF-13 (one of thirteen wells in the NRF groundwater monitoring network) between late 1999 and early 2006 showed elevated levels of chromium.

The results of assessments of the potential causes for the elevated chromium are presented in this appendix. The assessment concentrated on two areas: causes related to NRF-13 (sedimentation and corrosion) and causes external to the well (the NRF Industrial Waste Ditch).

This appendix concludes that suspended sediments, possibly in combination with corrosion products, caused the elevated chromium results. Furthermore, although influence from the IWD on NRF-13 can not be ruled out, evidence suggests that the influences are unlikely.

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1.0 Purpose

The purpose of this appendix is to evaluate the groundwater data associated with NRF-13 and to determine the likely cause for the high chromium concentrations found in NRF-13.

2.0 Introduction

NRF-13 is a groundwater monitoring well that was constructed in 1995, in which several monitored constituents (most notably chromium) are frequently elevated compared to background concentrations. This well has a naturally low water production rate of one to two gallons per minute. Well NRF-13 was constructed to measure upgradient groundwater quality near NRF and was expected to exhibit groundwater quality comparable to other background wells; however, this well has not exhibited upgradient groundwater quality since its construction. Beginning in 1999, a noticeable increase in the chromium concentrations were observed in NRF-13 data. Since 2000, the National Primary Drinking Water Standard Maximum Contaminant Level (MCL) of 100 parts per billion (ppb) (EPA, 2004) has been exceeded on four occasions in NRF-13.

The 2001 Five-Year Review for the Inactive Landfill Areas acknowledged the high chromium concentrations in NRF-13 and the inadequacy of NRF-13 to monitor upgradient groundwater. The source of chromium in NRF-13 was not positively identified although sedimentation in the well was proposed as a possible cause. The 2001 Review indicated that if NRF-13 exhibited an upward trend for chromium, and if sample results exceeded the MCL for a one year average, then additional evaluation and response actions may be necessary. Since the issuance of the 2001 Review, the chromium concentration in NRF-13 has exceeded the Federal MCL of 100 ppb over a one year average due primarily to isolated abnormally elevated results.

The nearest anthropogenic source of chromium to NRF-13 is the Industrial Waste Ditch (IWD), which is a Comprehensive Environmental Response Compensation and Liability Act (CERCLA) site known to have released water with elevated constituent concentrations, including chromium. A Record of Decision (ROD) was signed in 1994 that concluded the IWD did not pose a threat to human health and the environment and it was designated as a no action site. However, due to the elevated chromium concentrations in NRF-13 since 1999 and the proximity of NRF-13 to the IWD (800 feet at its closest point), there was concern that the groundwater at NRF-13 was being influenced by the IWD.

This report focuses on two aspects in the assessment of chromium in NRF-13. First and foremost, the report reviewed various data collected over the years associated with NRF-13 and surrounding wells that would help determine the cause of elevated chromium. Second, the report examined transport mechanisms that might allow the IWD to influence constituent concentrations in NRF-13.

The review and evaluation of data from NRF-13 strongly suggests that the elevated chromium is a result of suspended solids in the samples due to sedimentation in the well and perhaps, to a lesser extent, corrosion from well components (e.g., the well screen). Although NRF-13 has always exhibited some elevated constituents, the data show a change occurred in NRF-13 in 1999 when chromium concentrations began to trend upward and after which the MCL was exceeded on four occasions. A comparison of filtered and unfiltered data from NRF-13 shows that high chromium concentrations, along with certain other elevated metal concentrations, are reduced to near background levels after filtration. Also, when metal concentrations in NRF-13 are compared to turbidity data there is a strong correlation between samples with high turbidity and those with elevated metals. Both of these comparisons support the conclusion that suspended solids are likely the primary cause for elevated metals in NRF-13. This conclusion is further supported by the low production rate of NRF-13, which makes purging the well prior to sampling more difficult and could enhance entrainment of sediments in samples. Data collected from the sedimentary interbeds at NRF-13 show chromium concentrations high enough to cause elevated chromium in water samples if sedimentation were present.

The second aspect evaluates possible transport mechanisms from the IWD to NRF-13 and concludes that, evidence indicates that transport of constituents from the IWD to NRF-13 is not likely. Trend analyses performed in this report do not show a correlation between constituent concentrations in wells NRF-13 and NRF-6, a well known to be influenced by the IWD. In particular, ionic salts which are known to be released to the IWD have trended upward in NRF-6, but have been stable in NRF-13 since its construction. Chromium, which was historically discharged to the IWD, is declining in NRF-6, but has been increasing in NRF-13. Perched water, which would provide a possible contaminant transport path, is not currently known to exist near NRF-13 and was not encountered during well construction. The underlying geologic layers (e.g., a near surface clay rich layer and top of basalt) at NRF-13 slope away from NRF-13 and toward the IWD, which would make migration of water from the IWD to NRF-13 more difficult. Current water table elevation data indicate NRF-13 is upgradient in relation to the IWD. Likewise, evidence indicates that possible historic mounding of water beneath the IWD would not have been large enough to overcome the regional flow gradient and influence NRF-13. In addition, a remedial investigation of the IWD performed in conjunction with the 1994 ROD indicated that chromium is likely to bind to the soil within a few feet of the source, thereby reducing the likelihood of transport to groundwater.

The following section presents a history of well NRF-13 as well as a comparison of the well to the surrounding groundwater monitoring network in an effort to determine the extent of elevated constituents in NRF-13. This information is important in evaluating the potential source(s) for the elevated constituents in NRF-13.

3.0 History of Past Investigations and Well NRF-13

The following sections provide an overview of past hydrological investigations performed for the IWD area of NRF as well as a description of the construction and monitoring history of well NRF-13.

3.1 Hydrological Investigations of the Area Surrounding the IWD

Over the past nineteen years, NRF has performed a number of hydrological investigations of the area around the IWD and geochemical analyses of perched water and groundwater. These investigations were performed to better understand potential impacts of NRF operations on the Snake River Plain Aquifer.

The first major investigation was conducted in the mid-1980s. This investigation included performing seismic refraction studies and drilling numerous boreholes along the IWD.

In 1991, NRF drilled wells NRF-6 and NRF-7 and collected approximately 500 feet of basalt and interbed cores from locations next to each well. Numerous geochemical and physical property analyses of the cores were performed. Geophysical logging of the open boreholes was also performed. While drilling NRF-6, perched water was encountered in a red sedimentary interbed located approximately 110 feet below land surface (bls). Based on this discovery, an additional

14 shallow boreholes were drilled to delineate the one identified perched water zone, and to search for other zones. Perched water was encountered in four other locations: three within the perched water zone located near the outfall of the IWD, and one located between the IWD and the NRF Sewage Lagoon (WEC, 1992).

In 1992 and 1993, NRF collected extensive geological and hydrological data along the IWD in support of the 1994 Remedial Investigation (RI) of the IWD. This work included drilling 26 shallow auger boreholes (most 20 to 50 feet deep) for stratigraphic and moisture data, drilling and completing three perched water wells along the IWD, drilling a test well north of the IWD, performing gravimetric surveys to define the contours of the surface of the buried basalt, performing resistivity surveys along the IWD to predict the presence of perched water, and drilling four shallow borehole arrays (each consisting of 7 borings) oriented perpendicular to the IWD. Numerous physical studies were performed at each borehole location, which included geochemical analyses. Additional work consisted of performing an infiltration study of the IWD, a geochemical study of perched water, sampling of IWD sediments, and groundwater fate and transport modeling using the GWSCREEN modeling software (WEC, 1994).

In 1995, NRF constructed six new monitoring wells for inclusion into the NRF Groundwater Monitoring Network. Water from each well was collected and analyzed for various inorganic, organic, and radiological constituents both during and after construction. Numerous geochemical and physical properties samples from the wells were also collected and analyzed. The locations of these six wells were chosen based on modeling of groundwater flow directions and the physical properties of the aquifer. Geophysical logging was performed at each well location. Each well was drilled with instruction to stop drilling at signs of perched water (WEC, 1995).

In 1997, NRF issued a Hydrogeological Study as part of Comprehensive Remedial Investigation and Feasibility Study (RI/FS). This study discussed the geology and hydrogeology around NRF, and groundwater Modeling using GWSCREEN and MODFLOW software. This report also included a geochemical study of groundwater near NRF and a discussion of contaminant fate and transport issues (WEC, 1997).

In 2001, NRF issued its first Five-Year Review of the Inactive Landfill Areas. This review included a Hydrogeological Report which discussed the interpretation of groundwater, geological, and geochemical data collected to that date.

3.2 Construction of Well NRF-13

The location of NRF-13 was chosen with the intent of sampling water that would be representative of upgradient water conditions relative to NRF. Because of the lack of specific hydrogeologic data upgradient of the IWD, this well was not placed with the aid of computer modeling; however, the five other wells constructed concurrently with NRF-13 were placed based on modeling of groundwater flow directions and the physical properties of the aquifer. The main criterion for placing NRF-13 well was to choose the location nearest NRF that still collected upgradient groundwater unaffected by NRF activities. As a result, NRF-13 was placed several miles southeast of well USGS-12 and 800 feet northwest of the IWD (WEC, 1997). Figure 1 shows the location of NRF-13 relative to the other NRF wells. It should be noted that during the drilling of NRF-13, NRF personnel specifically watched for signs of perched water. When a significant interbed was encountered, drilling was stopped to allow water, if present, to fill the boring. No perched water was encountered while drilling NRF-13.

Construction of NRF-13 was completed in August 1995. Figure 2 presents the construction diagram for this well (WEC, 1995). Drilling of NRF-13 began on July 20, 1995 and continued through July 27 terminating at a total depth (TD) of 425 feet below land surface (bls). A stainless steel casing and well screen were installed from approximately 296 feet bls to 424 feet bls. The boring was completed as a monitoring well with the pump, riser pipe, measuring line, and cover installed on August 2, 1995. The pump intake was set at a depth of 405 feet bls with the screened interval extending from approximately 373 feet bls to 424 bls. Site logs indicate that the driller encountered a "sticky zone" at approximately 375 feet bls. The depth of the "sticky zone" was confirmed using a down-hole video camera that revealed a sandy interbed. Water was first encountered at approximately 395 feet bls but later equalized at 369.20 feet bls.

3.3 Groundwater Monitoring at Well NRF-13

Quarterly monitoring of NRF-13 began in January 1996 and continued through the end of 2002. A recommendation for modifying the sample collection frequency of the NRF Groundwater Monitoring Network was presented in the 2001 Five-Year Review for the NRF Inactive Landfill Areas; as a result, samples have been collected three times per year since the end of 2002. Table 4-1 of the 2006 Five-Year Review lists all the constituents currently analyzed by NRF.

Special samples have been collected periodically over the life of the well. Most of these samples were not collected as true split samples (i.e., one sample divided into two parts), but instead were collected consecutively. One sample was filtered prior to analysis for metals and the other sample was not. The purpose of the special samples was to help determine the relative quantity of dissolved metals in the groundwater versus the amount contained in a suspended state.

4.0 Analysis of Groundwater Monitoring Data

This section discusses the results of groundwater monitoring at NRF-13 and comparisons made between these results and results collected from surrounding wells.

Sections 4.1 and 4.2 provide background information useful in understanding the results of this report. First, the twelve chemical constituents used to perform various assessments are discussed. Table 1 provides information about why these constituents were chosen and for what assessment they were used. Next, the results of analysis of chromium data are presented and issues associated with these data were discussed.

The monitored constituents in NRF-13 are then compared to background concentrations to determine those constituents present at elevated concentrations. This information was important to help evaluate the possible source for the elevated constituents in NRF-13. In addition, the data prior to and after 1999 were compared, since 1999 marked an apparent fundamental change in the hydrological character of NRF-13, in that data collected after this date exhibited higher chromium concentrations than before.

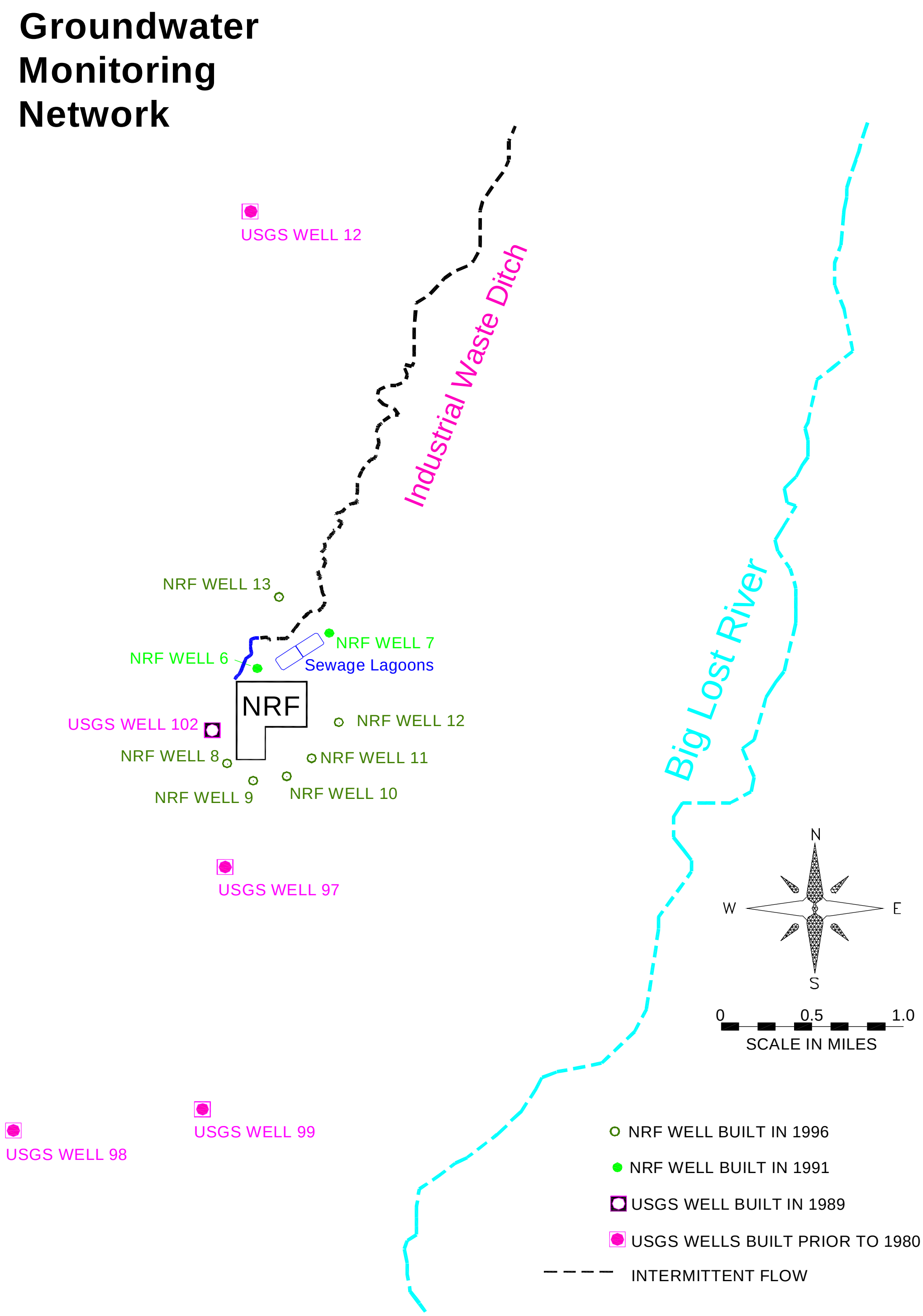

Figure 1 Location of NRF Wells

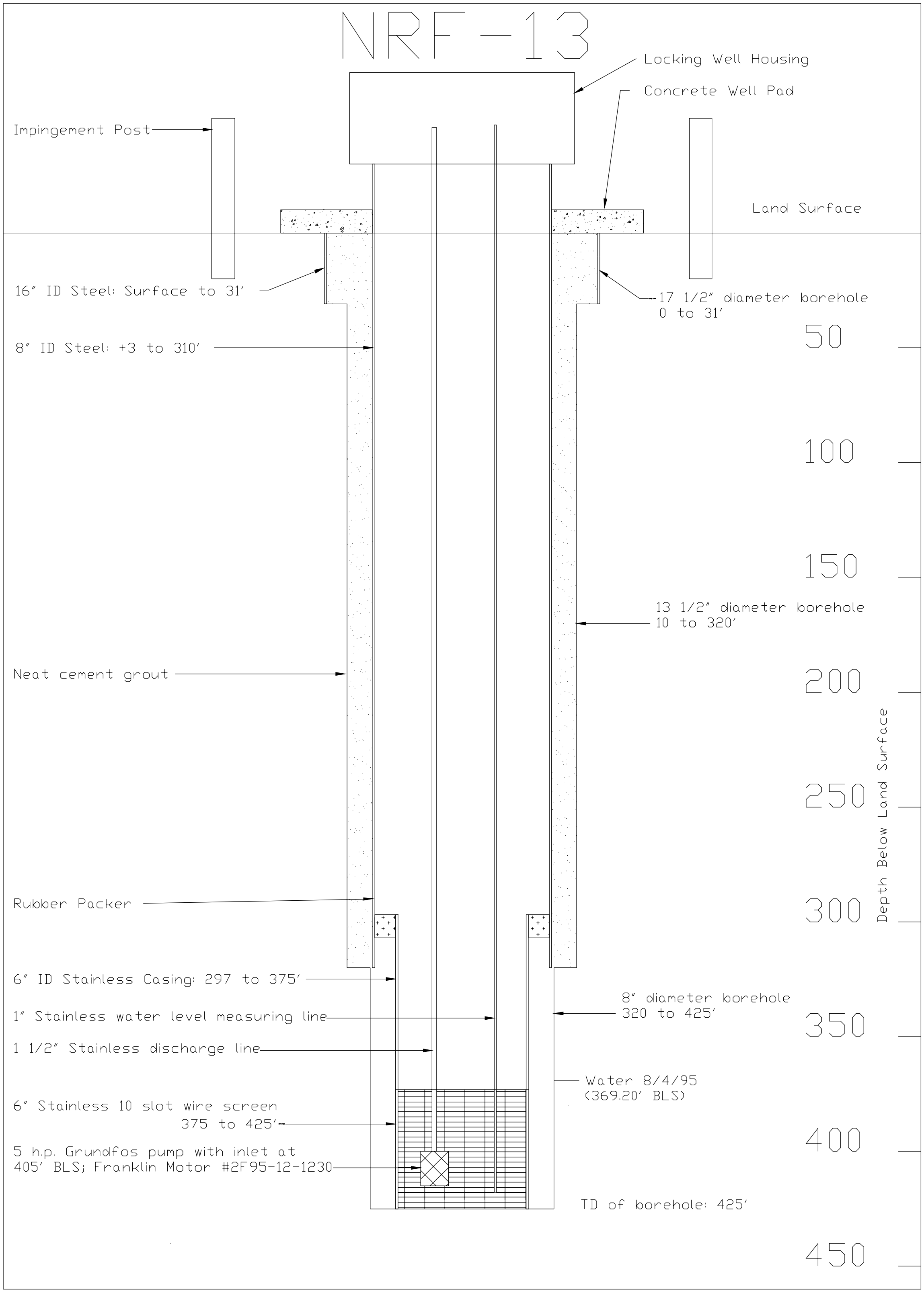

Figure 2 Construction Diagram for Well NRF-13 (WEC, 1995)

Since NRF-13 was constructed as an upgradient well, its water quality was expected to be comparable to background groundwater quality. The closest CERCLA site to NRF-13 is the IWD, which is known to have received past discharges elevated in chromium, and current discharges containing water with elevated ionic salts concentrations. This comparison of NRF-13 to background levels shows that analytical results from NRF-13 have several constituents that statistically exceed background concentrations including constituents that are not typically associated with the IWD but are commonly associated with sedimentation such as aluminum, iron, and manganese. In addition, a few constituents known to have been released in quantity to the IWD, such as sodium, are not elevated in NRF-13. Other constituents associated with the IWD, such as chloride, potassium, and sulfate are elevated in comparison to background.

In order to better understand the relationship, if any, between NRF-13 and the IWD, a comparison to NRF-6 groundwater quality was performed. Comparing NRF-13 to NRF-6, which is an effluent monitoring well known to be impacted by discharges to the IWD, allowed an assessment of whether the characteristics of NRF-13 are similar to NRF-6, which would provide evidence if a common source exists for elevated constituents in both wells. However, the comparison of NRF-13 to NRF-6 showed that none of the primary constituents of concern (i.e., chromium and ionic salts) have similar concentrations.

Finally, data from USGS-22, a well located southwest of NRF, is compared to data from NRF-13 to show the existence of another INL well with anomalous characteristics similar to those found in NRF-13.

4.1 Selection of Constituents

The purpose of this section is to provide some general information necessary to understand assessments that are presented later in the appendix. This section presents a brief discussion of the constituents that were used to perform the various assessments discussed in this appendix.

Twelve constituents were considered appropriate for performing data assessments and examining groundwater quality at well NRF-13. These constituents, the assessments in which they were used, and the reasons for their inclusion in this appendix are listed in Table 1.

The “Reason for Inclusion” column includes the following explanations: “rock forming element” denoted by (1), “good tracer” denoted by (2), “discharged to the IWD” denoted by (3), and “corrosion indicator” denoted by (4). Notes in this column were added for clarity. The “common rock forming element” indicates that the constituent is naturally occurring in abundance and would be expected to occur in sediments. “Good tracer” indicates that the constituent migrates easily in the aqueous phase and does not easily precipitate out or interact with aquifer material. “Discharged to the IWD” indicates that the constituent was known to exist in historic and/or current IWD discharges. Finally, “corrosion indicator” indicates that this is a component that can be released as a result of corrosion of stainless steel.

Table 1 Constituents Used in NRF 13 Investigation

Constituent	Assessment for which Constituent was Used	Reason for Inclusion
Aluminum	Comparison to Background and Surrounding Wells, Filtered vs. Unfiltered Sample Comparison	1
Calcium	Comparison to Background and Surrounding Wells, Trend Analysis	1, 2, 3
Chloride	Comparison to Background and Surrounding Wells, Trend Analysis	2, 3 (in significant quantities)
Chromium	Comparison to Background and Surrounding Wells, Trend Analysis, Filtered vs. Unfiltered Sample Comparison	1, 3 (historically), 4
Iron	Comparison to Background and Surrounding Wells, Filtered vs. Unfiltered Sample Comparison	1, 4
Magnesium	Comparison to Background and Surrounding Wells	3
Manganese	Comparison to Background and Surrounding Wells, Filtered vs. Unfiltered Sample Comparison	1 (in trace amounts), 4
Nickel	Comparison to Background and Surrounding Wells, Filtered vs. Unfiltered Sample Comparison	1 (in trace amounts), 4
Nitrate plus Nitrite	Comparison to Background and Surrounding Wells	2
Potassium	Comparison to Background and Surrounding Wells, Trend Analysis	2, 3
Sodium	Comparison to Background and Surrounding Wells, Trend Analysis	1, 2, 3
Sulfate	Comparison to Background and Surrounding Wells, Trend Analysis	2, 3

1) Rock forming element
2) Good tracer
3) Discharged to the IWD
4) Possible corrosion indicator

4.2 Analysis of Chromium Data in NRF-13

Because chromium is the only constituent that has exceeded a primary MCL, much of this appendix is directed toward analyzing this constituent or factors that effect this constituent (e.g. sedimentation, and potential for migration). This section discusses chromium data analysis results to provide a foundation for the remainder of the appendix.

Beginning in mid-1999 the concentration of chromium began to increase. The average chromium concentration in NRF-13 prior to January 1999 was 34 ppb. The average concentration after January 1999 was 93 ppb. This represents an increase of 159% in the average chromium concentrations before and after 1999. It should be noted that the only other constituent to show an increase on the same order of magnitude was nickel, with a 115% increase. This period of increasing chromium concentration corresponds to an increase in sample turbidity (representing increase in suspended solids).

Figure 3 is a time versus concentration graph of chromium data from NRF-13 (shown as the dark blue line). Since 1999, the concentration of chromium in NRF-13 has exceeded the National Drinking Water Standard MCL (shown as the dotted red line) four times. These exceedences occurred in February 2000 (310 ppb), November 2000 (190 ppb), December 2004 (180 ppb), and July 2006 (230 ppb).

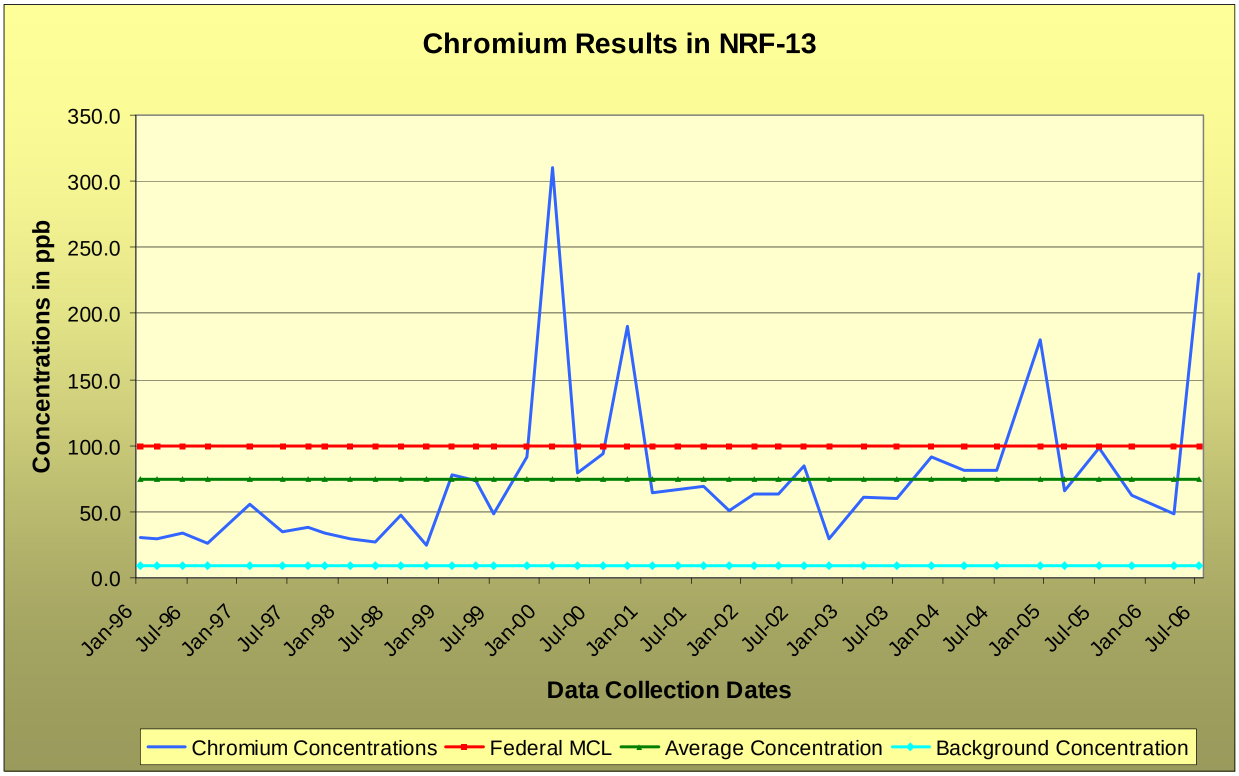

Figure 3 Time versus Concentration Graph for Chromium in NRF-13

Figure 3 also shows the relationship of chromium concentrations in NRF-13 to background (shown as the dotted light blue line) and the average life-time concentration in NRF-13 (shown as the dotted green line). Almost all the observed increase in chromium concentration since 1999 is attributable to suspended material in the samples while dissolved chromium has averaged 15.5 ppb during that time frame as discussed in Section 5.0.

4.3 Comparison of NRF-13 to Background

Groundwater data collected from NRF-13 were compared to background values. The concentrations of many of the 12 primary constituents evaluated have been consistently elevated in NRF-13 in comparison to regional background concentrations, which includes wells USGS-12 (located hydrologically upgradient to NRF-13) and NRF-7 (located cross-gradient to NRF-13).

Attachment 1 provides groundwater data collected from NRF-6, NRF-7, NRF-13, and USGS-12 for the analyzed constituents since early 1996. compares mean groundwater concentrations in NRF-13 to regional background water quality represented by combining USGS-12 and NRF-7 data. NRF-13 data were also individually compared to USGS-12 and NRF-7 data. It was observed that constituent means for the regional background were often strongly influenced by unusually large data points that could be considered anomalous (outliers). Refer to Section 1.1 of Attachment 1 to this appendix for an explanation on the determination of outliers.

In , rows highlighted in green indicate constituent concentrations in NRF-13 which were statistically equal to regional background concentrations. The constituents statistically equal to regional background concentrations include nitrate plus nitrite and sodium. Rows highlighted in yellow indicate constituent concentrations in NRF-13 which were slightly elevated in comparison to regional background concentrations (i.e., calcium and magnesium). This slight elevation was defined as being within 15 percent of one of the regional background wells in conjunction with the visual analysis of the box plots presented in Section 1.3 of Attachment 1. The concentrations of aluminum, chloride, chromium, iron, manganese, nickel, potassium, and sulfate statistically exceeded regional background concentrations. A statistical analysis of mean groundwater concentrations is discussed in Attachment 1.

Table 2 Comparison of Mean Concentrations in NRF 13 to Regional Background

Constituent	NRF 13 (ppb)	Background (ppb)	NRF 7 (ppb)	USGS 12 (ppb)
Aluminum	2,882	100	150	32
Calcium	71,943	45,159	25,912	61,938
Chloride	63,944	17,135	5,065	27,671
Chromium	72	9	12	7
Iron	3,500	319	514	161
Magnesium	21,766	15,005	9,266	19,862
Manganese	58	6	10	3
Nickel	29	5	8	2
NO_2+NO_3	861	1,102	518	1,630
Potassium	4,089	2,482	3,016	2,017
Sodium	12,582	11,456	8,823	13,838
Sulfate	74,190	22,655	14,412	30,113

Green denotes NRF-13 concentrations that are statistically equal to regional background concentrations
Yellow denotes NRF-13 concentrations that are slightly elevated in comparison to regional background concentrations
Gray denotes NRF-13 concentrations that statistically exceed regional background concentrations

4.4 Comparison of NRF-13 to NRF-6

The mean concentrations of the 12 constituents identified above were compared with the corresponding constituents in NRF-6 to determine if data means in NRF-13 were statistically equal to means in NRF-6. If the means are statistically equal for those constituents historically or currently released to the IWD (e.g., calcium, chloride, magnesium, etc.), this would identify possible influence of the IWD on groundwater quality at NRF-13. Based upon this comparison, it was determined that the mean constituent concentrations in NRF-13 are not statistically equal to concentrations in NRF-6. Table 3 shows the results of the comparison of NRF-13 and NRF-6 data.

As mentioned previously, the mean concentration for chromium increased 159% and the average concentration of nickel increased by 115% in NRF-13. It was determined that these same constituent concentrations have decreased in NRF-6 (-38% for chromium and -48% for nickel) since 1999. In addition, the concentration of sulfate has decreased in NRF-6 since 1999, while it remained steady in NRF-13. More detailed discussions of trends in NRF-6 and NRF-13 data are presented in Section 6.1.

Table 3 Comparison of Mean Concentrations in NRF 13 to NRF 6

Constituent	NRF 13 (ppb)	NRF 6 (ppb)
Aluminum	2,882	32
Chromium	72	39
Iron	3,500	749
Manganese	58	7
Nickel	29	15
Calcium	71,943	124,130
Chloride	63,944	264,963
Magnesium	21,766	33,437
NO_2+NO_3	861	1,782
Potassium	4,089	4,860
Sodium	12,582	110,209
Sulfate	74,190	156,146

Green denotes constituents that are elevated in comparison to opposing data

4.5 Comparison of Chloride Concentrations in NRF-13 to USGS-22

A search of data from other groundwater quality wells at the INL has identified another low producing well, much like NRF-13, with elevated chloride levels and no apparent source. Well USGS-22 is located five miles west of the Test Reactor Area, and is not hydrologically connected to any INL discharge source. However, this well has elevated chloride levels (approximately 60,000 ppb), which is on par with NRF-13, and sodium levels near background (approximately 20,000 ppb). It should also be noted that when unfiltered chromium samples were collected for this well, they were elevated, in one instance greater than the MCL at a concentration of 140 ppb.

4.6 Groundwater Monitoring Summary

The preceding results coupled with box plots of groundwater data for NRF-13, NRF-7, USGS-12, and the regional background, found in Attachment 1 support the following conclusions. The concentrations of aluminum, chloride, chromium, iron, manganese, nickel, potassium, and sulfate in NRF-13 exceeded regional background concentrations, while calcium and magnesium concentrations exceeded regional background concentrations to a lesser degree. Sodium and nitrate plus nitrite are statistically the same as background. The concentrations of ionic salts in the effluent monitoring well, NRF-6, statistically exceed the corresponding constituents in NRF-13.

The majority of the constituents which exceed regional background concentrations can be associated with naturally occurring sediments (aluminum, chromium, iron, and manganese) as discussed in Sections 5.1 and 5.2. Some elevated constituents are common salts (e.g., chloride) which have been discharged to the IWD; however, the trend analyses presented in Section 6.1, coupled with hydrogeological factors discussed in Section 6.2, indicate that current transport of these constituents to NRF-13 is unlikely. Chloride data and limited unfiltered chromium data from well USGS-22 (a well not known to be impacted by INL operations) are elevated and are comparable to results from NRF-13.

5.0 Factors that Affect Chromium Concentration in NRF-13

5.1 Filtered Versus Unfiltered Comparisons

Chromium is a naturally occurring groundwater constituent. In uncontaminated systems, under normal aquifer conditions (like those that occur at NRF), chromium occurs in a dissolved state at levels well below drinking water standards. Chromium can also occur in water samples as a part of the suspended solids present in the samples. Suspended solids are most commonly from naturally occurring sediments or corrosion products while dissolved solids are more likely associated with aquifer conditions or potential chemical releases. Filtering samples prior to analysis removes the suspended solids. Analyses of samples after filtering helps to determine the relative quantity of dissolved metals in the groundwater versus those contained in a suspended state.

Aluminum, chromium, iron, manganese, and nickel data are particularly useful when evaluating filtered versus unfiltered data. Aluminum is abundantly present in common rock forming minerals. This constituent was not released to the IWD, nor is it a constituent in well components; therefore, aluminum is primarily an indicator of the presence of sediments in water samples. Chromium, iron, and manganese are indicators for sedimentation and corrosion products, while nickel is primarily a corrosion product indicator. Iron, manganese and nickel were not released in quantity to the IWD.

Collection of filtered versus unfiltered samples at NRF began with a set of split samples in August 1995 from various NRF wells. These samples were collected after conditioning the wells (preparing the well for final use), but before installing the pumps/motors, well screens, riser pipes, and measuring lines. The well was not purged before sampling. Under these conditions, suspended solids were expected to be present in water samples. Split samples were collected using a hand operated bailer from the open borehole. One sample was filtered and the other unfiltered. Table 4 summarizes the chromium analysis results for selected wells. The results in this table demonstrate that sediments can cause a significant elevation in chromium levels in wells at NRF and that filtering the samples (which removes sediments from the samples) can significantly reduce the reported concentration of chromium. In these wells, chromium (mostly from sediments) was present before any potential corrosion of well components could occur.

Table 4 Filtered/Unfiltered Samples from NRF Wells Collected August 1995 in ppb

Well	Analyte	Bailed Unfiltered	Bailed Filtered	Difference
NRF 8	Chromium	1,870	<7	(>1,863)
NRF 9	Chromium	32	<7	(>25)
NRF 10	Chromium	71	<7	(>64)
NRF 11	Chromium	1,020	12	(1,008)
NRF 12	Chromium	877	19	(858)

On May 8, 2001, additional samples were collected from NRF-13 in conjunction with the regularly scheduled sampling event. Filtered/unfiltered samples were collected sequentially (one right after the other) and analyzed for total metals for the selected constituents. Results of the filtered versus unfiltered samples are summarized in Table 5. The concentrations of chromium, iron, and aluminum were significantly reduced. An additional unfiltered sample was collected after purging and was analyzed for hexavalent chromium. The hexavalent form of chromium is more mobile in nature and possesses the higher carcinogenic risk factor. Hexavalent chromium was detected below the reporting limit at an estimated 5 ppb.

Table 5 Filtered/Unfiltered Samples From NRF 13 Collected May 8, 2001 in ppb			
Constituent	Total (Unfiltered)	Dissolved (Filtered)	Difference
Chromium	67	15	(52)
Iron	2,000	20	(1980)
Aluminum	2,100	<100	(>2000)

On March 31, 2004, filtered and unfiltered samples were collected sequentially and are shown in Table 6. Analytical results were nearly identical with results shown in Table 5 in that the concentrations of aluminum, chromium, and iron were all significantly reduced. In addition to the constituents in the previous table, these samples were analyzed for manganese and nickel. These constituents also showed a reduction in filtered/unfiltered results.

Table 6 Filtered/Unfiltered Samples From NRF 13 Collected March 31, 2004 in ppb			
Constituent	Total (Unfiltered)	Dissolved (Filtered)	Difference
Chromium	64	10	(54)
Iron	2590	234	(2356)
Aluminum	1670	<9	(>1661)
Manganese	54	8	(46)
Nickel	39	20	(19)

In March 2006, NRF began collecting sequential filtered and unfiltered samples on a regular basis. Table 7 shows the results from samples collected during the first trimester 2006. Results in this table again showed a significant drop in concentrations of aluminum, chromium, iron, manganese, and nickel after filtering.

Table 7 Filtered/Unfiltered Samples From NRF 13 Collected March 6, 2006 in ppb			
Constituent	Total (Unfiltered)	Dissolved (Filtered)	Difference
Chromium	49	17	(32)
Iron	860	<21	(>839)
Aluminum	680	<17	(>663)
Manganese	15	1.8	(13.2)
Nickel	14	7.5	(6.5)

Table 8 is a comparison of filtered versus unfiltered data collected in July 2006. Once again, metal concentrations dropped significantly with filtering. Of particular note, the concentration of chromium was 230 ppb before filtering, which is almost 2.5 times its MCL of 100 ppb. Filtering reduced the chromium concentration to 20 ppb indicating that it is likely that past high chromium results above the MCL would have been similarly reduced through filtering.

Table 8 Filtered/Unfiltered Samples From NRF 13 Collected July 20, 2006 in ppb			
Constituent	Total (Unfiltered)	Dissolved (Filtered)	Difference
Chromium	230	20	(210)
Iron	5,600	<18	(>5,582)
Aluminum	3,400	<22	(>3,378)
Manganese	79	3.2	(75.8)
Nickel	69	24	(45)

Analyses of the filtered versus unfiltered data show that the concentrations of aluminum and iron have been consistently and significantly reduced in concentration by filtering. This has been true since near the time of construction of the well. Since May 2001, filtering has dramatically reduced the concentration of chromium to an average of 15.5 ppb. In 2004 and 2006, the concentrations of manganese and nickel were reduced by similar magnitudes. The preceding analysis indicates that a high percentage of the metal concentrations contained in water samples collected from NRF-13 are due to suspended solids in the well. The consistent reduction in aluminum concentrations indicates sediment as the primary source of elevated constituents in NRF-13. The reduction of chromium, iron, manganese, and nickel concentration support sediments as the possible source, but corrosion products may be a secondary source of the elevated metals as discussed in Section 5.2.

5.2 Comparison of Selected Metals to Turbidity Data

Turbidity in groundwater is an indication of the amount of suspended solids that are present. This measurement does not indicate the type or source of the suspended solids; however, past experience suggests two probable sources, sediments (from interbeds intersecting the well) and corrosion products (from the well pump and motor components). Other possibilities include a biological agent (algal or bacterial) or chemical precipitate.

Suspended solids, whether from sediments or corrosion products, will likely contain metal constituents. When analyzed, samples containing these solids can produce results with elevated metal concentrations. Because chromium is naturally occurring in sediments (see Section 5.4) and can be a corrosion product from well components, samples with suspended solids would likely show elevated chromium. Comparing chromium concentrations and other naturally occurring metals concentrations to turbidity and total dissolved solids (TDS), which is a measure of dissolved fraction of the constituents, allows conclusions to be drawn on the amount of suspended solids in the samples.

NRF has been collecting turbidity data from the groundwater monitoring wells for approximately 10 years. This section analyzes turbidity data from NRF-13. The turbidity data from NRF-6 and NRF-7 are also examined. Both NRF-6 and NRF-7 have had episodes when anomalous data were seen in the analysis of samples. Refurbishment of the wells and subsequent collection of data provided insight into the causes of the anomalous data (i.e., both being linked to high turbidity). Comparing what was learned from these two wells provides further insight into the possible mechanisms causing elevated metal concentrations in NRF-13.

The magnitude and distribution of turbidity values in NRF-13 is unique among all NRF wells. The average turbidity in NRF-13 is 69 Nephelolometric Turbidity Units (NTU)s. The average turbidity in NRF-6 and NRF-7 are 5 NTU and 23 NTU, respectively. Figure 4 is a comparison of chromium data in NRF-13 to turbidity. Figure 4 shows a significant positive correlation between chromium concentration and turbidity indicating that suspended solids in the well are a substantial source of chromium detected in water samples.

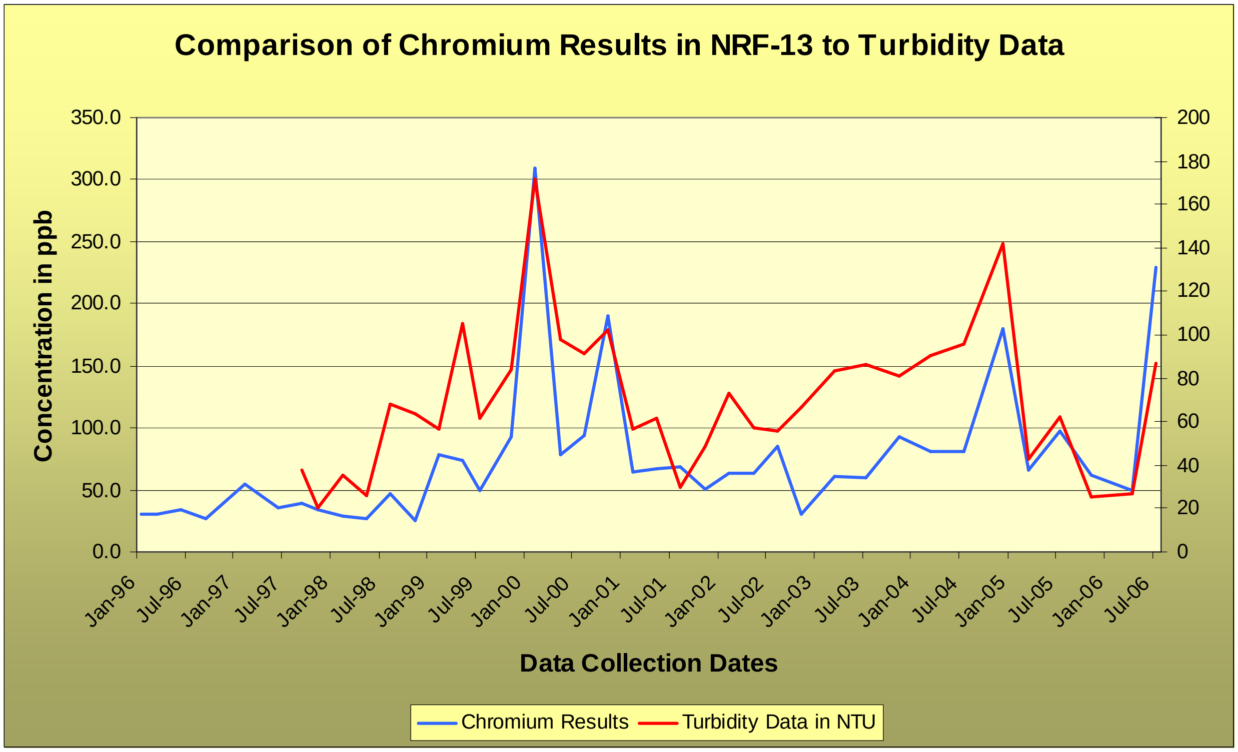

Figure 4 Comparison of Chromium Concentration to Turbidity in NRF-13

Figure 5 compares normalized aluminum, chromium, iron, manganese, and nickel concentrations (all naturally occurring metal constituents) to turbidity. Normalization is performed by dividing all groundwater concentrations in a particular data set by the highest concentration occurring in that set and then multiplying by 100. The result is a number between 0 and 100 for all data regardless of the data's original magnitude. This method preserves trends in the data with the added benefit of grouping graphs of similar characteristics (i.e., salts) that may have different concentration magnitudes. It should be noted that highly variable data tend to plot low on the chart while more consistent data tends to plot high on the chart. This method allows data that varies by several orders of magnitude to be plotted on the same graph (e.g., chloride and calcium data from NRF-6 shown in Figure 9). Again, this comparison shows a strong correlation between elevated metal concentrations and high turbidity results. For each peak in metals concentrations, there is a corresponding peak in turbidity.

Figure 6 compares these same constituents with TDS concentrations on a logarithmic scale. The TDS graph demonstrates the consistency of the dissolved fraction of aquifer constituents even though the suspended fraction varied significantly. If the chromium in NRF-13 were associated with the IWD, it would be in a dissolved form since leaching chromium from the sediments of the IWD would be the only plausible way for chromium to move from one location to the other.

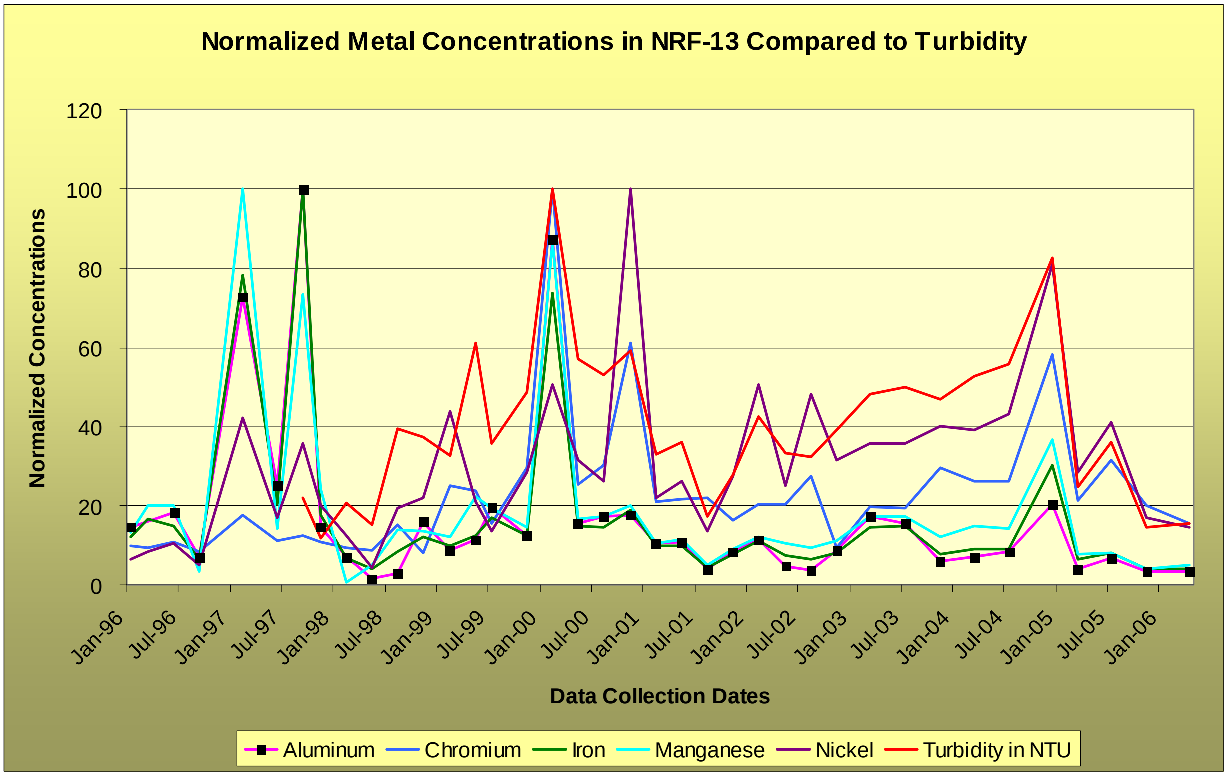

Figure 5 Comparison of Metal Concentrations to Turbidity in NRF-13

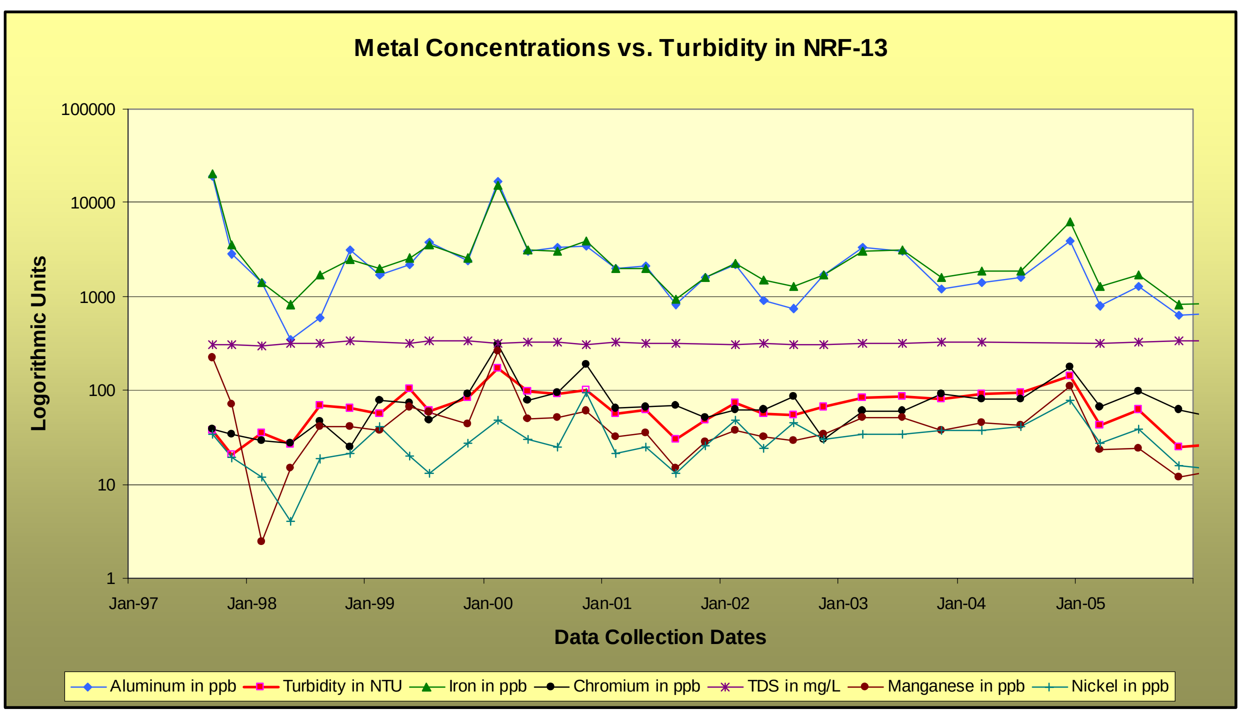

Figure 6 Comparison of Metal Concentrations to Turbidity in NRF-13 (Logarithmic Scale)

Figure 7 shows the same constituent data from NRF-6 plotted on a logarithmic scale. The significance of this figure is as follows: First, it demonstrates positive correlation between most of the metal concentrations prior to late 2003 and turbidity, although the correlations are not as pronounced as they are in NRF-13. Secondly, the anomalous event that occurred in November 2003 is very pronounced. The meaning of this spike is probably tied into observations made by USGS personnel while collecting third trimester groundwater samples. They noted in their logbook that the pump/motor repeatedly cut out while purging and that the purge water was dark red for almost one minute after turning the pump on. This indicates that the spike in data is probably related to sedimentation. Failure of the pump motor in NRF-6 was most likely caused by sediment in the well settling around the motor causing it to overheat and fail. The presence of sediments so close to the pump intake would undoubtedly increase the likelihood of pulling sediment into the water samples. After the well pump and motor were subsequently replaced and raised by five feet, average sample turbidity and the concentrations of iron, manganese, and nickel fell significantly indicating that corrosion was probably an issue in this well prior to November 2003. This conclusion is supported by visual evidence of corrosion of the pump motor casing, riser pipe, and measuring line. Note that the TDS graph was unaffected by the events of November 2003 once again confirming that most of the variations observed in the wells are due to suspended solids (sedimentation or corrosion products).

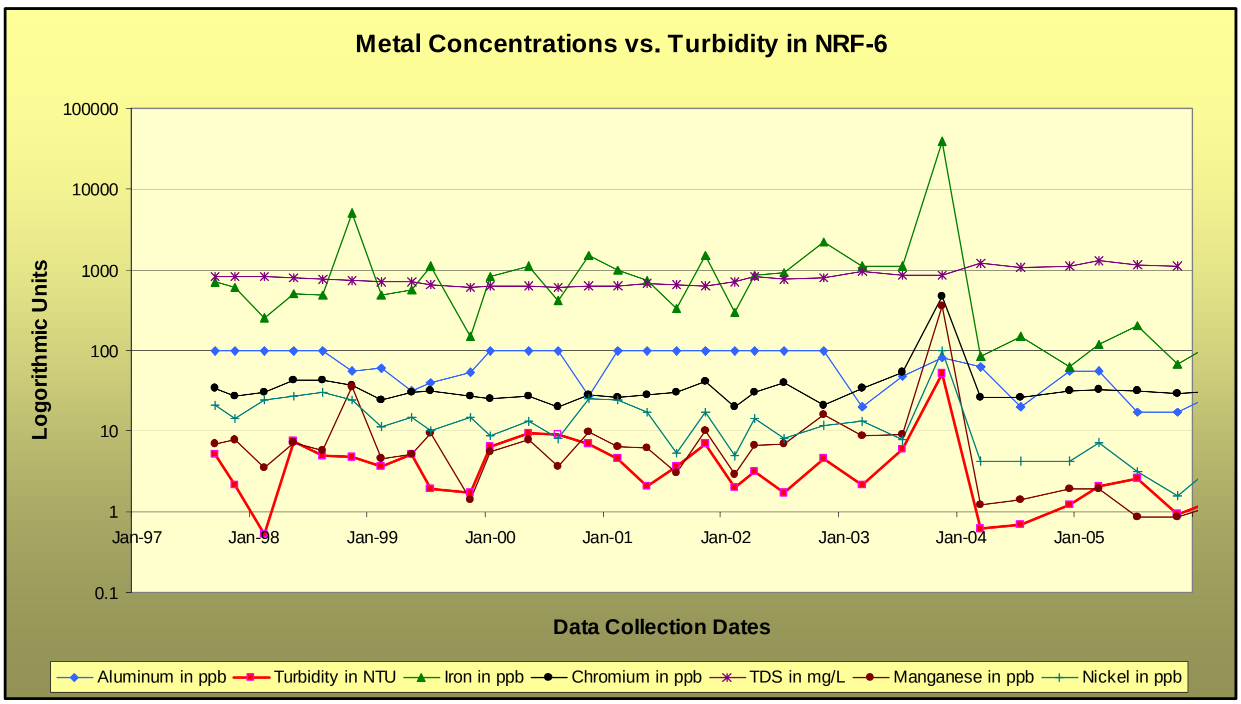

Figure 7 Comparison of Various Metal Concentrations to Turbidity in NRF-6

Figure 8 shows the same constituent data from NRF-7 plotted on a logarithmic scale. This figure shows excellent correlation between turbidity and aluminum, iron, and manganese. This figure also defines an anomalous period for the well which occurred between November 2002 and March 2004. During this period many of the metal constituents in this well including aluminum, chromium, iron, manganese, and nickel were significantly elevated compared to historical analytical results. Although NRF eventually pulled and replaced the pump and motor from this well, analytical results had already returned to near historical levels prior to this work being performed. Inspection of the well's screen and internal components failed to reveal any signs of corrosion or significant chemical precipitation. The apparent cause for the elevated metals in this well was entrainment of sediments into water samples as evidenced by Figure 8 which shows that the elevated constituents were accompanied by a rise in turbidity. Analytical and field results from NRF-7 are summarized in Table 9. The average turbidity in NRF-7, excluding data from the anomalous period (November 2002 to March 2004) was 9 NTU, while during that period the average was 104 NTU.

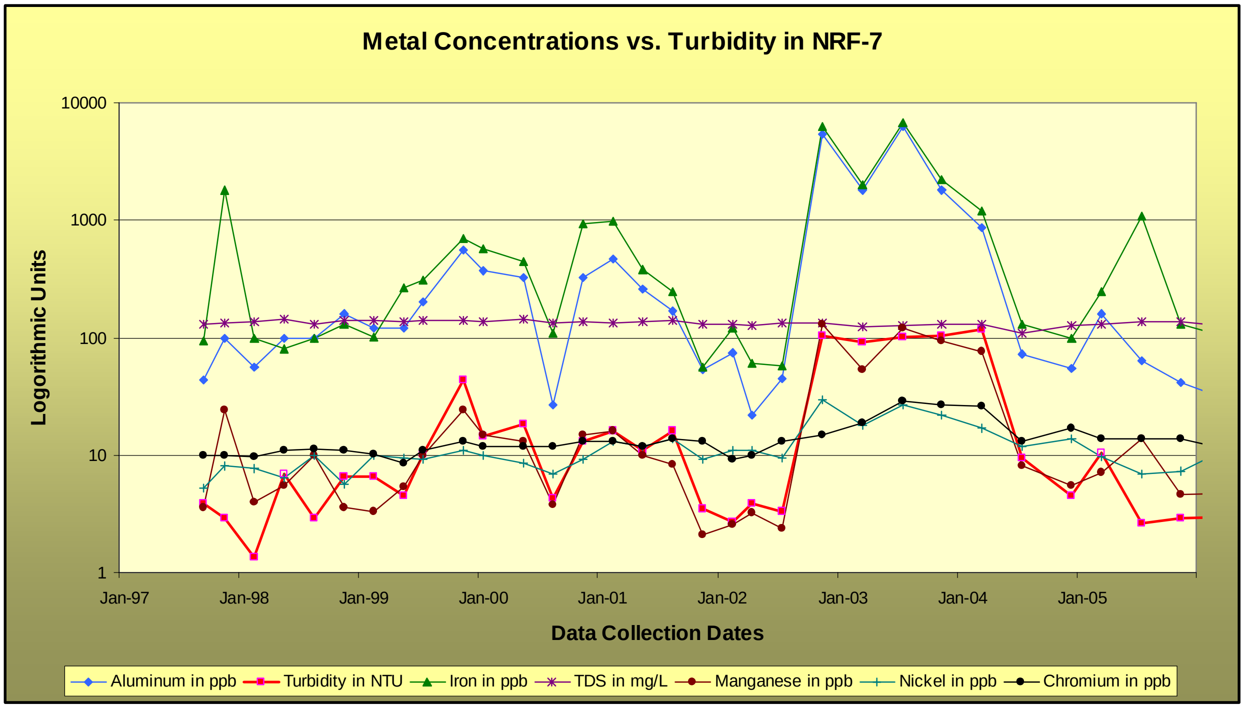

Figure 8 Comparison of Various Metal Concentrations to Turbidity in NRF-7

Table 9 Comparison of Turbidity and Metal Results from NRF 7*

	Turbidity (NTU)	Aluminum (ppb)	Chromium (ppb)	Iron (ppb)	Manganese (ppb)	Nickel (ppb)
Before 11/2002	9.4	177	11	365	8.8	9.4
After 3/2004	5.5	70	14	302	7.3	10.3
11/2002 3/2004	104	3234	23	3700	95	22

The average concentrations of aluminum, chromium, iron, manganese, and nickel before and after the anomalous period were essentially the same. Again, the exact cause for the elevated constituents in NRF-7 is not known; however, these data strongly suggest that it is related to suspended sediments. This conclusion is supported by filtered versus unfiltered data collected in 2004 from NRF-7, which are summarized in Table 10. These data show that filtering significantly lowered the concentration of all metal constituents indicating a high level of suspended solids.

Table 10 Filtered/Unfiltered Samples From NRF 7 Collected March 31, 2004 in ppb			
Constituent	**Total (Unfiltered)**	**Dissolved (Filtered)**	**Difference**
Chromium	23	12	(11)
Iron	3,280	<15	(>3,265)
Aluminum	3,490	<15	(>3,475)
Manganese	84	5	(79)
Nickel	22	6	(19)

In conclusion, it seems very likely that the elevated metal results that occurred in NRF-7 were related to elevated suspended sediments in the well. The source of the suspended sediments is not known, but may have been caused by changes in regional water flow due to changing water table elevations. Conversely, in NRF-6, corrosion products seem to have significantly contributed to the elevated results considering the elevated levels of iron, manganese, and nickel in the well, although sedimentation cannot be eliminated as at least a partial cause. The patterns observed in NRF-13 are consistent with those seen in NRF-7, which indicates that sedimentation may be a major contributor to the elevated metals in the well. However, based on other evidence presented in the appendix, corrosion may also be a contributing factor.

5.3 Discussion of Low Flow in NRF-13

Both NRF-7 and NRF-13 are low producing wells, and sustain pumping rates of approximately three gallons per minute or less. Pump tests conducted on each well prior to well completion show that the aquifer possesses low hydraulic conductivities. When these wells are purged, (pumped to ensure fresh water is being sampled), the water level in the wells drops significantly (20 feet or more). A localized steep flow gradient can occur at the boundary between the vacated well and the wetted portion of the aquifer. The steep flow gradients can cause higher localized water flow velocities and perhaps create turbulence, which could enhance the entrainment of sediments into water samples thus raising turbidity and producing the result observed in the wells.

5.4 Bedrock and Sediment Chemistry

The preceding sections have shown that elevated suspended solids (most likely natural sediments) in the various wells are closely related to the occurrence of elevated concentrations of metals in the wells. This section examines various data from NRF-13 and other sources with the intent to characterize the chemical contents of aquifer material (sediments and basalt). The purpose of this examination is to show that sediments and basalt material near NRF-13 contain sufficient concentrations of chromium to account for the elevated chromium results obtained from NRF-13. In addition, naturally occurring aluminum, iron, manganese, and nickel in the sediment and basalt, can account for the elevated results of these constituents in NRF-13.

A stratigraphic log constructed from notes taken during the drilling of NRF-13 shows that this borehole penetrated, from the surface down, approximately 5 feet of loess, 20 feet of sand and gravel, and 395 feet of basalt and interbeds. The information contained in Table 11 describes the interbeds encountered, which are common at the INL and NRF. For reference, the results from analysis of cuttings at the given depth are also presented. Table 11 also represents a general stratigraphy at the INL and NRF. This table shows that the interbeds encountered while drilling contained an average of 21,500 ppb chromium. Also, the interbed located near the top of the well screen contains 33,000 ppb chromium. These concentrations are within the expected background concentrations for chromium at the INL and do not reflect elevated levels that would be associated with an outside source such as the IWD. The background concentration for chromium in surficial soils at the INL is 50,000 ppb (INEL, 1996).

Table 11 Interbeds Encountered Beneath NRF 13			
Depth Interval in feet bls	Description	Sample Depth in feet	Chromium Concentration in ppb
42 to 43	Small Gravel	35	23,600
57 to 61	Yellowish brown sand with some silt and gravel		
80 to 82	Yellowish brown sand with some silt and gravel		
87 to 90	Light brown silt and sand with some gravel	89	22,700
145 to 149	Grayish red, fine to med sand		
156 to 159	Grayish red, fine to med sand/w some silt and gravel		
220 to 224	Dark yellowish brown mottled clay	209	12,700
224 to 226	Brownish gray fine to med sand/w some silt and gravel		
270 to 271	Brownish gray silt and fine sand/w small gravel		
296 to 297	Pale red, very fine to fine sand/w trace gravel	300	15,700
343 to 344	Pale red sand/ small gravel		
375 to 376	Dark yellowish brown sand/w small gravel	370	33,000
376 to 400	Clay balls in cyclone		
	Average Interbed Concentration		21,540

In 1991, a 500 foot deep core hole was drilled next to the current location of well NRF-6 (located approximately 1000 feet south of NRF-13). The basalt comprising the Snake River Plain Aquifer near NRF was analyzed for chromium. Analytical results show that the basalt contained an average of 49,000 ppb chromium between 350 and 400 feet below land surface. Given the mineralogic composition of the basalt, it would be expected that it would contain comparable amounts of manganese, and much greater quantities of aluminum and iron (WEC, 1992). The basalt near NRF-13 would be expected to have similar characteristics.

In summary, NRF-13 water samples contain elevated levels of aluminum, chromium, iron, manganese, and nickel (see Section 4.3). Analysis of interbed and basalt cuttings indicates they contain concentrations of chromium many thousands of times higher than those found in groundwater samples. In addition, the sediment interbed near the top of the well screen was determined to contain approximately 33,000 ppb chromium. Aluminum and iron can be present in significant quantities in both basalt and sediment. Manganese and nickel can also be present in smaller quantities. To the extent that groundwater samples contain suspended sediments, analytical results with elevated chromium (and other metals) would be expected.

5.5 Summary and Conclusions for Chromium in NRF-13

The preceding sections show that filtering water samples from NRF-13 before analysis sharply reduces the concentrations of most metals. The high concentrations of metal are very often associated with high suspended solids. Sediments from near NRF-13 contain naturally high chromium concentrations. The basalt near NRF-13 contains high concentrations of chromium and nickel and probably, aluminum, iron, and manganese. Water samples from NRF-13 containing sediments are expected to be elevated in metals. NRF-7 is another example of a well where metals were elevated due to suspended sediments. A secondary cause of elevated constituents in NRF-13 may be corrosion products. NRF-6 is an example of a well where metals were likely elevated due to a combination of suspended sediments and corrosion.

The overall conclusion of this section is that the elevated metals present in NRF-13 are a result of suspended sediments; however, corrosion may be a secondary factor.

6.0 Factors that Affect Migration of Contaminants from the IWD

The purpose of this section is to provide the information available to show that NRF-13 is unlikely to be influenced by effluent discharged to the IWD. The following sections discuss hydrogeological factors which reduce the likelihood that contaminants migrated from the IWD to NRF-13. Evidence to support this claim is provided by trend analysis and hydrogeological investigations discussed below.

Constituents found in elevated quantities in NRF-6 are compared in Section 6.1 to the same constituents in NRF-13. NRF-6 is known to be influenced by the IWD, and if a connection exists between the IWD and NRF-13, then trends in NRF-13 should be similar to trends in NRF-6. The results of the comparison show that data from NRF-6 does not correlate well with data from NRF-13.

Hydrogeological factors affecting contaminant migration were examined in Section 6.2. These include sedimentary interbeds that may affect infiltration, the sources and current and past locations of perched water, interactions between perched water and interbeds, and potential transport of contaminants in groundwater. Finally, miscellaneous factors are discussed including a summary of work performed as part of the 1994 IWD RI/FS that suggested that most chromium would remain bound in IWD sediments.

6.1 Trend Analysis

The primary purpose of the trend analysis discussed below was to look for evidence that may indicate if water quality in NRF-13 is influenced by the IWD. This was accomplished by comparing graphs of NRF-13 data to graphs from NRF-6 and NRF-7.

At their nearest point, NRF-6 and NRF-13 are located approximately 300 and 800 feet, respectively, from the IWD (refer to Figure 1). The water quality in NRF-6 is known to be influenced by the IWD based on studies performed as part of the 1994 Remedial Investigation of the IWD. Because discharges to the IWD influence water quality in NRF-6 (as evidenced by the graphs), it follows then that similar changes in water quality should be evident in graphs of NRF-13 data, if it is also hydraulically connected to the IWD.

It is also known that the water in NRF-7 (which is located downgradient of the IWD, and is closer to the IWD than is NRF-13 at approximately 540 feet) is not influenced by the IWD and that the water quality in NRF-7 more closely represents upgradient quality water. This was established in the 2001 Five-Year Review and was the basis for including data from NRF-7 in the Regional Upgradient Well Group. Past studies have shown that the aquifer properties associated with NRF-7 and NRF-13 are similar in that both are low producing wells reflecting low aquifer permeability. Comparing graphs of NRF-7 and NRF-13 data aids in the recognition of influences by the IWD by highlighting similar or dissimilar characteristics in each graph (i.e., both showing the same trends or different trends). If NRF-13 is not impacted by the IWD, then it would be expected that its trends would more closely reflect trends in NRF-7 than trends in NRF-6.

Trends in USGS-12 were also examined and compared to the other wells to establish a baseline since USGS-12 is unaffected by the IWD. Examining how natural changes in USGS-12 are manifested in the downgradient wells will aid in recognizing if trends in these wells are related to the IWD or regional influences.

The best indicators for assessing trends in the various wells are ionic constituents (particularly calcium, chloride, potassium, sodium, and sulfate). These constituents exist naturally in the aquifer at various concentrations related to source areas of the water and aquifer characteristics. In addition, the IWD effluent is high in ionic constituents as a result of NRF operations. Any changes in the IWD effluent (i.e., volume and ionic salt concentrations) would also be expected to be present in wells influenced by the IWD. Because of their ionic nature, these constituents flow with the water and do not readily “stick” to the rocks and sediments; therefore, these constituents are good tracers. It should be noted that it is the change in concentration of these constituents over time that is being compared, not necessarily their magnitude.

Figure 9 is a graph of all salt data from NRF-6. This graph is particularly important in understanding the relationship between the IWD and NRF-6. Several important observations can be made:

1) The graph of each constituent (except sulfate) is distinctive in that each tends to rise, fall, and then rise to a new high;
2) Sodium and chloride graphs track each other nearly perfectly, and for most of the past 10 years are distinctively separated from the other constituents on the graph;
3) The calcium and potassium graphs also show excellent correlation;
4) The graphs for calcium, chloride, potassium, and sodium converge in 2004 and begin a close correlation relationship; and,
5) The graph for sulfate is unique and does not correlate with any of the other constituents.

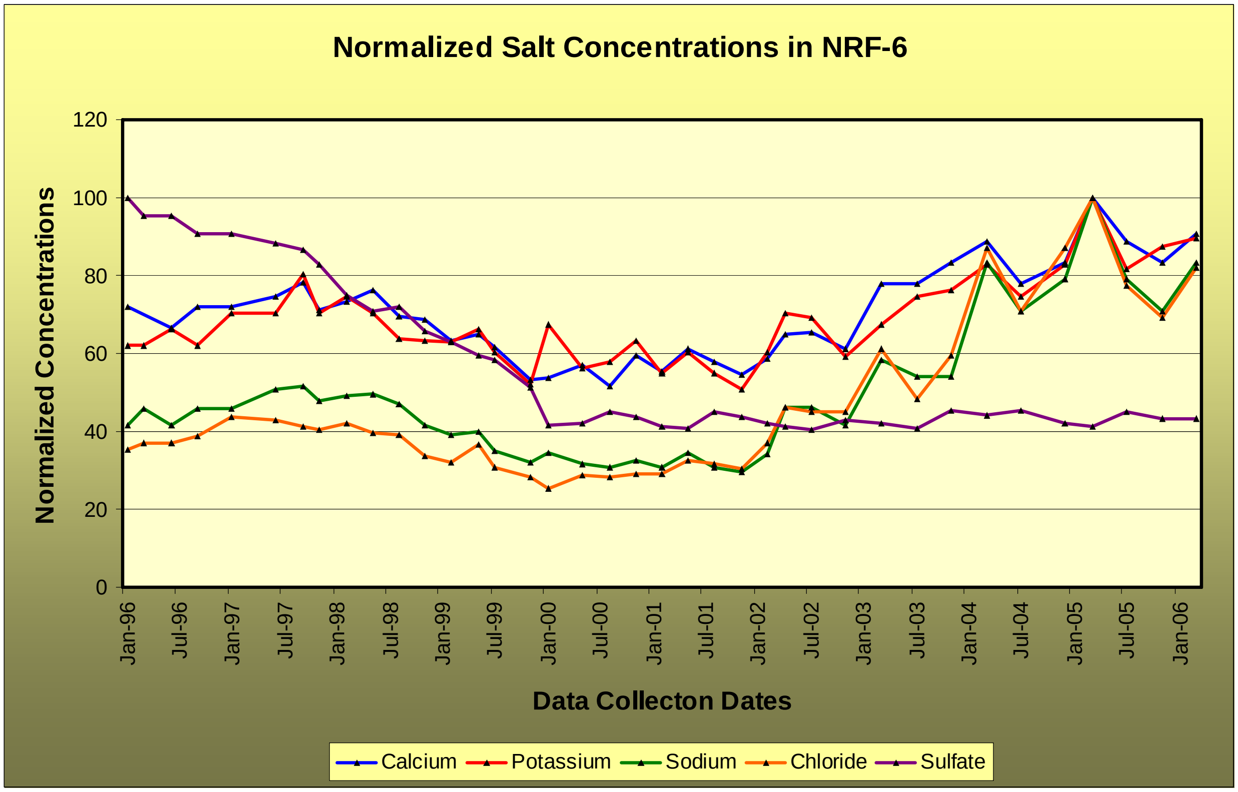

Figure 9 Time vs Concentration Plot for Various Salts in NRF-6

The shape of graphs presented in Figure 9 can be explained by the declining discharge volumes to the IWD. In 1996, discharges to the IWD were approximately 63 million gallons. By 2005, discharges declined to less than 10 million gallons (an 84% decrease). While total discharge to the IWD was declining, the amount of softened water produced by NRF declined as well, but at a slower rate (a decrease of 38% between 1998 and 2005). This resulted in higher water softening constituent concentrations in the IWD effluent. The by-products of producing softened water discharged to the IWD are calcium, chloride, magnesium, and sodium. The net result of softening operations coupled with decreasing effluent discharge to the IWD is that the IWD effluent has been increasing in concentration for these constituents. In addition, increased use of ice melt over the past five years (which contains mostly sodium chloride, but also chlorides of calcium and potassium) during the winter has also contributed to increasing the concentration of the salts in IWD effluent. As a result, the concentration of salts (excluding sulfate) in the groundwater at NRF-6 has also increased.

The shape of the sulfate graph reflects a change in the way NRF produced its deionized water. Prior to 1995, NRF used a process that utilized sodium hydroxide (NaOH) and sulfuric acid (H_2SO_4) to regenerate ion-exchange columns. The sulfate detected in the IWD would be from the SO_4 associated with the sulfuric acid. After 1995, NRF began using a reverse osmosis system, which no longer utilized sulfuric acid. The slope in the graph between the end of 1995 and 2000 reflects the gradual reduction in sulfuric acid used at NRF and the delay between discharge to the IWD and detection in NRF-6. This delay may be the result of residual sulfate in the perched water zone near NRF-6 continuing to be discharged to the aquifer in decreasing amounts.

Figure 10 and Figure 11 are time versus concentration plots for wells NRF-7 and NRF-13, respectively. These graphs demonstrate that:

1) These two sets of graphs are much more similar to each other than they are to the corresponding graphs from NRF-6 (Figure 9);
2) The graphs of NRF-7 data show no discernable long-term trends for any of the constituents;
3) The graphs of NRF-13 data also show no significant trends.

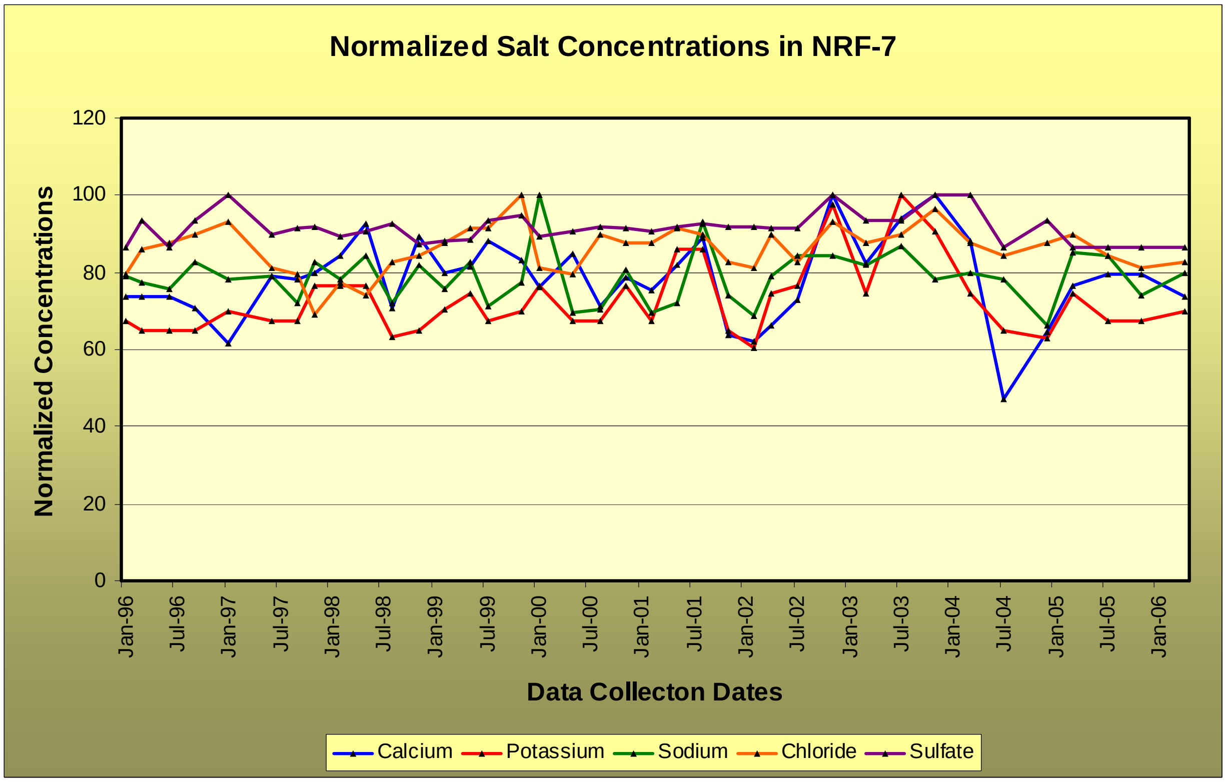

Figure 10 Time vs Concentration Plots for Various Salts in NRF-7

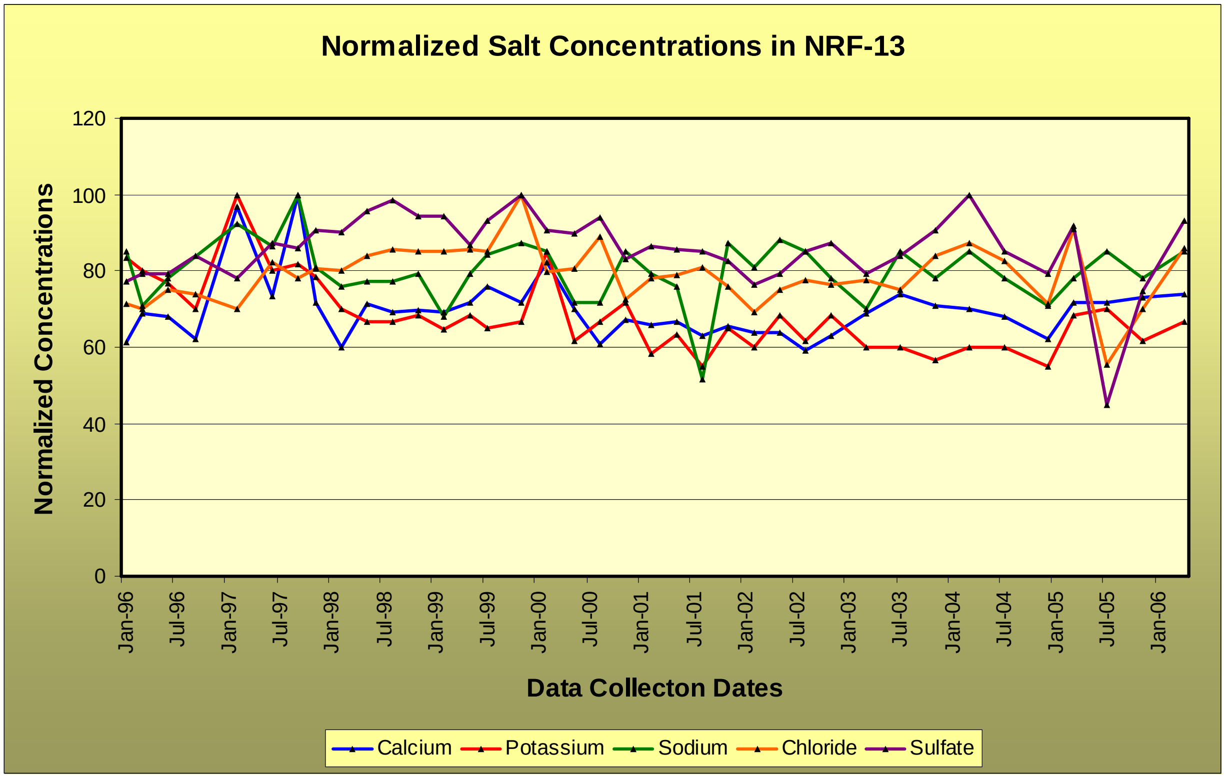

Figure 11 Time vs Concentration Plots for Various Salts in NRF-13

A comparison of Figure 9, Figure 10 and Figure 11 shows that the trends observed in NRF-7 or NRF-13 do not appear to correlate with trends observed in NRF-6. Figure 12, Figure 13, and Figure 14 provide this comparison for the individual graphs for sodium, sulfate, and chloride at wells NRF-6, NRF-7 and NRF-13. Data from USGS-12 were added to Figure 14 to show that regional trends for chlorides are not evident in wells NRF-7 and NRF-13 illustrating their possible hydraulic isolation from the surrounding aquifer. These graphs emphasize the lack of correlation between wells for the selected constituents.

In conclusion, the preceding trends observed at NRF-6 (which is known to be impacted by the effluent to the IWD) do not correspond to trends in NRF-7 or NRF-13. The trends present in NRF-6 data reflect the history of the contaminants released to the IWD and regional effects (e.g., changes in water table elevations referred to in Section 6.2.3). There are no obvious or distinctive trends in NRF-7 and NRF-13, which, if impacted by the IWD, would be expected to show trends similar to NRF-6 (although possibly on a smaller scale). This trend analysis indicates that the IWD does not appear to influence water quality in either NRF-7 or NRF-13.

It should also be noted that at the current time, water in the IWD extends approximately 150 yards from the IWD outfall. Eleven years ago, when NRF-13 was constructed, water was present in the IWD perhaps as far as 1.8 miles from the outfall. Yet, even with extensive inundation of the IWD channel, no trending evidence of an influence was present. As the wetted portion of the IWD channel receded, the possibility of transporting water from the IWD to either NRF-7 or NRF-13 also diminished.

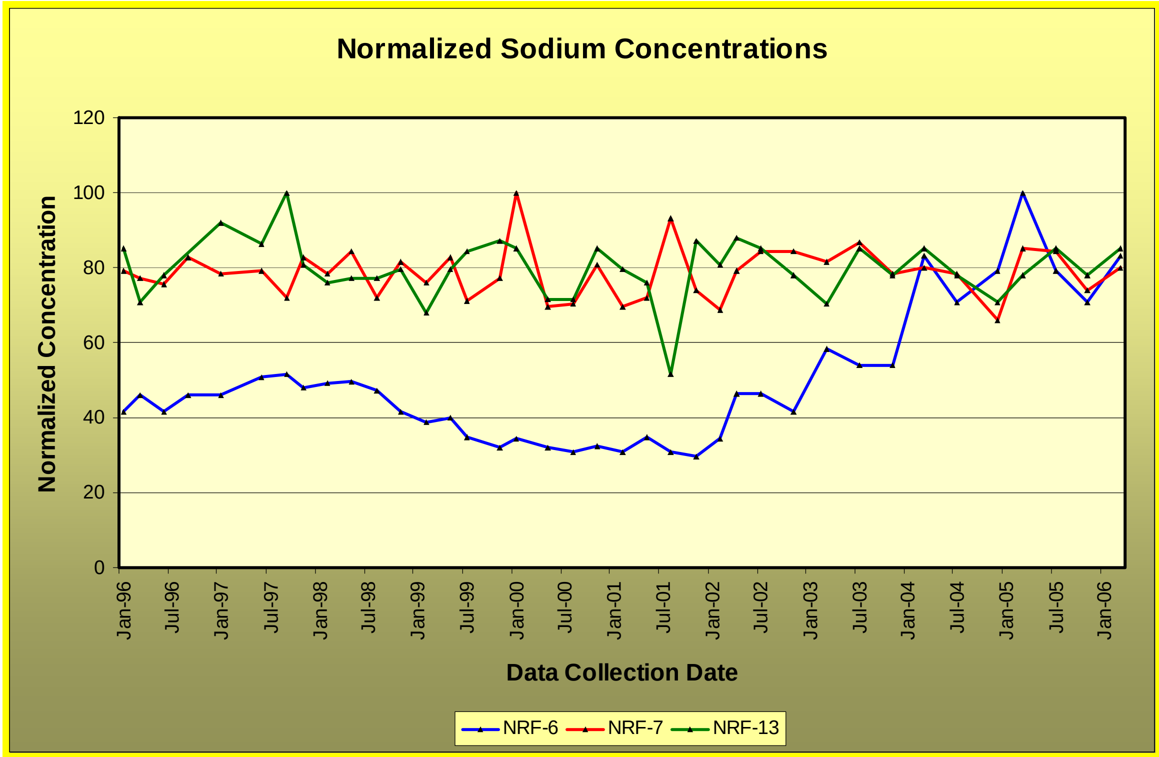

Figure 12 Time vs Concentration Plots for Sodium in NRF-6, NRF-7, and NRF-13

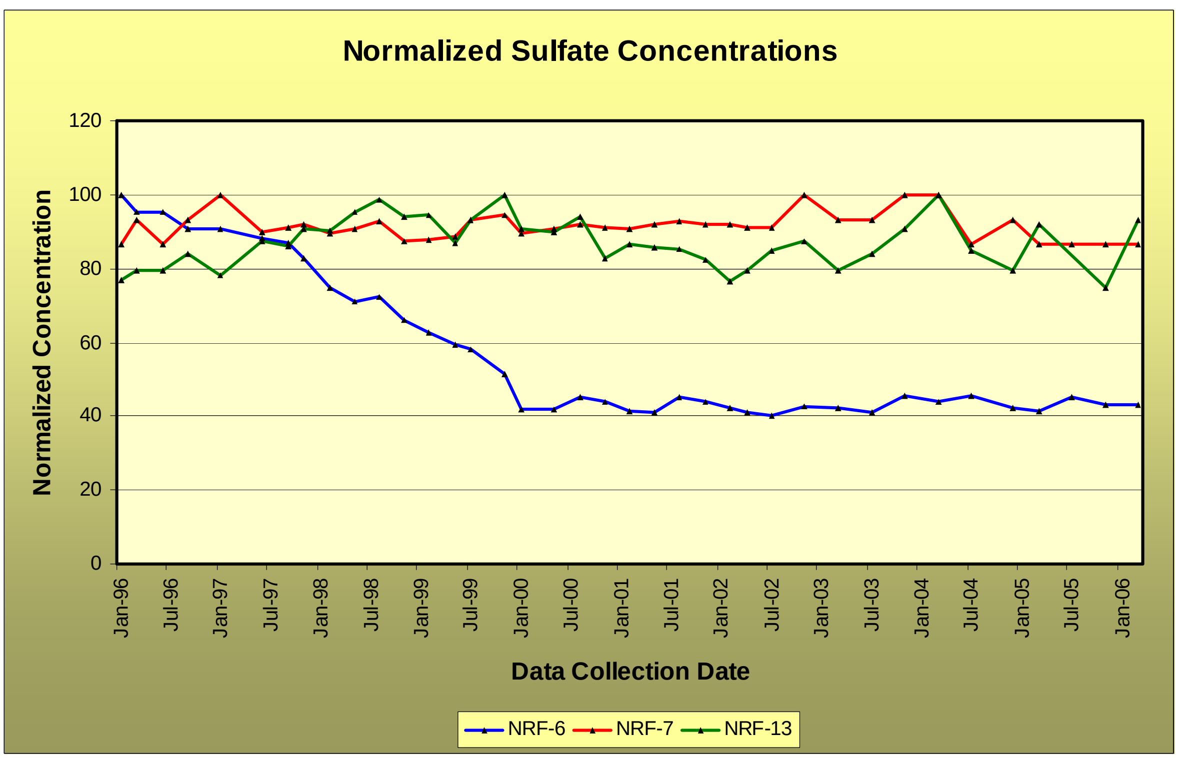

Figure 13 Time vs Concentration Plots for Sulfate in NRF-6, NRF-7, and NRF-13

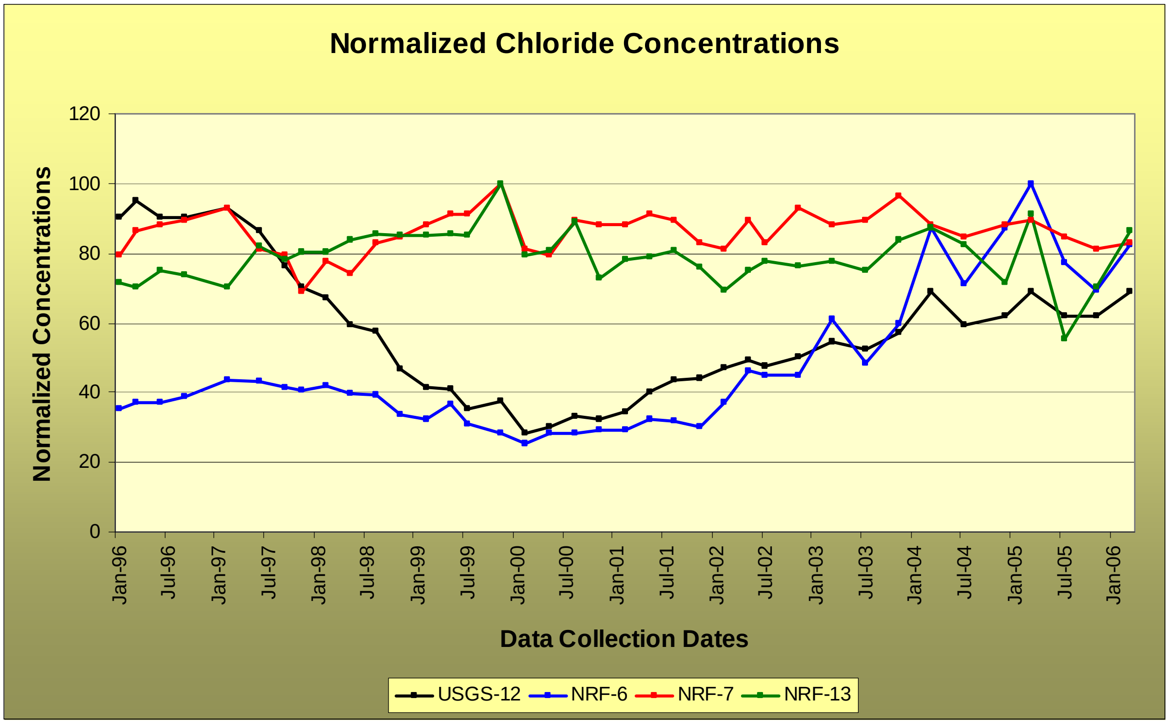

Figure 14 Time vs Concentration Plots for Chloride in USGS-12, NRF-6, NRF-7, and NRF-13

6.2 Hydrogeological Factors Affecting Contaminant Migration

The following sections will examine hydrogeological factors that can influence whether or not contaminants in the IWD can migrate from the IWD to NRF-13. In order for IWD water (which carries the potential contaminants from the IWD) to influence water quality in well NRF-13, one or several mechanisms must be present to physically move water from one location to the other. This section looks at possible transport mechanisms and assesses whether the hydrological conditions at NRF near the IWD are conducive to subsurface contaminant transport.

The primary water transport mechanism is flow along sedimentary interbeds that impede downward migration of water. Water can flow along these surfaces for hundreds of feet. When conditions permit, large perched water zones can form on top of these interbeds. Water then flows downgradient from these perched water zones along the interbed. A secondary transport mechanism is through fractures in the basalt (often facilitating vertical flow) and along impermeable basalt surfaces. Another potential secondary transport mechanism is aquifer mounding due to recharge from the IWD, which can potentially result in a local reversal in flow direction.

This section of the report first discusses known locations of perched water. Next, how these perched water zones interact with the known perching surfaces (sedimentary interbeds) are discussed. The top of the aquifer and the potential mounding of water are discussed next. Finally, geochemistry of the IWD sediments is addressed. In each case, the assessment indicates that migration of potential contaminants from the IWD to NRF-13 is unlikely.

6.2.1 Perched Water

Since 1988, NRF has performed many hydrogeological investigations that include the area around the IWD. One of the main purposes of these investigations was to find perched water zones and evaluate their size and extent. These investigations included drilling in excess of 100 boreholes to various depths on either side of the IWD and near NRF-13. Although perched water was found in some boreholes, by far most of the boreholes were dry.

This section summarizes the efforts to find perched water at NRF and discusses the locations of known perched water. Perched water zones are often the first stage to the downward migration of water. Where, and at what depth, water is impeded will often dictate potential flow paths to the aquifer as controlled by hydrogeologic conditions. Therefore, if the locations of perched water are known, the likelihood of this water migrating to NRF-13 can be assessed.

Determining the locations of all the perched water associated with the IWD is difficult; however, it is believed that the larger zones have been found. If any additional perched water zones are present, they are expected to behave similarly to known perched water zones, since the same hydrogeological processes would influence all the perched water zones.

Since the early 1960's, a number of boreholes have been drilled near NRF into shallow perched water zones. In all cases, perched water was found only where a significant surface water source was nearby. Historically, perched water has been found beneath the A1W leaching beds, the S1W leaching beds and leaching pit, the sewage lagoons, and the IWD (in three locations, and at two depths). Figure 15 shows the past and present extent of perched water near the IWD including the locations of some of the boreholes that did not find perched water (Envirodyne Engineers, 1988; WEC, 1992). Of particular interest are the boreholes around NRF-13 and those between NRF-13 and the IWD where no perched water was encountered.

In 1987, when water flowed up to 1.8 miles north of the IWD outfall, 29 boreholes were drilled along the length of the IWD. These boreholes encountered perched water at varying depths ranging from 20 to 200 feet and at various distances from the IWD outfall. In all cases, insufficient water was present to warrant the completion of the boreholes as monitoring wells. This document concluded that migration of water was generally downward in a stair-step manner.

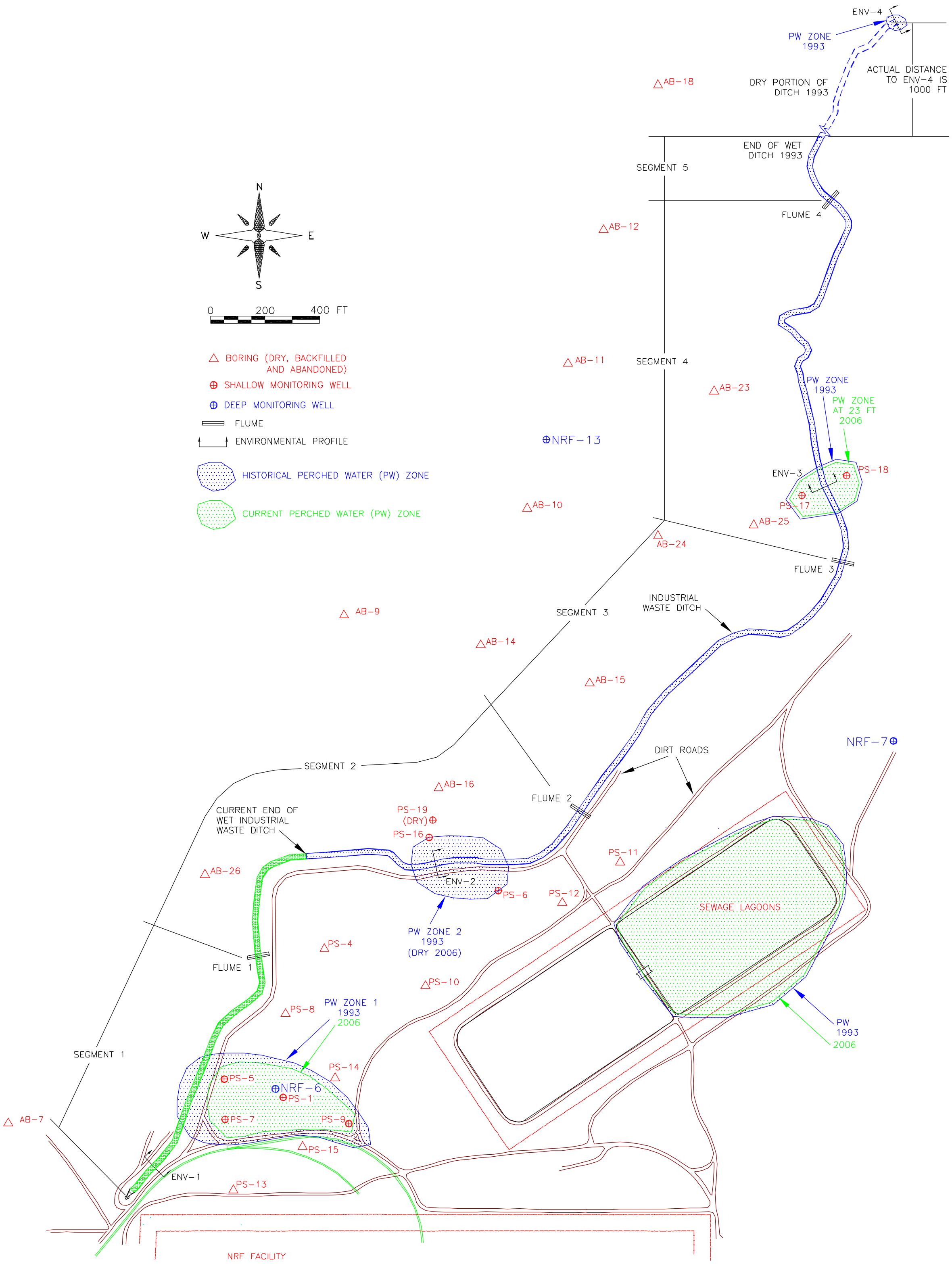

Figure 15 Locations of Past and Present Perched Water at NRF

During the summer of 1991, five shallow wells (approximately 90 feet deep) encountered perched water near the IWD. Four of these wells define the approximate areal extent of a perched zone located just north and east of the IWD outfall (known as PW Zone 1). The depth to perched water ranged from approximately 70 feet to 90 feet. Approximately 10 other boreholes around PW Zones 1 and 2 (PW Zone 2 - see next paragraph) did not find water and were used to delineate the zones that were found. Figure 16 shows the top of PW Zone 1 on August 23, 2006. Since 1991, the shape of the perched water zone did not change substantially; however, the elevation of the top of the perched water zone declined approximately 13 feet in some wells. During this same period, effluent discharge to the IWD declined from 170 million gallons per year to approximately 9 million gallons per year. Water from PW Zone 1 flows from beneath the IWD to an undetermined location southeast of the IWD. This is based on perched water contours shown in Figure 16.

Also during the summer of 1991, one of the deep boreholes (PS-6 – located approximately 100 feet south of the IWD – refer to Figure 15) encountered perched water at a depth of approximately 100 feet (known as PW Zone 2). The water in this well was only several feet deep. In August 2006, no standing water was found in this well. The bottom of the hole was slightly damp.

In 1992, NRF collected resistivity data from three locations on the northwest side of the IWD adjacent to PW Zone 1. Resistivity data provides an indication of perched water by measuring the ground's resistance to the flow of an electrical current. Because the perched water originating from the IWD would contain a high concentration of electrical conductors (i.e., ionic salts), the electrical resistance drops. Mapping changes in resistance with distances provides an indication of the presence of perched water. This is still a viable method to screen for the presence of perched water. At the first location near the outfall of the IWD, the data indicated perched water did not extend more than 40 feet to the northwest of the IWD. At the second location, which was located on the northwest side of the IWD approximately 0.4 miles from the outfall, the data indicated that perched water was not present.

During the summer of 1992, NRF drilled four sets of seven boreholes (28 total) at various distances from the outfall of the IWD. These boreholes were drilled along lines oriented perpendicular to the IWD at various distances from the center of the IWD. The lines were designated ENV-1 through ENV-4 (refer to Figure 15). Shallow perched water was found at the ENV-2 cross-sectional borings (located near PS-6) in five boreholes. Resistivity measurements on the northwest side of the IWD, opposite from PS-6, suggested the presence of perched water. Two boreholes were drilled near the location flagged by the resistivity lines. One borehole (AB-16) terminated at the top of basalt at a depth of 42 feet. A fluvial (river)/lacustrine (lake) (F/L) deposit was encountered at a depth of 20 feet; however, no water was encountered. The F/L deposit is composed of silt and clay, which facilitate the formation of perched water. A second deeper borehole (PS-19) was drilled near the north end of the ENV-2 cross-sectional borings. This borehole terminated at a depth of approximately 96 feet just below the red sedimentary interbed identified in NRF-6. No perched water was present at any depth in the borehole. Perched water was present in ENV-2-50 W at approximately 23 feet. A perched water well (PS-16) was drilled and completed next to this borehole approximately 50 feet from the center of the IWD on the northwest side. Subsequently, this well went dry before samples could be collected.

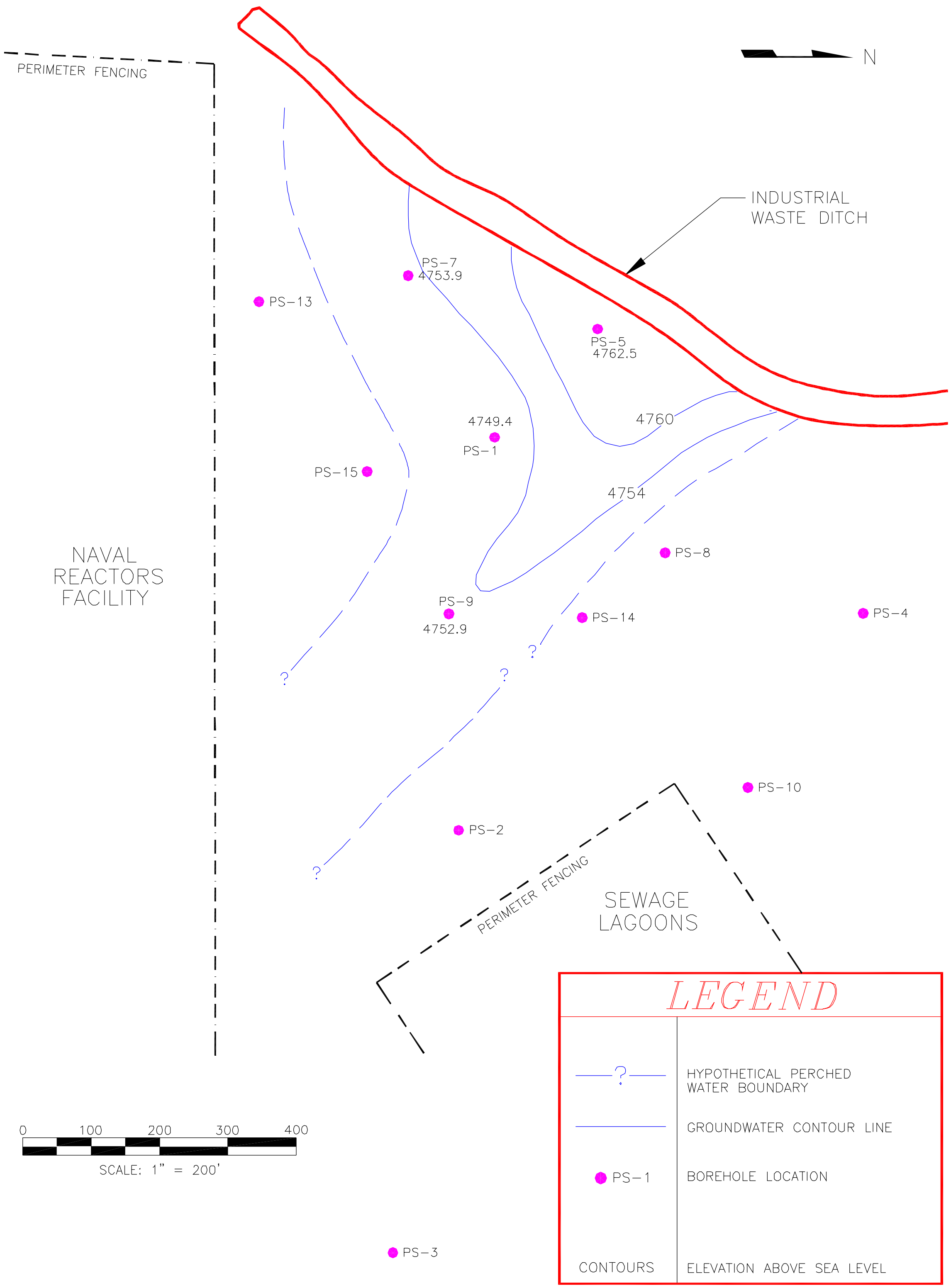

Figure 16 Extent of Perched Water on August 23, 2006

Perched water was also found at the ENV-3 cross-sectional borings in all seven boreholes. Two perched water wells were constructed (PS-17 and PS-18) 50 feet from the center of the IWD (on opposite sides). Perched water stabilized at a depth of 23 feet bls in each well. Perched water was also found at the ENV-4 cross-sectional borings in two boreholes (10 feet and 50 feet east of the IWD). ENV-4 was located approximately 2,400 feet northeast of NRF-13. Water was found at approximately 16 feet bls. No water was found at the other five wells.

On August 23, 2006, all the perched water wells were tested to determine current water depths. Well PS-6 (PW Zone 2) did not contain standing water, but the bottom of the borehole was damp. PS-16 contained slightly damp mud, but no standing water. Perched water was found in PS-17 and PS-18 near ENV-3. The depth of water in both wells exceeded 3 feet. Finding water in these wells was somewhat unexpected since water in the IWD has not reached the distance of these two wells for approximately 10 years. The presence of water in these two wells may be due to natural precipitation or it could be residual from when water in the IWD reached the wells. If this is the case, it could exemplify the enduring nature of perched water zones at the IWD. The presence of perched water after discharges have ceased is not unprecedented at NRF. A residual perched water zone located beneath the S1W Leaching Beds/Pits, which are now covered by an engineered earthen cover, is the primary mechanism postulated for the continued release of water containing small quantities of tritium to the aquifer. In this case, water appears to migrate vertically to the aquifer with little lateral movement.

6.2.2 Connection Between Perched Water and Infiltration

This section examines the interaction between IWD water, the top of basalt, and several sedimentary interbeds located beneath the IWD. The way that the water and these surfaces interact influences where the infiltrating water will eventually enter the aquifer. In general, interbeds interact with water infiltrating from the IWD in one of three ways. Water either flows through, perches upon, or flows along these surfaces.

Based on previous work, it has been determined that the IWD is underlain by a basalt depression with an undulating surface. The basalt in this area is overlain by the F/L deposit, which is present beneath a large portion of the IWD. Localized depressions in this surface also aid in the formation of perched water. The F/L deposit fills the basalt depressions forming a surface that on a large scale gently slopes to the east away from NRF-13. A third prominent interbed occurs at a depth of approximately 90 feet bls. This surface is associated with the formation of PW Zones 1 and 2.

An infiltration study was performed 1993 on the IWD during the RI for OU 8-07 to estimate volume losses and infiltration rates over five segments of the IWD (refer to Figure 15). Water in the IWD ended at 5,800 feet from the outfall during the study. Table 12 summarizes the infiltration data obtained from this study. This table shows infiltration rates at the IWD were somewhat uniform (ranging between 11 and 14 gallons per foot of IWD channel per day), with the exception of segments three and five (which were 1 and 34 gallons per day, respectively) (WEC 1994). This table also indicates that the large volumes of water discharged to the IWD would be sufficient to form perched water zones and perhaps cause mounding on top of the aquifer (localized increase in water table elevation).

The extent of the known perched water zones does not correlate well with the volume of water discharged. Although infiltration was highest at Segments 2 and 4, perched water zones encountered at these locations are small in comparison to the perched water zone located in Segment 1, indicating that hydraulic properties of the perching boundaries are more important than the volume of water that infiltrates in controlling the size of perched water zone.

Table 12 IWD Infiltration Data

IWD Segment	Distance from Outfall In feet	Gallons Passed	Gallons Infiltrated	Total Days	Gallons Infiltrated per day
Segment 1	63 to 1,363	9,418,248	1,926,700	137	14,064 (11 gallons per foot of channel /day)
Segment 2	1,363 to 2,683	7,491,547	2,625,394	143	18,359 (14 gallons per foot of channel /day)
Segment 3	2,683 to 4,012	4,866,153	232,898	142	1,640 (1 gallon per foot of channel/day)
Segment 4	4,012 to 5,421	4,633,256	2,793,363	142	19,672 (14 gallons per foot of channel/day)
Segment 5	5,421 to 5,799	1,839,893	1,839,893	142	12,957 (34 gallons per foot of channel/day)

The first significant perching boundary encountered by water infiltrating from the IWD is the F/L deposit (refer to Figure 17). Based on the studies performed in the OU 8-07 RI, the F/L deposit is clay rich and dips gently to the east on the west side of the IWD (in a direction away from NRF-13). There is approximately a four foot drop in elevation along this surface from NRF-13 to the IWD. The entire length of the IWD to its 1993 terminus (approximately 5,800 feet from the IWD outfall) is underlain by the F/L deposit such that at any point where water infiltrating from the IWD encounters its surface, the water will be directed away from NRF-13. This is not to say that small localized depressions in the surface of the F/L deposit are not present. To the extent they exist, near surface perched water zones may form. Previous studies show that shallow perched water zones, at or near the top of the F/L deposit (20 to 30 feet bls), was common beneath the IWD whenever water was present in the IWD. Figure 17 shows the sub-surface elevation contours of the F/L deposit, the location of the IWD and sewage lagoons, NRF-13, and associated perched water zones.

At the surface of the basalt, water may again be redirected towards low areas depending on the degree to which the surface of the basalt has in-filled with sediments; otherwise, water will tend to pass through and migrate deeper into the subsurface. The 8-07 RI/FS provided a detailed interpretation of the surface of basalt. In general, the RI/FS concluded that the surface of the basalt beneath NRF-13 slopes towards the southeast (toward the IWD); therefore, the formation of perched water near NRF-13 at this surface is not likely.

Figure 17 Fluvial Lacustrine Contour Map

A red sedimentary interbed (known as the red bed) is present beneath the IWD. This interbed is wide spread at NRF. The surface of this interbed has been mapped (OU 8-07 RI/FS Final Work Plan) and suggests that the surface of the red bed is very uneven such that alternating topographic highs and lows may vary by as much as 20 feet within a distance of 500 feet.

Although little is known of the exact nature of the red bed north of the IWD, maps of the interbed in conjunction with data obtained from drilling efforts at NRF-13 indicated that this interbed dips towards the IWD in the areas beneath NRF-13. PW Zones 1 and 2 are both associated with the red bed. The size and extent of deeper perched water occurring at a depth of approximately 100 feet bls appears to decrease with distance from the IWD.

Three important surfaces (F/L, basalt, and red bed) that have the potential of affecting the flow of water in the vadose zone slope away from NRF-13 and towards the IWD. Given the configuration of these surfaces, it is unlikely that they could direct water towards NRF-13. If water from the IWD did interact with NRF-13, it would likely have been through one of the alternate mechanisms discussed below.

The subsurface transport of water from a surface source to a distant location has been documented at NRF and at other INL locations. The transport mechanisms involve large quantities of water, subsurface fractures, and/or interbeds. Water usually moves away from the source in a series of stair-steps. At NRF, water from the S1W leaching beds/pits was detected in a domestic well located approximately 1,150 feet away (documented in Appendix H of the OU 8-08 RI/FS). In this case, water was transported over the surface of buried basalt with some wide-spread sediment infilling and a deeper sediment interbed. Once the source water was removed, water associated with this mechanism stopped relatively quickly. Since past investigations of the IWD, including drilling of numerous dry boreholes, show that near surface perching (or semi-permeable) horizons dip away from NRF-13, the likelihood of this mechanism facilitating the movement of water from the IWD to NRF-13 is low.

Given the preceding examples, it is possible that historically, water in the northern segments of the IWD could have migrated 800 feet to NRF-13. It is less likely that water from southern segments could have traveled the required 1,450 feet. In either case, the fact that near surface mechanisms did not favor water transport towards NRF-13 (but rather away from it), and the fact that no perched water was found while drilling NRF-13 (refer to Section 3.2) reduces the potential that long distance transport occurred. Additionally, the high infiltration rates essential for making long distance transport of water possible no longer exists.

6.2.3 Water Table Elevation

As discussed above, another potential mechanism for moving contaminants from the IWD to area near NRF-13 is through mounding of water beneath the IWD. This section briefly discusses the history of the development of the NRF hydrological model, and then discusses mounding as a potential contaminant transport mechanism. This section also discusses anomalous data collected from NRF-7 in terms of changes in water table elevations.

Based on the studies documented in the OU 8-08 Comprehensive RI/FS, the following conclusions related to water table elevation were made. First, NRF appears to be located in an area where the flow gradient in the SRPA is naturally low. Modeling of groundwater indicated that this may be due to a low permeability zone located northeast of NRF. Second, the flatness of the SRPA near NRF may allow anthropogenic activities (e.g., IWD, sewage lagoon, water production, etc.) to influence its shape (localized highs and lows in the water table). Because of the limited number of wells surrounding NRF prior to 1995, it was difficult to create detailed maps based on well data alone. Maps created from water table data collected in 1985 and 1993 showed general flow lines at NRF that represented water flow directions on a regional basis. These maps did not show any influences due to localized activities (such as infiltration losses from the sewage lagoon and withdrawal of water from production wells within the confines of NRF). In 1995 (when NRF still discharged a large volume of water to the IWD), NRF used water table data collected from newly constructed wells to show the possible effects that localized recharge and withdrawal of water for productive uses at NRF could have on the aquifer. The shape of the water table maps changed to show a cone of depression (localized low) in the water table under NRF and a mound (localized high) in the water table located east of NRF. This conceptual model also predicted the possibility that mounding of water was occurring beneath the IWD, which predicts the possibility of aquifer back flow (a local reversal in aquifer flow direction counter to the prevailing regional flow direction) such that water infiltrating from the IWD could flow north towards NRF-13.

Figure 18 shows the configuration of the NRF water table from August 2006. This figure predicts the presence of a small mound of water east of NRF, with a depression centered near NRF. This map also shows that the aquifer is nearly flat. For example, the difference in water table elevation between USGS-102 located near the southwest NRF boundary fence and NRF-7 located northeast of the sewage lagoons, a distance of nearly 5,000 feet, is 0.79 feet (9.5 inches). Based on this observation, it is likely that any changes in NRF water usage can have an inflated impact on the configuration of the water table near NRF. More accurate maps would require additional wells and water table data.

Figure 19 is a graph showing the water table elevations in NRF-6, NRF-7, NRF-13, and USGS-12. This graph illustrates the changes in groundwater table elevation over time and exemplifies the highly variable nature of the aquifer near NRF. Each well displays the same general shape in that they steadily rise between mid 1995 and June 2000 after which the water table began declining again. The maximum change in water table elevation was approximately 20 feet.

Table 13 summarizes peak dates and elevation difference in the four wells as depicted on the graphs. The peak dates on this table were derived from examination of individual graphs. The graph peak was projected to the x-axis (Data Collection Dates) and the table dates were interpolated from the discrete dates presented on the various graphs. This table illustrates several interesting facts. The peak date for USGS-12 leads the others by up to 6 months. This is expected since this well is the closest to the primary recharge areas of the Little and Big Lost Rivers (i.e., the sinks located north of NRF). Although NRF-6 has a water table that is consistently lower than NRF-7 and NRF-13, based on interpretation of graphs with expanded time scales, the water table appears to peak nearly one and a half months before either NRF-7 or NRF-13 even though NRF-13 is closer to USGS-12. The elevations in both NRF-7 and NRF-13 peak at nearly the same time. Although wells NRF-6, NRF-7, and NRF-13 are relatively close together the difference between the maximum and the minimum water table elevation is different. Although there may be other explanations for the observed elevation differences (e.g. how straight the borehole were drilled), given what is known of the hydrogeology of the area, the most plausible explanation seems to be related to the relatively low permeability of the aquifer around NRF-7 and NRF-13, compared to the permeability of the aquifer surrounding USGS-12 and NRF-6.

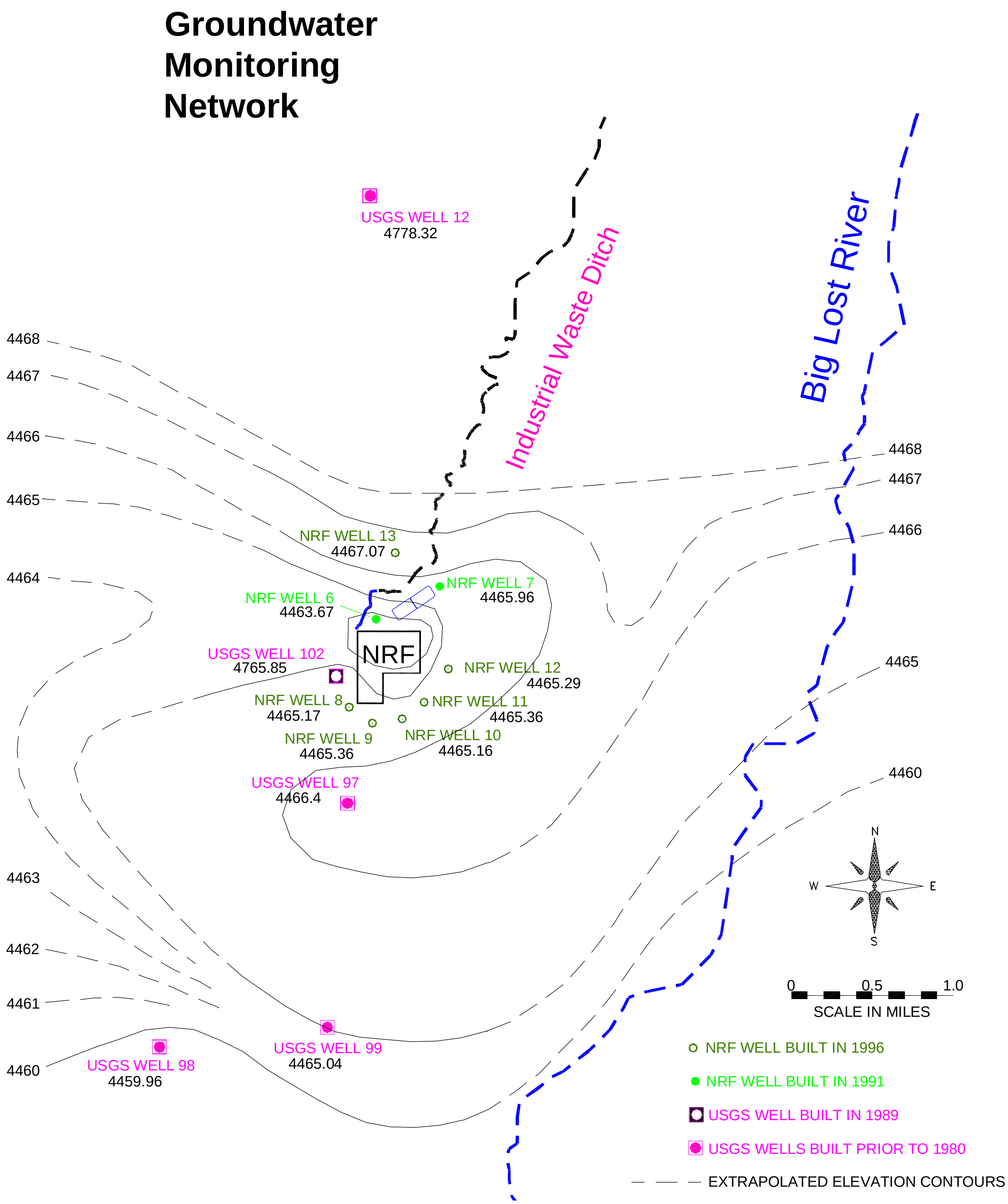

Figure 18 Groundwater Table Elevation Map – August 2006

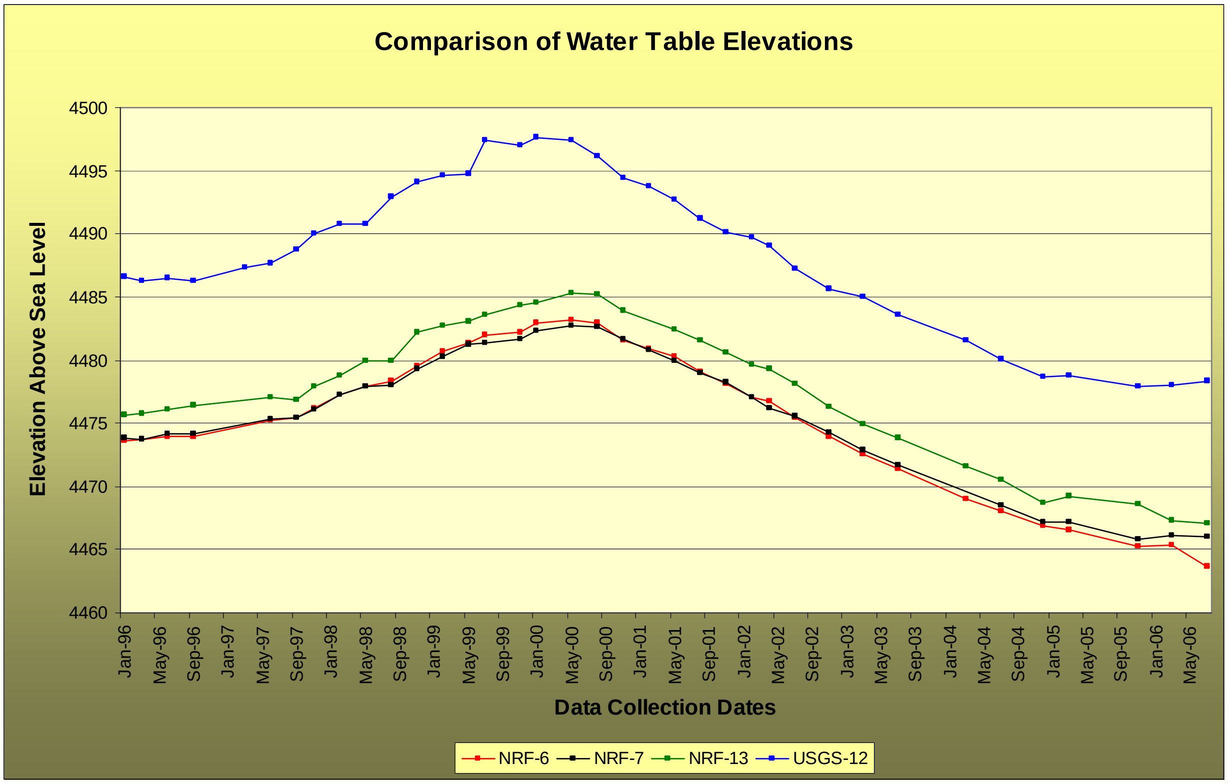

Figure 19 Water Table Elevation at NRF-6, NRF-7, NRF-13, and USGS-12

Table 13 Summary of Hydrograph Data for Wells USGS 12, NRF 6, NRF 7 and NRF 13

Well	Maximum Elevation (feet)	Peak Date*	Maximum Elevation Difference
USGS 12	4497.77	January 2000	19.72
NRF 6	4483.16	April-May 2000	19.49
NRF 13	4485.36	June-July 2000	18.27
NRF 7	4482.71	June-July 2000	16.91

*These are the interpolated peak dates based on examination of individual graphs – not actual maximums as shown in the data.

Figure 20 is a graph showing the water elevation difference between NRF-13 and NRF-6. The trend in this graph shows that the difference in elevation between these two wells is increasing at a uniform rate. Assuming that regional changes in water table elevation effect both NRF-6 and NRF-13 the same, the increasing elevation difference may reflect reduced discharge volume to the IWD, which in turn would reduce the size (height and width) of the hypothetical mound beneath the IWD. It should be noted that the NRF was still discharging approximately 110 million gallons per year to the IWD at the beginning of 1996, when the data in Figure 20 begins.

Reduction of mounding beneath the IWD would make any flow reversal from the IWD toward NRF-13 more difficult. Any mounding created by the IWD would be expected to be seen in water table data in NRF-6, which is directly influenced by the IWD, and based on the difference in water table elevation between NRF-6 and NRF-13 the mounding would not be significant enough to create flow reversal reaching NRF-13 during the time interval represented by this graph. Even during the time period of peak discharge to the IWD (late 1980s to early 1990s), an extrapolation of the data in Figure 20 indicates that the water elevation in NRF-6 was never higher than at NRF-13.

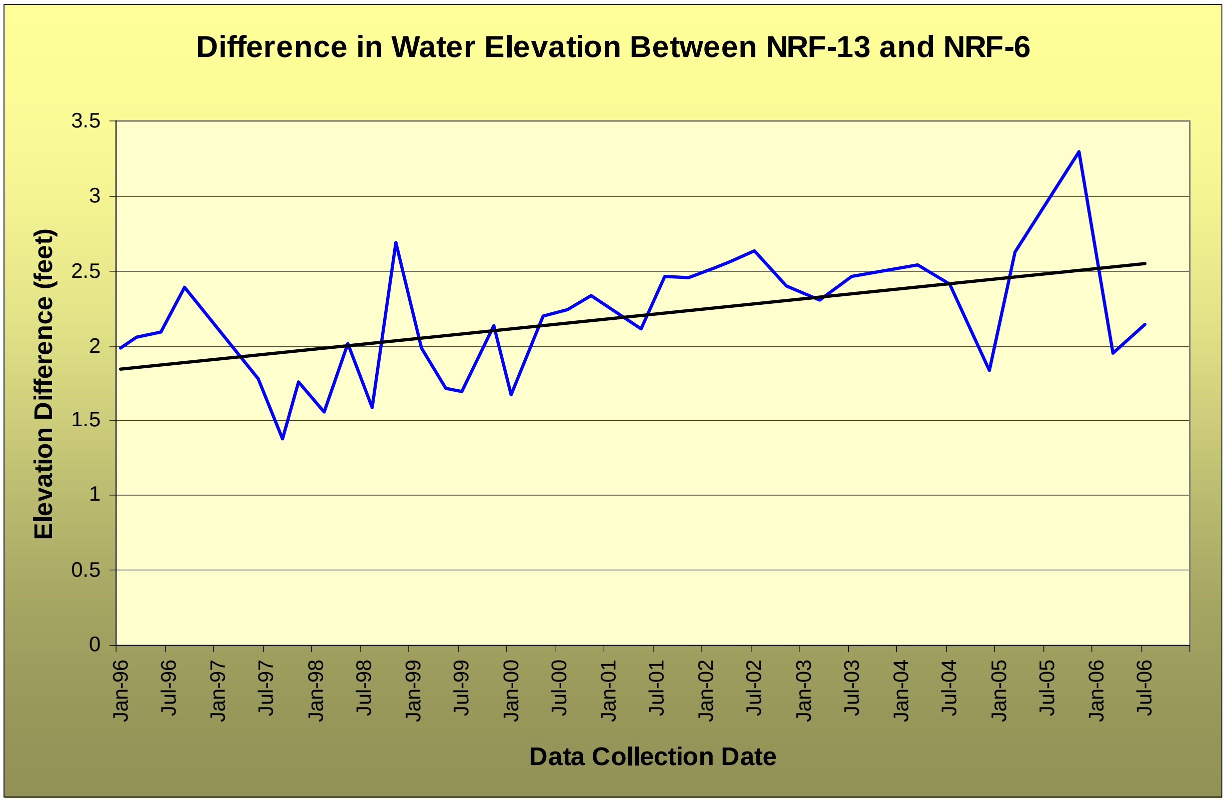

Figure 20 Water Table Comparison Between Wells NRF-13 and NRF-6

Figure 21 is a graph of the groundwater elevation difference between NRF-13 and NRF-7. As noted by the trend line, the difference in water table elevation between NRF-13 and NRF-7 increased while the regional aquifer was rising in elevation. The water table elevation difference in the two wells returned to near 1996 levels once the aquifer returned to near its 1996 levels. This graph illustrates the effects due to localized variations in aquifer properties (i.e., permeability). The low aquifer permeability around NRF-7 tends to dampen the regional increases or decreases in water table elevation by the time it reaches NRF-7; therefore, the trends due to regional influences are not as great as at NRF-13. Another important aspect of this graph shows the consistency of water table elevation at NRF-13 being higher than NRF-7, which is on the opposite side of the IWD. Based on water table elevation differences between NRF-7 and NRF-13, any flow associated with effluent from the IWD would be expected to flow away from NRF-13, not toward NRF-13.

In summary, the preceding data show that the water table elevations at NRF-6 and NRF-7 have probably never been higher than the elevations at NRF-13, and that any mounding that may have resulted from large volume discharges to the IWD likewise would not have been great enough to overcome the regional water table and affect the water quality at NRF-13.

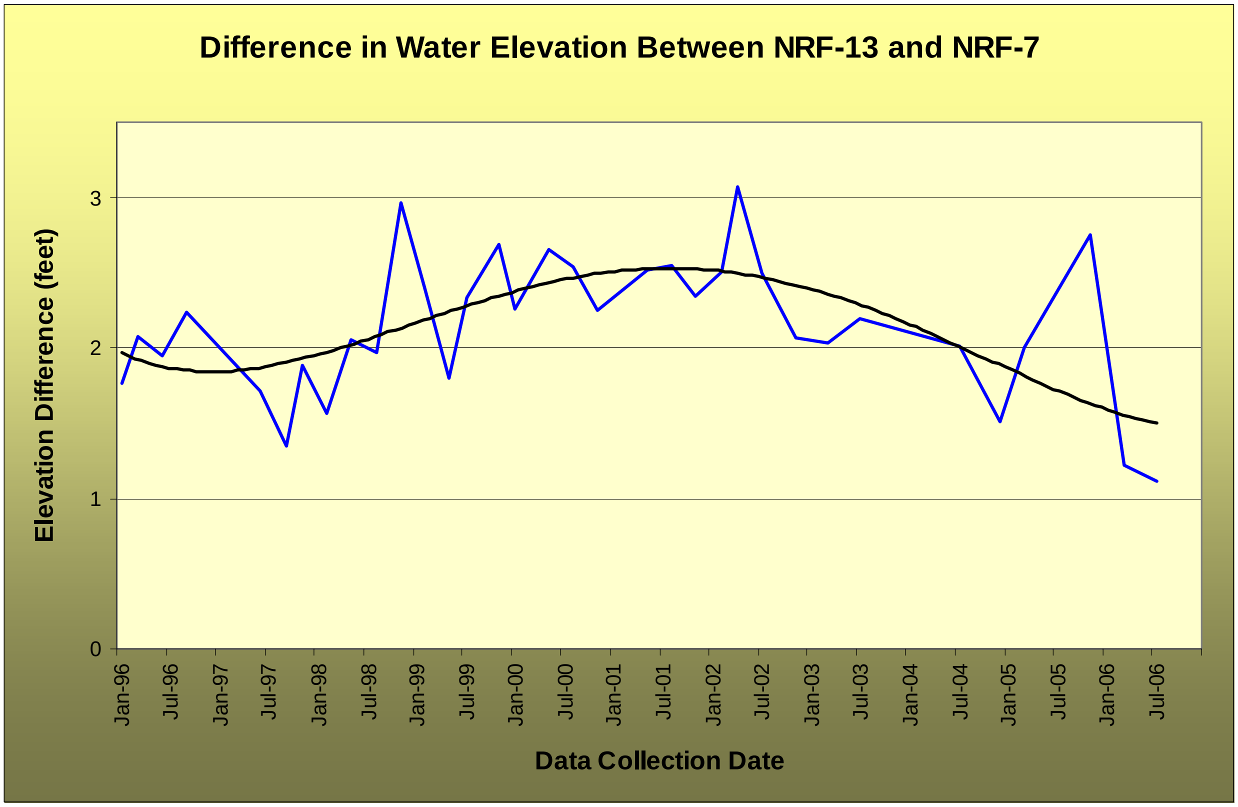

Figure 21 Water Table Comparison for Wells NRF-13 and NRF-7

6.2.4 Migration of Chromium from IWD Sediment

This section discusses results of studies performed during the OU 8-07 RI/FS associated with the potential migration of metals at the IWD. Samples collected from the IWD during previous investigations showed that IWD sediments contained elevated concentrations of various metals including barium, copper, mercury, silver, and chromium. Furthermore, these investigations showed that most of the contaminants stayed in the sediment within approximately five feet of the IWD channel.

The migration potential of contaminants contained in the IWD sediments is controlled by both the chemical characteristics of the contaminants and the chemical and physical characteristics of the sediments. The chemical characteristics of metal contaminants affect migration potential. Properties such as solubility and ionic charge greatly influence the media the contaminant will accumulate in, and the interactions the contaminant will undergo.

The characteristics of the media that a contaminant comes into contact also affect migration potential. These characteristics may include reduction-oxidation potential (Eh), pH, cation exchange capacity, and distribution coefficients. The mobility of a contaminant is often dependent upon the Eh-pH status of the soil system, as the interaction of these two properties determines the form the contaminant will take and the interactions in which it will participate. Cation exchange is an important parameter in soils, as the positively charged metal ions are readily attracted to negatively charged sediment particles.

The hexavalent form of chromium is more mobile in the environment than its trivalent form. Hexavalent chromium is readily reduced to trivalent chromium in media that contain a significant amount organic material, iron, and manganese, like the IWD sediments. Trivalent chromium is relatively immobile in soil due to its affinity for negatively charged clay particles and biological uptake processes. As a result, chromium tends to accumulate in the sediments over time. Because surficial sediments are finer grained and have a higher clay content than the underlying alluvium, and because the biological community of surficial soils is more active than in the underlying alluvium, metal deposition occurs preferentially in surficial soils than in deeper, more coarse-grained alluvial material. Thus, the migration of most of the chromium is arrested in the surficial soil.

A combination of these processes is at work in the media underlying the IWD. Samples collected of IWD sediments show that they possess a high cationic exchange capacity and that they have pH and Eh characteristics consistent with the formation of stable metal oxides. Therefore, the migration of metal contaminants, specifically chromium, should be arrested within the first several feet of sediment underlying the IWD. Ditch boring data confirm that most dissolved phase metals (including chromium) adsorb onto soil particles or organic material within five feet of the bottom of the ditch. These surficial soils are apparently acting as an effective filter, removing reactive metal species before soil water containing these species comes in contact with underlying soils. Because the bulk of the metal contaminants do not migrate beyond a limited radius, it appears unlikely that the elevated metals found in NRF-13, notably chromium, originated from the IWD.

6.2.5 Conclusions on Hydrogeological Factors Effecting Contaminant Migration

The IWD is the only man-made source for chromium near NRF-13, and only a few possible mechanisms exist that can explain the transport of chromium from the IWD to the well. The first mechanism would be transport from perched water which has been found at many stratigraphic levels at NRF. Evidence from geotechnical and hydrogeological studies suggests that perched water does not extend very far north and west of the IWD, and does not approach NRF-13. All likely perching boundaries near the IWD dip away from NRF-13. If perched water does migrate as far as NRF-13 it would likely be at deeper levels; however, no evidence has been found that the sediments in well NRF-13 encountered water from the IWD. Thus, migration of perched water to NRF-13 as a transport mechanism is considered unlikely.

The other mechanism would be northward migration of water from the IWD to NRF-13, which could possibly occur if the aquifer hydraulic head at NRF-13 is less than the aquifer hydraulic head beneath the IWD. There are isolated instances where it is believed that groundwater flow reversals may have occurred at NRF. However, fairly reliable evidence indicates that if a gradient reversal ever existed beneath the IWD it was not substantial enough to overcome the regional gradient and allow IWD water to reach NRF-13. If mounding did exist, it is likely gone due to the substantial decline in discharge volume to the IWD. Additionally, if the IWD is the chromium source at NRF-13 then it would be expected that chromium concentrations in NRF-6 would show a similar pattern of elevation.

In addition, past studies have shown a strong correlation of chromium binding to surficial soils near the source and, unless there has been a sudden shift in soil chemistry, the chromium would be expected to remain bound to the soil. There has been no evidence that a shift in soil chemistry at the IWD has occurred. In conclusion, the evidence discussed above strongly indicates that the source of the chromium is endemic to NRF-13.

7.0 Appendix Summary

This assessment provides evidence and supports the conclusion that the high chromium concentrations in NRF-13 are a result of sedimentation released from interbeds within the aquifer. There is also the possibility that corrosion of well components contributes to the elevated chromium concentrations in NRF-13. The following list provides a summary of the justification provided in Section 5.0 which supports sedimentation affecting chromium levels in well NRF-13:

- Filtered and unfiltered sample analysis from NRF-13 indicates sediment being present in the unfiltered samples with low dissolved solids.
- Turbidity values in NRF-13 are much higher than other NRF wells and there is a significant correlation between turbidity and chromium concentrations in NRF-13.
- Because of low well production rates at NRF-13, purging is more difficult during sampling which could allow sediments to become entrained into samples.
- The interbeds and basalt near NRF-13 contain chromium concentrations much higher than the concentrations found in the groundwater samples which, if entrained, would likely result in elevated chromium levels in the ground water.

In addition, this assessment shows that the IWD does not appear to influence NRF-13. The following list provides an explanation as to why transport mechanisms do not support migration from the IWD to NRF-13:

- NRF-13 water quality and trends in data are more closely related to NRF-7, an upgradient water quality well, than NRF-6, which is known to be impacted by the IWD.
- The trends in ionic salts and chromium concentrations in NRF-6 do not correlate to observed trends in NRF-13.
- Chromium levels have statistically increased in NRF-13 while they have decrease in NRF-6.
- Each subsurface layer beneath NRF-13 (basalt, F/L, and red bed) slopes towards the IWD at NRF-13, which reduces the likelihood of migration from the IWD towards NRF-13.
- Based on past investigations, there has been no evidence of perched water existing between NRF-13 and the IWD.
- The regional groundwater flow direction does not support migration of water from the IWD toward NRF-13. Mounding beneath IWD may have occurred, but does not appear to have been significant enough to cause flow reversal.
- The chromium released into the IWD has been shown in past investigations to bind to the surficial sediments in the IWD with little potential for migration.
- Flow velocities in the vicinity of NRF-13 are very low compared to the aquifer surrounding NRF, which would limit the potential for reverse migration of constituents.

Based on the evidence provided, the chromium detected in well NRF-13 is likely naturally occurring and did not originate from the IWD. The analysis presented in the sections above indicates that corrosion cannot be eliminated as a factor; however, its contribution is believed to be minor. Although influences on NRF-13 due to the IWD can not be ruled out, evidence indicates that a connection is not likely.

Attachment 1

to Appendix A

of the

NRF Five-Year Review

Explanation of Statistical Analysis and Groundwater Data

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References

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1.0 Statistical Analysis of Data

To determine the mean, standard deviation, maximum, and minimum constituent concentrations for the wells and well groups, the following statistical procedure was used. The data for individual wells were analyzed for outliers, outliers were removed, and then the mean, standard deviation, maximum, and minimum were determined utilizing built-in functions in Microsoft Excel. The means of the data were then statistically compared using the Wilcoxon Rank-Sum Test. Finally, box plots for each constituent were constructed to provide a visualization of data variation.

1.1 Outlier Determination

An outlier is considered to be an observation in a group of samples that is so far from the main body of data that it gives rise to the question that it may be from another population. However, outliers are valuable sources of information and should never be discarded without thorough investigation. There are three typical causes for an outlier to show up in a set of observations (Millard, 2001):

1) The outlier is not a valid value, but is the result of a measurement or coding error.
2) The outlier is associated with a different population than the population the rest of the data were drawn from. For example, a different laboratory analysis was used on the physical sample associated with the outlier.
3) The outlier is a valid value from the sample population as the other observations; however, it is the result of a rare event in the sample.

Outliers were determined based on errors from laboratory analysis and rare events. The outliers associated with laboratory analysis include data reported as the method detection limit (MDL). If the MDLs of the laboratory were higher than a large majority of the actual constituent concentrations, then the higher MDLs were considered outliers. Inclusion of these MDLs would skew the data, erroneously increase the data mean, and cause statistical tests to report inaccurate conclusions regarding data means, since nonparametric statistical tests are more sensitive to the number of data points at a given rank rather than the data value. The outliers associated with rare events include:

- Groups of data with high turbidity levels which are an order of magnitude greater than average, and correspondingly high metal concentrations associated with indigenous geology were considered outliers.
- Groups of data with high metallic concentrations commonly found in well components which were present after component failure were considered outliers.

Based on these criteria, the following data were considered outliers. It should be noted that outliers were not removed from NRF-13 since the purpose of this study is to address the increase in constituent concentrations in NRF-13.

For NRF-6, aluminum concentrations reported as the MDL of 100 ppb and manganese concentrations reported as the MDL of 10 ppb were considered outliers, since all of the actual aluminum concentrations and a large majority of the actual manganese concentrations in NRF-6 were less than 100 and 10 ppb, respectively. In addition, the sample drawn on November 17, 2003, was considered to be influenced by the failure of the well pump and motor, which resulted in a high turbidity reading and correspondingly high concentrations of metals commonly used in well material construction. As a result, the data points for chromium, iron, manganese, and nickel are considered outliers for this date.

For NRF-7, manganese concentrations reported as the MDL of 10 ppb were considered outliers, since a large majority of the actual manganese concentrations in NRF-7 were less than 10 ppb. In addition, the samples drawn between November 4, 2002, and March 29, 2004, were considered to be influenced by a release of interbed sediments, which resulted in high turbidity readings and correspondingly high concentrations of metals associated with the indigenous geology. As a result, the data points for aluminum, chromium, iron, manganese, nickel, calcium, potassium, and magnesium are considered outliers for these dates.

For USGS-12, aluminum concentrations reported as the MDL of 100 ppb, manganese concentrations reported as the MDL of 10 ppb, and nickel concentrations reported as the MDLs of 4.2, 10, and 40 ppb were considered outliers, since a large majority of the actual aluminum, manganese, and nickel concentrations in USGS-12 were less than 100 ppb, 10 ppb, and 4.2 ppb, respectively.

Table 3, at the end of this attachment, presents the groundwater data for NRF-13, NRF-6, NRF-7, and USGS-12. Data points highlighted in orange were determined to be outliers using the above methodology. The mean, standard deviation, maximum, and minimum for wells were determined using individual well data with outliers removed as described above.

1.2 Comparison of Constituent Concentrations in Wells

A nonparametric statistical test was used, rather than the parametric ANOVA test used in the previous Five-Year Review, because many of the data sets were skewed due to the desire to limit the number of outliers. Also, for the most part, skewed, non-normal distributions provide better models for environmental data (Millard, 2001). Therefore, the data sets for the wells were statistically compared using the nonparametric Wilcoxon Rank-Sum Test.

The Wilcoxon Rank-Sum Test tests the equality of the means of two independent, non-normal, continuous distributions (which bests describes the data associated with the various wells at NRF). This test is accomplished by comparing the test statistic, which is based upon the ranks of the observations, to the critical test value at a given confidence level. If the absolute value of the test statistic is greater than the critical test value the hypothesis is rejected, and it is concluded that the means are different. Because the Wilcoxon Rank Sum-Test is based on the ranks of the observations it is unaffected by gross outliers (Millard, 2001).

The following statistical procedure was used for comparing two groups of data utilizing the Wilcoxon Rank-Sum Test. Let X_{11}, X_{12}, . . . ,X_{1n1}, and X_{21}, X_{22}, . . . ,X_{2n2} be two independent random samples of sizes $n_1 \le n_2$ from the continuous populations X_1 and X_2. Assign ranks to all $n_1 + n_2$ observations, if two or more observations are tied, use the mean of the ranks that would have been assigned if the observations differed. If W_1 is the sum of the ranks in the smaller sample (1) and W_2 is the sum of the ranks in the other sample (2), then

$$W_2 = \frac{(n_1 + n_2)(n_1 + n_2 + 1)}{2} - W_1$$

If the sample means do not differ, it is expected that the sum of the ranks to be nearly equal for both samples after adjusting for the difference in sample size. When both n_1 and n_2 are large, i.e. greater than eight, the distribution of the sum of the ranks for sample 1 (W_1) can be well approximated by the normal distribution with mean

$$\mu_{W_1} = \frac{n_1(n_1 + n_2 + 1)}{2}$$

and deviation

$$\sigma_{w_1}^2 = \frac{n_1 n_2 \left(n_1 + n_2 + 1\right)}{12}$$

Therefore the test statistic is

$$Z_0 = \frac{W_1 - \mu_{w_1}}{\sigma_{W_1}}$$

and the appropriate critical region is $| z_0 | > z_{\alpha/2}$. Again, if the absolute value of the test statistic is greater than the critical test value the null hypothesis is rejected, and it is concluded that the means are different. The critical test value is the two tailed cumulative standard normal distribution at the chosen confidence interval. For this test, a confidence interval of 99% was chosen, yielding an alpha of 0.1. This means that there is a 99% probability that the true value, or test decision, falls within this confidence interval (Montgomery, 2003).

The following data sets were compared utilizing the Wilcoxon Rank-Sum Test for the following constituents: aluminum, calcium, chloride, chromium, iron, magnesium, manganese, nickel, potassium, sodium, sulfate, and total nitrogen. NRF-13 data were statistically compared with data collected from USGS-12, NRF-6, and NRF-7. These wells were chosen for their proximity to NRF-13. USGS-12 is located hydrologically upgradient to NRF-13 while NRF-6 and NRF-7 are downgradient and cross-gradient to NRF-13, respectively. In addition, NRF-13 data were statistically compared to estimated regional background concentrations. The regional background group for this analysis was considered to be a combination of wells NRF-7 and USGS-12. Using the above wells and well groups, the following statistical comparisons were made:

- NRF-13 constituent means before and after 1999 to determine if a statistical difference was exhibited for the analyzed constituents
- Constituent means in NRF-13 to the corresponding constituent means in NRF-6, NRF-7, USGS-12, and the regional background

1.2.1 Summary of Statistical Results

The summary of the results for the Wilcoxon Rank-Sum Test can be found in the following tables. Table 1 summarizes the statistical values for the Wilcoxon Rank-Sum Test for a comparison of the constituent concentration means for NRF-13 before and after 1999. If the Test Result is “ACCEPT” then the test concluded that the means for the specific constituent concentration were statistically equal before and after 1999 and “REJECT” is the opposite. Test results which were rejected are highlighted in green.

Table 1 – Wilcoxon Rank-Sum Sample Statistical Values for NRF-13 Before and After 1999									
	n_1	n_2	W_1	W_2	μ_{W1}	σ^2_{W1}	Z_0	$Z_{\alpha/2}$	Test Result
Aluminum	11	26	213.0	490.0	209.0	30.1	0.13	2.58	ACCEPT
Calcium	12	26	248.5	492.5	234.0	31.8	0.46	2.58	ACCEPT
Chloride	12	26	218.5	522.5	234.0	31.8	0.49	2.58	ACCEPT
Chromium	12	26	87.5	653.5	234.0	31.8	4.60	2.58	REJECT
Iron	12	26	271.0	470.0	234.0	31.8	1.16	2.58	ACCEPT
Magnesium	12	26	177.5	563.5	234.0	31.8	1.77	2.58	ACCEPT
Manganese	12	26	256.0	485.0	234.0	31.8	0.69	2.58	ACCEPT
Nickel	12	26	125.0	616.0	234.0	31.8	3.42	2.58	REJECT
NO_2+NO_3	12	26	215.5	525.5	234.0	31.8	0.58	2.58	ACCEPT
Potassium	12	26	357.0	384.0	234.0	31.8	3.86	2.58	REJECT
Sodium	12	26	261.0	480.0	234.0	31.8	0.85	2.58	ACCEPT
Sulfate	12	26	245.0	496.0	234.0	31.8	0.35	2.58	ACCEPT

Table 2 summarizes the test results of the Wilcoxon Rank-Sum Test for the comparison of constituent means in NRF-13 to the corresponding constituent means in NRF-6, NRF-7, USGS-12 and the regional background. If the test result reads "ACCEPT" then the test concluded that the means are statistically equal, and "REJECT" is the opposite. Comparisons which show agreement between constituent means for the total data sets are highlighted blue.

Table 2 – Wilcoxon Rank-Sum Test Results for NRF-13 Comparison				
	NRF-13 vs NRF-6	NRF-13 vs NRF-7	NRF-13 vs USGS-12	NRF-13 vs Background
Aluminum	REJECT	REJECT	REJECT	REJECT
Calcium	REJECT	REJECT	REJECT	REJECT
Chloride	REJECT	REJECT	REJECT	REJECT
Chromium	REJECT	REJECT	REJECT	REJECT
Iron	REJECT	REJECT	REJECT	REJECT
Magnesium	REJECT	REJECT	REJECT	REJECT
Manganese	REJECT	REJECT	REJECT	REJECT
Nickel	REJECT	REJECT	REJECT	REJECT
NO_2+NO_3	REJECT	REJECT	REJECT	ACCEPT
Potassium	REJECT	REJECT	REJECT	REJECT
Sodium	REJECT	REJECT	REJECT	ACCEPT
Sulfate	REJECT	REJECT	REJECT	REJECT

1.3 Box Plot Analysis

Box plots provide visual representations of several features of a data set, including center, spread, and departure from symmetry. A box plot displays the three quartiles, the minimum, and the maximum of the data on a rectangular box. The box encloses the interquartile range with the left edge at the first quartile and the right edge at the third quartile. A line is drawn through the box at the second quartile. A line extends from the end of each box. The lower whisker is a line from the first quartile to the smallest data point within 1.5 interquartile ranges from the first quartile. The upper whisker is a line from the third quartile to the largest data point within 1.5 interquartile ranges from the third quartile. The first quartile is a value that has approximately 25% of the observations below it and 75% of the observations above. The second quartile is a value that has approximately 50% of the observation below and above it, also known as the median. The third quartile is a value that has approximately 75% of the observations below it and 25% of the observations above (Montgomery, 2003).

Using the above criteria box plots were generated for several wells for the following constituents: aluminum, barium, calcium, chloride, chromium, copper, iron, magnesium, manganese, nickel, potassium, sodium, sulfate, total nitrogen, and zinc. Figure 1 though Figure 12 presents the box plots for each constituent combining data for NRF-13, NRF-6, NRF-7, USGS-12, and regional background on each figure for ease of comparison.

Figure 1, the box plot for aluminum, depicts that NRF-13 has elevated levels of aluminum when compared to the surrounding wells and the regional background. In addition, the variation in the concentrations of aluminum in NRF-13 is larger than the variation in the concentrations of the surrounding wells and the regional background.

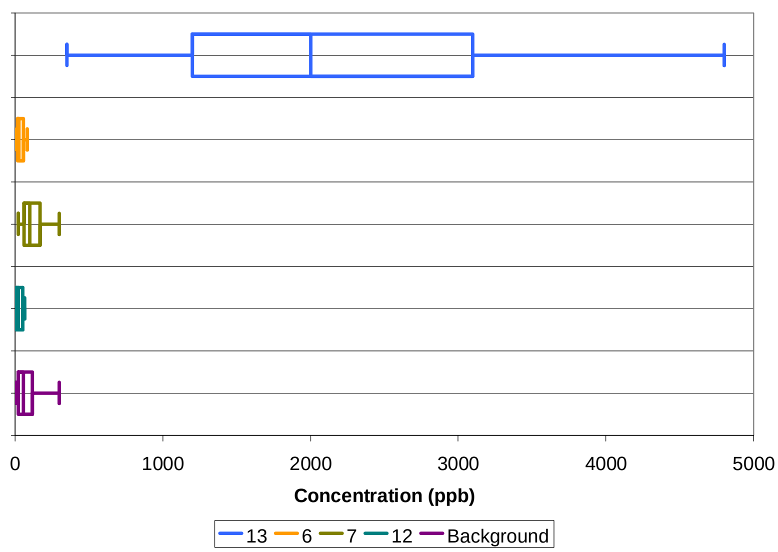

Figure 1 – Box Plot for Aluminum

Figure 2, the box plot for calcium, depicts that NRF-13 has slightly elevated calcium concentrations when compared to the surrounding wells and the regional background, except NRF-6 and NRF-7 which are higher and lower than all wells and the regional background, respectively. The variation in the concentrations of calcium in NRF-13 is similar to the surrounding wells, except NRF-6 which exhibits a larger variation in concentration.

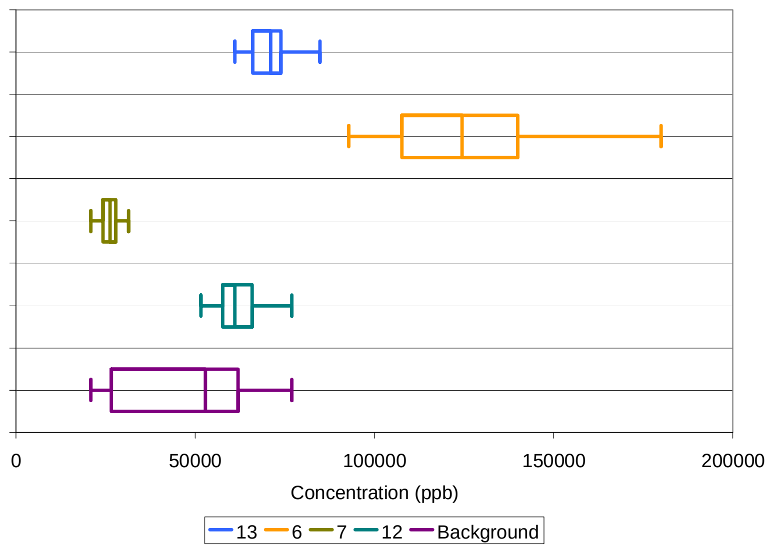

Figure 2 – Box Plot for Calcium

Figure 3, the box plot for chloride, depicts that NRF-13 has elevated chloride concentrations when compared to the surrounding wells and the regional background, except NRF-6, which has a much higher chloride concentration. The variation in the concentrations of chloride in NRF-13 is similar to the surrounding wells and the regional background, except NRF-6 which exhibits a larger variation in concentration.

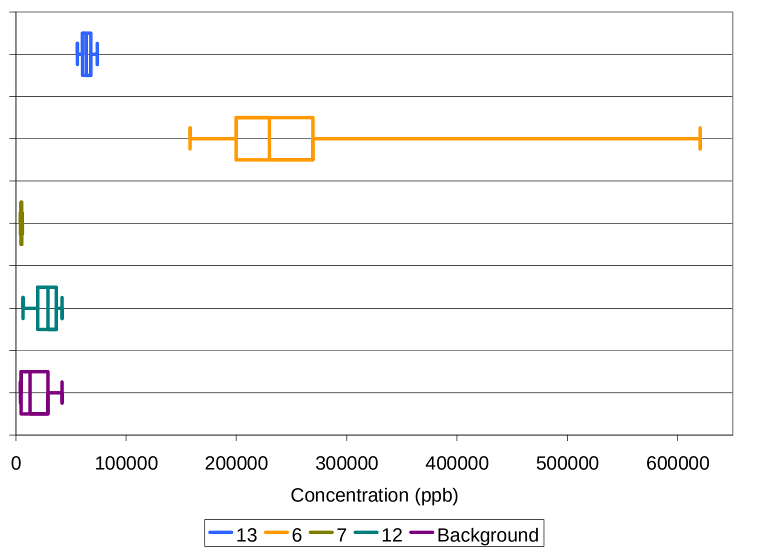

Figure 3 – Box Plot for Chloride

Figure 4, the box plot for chromium, depicts that NRF-13 has elevated chromium concentrations when compared to the surrounding wells and the regional background. NRF-6 has the next highest chromium concentrations, followed by NRF-7. The variation in the concentrations of chromium in NRF-13 is also greater than the surrounding wells and the regional background. NRF-6 also exhibits large variation in chromium concentrations; however, this variation is less than in NRF-13.

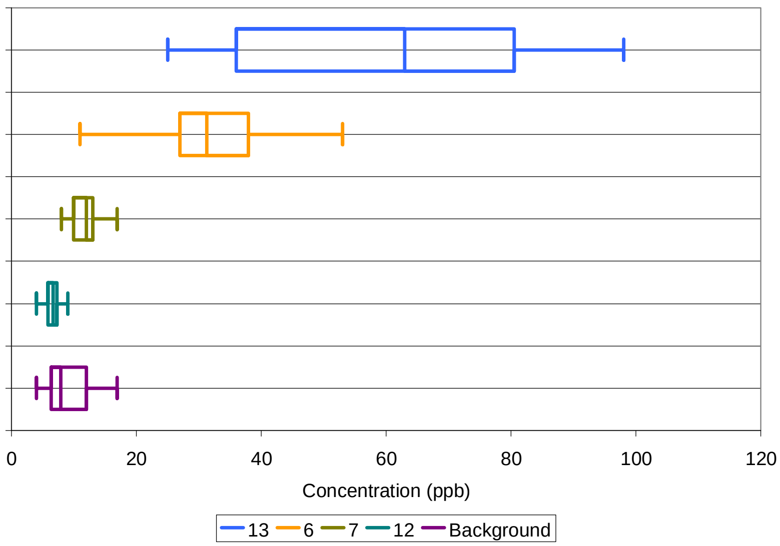

Figure 4 – Box Plot for Chromium

Figure 5, the box plot for iron, depicts that NRF-13 has elevated iron concentrations when compared to the surrounding wells and the regional background. NRF-6 and NRF-7 have the next highest concentrations of iron, respectively. The variation in the concentrations of iron in NRF-13 is greater than the variation in the surrounding wells and the regional background. NRF-6 also exhibits large variation in iron concentrations; however, this variation is much less than in NRF-13.

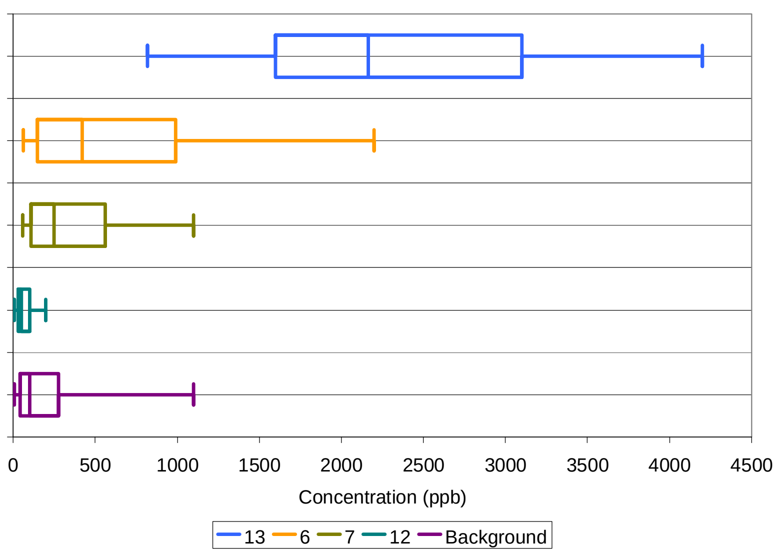

Figure 5 – Box Plot for Iron

Figure 6, the box plot for magnesium, depicts that NRF-13 has slightly elevated magnesium concentrations when compared to the surrounding wells and the regional background, except NRF-6 which is higher than all wells and the regional background. The variation in the concentrations of magnesium in NRF-13 is similar to the variation in USGS-12. In addition, NRF-6 and the regional background have larger variations in magnesium concentrations.

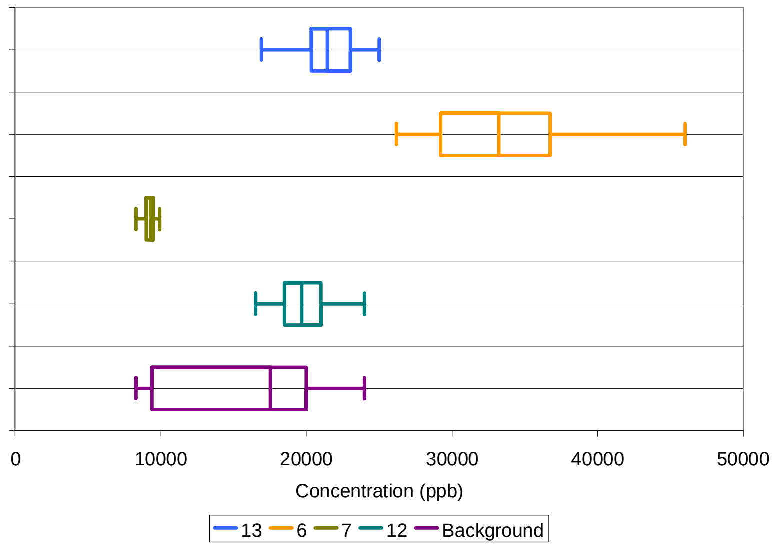

Figure 6 – Box Plot for Magnesium

Figure 7, the box plot for manganese, depicts that NRF-13 has elevated levels of manganese when compared to the surrounding wells and the regional background. In addition, the variation in the concentrations of manganese in NRF-13 is more spread out than the concentrations in the surrounding wells and the regional background.

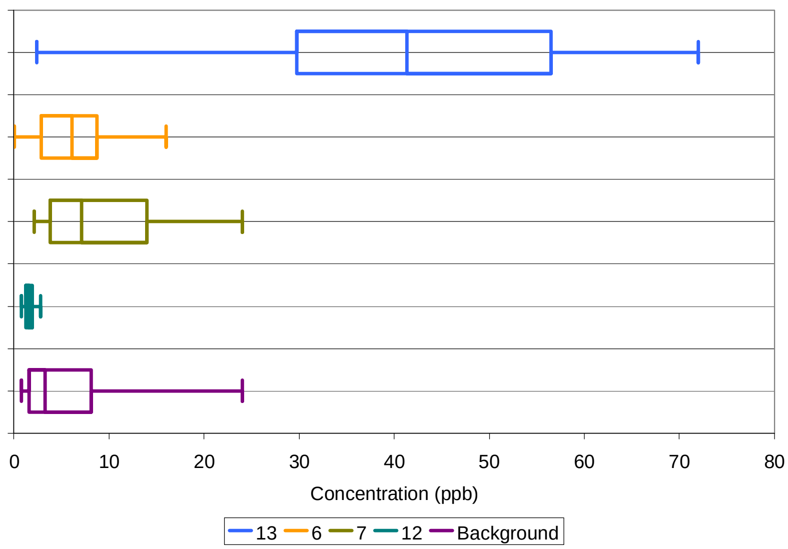

Figure 7 – Box Plot for Manganese

Figure 8, the box plot for nickel, depicts that NRF-13 has elevated nickel concentrations when compared to the surrounding wells and the regional background. NRF-6 and NRF-7 have the next highest concentrations of nickel, respectively. The variation in the concentrations of nickel in NRF-13 is greater than the variation in the surrounding wells and the regional background. NRF-6 also exhibits a large variation in nickel concentrations.

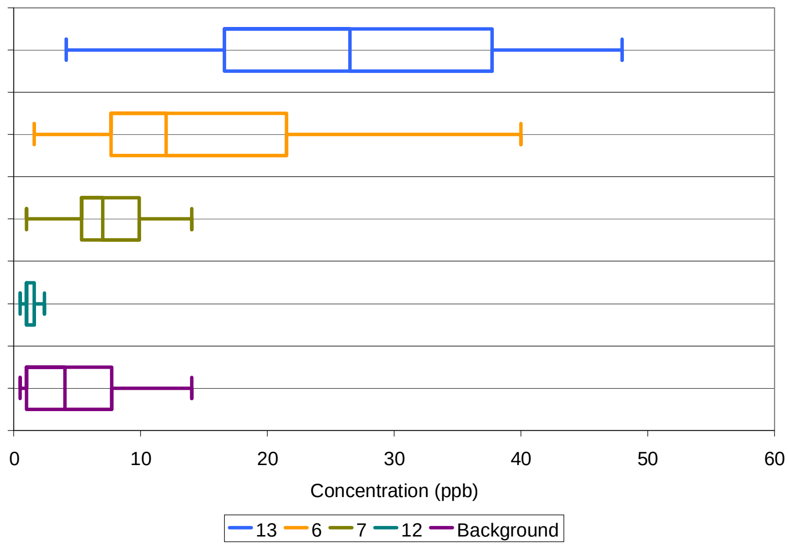

Figure 8 – Box Plot for Nickel

Figure 9, the box plot for potassium, depicts that NRF-13 has elevated potassium concentrations when compared to the surrounding wells and the regional background, except NRF-6 and NRF-7 which also have elevated potassium levels. NRF-6 has the highest potassium concentrations of all the surrounding wells and the regional background. The variation in the concentrations of potassium in NRF-13 is similar to the variation in the surrounding wells and the regional background, except NRF-6 which has a larger variation.

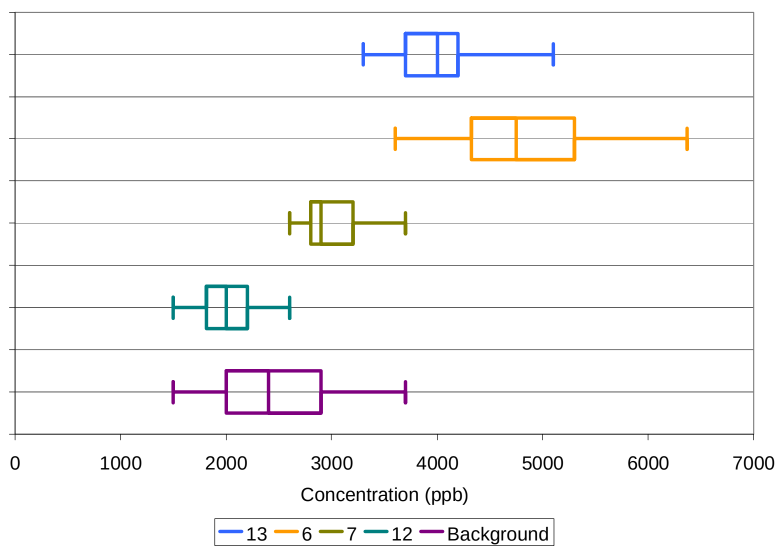

Figure 9 – Box Plot for Potassium

Figure 10, the box plot for sodium, depicts that NRF-13 has similar sodium concentrations when compared to the surrounding wells and the regional background, except NRF-6 which has elevated sodium levels. This similarity in concentrations is confirmed by results of the Wilcoxon Rank-Sum Test. The variation in the concentrations of sodium in NRF-13 is similar to the variation of the surrounding wells and the regional background, except NRF-6 which shows a larger variation in concentration.

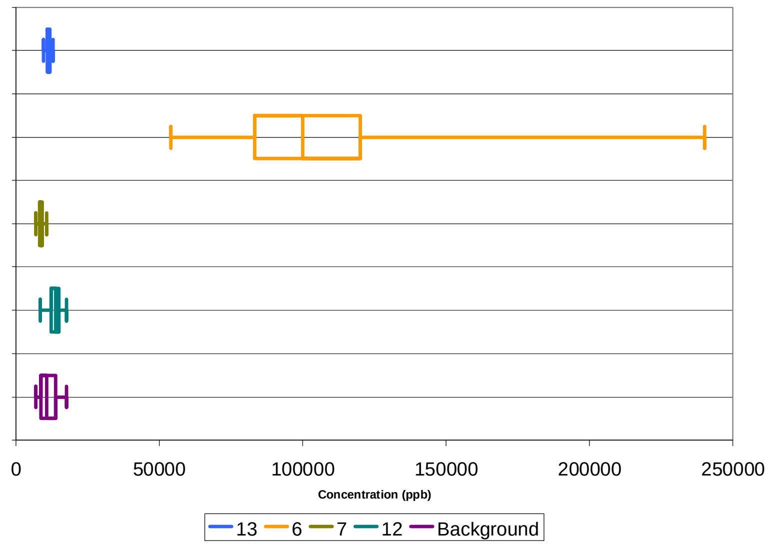

Figure 10 – Box Plot for Sodium

Figure 11, the box plot for sulfate, depicts that NRF-13 has elevated sulfate concentrations when compared to the surrounding wells and the regional background, except NRF-6. NRF-6 has much higher sulfate concentrations than the surrounding wells and the regional background. The variation in the concentrations of sulfate in NRF-13 is similar to the surrounding wells and the regional background, except NRF-6 which exhibits a larger variation in concentration.

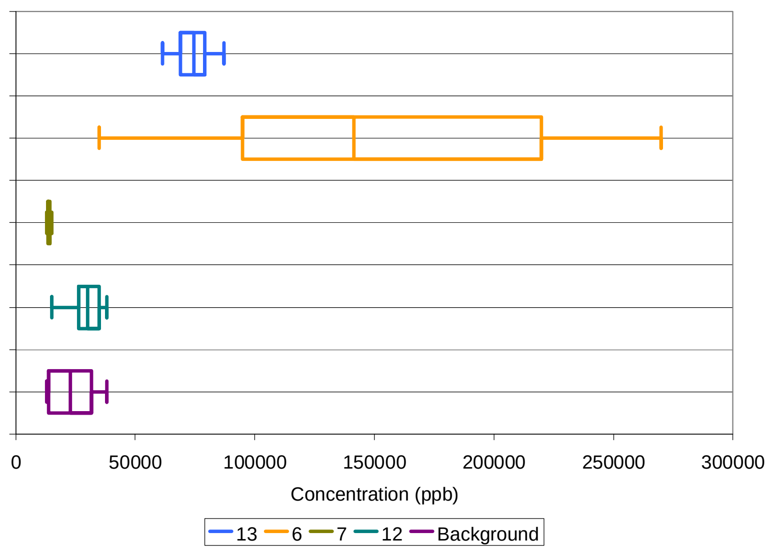

Figure 11 – Box Plot for Sulfate

Figure 12, the box plot for nitrogen, depicts that NRF-13 has lower nitrogen concentrations when compared to the surrounding wells, excluding NRF-7 which is slightly lower than NRF-13. The variation in the concentrations of nitrogen in NRF-13 is smaller than the variation in USGS-12 and the regional background but similar to the variation in NRF-6 and NRF-7.

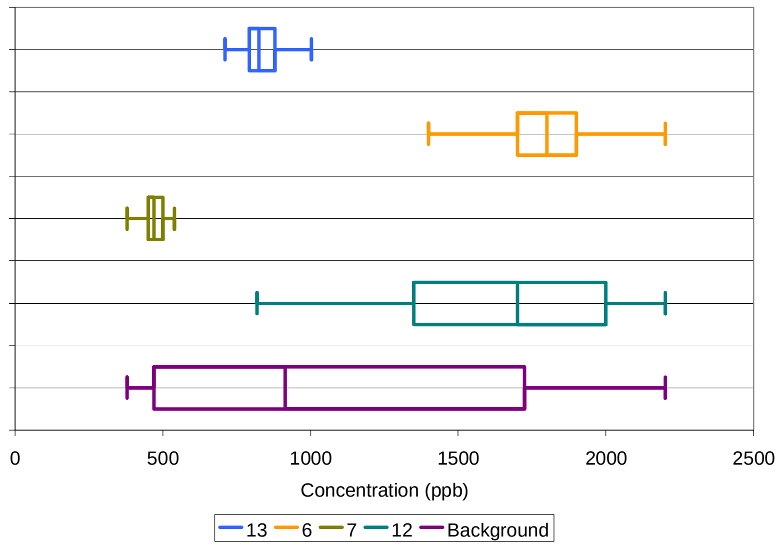

Figure 12 – Box Plot for Total Nitrogen

2.0 Groundwater Data

The following table presents the groundwater data for NRF-6, NRF-7, NRF-13, USGS-97, USGS-98, and USGS-99. Data points highlighted in orange were determined to be outliers using the methodology presented in Section 1.2.

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
NRF-6	1/8/1992	7.82	1310				41.0	110		16.0				54000	200000	230000	1600
NRF-6	3/10/1992	7.92	1315				45.0	120		21.0				81000	200000	230000	1700
NRF-6	5/14/1992	7.92	1340				35.0	80		5.0				72000	190000	210000	1700
NRF-6	7/8/1992	7.88	1390				1.0	70		7.0				91000	200000	220000	1800
NRF-6	9/18/1992	8.05	1400				1.0	140		10.0				90000	210000	240000	1700
NRF-6	12/9/1992	7.86	1400				41.0	100		8.0				95000	210000	240000	1800
NRF-6	4/9/1993	7.89	1470				11.0	280		13.0				100000	230000	250000	1900
NRF-6	9/14/1993	7.83	1450				42.0	1100		48.0				97000	210000	240000	1800
NRF-6	11/4/1993	7.76	1428				32.0	400						95000	205000	35000	1900
NRF-6	3/10/1994	7.82	1415				40.0	150		23.0				88000	200000	230000	1800
NRF-6	6/9/1994	7.87	1357				40.0	2200		47.0				86000	190000	220000	1800
NRF-6	12/21/1994	7.68	1620				33.0	370		4.0					250000	260000	1900
NRF-6	3/16/1995	7.80	1601			10.0	37.0	800	10.0	12.0				73000	250000	270000	1900
NRF-6	6/9/1995	7.84	1638			40.0	38.0	940	10.0	9.0				130000	250000	270000	1900
NRF-6	9/13/1995	7.88	1526			20.0	34.0	1500	10.0	40.0				120000	230000	240000	1900
NRF-6	11/7/1995	7.88	1460			10.0	38.0	370	10.0	28.0				100000	220000	230000	1800
NRF-6	1/16/1996	7.37	1447			20.0	34.0	150	10.0	6.0	130000	4400	37000	100000	220000	220000	1900
NRF-6	3/19/1996	7.86	1478			10.0	30.0	130	10.0	8.0	52000	4400	35000	110000	230000	210000	1900
NRF-6	6/10/1996	7.91	1454			10.0	30.0	320	10.0	11.0	120000	4700	36000	100000	230000	210000	1900
NRF 6	9/5/1996	7.85	1480			10.0	27.0	240	10.0	8.0	130000	4400	35000	110000	240000	200000	1700
NRF 6	1/31/1997	7.88	1500			10.0	95.0	2100	25.0	40.0	130000	5000	32000	110000	270000	200000	1800
NRF-6	6/5/1997	7.83	1440			100.0	400.0	3400	14.0	28.0	134000	5000	34400	122000	267000	194000	2000
NRF-6	9/2/1997	7.87	1450	818	5.04	100.0	34.0	710	7.0	21.0	141000	5700	35900	124000	257000	191000	1900
NRF-6	11/17/1997	7.85	1420	816	2.12	100.0	27.0	610	7.8	14.0	128000	5000	33000	115000	251000	182000	1800
NRF-6	2/9/1998	7.91	1492	810	0.53	100.0	30.0	250	3.5	24.0	132000	5300	33700	118000	261000	165000	2000
NRF-6	5/11/1998	7.97	1451	788	7.52	100.0	42.0	500	7.1	27.0	137000	5000	34200	119000	245000	156000	1700
NRF-6	8/4/1998	7.90	1418	770	4.93	100.0	42.8	490	5.7	29.9	125000	4530	33400	113000	243000	159000	1600
NRF-6	11/2/1998	7.94	1347	731	4.69	56.0	37.0	5100	35.9	24.2	124000	4500	32100	100000	209000	145000	1600

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
NRF-6	2/4/1999	7.98	1290	700	3.66	60.6	24.2	486	4.6	11.5	114000	4480	29300	93600	199000	138000	1700
NRF-6	5/3/1999	8.05	1301	706	5.07	31.0	30.0	570	5.2	15.0	117000	4700	30400	95600	228000	131000	470
NRF-6	7/27/1999	7.89	1212	658	1.91	39.0	31.0	1100	9.3	10.0	111000	4300	28800	83900	191000	128000	1800
NRF-6	11/1/1999	7.80	1114	605	1.72	54.0	27.0	150	1.4	15.0	96300	3700	26500	77200	176000	113000	1800
NRF 6	1/31/2000	7.86	1154	627	6.46	100.0	25.0	810	5.6	8.8	96900	4800	27100	82900	158000	92100	1700
NRF-6	5/1/2000	8.00	1168	634	9.23	100.0	27.0	1100	7.7	13.0	103000	4000	27000	76400	177000	92200	1800
NRF-6	8/1/2000	7.72	1097	596	8.91	100.0	20.0	420	3.7	8.0	92800	4100	26200	73800	176000	99400	1900
NRF-6	11/7/2000	7.90	1150	624	6.94	27.0	28.0	1500	9.6	25.0	107000	4500	30100	78000	181000	96200	1900
NRF 6	2/5/2001	7.96	1166	633	4.52	100.0	26.0	990	6.4	24.0	99400	3900	27300	74200	182000	90800	1700
NRF-6	5/8/2001	7.84	1239	673	2.07	100.0	28.0	740	6.1	17.0	110000	4300	29200	83200	201000	89800	2100
NRF-6	8/8/2001	7.76	1183	642	3.67	100.0	30.0	330	3.0	5.4	104000	3900	27600	73700	197000	99400	1500
NRF-6	11/1/2001	7.92	1148	623	7.04	100.0	41.0	1500	10.0	17.0	98200	3600	26700	71300	188000	96400	1600
NRF 6	2/4/2002	7.79	1294	703	2.00	100.0	20.0	290	2.9	5.0	106000	4300	27900	82300	229000	92500	1400
NRF-6	4/29/2002	7.82	1504	816	3.10	100.0	30.0	840	6.8	14.0	117000	5000	32400	111000	287000	90600	1800
NRF-6	7/29/2002	7.77	1459	792	1.71	100.0	39.0	910	7.0	8.0	118000	4900	32400	111000	280000	88500	1600
NRF-6	11/4/2002	7.84	1437	780	4.58	100.0	21.0	2200	16.0	12.0	110000	4200	30000	100000	280000	94000	1600
NRF 6	3/24/2003	7.79	1760	956	2.16	20.0	34.0	1100	8.7	13.0	140000	4800	37000	140000	380000	93000	1600
NRF-6	7/28/2003	7.86	1550	842	5.98	47.0	53.0	1100	9.1	7.8	140000	5300	36000	130000	300000	90000	1800
NRF-6	11/17/2003	7.56	1560	847	51.60	80.0	460.0	39000	350.0	1000.0	150000	5400	38000	130000	370000	100000	1500
NRF 6	3/29/2004	7.64	2210	1200	0.61	62.0	26.0	84	0.1	4.6	160000	5900	42000	200000	540000	97000	2100
NRF-6	7/19/2004	7.63	1960	1064	0.69	20.0	26.0	150	0.0	4.6	140000	5300	37000	170000	440000	100000	2000
NRF-6	12/14/2004	7.66	2020	1097	1.21	55.0	31.0	62	0.0	3.3	150000	5900	42000	190000	540000	93000	2000
NRF 6	3/22/2005	7.52	2360	1265	2.05	55.0	33.0	120	1.9	7.2	180000	7100	46000	240000	620000	91000	2200
NRF-6	7/19/2005	7.39	2140	1162	2.61	17.0	32.0	200	0.9	3.1	160000	5800	41000	190000	480000	99000	2100
NRF-6	11/2/2005	7.48	2010	1091	0.94	17.0	29.0	68	0.9	1.6	150000	6200	39000	170000	430000	95000	1800
NRF 6	3/28/2006	7.46	2170		1.44	29.7	31.3	129	1.2	4.0	163333	6367	42000	200000	510000	95000	2033
NRF-7	9/10/1991	8.50	257			400.0	10.0	670	20.0	9.0	30000	2800	9000	9300	0	14000	380
NRF-7	1/8/1992	8.46	232				9.0	330		4.0				8100	6500	19000	390
NRF-7	3/10/1992	8.50	232											7000	6500	17000	440
NRF-7	5/14/1992	8.42	240				8.0	620		5.0				8700	5100	15000	420
NRF-7	7/8/1992	8.72	255				1.0	3900		3.0				8900	5100	16000	460

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
NRF-7	9/18/1992	8.50	244				5.0	180		1.0				11000		35000	500
NRF-7	12/9/1992	8.32	243				11.0	210		6.0				8400	5500	16000	540
NRF-7	4/9/1993	8.26	243				13.0	330		5.0				8100	5400	15000	470
NRF-7	6/10/1993	8.37	245				11.0	600		6.0				7800	5500	15000	480
NRF-7	9/14/1993	8.11	254				10.0	180		4.0				8500	5000	15000	530
NRF-7	11/3/1993	8.07	257				12.0	330						8700	4800	15000	530
NRF-7	3/15/1994	8.10	243				10.0	280		4.0				8100	5000	14000	470
NRF-7	6/13/1994	8.14	240				27.0	4800		1.0				8300	4900	14000	430
NRF-7	9/12/1994	8.30	250				12.0	550		7.0				8600	5200	14000	460
NRF-7	11/4/1994	8.30	254				13.0	210		4.0				8000	4900	14000	460
NRF-7	3/17/1995	8.11	238			70.0	12.0	110	10.0	3.0				4500	5300	13000	380
NRF-7	6/9/1995	8.21	243			110.0	14.0	1100	10.0	5.0				9300	4800	13000	450
NRF-7	9/14/1995	8.47	248			70.0	13.0	110	10.0	4.0				9000	4900	13000	500
NRF-7	11/8/1995	8.27	259			300.0	14.0	690	20.0	6.0				8600	4900	13000	430
NRF-7	1/16/1996	7.98	248			160.0	14.0	180	10.0	6.0	25000	2900		9100	4600	13000	490
NRF-7	3/19/1996	8.15	249			80.0	15.0	160	10.0	6.0	25000	2800	8900	8900	5000	14000	460
NRF-7	6/10/1996	8.34	250			60.0	15.0	70	10.0	6.0	25000	2800	9300	8700	5100	13000	500
NRF-7	9/3/1996	8.51	236			70.0	13.0	230	10.0	6.0	24000	2800	9000	9500	5200	14000	470
NRF-7	1/31/1997	8.55	210			100.0	12.0	340	9.0	10.0	21000	3000	8300	9000	5400	15000	450
NRF-7	6/5/1997	8.15	238			130.0	9.7	540	7.6	6.3	26900	2900	8900	9100	4700	13500	720
NRF-7	9/2/1997	8.46	240	130	3.85	44.0	10.0	93	3.6	5.2	26600	2900	9100	8300	4600	13700	680
NRF-7	11/17/1997	8.41	247	134	2.94	100.0	10.0	1800	24.0	8.2	27200	3300	9500	9500	4000	13800	440
NRF-7	2/9/1998	8.21	255	138	1.36	57.0	9.6	100	4.0	7.7	28700	3300	9600	9000	4500	13400	590
NRF-7	5/11/1998	8.25	265	144	7.00	100.0	11.0	80	5.5	6.5	31500	3300	9500	9700	4300	13600	470
NRF-7	8/5/1998	8.50	240	130	2.92	100.0	11.4	100	10.0	10.0	24100	2720	9390	8270	4800	13900	470
NRF-7	11/2/1998	8.28	258	140	6.63	160.0	11.0	130	3.6	5.7	30400	2800	9400	9400	4900	13100	460
NRF-7	2/4/1999	8.16	261	142	6.56	120.0	10.1	101	3.3	10.0	27100	3020	9480	8730	5100	13200	530
NRF-7	5/3/1999	8.44	255	138	4.48	120.0	8.5	270	5.4	9.5	27700	3200	9700	9500	5300	13300	660
NRF-7	7/27/1999	8.05	262	142	10.10	200.0	11.0	310	10.0	9.3	30000	2900	9800	8200	5300	14000	470
NRF-7	11/1/1999	8.12	261	142	43.70	560.0	13.0	700	34.0	11.0	28300	3000	9800	8900	5800	14200	470
NRF 7	1/31/2000	8.33	250	136	14.70	370.0	12.0	570	15.0	9.9	25900	3300	9400	11500	4700	13400	500
NRF-7	5/1/2000	8.27	263	143	18.40	330.0	12.0	440	13.0	8.5	28900	2900	9100	8000	4600	13600	460

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
NRF-7	8/1/2000	8.01	245	133	4.30	27.0	12.0	110	3.8	7.0	24200	2900	9000	8100	5200	13800	460
NRF-7	11/6/2000	8.16	253	137	13.00	330.0	13.0	940	15.0	9.2	26700	3300	9800	9300	5100	13700	540
NRF 7	2/5/2001	8.33	249	135	16.10	470.0	13.0	990	16.0	13.0	25600	2900	9400	8000	5100	13600	490
NRF-7	5/7/2001	8.23	253	137	11.10	260.0	12.0	380	10.0	12.0	27900	3700	9400	8300	5300	13800	2500
NRF-7	8/6/2001	8.16	257	140	16.20	170.0	14.0	250	8.4	14.0	30300	3700	9900	10700	5200	13900	430
NRF-7	11/1/2001	8.40	243	132	3.46	53.0	13.0	57	2.1	9.1	21600	2800	8600	8500	4800	13800	430
NRF 7	2/4/2002	8.43	239	130	2.72	75.0	9.1	120	2.6	11.0	21100	2600	8700	7900	4700	13800	360
NRF-7	4/29/2002	8.40	235	128	3.84	22.0	10.0	61	3.2	11.0	22500	3200	9300	9100	5200	13700	540
NRF-7	7/29/2002	8.18	249	135	3.30	45.0	13.0	58	2.4	9.4	24800	3300	9400	9700	4800	13700	460
NRF-7	11/4/2002	8.38	246	134	104.00	5400.0	15.0	6300	130.0	30.0	34000	4200	12000	9700	5400	15000	470
NRF 7	3/24/2003	8.26	231	125	92.50	1800.0	19.0	2000	54.0	18.0	28000	3200	11000	9400	5100	14000	440
NRF-7	7/28/2003	8.12	237	129	101.00	6300.0	29.0	2200	120.0	27.0	32000	4300	12000	10000	5200	14000	480
NRF-7	11/17/2003	8.21	240	130	104.00	1800.0	27.0	1200	95.0	22.0	34000	3900	11000	9000	5300	15000	400
NRF 7	3/29/2004	8.25	241	131	117.00	870.0	26.0	1200	77.0	17.0	30000	3200	10000	9200	4900	15000	480
NRF-7	7/19/2004	8.87	202	110	9.33	72.0	13.0	130	8.1	12.0	16000	2800	8900	9000	4900	13000	450
NRF-7	12/14/2004	8.11	236	128	4.50	55.0	17.0	99	5.5	14.0	22000	2700	9300	7600	5100	14000	410
NRF 7	3/22/2005	7.90	242	131	10.50	160.0	14.0	250	7.1	9.8	26000	3200	9600	9800	5200	13000	700
NRF-7	7/21/2005	7.83	255	138	2.65	64.0	14.0	1100	14.0	6.9	27000	2900	9200	9700	4900	13000	540
NRF-7	11/1/2005	7.74	251	136	2.94	41.0	14.0	130	4.6	7.3	27000	2900	9000	8500	4700	13000	450
NRF 7	4/4/2006	8.21	226	123	2.99	29.0	11.0	100	4.7	12.0	25000	3000	9100	9200	4800	13000	460
NRF-13	1/22/1996	8.17	496			2800.0	31.0	2500	40.0	6.0	63000	5000	18000	12000	58000	67000	810
NRF-13	3/20/1996	8.35	489			10.0	30.0	3400	60.0	8.0	71000	4800	18000	10000	57000	69000	740
NRF-13	6/13/1996	8.36	532			3500.0	34.0	3100	60.0	10.0	70000	4600	22000	11000	61000	69000	800
NRF-13	9/5/1996	8.51	540			1400.0	26.0	1300	10.0	5.0	64000	4200	19000	62000	60000	73000	750
NRF-13	2/3/1997	8.37	430				55.0	16000	300.0	40.0	100000	6000	25000	13000	57000	68000	750
NRF-13	6/9/1997	8.26	506			4800.0	35.0	4200	43.0	16.0	75600	4800	21200	12200	66700	76100	900
NRF-13	9/5/1997	8.26	562	305	37.80	19200.0	39.0	20500	220.0	34.0	103000	4900	32600	14100	63300	74800	800
NRF-13	11/19/1997	8.21	556	302	20.20	2800.0	34.0	3600	72.0	19.0	74100	4700	20200	11400	65300	78800	980
NRF-13	2/11/1998	8.27	548	298	35.70	1400.0	29.0	1400	2.4	12.0	61800	4200	16900	10700	65200	78600	1100
NRF-13	5/13/1998	8.18	587	319	26.30	350.0	27.0	820	15.0	4.1	73300	4000	20000	10900	68000	83100	830
NRF-13	8/5/1998	8.20	587	319	67.80	597.0	47.2	1710	41.7	18.4	71200	4000	20700	10900	69400	85800	740

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
NRF-13	11/4/1998	7.99	616	334	64.10	3100.0	25.0	2500	41.0	21.0	71900	4100	21900	11200	69100	82000	890
NRF-13	2/11/1999	8.11	623		56.40	1680.0	78.0	2030	37.0	41.8	71100	3870	20400	9590	69000	82100	910
NRF-13	5/5/1999	7.96	578	314	105.00	2200.0	74.0	2600	67.0	20.0	74000	4100	20500	11200	69600	75600	800
NRF-13	7/29/1999	7.89	624	339	61.40	3800.0	49.0	3500	58.0	13.0	78100	3900	24100	11900	69000	81000	870
NRF-13	11/3/1999	7.96	618	336	83.80	2400.0	92.0	2600	44.0	27.0	73900	4000	21900	12300	81200	86900	840
NRF-13	2/2/2000	8.02	586	318	172.00	16800.0	310.0	15100	260.0	48.0	84800	5100	27200	12000	64600	78800	750
NRF-13	5/3/2000	7.98	596	324	98.00	3000.0	79.0	3100	50.0	30.0	72000	3700	21500	10100	65400	78200	850
NRF-13	8/3/2000	7.83	609	331	91.00	3300.0	94.0	3000	52.0	25.0	62600	4000	20200	10100	72300	81800	820
NRF-13	11/9/2000	8.05	567	308	102.00	3400.0	190.0	3900	60.0	95.0	69100	4300	20400	12000	59000	72100	810
NRF 13	2/7/2001	7.93	597	324	56.50	2000.0	65.0	2000	32.0	21.0	67700	3500	21400	11200	63500	75200	820
NRF 13	5/9/2001	7.98	585	318	61.90	2100.0	67.0	2000	35.0	25.0	68600	3800	21500	10700	64200	74400	1300
NRF 13	8/8/2001	7.96	590	320	29.90	810.0	69.0	930	15.0	13.0	64900	3300	20300	7300	65600	74200	720
NRF 13	11/6/2001	7.96	581	581	48.20	1600.0	51.0	1600	28.0	26.0	67500	3900	21300	12300	61500	71800	860
NRF 13	2/7/2002	8.03	568	308	73.00	2200.0	63.0	2300	37.0	48.0	65600	3600	20200	11400	56200	66600	790
NRF 13	5/1/2002	8.01	580	315	57.10	900.0	63.0	1500	32.0	24.0	65700	4100	21700	12400	61100	69000	870
NRF 13	8/1/2002	7.98	571	310	55.60	740.0	85.0	1300	29.0	46.0	61000	3700	20000	12000	63000	74000	750
NRF 13	11/6/2002	8.00	573	311	67.00	1700.0	30.0	1700	34.0	30.0	65000	4100	21000	11000	62000	76000	1100
NRF 13	3/26/2003	7.81	591	321	83.00	3300.0	61.0	3000	52.0	34.0	71000	3600	23000	9900	63000	69000	800
NRF 13	7/30/2003	7.98	590	320	86.10	3000.0	60.0	3100	52.0	34.0	76000	3600	24000	12000	61000	73000	830
NRF 13	11/19/2003	7.74	597	324	80.80	1200.0	92.0	1600	37.0	38.0	73000	3400	23000	11000	68000	79000	730
NRF 13	3/30/2004	7.70	610	331	90.90	1400.0	81.0	1900	45.0	37.0	72000	3600	22000	12000	71000	87000	880
NRF 13	7/21/2004	7.60	589		95.60	1600.0	81.0	1900	43.0	41.0	70000	3600	23000	11000	67000	74000	810
NRF 13	12/16/2004	7.84	475	258	142.00	3900.0	180.0	6200	110.0	77.0	64000	3300	21000	10000	58000	69000	710
NRF 13	3/23/2005	7.74	588	319	42.70	800.0	66.0	1300	23.0	27.0	74000	4100	23000	11000	74000	80000	830
NRF 13	7/20/2005	7.47	606	329	62.00	1300.0	98.0	1700	24.0	39.0	74000	4200	23000	12000	45000	39000	1300
NRF 13	11/2/2005	7.43	617	335	25.20	630.0	62.0	830	12.0	16.0	75000	3700	23000	11000	57000	65000	880
NRF 13	4/3/2006	7.55	604	336	27.00	910.0	75.3	1277	19.7	27.3	74333	4000	23000	11333	58667	61333	1003
USGS-12	6/15/1990	7.80	550			50.0	8.0	30	10.0	1.0	64000	1900	20000	13000	31000	32000	1600
USGS-12	8/6/1990	7.90	595				8.0	10	10.0	1.0				10000	32000	32000	1600
USGS-12	10/10/1990	7.80	545				8.0	40	10.0	1.0				12000	32000	33000	1700
USGS-12	12/11/1990	7.90	552				7.0	140	10.0	1.0				12000	35000	35000	1800

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
USGS-12	2/7/1991	7.80	600				7.0	60	10.0	1.0				12000	34000	35000	1700
USGS-12	4/11/1991	7.80	560					140	10.0					13000	33000	37000	1700
USGS-12	6/10/1991	7.80	575				4.0	120		1.0				13000	31000	26000	1800
USGS-12	9/6/1991	7.90	590				7.0	50		1.0				13000	29000	29000	1700
USGS-12	12/5/1991	7.90	575				6.0	70		1.0				12000	36000	36000	1800
USGS-12	3/12/1992	7.84	610				7.0	20		1.0				14000	40000	38000	1900
USGS-12	6/19/1992	7.93	580				5.0	50		1.0				15000	40000	35000	2000
USGS-12	9/18/1992	8.01	560				9.0	260		6.0				8500	6300	15000	950
USGS-12	12/1/1992	7.89	560				10.0	3000		7.0				7700	7100	19000	2000
USGS-12	4/13/1993	7.83	582				5.0	40		1.0				14000	37000	36000	2000
USGS-12	6/14/1993	7.92	600				5.0	40		1.0				13000	38000	37000	2100
USGS-12	9/16/1993	7.76	580				6.0	40		1.0				15000	36000	38000	2000
USGS-12	11/5/1993	7.80	590				5.0	140		2.0				16000	37000	35000	2000
USGS-12	3/11/1994	7.73	606				7.3	1300		1.0				15000	38000	37000	2200
USGS-12	6/10/1994	7.80	605				8.0	200		1.0				15000	21000	26000	2100
USGS-12	9/9/1994	7.92	600				7.3	190		1.0				15000	38000	36000	2000
USGS-12	10/27/1994	7.84	600				7.3	20		4.0				16000	39000	35000	2000
USGS-12	3/20/1995	7.76	604			10.0	6.7	320	10.0	1.0				13000	42000	35000	2100
USGS-12	6/14/1995	7.83	602			50.0	7.0	60	10.0	1.0				17000	38000	35000	2100
USGS-12	9/12/1995	7.88	598			10.0	6.5	600	10.0	1.0				17000	39000	36000	2100
USGS-12	11/2/1995	7.96	605			10.0	7.2	60	20.0	1.0				17000	40000	34000	2000
USGS-12	1/16/1996	7.47	606			10.0	6.5	30	10.0	1.0	70000	2100	24000	17000	38000	34000	2200
USGS-12	3/21/1996	7.70	597			10.0	6.9	50	10.0	1.0	77000	2100	23000	16000	40000	36000	2100
USGS-12	6/10/1996	7.94	607			10.0	7.8	30	10.0	1.0	66000	2000	24000	16000	38000	34000	2200
USGS-12	9/3/1996	7.96	595			10.0	6.8	50	10.0	1.0	68000	1900	23000	17000	38000	35000	2000
USGS-12	2/4/1997	7.85	560			10.0	10.0	830	14.0	10.0	65000	2000	21000	17000	39000	36000	1800
USGS-12	6/9/1997	7.81	526			100.0	4.9	59	1.3	2.8	70900	2200	22700	17700	36300	35400	2200
USGS-12	9/3/1997	7.88	528	308	0.49	100.0	5.3	42	1.6	2.4	67800	2000	22600	16700	32000	32100	2000
USGS-12	11/18/1997	7.79	405	301	0.79	100.0	5.8	30	1.7	3.4	66200	2200	20900	16500	29500	31500	1800
USGS-12	2/11/1998	7.74	544	295	0.89	100.0	5.7	32	2.5	4.2	66100	2300	21000	16400	28200	30100	1600
USGS-12	5/12/1998	7.98	528	287	0.78	100.0	6.2	100	1.3	0.5	65100	2100	19700	16100	25000	28400	1400
USGS-12	8/4/1998	7.93	518	281	0.30	100.0	5.9	100	10.0	10.0	59000	1830	19400	15200	24200	28200	1300

Table 3 – Groundwater Data for NRF-6, NRF-7, NRF-13, and USGS-12

Well Number	Sample Date	pH	SC µS/cm	TDS mg/L	Turbidity NTU	Al ppb	Cr ppb	Fe ppb	Mn ppb	Ni ppb	Ca ppb	K ppb	Mg ppb	Na ppb	Cl ppb	SO4 ppb	Tot N ppb
USGS-12	11/4/1998	7.87	507	275	0.46	100.0	6.3	100	0.8	0.8	57400	1800	18600	14500	19600	25000	1500
USGS-12	2/11/1999	7.99	491	267	0.42	100.0	5.1	100	10.0	10.0	56000	1940	17700	13300	17400	24300	1100
USGS 12	5/5/1999	7.76	479	260	0.28	25.0	5.7	86	10.0	10.0	58700	2200	18600	13400	17300	23200	1000
USGS 12	7/29/1999	7.80	472	256	0.59	15.0	6.5	85	10.0	10.0	57500	1700	18400	13300	14900	23900	950
USGS 12	11/3/1999	7.93	470	255	1.20	56.0	6.4	77	1.7	10.0	57300	1800	18600	13100	15800	24000	820
USGS 12	2/2/2000	7.93	465	252	0.21	100.0	5.7	57	1.2	40.0	52000	1800	17700	10800	12000	21800	900
USGS 12	5/3/2000	7.93	463	251	0.30	35.0	5.9	27	10.0	40.0	55100	1800	17400	11100	12600	22700	890
USGS 12	8/2/2000	7.78	461	250	0.34	100.0	5.9	21	10.0	40.0	51600	1900	17400	11000	14000	23500	930
USGS 12	11/8/2000	7.86	471		0.43	190.0	5.9	430	5.3	40.0	57800	1900	18000	11300	13600	23500	890
USGS 12	2/6/2001	7.97	480	261	0.62	64.0	6.3	26	10.0	40.0	57200	1800	18200	11900	14400	23600	1000
USGS 12	5/9/2001	7.90	482	262	0.35	100.0	5.5	26	1.1	40.0	58700	2300	18500	10900	16900	24900	1200
USGS 12	8/7/2001	7.83	489	266	3.05	100.0	7.9	160	2.0	40.0	58100	2100	18300	11400	18300	26300	990
USGS 12	11/6/2001	7.87	497	266	0.67	100.0	6.7	37	2.8	40.0	60500	1900	19200	13300	18500	26100	1200
USGS 12	2/6/2002	7.69	506	275	0.92	100.0	5.3	23	1.1	40.0	52900	1600	16500	10400	19800	26600	1300
USGS 12	5/1/2002	7.92	506	275	0.31	100.0	5.5	68	1.5	40.0	59100	2300	19700	14600	20700	26500	1400
USGS 12	7/30/2002	7.58	505	274	0.67	23.0	6.1	43	1.2	40.0	57600	2200	18500	12700	19900	26500	1300
USGS 12	11/6/2002	7.97	513	279	1.73	54.0	2.9	68	3.5	40.0	62000	2200	20000	13000	21000	28000	1400
USGS 12	3/26/2003	7.89	517	281	0.70	20.0	6.9	42	1.8	4.2	60000	1800	20000	12000	23000	27000	1500
USGS 12	7/30/2003	7.94	517	281	0.35	20.0	7.0	23	1.3	4.2	66000	1500	20000	14000	22000	27000	1500
USGS 12	11/19/2003	7.63	516	280	0.56	24.0	7.1	28	1.5	4.2	66000	2500	21000	14000	24000	30000	1400
USGS 12	3/31/2004	7.56	528	287	0.49	20.0	7.4	19	1.4	4.2	64000	2400	20000	15000	29000	33000	1700
USGS 12	7/21/2004	7.40	513	279	0.43	20.0	7.5	34	1.4	4.2	60000	1900	19000	13000	25000	28000	1600
USGS 12	12/15/2004	7.51	527	286	1.12	55.0	7.0	47	1.9	2.0	68000	1800	21000	15000	26000	29000	1600
USGS 12	3/23/2005	7.54	523	284	0.62	55.0	7.8	34	1.9	2.0	66000	2300	21000	15000	29000	30000	1800
USGS 12	7/20/2005	7.35	536	291	0.44	17.0	7.9	41	0.9	1.2	61000	2000	19000	14000	26000	30000	1800
USGS 12	11/1/2005	7.46	535	291	0.49	17.0	7.4	43	1.8	1.2	66000	2000	21000	15000	26000	28000	1600
USGS 12	3/28/2006	7.75	531	288	0.54	17.0	7.8	22	1.1	1.2	64000	2600	20000	15000	29000	32000	1900

Appendix B

Concentration Graphs

For

Chromium, Chloride, and Tritium

In NRF Groundwater Monitoring Wells

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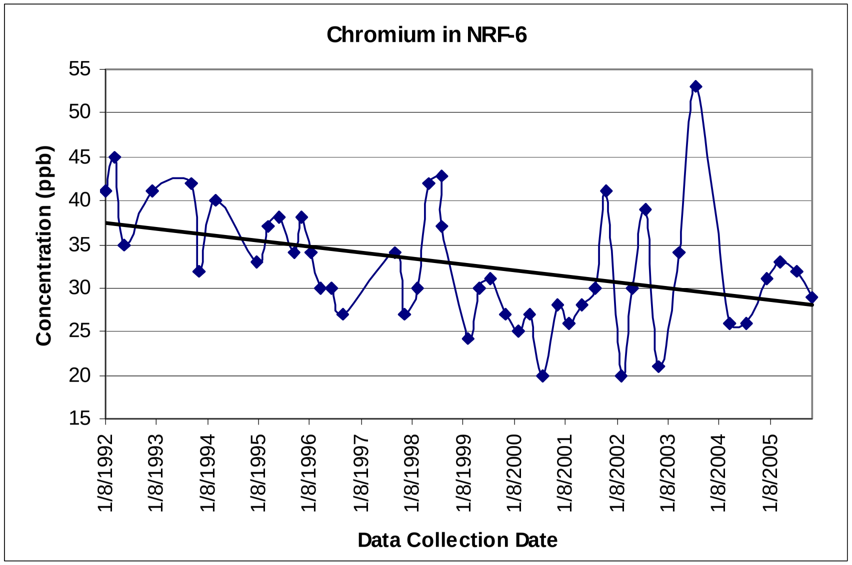
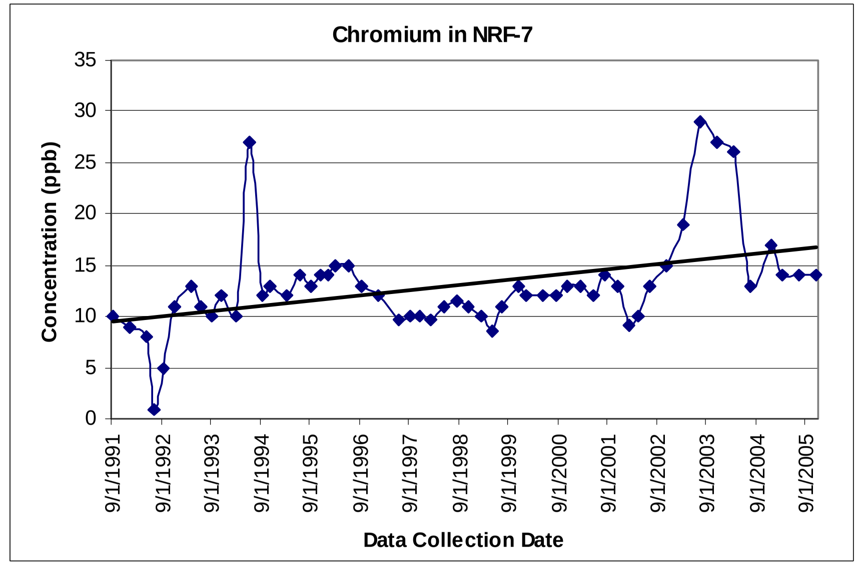
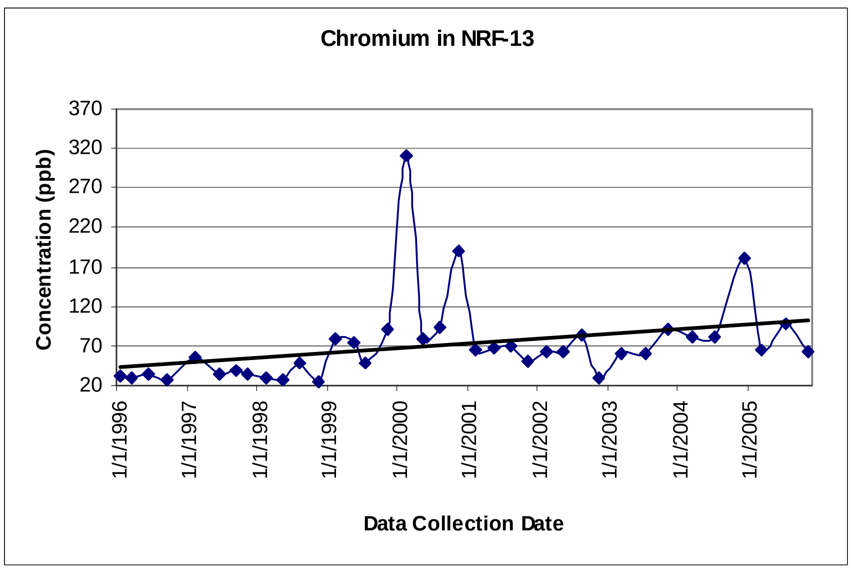
The attached figures provide groundwater data plotted on graphs showing time versus concentration. These graphs help evaluate the trend of chromium, chloride, and tritium in each NRF well. The method of least squares was used to ascertain whether the contaminant concentration was increasing, decreasing, or remaining stable over time. Section 6.3.2.4, Data Trends, of the 2006 NRF Five Year Review provides the basis for the constituents selected and a discussion of their trends.

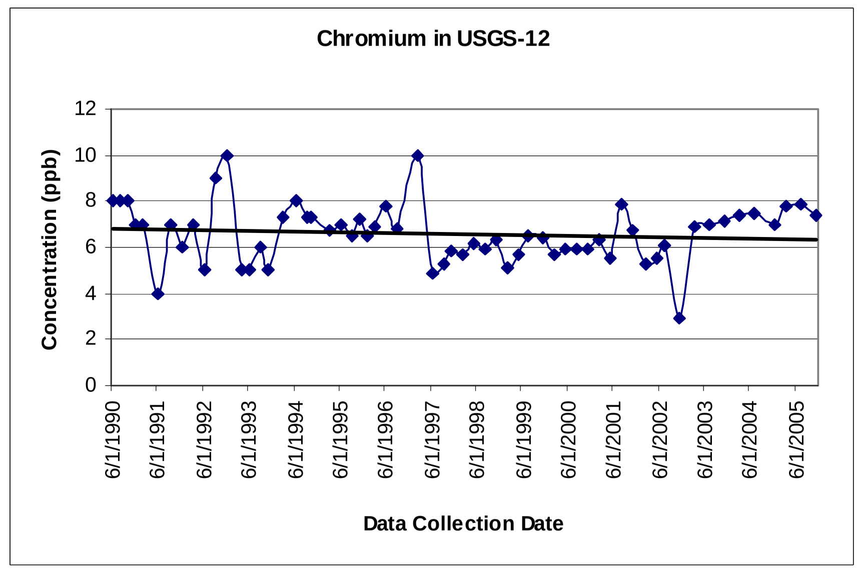
Concentration data that were considered to be extreme outliers were excluded from the graphs. For the purpose of these graphs, outliers were considered to be values that are significantly different from the remainder of the data set. Specifically, values greater than three times the well average were removed so that trends would be more apparent in the graphs.

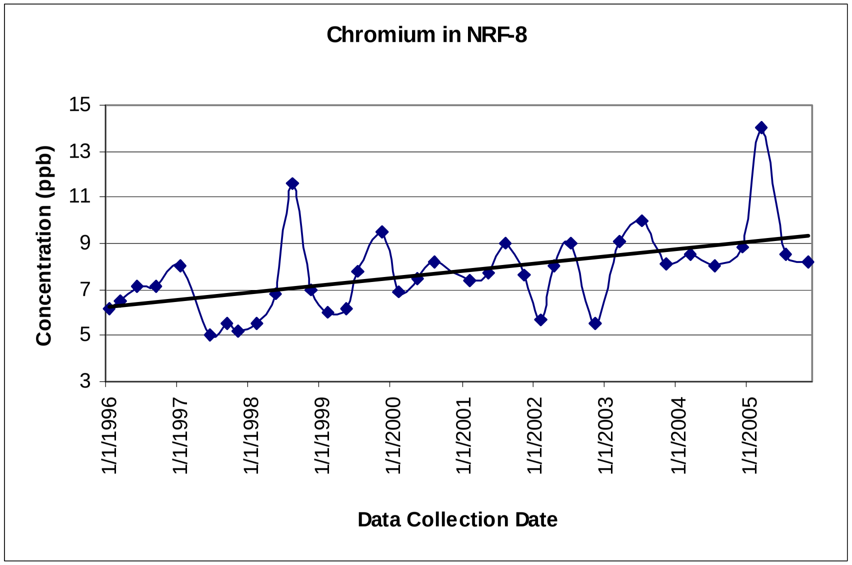
For chromium, outliers were removed for wells NRF-6, NRF-8, NRF-10, NRF-12, and USGS-97. It should be noted that outliers were not removed from NRF-13 since the increase in constituent concentrations in NRF-13 is currently of interest. No outliers were identified in the chloride concentration data. In addition, tritium concentrations measured for the third sample date in 1998 were excluded for wells NRF-6, NRF-7, NRF-8, NRF-9, NRF-10, NRF-12, USGS-12, USGS-98, and USGS-102, as these values all exhibited a similar pattern that may be attributable to laboratory error. Additional tritium concentration outliers were removed for wells NRF-7 and USGS-98.

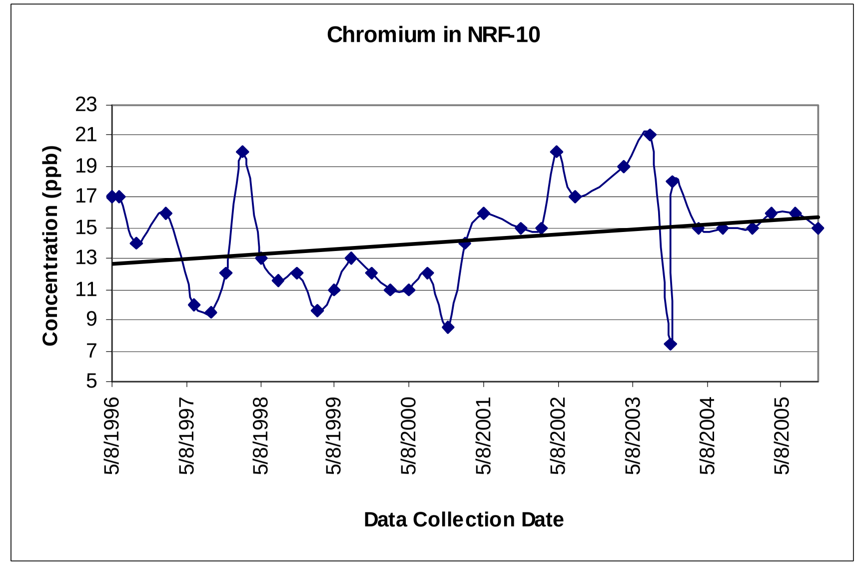

Chromium in NRF-6
Concentration (ppb)
55
50
45
40
35
30
25
20
15
1/8/1992
1/8/1993
1/8/1994
1/8/1995
1/8/1996
1/8/1997
1/8/1998
1/8/1999
1/8/2000
1/8/2001
1/8/2002
1/8/2003
1/8/2004
1/8/2005
Data Collection Date

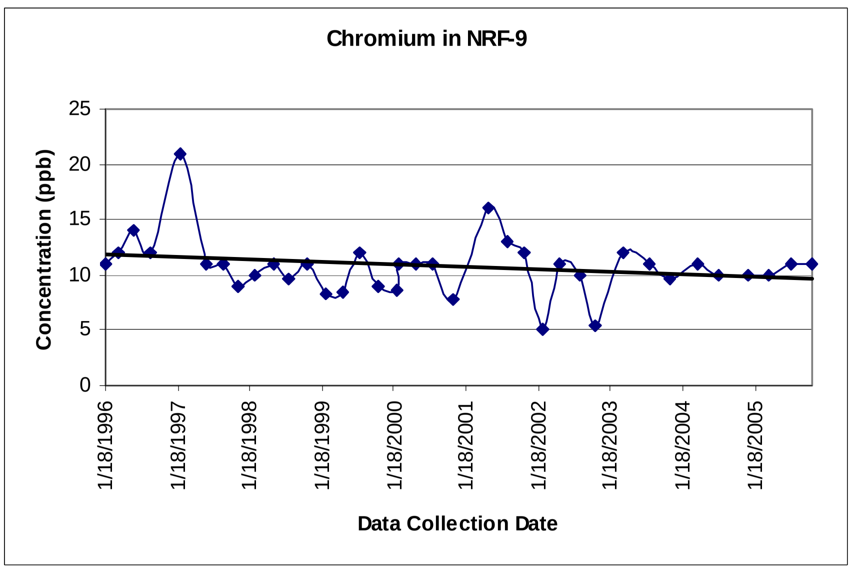

Chromium in NRF-7
Concentration (ppb)
35
30
25
20
15
10
5
0
9/1/1991
9/1/1992
9/1/1993
9/1/1994
9/1/1995
9/1/1996
9/1/1997
9/1/1998
9/1/1999
9/1/2000
9/1/2001
9/1/2002
9/1/2003
9/1/2004
9/1/2005
Data Collection Date

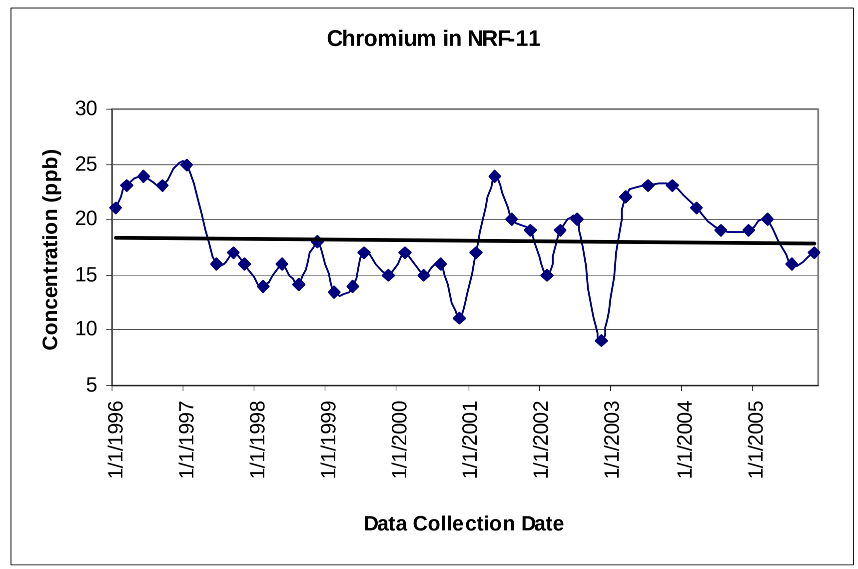

Chromium in NRF-13
Concentration (ppb)
370
320
270
220
170
120
70
20
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

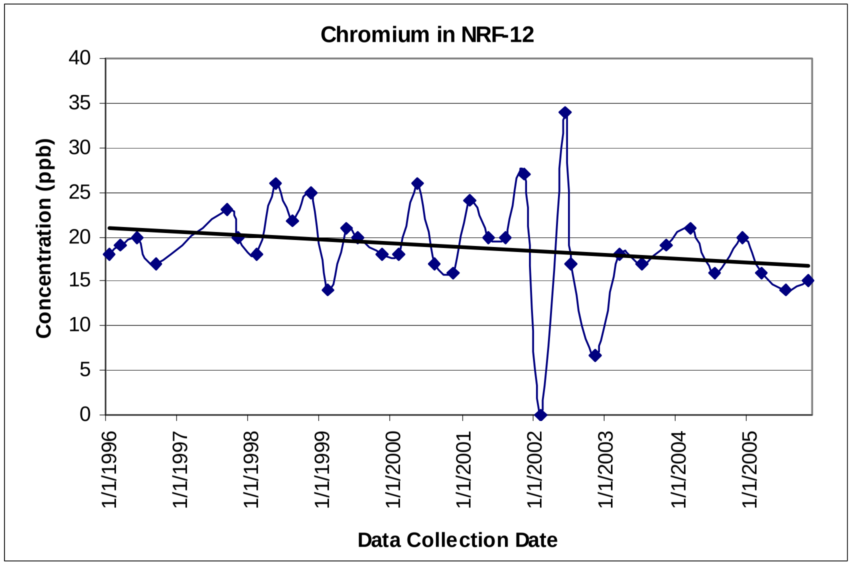

Chromium in USGS-12
Concentration (ppb)
12
10
8
6
4
2
0
6/1/1990
6/1/1991
6/1/1992
6/1/1993
6/1/1994
6/1/1995
6/1/1996
6/1/1997
6/1/1998
6/1/1999
6/1/2000
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
Data Collection Date

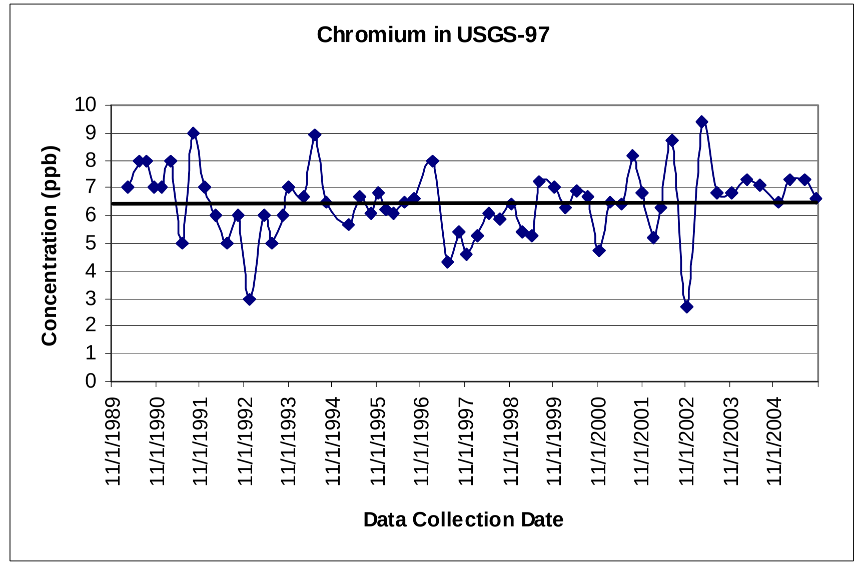

Chromium in NRF-8
Concentration (ppb)
3
5
7
9
11
13
15
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

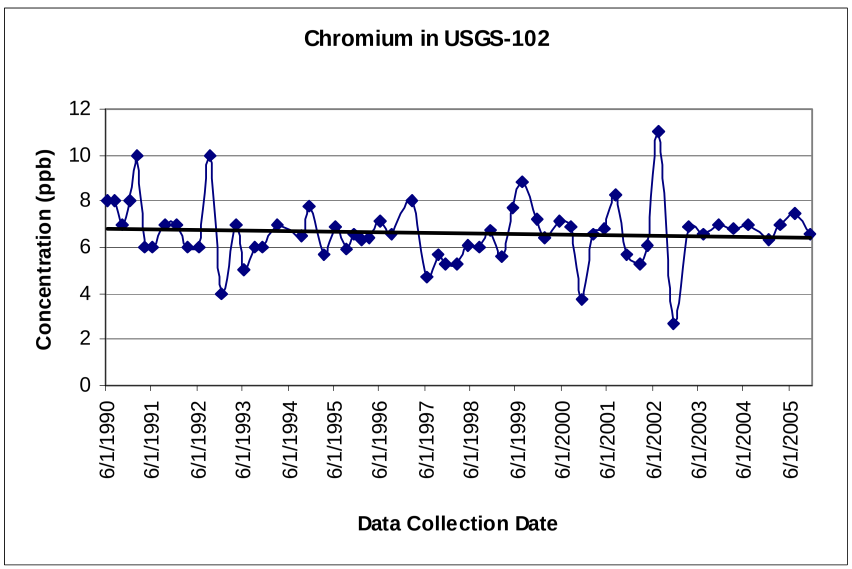

Chromium in NRF-10
Concentration (ppb)
5
7
9
11
13
15
17
19
21
23
5/8/1996
5/8/1997
5/8/1998
5/8/1999
5/8/2000
5/8/2001
5/8/2002
5/8/2003
5/8/2004
5/8/2005
Data Collection Date

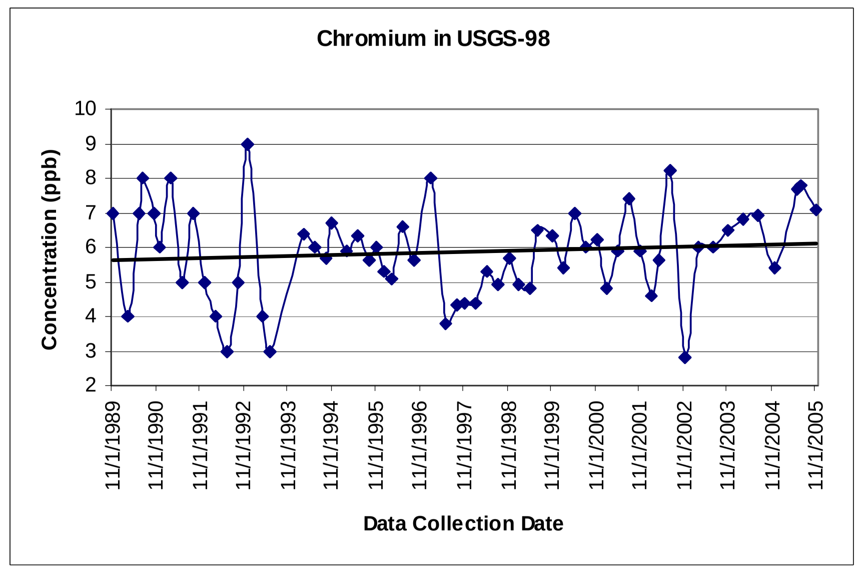

Chromium in NRF-9
Concentration (ppb)
0
5
10
15
20
25
1/18/1996
1/18/1997
1/18/1998
1/18/1999
1/18/2000
1/18/2001
1/18/2002
1/18/2003
1/18/2004
1/18/2005
Data Collection Date

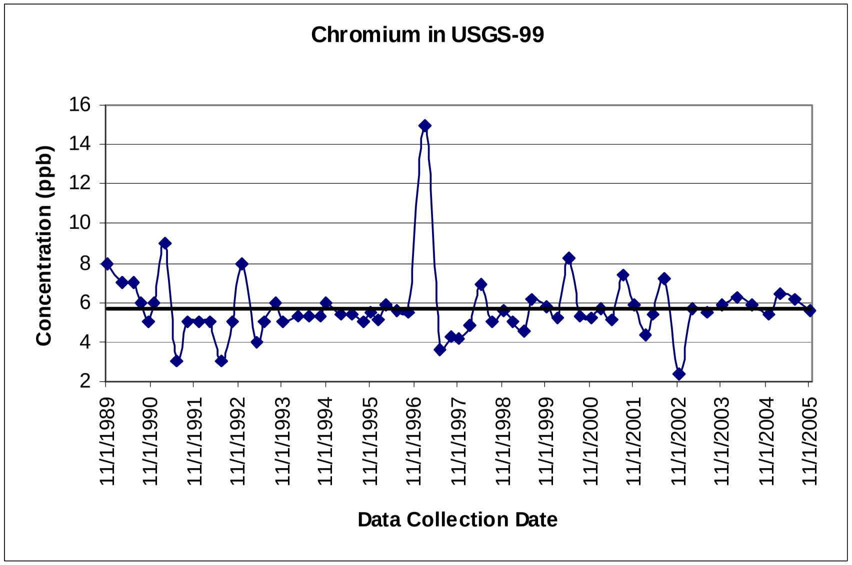

Chromium in NRF-11
Concentration (ppb)
5
10
15
20
25
30
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

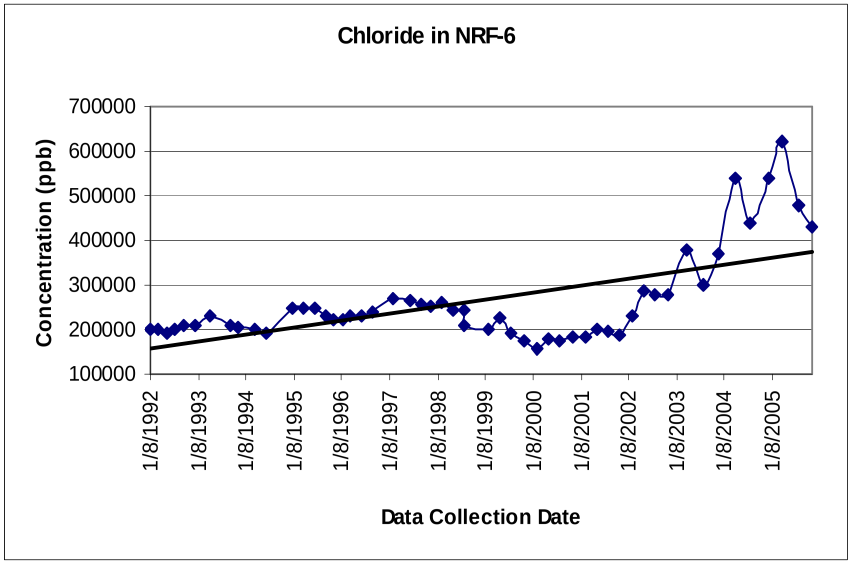

Chromium in NRF-12
Concentration (ppb)
0
5
10
15
20
25
30
35
40
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

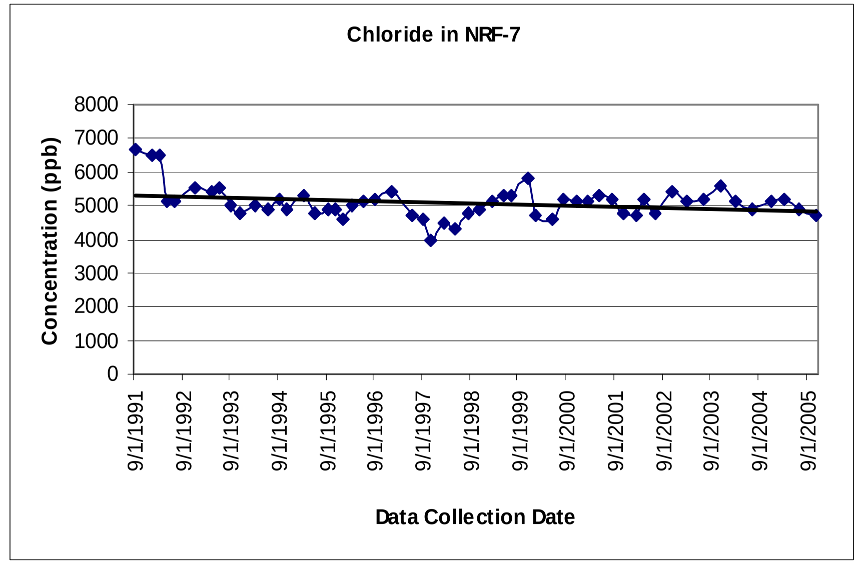

Chromium in USGS-97
Concentration (ppb)
0
1
2
3
4
5
6
7
8
9
10
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
Data Collection Date

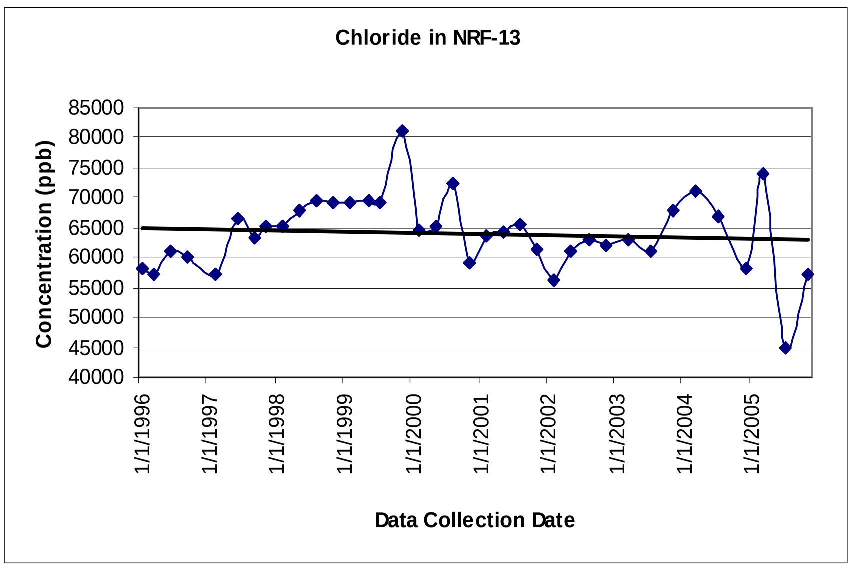

Chromium in USGS-102
Concentration (ppb)
0
2
4
6
8
10
12
6/1/1990
6/1/1991
6/1/1992
6/1/1993
6/1/1994
6/1/1995
6/1/1996
6/1/1997
6/1/1998
6/1/1999
6/1/2000
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
Data Collection Date

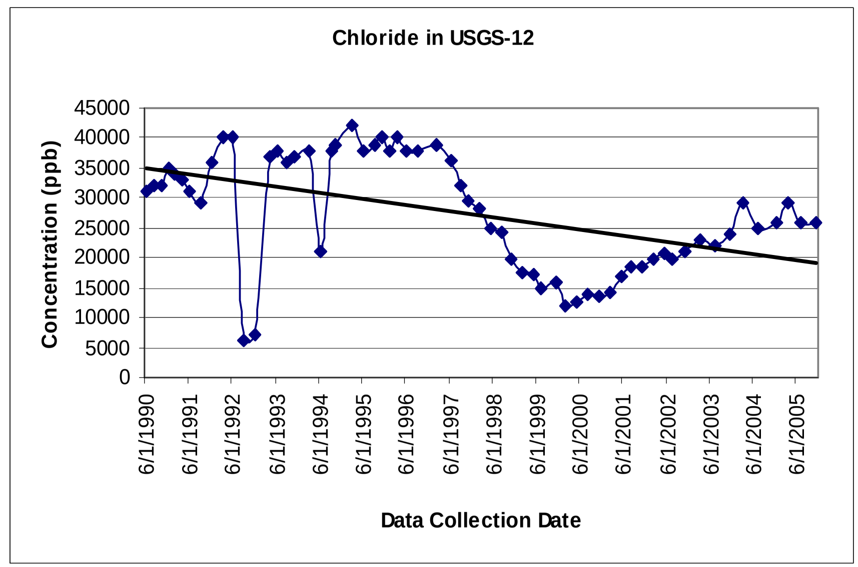

Chromium in USGS-98
Concentration (ppb)
2
3
4
5
6
7
8
9
10
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
Data Collection Date

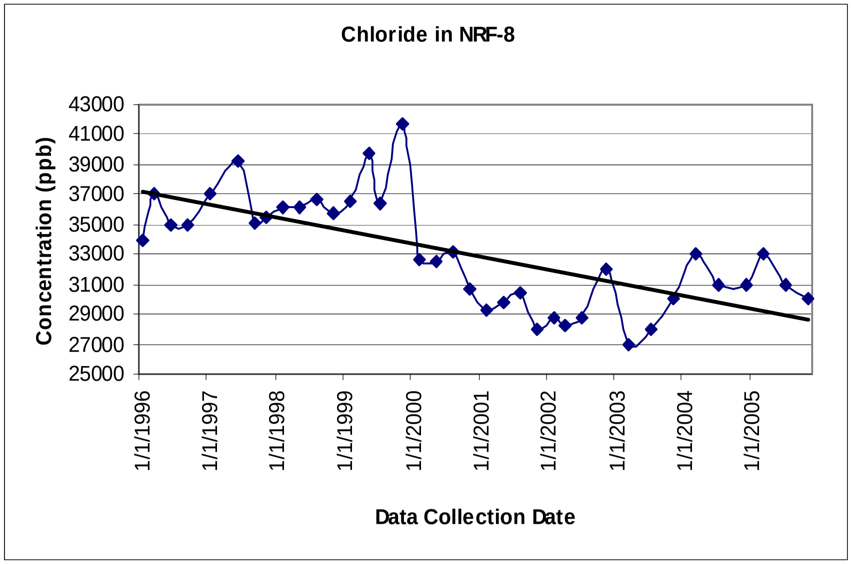

Chromium in USGS-99
Concentration (ppb)
16
14
12
10
8
6
4
2
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
Data Collection Date

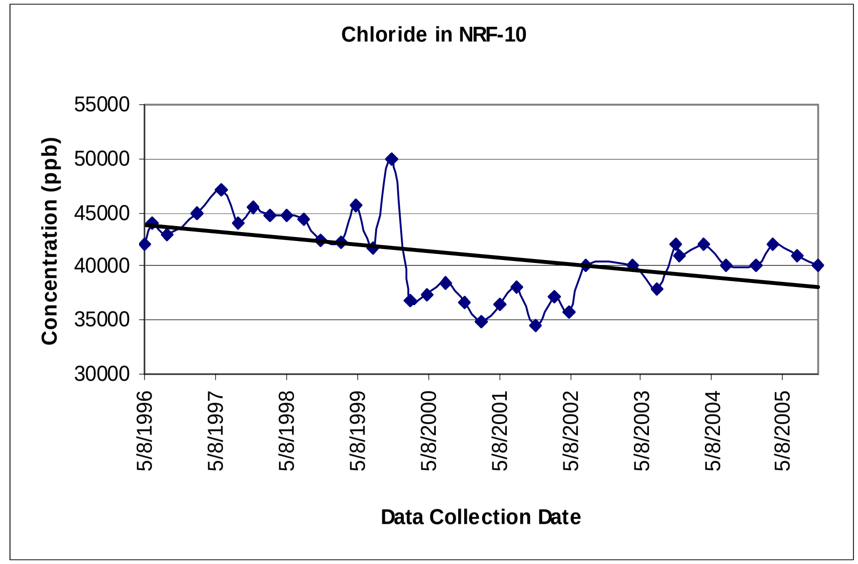

Chloride in NRF-6
Concentration (ppb)
Data Collection Date

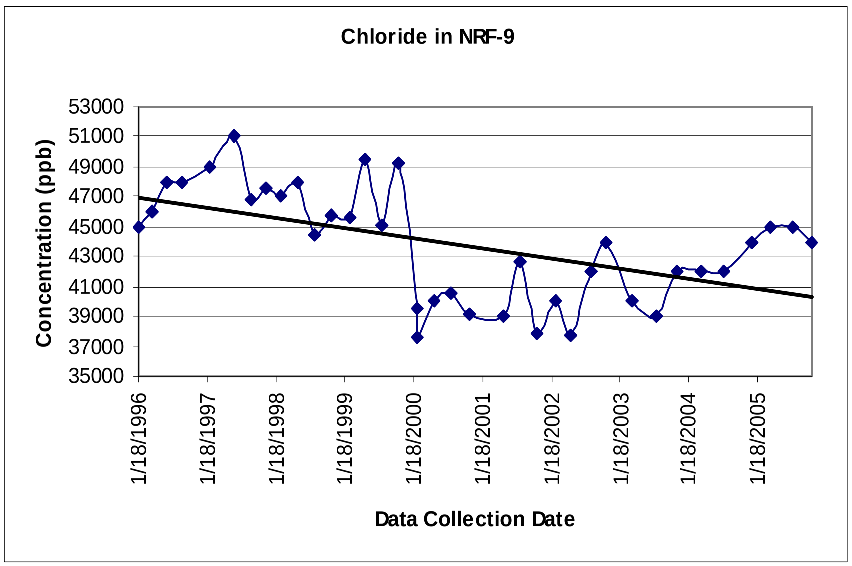

Chloride in NRF-7
Concentration (ppb)
Data Collection Date

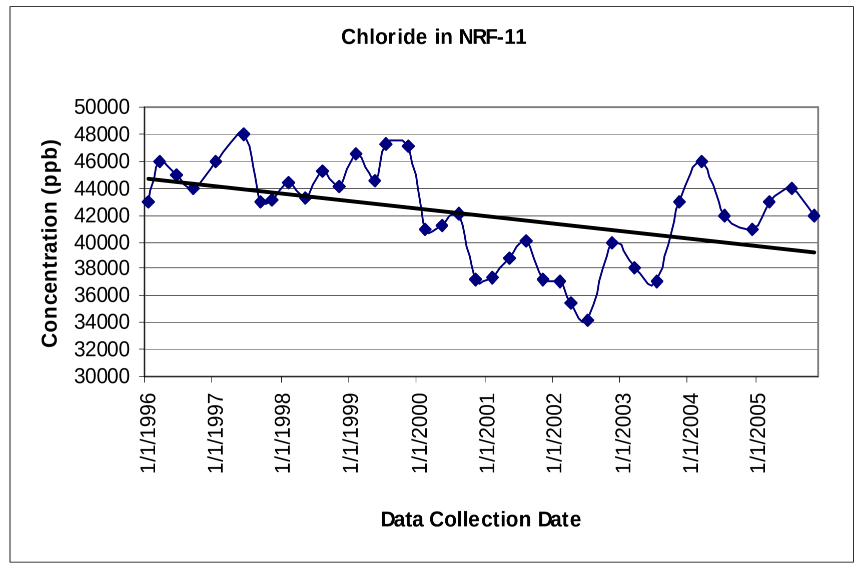

Chloride in NRF-13
Concentration (ppb)
Data Collection Date

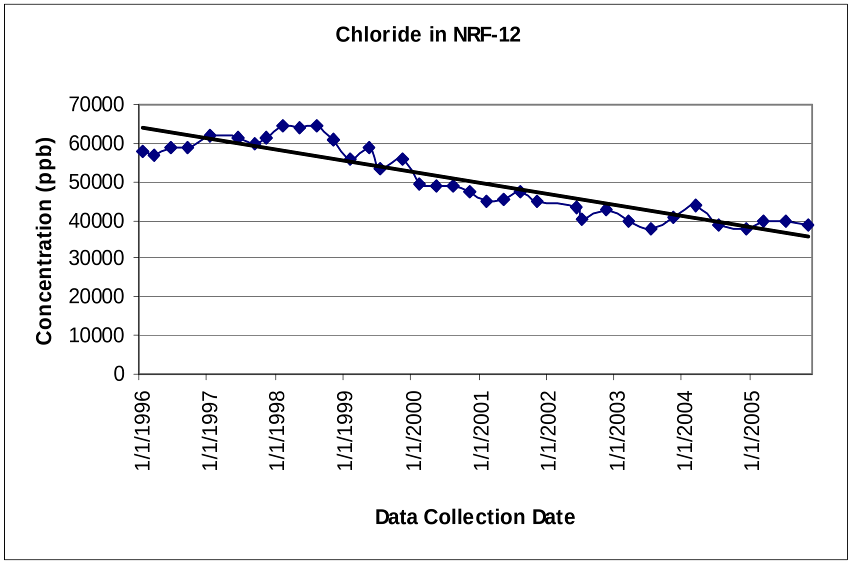

Chloride in USGS-12
Concentration (ppb)
Data Collection Date

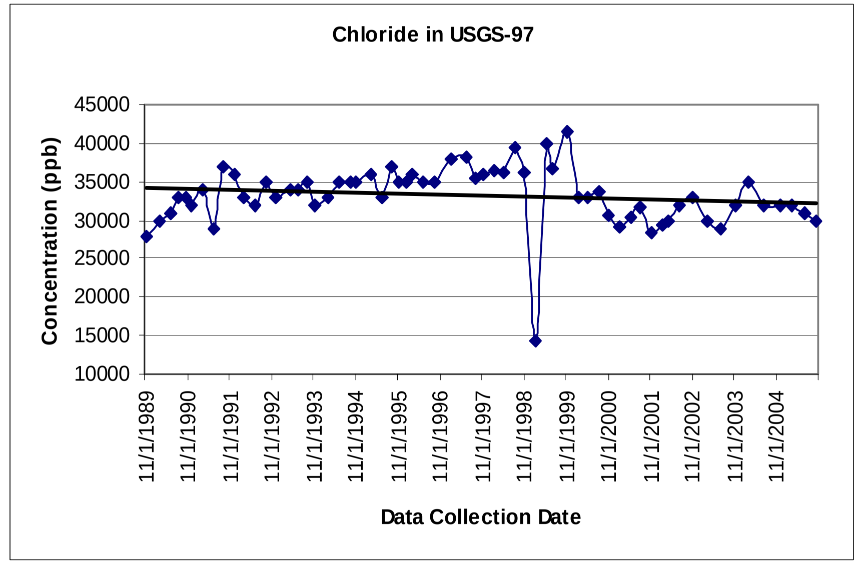

Chloride in NRF-8
Concentration (ppb)
43000
41000
39000
37000
35000
33000
31000
29000
27000
25000
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

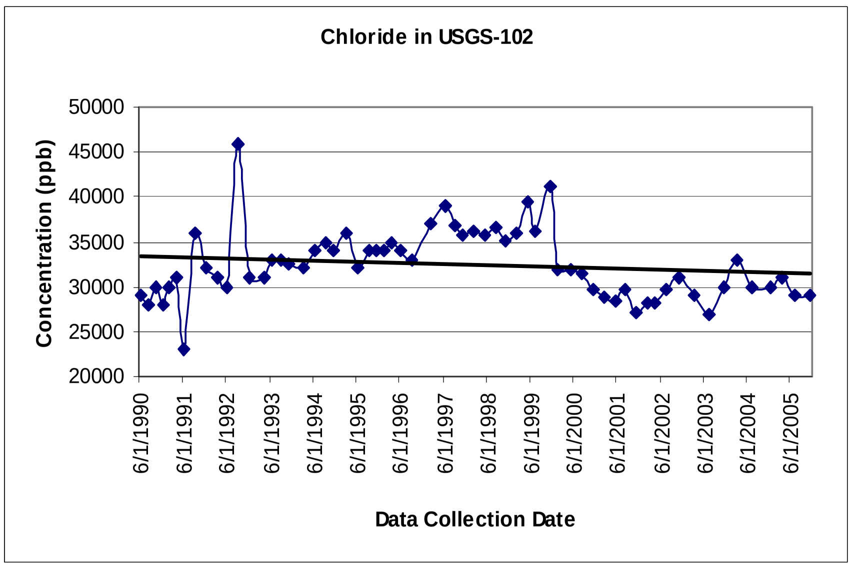

Chloride in NRF-10
Concentration (ppb)
55000
50000
45000
40000
35000
30000
5/8/1996
5/8/1997
5/8/1998
5/8/1999
5/8/2000
5/8/2001
5/8/2002
5/8/2003
5/8/2004
5/8/2005
Data Collection Date

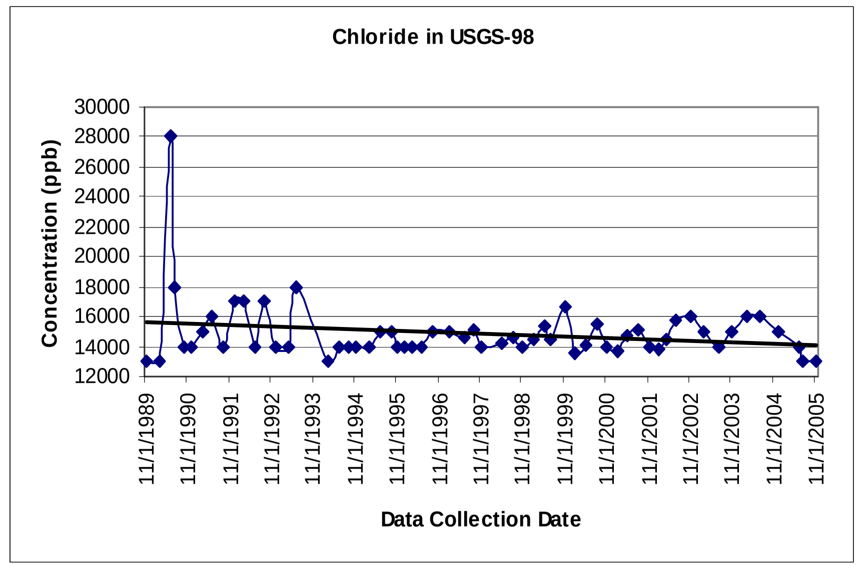

Chloride in NRF-9
Concentration (ppb)
53000
51000
49000
47000
45000
43000
41000
39000
37000
35000
1/18/1996
1/18/1997
1/18/1998
1/18/1999
1/18/2000
1/18/2001
1/18/2002
1/18/2003
1/18/2004
1/18/2005
Data Collection Date

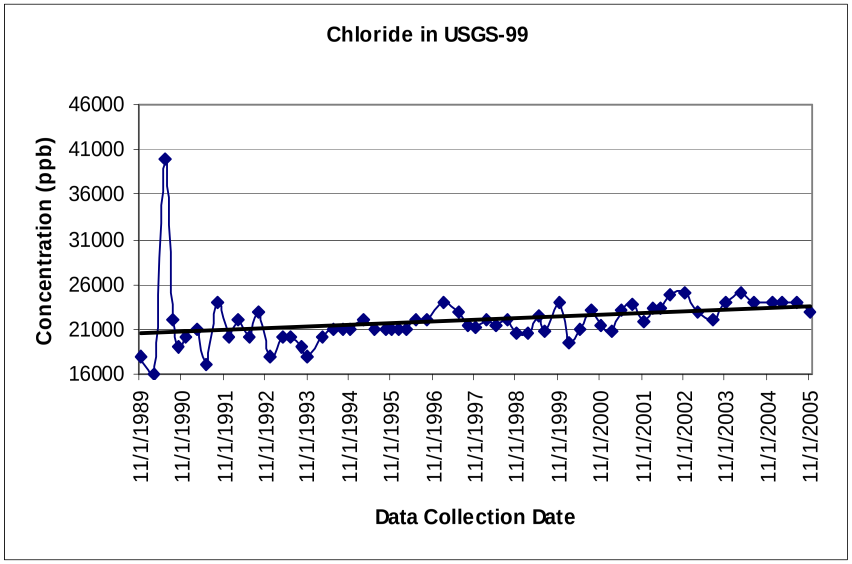

Chloride in NRF-11
Concentration (ppb)
50000
48000
46000
44000
42000
40000
38000
36000
34000
32000
30000
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

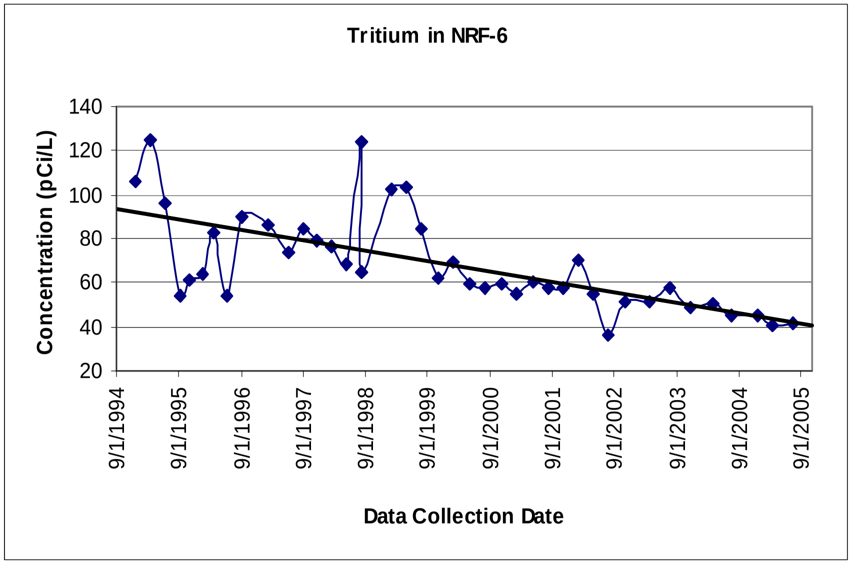

Chloride in NRF-12
Concentration (ppb)
0
10000
20000
30000
40000
50000
60000
70000
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

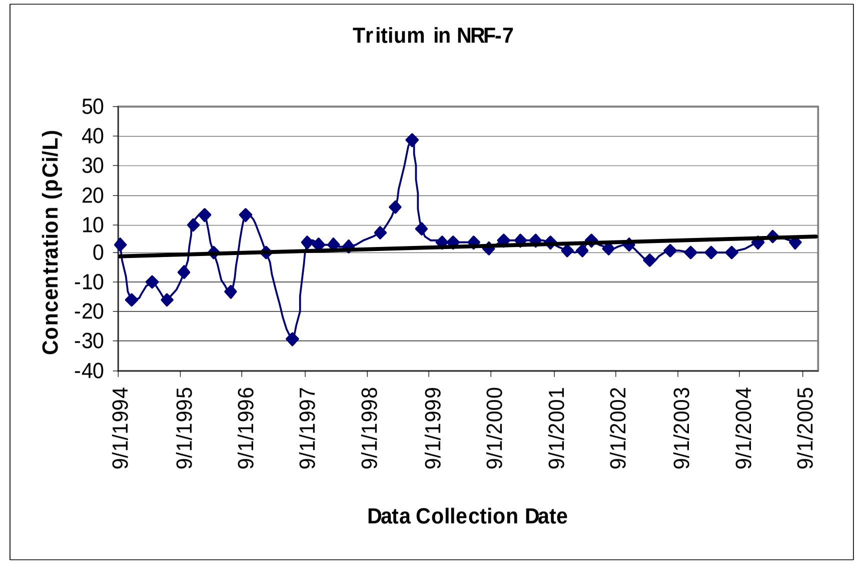

Chloride in USGS-97
Concentration (ppb)
10000
15000
20000
25000
30000
35000
40000
45000
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
Data Collection Date

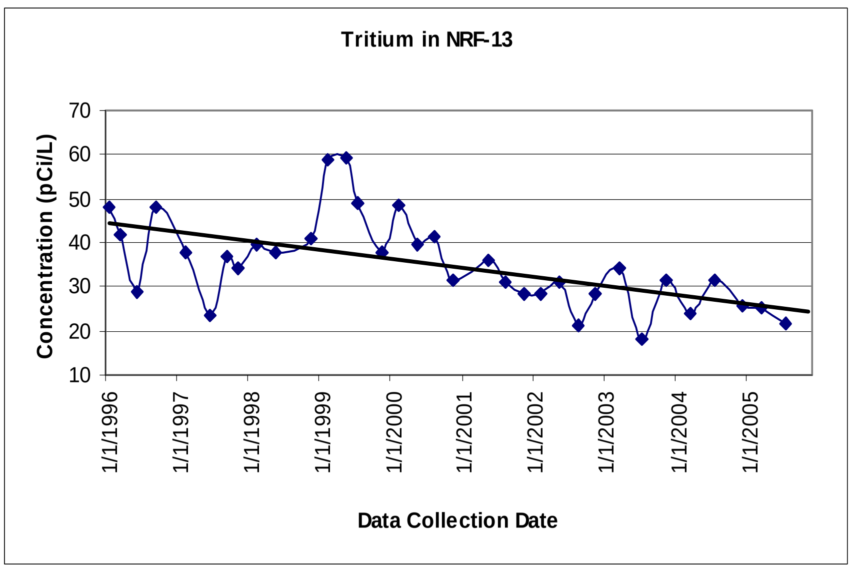

Chloride in USGS-102
Concentration (ppb)
20000
25000
30000
35000
40000
45000
50000
6/1/1990
6/1/1991
6/1/1992
6/1/1993
6/1/1994
6/1/1995
6/1/1996
6/1/1997
6/1/1998
6/1/1999
6/1/2000
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
Data Collection Date

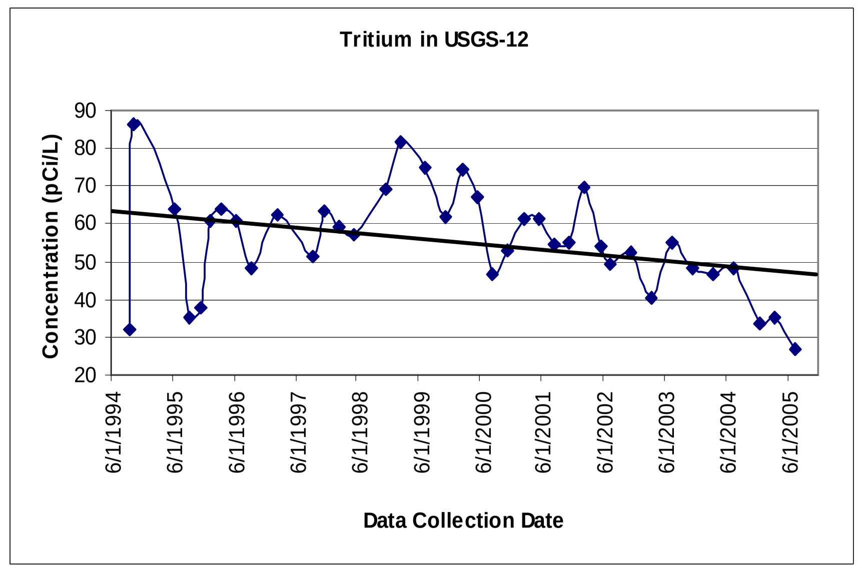

Chloride in USGS-98
Concentration (ppb)
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
Data Collection Date

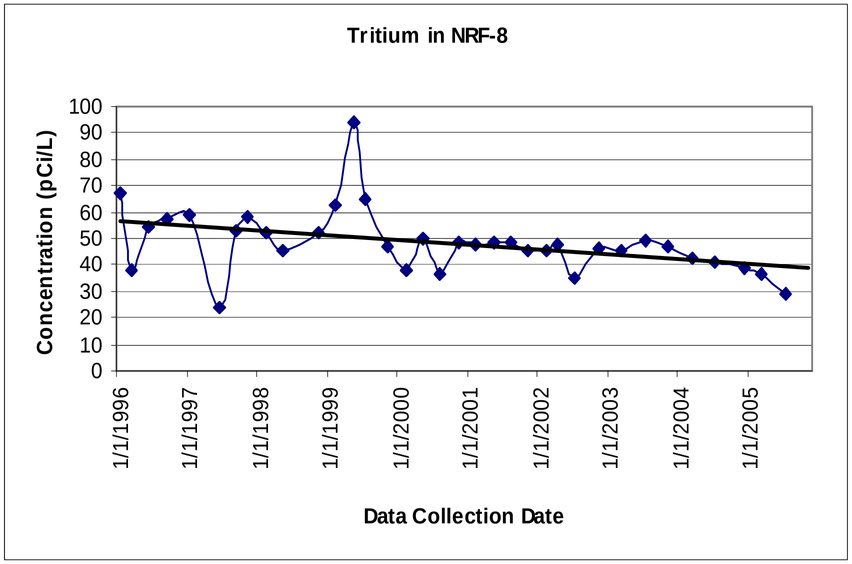

Chloride in USGS-99
Concentration (ppb)
46000
41000
36000
31000
26000
21000
16000
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
Data Collection Date

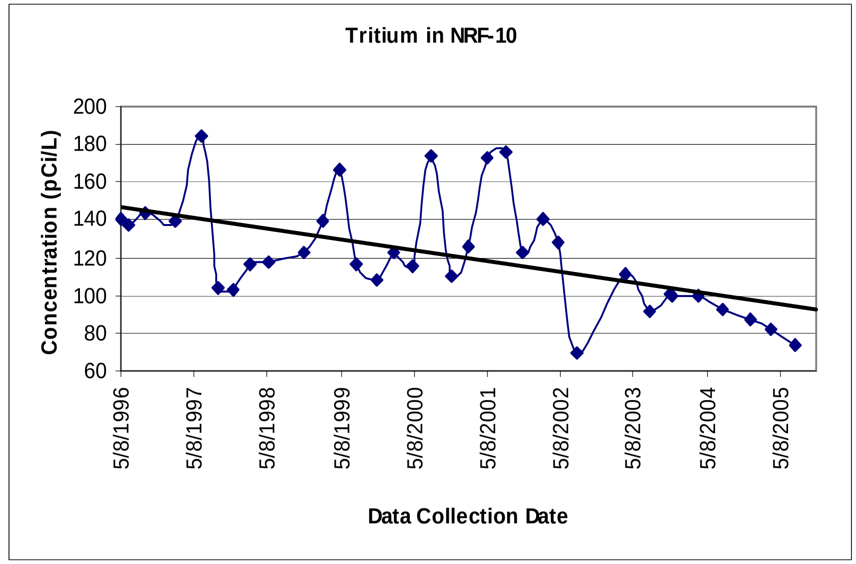

Tritium in NRF-6
Concentration (pCi/L)
140
120
100
80
60
40
20
9/1/1994
9/1/1995
9/1/1996
9/1/1997
9/1/1998
9/1/1999
9/1/2000
9/1/2001
9/1/2002
9/1/2003
9/1/2004
9/1/2005
Data Collection Date

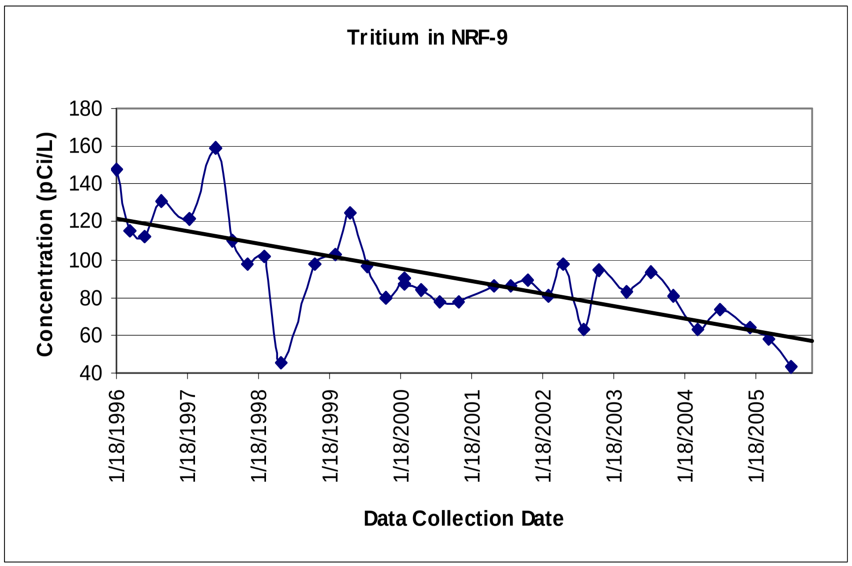

Tritium in NRF-7
Concentration (pCi/L)
50
40
30
20
10
0
-10
-20
-30
-40
9/1/1994
9/1/1995
9/1/1996
9/1/1997
9/1/1998
9/1/1999
9/1/2000
9/1/2001
9/1/2002
9/1/2003
9/1/2004
9/1/2005
Data Collection Date

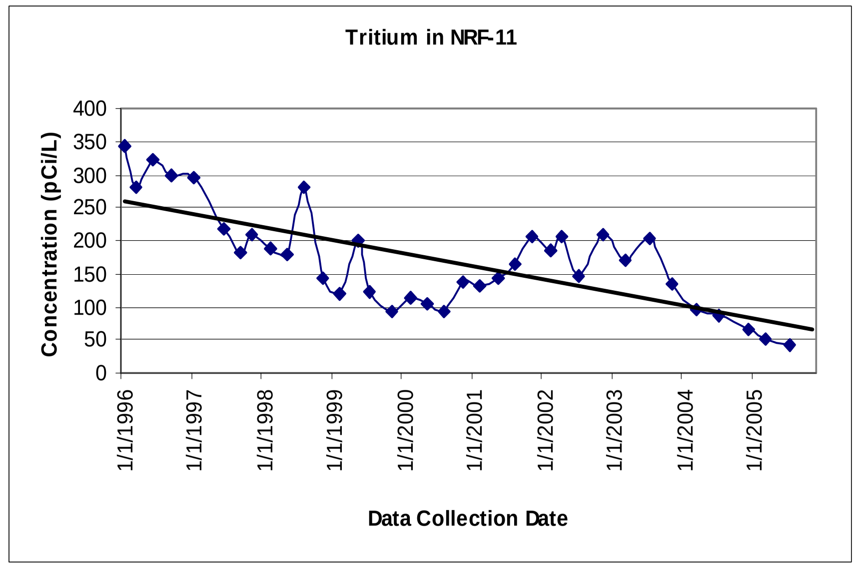

Tritium in NRF-13
Concentration (pCi/L)
70
60
50
40
30
20
10
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

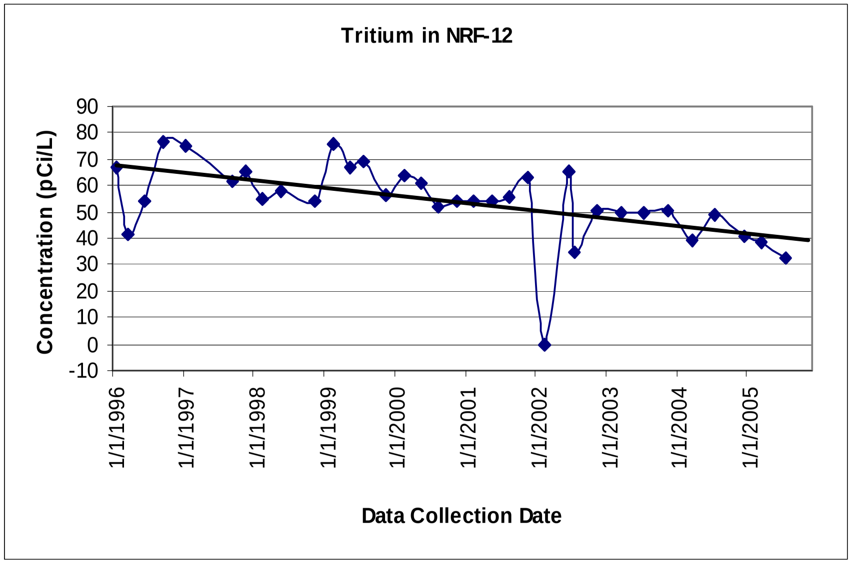

Tritium in USGS-12
Concentration (pCi/L)
90
80
70
60
50
40
30
20
6/1/1994
6/1/1995
6/1/1996
6/1/1997
6/1/1998
6/1/1999
6/1/2000
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
Data Collection Date

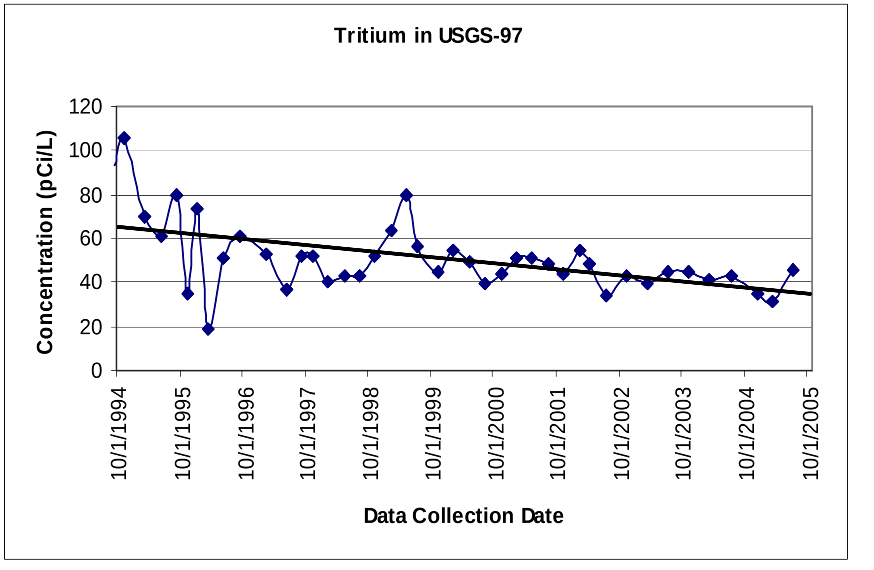

Tritium in NRF-8
Concentration (pCi/L)
100
90
80
70
60
50
40
30
20
10
0
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date

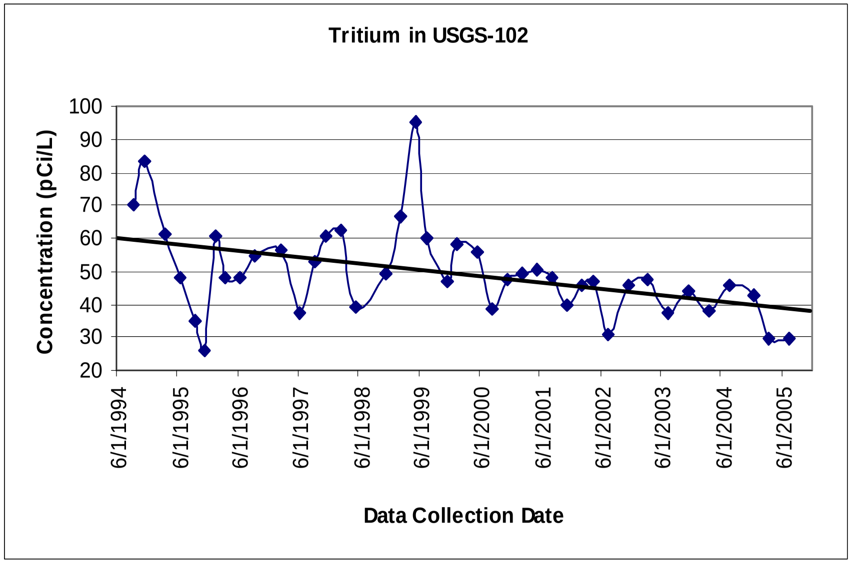

Tritium in NRF-10
Concentration (pCi/L)
200
180
160
140
120
100
80
60
5/8/1996
5/8/1997
5/8/1998
5/8/1999
5/8/2000
5/8/2001
5/8/2002
5/8/2003
5/8/2004
5/8/2005
Data Collection Date

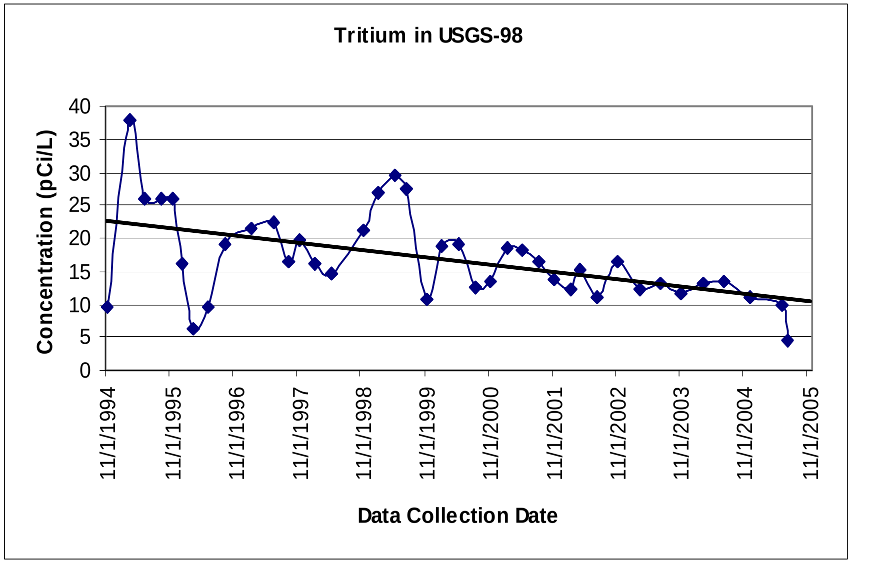

Tritium in NRF-9
Concentration (pCi/L)
180
160
140
120
100
80
60
40
1/18/1996
1/18/1997
1/18/1998
1/18/1999
1/18/2000
1/18/2001
1/18/2002
1/18/2003
1/18/2004
1/18/2005
Data Collection Date

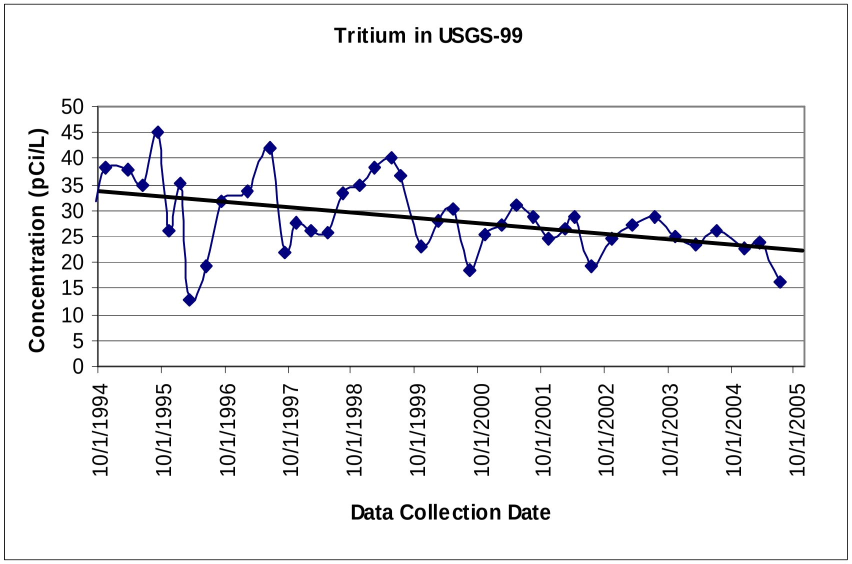

Tritium in NRF-11
Concentration (pCi/L)
400
350
300
250
200
150
100
50
0
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date


Tritium in NRF-12
Concentration (pCi/L)
90
80
70
60
50
40
30
20
10
0
-10
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
Data Collection Date


Tritium in USGS-97
Concentration (pCi/L)
120
100
80
60
40
20
0
10/1/1994
10/1/1995
10/1/1996
10/1/1997
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
10/1/2004
10/1/2005
Data Collection Date


Tritium in USGS-102
Concentration (pCi/L)
100
90
80
70
60
50
40
30
20
6/1/1994
6/1/1995
6/1/1996
6/1/1997
6/1/1998
6/1/1999
6/1/2000
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
Data Collection Date


Tritium in USGS-98
Concentration (pCi/L)
40
35
30
25
20
15
10
5
0
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
Data Collection Date


Tritium in USGS-99
Concentration (pCi/L)
0
5
10
15
20
25
30
35
40
45
50
10/1/1994
10/1/1995
10/1/1996
10/1/1997
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
10/1/2004
10/1/2005
Data Collection Date

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Appendix C

Concentration Graphs

For

Selected Organic Compounds

In NRF Soil Gas Monitoring Wells

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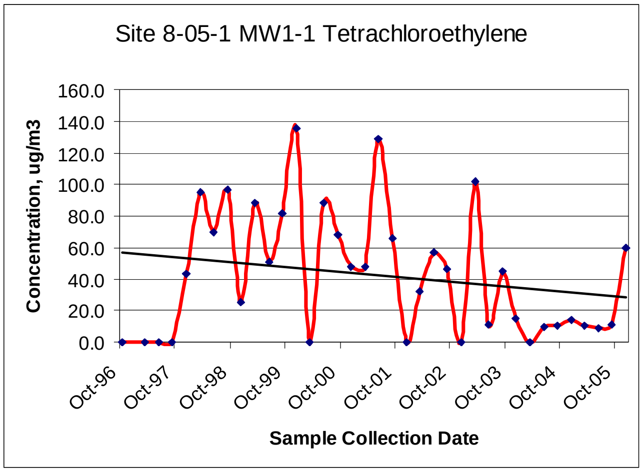
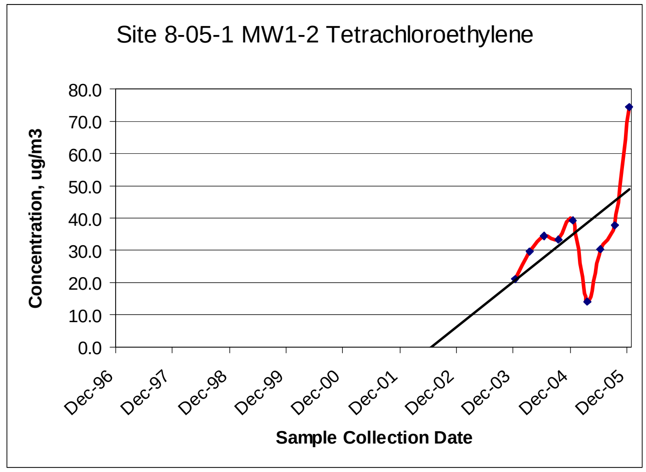
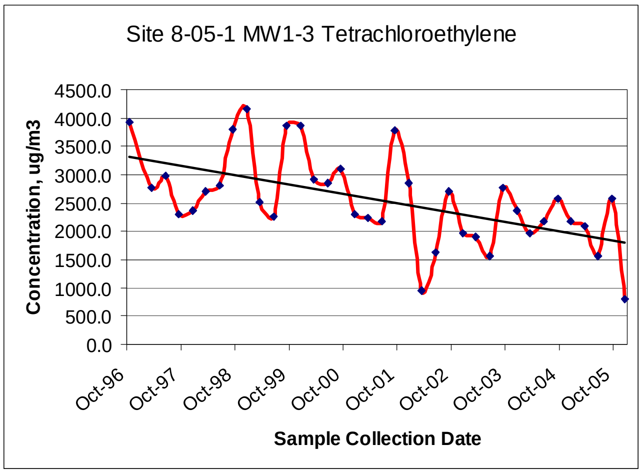
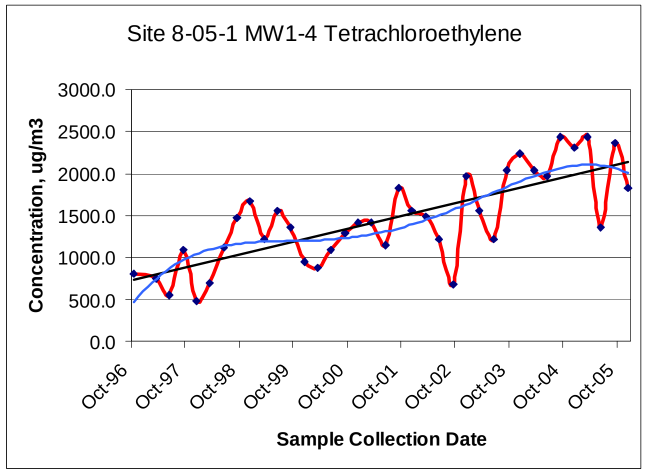
The attached figures provide soil gas data plotted on time versus concentration graphs. These graphs help evaluate any specific patterns, trend, and/or anomalies of the data. The data consists of the following volatile organic compounds consistently detected at the landfill cover areas: dichlorodifluoromethane (Freon 12); trichlorofluoromethane (Freon 11); 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113); 1,1,1-trichloroethane; chloroform; trichloroethylene; and tetrachloroethylene. In general, the method of least squares was used to ascertain whether the contaminant concentration was increasing, decreasing, or remaining stable over time. A discussion of these trends can be found in the 2006 Five Year Review, Section 6.3.3.3, Trend Analysis.

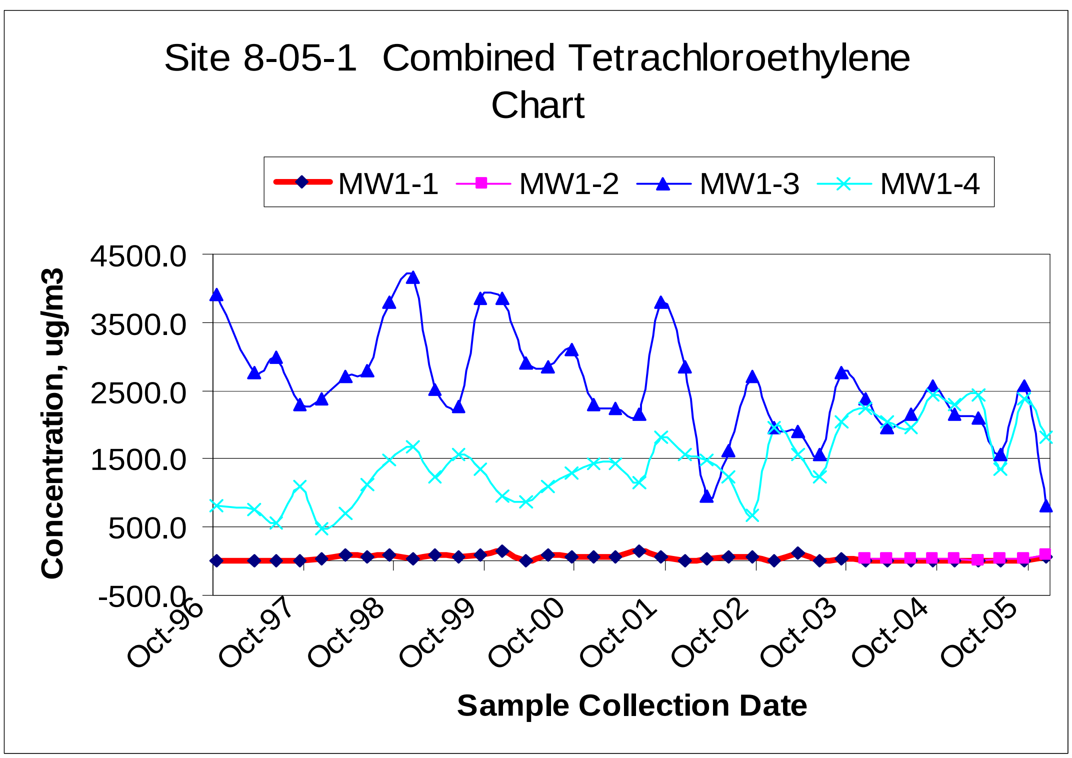
No significant outliers were observed in the data for this Five Year Review. Therefore, there was no need to exclude any values for this review period.

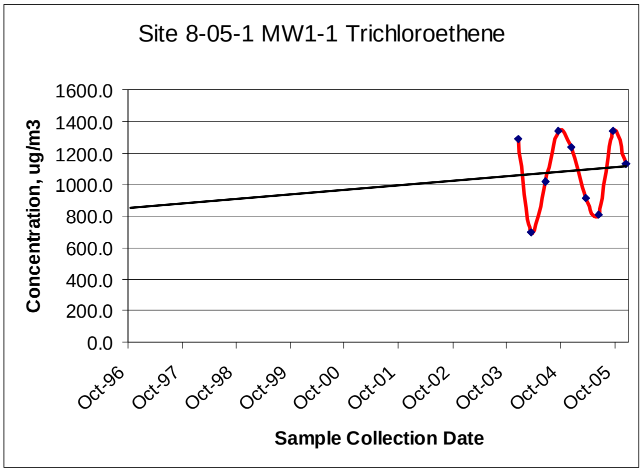

Site 8-05-1 MW1-1 Tetrachloroethylene
Concentration, ug/m3
Sample Collection Date
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05

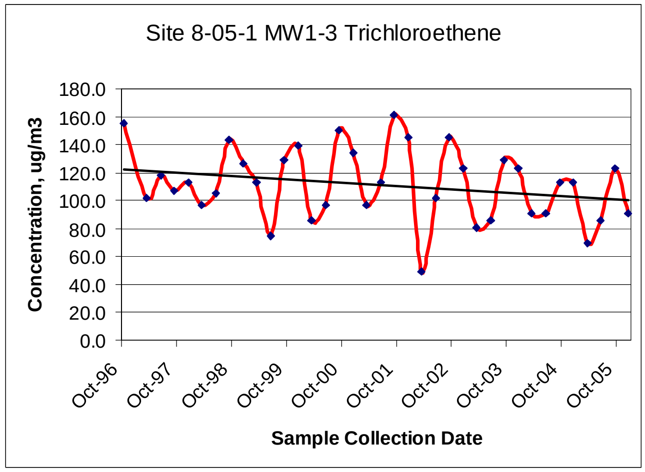

Site 8-05-1 MW1-2 Tetrachloroethylene
Concentration, ug/m3
Sample Collection Date
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05

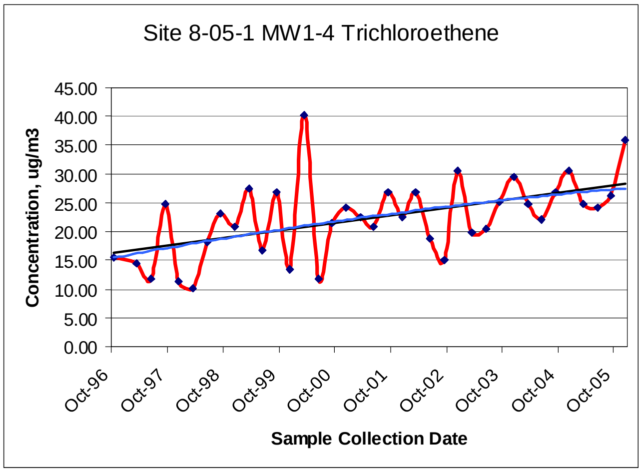

Site 8-05-1 MW1-3 Tetrachloroethylene
Concentration, ug/m3
Sample Collection Date
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
4500.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05

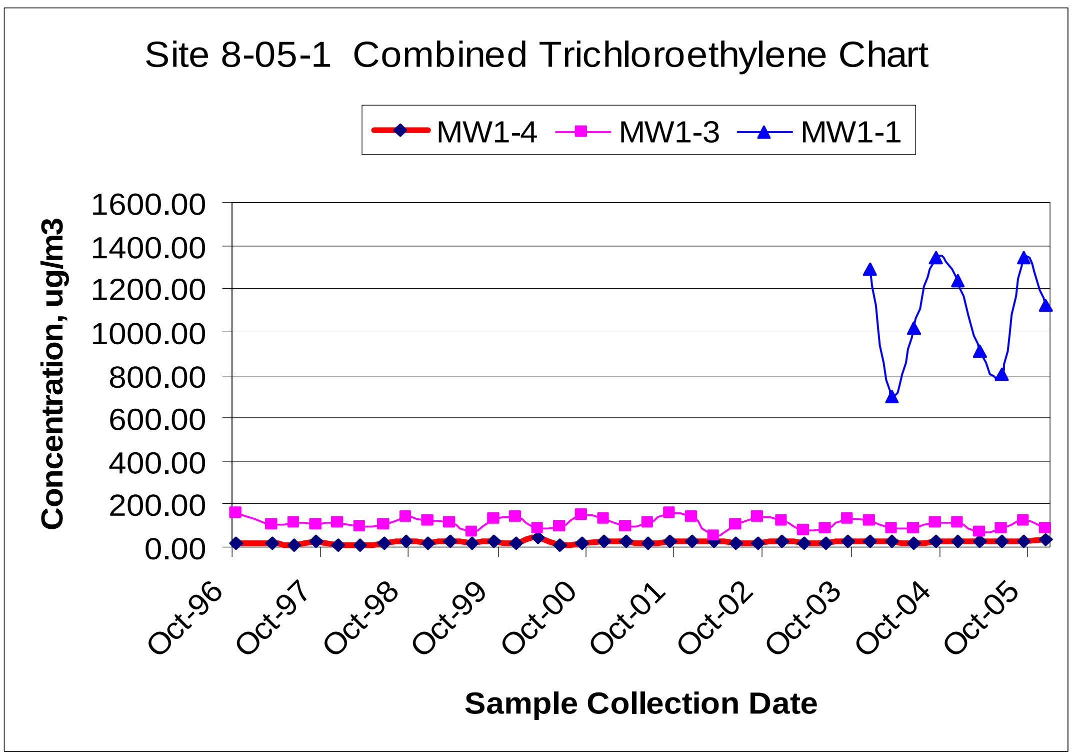

Site 8-05-1 MW1-4 Tetrachloroethylene
Concentration, ug/m3
Sample Collection Date
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05

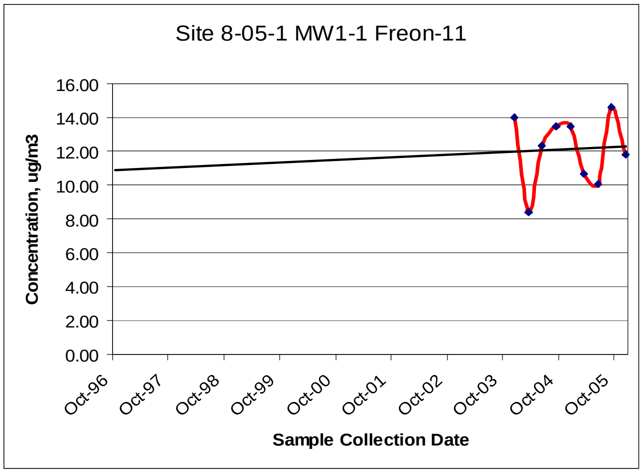

Site 8-05-1 Combined Tetrachloroethylene
Chart
MW1-1
MW1-2
MW1-3
MW1-4
Concentration, ug/m3
Sample Collection Date
-500.0
500.0
1500.0
2500.0
3500.0
4500.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05

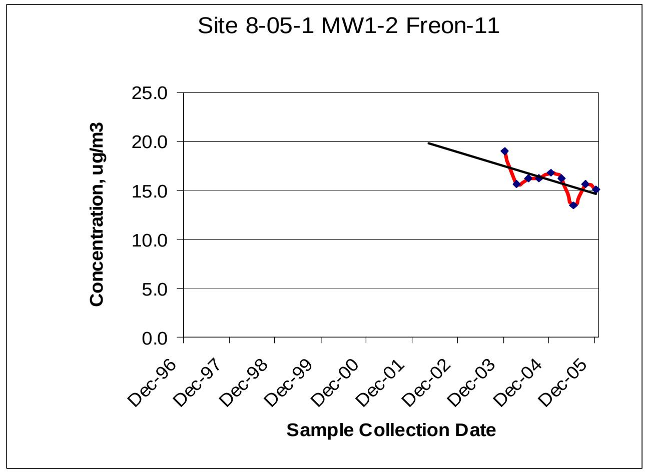

Site 8-05-1 MW1-1 Trichloroethene
Concentration, ug/m3
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

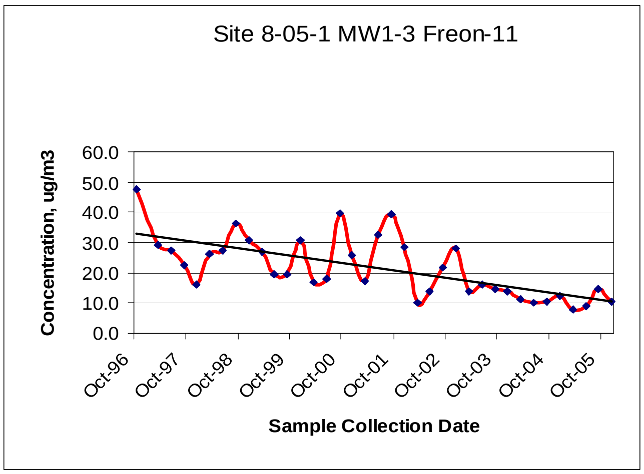

Site 8-05-1 MW1-3 Trichloroethene
Concentration, ug/m3
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

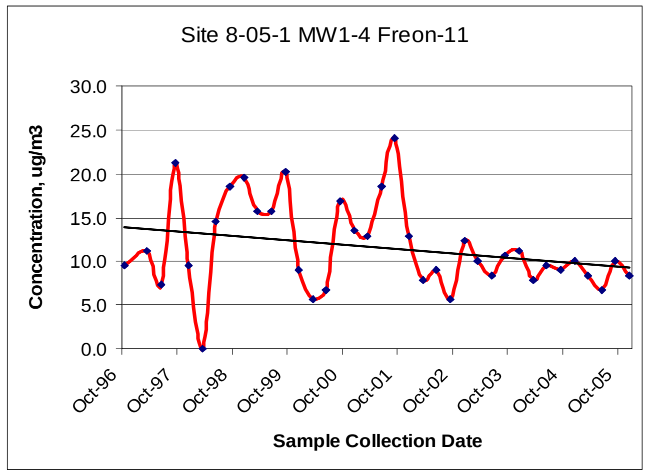

Site 8-05-1 MW1-4 Trichloroethene
Concentration, ug/m3
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

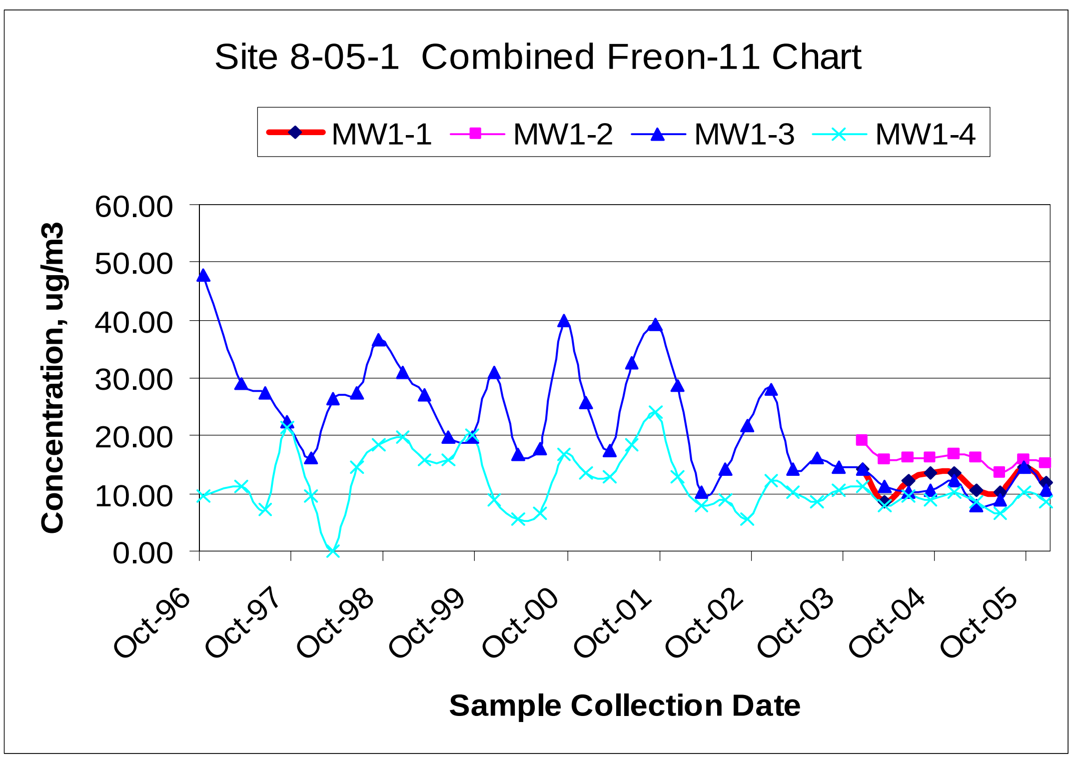

Site 8-05-1 Combined Trichloroethylene Chart
MW1-4
MW1-3
MW1-1
Concentration, ug/m3
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

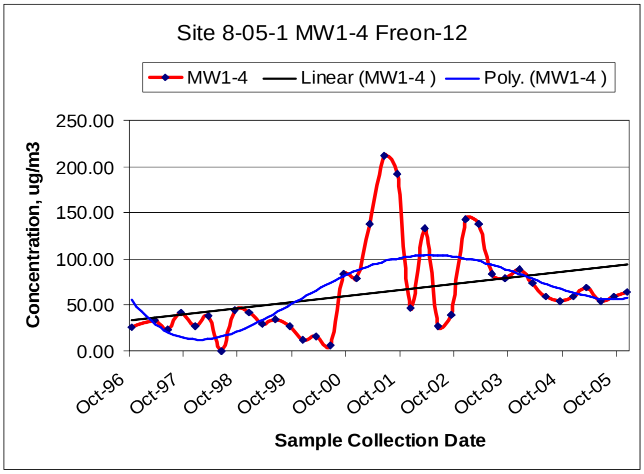

Site 8-05-1 MW1-1 Freon-11
Concentration, ug/m3
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

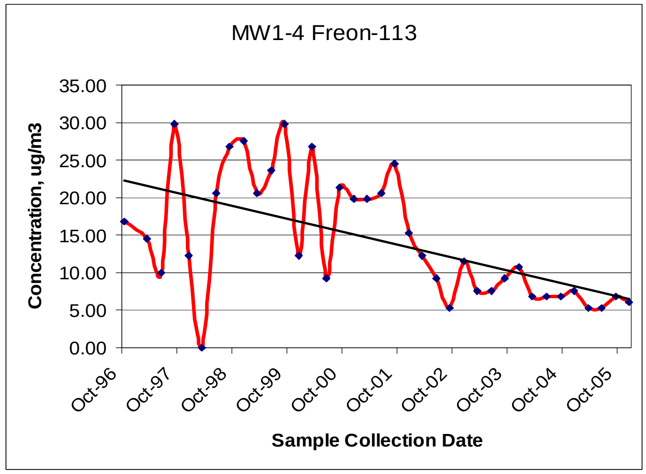

Site 8-05-1 MW1-2 Freon-11
Concentration, ug/m3
25.0
20.0
15.0
10.0
5.0
0.0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Sample Collection Date

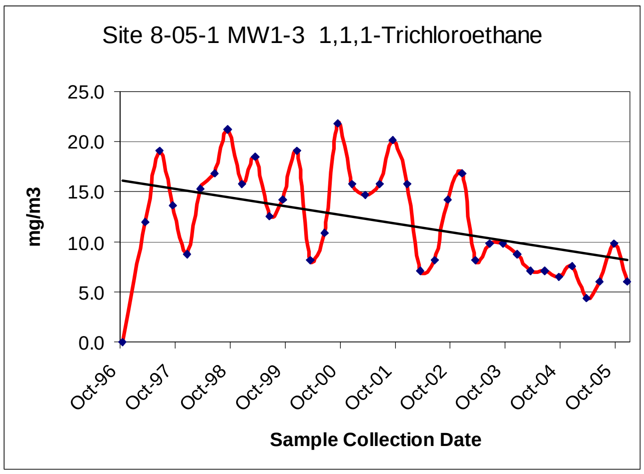

Site 8-05-1 MW1-3 Freon-11
Concentration, ug/m3
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

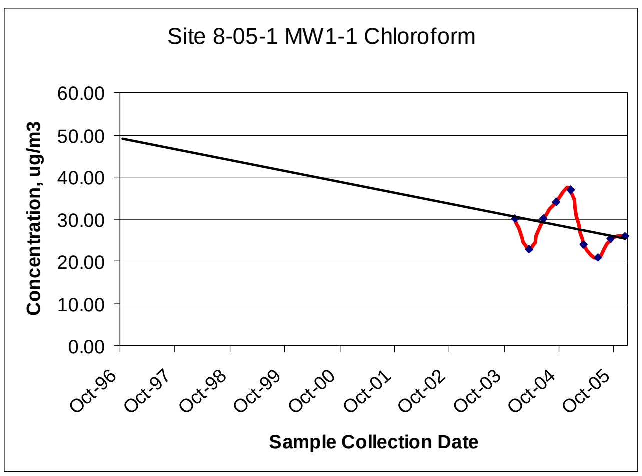

Site 8-05-1 MW1-4 Freon-11
Concentration, ug/m3
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

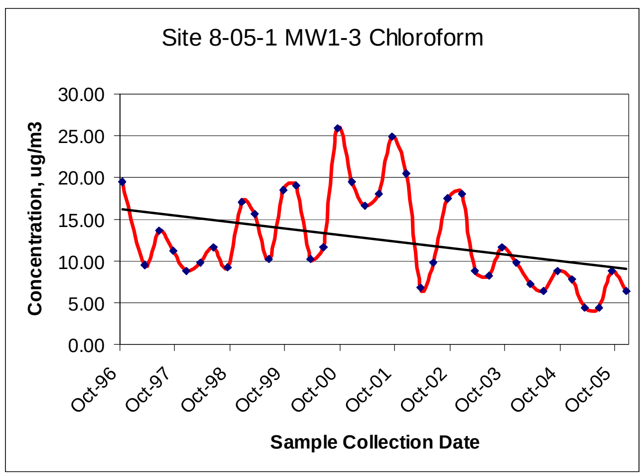

Site 8-05-1 Combined Freon-11 Chart
MW1-1
MW1-2
MW1-3
MW1-4
Concentration, ug/m3
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

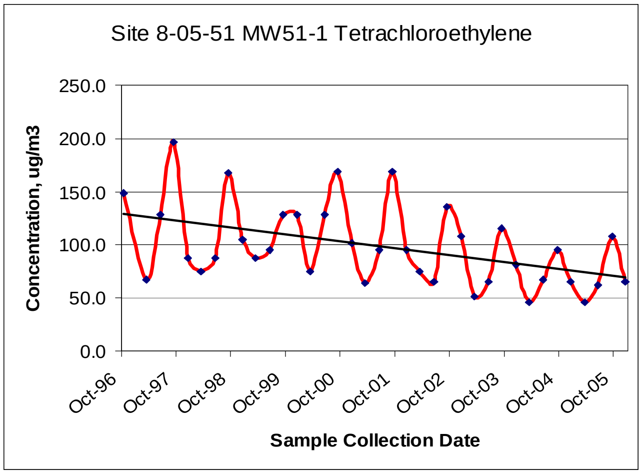

Site 8-05-1 MW1-4 Freon-12
MW1-4
Linear (MW1-4)
Poly. (MW1-4)
Concentration, ug/m3
250.00
200.00
150.00
100.00
50.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

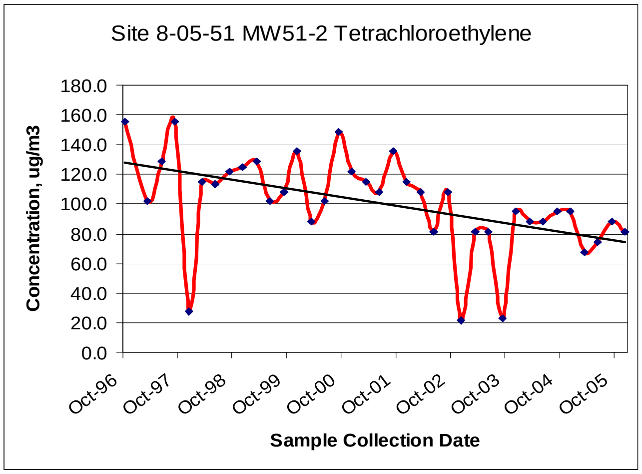

MW1-4 Freon-113
Concentration, ug/m3
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

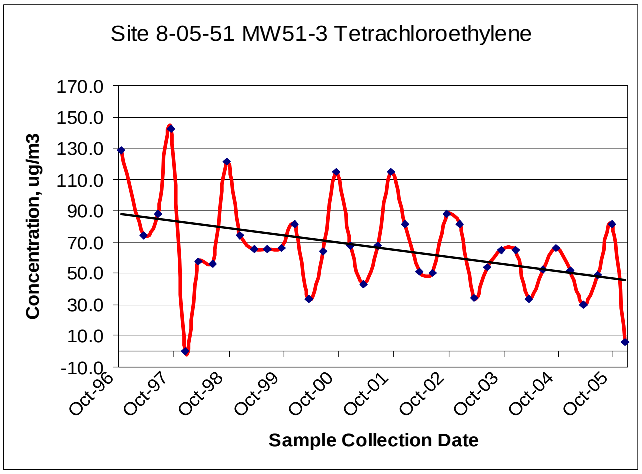

Site 8-05-1 MW1-3 1,1,1-Trichloroethane
mg/m3
25.0
20.0
15.0
10.0
5.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

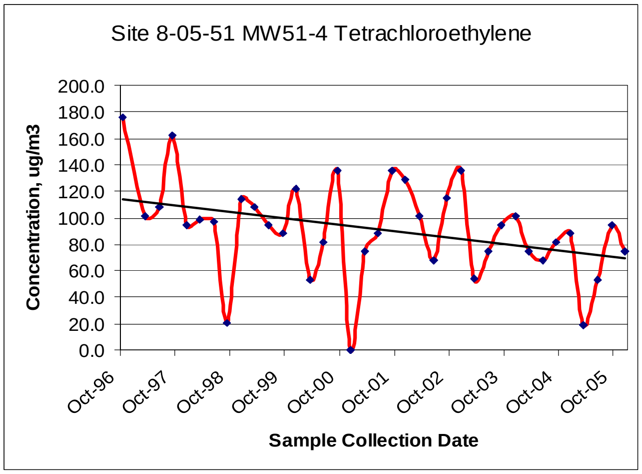

Site 8-05-1 MW1-1 Chloroform
Concentration, ug/m3
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

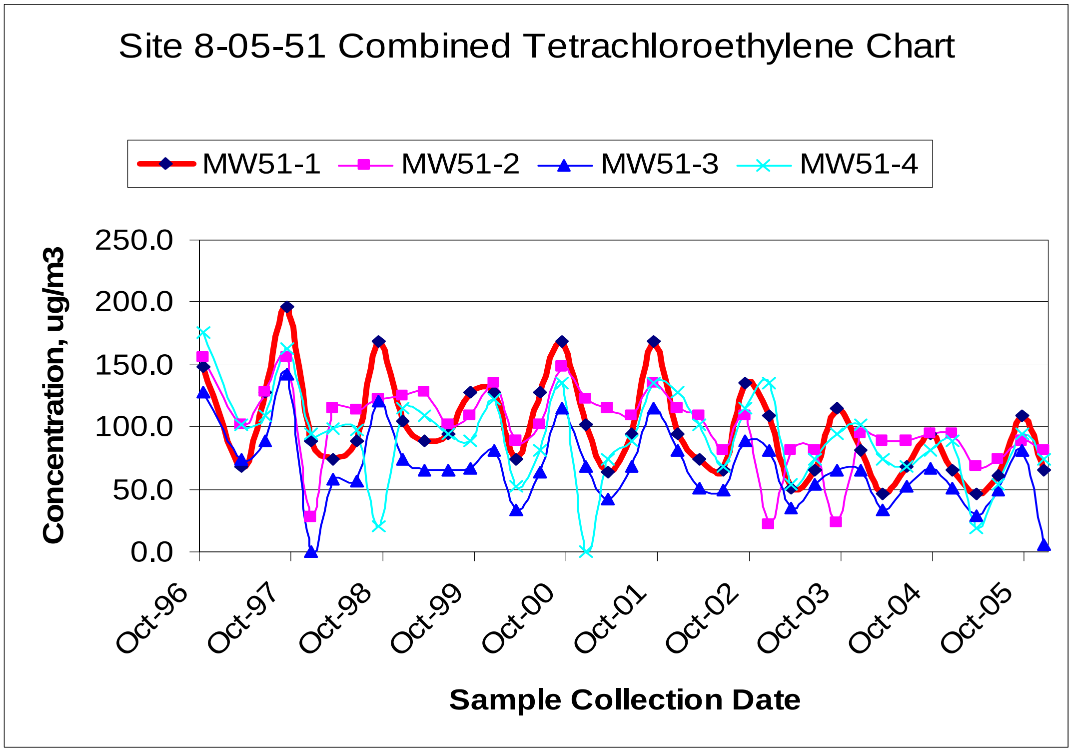

Site 8-05-1 MW1-3 Chloroform
Concentration, ug/m3
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

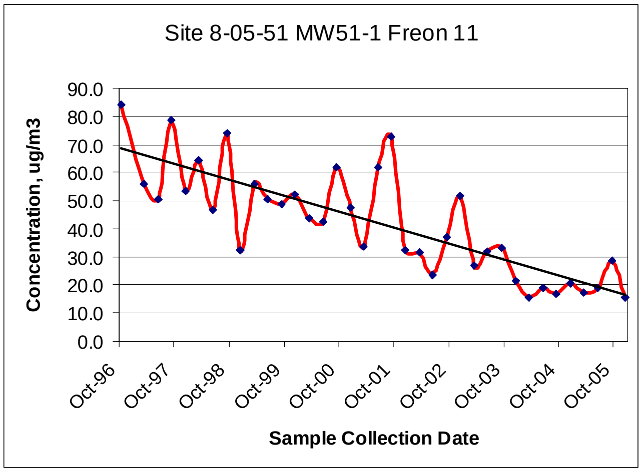

Site 8-05-51 MW51-1 Tetrachloroethylene
Concentration, ug/m3
250.0
200.0
150.0
100.0
50.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

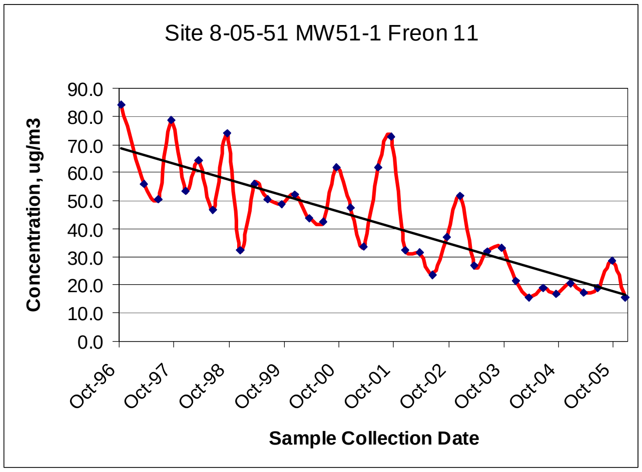

Site 8-05-51 MW51-2 Tetrachloroethylene
Concentration, ug/m3
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

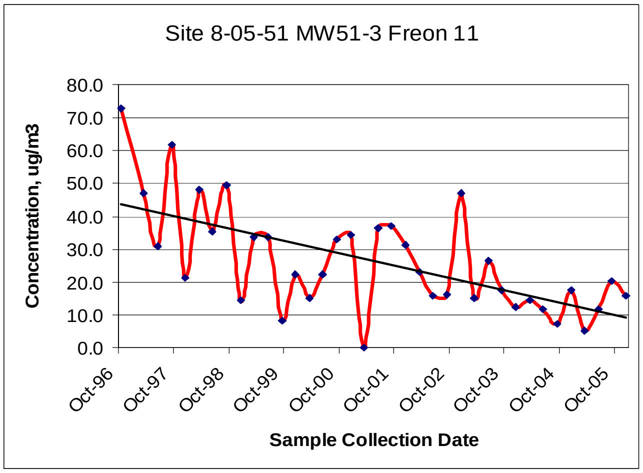

Site 8-05-51 MW51-3 Tetrachloroethylene
Concentration, ug/m3
170.0
150.0
130.0
110.0
90.0
70.0
50.0
30.0
10.0
-10.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

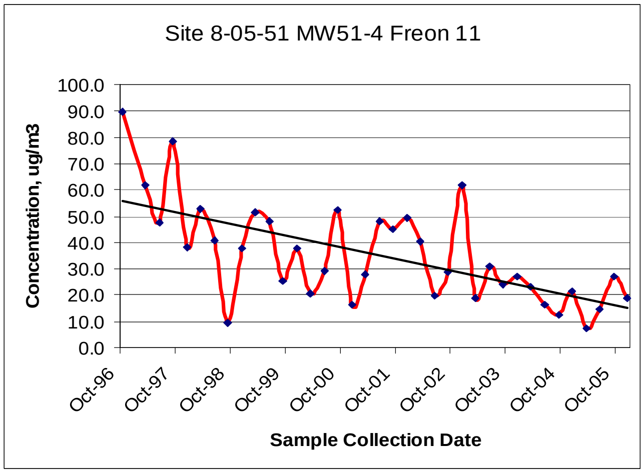

Site 8-05-51 MW51-4 Tetrachloroethylene
Concentration, ug/m3
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

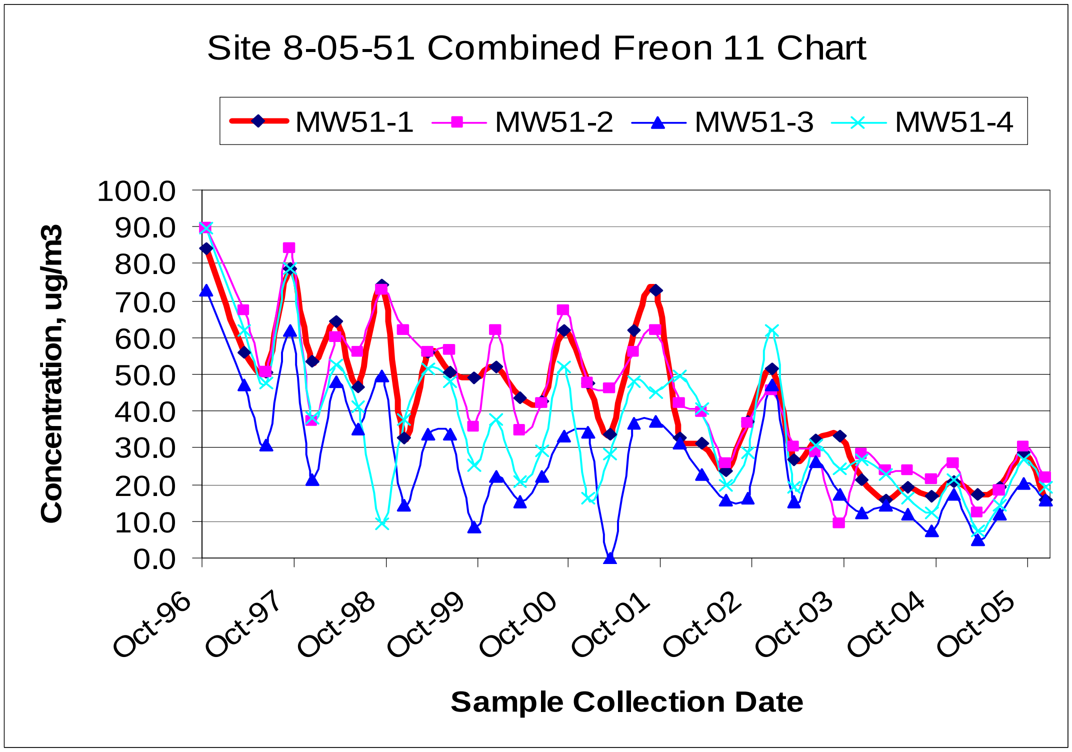

Site 8-05-51 Combined Tetrachloroethylene Chart
MW51-1
MW51-2
MW51-3
MW51-4
Concentration, ug/m3
250.0
200.0
150.0
100.0
50.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

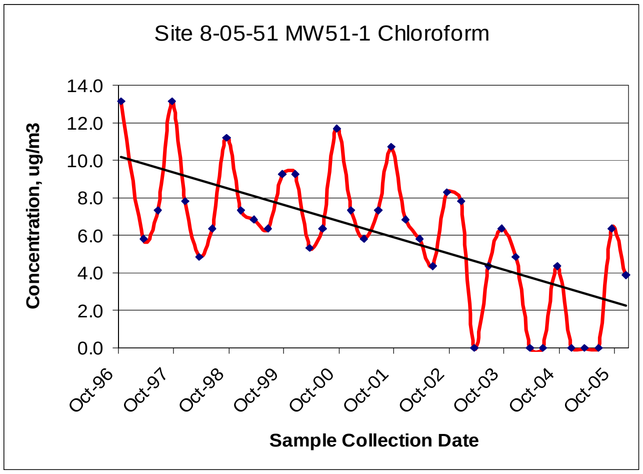

Site 8-05-51 MW51-1 Freon 11
Concentration, ug/m3
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

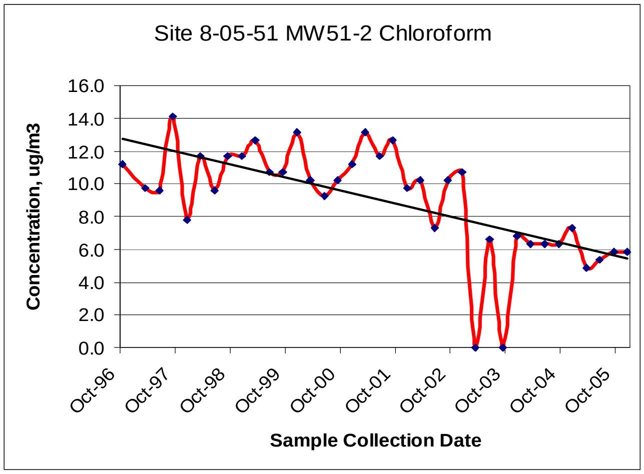

Site 8-05-51 MW51-1 Freon 11
Concentration, ug/m3
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

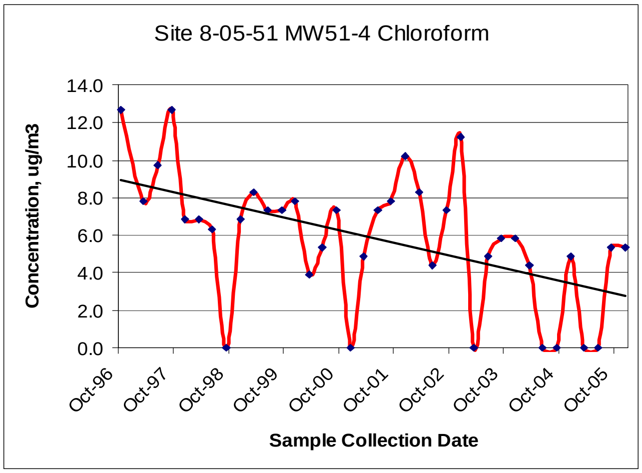

Site 8-05-51 MW51-3 Freon 11
Concentration, ug/m3
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

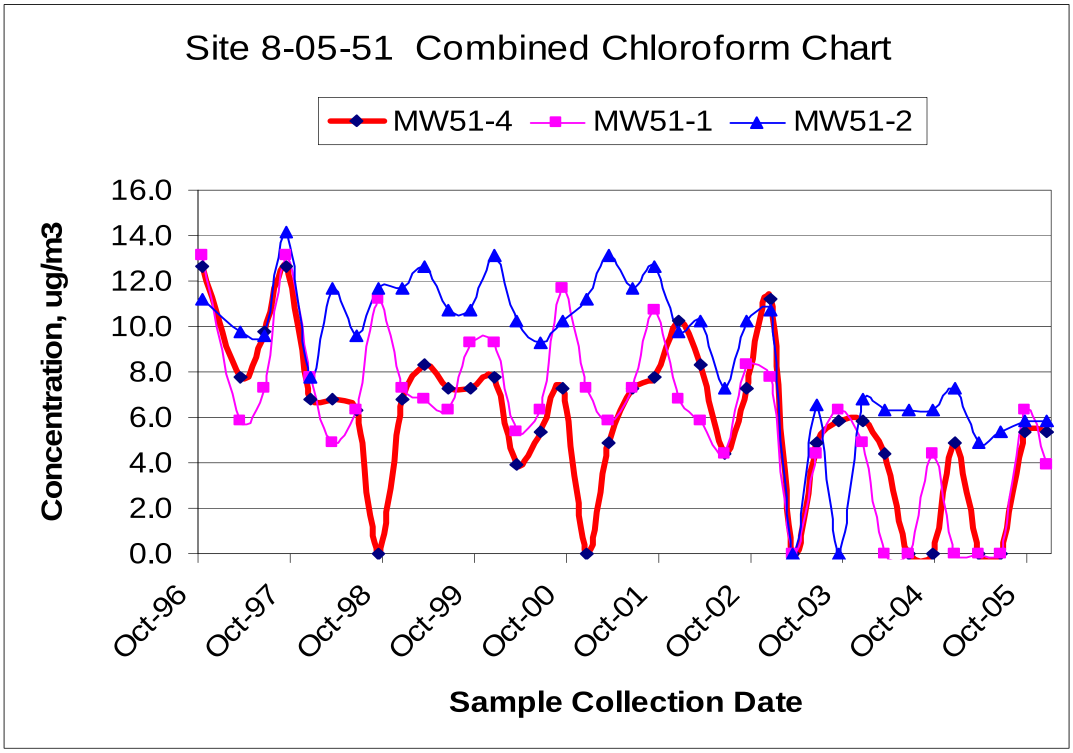

Site 8-05-51 MW51-4 Freon 11
Concentration, ug/m3
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

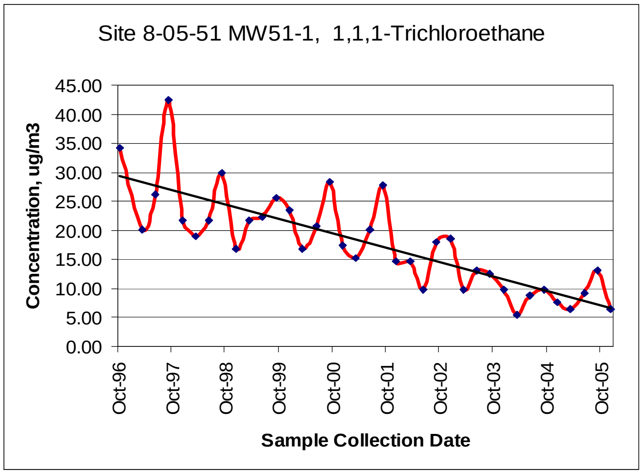

Site 8-05-51 Combined Freon 11 Chart
MW51-1
MW51-2
MW51-3
MW51-4
Concentration, ug/m3
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

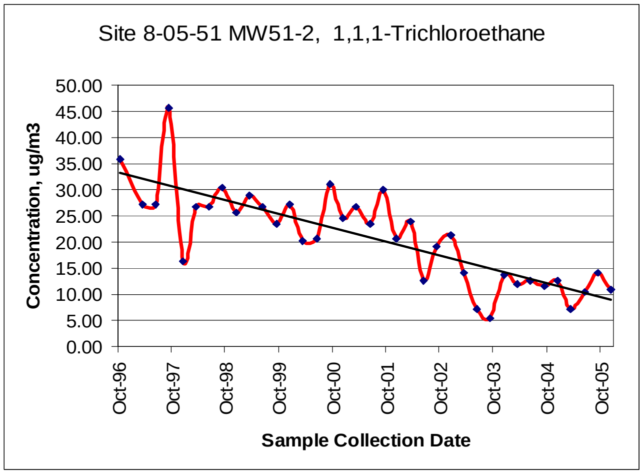

Site 8-05-51 MW51-1 Chloroform
Concentration, ug/m3
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Site 8-05-51 MW51-2 Chloroform
Concentration, ug/m3
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Site 8-05-51 MW51-4 Chloroform
Concentration, ug/m3
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Site 8-05-51 Combined Chloroform Chart
MW51-4
MW51-1
MW51-2
Concentration, ug/m3
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Site 8-05-51 MW51-1, 1,1,1-Trichloroethane
Concentration, ug/m3
Sample Collection Date
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05


Site 8-05-51 MW51-2, 1,1,1-Trichloroethane
Concentration, ug/m3
Sample Collection Date
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
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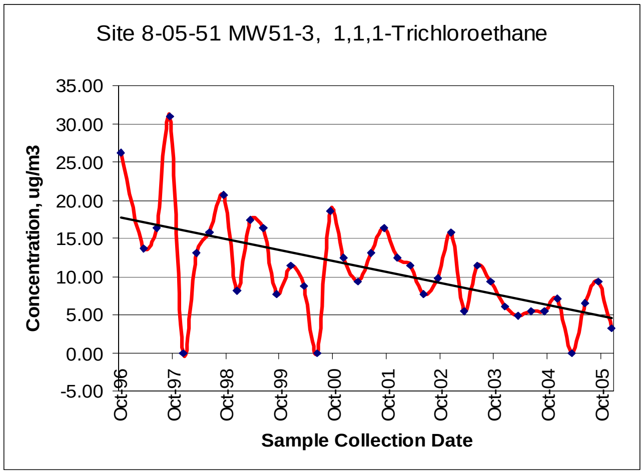
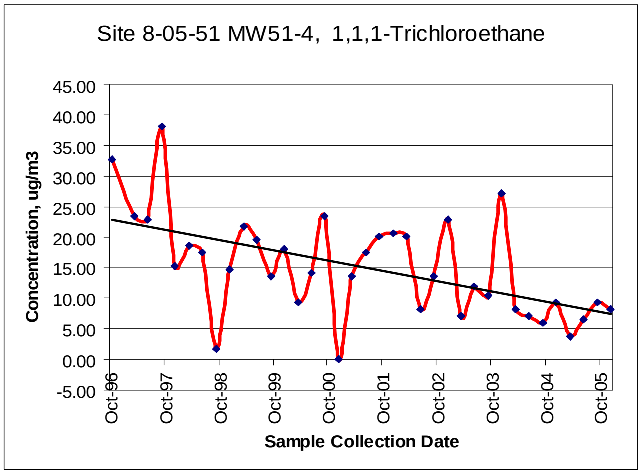
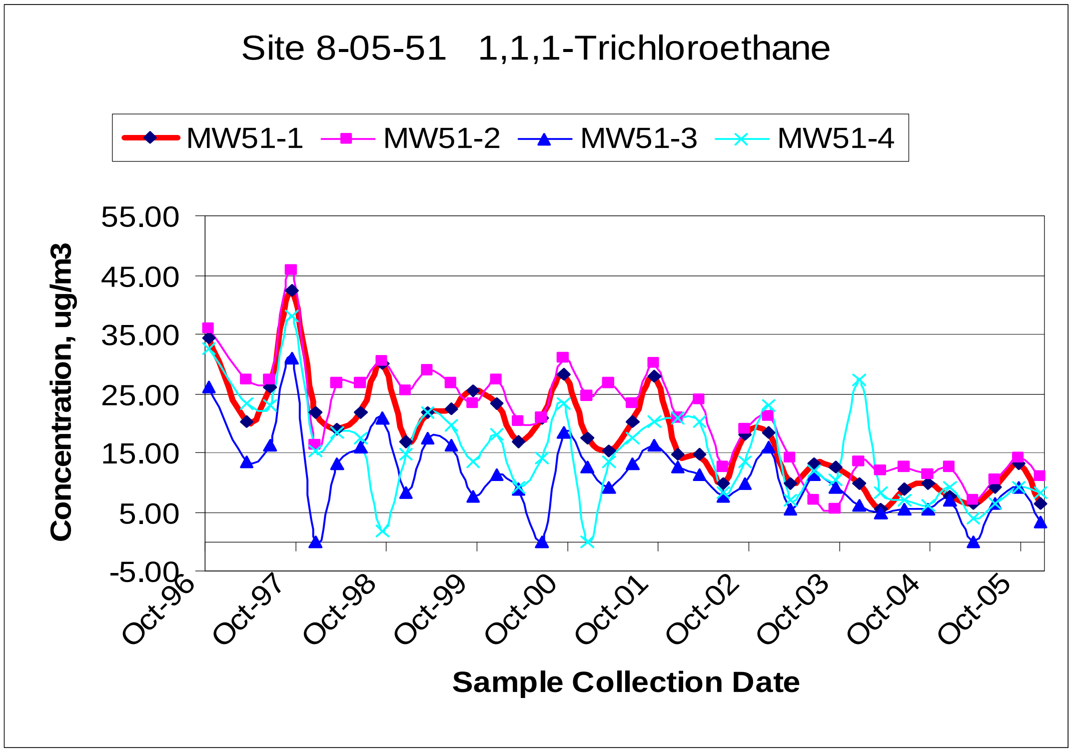
Oct-02
Oct-03
Oct-04
Oct-05


Site 8-05-51 MW51-3, 1,1,1-Trichloroethane
Concentration, ug/m3
Sample Collection Date
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05


Site 8-05-51 MW51-4, 1,1,1-Trichloroethane
Concentration, ug/m3
Sample Collection Date
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05


Site 8-05-51 1,1,1-Trichloroethane
MW51-1
MW51-2
MW51-3
MW51-4
Concentration, ug/m3
Sample Collection Date
55.00
45.00
35.00
25.00
15.00
5.00
-5.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
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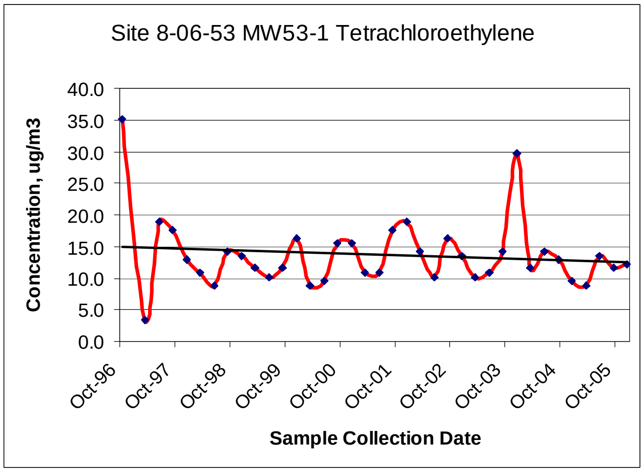
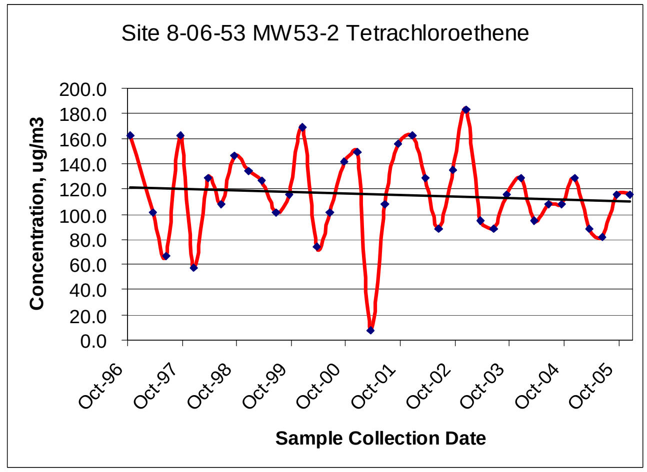
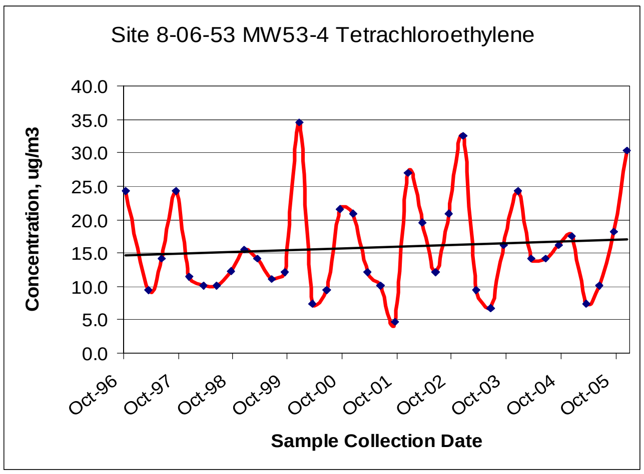
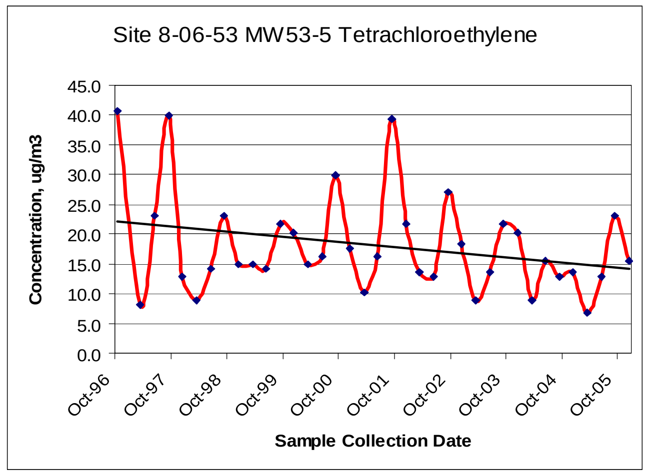
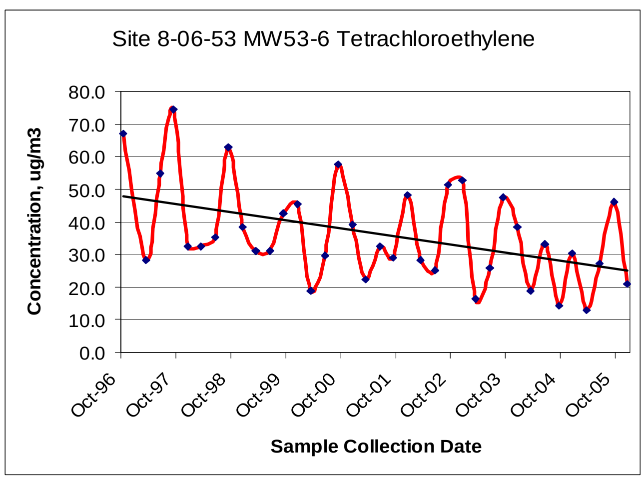
Oct-02
Oct-03
Oct-04
Oct-05

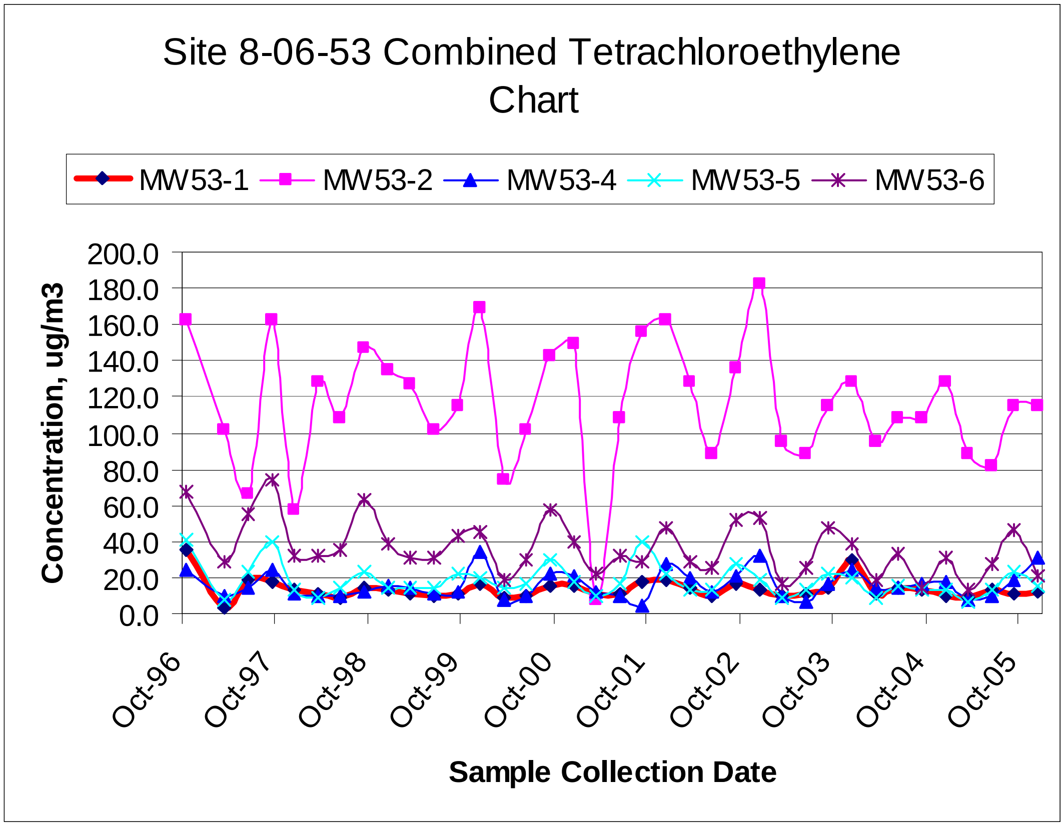

Site 8-06-53 MW53-1 Tetrachloroethylene
Concentration, ug/m3
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

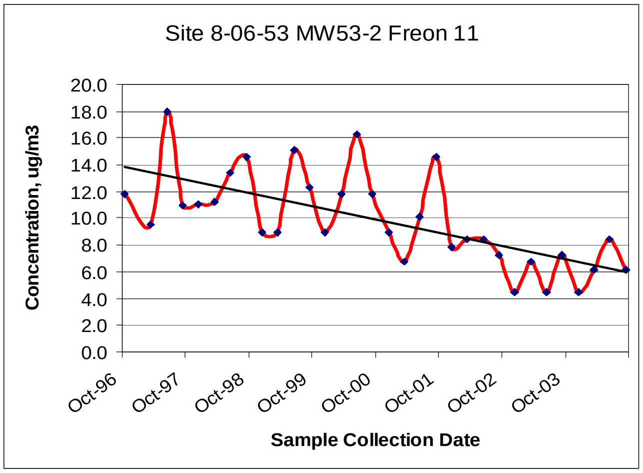

Site 8-06-53 MW53-2 Tetrachloroethene
Concentration, ug/m3
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

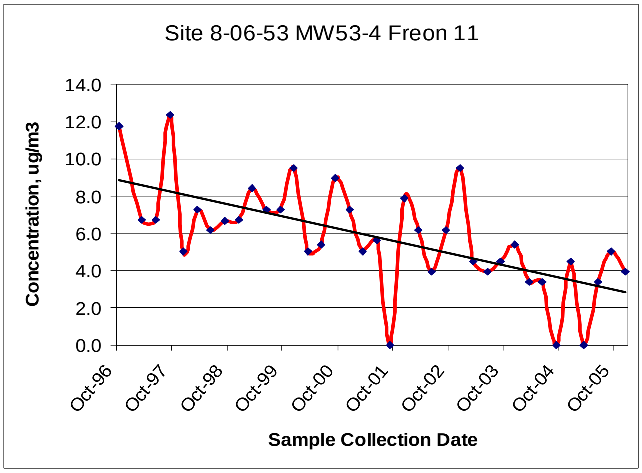

Site 8-06-53 MW53-4 Tetrachloroethylene
Concentration, ug/m3
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

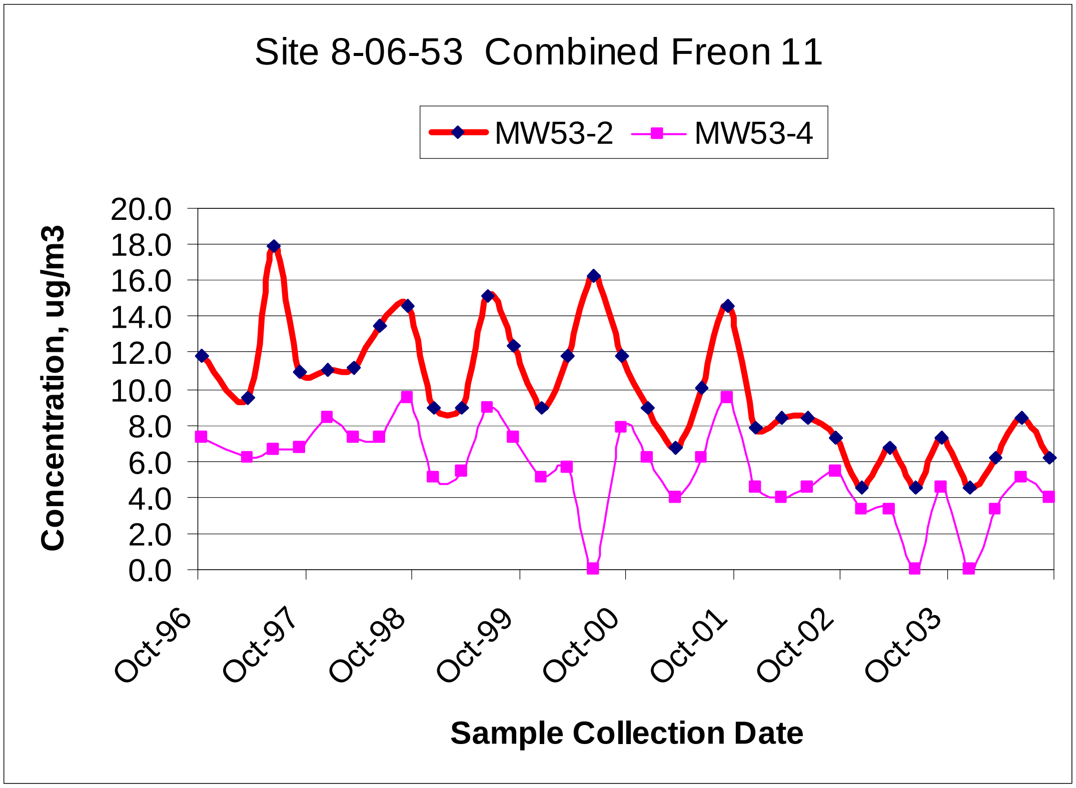

Site 8-06-53 MW53-5 Tetrachloroethylene
Concentration, ug/m3
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

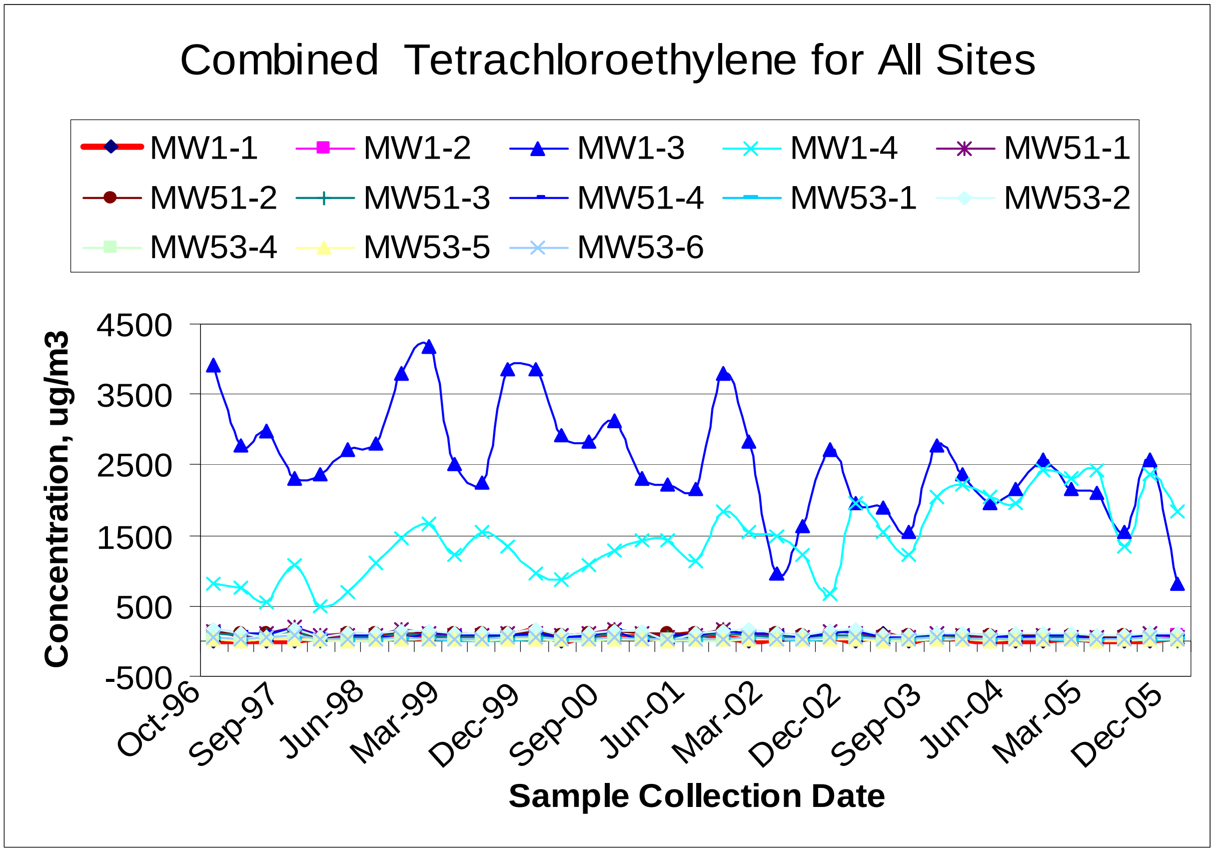

Site 8-06-53 MW53-6 Tetrachloroethylene
Concentration, ug/m3
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

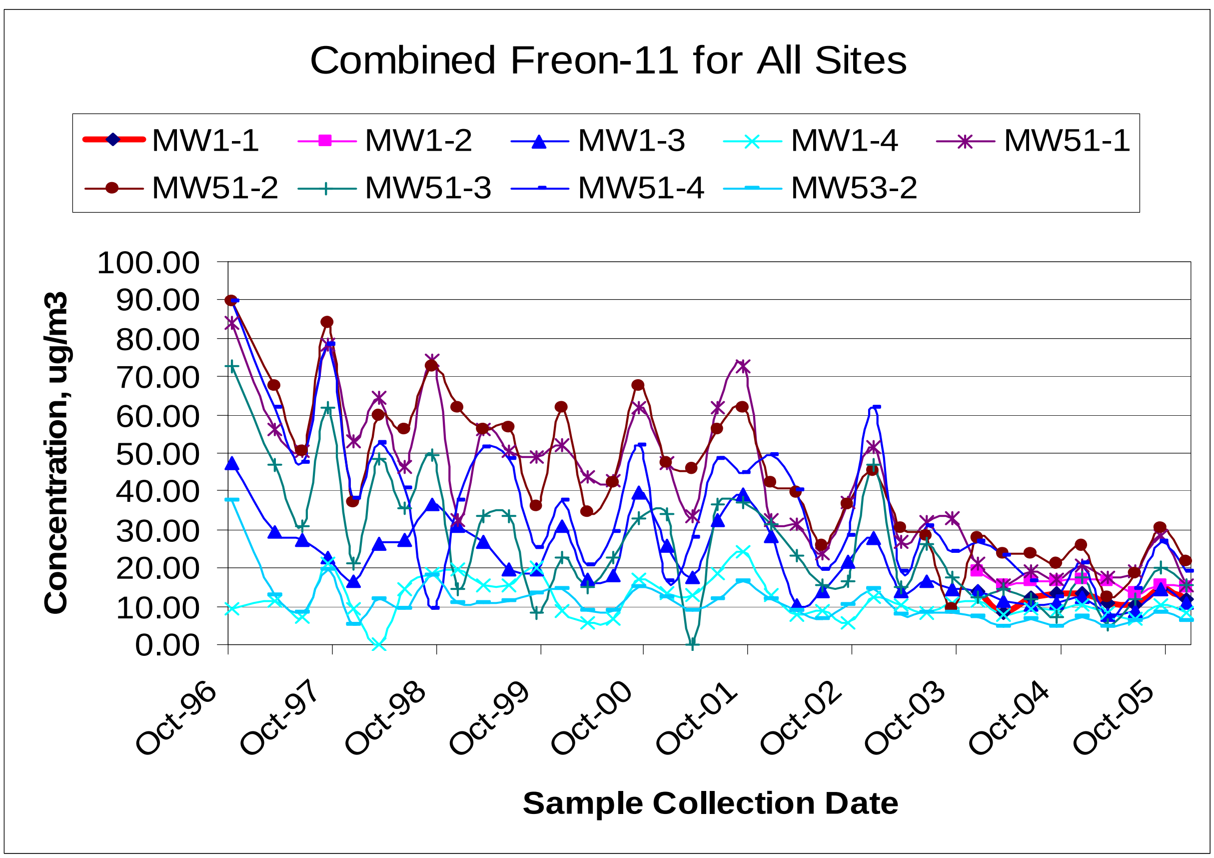

Site 8-06-53 Combined Tetrachloroethylene Chart
MW53-1
MW53-2
MW53-4
MW53-5
MW53-6
Concentration, ug/m3
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

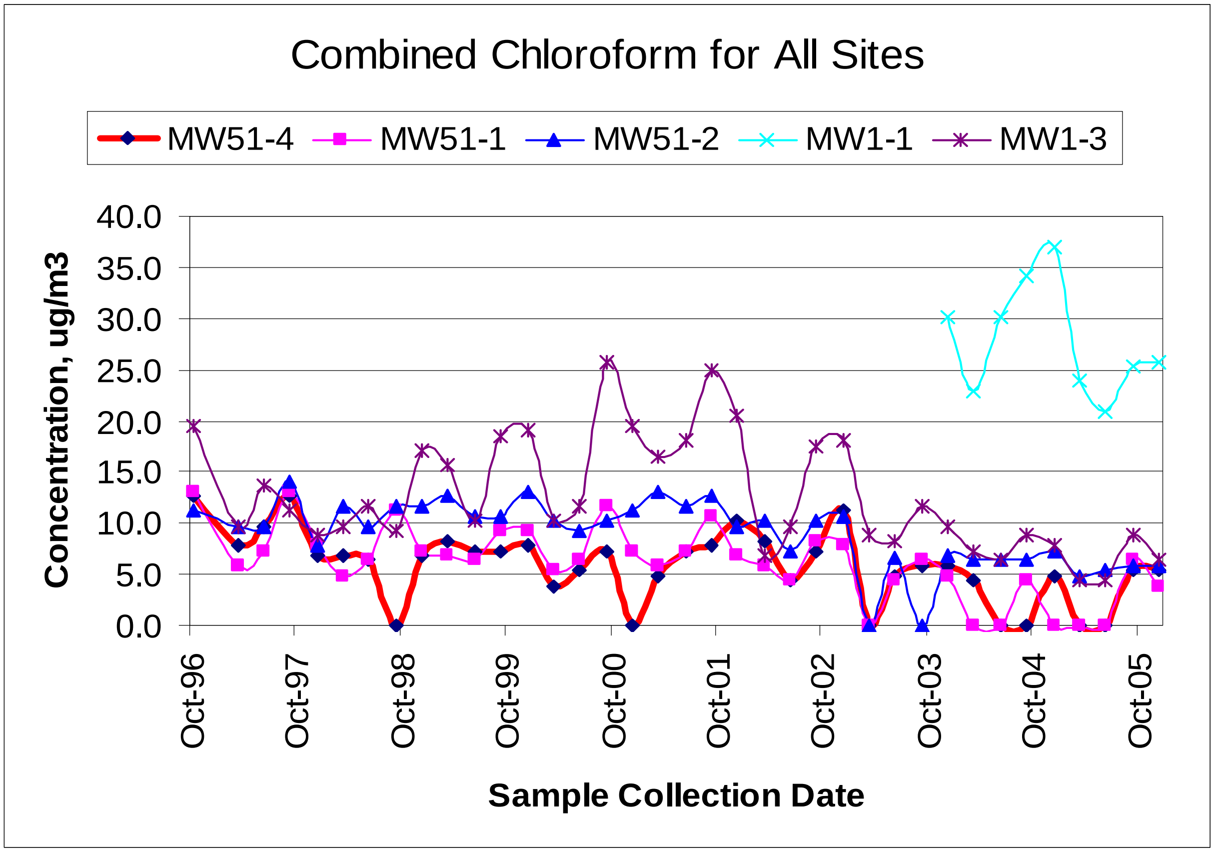

Site 8-06-53 MW53-2 Freon 11
Concentration, ug/m3
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Sample Collection Date

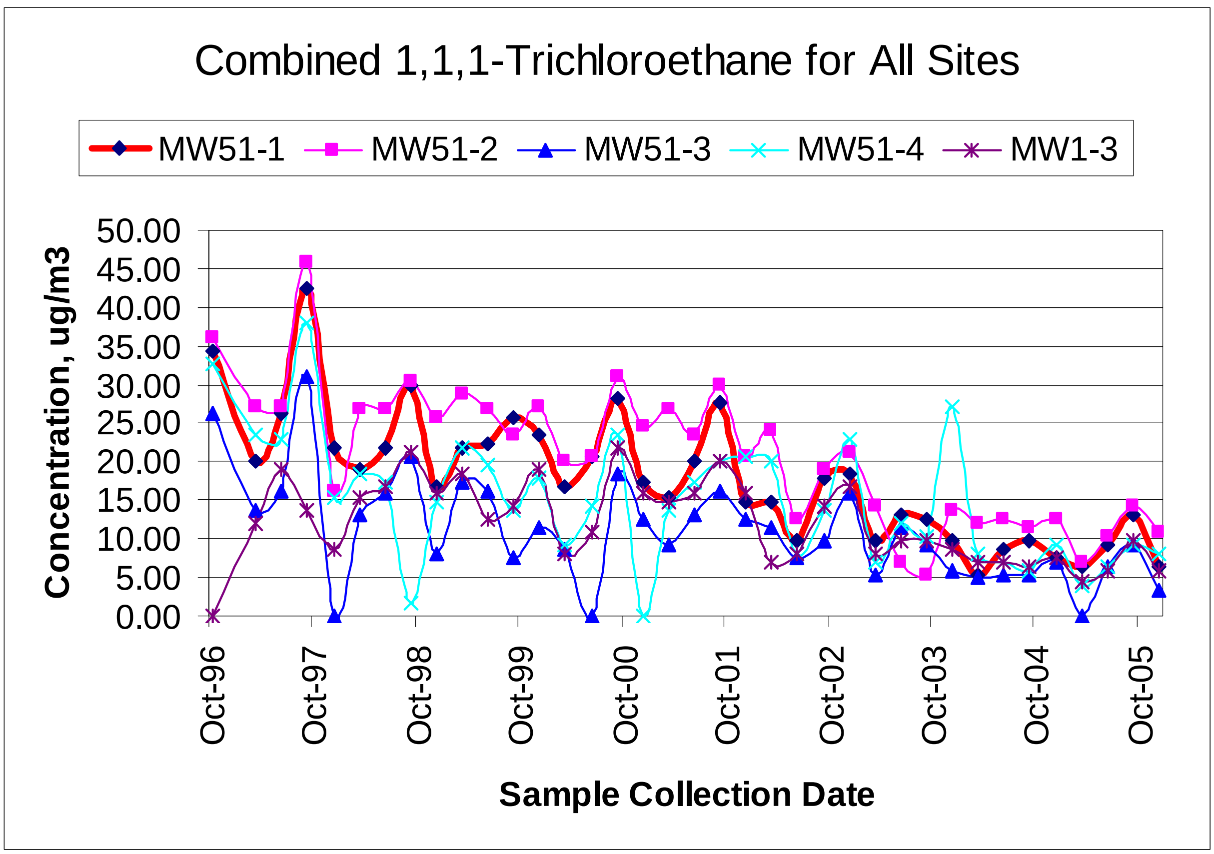

Site 8-06-53 MW53-4 Freon 11
Concentration, ug/m3
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Site 8-06-53 Combined Freon 11
MW53-2
MW53-4
Concentration, ug/m3
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Sample Collection Date


Combined Tetrachloroethylene for All Sites
MW1-1
MW1-2
MW1-3
MW1-4
MW51-1
MW51-2
MW51-3
MW51-4
MW53-1
MW53-2
MW53-4
MW53-5
MW53-6
Concentration, ug/m3
4500
3500
2500
1500
500
-500
Oct-96
Sep-97
Jun-98
Mar-99
Dec-99
Sep-00
Jun-01
Mar-02
Dec-02
Sep-03
Jun-04
Mar-05
Dec-05
Sample Collection Date


Combined Freon-11 for All Sites
MW1-1
MW1-2
MW1-3
MW1-4
MW51-1
MW51-2
MW51-3
MW51-4
MW53-2
Concentration, ug/m3
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Combined Chloroform for All Sites
MW51-4
MW51-1
MW51-2
MW1-1
MW1-3
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Concentration, ug/m3
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date


Combined 1,1,1-Trichloroethane for All Sites
MW51-1
MW51-2
MW51-3
MW51-4
MW1-3
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Concentration, ug/m3
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Sample Collection Date

Appendix D

Responses to IDEQ and EPA Comments

on Draft Five-Year Review

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Preface

The following text provides the Naval Reactors Facility's (NRF's) responses to comments on the Draft NRF Five-Year Review Operable Unit (OU) 8-05/06 Inactive Landfill Areas and OU 8-08 Remedial Action Sites received from the Idaho Department of Environmental Quality (IDEQ) and U.S. Environmental Protection Agency (EPA) on March 22 and March 23, 2006. Responses to the comments were submitted per NR:IBO-06/048 on April 27, 2006. The only modifications made to the text since this submittal were to provide a cross reference to new section numbers that were created while incorporating comments into the Five-Year Review and an additional clarification note added after the response to IDEQ Specific Comment #6 and EPA General Comment #3. The updates on section numbers were bracketed and italicized. This should make it easier for the reader to identify the changes in the revised NRF Five-Year Review document.

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NRF Responses to IDEQ Comments on the Draft Five-Year Review of
Naval Reactors Facility Operable Unit 8-05/06 Inactive Landfill Areas and
Operable Unit 8-08 Remedial Action Sites

General Comment

1) This Five Year Review lacks detail found in the 2001 Five Year Review Document. In particular, the results of periodic monitoring are not as well described or presented. For example, concentration versus time plots, similar to those found in Figures 6-8, and Appendix A of the 2001 document should be included in this five-year review. Also, actual versus expected costs for long term operations and maintenance of the remedies should be included (e.g., see Tables 6 and 7 of 2001 Review Report).

Response:

As discussed with IDEQ and EPA in a telephone conversation on April 5, 2006, NRF will include some of the additional detail in the Five-Year Review. In addition to the details discussed in the responses to IDEQ specific comments, the following information will be included: (1) updated time vs. concentration groundwater graphs and (2) actual versus expected costs for long-term operations and maintenance of the remedies.

Specific Comments

2) Section 1, figures 1-1 and 1-2, pages 2 and 3

Since the sites depicted in these figures were covered under different records of decision, it would be helpful to include the operable unit identifier in the figure titles.

Response:

Figure 1-1 will be modified to include "OU 8-05/6" in the title. Figure 1-2 will be modified to include "OU 8-08" in the title.

3) Section 3.2, general comments, pages 7-12

This section lacks some necessary detail found in the 2001 Five Year Review for the Inactive Landfill Sites. In particular, ecological characteristics, more detailed geologic (including suspected locations of perched water) and geomorphologic descriptions should be presented. Please incorporate some of the information found in the previous report. Additionally, please include a water table contour map depicting groundwater flow directions.

Response:

As discussed with IDEQ and EPA on April 5, 2006, NRF will add the following additional detail to the Five-Year Review:

- Geological, hydrological, geomorphological, and ecological data similar to the 2001 Five-Year Review.
- An updated map on the location of perched water.

- An updated water table contour map.

4) Section 3.4.2.4 [*now Section 3.5.2.4*], page 17

Please add the following sentence, from Section 3.13 of the OU 8-8 ROD, to the end of this description: *"Although no exposure route is present, a source remains at the site."* This statement illustrates the need for the continued five-year review process.

Response:

This comment will be incorporated as requested.

5) Section 3.4.2.7 [*now Section 3.5.2.7*], last sentence, page 17

Please update the text to indicate that the cover has been completed. Additionally, please identify the contaminants that were found at this site.

Response:

The word "initiated" will be changed to "completed" in the referenced sentence. The text will be modified to identify the contaminants found at this site.

6) Section 3.4.3.1 [*now Section 3.5.3.1*], general comment, pages 18 through 21

This section describes the operable unit 8-8 sites, which were excavated as part of the remedial action. The text should explain why institutional controls are still necessary (i.e., contaminant levels exceed concentration limits for current unrestricted use). In at least one case (NRF-12A), contamination levels below 10 foot depths exceed remediation goals for a hypothetical future resident. It is important to discuss why institutional controls must be maintained as this provides the rationale for continuation of the five-year review process.

Response:

The existing last sentence of Section 3.4.3 [*now Section 3.5.3*] and the following sentences will become a new second paragraph in Section 3.4.3 [*now Section 3.5.3*]: "Since contaminated soil remains at these sites above background levels, Institutional Controls (ICs) have been implemented. ICs used at NRF preserve the underlying assumptions of the RI/FSs developed for WAG 8 that will protect human health and the environment. Section 6.2.1 [*now Section 7.2.1*] discusses site ICs in more detail." Similar words will be added to Sections 3.4.1 and 3.4.2 [*now Sections 3.5.1 and 3.5.2*]. In addition, the Five-Year Review will be modified to reference the Institutional Control Plan (Attachment E to the NRF Remedial Action Report) in Section 6.2.1 [*now Section 7.2.1*]. A table summarizing ICs will also be inserted in Section 6.2.1[*now Section 7.2.1*].

Note: Based on IDEQ Comment #11 and EPA General Comment #3 to the Revised Draft Five-Year Review (Appendix E to NRF Five-Year Review) the first sentence of the modified text above was changed in the Five-Year Review to read: "Since contaminated soil remains at these sites with concentrations of contaminants of concern above risk-based concentrations that prevent unrestricted use of the area, Institutional Controls (ICs) have been implemented". These words were added to Sections 3.5.1, 3.5.2, and 3.5.3.

7) Section 3.5.1 [*now Section 3.6.1*], table 3-3, page 21

The footnote should be modified to indicate that the Freon 12 was detected in soil gas samples.

<u>Response:</u>

The footnote for Table 3-3 in Section 3.5.1 [*now Section 3.6.1*] will be modified to read: “Freon 12 was detected in soil gas samples collected at NRF-1 after remedial actions were completed.”

8) Section 3.5.4 [*now Section 3.6.4*], page 23, section 5.3.2.2 [*now Section 6.3.2.2*], pages 46-47, and section 5.3.2.4 [*now Section 6.3.2.4*], general comments, pages 48-49

The 2001 five-year review provided an excellent account of information available regarding the elevated chromium results in NRF-13 and NRF-6 (i.e., 2001 5-yr Report, Section 5.3.2.2 and Appendix A, Section 3.2.1). The information was presented in a very straightforward manner with numerous concentration-trend plots that helped frame the issue. This five-year review should present a similar level of detail. The concentration plots prepared for the 2001 document should be augmented with data collected since the last review. The current document provides very little information, and includes general statements indicating that the causes for the elevated concentrations are “under investigation.” One of the necessary aspects of a Five Year Review Document is a discussion of progress made since the last five-year review. Section 8.3 of the 2001 document describes the need for development of a list of criteria for re-evaluating chromium in NRF-13. These criteria should be discussed in the current document, along with any new information since 2001, as well as outlining project deliverables (work plan), costs, and schedules for this evaluation effort.

<u>Response:</u>

As discussed with IDEQ and EPA on April 5, 2006, NRF will provide additional detail in this Five-Year Review, although the detail provided will not be as comprehensive as the 2001 Five-Year Review. The additional detail will include:

- Updated time vs. concentration groundwater graphs with additional text in the trend analysis section to explain the graphs.
- Additional detail in Section 5.3.2.2 [*now Section 6.3.2.2*] to identify the issues related to NRF-13, NRF-6, and upgradient water monitoring.
- An assessment of data related to NRF-13, NRF-6, and upgradient water monitoring.
- An expanded Section 8.3 [*now Section 9.3*] that includes specific actions NRF plans to take in relation to NRF-13.
- Additional discussion of progress made since the last Five-Year Review.

Should additional analyses of NRF-13 beyond that shown above be necessary, it will be accomplished following additional dialogue with the agencies in separate correspondence.

9) Section 3.5.4 [*now Section 3.6.4*], second paragraph, page 23

It is unclear why the background concentration for chloroform and PCE is "near zero" rather than being zero. Please correct or clarify.

<u>Response:</u>

This sentence will be changed to read: "The natural background concentration for these organic compounds is zero."

10) Section 3.5.4 [*now Section 3.6.4*], [third] paragraph, page 23

Unless there is evidence that contaminants from the Big and Little Lost Rivers are degrading the SRPA on INL, the fourth sentence should be deleted.

<u>Response:</u>

This paragraph will be replaced with the following text: "Water upgradient to NRF could theoretically contain man-caused contamination that is unrelated to the Naval Reactors Program. The Big and Little Lost River systems are the primary source of recharge to the SRPA north (or upgradient) of NRF. No contaminants are known to exist in groundwater sampled by the Regional Upgradient wells."

11) Section 4.1.1. page 23

For clarity, please add *"OU 8-5/8-6"* to the section title.

<u>Response:</u>

"(OU 8-05/06)" will be added to the end of the title.

12) Section 4.1.2 page 24

For clarity, please add *"OU 8-8"* to the section title.

<u>Response:</u>

"(OU 8-08)" will be added to the end of the title. Although some of the No Further Action Sites were associated with other operable units, these sites were determined to be No Further Action in the OU 8-08 Record of Decision.

13) Section 4.1.3 page 24

For clarity, please add *"OU 8-8"* to the section title.

<u>Response:</u>

"(OU 8-08)" will be added to the end of the title.

14) Section 4.2.5.2.4.2, last sentence on page, page 37

Please add *"temporarily"* before *"applied."*

Response:

This comment will be incorporated.

15) Sections 5.2.1.5.2 and 5.2.1.5.3 [*now Sections 6.2.1.5.2 and 6.2.1.5.3*], page 44

Please state which metals analyte(s) were elevated, and by how much. Also, please explain the apparent interpretation that the elevated results were related to the in-well equipment.

Response:

These sections will be expanded to discuss the metal analytes that were elevated and by how much they were elevated. Additionally, an explanation for the apparent cause of the elevated metals will be presented.

16) Section 5.3.2.3 [*now Section 6.3.2.3*], page 48

Please provide more information regarding the frequency and concentrations of solvent compounds in NRF-6.

Response:

This section will be expanded to discuss in more detail the frequency and concentrations of organic compounds found in NRF-6.

17) Section 5.3.3.3 [*now Section 6.3.3.3*], pages 60 through 61

The addition of concentration versus time plots is requested here. A continuation of the plots found in Appendix H of the 2001 Five-year Review is requested.

Response:

The time vs. concentration plots will be included in the Five-Year Review.

18) Section 6.2.2.2.1 [*now Section 7.2.2.2.1*], last sentence on page, page 66

This sentence requires clarification. Please indicate in the text what type of well refurbishment is envisioned, and what the decision criteria are for doing so. Also, please note that if the pump intake is deepened, this should be identified to the Agencies, as there could be water quality differences associated with drawing water from another portion of the aquifer.

Response:

The fourth paragraph of Section 6.2.2.2.1 [*now Section 7.2.2.2.1*] will be revised to read: Currently, NRF plans to inspect and refurbish wells on a routine basis. This includes pulling well hardware from the well and observing its condition, and generally using a video camera to observe the condition of the well casing and screen. Refurbishment may include replacing worn or inoperative parts (e.g., riser pipe, pump, motor, etc.), pulling and cleaning well screens, adjusting pump intake depth, or deepening the well. The regulatory agencies will be notified whenever significant modifications appear appropriate, such as deepening wells or changing the intake depth."

19) Section 6.2.2.2.2 [*now Section 7.2.2.2.2*], page 67

The ability of the existing well network to monitor local upgradient water quality is questionable. This problem should be discussed in this section.

Response:

Discussion of this topic will be expanded in this section. As noted in IDEQ Comment 8 above, further discussion of upgradient monitoring capability will be addressed.

20) Section 7.3 [*now Section 8.3*], item 1, page 70

As noted in Comment # 19, the questionable ability to sample local upgradient water quality through the existing well network is also a deficiency, which should be acknowledged in the text.

Response:

The uncertainty of the current well network to sample local upgradient water quality will be noted as a potential deficiency.

21) Section 8.3 [*now Section 9.3*], third paragraph, page 71

The problems with NRF-13 were discovered in the course of implementing the OU 8-5/8-6 Record of Decision. Therefore, further evaluations, decisions, and corrective actions regarding the well should be conducted pursuant to the FFA/CO. We recommend that the Agencies participate in a scoping session prior to developing a work plan to investigate the cause for the elevated chromium detected in samples from this well. As stated in our previous comments on the 2001 Five Year Review document (IDEQ 2001, Comment # 10), the DEQ recommends determining the vertical extent of the contamination in this well. This information would help determine whether the contamination is related to the interbed near the top of the water column.

Response:

As discussed with IDEQ and EPA on April 5, 2006, NRF will perform a comprehensive review of the data related to NRF-13, including drilling records, construction diagrams, and groundwater and cutting analytical results. Results of this review will be presented in the Five-Year Review along with any recommendations for future work (e.g., pulling the pump/motor, inspecting the well, and replacing well components). Depending on the results of this review, a scoping meeting with the agencies may be needed to evaluate additional actions necessary to investigate NRF-13.

NRF Responses to EPA Comments on the
Draft Five-Year Review for Naval Reactors Facility Operable Unit 8-05/06 Inactive Landfill Areas and Operable Unit 8-08 Remedial Action Sites

General Comments

1. The first page of the review needs to explain why this five year review is being preformed separately from the site-wide five year review. This can be accomplished in one sentence or so.

Response:

The following sentences will be added to both the Executive Summary and Section 1.0: "The INL recently completed a site-wide Five-Year Review for all Waste Area Groups (WAG) except WAG 8 (NRF). WAG 8 is addressed separately since it is under the jurisdiction of the Naval Nuclear Propulsion Program (NNPP) rather than the U.S. Department of Energy Idaho Operations Office or DOE-EM, and cleanup is overseen and funded solely by the NNPP."

2. A special summary form is needed at the beginning of the report. A blank version of the form is available at http://www.epa.gov/superfund/resources/5year/index.htm .

Response:

A copy of this form has been obtained and will be filled out and included in the Five-Year Review.

3. The report does mention repeatedly the inspections of the sites, but does not provide any information on the system behind the institutional controls. For example, how are the land use controls put into place? Are there dig permits? How will this system be maintained over time? Also, we generally want a clear list of all the sites that are required to have institutional controls and the goals of those institutional controls [ICs].

Response:

The existing last sentence of Section 3.4.3 [*now Section 3.5.3*] and the following sentences will become a new second paragraph in Section 3.4.3 [*now Section 3.5.3*]: "Since contaminated soil remains at these sites above background levels, Institutional Controls (ICs) have been implemented. ICs used at NRF preserve the underlying assumptions of the RI/FSs developed for WAG 8 that will protect human health and the environment. Section 6.2.1 [*now Section 7.2.1*] discusses site ICs in more detail." Similar words will be added to Sections 3.4.1 and 3.4.2 [*now Sections 3.5.1 and 3.5.2*]. In addition, the Five-Year Review will be modified to reference the Institutional Control Plan (Attachment E to the NRF OU 8-08 Remedial Action Report) in Section 6.2.1 [*now Section 7.2.1*]. A table summarizing ICs will also be inserted in Section 6.2.1 [*now Section 7.2.1*].

Note: Based on IDEQ Comment #11 and EPA General Comment #3 to the Revised Draft Five-Year Review (Appendix E to NRF Five-Year Review) the first sentence of the modified text above was changed in the Five-Year Review to read: "Since contaminated soil remains at these sites with concentrations of contaminants of concern above risk-based concentrations that *prevent unrestricted use of the area, Institutional Controls (ICs) have been implemented". These words were added to Sections 3.5.1, 3.5.2, and 3.5.3.*

4. The issues and recommendations sections must include the tables in EPA's guidance. (See Exhibit 4-3 and 4-4 in the 2001 Comprehensive Five Year Review Guidance.) In particular, the recommendations form with the date by which something is expected to take place is needed.

Response:

The Five-Year Review will include a table like Exhibit 4-3 in a new section titled "7.6 [*now 8.6*] Deficiencies Summary." The document will also include a table like Exhibit 4-4 in a new section titled "8.6 [*now 9.*6] Recommendations Summary."

5. The draft five-year review report seems to omit a summary of the conclusions and issues and recommendations (and follow-up) from the first five-year review. See the 2001 guidance, Exhibit 3-3, Section V. This section is important to demonstrate the facility's focus on the necessary environmental issues.

Response:

A new section presenting a summary of the conclusions, issues, and recommendations (and follow-up) from the first five year review will be included in the document.

6. The institutional control objectives in the record of decision will eventually need to be revised. The record of decision only really addresses unauthorized access and should address unauthorized excavation like the institutional control plan does. A note should be made of this in the issues and recommendations section with a proposed date of the next five-year review.

Response:

As noted in an e-mail from EPA (D. Thangamoni) on April 6, 2006, this comment has been withdrawn.

Specific Comments

1. **Section 1.0, Page 1.** The date of when the review was initiated and completed is needed.

Response:

The dates when the review was initiated and completed will be added to Section 1.0. A second sentence will be added to paragraph 3 that will read, "This Five-Year Review was initiated in October 2005 and the draft document was submitted to EPA and IDEQ in February 2006."

2. **Section 3.4 [*now Section 3.5*], Page 17 through Page 20**. There are sentences mentioning that risks are acceptable, risks were low, or below remediation level." It would be helpful if this section discussed what the actual estimated risk was and what it is based on.

Response:

Section 3.4 [*now Section 3.5*] was intended to provide a brief description and summary of the history of the sites. Many of the risks referenced in the Five-Year Review were derived qualitatively. For those that were not qualitative, the underlying risk assessments tended to be overly conservative and thus risk management decisions were used. For example, the calculated risks for arsenic were generally high; however, based on comparison to background concentrations and upon the tendency of the assumptions used to calculate the risks to over-estimate the quantity of arsenic at the various sites, a risk management decision was made that the risks were acceptable. Providing the actual estimated risk in the Five-Year Review without providing the context contained in prior documents would be misleading (i.e., show a large risk that was otherwise clarified in other documents). Those prior evaluations remain in the public domain. Since the present Five-Year Review text consists of brief summaries that are consistent with text provided in other documents, it appears acceptable to keep the summaries as-is.

3. **Section 5.3.2.2 [*now Section 6.3.2.2*], Page 47**. The section mentions that NRF-13 is under investigation, but does not include any details of the investigation or when it will be complete. The agencies should probably discuss the investigation further. The details should then be included in the issues and recommendations table.

Response:

As noted in responses to IDEQ comments, NRF will perform a comprehensive assessment of issues associated with well NRF-13. Should there be a need for additional investigations, they will be performed outside this Five-Year Review.

4. **Section 5.3.2.4 [*now Section 6.3.2.4*], Page 51, Table 5-2.** The monitoring period for these averages should be included.

Response:

The monitoring period for the averages will be included as a footnote below the table. The new footnote will read, “Averages are for the period 1989 to present for wells USGS-12, 97, 98, 99, and 102; 1991 to present for NRF-6 and 7; and 1996 to present for NRF-8, 9, 10, 11, 12, and 13.”

5. **Section 6.1 [*now Section 7.1*], Page 64 through Page 65.** This section seems to be missing the topic of whether the toxicity data used at the time of the remedy selection are still valid. Please include a brief discussion of this.

Response:

The text will be modified to include a discussion on toxicity data and whether the data used at the time of the remedy selection are still valid.

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Appendix E

Responses to IDEQ and EPA Comments

on Revised Draft Five-Year Review

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Preface

The following text provides the Naval Reactors Facility's (NRF's) responses to comments on the Revised Draft NRF Five-Year Review Operable Unit (OU) 8-05/06 Inactive Landfill Areas and OU 8-08 Remedial Action Sites received from the Idaho Department of Environmental Quality (IDEQ) and U.S. Environmental Protection Agency (EPA) received on November 2 and November 6, 2006, respectively.

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NRF Responses to IDEQ Comments on the Revised Draft Five-Year Review of Naval Reactors Facility Operable Unit 8-05/06 Inactive Landfill Areas and Operable Unit 8-08 Remedial Action Sites

1) Section 3.2.2.1, paragraph 3, page 11 and Figure 3-4, page 12

Please clarify in the text or footnote to the figure whether the data used to create this ground water table map include other site data such as the water level data collected under WAG 10 or whether this figure is based only on the data shown on the figure.

Response:

Figure 3-4 is based only on NRF data. The second to last sentence of the third paragraph in Section 3.2.2.1 was changed to read: "Figure 3-4 is a map showing the top of the aquifer near NRF during March 2006 *based on water table elevation data collected from NRF wells*."

2) Section 3.3.2, paragraph 1, page 20

The paragraph states elevations of the Snake River Plain range from about 6500 feet near Ashton on the eastern side of the plain to about "1600 feet west of Boise" on the western side of the plain. A quick review of elevations near the Oregon/Idaho border indicates an elevation nearer 2100 feet for the western side of the plain. Please verify this elevation and correct as needed.

Response:

The sentence was changed to read: "…to approximately *2100* feet west of Boise, Idaho."

3) Section 4.2.5.2.3, Figures 4-4 & 4-5, pages 50-51

Please add a north arrow to Figure 4-4.

Response:

A north arrow was added to Figure 4-4.

4) Section 7.2.2.2.1, paragraph 1, page 91

The DEQ agrees with the assessment that the four older wells which includes USGS-12 are not "optimally constructed for specifically monitoring the upper 50 feet of the aquifer…" It appears that the open interval in USGS-12 is about 260 feet or more below the water table based on data provided on the next page. Further discussion is warranted regarding the suitability of this well for monitoring upgradient conditions.

Response:

NRF agrees that further discussion of this issue is warranted. The text in Section 9.3 was changed to include the following sentence: "*The adequacy of USGS-12 to continue to be used as an upgradient well, and whether a new upgradient well needs to be constructed will be discussed with IDEQ and EPA pending the outcome of the field inspection and assessment of NRF-13 discussed above*."

5) Section 7.2.2.6.2, page 95

Soil gas monitoring on a quarterly basis appears excessive because of the lack of variability exhibited by the data and the generally low concentrations found to date. The agencies should discuss reducing the frequency to semiannual and then annual after a few more years of monitoring.

Response:

The last sentence of Section 9.4 was replaced with the following sentences: "*Soil gas monitoring on a quarterly basis no longer appears to be necessary because of the lack of variability exhibited by the data and the generally low concentrations found to date; therefore the sampling frequency will be reduced to semiannual beginning in 2007. NRF will reduce sampling frequency to annual after three years of additional sample collection provided the data supports this change."*

6) Section 9.3, paragraph 2, page 99

The DEQ concurs with the reduction of sampling frequency from three times per year to two times per year based on the analysis provided in this Five-Year Review. A reduction in frequency is warranted at this time.

Response:

The first sentence of the second paragraph of Section 9.3 has been modified to read: "*Beginning in 2007, NRF will reduce* the sampling frequency of all wells from three times per year to twice per year".

7) Appendix A, section 5.2, Figure 5, page A-16

Normalized concentrations do not have units. Please revise the Y-axis description on this figure to match the description on later figures.

Response:

The Y-axis description of Figure 5 has been changed to be consistent with similar Appendix A figures.

8) Appendix A, section 5.2, top paragraph on page A-17

Please specify which "well components" showed evidence of corrosion in the visual analysis.

Response:

The second to last sentence of the identified paragraph was modified to read: "This conclusion is supported by visual evidence of corrosion of *the pump motor casing, riser pipe, and measuring line*."

9) Appendix A, section 5.3, page A-19

a) Should further well development of NRF-13 fail to improve the representativeness of the samples from this well, DEQ recommends consideration of micro-purging/sampling to alleviate the sediment problems. The sediment issue may be alleviated by reducing the drawdown created by the current purging and sampling approach.

b) A strong case is presented for the elevated concentrations of chromium in NRF-13. DEQ recommends filtering the samples to obtain consistent data should NRF prefer to sample this well using the current procedure.

Response:

As long as water samples are collected from this well, NRF intends to collect filtered and unfiltered samples from NRF-13 instead of developing a new procedure for micro-purging. Section 9.3 of the main Five-Year Review text discusses continued collection of filtered and unfiltered samples.

10) Appendix A, section 6.2.3, last paragraph on page A-36 and Figure 19, page A-38

a) The time lag in ground water level changes described in this paragraph is not evident in the figure except for the lag between water level changes in USGS-12 and the other wells. Please describe more clearly how these lags were determined.

Response:

To clarify the time lag, new second and third sentences were added to the last paragraph on page A-36. This new sentence states: "*The peak dates on this table were derived from examination of individual graphs. The graph peak was projected to the x-axis (Data Collection Dates) and the table dates were interpolated from the discrete dates presented on the various graphs*". Furthermore, the seventh sentence (formerly the fifth sentence) of the same paragraph was modified to read: Although NRF-6 has a water table that is consistently lower than NRF-7 and NRF-13, *based on interpretation of graphs with expanded time scales, the water table appears to* peak nearly one and a half months before either NRF-7 or NRF-13 even though NRF-13 is closer to USGS-12.

b) The noted differences in ground water elevations between NRF-6, NRF-7, and NRF-13 may be caused by other factors than differences in permeability. Please note if these wells have been surveyed for borehole deviation and indicate the amount of correction needed to compensate for said deviation. Borehole deviation is another potential reason for apparent water level differences on wells located in close proximity to each other and with these well depths.

Response:

The borehole deviation for NRF-13 was approximately 3.5 feet (horizontal) over 418 feet (vertical) or 0.83%. The total length extension of the borehole compared to vertical was approximately 3/16". Although the deviations associated with NRF-6 and NRF-7 were not measured, other boreholes drilled using the same equipment at the same time showed little or no deviation. The deviations, if any, associated with NRF-6 and NRF-7 are also expected to be small (on the order of a fraction of an inch). Since the maximum elevation differences between NRF-6 and NRF-13 is 1.22 feet and between NRF-6 and NRF-7, is 2.58 feet, borehole deviation probably is not a viable explanation for the observed differences. Although NRF acknowledges that there may be other explanations for observed elevation differences, given what is known of the hydrogeology of the area, differences in permeability seems the most plausible explanation. The last sentence of the last paragraph on page A-36 was modified to read: "*Although there may be other* explanation*s for the observed elevation differences (e.g., how straight the boreholes were drilled), given what is known of the hydrogeology of the area, the most plausible explanation seems to be* related to the relative*ly* low permeability of the aquifer around NRF-7 and NRF-13, compared to the permeability of the aquifer surrounding USGS-12 and NRF-6."

11) Appendix D, Response to Comment # 6, Page D-5

This response should be modified. Institutional controls (ICs) would not necessarily be required due to an exceedance of background concentrations, but rather only if the concentrations of COCs exceed health-based RBCs in unrestricted use. Therefore, if contaminants remain at depths in excess of 10 feet, but at concentrations that would pose an unacceptable risk if those soils were brought to the surface, then ICs will be required to limit future use.

Response:

A note was added to IDEQ Comment #6 and EPA General Comment #3 of Appendix D to alert readers of the above changes. Sections 3.5.1, 3.5.2, and 3.5.3 of the main Five-Year Review document were changed to read: "Since contaminated soil remains at these sites *with concentrations of contaminants of concern above risk-based concentrations that* prevent unrestricted use of the area, Institutional Controls (ICs) have been implemented".

12) Editorial Comment: Appendix A, section 6.2.3, first paragraph, page A-39

There is a minor typographical error in the fifth line ("affects" should be effects).

Response:

The word "affects" was changed to "effects".

NRF Responses to EPA Comments on the Revised Draft Five-Year Review of Naval Reactors Facility Operable Unit 8-05/06 Inactive Landfill Areas and Operable Unit 8-08 Remedial Action Sites

General Comments

1. The location and configuration of the wells being used to collect background groundwater quality data is inadequate. Background is discussed as an inadequacy of the monitoring system and, it would appear appropriate to discuss why a new background well is not being used instead of using ones such as USGS 12. USGS 12 does not monitor the upper portion of the Snake River Plain Aquifer as it is constructed to collect groundwater from about 250 feet below the aquifer surface.

Response:

NRF agrees that further discussion of this issue is warranted. The text in Section 9.3 was changed to include the following sentence: "*The adequacy of USGS-12 to continue to be used as an upgradient well, and whether a new upgradient well needs to be constructed will be discussed with IDEQ and EPA pending the outcome of the field inspection and assessment of NRF-13 discussed above*."

2. In pages 87-90, a discussion of how excavation controls are implemented, monitored and enforced should be included. Do you have a permit system? How many applications do you get a year? How many do you approve, disapprove, and modify?

Response:

NRF organizations are required to prepare excavation permits which are monitored by that organization. Environmental Personnel, who are required to approve all excavation permits do not track the number of permits issued each year; however, there have been no excavations in any CERCLA areas since implementation of excavation controls.

The following sentences were added to the end of the first paragraph of Section 7.2.1: *"Excavation controls are enforced by use of formal excavation permits which are required before any excavation at NRF may begin. These permits require the review and formal approval of Environmental Personnel prior to performing the excavation."*

Specific Comments

1. Section 10.0, Protectiveness Statements, Pages 101-102. The protectiveness statements should be modified into a table format to more closely follow EPA guidance. Below is a suggestion for the table.

Area	Protectiveness Determination	Protectiveness Statement
OU 8-05/06 Landfill Covers	Protective	The remedy at OU 8-05/06 Landfill Covers is protective of human health and the environment. The analytical data shows that the covers are effective at containing contaminants. The covers and direct contact with contaminated soils and landfill wastes are being controlled by institutional controls.
OU 8-08 "No Further Action" Sites	Protective	The remedy at OU 8-08 No Further Action Sites is protective of human health and the environment because the remedy has been effective in limiting unauthorized access and excavation. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the No Further Action designation of the sites.
OU 8-08 Remediated Radiological Sites	Protective	The remedy at OU 8-08 Remediated Radiological Sites is protective of human health and the environment. The OU 8-08 Remedial Action (RA) report indicates that pipe removal and consolidation of contaminated soil has been successful in achieving remedial action objectives (RAOs).
OU 8-08 Engineered Cover Sites	Protective	The remedy at OU 8-08 Engineered Cover Sites is protective of human health and the environment. The OU 8-08 RA report indicates that the construction of an engineered earthen cover has been successful in achieving RAOs. Exposure pathways that could result in unacceptable risks are being controlled by institutional controls.

Response:

Section 10.0 of the Five-Year Review was replaced with the following paragraph and table:

10.0 Protectiveness Statements

The protectiveness of the remedies selected for the areas discussed in this NRF Five-Year Review for the OU 8-05/06 Inactive Landfill Areas and OU 8-08 Remedial Action Sites are summarized in Table 10-1.

Table 10 1 Summary of Protectiveness Statements for NRF CERCLA Sites

Area	Protectiveness Determination	Protectiveness Statement
OU 8 05/06 Landfill Covers	Protective	The remedy at OU 8-05/06 Landfill Covers is protective of human health and the environment. The analytical data shows that the covers are effective at containing contaminants. The covers and direct contact with contaminated soils and landfill wastes are being controlled by institutional controls.
OU 8 08 "No Further Action" Sites	Protective	The remedy at OU 8-08 No Further Action Sites is protective of human health and the environment because the remedy has been effective in limiting unauthorized access and excavation. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the No Further Action designation of the sites.
OU 8 08 Remediated Radiological Sites	Protective	The remedy at OU 8-08 Remediated Radiological Sites is protective of human health and the environment. The OU 8-08 Remedial Action (RA) report indicates that pipe removal and consolidation of contaminated soil has been successful in achieving remedial action objectives (RAOs). The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statement for the sites.
OU 8 08 Engineered Cover Sites	Protective	The remedy at OU 8-08 Engineered Cover Sites is protective of human health and the environment. The OU 8-08 RA report indicates that the construction of an engineered earthen cover has been successful in achieving RAOs. Exposure pathways that could result in unacceptable risks are being controlled by institutional controls. The data also indicates that activities at NRF have not adversely affected the groundwater, thereby supporting the protectiveness statements for the sites.

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