LMS/WEL/S07406

United States Department of Energy
Office of Legacy Management

Weldon Spring Site
Fourth Five-Year Review

September 2011

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Weldon Spring Site Fourth Five-Year Review

September 2011

Approved by: Date:

V. V. Kothari 9/21/2011

Vijendra Kothari
Weldon Spring Site Manger
Department of Energy
Legacy Management

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Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name *(from WasteLAN)*: Weldon Spring Quarry/Plant/Pits (USDOE/Army)		
EPA ID *(from WasteLAN)*: MO3210090004		
Region: 7	**State: MO**	**City/County: St. Charles/St. Charles**
SITE STATUS		
NPL status: X Final Deleted Other (specify)		
Remediation status (choose all that apply): Under Construction **X** Operating Complete		
Multiple OUs?* **X** YES NO		**Construction completion date:** 08 / 22 / 2005
Has site been put into reuse? X YES NO		
REVIEW STATUS		
Lead agency: X EPA State Tribe Other Federal Agency __DOE_________		
Author name: S.M. Stoller Corporation		
Author title: Subcontractor		**Author affiliation:** Subcontractor
Review period:** 10 / 1 / 2010 to 9 / 29 / 2011		
Date(s) of site inspection: 10 / 26–28 / 2010		
Type of review: **X** 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) **X** Other (specify) _4 (fourth)______		
Triggering action: Actual RA Onsite Construction at OU #_____ Actual RA Start at OU#____ Construction Completion **X** Previous Five-Year Review Report Other (specify)		
Triggering action date *(from WasteLAN)*: 9 / 29 / 2006_		
Due date *(five years after triggering action date)*: 9/ 29 / 2011_		

* "OU" refers to operable unit.
** Review period should correspond to the actual start and end dates of the Five-Year Review in WasteLAN.

Five-Year Review Summary Form, cont'd.

Issues:

Erosion areas have been identified on the Chemical Plant Property.

Small depressions and bulges have been identified on the disposal cell.

Uranium levels in the GWOU Objective 2 wells have been greater than the trigger of 100 pCi/L since installation.

There are vandalism issues.

DOE has finalized all the ICs with the exception of an easement with MoDOT.

Recommendations and Follow-up Actions:

Erosion issues are discussed in detail in Section 4.1.3.5 of this report. The recommendations and follow-up actions are as follows: It has been determined that existing erosion continues to be fairly typical for a reclaimed site and that no channels threaten the integrity of the disposal cell. It has been recommended that continued monitoring of erosion would be prudent. The erosion will continue to be monitored, and another mapping and evaluation is scheduled for the spring or early summer of 2011.

These types of areas on the disposal cell are not unexpected for a disposal cell of this type and are not a cause for concern. DOE will continue to monitor the areas.

The recommendation is for the MNA program regarding the uranium impact on the unweathered unit to be evaluated and possibly modified, which could include new trigger values and additional monitoring locations.

For the various vandalism issues, such as moving rocks on the disposal cell and vandalism of the cell monuments, it is recommended to continue the security patrols and to place signs on the disposal cell stating that the video surveillance is in use (or a similar type of action). These signs have been put in place.

It is recommended that DOE work with MDNR and MoDOT to resolve landowner and other issues. Reevaluate whether IC is necessary.

Protectiveness Statements:

The remedy for the completed activities for the Chemical Plant and Quarry Bulk Waste OUs is protective of human health and the environment. The remedies for the Groundwater and Quarry Residuals OUs are protective of human health and the environment upon attainment of groundwater cleanup goals. In the interim, exposure pathways that could result in unacceptable risks are being controlled, and institutional controls are in place and in the process of being put into place to prevent the groundwater from being used in the restricted areas.

Other Comments:

There are no other comments to make at this time.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
901 NORTH 5TH STREET
KANSAS CITY, KANSAS 66101

SEP 2 7 2011

MEMORANDUM:

SUBJECT: Request for Approval of Fourth Five-Year Review Report
Weldon Spring Site, St. Charles County, Missouri

FROM: Hoai Tran, Remedial Project Manager
Missouri/Kansas Remedial Branch

THRU: DeAndre Singletary, Chief
Missouri/Kansas Remedial Branch

TO: Cecilia Tapia, Director
Superfund Division

Attached for your approval is the *Fourth Five-Year Review Report* for the Weldon Spring site in Weldon Spring, St. Charles County, Missouri. The site is located about 30 miles west of St. Louis and is comprised of two geographically distinct Department of Energy-owned properties: the Weldon Spring Chemical Plant and the Weldon Spring Quarry. The site is separated into four operable units: the Chemical Plant Operable Unit which includes the Southeast Drainage, the Groundwater Operable Unit, the Quarry Bulk Operable Unit, and the Quarry Residuals Operable Unit.

The Atomic Energy Commission, a predecessor to DOE, used the Weldon Spring Chemical Plant to convert processed uranium ore concentrates to pure uranium trioxide, intermediate metals and pure uranium metal. These processes resulted in contaminated wastes and groundwater. The remedy for the Chemical Plant Operable Unit included removal of contaminated material, treatment of wastes by chemical stabilization/solidification and disposal of wastes in an engineered disposal facility constructed on-site. The remedy at the Chemical Plant Operable Unit is complete and functioning as designed. Contaminant sources are contained in an on-site disposal cell, and environmental monitoring data and annual inspections continue to verify that the disposal cell is functioning as intended. The remedy for the Chemical Plant Operable Unit is protective of human health and the environment.

The Southeast Drainage is part of the Chemical Plant Operable Unit, but it was addressed as a separate removal action. The remedy for the Southeast Drainage was the removal of contaminated soils and sediment to levels that are protective under current land use. Institutional controls are being used to maintain appropriate land and resource use. The remedy at the Southeast Drainage is protective of human health and the environment.

The Groundwater Operable Unit addresses contaminated groundwater underneath the chemical plant area. The remedy for the Groundwater Operable Unit is monitored natural attenuation with ICs. The MNA remedy is expected to require 100 years to achieve groundwater cleanup goals. In the interim, exposure pathways that could result in unacceptable risks are being controlled, and ICs are in place to prevent the groundwater from being used in restricted areas. The remedy for the Groundwater Operable Unit is protective of human health and the environment.

The Weldon Spring Quarry was used for disposal of uranium and thorium residues, contaminated building rubble, process equipment and soils. The remedy for the Quarry Bulk Operable Unit included excavation of bulk waste from the quarry and placing them in controlled temporary storage pending final placement in the on-site disposal cell at the chemical plant. Bulk waste removal was completed in 2004, and the remedy at the Quarry Bulk Operable Unit is protective of human health and the environment.

The Quarry Residuals Operable Unit addresses residual contamination and long-term monitoring and maintenance for the Quarry Bulk Operable Unit. The remedy for the Quarry Residual Operable Unit includes long-term monitoring of the groundwater in the Missouri River alluvium to ensure that the contaminant plume is decreasing and stable and ICs to prevent exposure to contaminated groundwater. The remedy at the Quarry Residuals Operable Unit is protective of human health and the environment.

For the entire site, the remedies at all the operable units are protective of human health and the environment. This protectiveness statement will be reported to Congress.

As a follow-up to the five-year review, DOE is working to obtain an easement with the Missouri Department of Transportation. DOE has set the date to achieve this milestone by September 30, 2014. The U.S. Environmental Protection Agency will track this in the Comprehensive Environmental Response, Compensation, and Liability Information System to ensure this follow-up is implemented by the due date.

This is the fourth statutory five-year review. The next five-year review for the Weldon Spring site is due September 30, 2016.

Approve [signature] Date 9/27/11

Disapprove ______________ Date ______________

Contents

Figures

Tables

Appendixes

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Abbreviations

ACM	asbestos-containing materials
AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
BTL	baseline tolerance limit
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CLU-IN	Hazardous Waste Clean-Up Information
COC	contaminant of concern
COD	chemical oxygen demand
COPC	contaminant of potential concern
CPOU	Chemical Plant Operable Unit
CSR	Missouri Code of State Regulations
DA	Department of the Army
DNB	dinitrobenzene
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
ESTCP	Environmental Security Technology Certification Program
FFA	Federal Facility Agreement
FIMS	Facilities Information Management System
FP	Frog Pond
FRTR	Federal Remediation Technologies Roundtable
ft	feet
FY	fiscal year
gpa	gallons per acre
gpd	gallons per day
gpm	gallons per month
GWOU	Groundwater Operable Unit
GWRTAC	Groundwater Remediation Technologies Analysis Center
ha	hectares
HDPE	high-density polyethylene
HEAST	Health Effects Summary Tables
IC	institutional control
ICO	in-situ chemical oxidation
IRA	Interim Response Action

IRIS	Integrated Risk Information System
K	conductivity
kg	kilograms
km	kilometers
LCRS	Leachate Collection and Removal System
LTS&M	long-term surveillance and maintenance
m	meters
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
µg	micrograms
µg/L	micrograms per liter
µg/L/yr	micrograms per liter per year
$\mu g/m^3$	micrograms per cubic meter
mg	milligrams
mg/kg-d	milligrams per kilogram per day
mg/L	milligrams per liter
mg/L/yr	milligrams per liter per year
MNA	monitored natural attenuation
MoDOT	Missouri Department of Transportation
MOU	Memorandum of Understanding
mrem	millirem
MSD	Metropolitan St. Louis Sewer District
msl	mean sea level
mV	millivolts
MW	Monitoring Well
NA	not applicable
NB	nitrobenzene
NCP	National Contingency Plan
ND	not detected
NDA	no data available
NDL	not detected above the reporting limit/the method detection limit
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NR	analyte not required
NS	not sampled
NT	nitrotoluene
ORAU	Oak Ridge Associated Universities
ORP	oxidation-reduction potential
OU	operable unit

PAH	polyaromatic hydrocarbon
PCB	polycyclic aromatic biphenyl
pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/L/yr	picocuries per liter per year
QBWOU	Quarry Bulk Waste Operable Unit
QROU	Quarry Residuals Operable Unit
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RAR	relevant and appropriate
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROD	Record of Decision
ROW	right-of-way
RP	Raffinate Pits
SED	Southeast Drainage
SOARs	System Operation and Analysis at Remote Sites
TCE	trichloroethylene
TDS	total dissolved solids
TEDE	total effective dose equivalent
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	total organic carbon
TSA	Temporary Storage Area
UCL	upper confidence limit
UUUE	unlimited use and unrestricted exposure
WSSRAP	Weldon Spring Site Remedial Action Project
yd^3	cubic yard

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Executive Summary

The Weldon Spring Site in St. Charles, Missouri, also known as the Weldon Spring Site Remedial Action Project, has been remediated by the U.S. Department of Energy in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986. The Weldon Spring Site includes the Chemical Plant Area and the Quarry. Remediation of the Weldon Spring Site was administratively divided into four Operable Units: the Chemical Plant Operable Unit (CPOU), the Groundwater Operable Unit (GWOU), the Quarry Bulk Waste Operable Unit (QBWOU), and the Quarry Residuals Operable Unit (QROU).

The CERCLA Five-Year Review is required by statute. Section 121(c) of CERCLA requires that remedial actions resulting in any hazardous substances, pollutants, or contaminants remaining at a site above levels that allow for unlimited use and unrestricted exposure be reviewed every 5 years to ensure protection of human health and the environment. This is a statutory review.

This is the fourth Five-Year Review conducted for the Weldon Spring Site. Remedial activities at the Chemical Plant and the Quarry have been completed with the exception of long-term groundwater monitoring at both locations. The GWOU Record of Decision (ROD) (DOE 2004a) was finalized in January 2004 and was signed by the U.S. Environmental Protection Agency (EPA) in February 2004. The GWOU ROD selected the remedy of monitored natural attenuation (MNA) with institutional controls (ICs) to limit groundwater use during the period of remediation. The site has reached construction completion, which was documented in the Preliminary Closeout Report issued by EPA on August 22, 2005. Since the site has reached physical completion, the long-term surveillance and maintenance activities have become the main focus of the project. Progress on the establishment of ICs, conducting annual surveillance inspections, monitoring the groundwater, and establishing the Interpretive Center and Howell Prairie have been major activities for the project.

This five-year review found the remedy for the entire site to be protective of human health and the environment for all the operable units. The remedies for the completed activities for the CPOU and QBWOU are protective of human health and the environment, with ICs to restrict certain land use. The remedy for the GWOU is protective of human health and the environment upon attainment of groundwater cleanup goals through MNA, with ICs. The cleanup times for completion of the MNA remedy are within the projected time frame of 100 years. The remedy for the QROU is protective through long-term monitoring with ICs. In the interim, exposure pathways that could result in unacceptable risks are being controlled, and ICs are in place to prevent the groundwater from being used in the restricted areas.

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1.0 Introduction

The purpose of the Five-Year Review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review reports. In addition, Five-Year Review reports identify issues found during the review, if any, and identify recommendations to address them.

The U.S. Department of Energy (DOE) is preparing this Five-Year Review report pursuant to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121 and the National Contingency Plan (NCP). CERCLA §121 states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The U.S. Environmental Protection Agency (EPA) interpreted this requirement further in the NCP; Title 40 *Code of Federal Regulations* (CFR) §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

DOE, with the assistance of the DOE long-term surveillance and maintenance (LTS&M) contractor, conducted the Five-Year Review of the remedies implemented at the Weldon Spring Site in St. Charles, Missouri. This review was conducted for the entire site, which includes four operable units (OUs), from October 2010 through September 2011. This report documents the results of the review.

This is the fourth Five-Year Review for the Weldon Spring Site. The triggering action for this statutory review is the completion of the third Five-Year Review, on September 29, 2006. The Five-Year Review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure.

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2.0 Site Chronology

Table 1. Site Chronology

Event	Date
Army Ordnance Works begins operations	1941
Army begins burning waste and dumping rubble	1942
Army Ordnance Works ends operations	1945
Majority of Army Ordnance Works property transferred to State of Missouri	1949
Army stops Quarry activity	1949
Chemical Plant Site Site transferred to U.S. Atomic Energy Commission (AEC)	1955
Uranium Feed Materials Plant operations begin	1958
AEC acquires Quarry title	1958
AEC begins waste disposal in Quarry	1963
Uranium Feed Materials Plant operations end	1966
Chemical Plant site transferred to Army	1967
AEC stops waste disposal at Quarry	1967
Army starts waste disposal at Quarry	1968
Army begins decontaminating buildings and removing equipment at Chemical Plant	1968
Army stops waste disposal in Quarry	1969
Army transfers Raffinate Pits to AEC	1971
DOE designates Weldon Spring Site Remedial Action Project (WSSRAP) as a major project	1985
Federal Facility Agreement (FFA) signed between EPA and DOE	1986
Prime management contractor is selected	2/1986
DOE and prime management contractor establish site office	7/1986
Prime management contractor assumes site control	10/1986
Quarry is placed on National Priorities List (NPL)	7/1987
WSSRAP designated as a major systems acquisition	5/1988
Chemical Plant and Raffinate Pits added to NPL	3/1989
Remedial Investigation for the Quarry Bulk Waste complete	12/1989
Feasibility Study for the Quarry bulk waste complete	2/1990
Record of Decision (ROD) for management of the bulk waste at the Quarry complete	9/1990
Quarry Bulk Waste excavation support begins	6/1991
FFA amended	1992
Building dismantlement begins	3/1992
Remedial Investigation/Feasibility Study (RI/FS) for Chemical Plant complete	11/1992
First batch of water discharged from Quarry Water Treatment Plant	1/1993
Quarry bulk waste excavation begins	5/1993
First batch of water discharged from Site Water Treatment Plant	5/1993
ROD for Remedial Action at the Chemical Plant Area of the Weldon Spring Site complete	9/1993
Remedial Design Work Plan for the Chemical Plant complete	1/1994
Chemical Stabilization/Solidification Pilot Plant testing	1995
Building dismantlement complete	1/1995
Remedial Action Work Plan for the Chemical Plant complete	11/1995
Quarry bulk waste excavation complete	12/1995
Remedial Action Report for the Quarry bulk waste complete	3/1997
Remedial Investigation for Groundwater Operable Unit (GWOU) complete	7/1997
Remedial Investigation for Quarry Residuals Operable Unit (QROU) complete	2/1998
Feasibility Study for QROU complete	3/1998
First load of waste placed in disposal cell	3/5/1998
Chemical Stabilization/Solidification Plant begins operation	7/1998
ROD for QROU complete	9/1998
Chemical Stabilization/Solidification Plant completes operations	11/13/1998
Feasibility Study for GWOU complete	12/1998

Table 1 (continued). Site Chronology

Event	Date
Supplemental Feasibility Study for GWOU complete	6/1999
Remedial Design/Remedial Action Work Plan for QROU complete	1/2000
Demolition of Site Water Treatment Plant complete	7/6/2000
Interim ROD for GWOU complete	9/2000
Confirmation of Chemical Plant soil complete	3/2001
Demolition of Quarry Water Treatment Plant complete	5/2001
Placement of waste in disposal cell complete	6/3/2001
Last rock placed on disposal cell	10/23/2001
150 acres around disposal cell prepared for planting of Howell Prairie	6/2002
Interceptor Trench Field Study complete	4/26/2002
Ribbon-cutting for and opening of Interpretive Center	8/5/2002
Site transferred to DOE LTS&M program	10/1/2002
Second planting for Howell Prairie	1/2003
Performance Evaluation Report for Interceptor Trench Field Study complete	5/8/2003
First annual LTS&M inspection	10/28–29/2003
Third planting for Howell Prairie	1/2004
Remedial Action Report for CPOU complete	1/30/2004
Remedial Action Report for QROU complete	1/30/2004
ROD for groundwater complete	2/20/2004
Inspection Report issued	2/25/2004
Annual public meeting	3/25/2004
Groundwater remedial action inspection complete	7/20/2004
Remedial Design/Remedial Action Work Plan for GWOU complete	7/29/2004
Second annual LTS&M inspection	11/17–18/2004
Inspection Report issued	1/2005
Explanation of Significant Differences for institutional controls complete	2/2005
Interim Remedial Action Report for Groundwater complete	3/2005
Annual public meeting	4/6/2005
Final LTS&M Plan issued	7/2005
Preliminary Closeout Report issued by EPA	8/22/2005
Third annual (5-year) LTS&M inspection	11/7-8/2005
Inspection Report issued	3/2006
Annual public meeting	5/11/2006
CERCLA Five-Year Review Report issued	9/2006
Fourth annual LTS&M inspection	12/5,6,15/2006
Inspection Report issued	1/2007
Annual public meeting	3/22/2007
Fifth annual LTS&M inspection	10/24–26/2007
Inspection Report issued	12/2007
Annual public meeting	4/30/2008
Sixth annual LTS&M inspection	10/28–30/2008
LTS&M Plan revised	12/2008
Inspection Report issued	1/2009
Annual public meeting	5/6/2009
Seventh annual LTS&M inspection	10/27–29/2009
Inspection Report issued	1/2010
Annual public meeting	5/19/2010
Eighth annual LTS&M inspection	10/26–28/2010
Inspection Report issued	1/2011

3.0 Background

3.1 Physical Characteristics

3.1.1 Site Description

The Weldon Spring Site is located in St. Charles County, Missouri, about 30 miles (48 kilometers [km]) west of St. Louis (Figure 1). The site comprises two geographically distinct DOE-owned properties: the Weldon Spring Chemical Plant and Raffinate Pit Sites and the Weldon Spring Quarry. The Chemical Plant is located about 2 miles (2.3 km) southwest of the junction of Missouri State Route 94 and U.S. Highway 40/61. The Quarry is about 4 miles southwest of the Chemical Plant. Both sites are accessible from Missouri State Route 94.

During the early 1940s, the Department of the Army (DA) acquired 17,232 acres (6,974 hectares [ha]) of private land in St. Charles County for construction of the Weldon Spring Ordnance Works facility. The former Ordnance Works site has since been divided into several contiguous areas under different ownership as depicted in Figure 2. Current land use of the former Ordnance Works area includes the DOE Weldon Spring Chemical Plant and Weldon Spring Quarry, the U.S. Army Reserve Weldon Spring Training Area, Missouri Department of Conservation (MDC) and Missouri Department of Natural Resources (MDNR) Division of State Parks managed lands, Francis Howell High School, a Missouri Department of Transportation (MoDOT) maintenance facility, the Public Water Supply District #2 (formerly St. Charles County) water treatment facility, a law-enforcement training center, the village of Weldon Spring Heights, and a University of Missouri research park.

The Chemical Plant and Quarry Areas total 228.16 acres (92.33 ha). The Chemical Plant property is located on 219.50 acres (88.83 ha); the Quarry occupies 8.66 acres (3.50 ha).

3.1.2 Geology and Hydrogeology

The Weldon Spring Site is situated near the boundary between the Central Lowland and the Ozark Plateau physiographic provinces. This boundary nearly coincides with the southern edge of Pleistocene glaciation that covered the northern half of Missouri over 10,000 years ago (Kleeschulte et al. 1986).

The uppermost bedrock units underlying the Weldon Spring Chemical Plant is the Mississippian Burlington-Keokuk Limestone. Overlying the bedrock are unconsolidated units consisting of fill, topsoil, loess, glacial till, and limestone residuum, of thicknesses ranging from a few feet to several tens of feet.

Three bedrock aquifers underlie St. Charles County. The shallow aquifer consists of Mississippian Burlington-Keokuk Limestone and Fern Glen Formation, and the middle aquifer consists of the Ordovician Kimmswick Limestone. The deep aquifer includes formations from the top of the Ordovician St. Peter Sandstone to the base of the Cambrian Potosi Dolomite. Alluvial aquifers of Quaternary age are present near the Missouri and Mississippi Rivers.

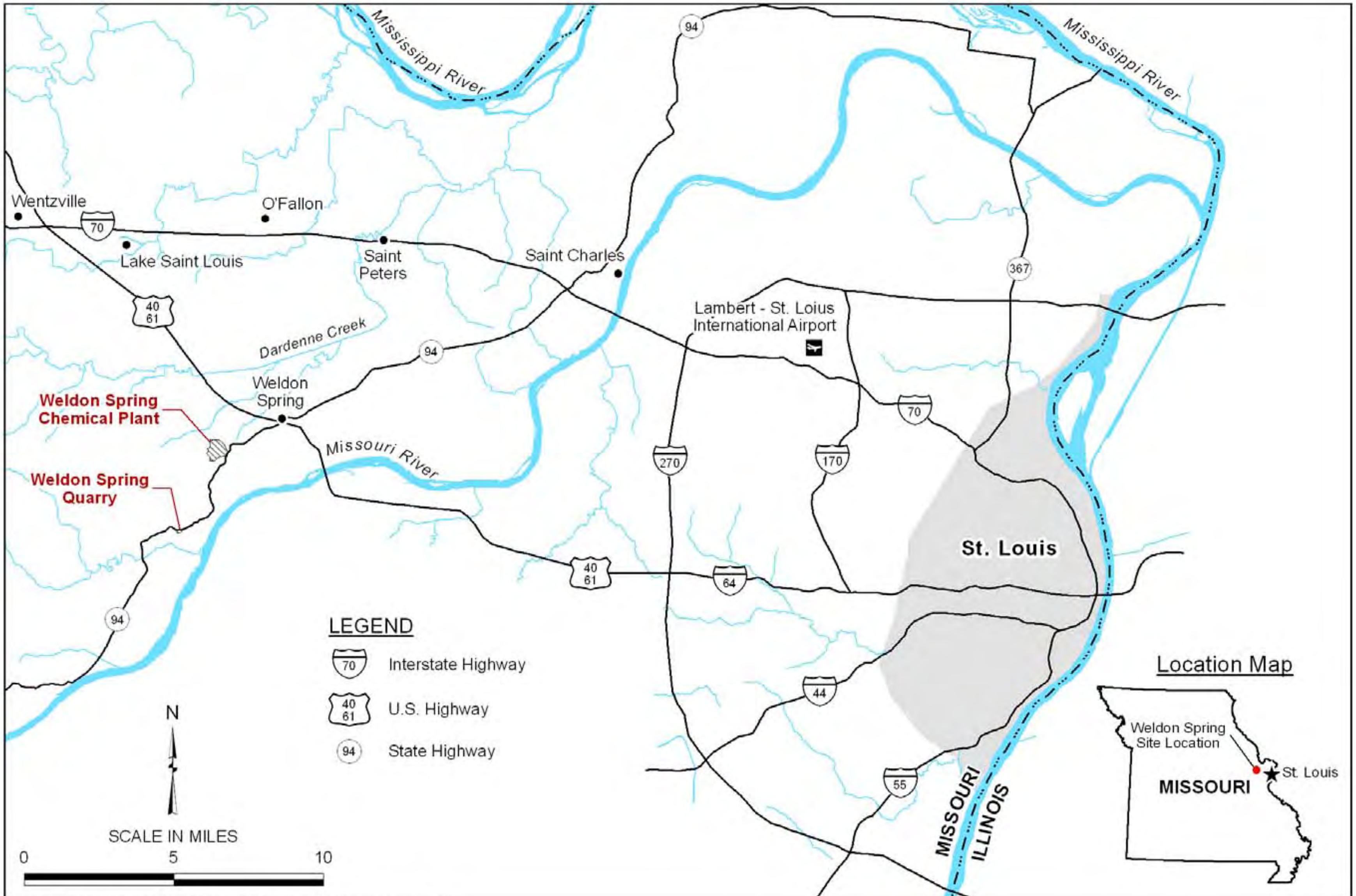

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Figure 1. Location of the Weldon Spring, Missouri, Site

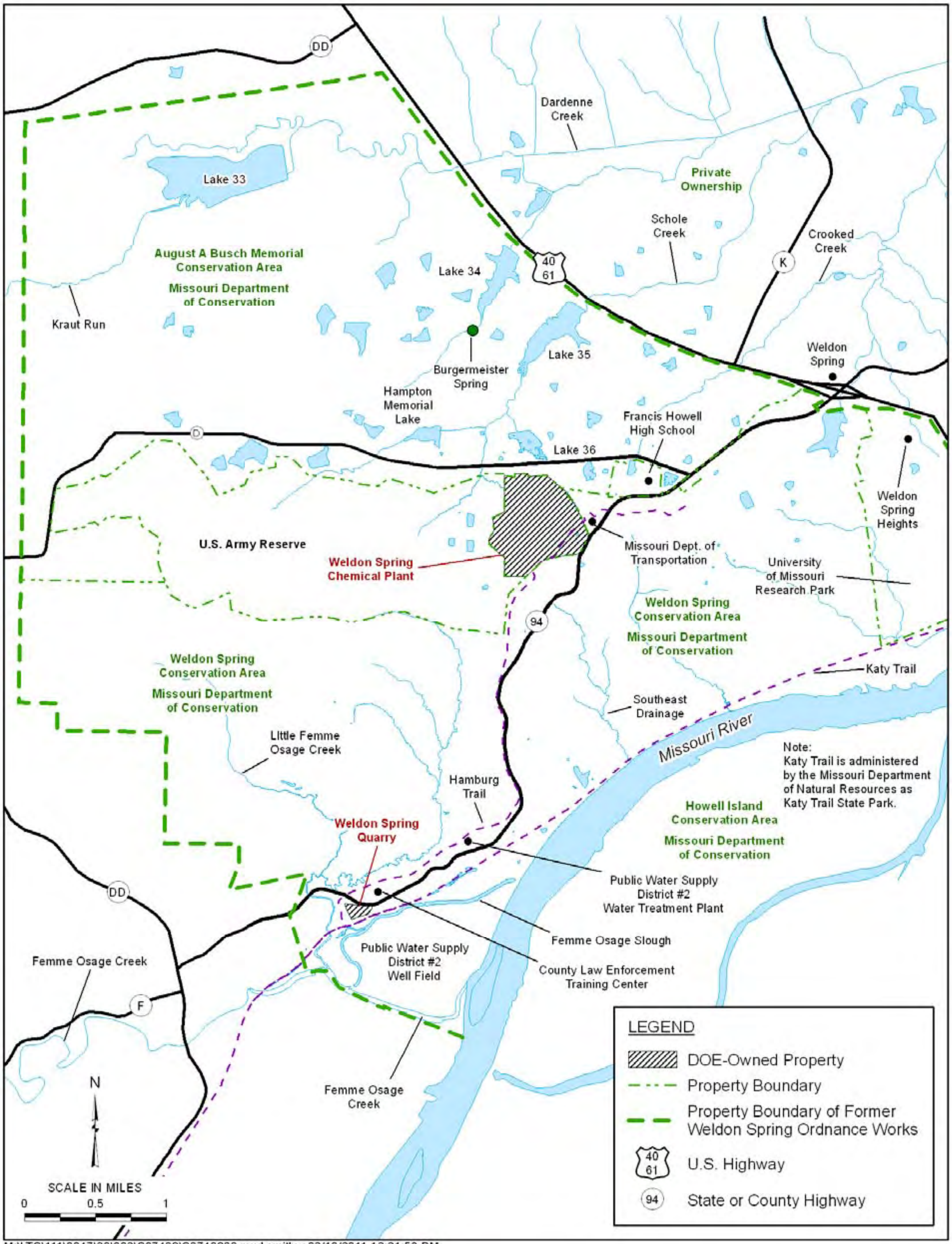

Figure 2. Vicinity Map of the Weldon Spring, Missouri, Site

The Weldon Spring Quarry is located in low limestone hills near the northern bank of the Missouri River. The middle Ordovician bedrock of the Quarry Area includes, in descending order, Kimmswick Limestone, Decorah Formation, and Plattin Limestone. These formations are predominantly limestone and dolomite. Massive quaternary deposits of Missouri River alluvium cover the bedrock to the south and east of the Quarry.

3.1.3 Surface Water System and Use

The Chemical Plant and Raffinate Pits areas are on the Missouri/Mississippi River surface drainage divide. Elevations on the site range from approximately 185 meters (m) (608 ft) above mean sea level (msl) near the northern edge of the site to 203 m (665 ft) above msl near the southern edge. (The cell is not included in these elevation measurements.) The natural topography of the site is gently undulating in the upland areas, typical of the Central Lowlands physiographic province. South of the site, the topography changes to the narrow ridges and valleys and short, steep streams common to the Ozark Plateau physiographic province (Kleeschulte et al. 1986).

No natural drainage channels traverse the site. Drainage from the southeastern portion of the site generally flows southward to a tributary referred to as the Southeast Drainage (or 5300 Drainage, based on the site’s nomenclature) that flows to the Missouri River.

The northern and western portions of the Chemical Plant site drain to tributaries of Schote Creek and Dardenne Creek, which ultimately drain to the Mississippi River. The manmade lakes in the August A. Busch Memorial Conservation Area, which are used for public fishing and boating, are located within these surface drainages. No water from the lakes or creeks is used for irrigation or for public drinking water supplies.

Before remediation of the Chemical Plant and Raffinate Pits areas began, there were six surface water bodies on the site: the four Raffinate Pits, Frog Pond, and Ash Pond. The water in the Raffinate Pits was treated prior to release, and the pits were remediated and confirmed clean. The Frog Pond and Ash Pond were flow-through ponds that were monitored prior to being remediated and confirmed clean. Throughout the project, retention basins and sedimentation basins were constructed and used to manage potentially contaminated surface water. During 2001, the four sedimentation basins that remained were remediated, and the entire site was brought to final grade and seeded with temporary vegetation. Final seeding was conducted during 2002.

The Weldon Spring Quarry is situated within a bluff of the Missouri River valley about 1.6 km (1 mile) northwest of the Missouri River at approximately River Mile 49. Because of the topography of the area, no direct surface water entered or exited the Quarry before it was remediated. A 0.2-acre (0.07 ha) pond within the Quarry proper acted as a sump that accumulated direct rainfall within the Quarry. Past dewatering activities in the Quarry suggested that the sump interacted directly with the local groundwater. All water pumped from the Quarry before remediation was treated before it was released. Bulk waste removal, which included the removal of some sediment from the sump area, was completed during 1995. The Quarry was backfilled, graded, and seeded during 2002.

The Femme Osage Slough, located approximately 213 m (700 ft) south of the Quarry, is a 2.4 km (1.5 miles) section of the original Femme Osage Creek and Little Femme Osage Creek. The University of Missouri redirected the creek channels between 1960 and 1963 during the construction of a levee system around the University experimental farms (DOE 1990b). The slough is essentially landlocked and is currently used for recreational fishing. The slough is not used for drinking water or irrigation.

3.1.4 Ecology

The Weldon Spring Site is surrounded primarily by State Conservation Areas that include the 6,988-acre (2,828 ha) Busch Conservation Area to the north, the 7,356-acre (2,977 ha) Weldon Spring Conservation Area to the east and south, and the Howell Island Conservation Area, an island in the Missouri River, which covers 2,548 acres (1,031 ha) (Figure 2).

The wildlife areas are managed for multiple uses, including timber, fish and wildlife habitat, and recreation. Fishing constitutes a relatively large portion of the recreational use. Seventeen percent of the area consists of open fields that are leased to sharecroppers for agricultural production. In these areas, a percentage of the crop is left for wildlife use. The main agricultural products are corn, soybeans, milo, winter wheat, and legumes (DOE 1992c). The Busch and Weldon Spring Conservation Areas are open year-round, and the number of annual visits to both areas totals about 1,200,000.

The biological assessment conducted for the Chemical Plant Area of the site in 1992 (DOE 1992e) identified several endangered species in the vicinity of the Weldon Spring Site. A comparison of those species with those currently identified as threatened or endangered [http://www.fws.gov/endangered/] indicates that two of the formerly endangered species have been delisted while two other species are identified as endangered in St. Charles County, Missouri. All those species and their status are listed in Table 2.

Table 2. 1992 and Current Threatened and Endangered Species, St. Charles County, Missouri

Species	Group	1992 Status	Current Status
Bald Eagle (*Haliaeetus leucocephalus)*	Birds	Endangered	Delisted
Decurrent False Aster (*Boltonia decurrens)*	Flowering plants	Threatened	Threatened
Interior Least Tern (*Sterna antillarum)*	Birds	Endangered	Endangered
Pallid Sturgeon (*Scaphirhynchus albus)*	Fishes	Endangered	Endangered
Peregrine Falcon (*Falco peregrinus)*	Birds	Endangered	Delisted
Running buffalo clover (Trifolium stoloniferum)	Flowering plants	Not listed	Endangered
Scaleshell mussel (*Leptodea leptodon)*	Clams	Not listed	Endangered

3.2 Land Use and Demography

The 2009 Census estimated the population of St. Charles County to be about 3,555,367. The three largest communities in St. Charles County are O'Fallon (population: 74,000), St. Charles (population: 62,000), and St. Peters (population: 58,000) (Figure 1). The two communities closest to the site are Weldon Spring and Weldon Spring Heights, about 3.2 km (2 miles) to the northeast. The combined population of these two communities is about 5,000. No private residences exist between Weldon Spring Heights and the site. Urban areas occupy about 6 percent of county land, and nonurban areas occupy 90 percent; the remaining 4 percent is dedicated to transportation and water uses.

Francis Howell High School is about 1 km (0.6 mile) northeast of the site along Missouri State Route 94 (Figure 2). The school employs approximately 150 faculty and staff, and about 1,780 students attend it. Approximately 50 bus drivers park their school buses in the adjacent parking lot. The Francis Howell School District is constructing a new school building at the high school, which is estimated to be complete for the start of the 2011–2012 school year.

The MoDOT Weldon Spring maintenance facility, located adjacent to the north side of the Chemical Plant, employs about 10 workers. The Army Reserve Training Area is to the west of the Chemical Plant, and Army trainees and law-enforcement personnel have visited it periodically. During 2008, about 40 full-time employees worked on military equipment at the Army site. At the end of 2008, this operation moved from the Army site. The Army Reserve is currently using the property for storing equipment. A Naval Reserve Center was built on the site in 2008 and is currently operational. An Army Reserve Center is under construction on the Army property at this time. About 741 acres (300 ha) of land east and southeast of the high school is owned by the University of Missouri. The northern third of this land is being developed into a high-technology research park. The conservation areas adjacent to the Chemical Plant are operated by MDC and employ about 50 people.

3.3 History of Contamination

3.3.1 Operations History

In 1941, the U.S. government acquired 17,232 acres (6,974 ha) of rural land in St. Charles County to establish the Weldon Spring Ordnance Works. In the process, the towns of Hamburg, Howell, and Toonerville and 576 citizens of the area were displaced (DA undated). From 1941 to 1945, the DA manufactured trinitrotoluene (TNT) and dinitrotoluene (DNT) at the Ordnance Works site. Four TNT-production lines were situated on what was to be the Chemical Plant. These operations resulted in nitroaromatic contamination of soil, sediments, and some off-site springs.

Following a considerable amount of explosives decontamination of the facility by the Army and the Atlas Powder Company, 205 acres (83.0 ha) of the former Ordnance Works property were transferred to the U.S. Atomic Energy Commission (AEC) in 1956 for construction of the Weldon Spring Uranium Feed Materials Plant, now referred to as the Weldon Spring Chemical Plant. An additional 14.88 acres (6.02 ha) were transferred to AEC in 1964. The plant converted processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A small amount of thorium was also processed. Wastes generated during these operations were stored in four Raffinate Pits located on the plant property. Uranium processing operations resulted in radiological contamination of the same locations previously contaminated by former Army operations.

The Weldon Spring Quarry was mined for limestone aggregate used in construction of the Ordnance Works. The Army also used the Quarry for burning wastes from explosives manufacturing and disposal of TNT-contaminated rubble during operation of the Ordnance

Works. These activities resulted in nitroaromatic contamination of the soil and groundwater at the Quarry.

In 1960, the Army transferred the Quarry to AEC, who used it from 1963 to 1969 as a disposal area for uranium and thorium residues from the Chemical Plant (both drummed and uncontained) and for disposal of contaminated building rubble, process equipment, and soils from the demolition of a uranium processing facility in St. Louis. Radiological contamination occurred in the same locations as the nitroaromatic contamination.

Uranium processing operations ceased in 1966, and on December 31, 1967, AEC returned the facility to the Army for use as a defoliant production plant. In preparation for the defoliant process, the Army removed equipment and materials from some of the buildings and disposed of them principally in Raffinate Pit 4. The defoliant project was canceled before any process equipment was installed, and the Army transferred 50.65 acres (20.50 ha) of land encompassing the Raffinate Pits back to AEC while retaining the Chemical Plant. AEC, and subsequently DOE, managed the site, including the Army-owned Chemical Plant, under caretaker status from 1968 through 1985. Caretaker activities included site security oversight, fence maintenance, grass cutting, and other incidental maintenance. In 1984, the Army repaired several of the buildings at the Chemical Plant, decontaminated some of the floors, walls, and ceilings, and isolated some equipment. In 1985, the Army transferred full custody of the Chemical Plant to DOE, at which time DOE designated control and decontamination of the Chemical Plant, Raffinate Pits, and Quarry as a major project.

3.3.2 Nature and Extent of Contamination

Except for the discontinued decontamination effort by the Army in 1984, the Chemical Plant had been closed for 20 years when the remediation project began at the site. During this period, the infrastructure had deteriorated considerably. Many windows were broken, walls were separated from floors, floors had begun to break apart, and roofs had holes and had deteriorated to the extent that many leaked badly. There was radioactive contamination on various surfaces, polychlorinated biphenyl (PCB) contamination of floors, and deterioration of protective coverings for asbestos containing insulation.

On the Chemical Plant grounds, 300 utility poles supporting 150,000 linear feet of wiring were rotten, and many had fallen to the ground. There was an additional 33,000 linear feet of piping, some with deteriorating asbestos containing insulation. Active water mains leaked extensively and added to contaminated water leaving the site.

In addition to the buildings, four raffinate pits contained several hundred to several thousand pCi/g of uranium, radium, and thorium isotopes. Chemical analysis of the sludge showed relatively homogeneous material in all of the pits except Pit 4, which also contained a large number of discarded drums, containers, and debris from the Army's earlier partial decontamination. The sludge contained concentrations greater than background for all of the metals and anions included in the analysis. The pH of greater than 7 maintained low concentrations of heavy metals in the water. These four pits, Frog Pond, and Ash Pond all contained radionuclides, primarily thorium and uranium, metals such as arsenic and chromium, and inorganic anions such as nitrate and sulfate (Figure 3).

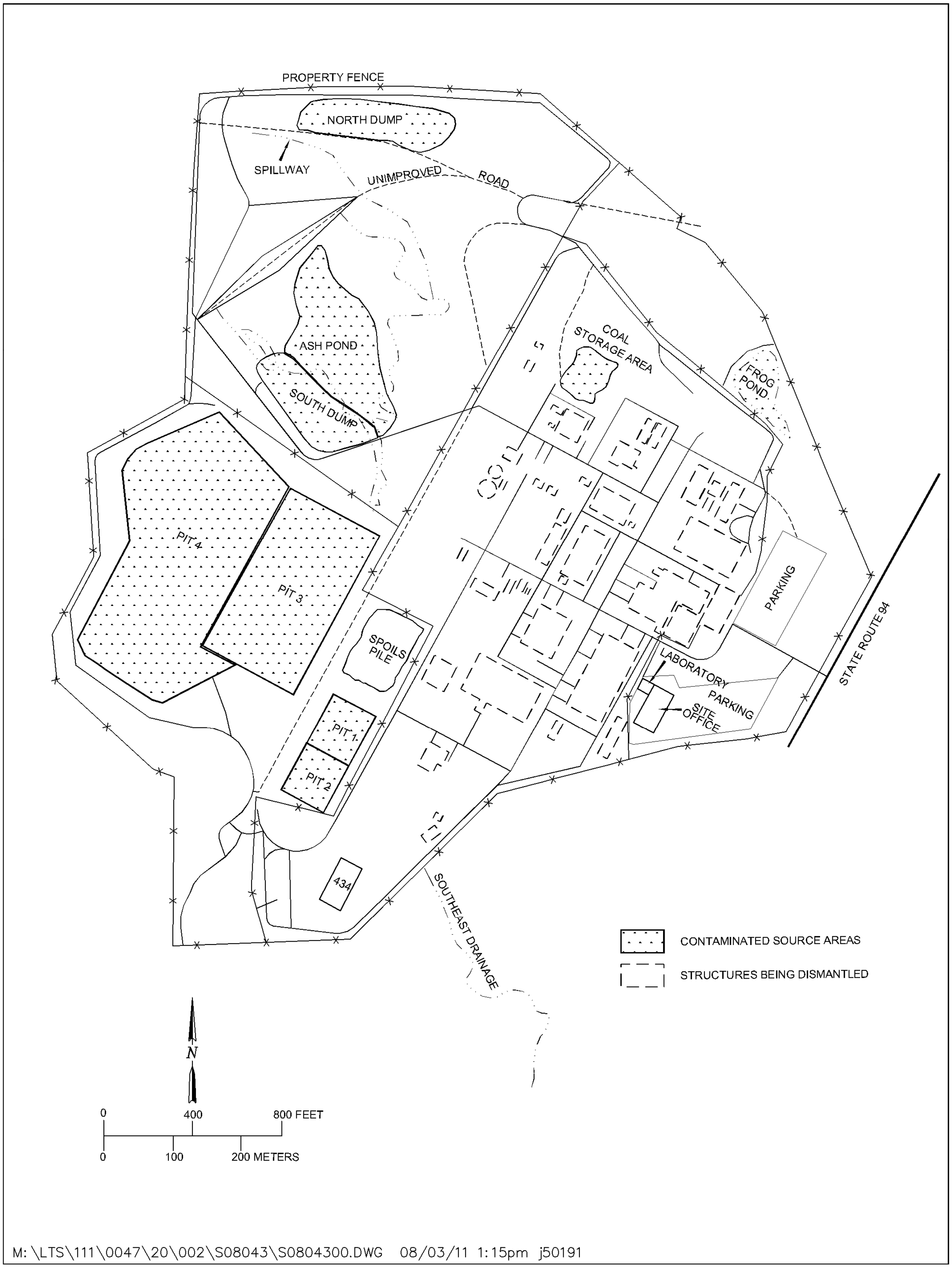

Figure 3. Location of Raffinate Pits, Frog Pond, and Ash Pond

Chemical plant soils generally contained low levels of radionuclides such as uranium, thorium, and radium; some heavy metals such as arsenic and lead; and inorganic ions such as sulfate. Characterization data indicated that uranium (U-238) was generally distributed at low levels across the Chemical Plant surface soils, but a few discrete areas of relatively high concentrations occurred at the north dump, at the south dump, and around the process buildings. Elevated levels of radium (Ra-226 and Ra-228) were detected in a few scattered areas around the process buildings, and elevated levels of thorium (Th-230) were detected in scattered locations around the raffinate pits and in the south dump.

The main chemical contaminants in the soil were metals and inorganic anions. Nitroaromatic compounds were present in the soil at discrete areas associated with former ordnance works operations, and low levels of polycyclic (or polynuclear) aromatic hydrocarbons (PAHs) were present in an area previously used for coal storage and at a concrete pad adjacent to two of the buildings. Areas adjacent to transformers and around the buildings were contaminated with low levels of PCBs. Although asbestos containing material was present throughout the Chemical Plant in buildings and overhead piping, asbestos fibers were not detected in surface or subsurface soil.

Several off-site locations were also radioactively contaminated as a result of releases from the site and were designated as vicinity properties. Low levels of radioactivity (primarily uranium and thorium) were present in several small areas of soil; in the surface water and sediments of Lakes 34, 35, and 36 in the Busch Wildlife Area; and in Burgermeister Spring and springs in the Southeast Drainage. Some higher levels of radionuclides (e.g., uranium, thorium, and radium) were present in sediment at certain locations in the Southeast Drainage because of past operational discharges.

In general, contaminated groundwater was contained within the site boundaries, but low levels of nitrate and nitroaromatics had migrated offsite. Low levels of sulfate and nitroaromatics had migrated into the deeper, competent aquifer on site. Uranium in concentrations slightly above background were primarily transported toward the north and southeast in surface water released from National Pollutant Discharge Elimination System (NPDES) discharge points on the site perimeter.

Specific chemicals and their source areas prior to remediation are listed in Table 3.

Table 3. Specific Chemicals and Source Areas

Source Area	Chemical Contaminants	Radiological Contaminants
Chemical Plant Soils	Non-friable asbestos-containing material (ACM), PCBs, heavy metals, nitroaromatics, PAHs, nitrates, sulfates	Uranium, thorium, radium
North Dump	Non-friable ACM	Uranium, thorium, radium
South Dump	Non-friable ACM	Uranium, thorium, radium
Ash Pond	Non-friable ACM	Uranium, thorium, radium
Raffinate Pit Berms	PCBs, lead chromium, cadmium, tetrachloroethylene, nitrates	Uranium, thorium, radium
Raffinate Pit Water	Antimony, arsenic, magnesium, manganese, molybdenum, selenium, zinc, mercury	Uranium, thorium, radium
Raffinate Pit Sludge	PCBs, heavy metals, mercury	Uranium, thorium, radium
Chemical Plant Building	Friable ACM, non-friable ACM, PCBs, nitric acid, hydrofluoric acid, sodium hydroxide, tributyl phosphate, heavy metals, calcium hydroxide, potassium hydroxide, ethylene glycol, mercury, perchloric acid, magnesium, magnesium fluoride	Uranium, thorium, radium
Frog Pond Water	Arsenic, lead, chromium, mercury, magnesium, magnesium fluoride, nitroaromatics	Uranium
Frog Pond Sediment	Lead, cadmium, chromium, mercury	Uranium
Quarry Pond Water	Friable ACM, PCBs, arsenic, manganese, nitroaromatics, PAHs,	Uranium, thorium, radium
Quarry Pond Sediment	Friable ACM, arsenic, manganese, nitroaromatics, PAHs	Uranium, thorium, radium
Quarry Bulk Wastes	Friable ACM, PCBs, mercury, arsenic, lead, cadmium, nickel, selenium, nitroaromatics, PAHs	Uranium, thorium, radium

3.4 Initial Response

3.4.1 Interim Response Actions

Initial remedial activities at the Chemical Plant, a series of Interim Response Actions (IRAs) authorized through the use of Engineering Evaluation/Cost Analysis (EE/CA) reports, included:

- Removal of electrical transformers, electrical poles and lines, and overhead piping and asbestos that presented an immediate threat to workers and the environment.
- Construction of an isolation dike to divert runoff around the Ash Pond area to reduce the concentration of contaminants going off site in surface water.
- Detailed characterization of on-site debris, separation of radiological and nonradiological debris, and transport of materials to designated staging areas for interim storage.
- Dismantling of 44 Chemical Plant buildings under four separate IRAs.
- Treatment of contaminated water at the Chemical Plant and the Quarry.

Originally, 23 IRAs (Table 4) were scoped, but some of these were cancelled and others combined so that 14 were completed. Any of the IRAs cancelled were covered by other environmental documentation.

Table 4. Weldon Spring Site Interim Response Actions

Number	Description	Status
1	Electrical Transformer Removal	Complete
2	Ash Pond Isolation System	Complete
3	Material Staging Area (Moved to IRA 15)	Cancelled
4	Army Property 7	Complete
5	August A. Busch and Weldon Spring Wildlife Areas 3, 4, 5, and 6	Cancelled
6	Overhead Piping/Asbestos Removal	Complete
7	Containerized Chemicals	Complete
8	Electrical Pole/Overhead Line Removal	Complete
9	Debris Consolidation	Complete
10	Building 409 Dismantlement	Complete
11	Building 401 Dismantlement	Complete
12	Isolation Dike for Surface Water Management on the Southeast Drainage (SED)	Cancelled
13	Army Reserve Properties 1, 2, 3, and 7	Cancelled
14	Dismantlement and Removal of Non-Process Buildings, Structures, and Equipment (Moved to IRA 15-19)	Cancelled
15	Non-Process Building Dismantlement Task 1	Complete
16	Remaining Process and Non-Process Building Dismantlement (Moved to IRA 18)	Cancelled
17	Water Tower Removal (Moved to IRA 18)	Cancelled
18	Process (Contaminated Structures) Building Dismantlement	Complete
19	Decontamination Facility	Cancelled
20	Site Water Treatment Plant	Complete
21	Quarry Water Treatment Plant	Complete
22	Quarry Construction Staging Area (Incorporated into Quarry Bulk Waste ROD)	Cancelled
23	Southeast Drainage Soil Removal	Complete

EPA placed the Quarry and Chemical Plant areas on the National Priorities List on July 30, 1987, and March 30, 1989, respectively.

A Federal Facility Agreement (FFA) was signed by EPA and DOE in 1986, and it was amended in 1992. The main purpose of this FFA was to establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the site in accordance with CERCLA.

A revised FFA between EPA, DOE, and MDNR was signed by all parties by March 31, 2006. The focus of the new FFA is LTS&M activities.

Remediation of the Weldon Spring Site was administratively divided into the four OUs: the Quarry Bulk Waste Operable Unit (QBWOU), Quarry Residuals Operable Unit (QROU), Chemical Plant Operable Unit (CPOU), and Groundwater Operable Unit (GWOU). The Southeast Drainage was remediated as a separate action through an EE/CA report (DOE 1996). The selected remedies are described in Section 4.0.

3.5 Basis for Taking Actions

3.5.1 Chemical Plant Contaminants of Concern

Table 5. Concentration and Location of Chemicals of Concern at the Chemical Plant

	On-Site Concentration Range[a]			Off-Site Concentration Range[b]	
Contaminant	**Soil (mg/kg)**	**Surface Water (µg/L)**	**Raffinate Pit Sludge (mg/kg)**	**Surface Water (µg/L)**	**Sediment (mg/kg)**
Antimony	6.4–110	65–400	6.0–87	70–76	ND
Arsenic	1.3–130	12–120	3.1–1,100	12–29	3.0–19
Barium	25–5,200	ND	20–7,700	78–110	10–330
Beryllium	0.51–5.5	7.0–9.0	0.59–25	ND	ND
Cadmium	0.51–11	37	0.94–14	ND	ND
Chromium III	2.0–280	28–170	4.5–150	13–23	6.3–23
Chromium VI	0.22–31	3.1–19	0.5–17	1.4–2.6	0.7–2.5
Cobalt	2.8–110	ND	5.1–144	ND	7.0–37
Copper	3.6–460	30–45	3.7–510	ND	5.0–170
Lead	1.3–1,900	22–450	2.1–640	9.5–15	9.0–48
Lithium	5.3–71	61–4,500	5.0–120	ND	-
Manganese	3.3–13,000	16–33	25–3,000	18–870	280–6,500
Mercury	0.11–2.1	0.29–0.36	0.10–15	0.35–1.3	ND
Molybdenum	4.1–120	690–4,100	16–1.600	22–42	-
Nickel	5.6–270	47–170	3.3–8,800	ND	8.0–66
Selenium	0.63–47	7.5–220	2.7–81	ND	ND
Silver	0.92–13	25–40	1.0–5.0	4.0–6.0	ND
Thallium	1.0–80	ND	1.1–58	33	ND
Vanadium	7.2–380	90–2,100	26–8,700	ND	14–75
Zinc	6.1–1,100	26–60	7.9–1,600	21–78	24–220
Fluoride	1.3–45	230–19,000	3.2–170	170–600	-
Nitrate	0.54–3,800	190–200,000	0.6–160.000	300–260.000	-
Nitrite	1.5–29	-	1.0–1,600	-	-
Acenaphthene	1.9	-	ND	-	ND
Anthracene	3.4	-	ND	-	ND
Benz*[a]*anthracene	0.41–8.2	-	ND	-	ND
Benzo*[b]*fluoranthene	4.6	-	ND	-	ND
Benzo*[k]*fluoranthene	3.9	-	ND	-	ND
Benzo*[g,h,i]*perylene	2.1	-	ND	-	ND
Benzo*[a]*pyrene	5.1	-	ND	-	ND
Chrysene	0.39–8.0	-	ND	-	ND
Fluoanthene	0.58–11	-	ND	-	ND
Fluorene	1.6	-	ND	-	ND
Indeno*[*1,2,3,-*d]*pyrene	3.2	-	ND	-	ND
2-Methylnaphthalene	0.52–4.6	-	ND	-	ND
Naphthalene	1.8	-	ND	-	ND
Phenanthrene	0.42–11	-	ND	-	ND
Pyrene	0.35–19	-	ND	-	ND
PCBs	0.28–12	-	0.15–11	ND	0.2
DNB	1.0–3.8	ND	ND	0.18–0.81	ND
2,4-DNT	0.83–6.3	ND	ND	0.3–11	ND
2,6-DNT	1.6–3.5	ND	ND	0.19–18	ND

Table 5 (continued). Concentration and Location of Chemicals of Concern at the Chemical Plant

	On-Site Concentration Range[a]			Off-Site Concentration Range[b]	
Contaminant	**Soil (mg/kg)**	**Surface Water (µg/L)**	**Raffinate Pit Sludge (mg/kg)**	**Surface Water (µg/L)**	**Sediment (mg/kg)**
NB	1.6–3.8	ND	ND	0.87	ND
TNB	0.63–5.7	0.04–1.4	ND	0.02–0.84	ND
TNT	1.3–32	0.80–7.5	ND	0.05–110	ND

Notes:

[a] The term "on-site" refers to all areas, contaminated or otherwise, within the physical boundaries of the Chemical Plant and Quarry.

[b] The term "off-site" refers to Busch Conservation Area vicinity properties, Weldon Spring Training Area vicinity properties, Weldon Spring Conservation Area vicinity properties, Burgermeister Spring, and the Southeast Drainage.

Abbreviations:

µg/L = micrograms per liter
mg/kg = milligrams per kilogram
NB = nitrobenzene
ND = not detected
TNB = trinitrobenzene

Table 6. Concentration Ranges and Locations of Radioactive Contaminants of Concern

Contaminant	On-Site Concentration Range[a]			Off-Site Concentration Range[b]	
	Soil (pCi/g)	**Surface Water (pCi/L)**	**Raffinate Pit Sludge (pCi/g)**	**Surface Water (pCi/L)**	**Sediment (pCi/g)**
Pb-210	0.4–450	-	1.0–1,700	-	-
Ra-226	0.4–450	3.4–130	1.0–1,700	ND	0.7–220
Ra-228	0.4–450	1.5–25	4.0–1,400	ND	0.4–480
Rn-220 progeny	-	-	-	-	-
Rn-222 progeny	-	-	-	-	-
Th-228	0.4–450	1.5–25	4.0–1,400	ND	0.4–480
Th-230	0.3–97	1.4–760	8.0–34,000	1.0–8.0	1.5–10,000
Th-232	0.4–150	0.2–7.6	3.0–1,400	ND	0.7–2.5
U-234[c]	0.3–2,300	28–1,300	4.9–1,700	2.0–590	0.5–720
U-235	0.01–110	1.3–60	0.2–78	0.09–27	0.02–33
U-238	0.3–2,300	28–1,300	4.9–1,700	2.0–590	0.5–720

[a] The term "on-site" refers to all areas, contaminated or otherwise, within the physical boundaries of the Chemical Plant and Quarry.

[b] The term "off-site" refers to Busch Conservation Area vicinity properties, Weldon Spring Training Area vicinity properties, Weldon Spring Conservation Area vicinity properties, Burgermeister Spring, and the Southeast Drainage.

[c] Estimated on the basis of expected equilibrium conditions.

ND = not detected
pCi/g = picocuries per gram
pCi/L = picocuries per liter

3.5.2 Quarry Contaminants of Concern

Table 7. Concentration of Radionuclides in the Quarry Bulk Wastes

Radionuclide	Bulk Waste Concentration (pCi/g)		Average Surficial Concentration[a] (pCi/g)	Average Background Concentration (pCi/g)
	Range	Average		
Uranium-238	1.4–2,400	200	170	1.3
Thorium-238	0.7–36	26	NDA	1.0
Thorium-230	0.7–6,800	330	150	1.3
Radium-228	0.1–2,200	96	20	1.0
Radium-226	0.2–2,800	110	110	0.9

[a] Samples obtained from the top 15 centimeters (6 inches) of the Quarry bulk wastes.
NDA = No data available.

Table 8. Concentration of Chemicals Detected in the Quarry Bulk Wastes in the 1984–1985 Characterization Study and Background Concentrations in Missouri Soils

Chemical[a]	Composite Borehole Sample Concentration (mg/kg)		Number of Boreholes in Which Chemical Detected	Surface Sample Concentration (mg/kg)	Average Background Concentration[c] (mg/kg)
	Range[b]	Average[b]			
Antimony	<20[d]		0	71	<200[d]
Arsenic	73–120	100	6	100	8.7
Beryllium	0.45–0.83	0.62	6	0.61	0.8
Cadmium	1.8–98	19	6	2.0	<1
Chromium	19–49	30	6	24	54
Copper	38–160	100	6	140	13
Lead	130–410	280	6	950	20
Mercury	0.18–6.3	2.0	6	0.7	0.039
Nickel	19–120	43	6	300	14
Selenium	17–28	23	6	22	0.28
Silver	5.8–8.3	7.0	3	7.5	.0.7
Thallium	3.0–6.2	4.7	6	5.1	<50[d]
Zinc	68–870	340	6	39	49
Cyanide	0.2–0.6	0.38	5	0.2	NA
PCBs (Aroclor 1254)	0.56–46	12	5	1.00	NA
PCBs (Aroclor 1260)	9.0	9.0	1	-	NA

Notes:
[a] All compounds that had one or more positive results above detection limits are listed; concentrations are rounded to two significant figures. Samples were taken from six boreholes in the bulk wastes and from a surface waste pile.
[b] Ranges and averages are for detected values only and do not necessarily indicate the average concentrations for the entire waste material.
[c] Concentration in Missouri agricultural soils
[d] Lower limit of detection.

Abbreviations:
mg/kg = millgrams per kilogram
NA = not applicable

3.5.3 Quarry Residuals

See Table 9 for a summary of quarry residuals contaminants of concern.

Table 9. Summary of Contaminant Data Collected for the QROU[a]

	Quarry Proper		Femme Osage Slough/Creeks			Background			
Contaminant	**Soil**	**Fractures**	**Surface Water**	**Sediment**	**Groundwater**	**Soil**	**Surface Water**	**Sediment**	**Groundwater**
Radionuclides	*(pCi/g)*[b]	*(pCi/g)*[b]	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*
Radium–226	0.28–50	0.20–96	-[c]	-	-	0.69–1.2	0.060–0.24	0.56–1.2	0.040–1.4
Radium–228	0.16–23	0.22–84	-	-	-	0.70–1.4	0.060–0.86	0.28–2.1	0.20–7.3
Thorium–230	0.81–570	0.77–630	-	-	-	0.72–1.2	0.080–1.3	0.54–2.2	0.040–9.7
Thorium–232	0.45–25	0.21–60	-	-	-	0.60–1.2	0.040–0.32	8.2–1.1	0.010–1.0
Uranium-238[d]	0.44–21	1.3–200	0.47–53	1.0–180	0.020–4,200	0.94–1.6	2.5–2.9	0.64–0.69	0.20–11
Chemicals	*(mg/kg)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*
Metals									
Aluminum	4,200–20,000	4,000–31,000	67–200	1,100–20,000	22–26,000	1,300–12,000	67–200	1,100–13,000	18–4,800
Antimony	-	-	-	6.9–36	-	ND	33	ND	86
Arsenic	-	-	3.1–6.8	-	-	3.5–15	ND	2.5–6.8	2.0–8.8
Barium	-	-	-	-	29–1,200	9.3–210	56–97	27–150	75–700
Beryllium	-	-	-	0.27–1.6	-	0.44–0.74	ND	0.27–0.85	0.7–1.7
Cadmium	-	-	-	0.20–3.5	0.26–4.3	0.46–0.98	ND	ND	ND
Chromium	-	-	ND	2.8–24	0.72–150	3.3–13	ND	2.8–16	3.0–54
Cobalt	-	-	-	-	1.4–15	2.0–9.1	ND	2.2–9.5	4.3–6.6
Copper	-	-	-	2.9–30	2.2–120	11–19	16–17	2.9–14	2.2–49
Lead	-	-	ND	-	-	9.2–27	ND	2.7–15	1.0–77
Manganese	-	-	240–1,300	58–1,100	4.3–5,000	170–1,000	270–370	58–810	16–790
Mercury	-	-	-	0.060–0.10	0.16–2.4	0.090–0.10	ND	0.10	0.040–0.40
Molybdenum	-	-	-	0.80–3.9	-	0.59–1.3	ND	ND	17–19
Nickel	-	-	ND	12.3–28	4.2–66	15–28	ND	12–22	12–43
Selenium	0.21–6.0	23–150	-	0.77–2.7	-	0.62–2.0	ND	0.99	2.6–8.9
Silver	0.36–11	10–39	ND	-	-	0.97	ND	ND	22
Strontium	-	-	120–260	-	-	ND	100–110	5.5–17	250–1,200
Thallium	-	-	-	-	1.1–8.3	0.61–2.0	ND	1.5–14	2.9–6.1
Uranium, total	1.4–63	3.9–600	0.70–80	3.0–540	0.03–10,000	0.72–3.0	3.7–4.3	1.6–3.7	0.45–17
Vanadium	-	-	-	4.8–44	1.2–67	6.2–20	10–14	4.8–31	3.2–41
Zinc	24–810	60–820	8.9–78	-	2.4–160	18–66	8.9–13	8.9–69	4.7–53
Organic Compounds									
1,3,5-TNB	0.0030–3.8	1.3	ND	0.14	0.015–270	NA	NA	NA	NA
1,3-DNB	0.002	ND	ND	ND	0.045–3.5	NA	NA	NA	NA
2,4,6-TNT	0.00020–0.69	0.0010–1.2	ND	ND	0.014–60	NA	NA	NA	NA
2,4-DNT	0.0003–0.05	0.00040–1.2	ND	0.0070	0.011–4.6	NA	NA	NA	NA
Nitrobenzene	-	ND	ND	ND	ND	NA	NA	NA	NA
PAHs	0.0075–1.4	0.009–1.4	ND	ND	ND	NA	NA	NA	NA
PCBs	0.031–4.5	0.036–1.5	ND	ND	ND	NA	NA	NA	NA

Table 9 (continued). Summary of Contaminant Data Collected for the QROU[a]

Notes:

[a] The range of detected concentrations for contaminants of potential concern (COPCs) identified for each medium are provided. Contaminants identified as COPCs are those contaminants with concentrations exceeding the statistically determined background concentration. The identification of COPCs was performed by using all the data collected for each medium (i.e., since 1987). For groundwater and surface water, the ranges of reported concentrations are for recent data collected from 1995 to 1997. These recent data are considered more representative of current conditions and indicate a decreasing trend as a result of bulk waste removal from the Quarry. Sources: Weldon Spring Remedial Action Project Database 1997; DOE 1998d.

[b] The majority of the samples from Quarry soil and fractures indicate low concentrations for radionuclides, as reflected by low mean concentrations. Mean Quarry concentrations for Quarry soil and fractures are as follows:

Soil	Mean	Fractures	Mean
Radium-226	2.4	Radium-226	4.5
Radium-228	2.3	Radium-228	4.6
Thorium-230	30	Thorium-230	58
Thorium-232	1.5	Thorium-232	5.7
Uranium-238	4.8	Uranium-238	17

[c] A hyphen denotes that the contaminant was not identified as a COPC.

[d] For groundwater and surface water, reported concentrations are for total uranium.

Abbreviations:

NA = not applicable; (background concentrations of organic compounds that are considered anthropogenic are assumed to be zero)

ND = not detected

3.5.4 Southeast Drainage

Initial soil characterization for the Southeast Drainage was conducted by Oak Ridge Associated Universities (ORAU) from July 1984 through September 1985. During the survey, surface beta and gamma measurements, surface and subsurface soil samples, water samples, and sediment samples were collected. Both vicinity properties that make up the Southeast Drainage (DA 4 and MDC 7) were surveyed separately. During the soil and sediment sampling of MDC 7, five samples were analyzed for Th-230 in addition to Ra-226, Th-232, and U-238. The ORAU data for the Southeast Drainage (both surface and subsurface sediment and soil) are summarized in Table 10.

Table 10. Summary of ORAU Data for Southeast Drainage

Southeast Drainage Area	Ra-226 Concentration Range (pCi/g)	Th-230 Concentration Range (pCi/g)	Th-232 Concentration Range (pCi/g)	U-238 Concentration Range (pCi/g)	Primary Contaminant	Estimated Volume (yd^3)
DA 4	0.76–210	Not Analyzed	0.43–69.1	<1.56–1,010	Ra-226 Th-232 Th-230	3,270
MDC 7	2.57–130	570–10,100	0.51–240	9.58–810	Ra-226 Th-230 Th-232 U-2383	6,997

yd^3 = cubic yard

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4.0 Remedial Actions

4.1 Chemical Plant Operable Unit

4.1.1 Chemical Plant Operable Unit Remedy Selection

The Remedial Investigation/Feasibility Study (RI/FS) process was conducted for the Weldon Spring Chemical Plant Operable Unit in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Chemical Plant area as an operable unit for overall site remediation and to support the comprehensive disposal options for the entire cleanup. Documents developed during the RI/FS process included the following:

- *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site* (DOE 1992a)
- *Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site* (DOE 1992d)
- *Feasibility Study for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1992b)
- *Proposed Plan for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1992f)

In September 1993, DOE finalized the *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993) for managing contaminated materials (except groundwater) at the Chemical Plant. The CPOU addressed the various sources of contamination in the Chemical Plant, including soils, sludge, sediment, and materials placed in short-term storage as a result of previous response actions. The remedial action included in the Chemical Plant Record of Decision (ROD) was the major component of site cleanup and addressed comprehensive disposal options for the project. The primary focus was the contaminated material in the Chemical Plant, including that generated as a result of previous response actions, but it also addressed the disposal of materials generated by the other OUs in order to facilitate a disposal decision that would integrate all of the OUs. The three key components of the remedy or remedial action objectives (RAOs) were:

- Remove the contaminated materials.
- Treat the wastes as appropriate by chemical stabilization/solidification.
- Dispose of the wastes in an engineered disposal facility constructed on site.

These RAOs were all met as discussed below and documented in the *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004b).

The remedy included remediation of 17 off-site vicinity properties affected by Chemical Plant operations. The vicinity properties were remediated in accordance with Chemical Plant ROD cleanup criteria. Appendix A to the LTS&M Plan includes a summary of the vicinity property remediation projects and references to the close-out reports.

Contaminant of concern (COC) information is discussed in Section 3.0.

4.1.2 Chemical Plant Operable Unit Remedy Implementation

The *Conceptual Design Report for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1994) was issued in December 1994 and comprised the Remedial Design Work Plan. The *Remedial Action Work Plan of the Chemical Plant Area of the Weldon Spring Si*te (DOE 1995b) was issued in November 1995.

The majority of the activities and components of the Chemical Plant remedial action were discussed in the second Five-Year Review (DOE 2001b). The cell was close to completion at the time of the report, which was dated August 2001. The cell cover was completed in October 2001. The components of the remedy that have been ongoing since the time of the second and third review are the Leachate Collection and Removal System (LCRS), leachate monitoring, disposal cell groundwater monitoring, and LTS&M activities, such as inspections, monitoring and maintenance, and ICs. The description of the remedial action are detailed in the *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004b), which describes the remedial action in detail.

The *Post-Remediation Risk Assessment for the Chemical Plant Operable Unit Weldon Spring Site, St. Charles, Missouri* (DOE 2002d) documents the risk estimates for residual soil after the remedial action was completed.

4.1.2.1 Disposal Cell Design and Leachate Collection and Removal System

The disposal cell is located on the northeastern portion of the Chemical Plant property, and the outer perimeter protection system encompasses an area of approximately 41 acres (16.6 ha). The five-sided cell has 4:1 side slopes over the clean-fill dike, and cover slopes of approximately 13:1 over the waste. The maximum width of the cell footprint, including the rock-covered apron, is approximately 1,500 ft (457 m), and the maximum height above grade is approximately 91 ft (28 m). The cell contains approximately 1.48 million cubic yards (1.13 million cubic meters) of contaminated waste, with a total activity of 6,570 curies. The waste column has a maximum thickness of 63 ft (19 m), and the waste footprint, including the lower interior dike slopes, is approximately 24 acres (9.7 ha).

Six primary systems were incorporated into the cell design: the cover, the waste, a surrounding clean-fill dike, a geochemical barrier, a basal liner system, and the LCRS.

The cell cover system is approximately 8.5 ft (2.6 m) thick; the upper 3.5 ft (1.1 m) of the top slope consists of limestone riprap with an average diameter of 8 inches (20 centimeters); the riprap is 2 ft thick on the side slopes. The riprap layer protects the cover from erosion and restricts penetration of the cover by plant roots and burrowing animals. This riprap layer overlies a sequence of aggregate bedding and drainage layers. Beneath these layers is a high-density polyethylene (HDPE) liner with an attached layer of bentonite. The principal radon/infiltration barrier consists of a layer of compacted low-permeability clayey soil, 3 ft (0.9 m) thick, beneath the HDPE liner.

Three drainage bays were created at the cell bottom sloping toward two low points on the north side of the cell floor to facilitate leachate flow. The west bay includes a monolith of debris cemented with grout containing raffinate sludges.

The cell bottom liner incorporates two HDPE layers separated by a synthetic drainage layer consisting of geotextile and geonet. The upper HDPE liner system is covered with drainage aggregate and a layer of peat mixed with low-radioactivity soil that will adsorb some leachate contaminants. The lower HDPE liner system was placed on a bentonite mat-covered 3 ft (0.9 meter)-thick layer of compacted clay that is 3 ft (0.9 m) thick. The mat and clay layer provide an additional low-permeability liner and geochemical barrier that will adsorb uranium and other constituents in leachate that could leak through the HDPE liner system. The cell foundation complies with a siting requirement included in the Missouri regulations for the equivalent of a 30 ft (9.1 m) thickness of clay with a permeability of 10 to 7 centimeters per second under the contained waste.

Specific performance and design criteria for the cell include the following:

- Sustain a maximum credible earthquake, defined as such:
  - Peak ground acceleration = 0.26 g (gravitation constant)
  - Period of design ground motion = 0.3 second
  - Duration of design ground motion = 24 to 30 seconds
  - Horizontal seismic acceleration coefficient (long-term) = 0.17
  - Horizontal seismic acceleration coefficient (short-term) = 0.13
- Sustain a probable maximum precipitation event, defined as 38.4 inches in 24 hours.

Leachate from the cell is collected in a primary collection system under the cell. The primary collection system consists of perforated HDPE pipes, 4 inches (10 centimeters) in diameter, placed in the drainage material on top of the primary liner. The pipes convey leachate by gravity to a sump north of the disposal cell. The sump consists of an HDPE pipe (measuring 200 ft [61 m] long and 42 inches [107 centimeters] in diameter) for storage and an HDPE manhole (with a diameter of 60 inches [152 centimeters]) for access. A zone of drain gravel in an annulus enclosed by an HDPE geomembrane liner that is 80 mil (2 millimeters) thick was placed around the leachate piping between the cell liner and the sump and also around the sump itself to provide secondary containment. Within the cell, the primary collection pipes are configured to overflow into the drain gravel if they become clogged or if water levels exceed 12 inches (30 centimeters), to be conveyed inside the annulus to the secondary containment around the sump. A monitor well was installed adjacent to the sump manhole to detect leakage from the sump or overflow of the primary collection pipes into the secondary containment system. Primary collection system pipes converge at the sump.

A secondary collection system consists of an HDPE geonet placed between layers of geotextile (high-tensile-strength filter fabric), which is placed between the primary and secondary bottom liners. This system collects leakage through the primary liner. Fluids flow through the secondary collection system to two gravel-filled sumps, one for each basin, located along the north edge of the cell. The fluids are then conveyed by HDPE pipe through the gravel-filled annulus to the HDPE sump north of the cell. Flows in secondary collection system pipes can be monitored individually at the sump. A screened access point allows monitoring of the secondary containment sump.

Instrumentation sensors installed in the LCRS sump continue to be used to monitor the combined (primary and secondary) leachate volume. The east and west secondary leachate collection system flow is discretely monitored prior to being combined with the primary leachate through a system of volumetrically calibrated containers. These containers are equipped with level switches and dump valves. The container fills with secondary leachate to a predetermined level, and a valve is actuated that dumps the contents. The number of dumps is recorded electronically and displayed at the LCRS monitoring cabinet. The flow rates for primary and secondary discharges are calculated from these data. The LCRS monitoring cabinet is installed in the LCRS Support Building and displays the combined sump level and the discrete secondary collection system number of dumps. The operational capacity of the combined sump is approximately 11,200 gallons, and the sump secondary containment is approximately the same.

Leachate level and flow rates are now being uploaded electronically into the System Operation and Analysis at Remote Sites (SOARS). By using SOARS, these data can be remotely monitored and tracked instead of having to be downloaded at the LCRS. The remote data transfer equipment was installed in April 2007 and has been downloading data since then. SOARS records and tracks the leachate sump level and the secondary volumetric containers. Data are transferred via a land-connected phone line several times a day.

As a reliable database continues to be generated, DOE may modify the sump level monitoring frequency in accordance with regulations in 40 CFR 264.303(c), which requires only monthly and then quarterly flow recording. Flow rates are reported in units of gallons per day (gpd) and compared to the action leakage rate of 100 gallons per acre (gpa) per day established for the leachate collection system.

In 2010, the total primary and secondary leachate production, including secondary containment water, was approximately 36,000 gallons. In 2006, the total primary and secondary leachate production was approximately 51,000 gallons. This is a 30 percent reduction, and the trend is expected to continue.

Figure 4 shows the primary leachate monthly average flow rates for 2006 through 2010. The average monthly discharge from the primary leachate collection system has gone from an average of 135 gpd in 2006 to 88 gpd in 2010. This represents a 35 percent decrease in 5 years and shows that leachate production has decreased more slowly since the previous 5-year period, but continues to decrease as designed.

The combined leachate from the secondary leachate collection system averaged approximately 5.9 gpd for 2006 to 2.8 gpd in 2010. This is a significant decrease (over 50 percent) in the flow rate since 2006. The average leak rate for the entire secondary leachate collection system for 2001 was approximately 0.96 gpa per day. The average leak rate is 2010 was approximately 0.44 gpa per day. This trend is expected to continue as the secondary leachate system flow rate decreases. This trend is also much less than 1 percent of the action leakage rate (100 gpa per day). This is a result of excellent design and construction standards, as well as operational controls that optimized the moisture content of the compacted soil waste.

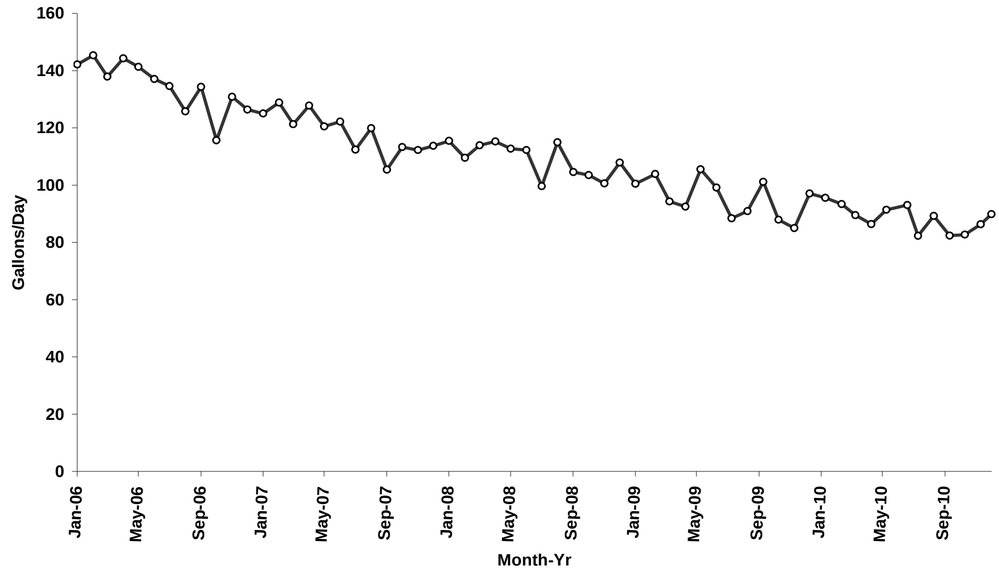

Figure 4. Primary Leachate Trends

The untreated leachate continues to be sampled semiannually in accordance with Appendix K, *Disposal Cell Monitoring Plan* of the LTS&M Plan (DOE 2008c). Table 11 summarizes analytical results for untreated leachate samples collected between 2006 and 2010.

Untreated combined leachate uranium activity during 2002 typically was 50 picocuries per liter (pCi/L). The uranium data have shown a continued, steady trend averaging about 18 pCi/L from 2006 to 2010. Figure 5 shows the untreated uranium concentrations from 2006 through 2010.

The final disposal of leachate continues to be by transferring the combined leachate to the Metropolitan St. Louis Sewer District (MSD) Bissell Point Plant. The MSD and DOE established an agreement in 2001 for MSD to receive the leachate, perform the final treatment on it, and discharge it. This agreement was the most cost-efficient plan to treat and discharge leachate; instead of implementing an on-site treatment plant operation and utilizing the DOE pipeline to the Missouri River. The DOE pipeline continues to be permitted and is the contingency system if the MSD agreement is not renewed.

The MSD agreement was modified in April 2004 to require that the leachate meet the radiological drinking water standard of 30 micrograms per liter (µg/L) (20 pCi/L) prior to acceptance. The disposal cell leachate was very close to this limit in 2004; therefore, DOE exercised a pretreatment contingency process and began treating the leachate through a system of cartridge filters and ion-exchange media that is selective for uranium. The leachate is regularly sampled after treatment and is always significantly below the 30 µg/L limit for uranium. Uranium-removal efficiencies range from 80 to 90 percent removal, so the final uranium concentrations to MSD range from 2 to 4 pCi/L. Also, DOE requested and received approval to raise the allocation of 15,000 gpd to 25,000 gpd. The disposal cell is not generating any additional leachate, but the increased volume limit provided additional operational flexibility related to the pretreatment options and hauling.

Table 11. Leachate Analytical Data

Parameter	June 2006	Dec 2006	June 2007	Dec 2007	June 2008	Dec 2008	June 2009	Dec 2009	June 2010	Dec 2010
Chloride (mg/L)	37.0	34.6	35.6	38.7	44.9	44.9	45.8	43.6	44.1	56.0
Fluoride (mg/L)	0.28	0.22	0.26	0.19	0.21	0.22	0.15	0.21	0.24	0.29
Nitrate-N (mg/L)	1.38	1.52	1.3	0.77	0.32	R	0.014	0.959	1.91	0.35
Sulfate (mg/L)	48.7	42.7	37.5	27.0	19.8	18.5	43.9	54.8	57.3	38.3
Arsenic (µg/L)	ND	ND	ND	ND	8.7	17.6	ND	5.1	ND	ND
Barium (µg/L)	799	768	781	830	1150	1120	817	687	692	843
Chromium (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt (µg/L)	ND	ND	ND	5.1	5.3	5.7	3.9	3.6	3.6	6.1
Iron (µg/L)	1210	3010	4130	3590	21200	19800	2200	5610	2480	8960
Lead (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese (µg/L)	514	369	389	477	543	496	585	402	680	685
Nickel (µg/L)	ND	ND	6.4	9.1	12.8	10.4	10.0	8.2	9.6	9.96
Selenium (µg/L)	ND	ND	ND	ND	1.6	ND	ND	0.9	4.4	3.97
Thallium (µg/L)	ND	ND	ND	7.9	ND	ND	ND	ND	ND	ND
COD (mg/L)	37.0	27.0	69.0	41.0	39	42	45	38	37.1	43.7
TDS (mg/L)	683	619	725	665	1550	636	786	653	756	684
TOC (mg/L)	ND	ND	12.0	13.5	11.0	12.7	11.9	10.4	14.4	15.1
1,3,5-TNB (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DNB (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-TNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-DNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Radium-226 (pCi/L)	0.32	0.45	0.56	0.57	0.52	0.85	0.45	0.32	ND	0.57
Radium-228 (pCi/L)	0.79	ND	0.79	ND	ND	1.09	0.79	0.69	ND	ND
Thorium-228 (pCi/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230 (pCi/L)	0.25	0.46	ND	0.41	0.26	0.55	ND	0.16	ND	0.36
Thorium-232 (pCi/L)	ND	ND	ND	ND	ND	0.22	ND	ND	ND	ND
Uranium (pCi/L)	20.2	24.7	17.1	2.7	17.2	6.0	14.7	21.3	13.9	12.6
PCBs/PAHs (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Abbreviations:
COD = chemical oxygen demand
mg/L= milligrams per liter
ND = not detected
R = validation rejected data point
TDS = total dissolved solids
TOC = total organic carbon

As needed, the leachate is pumped from the sump and transported to the MSD Bissell Point wastewater treatment facility for treatment and discharge. Samples of leachate are collected and analyzed in accordance with MSD requirements for each hauling event. This agreement has an allocation of 0.15 millicuries per year of radioactivity and 25,000 gallons per month (gpm). For the last 5 years, all of the requirements specified in the agreement have been in compliance. Transfers of leachate to MSD have been reduced from four times a year in 2005 to two times a year in 2010. In 2006, MSD granted a 5-year extension to the agreement, which will expire on December 21, 2011.

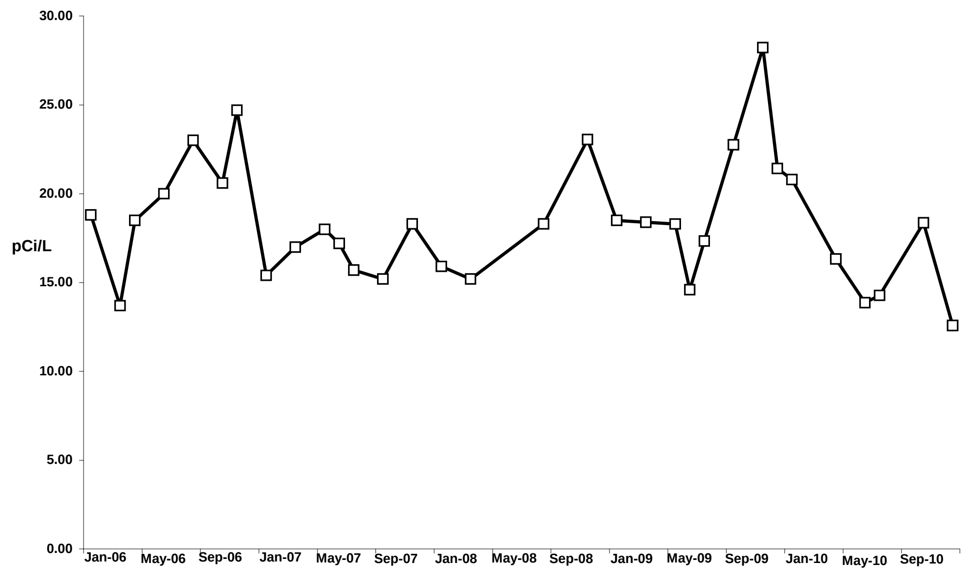

Figure 5. Leachate Concentration Trends

4.1.2.2 Disposal Cell Groundwater Monitoring

DOE established a groundwater detection monitoring network around the disposal cell to monitor cell performance, as required under 40 CFR 264 Subpart F and Title 10 *Missouri Code of State Regulations* Division 25, Chapter 7.264(s)(F) (10 CSR 25–7.264[2][F]). The network originally consisted of five wells and Burgermeister Spring. All wells are completed in the weathered portion of the Burlington-Keokuk Limestone. In 2001, monitor well MW-2048 was damaged and replaced with well MW-2055. Also, well MW-2051 was installed to replace well MW-2045, where anomalous, elevated metal concentrations were attributed to poor hydraulic performance. Burgermeister Spring (SP-6301) is a perennial downgradient point of emergence for groundwater from the Chemical Plant area. The wells, spring, and leachate are sampled semiannually (June and December) for a specific suite of analytes. Specific procedures for evaluating monitoring results and required responses are presented in the LTS&M Plan, Appendix K, "Disposal Cell Groundwater Monitoring Plan."

In 2008, the disposal cell monitoring program was modified based on the results of a periodic evaluation of the leachate composition and groundwater quality. It was determined that while the groundwater quality beneath the disposal cell had been stable, the composition of the leachate had changed. Concentrations of iron, manganese, and uranium in the leachate had shown a general decline since 2003. Barium and uranium were retained as signature parameters for the disposal cell detection monitoring program.

Under the detection monitoring program, signature parameter (barium and uranium) data from each monitoring event are compared to baseline tolerance limits (BTLs) to trace general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. Tolerance limits for signature parameters have been calculated using the dataset from 1997 through 2007, using 95 percent confidence and 95 percent coverage, based on the assumption that the data are normally distributed.

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if changes are occurring in the groundwater system. Data are compared to the 3 most recent years of data to determine if statistically significant increases or trends in concentrations are present. Data are considered statistically significant if they are greater than the arithmetic mean plus 3 times the standard deviation for each location.

Wells with data showing statistically significant increases or decreases are resampled to confirm the exceedance. If the results of the resampling confirm the exceedance, historical leachate analytical data and volumes are evaluated to assess the integrity of the disposal cell. If the leachate data do not indicate that the exceedance could be the result of leakage from the cell, an assessment of the analytical data and review of site-wide monitoring data is performed. If the exceeding parameter is a COC for the GWOU, this information is evaluated under the monitoring program for that OU.

4.1.3 CPOU System Operation and Maintenance

The project transferred LTS&M responsibility for the Weldon Spring Site from the DOE Oak Ridge Office to the DOE LTS&M program on October 1, 2002, and then to the Office of Legacy Management in December 2003. The LTS&M Plan for the Weldon Spring Site was finalized in July 2005. The following is a discussion of the LTS&M activities that took place during the last 5-year review period.

4.1.3.1 LTS&M Plan

The LTS&M Plan implements long-term components of remedies selected for the Weldon Spring Site. The LTS&M Plan was revised and finalized in December 2008 after review by EPA, MDNR, and the public, in accordance with the FFA. Revisions to the LTS&M Plan included changes to the monitoring programs at the Chemical Plant and the Quarry, the addition of the Special Use Area Well Drillers Rule as a final IC, the addition of language regarding potential discovery of contamination on MDNR Division of State Parks property in areas that fall under the proposed IC easement areas, and minor edits to the text and appendixes.

Minor revisions to the LTS&M Plan were submitted to EPA and MDNR on October 1, 2010.

4.1.3.2 Interpretive Center

The Weldon Spring Site Interpretive Center is part of DOE's LTS&M activities at the Weldon Spring Site. The purpose of this facility is to inform the public of the site's history, remedial action activities, and final conditions. The Center provides information about the LTS&M program for the site, provides access to surveillance and maintenance information, and supports community involvement activities.

Current exhibits in the Interpretive Center present:

- The history of the towns that once occupied the area.

- A timeline of significant events at the Weldon Spring Site from 1900 to the present.
- The legacy of the Weldon Spring Ordnance Plant and Uranium Feed Material Plant and the manufacturing wastes.
- The events and community efforts to clean up the site, and the people that made it happen.
- The multi-faceted phases of the Weldon Spring Site Remedial Action Project.

These exhibits may change as appropriate due to new conditions or emerging issues at and near the site. An exhibit upgrade was completed in 2010; it included updating information in several exhibits, adding interactive and multimedia components, creating several new exhibits that address site-related topics, and improving the flow of foot traffic through the Center. A wind turbine was also installed as part of a renewable-energy demonstration project for the public. The turbine currently supplements the power for the new renewable-energy display inside the Interpretive Center.

The Interpretive Center's hours of operation are posted at the site. The current hours of operation are:

- Monday through Friday: 9:00 a.m. to 5:00 p.m.
- Saturday: 10:00 a.m. to 4:00 p.m. (10:00 a.m. to 2 p.m. November 1 through March 31).
- Sunday: 12:00 p.m. to 4:00 p.m.

The Interpretive Center is closed on federal holidays.

Attendance is tracked through the following types of public activities:

- Individuals that walk into the Interpretive Center from the street during normal hours of operation.
- Scheduled groups that participate in Interpretive Center educational programs.
- Community-based organizations that use the Paul T. Mydler and Howell-Hamburg meeting rooms to conduct business meetings.
- Scheduled groups who are unable to visit the site but are recipients of Interpretive Center outreach presentations.

A significant number of individuals also use site amenities (e.g., the Hamburg Trail, the disposal cell perimeter road for prairie viewing, the disposal cell viewing platform, the Native Plant Education Garden); however, because this use does not involve entering the Interpretive Center and is often outside of normal hours of operation, it is not consistently tracked. It is estimated that between 5,000 and 15,000 individuals per year make use of site amenities in this way.

Attendance at the Interpretive Center has been steadily increasing (Table 12). The kindergarten-through-grade-12 educational community continues to have significant interest in Interpretive Center programs. Field trips are usually scheduled at least several months in advance, and available calendar dates fill up quickly. At times, this requires reservations to be made for the following school year. For a few school districts that have limited funding for field trips, outreach activities are scheduled, and Interpretive Center personnel give educational presentations at the school. Outreach activities usually involve several classes or the entire grade level of students.

Table 12. Interpretive Center Attendance

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002								301	224	190	40	31	786
2003	6	44	44	85	174	191	161	233	251	350	125	122	1,786
2004	52	61	166	182	104	324	192	353	379	850	556	354	3,573
2005	123	605	1,056	2,048	1,888	1,408	1,370	1,091	1,511	1,663	1,739	903	15,405
2006	542	1,136	1,595	1,874	1,685	1226	1,465	1,431	1,176	2,215	1,735	692	16,772
2007	1,157	1,022	2,786	2,479	2,192	1,960	1,703	1,129	1,843	2,811	1,569	882	21,524
2008	1,132	1,445	2,261	3,086	2,489	1,734	1,556	1,395	2,412	2,624	1,705	1,142	22,981
2009	1,418	1,987	3,183	2,181	2,036	1,928	1,299	1,492	2,591	2,857	1,522	1,106	23,600
2010	1,440	1,441	2,465	2,378	2,968	2,002	1,904	1,117	2,615	2,696	2,396	1,534	24,956
													131,912

Interpretive Center marketing efforts continue to be a critical component of making the public aware of Interpretive Center programs. In 2009 and 2010, several new educational programs were developed based on teacher requests and Missouri curriculum requirements. It was important that teachers be made aware of these new programs so that they could schedule class visits for the 2009–2010 school year.

The Interpretive Center continues to support community-based special events. On October 30, 2009, the site hosted an event to commemorate the National Day of Remembrance for Nuclear Weapons Workers. Nearly 400 members of the public were in attendance to walk through the Interpretive Center and participate in a ceremony honoring nuclear weapons workers from throughout the St. Louis metropolitan area and surrounding states.

4.1.3.3 Howell Prairie/Native Plant Education Garden

The 150 acres surrounding the disposal cell have been planted with over 80 species of native prairie grasses and wildflowers. Plants such as prairie blazing star, little bluestem, and wild bergamot will once again dominate this area, which was a large native prairie before European settlement. Howell Prairie is one of the largest plantings of its kind in the St. Louis metropolitan area.

A garden of plants native to Missouri was designed and constructed to surround the Interpretive Center and build awareness about the Weldon Spring Site. Garden maintenance consisting of manual weeding and occasional irrigation was performed throughout the growing season. Corn gluten, a cereal industry byproduct with pre-emergent herbicide qualities, was broadcast on garden beds throughout the spring to assist in weed control efforts and act as an organic fertilizer. Dried seed heads from forbs were harvested and utilized for hand overseeding in the prairie area. Locations in the prairie with erosion and less plant establishment were targeted. Volunteers continued to perform garden maintenance activities throughout this period. Volunteers have adopted a total of six large garden beds and are responsible for their maintenance.

Maintenance activities for the prairie that occurred from 2006 through 2010 are as follows:

Prescribed burning was performed in March 2006 in the drainage outlet areas, the southwest portion of the site between the disposal cell and the Hamburg Trail, and selected areas of the Native Plant Education Garden. Because the fuel load was relatively small, burning using traditional techniques was marginally effective; however, greater success was achieved with an alternative burning technique utilizing agricultural equipment designed to burn alfalfa fields.

A controlled burn was also performed in April 2009 on approximately 75 acres of the site. Due to seasonal plant-growth patterns and wind conditions, primarily the northern and western portions of the site were burned. Noticeable improvement in plant growth was observed in burned areas throughout the spring and summer.

In March 2010, wide burn breaks were mowed around the perimeters of prairie-management units to support a possible controlled burn. Approximately 38 acres of prairie were burned on March 30.

Later in the growing season during each year, spot-spraying individual *Sericea lespedeza* and *Robinia pseudoacacia* plants with herbicide is performed as part of ongoing efforts to reduce numbers and control encroachment of invasive weed species throughout the prairie area. The map of infested areas that was developed during fiscal year (FY) 2005 was utilized during this spot-spraying effort in order to streamline fieldwork and to track the effectiveness of the eradication program.

Significantly reduced numbers of plants have been observed from these eradication efforts which have been performed each year.

The Howell Prairie, Native Plant Educational Garden, and Interpretive Center were designed to serve as ICs. These areas will attract visitors to the Weldon Spring Site, thus ensuring long-term community education about the remediation project and enhancing the overall educational mission of the site.

4.1.3.4 Inspections

The annual LTS&M inspections took place at the Weldon Spring Site on December 5, 6, and 15, 2006; October 24 through 26, 2007; October 28 through 30, 2008; October 27 through 29, 2009; and October 26 through 28, 2010. The inspections were conducted in accordance with the LTS&M Plan and the associated inspection checklist. Representatives from EPA and MDNR participated in each of the inspections. Representatives from MDC, MoDOT, the MDNR Division of State Parks, the Weldon Spring Citizens Commission, and St. Charles County participated in portions of the inspections also.

The main areas inspected at the site were the Quarry, the disposal cell, the LCRS, monitoring wells, assorted general features, IC areas, and areas where future ICs will be established.

IC areas were inspected to ensure that pending restrictions on such activities as soil excavation, groundwater withdrawal, and residential use were not being violated. Each area was inspected, and no indication of violations of future restrictions was observed.

The disposal cell was inspected by walking 10 transects over the cell and around the cell perimeter. No unusual settlement or other unusual observations were noted. Five areas of the cell were marked for annual observations of rock degradation. The LCRS was also inspected and found to be in good condition. A majority of the groundwater-monitoring wells were inspected each year and found to be in generally good condition. A few of the wells needed to be labeled with the proper identification numbers or repainted. Other site features, including the prairie, site markers, and roads, were also inspected.

Details of the inspections can be found in the *2006 Annual Inspection Report for the Weldon Spring Site St. Charles, Missouri*, (DOE 2007a), *2007 Annual Inspection Report for the Weldon Spring Site St. Charles, Missouri*, (DOE 2008a), *2008 Annual Inspection Report for the Weldon Spring Site St. Charles, Missouri*, (DOE 2009a), *2009 Annual Inspection Report for the Weldon Spring Site St. Charles, Missouri*, (DOE 2010a), and *2010 Annual Inspection Report for the Weldon Spring Site St. Charles, Missouri* (DOE 2011). Details of the 2010 inspection, which also served as the Five-Year Review inspection, are found in Section 6.5 of this report.

Annual public meetings were held in 2006 through 2011 to discuss the annual inspections. Also discussed during the public meetings were the LTS&M Plan, ICs, a summary of environmental data, and the Interpretive Center and prairie.

4.1.3.5 Erosion

Areas of erosion in the prairie were identified during the 2006 inspection, and it was recommended that the prairie be inspected more thoroughly, the erosion areas be located and mapped by GPS, and the erosion areas be repaired. Erosion channels within the entire prairie were mapped with GPS in August 2007 and again in June 2008, June 2009, and May 2010 (Figure 50). The resulting information will be used to track the nature and extent of erosion in the future.

A field survey to evaluate erosion issues in the prairie was performed on August 2, 2007. The following individuals participated in the survey: Yvonne Deyo (S.M. Stoller Corporation [Stoller], Weldon Spring Project Manager), Marilyn Kastens (Stoller), Ben Moore (MDNR), Raymond Franson (MDNR), Frank Oberle (Pure Air Native Seed), and Jon Wingo (DJM Ecological Services). It was determined that existing erosion was temporary and typical of a newly reclaimed site in the process of stabilizing. It was recommended to monitor erosion channels and evaluate the other possible soil-amendment and vegetation-management strategies. Soil disturbance of any kind was not recommended at this time. The report that was prepared to document this trip was reviewed by the inspection participants during the 2007 inspection and included in the 2007 report.

In September 2009, a group of Legacy Management Support subject matter expert personnel met to discuss the current status of site erosion. It was determined that existing erosion continued to be fairly typical for a reclaimed site and that no channels threatened the integrity of the disposal cell. The group agreed that continued monitoring of erosion would be prudent. The erosion will continue to be monitored, and another mapping and evaluation is scheduled for the spring or early summer of 2011.

It was noted during the 2010 inspection that vegetation had taken over some of the worst erosion areas located on the north side of the disposal cell.

4.1.3.6 Institutional Controls

Institutional controls for the Chemical Plant Operable Unit are discussed in Section 6.5.1 and Section 7.1.5.

4.1.3.7 Culverts

Highway 94 culvert: As described in Appendix A of the LTS&M Plan, a corrugated metal culvert underneath Missouri State Route 94 at the Southeast Drainage contains fixed residual radioactivity on its inner surfaces in excess of DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, generic surface contamination guidelines for natural uranium, uranium-238 and associated decay products. A supplemental limit was approved by the DOE Oak Ridge Operations Office, Oak Ridge, Tennessee. The culvert is included on the annual inspection checklist and inspected each year. Also, MoDOT representatives are contacted each year prior to the inspection to remind them of the contamination issue, and they are asked to contact DOE if any maintenance is done in the area. MoDOT personnel did contact DOE in 2010 and asked if DOE would cut the end of the culvert as it had become crushed and was not functioning properly. DOE contractor representatives cut the culvert in August 2010. The culvert pieces that were removed are stored in a container in a Conex box behind the LCRS building and will be shipped to a low-level radiological landfill.

Highway D culvert: As described in Appendix A of the LTS&M Plan, soil containing elevated concentrations of uranium-238 was left under twin culverts in the Highway D right-of-way within the Frog Pond Outlet located north of the Chemical Plant. The inside surfaces of the corrugated metal culverts contain fixed residual radioactivity in excess of the DOE Order 5400.5 generic surface contamination guidelines for natural uranium, uranium-238, and associated decay products A supplemental limit was approved by the DOE Oak Ridge Operations Office, Oak Ridge, Tennessee. The culvert is included on the annual inspection checklist and inspected each year. Also, MoDOT representatives are contacted each year prior to the inspection to remind them of the contamination issue, and they are asked to contact DOE if any maintenance is done in the area. MoDOT personnel did notify DOE in 2010 that they plan to widen the shoulders of Highway D and the culverts will be need to be removed and replaced. DOE agreed to work with MoDOT and removed the culverts and soil.

4.1.3.8 Other Monitoring and Maintenance Activities

Other monitoring and maintenance activities for the CPOU include disposal cell monitoring and the collection and monitoring of the leachate, which are both discussed previously in this section. The LCRS Operating Plan is included as Appendix I to the LTS&M Plan. The LCRS/Train 3 Treatment Contingency Plan is included as Appendix J to the LTS&M Plan.

4.1.3.9 Operation and Maintenance Costs

The FY 2006 LTS&M costs for the Weldon Spring Site were budgeted at $1,253,355. The actual costs were $1,136,627.

The FY 2007 LTS&M costs for the Weldon Spring Site were budgeted at $1,665,857. The actual costs were $1,344,987.

The FY 2008 LTS&M costs for the Weldon Spring Site were budgeted at $1,892,907.34. The actual costs were $721,800.30.

The FY 2009 LTS&M costs for the Weldon Spring Site were budgeted at $1,225,234.19. The actual costs were $ 1,223,983.16.

The FY 2010 LTS&M costs for the Weldon Spring Site were budgeted at $1,667,325.96. The actual costs were $1,592,066.67.

4.2 Groundwater Operable Unit

4.2.1 Groundwater Operable Unit Remedy Selection

It was decided in 1993 to prepare separate environmental documentation regarding remediation of groundwater beneath the Chemical Plant Site. Prior to that decision the groundwater was being addressed as part of the Chemical Plant Operable Unit. It also was decided at that time that DOE and the DA would work jointly to address the groundwater issues for both sites. The remedial investigation was conducted in 1995 and included a joint sampling effort of all wells in the Chemical Plant and Ordnance Works areas by DOE and the DA. The *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1997a) and the *Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and Ordnance Works Area, Weldon Spring, Missouri* (DOE 1997c) were finalized in July 1997. The contaminants of potential concern were identified as nitrate, sulfate, chloride, lithium, molybdenum, nitroaromatic compounds, uranium, trichloroethylene (TCE), and 1,2-dichlororethylene. Contamination in groundwater is generally confined to the shallow, weathered portion of the uppermost bedrock unit, the Burlington-Keokuk Limestone.

The *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area at the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998c) was initiated in 1997. This study evaluated potential options for addressing groundwater contamination at both sites. The preferred alternative was long-term monitoring of groundwater in conjunction with in-situ treatment of portions of the shallow aquifer impacted by TCE. In 1998, a long-term pumping test was performed at the Chemical Plant to evaluate potential groundwater remediation methods for TCE contaminated groundwater. Results indicated that the transmissivity of the aquifer in the area of TCE impact was higher than expected; however, due to the geology in the area, dewatering of the aquifer occurred. Evaluation of conventional pump-and-treat technologies indicated that this would not be the most effective method for possible remediation of this area. These data were evaluated in the *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1999d) and utilized in preparation of the *Proposed Plan for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1999e).

The Proposed Plan was submitted to the public and the regulatory agencies on August 3, 1999. When the plan was issued, the MDNR did not concur with the proposal. To resolve these issues, the EPA facilitated an issue-resolution process. Specifics of the process are provided in the *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2000a).

DOE proposed active remediation of the TCE impacted groundwater at the Chemical Plant Site as presented in the proposed plan and to conduct further field studies to reexamine the effectiveness and practicability of further active remediation for the remaining contaminants of concern. An interim ROD related to the remediation for TCE contaminated groundwater at the Chemical Plant site was signed by DOE and EPA on September 29, 2000. This *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2000a) authorized treatment of TCE in groundwater utilizing in-situ chemical oxidation methods.

In 2003, the document *Supporting Evaluation for the Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003e) was prepared in conjunction with the *Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003f). The purpose of the Supporting Evaluation was to reevaluate the feasibility of groundwater removal, in-situ chemical oxidation (ICO), and MNA technologies and options on the basis of recent information collected from the ICO pilot-phase treatment and the additional groundwater field studies.

The *Record of Decision for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2004a) was signed by DOE in January 2004 and by EPA on February 20, 2004. The selected remedy of MNA with ICs to limit groundwater use during the period of remediation addresses cleanup of all COCs in groundwater and springs at the Chemical Plant Area. MNA relies on the effectiveness of naturally occurring processes to reduce contaminant concentrations over time. The GWOU ROD establishes remedial goals and performance standards for MNA. The selected remedy also serves as a change to the Interim ROD, which addressed TCE groundwater contamination. In-situ treatment of TCE did not perform adequately in the field and MNA is now considered the appropriate final remedy for TCE as well as the other groundwater contaminants.

The GWOU remedy and status is further described in Section 6.4.

The RAO listed in the GWOU ROD is to restore contaminated groundwater in the shallow aquifer to its beneficial use by attaining the cleanup standards. Section 4.2.2 and Section 6.4.1 give an update on the status of the attaining this RAO.

COC information is included in Section 3.0.

4.2.2 Groundwater Operable Unit Remedy Implementation

In July 2004, DOE initiated monitoring for MNA as outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004f). This network was modified as presented in the *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE 2005e) and is described below.

4.2.2.1 Monitoring Program

The objectives specified in the GWOU ROD (DOE 2004a) for the MNA monitoring network are as follows:

- Objective 1 is to monitor the unimpacted water quality at upgradient locations in order to maintain a baseline of naturally occurring constituents from which to evaluate changes in downgradient locations. This objective will be met by using wells upgradient of the contaminant plume.
- Objective 2 is to verify that contaminant concentrations are declining with time at a rate and in a manner that cleanup standards will be met in approximately 100 years as established by predictive modeling. This objective will be met using wells at or near the locations with the highest concentrations of contaminants, both near the former source areas and along expected migration pathways. The objective will be to evaluate the most contaminated zones. Long-term trend analysis will be performed to confirm downward trends in contaminant concentrations over time. Performance will be gauged against long-term trends. It is anticipated that some locations could show temporary upward trends due to the recent source control remediation, ongoing dispersion, seasonal fluctuations, analytical variability, or other factors. However, concentrations are not expected to exceed historical maximums.
- Objective 3 is to ensure that lateral migration remains confined to the current area of impact. Contaminants are expected to continue to disperse within known preferential flow paths associated with bedrock lows (paleochannels) in the upper Burlington-Keokuk Limestone and become more dilute over time as rain events continue to recharge the area. This objective will be met by monitoring various downgradient fringe locations that either are not impacted or are minimally impacted. Contaminant impacts in these locations are expected to remain minimal or nonexistent.
- Objective 4 is to monitor locations underlying the impacted groundwater system to confirm that there is no significant vertical migration of contaminants. This will be evaluated using deeper wells screened and influenced by the unweathered zone. No significant impacts at these locations should be observed.
- Objective 5 is to monitor contaminant levels at the impacted springs that are the only potential points of exposure under current land use conditions. The springs discharge groundwater that includes contaminated groundwater originating at the Chemical Plant area. Presently, contaminant concentrations at these locations are protective of human health and the environment under current recreational land uses. Continued improvement of the water quality in the affected springs should be observed.
- Objective 6 is to monitor for hydrologic conditions at the site over time in order to identify any changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevation of the monitoring network will be measured to establish that groundwater flow is not changing significantly and resulting in changes in contaminant migration.

The monitoring network is designed to collect data to either show that natural attenuation processes are acting as predicted or trigger the implementation of contingencies when these processes are not acting as predicted (i.e., unexpected expansion of the plume or sustained increases in concentrations within the area of impact). The data analysis and interpretation will satisfy the following:

- Baseline conditions (Objective 1) have remained unchanged.
- Performance monitoring locations (Objective 2) indicate that concentrations within the area of impact are decreasing as expected.
- Detection monitoring locations (Objectives 3, 4, and 5) indicate when a trigger has been exceeded.

The guidance documents *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites* (EPA 1999) and the *Technical Guidance for the Long-Term Monitoring of Natural Attenuation Remedies at Department of Energy Sites* (DOE 1999b) were used during the development of this monitoring program.

The monitoring network consists of 50 wells, four springs, and one surface water location. The locations and the objectives they satisfy are summarized in Table 13 and are depicted in Figure 6. COCs for groundwater and springs at the Chemical Plant area are TCE, nitrate, uranium, and nitroaromatic compounds. The set of COCs measured for each of the monitoring locations presented in Table 13 depends on the proximity of the particular well or spring to the contaminant plumes.

4.2.2.2 Baseline Concentrations and Data Evaluation

The *Baseline Concentrations of the Chemical Plant Groundwater Operable Unit Monitored Natural Attenuation Network at the Weldon Spring Site* (Baseline Concentrations Report) (DOE 2008d) was updated and revised in July 2008. The primary objective of the report was to evaluate monitoring data collected from the baseline monitoring period of July 2006 through May 2008 to establish baseline concentrations for the COCs for each well and spring in the MNA network. Baseline monitoring was performed as outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit* (DOE 2004f) to acquire a comprehensive set of data to reevaluate the MNA remediation time frames developed in 2002 during the remedial design phase of the GWOU and assess the long-term monitoring program. Also, this report presented the methodology for review and evaluation of future MNA data. Contingency actions associated with upward trends and trigger exceedences are outlined in the LTS&M Plan and were developed in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit* (DOE 2004f).

The initial modeling to evaluate remediation time frames using MNA was performed in 2002 and is documented in the *Supporting Evaluation for the Proposed Plan for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003e). It was determined that the desired concentrations of COCs in groundwater could be attained within 100 years. A comparison of the initial concentrations used in 2002 and the baseline concentrations indicates that the values were relatively similar for most of the COCs. A review of the contaminant distribution in the shallow groundwater at the Chemical Plant from 2002 and the baseline period (2004 through 2006) shows that the areal distribution of the COCs is essentially unchanged. The modeling performed in 2002 to evaluate MNA was not revised, and the projected cleanup times resulting from that earlier evaluation were considered applicable. The projected time to clean up the GWOU remains approximately 100 years.

Table 13. Monitoring Locations Retained for MNA Monitoring for the GWOU

Location	Objective	Unit	Sampling Frequency	TCE	Nitrate (as N)	Uranium	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-2017	1	Weathered	A				✓	✓	✓	✓	✓
MW-2035	1	Weathered	A	✓	✓	✓			✓		
MW-4022	1	Unweathered	A		✓	✓					
MW-4023	1	Weathered	A		✓	✓					
MW-2012	2	Weathered	S				✓	✓	✓	✓	✓
MW-2014	2	Weathered	S						✓	✓	
MW-2038	2	Weathered	S		✓				✓		
MW-2040	2	Weathered	S		✓						
MW-2046	2	Weathered	S					✓			
MW-2050	2	Weathered	S						✓	✓	
MW-2052	2	Weathered	S						✓	✓	
MW-2053	2	Weathered	S					✓	✓	✓	
MW-2054	2	Weathered	S						✓	✓	
MW-3003	2	Weathered	S		✓	✓					
MW-3024	2	Unweathered	Q			✓ (Q)					
MW-3030	2	Weathered	S	✓		✓			✓		
MW-3034	2	Weathered	S	✓	✓				✓		
MW-3039	2	Weathered	S						✓		
MW-3040	2	Unweathered	Q		✓	✓ (Q)					
MW-4013	2	Weathered	S		✓						
MW-4029	2	Weathered	S	✓	✓						
MW-4031	2	Weathered	S		✓						
MW-4040	2	Unweathered	Q		✓	✓ (Q)					
MW-2032	3	Weathered	A				✓	✓	✓	✓	✓
MW-2051	3	Weathered	A				✓	✓	✓	✓	✓
MW-3031	3	Weathered	A	✓		✓ (S)					
MW-3037	3	Weathered	A	✓		✓ (S)			✓		
MW-4013	3	Weathered	A						✓	✓	✓
MW-4014	3	Weathered	A		✓		✓	✓	✓	✓	✓
MW-4015	3	Weathered	A						✓	✓	✓
MW-4026	3	Alluvium/SED	A			✓ (S)					

Table 13 (continued). Monitoring Locations Retained for MNA Monitoring for the GWOU

Location	Objective	Unit	Sampling Frequency	TCE	Nitrate (as N)	Uranium	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-4036	3	Weathered	A	✓	✓	✓ (Q)					
MW-4039	3	Weathered	A				✓	✓	✓	✓	✓
MW-4040	3	Unweathered	A	✓					✓		
MW-4041	3	Weathered	A	✓	✓	✓ (S)	✓	✓	✓	✓	✓
MWS-1	3	Weathered	A	✓	✓	✓ (S)			✓		
MWS-4	3	Weathered	A	✓	✓	✓ (S)					
MW-2021	4	Unweathered	A		✓						
MW-2022	4	Unweathered	A	✓			✓	✓			
MW-2023	4	Unweathered	A				✓	✓	✓	✓	✓
MW-2056	4	Unweathered	A				✓	✓	✓	✓	✓
MW-3006	4	Unweathered	A	✓	✓	✓ (S)			✓		
MW-4007	4	Unweathered	A	✓	✓						
MW-4042	4	Unweathered	Q		✓	✓					
MWD-2	4	Unweathered	A		✓	✓ (S)					
SP-5303	5	Spring/SED	Q			✓					
SP-5304	5	Spring/SED	Q			✓					
SP-6301	5	Spring	Q	✓	✓	✓	✓	✓	✓	✓	✓
SP-6303	5	Spring	Q	✓	✓	✓	✓	✓	✓	✓	✓
SW-2007	5	Stream	A			✓					

Notes:
Objective 1 = Upgradient locations
Objective 2 = Area of groundwater impact
Objective 3 = Downgradient and lateral locations
Objective 4 = Locations beneath the area of groundwater impact
Objective 5 = Springs or surface water locations

Notes about sampling frequencies:
Frequencies in parentheses are performed in support of a special study
A = annual
Q = quarterly
S = semiannual

Abbreviations:
DNT = dinitrotoluene
DNB = dinitrobenzene
NB = nitrobenzene
SED = Southeast Drainage
TNT = trinitrotoluene

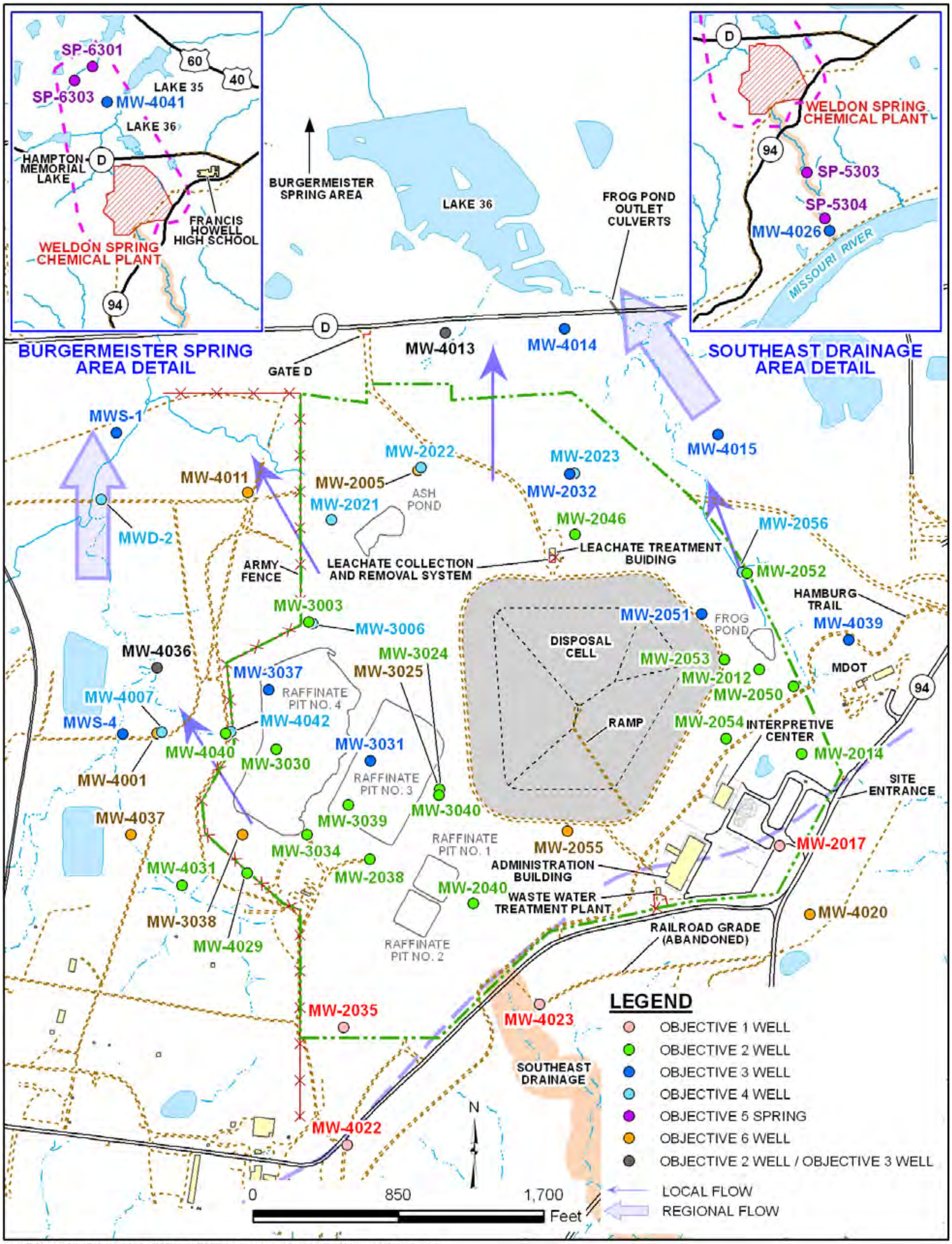

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Figure 6. GWOU MNA Monitoring Locations

It was determined in the Baseline Concentrations Report (DOE 2008d) that additional data were needed to establish better baseline concentrations for nitrate and uranium in wells MW-3040 and MW-4040, screened in the unweathered unit below the Raffinate Pits area. Data from these wells were not used in the reevaluation of MNA remediation time frames at that time. Additional data has continued to be collected and an evaluation of the concentrations of COCs in the unweathered unit needs be performed.

The monitoring network was designed to provide data to show that natural attenuation processes are acting as predicted or to trigger the implementation of contingencies. Methods to review and interpret data that will satisfy the monitoring objectives were defined in the revised Baseline Concentrations Report (DOE 2008d). Performance of the MNA remedy will be gauged against long-term trends in the Objective 2 wells. This progress will be reviewed and documented every 5 years in conjunction with the CERCLA Five-Year Review. This review includes trending analysis for the past 5 years of data.

4.2.2.3 Modification to Sampling Frequencies

As part of the Baseline Concentrations Report (DOE 2008d), an evaluation was performed to determine the appropriateness of the network to fulfill the intended objectives and the adequacy of the sampling frequencies that were initially specified for the MNA monitoring program. The following changes were recommended in the Baseline Concentrations Report and implemented through the LTS&M Plan in 2009:

- Objective 1: Reduced the sampling frequency to annual because concentrations in these upgradient wells were stable.
- Objective 2: Maintained semiannual sampling in the Objective 2 wells due to continued variability in the data.
- Objective 3: Reduced the sampling frequency to annual because concentrations have been behaving as expected.
- Objective 4: Reduced the sampling frequency to annual because concentrations have been behaving as expected.
- Objective 5: Increased the sampling frequency to quarterly due to variability in the springs and in some Objective 2 wells.

4.2.3 Groundwater Operable Unit System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in the CPOU section also apply to the GWOU. This includes the LTS&M Plan (DOE 2008c), inspections, and ICs. Other maintenance activities include maintenance of the wells, which are inspected during each sampling event and maintained regularly. Institutional controls for the Groundwater Operable Unit are discussed in Section 6.5.1and Section 7.2.5.

In November 2010, 16 monitoring wells that were not part of the MNA monitoring network were abandoned at the Chemical Plant site and adjacent Army property. These wells were decommissioned in accordance with the applicable state regulations and registered with MDNR. Details regarding the wells abandoned in November 2010 are discussed in Section 6.5.16.

4.3 Quarry Bulk Waste Operable Unit

4.3.1 Quarry Bulk Waste Operable Unit Remedy Selection

The RI/FS process was conducted for the Weldon Spring Quarry Bulk Waste Operable Unit in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Chemical Plant area as an operable unit for management of the bulk wastes from the Quarry. Documents developed during the RI/FS process included: (1) *Remedial Investigation for Quarry Bulk Wastes* (DOE 1989); (2) *Baseline Risk Assessment for Exposure to Bulk Wastes at the Weldon Spring Quarry* (DOE 1990d); (3) *Feasibility Study for the Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri* (DOE 1990c); and (4) *Proposed Plan for the Management of Bulk Wastes at the Weldon Spring Quarry, Weldon Spring Missouri* (DOE 1990a).

Remedial activities under the QBWOU were performed under the *Record of Decision for Management of Bulk Wastes at the Weldon Spring Quarry* (QBWOU ROD) (DOE 1990b). The QBWOU ROD (DOE 1990b) was signed by EPA on September 28, 1990, and by DOE on March 7, 1991. The primary activities or RAOs established were to:

- Excavate and remove bulk waste (i.e., structural debris, drummed and unconfirmed waste, process equipment, sludge, soil).
- Transport the waste along a dedicated haul road to the Temporary Storage Area (TSA), which was within the boundary of the CPOU.
- Stage bulk wastes at the TSA for ultimate disposal in the on-site disposal cell.

These RAOs were completed as discussed below. COC information is discussed in Section 3.0.

4.3.2 Quarry Bulk Waste Operable Unit Remedy Implementation

Removal of the bulk waste was performed in a multi-tiered process similar to the one used at the Chemical Plant. In the first tier, the Quarry Water Treatment Plant, which was designed to treat contaminated water from the Quarry sump, was constructed. In the second tier, the basic infrastructure, including decontamination facilities, a haul road, and the utilities needed to excavate and transport the waste from the Quarry to the Chemical Plant, was built. In the final tier, the waste was excavated.

The waste was removed with conventional equipment and excavation techniques, placed in covered trucks, and hauled via the haul road to the TSA at the Chemical Plant. The waste was retained in the TSA until it could be placed in the disposal cell. From May 1993 to October 1995, approximately 144,000 cubic yards (110,000 cubic meters) of soil and waste material were removed from the Quarry, transported to the Chemical Plant area, and placed in the TSA. All of the wastes were directly placed, or treated and placed, in the disposal cell by March 1999.

The Quarry Bulk Waste Operable Unit activities are documented in the *Quarry Bulk Waste Excavation Remedial Action Report* (DOE 1997d).

4.3.3 Quarry Bulk Waste Operable Unit System Operation and Maintenance

The QROU addresses residual contamination and long-term monitoring and maintenance for the Quarry.

4.4 Quarry Residuals Operable Unit

4.4.1 Quarry Residuals Operable Unit Remedy Selection

The QROU was the second of two operable units established for the Quarry Area of the Weldon Spring Site. An RI/FS process was conducted for the QROU in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Quarry proper, the Femme Osage Slough and nearby creeks, and groundwater north of the Femme Osage Slough. Documents developed during the RI/FS process included the:

1. *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998b)
2. *Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missou*ri (DOE 1997b)
3. *Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998d)
4. *Proposed Plan for Remedial Action at the Quarry Residuals Operable Unit of the Weldon Spring Site* (DOE 1998e)

The QROU remedy was described in the *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (QROU ROD) (DOE 1998a). The QROU addressed residual soil contamination in the Quarry proper, surface water and sediments in the Femme Osage Slough and nearby creeks, and contaminated groundwater.

The selected remedy or RAOs included:

- Long-term monitoring of groundwater in the Missouri River alluvium to ensure that water quality in the public water supply remains protective of human health and the environment.
- Long-term monitoring of contaminated groundwater north of the Femme Osage Slough until levels are attained that pose a negligible potential impact on the groundwater in the Missouri River alluvium.
- ICs to prevent exposure to the contaminated groundwater north of the Femme Osage Slough.

The long-term monitoring status is discussed in Section 4.4.2 and Section 6.4.2. The ICs for the QROU have been implemented and are reviewed annually during the annual inspection.

The selected remedy in the QROU ROD (DOE 1998a) outlined the performance of two field studies to support the decision for long-term monitoring of groundwater and reliance on natural conditions to limit potential migration of uranium south of the slough. These field studies consisted of the installation and operation of an interceptor trench and hydrologic/geochemical sampling within the area of uranium impact to verify the effectiveness of uranium removal by groundwater extraction methods and support the conceptual fate and transport model for the Quarry. The interceptor trench study was performed from 2000 through 2002, and results indicated that modeled prediction for active removal of uranium from groundwater was optimistic and that further evaluation of groundwater treatment was not warranted (DOE 2003b). The result of the hydrologic and geochemical field studies performed from 2000 through 2002 provided a better understanding of the natural geochemistry of the alluvial aquifer north of the slough and led to the inclusion of this area in the ICs for the QROU (DOE 2002a).

Reclamation of the Quarry was completed on September 6, 2002. Backfilling of the Quarry was designed to reduce physical hazards associated with an open Quarry, eliminate the ponding of water, and reduce infiltration of precipitation water into the groundwater system. Fill material was placed and compacted to design elevations within the Quarry proper. During backfilling of the Quarry, selected wall and floor fractures were sealed to prevent infiltration of water and reduce the likelihood of later subsidence of the backfill.

COC information is discussed in Section 3.0.

4.4.2 Quarry Residuals Operable Unit Remedy Implementation

DOE implemented long-term monitoring at the Quarry in October 2002. Monitoring is conducted in accordance with the *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit* (DOE 2000b), which was finalized in January 2000. Long-term groundwater monitoring for the QROU consists of two separate programs. The first program details the monitoring of uranium and 2,4-DNT south of the slough to ensure that levels remain protective of human health and the environment. The second program consists of monitoring groundwater contaminant levels within the area north of the slough until a predetermined target level indicating negligible potential to affect groundwater south of the slough is attained.

Groundwater monitoring is necessary to continue to ensure that uranium contaminated groundwater has a negligible potential to affect the St. Charles County well field. Under current conditions, groundwater north of the slough poses no imminent risk to human health from water obtained from the well field. A target level of 300 pCi/L for uranium (10 percent of the maximum measured in 1999) was established to represent a significant reduction in the contaminant levels north of the slough. The target level for 2,4-DNT has been set at 0.11 µg/L, the Missouri Water Quality Standard. Upon attainment of these target levels, it will be determined that the goal for the monitoring program has been met, and the long-term monitoring activities for the QROU will be concluded. Following attainment of the long-term monitoring target levels in groundwater north of the slough, an assessment of the residual risks based on actual groundwater concentrations will be performed to determine the need for future ICs.

To implement the two monitoring objectives, the wells were categorized into monitoring lines (Figure 7). Each line provides specific information relevant to long-term goals at the Quarry:

- The first line of wells (Line 1) monitors the area of impact within the bedrock rim of the Quarry proper. These wells (MW-1002, MW-1004, MW-1005, MW-1027, MW-1030) are sampled to establish trends in contaminant concentrations within the areas of higher impact. Well MW-1012 is monitored as a background location.

- The second line of wells monitors the area of impact within the alluvial materials and shallow bedrock north of the slough. These wells (MW-1006, MW-1007, MW-1008, MW 1009, MW-1013, MW-1014, MW-1015, MW-1016, MW-1028, MW-1031, MW-1032, MW-1045, MW-1046, MW-1047, MW-1048, MW-1049, MW-1051, MW-1052) are also sampled to establish trends in contaminant concentrations within the areas of higher impact and to monitor the oxidizing and reducing environments that are present within this area.
- The third line of wells monitors the alluvial material directly south of the slough. These wells (MW-1017, MW-1018, MW-1019, MW-1021, MW-1044, MW-1050) have shown no impact from Quarry contaminants and are monitored as the first line of warning for potential migration of uranium south of the slough.
- The fourth line of wells monitors the same portion of the alluvial aquifer that supplies the well field. These wells (RMW-1, RMW-2, RMW-3, RMW-4) are sampled to monitor the groundwater quality of the productive portions of the alluvial aquifer and to determine the occurrence of uranium outside the range of natural variation.

The sampling frequency for each location was selected to provide adequate reaction time on the basis of travel times from the residual sources and areas of impact to potential receptors. Monitoring wells on the Quarry rim (Line 1) are sampled semiannually, and wells north of the Femme Osage Slough (Line 2) are sampled quarterly. Locations south of the slough are sampled semiannually (Line 3) or annually (Line 4). All locations in the Quarry Area are sampled for uranium, sulfate, and dissolved iron. A selected group of wells north of the slough was sampled for nitroaromatic compounds.

The production wells south of the Quarry Area have had a separate well field monitoring program that was initiated in 1989 as a result of cooperative efforts between DOE, St. Charles County, and MDNR. This program is funded by a DOE grant. The well field was originally owned and operated by St. Charles County; however, in 2005 the well field was sold to Public Water Supply District #2 (PWSD #2). The monitoring program has been continued by PWSD #2 and consists of annual, quarterly, and monthly sampling events of operating production wells, the RMW-series wells, and raw and treated water from the water plant. Results of this monitoring program can be obtained through the PWSD #2.

The Quarry Residuals Operable Unit activities are documented in the *Quarry Residuals Operable Unit Interim Remedial Action Report* (DOE 2003a)

4.4.3 Quarry Residuals Operable Unit System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in the CPOU section also apply to the QROU. This includes the LTS&M Plan (DOE 2008c), inspections, and ICs. Other maintenance activities include maintenance of the wells, which are inspected during each sampling event and maintained regularly. Institutional controls for the Quarry Residuals Operable Unit are discussed in Section 6.5.1 and Section 7.3.5.

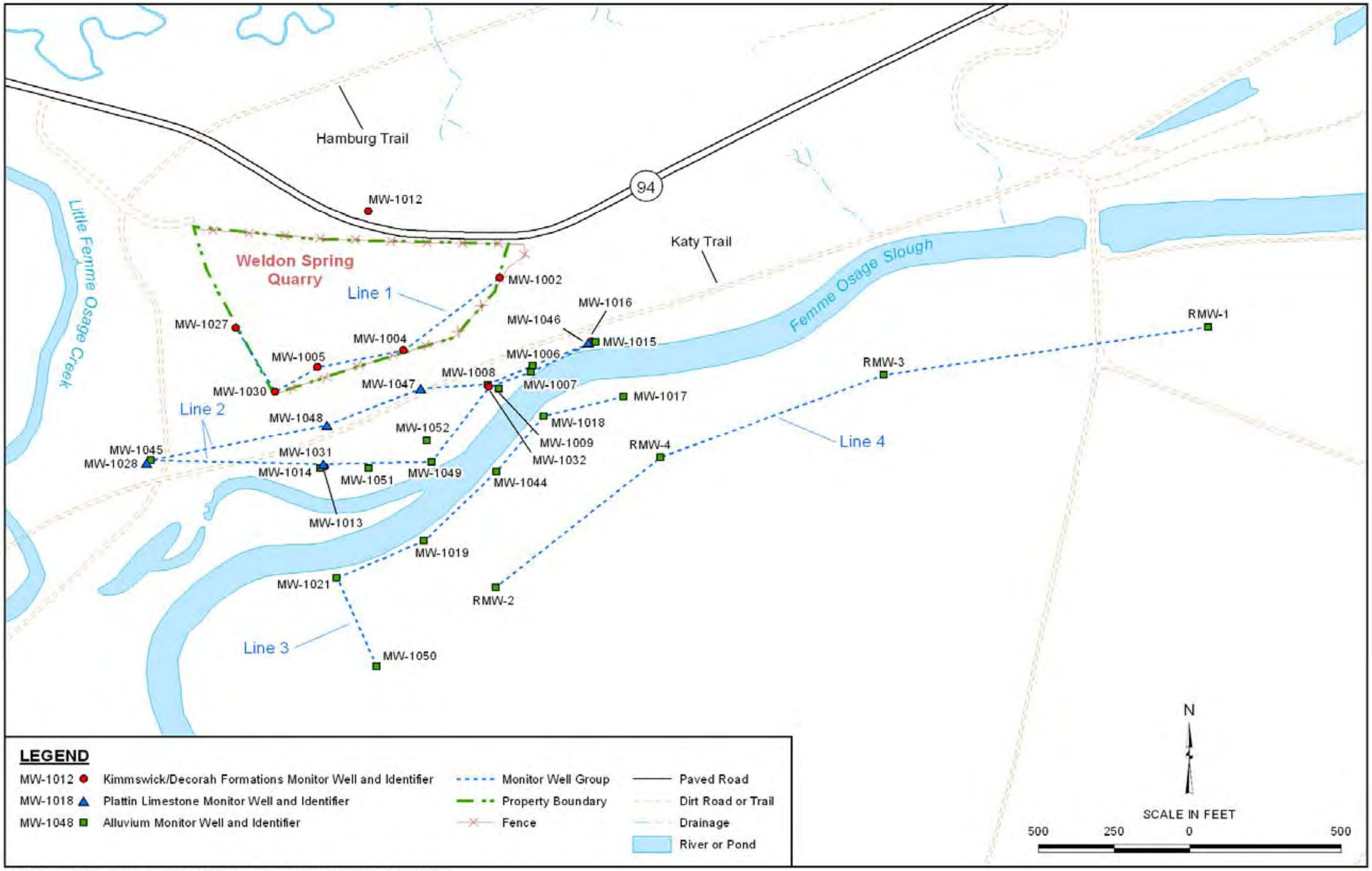

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Figure 7. QROU Monitoring Locations

4.5 Southeast Drainage

4.5.1 Southeast Drainage Remedy Selection

Cleanup for the Southeast Drainage was addressed as a removal action under CERCLA. The *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1996) evaluated options for addressing contaminated soils and sediments in the Southeast Drainage. The EE/CA recommended that sediment in accessible areas of the drainage should be removed. The excavated materials would be stored temporarily at an on-site storage area until final disposal in the disposal cell.

The RAO for the Southeast Drainage was source removal. This was completed as discussed below in Section 4.5.2.

4.5.2 Southeast Drainage Remedy Implementation

The Southeast Drainage is a natural drainage area with intermittent flow that traverses both the Army property and the Weldon Spring Conservation Area from the Chemical Plant site to the Missouri River (Figure 2). Both the Army and AEC used the drainage to discharge water from sanitary and process sewers to the Missouri River. Also, contaminated liquids in the Raffinate Pits were decanted to the plant process sewer and subsequently discharged to the Southeast Drainage; overflow from the Raffinate Pits continued to discharge into the drainage after plant operations ceased. As a result, sediments and soils in the Southeast Drainage were contaminated. Radioactive contaminants of concern were uranium-238, radium-226, thorium-232, and thorium-230. Spring water in the Southeast Drainage (Springs SP-5303 and SP-5304) was contaminated with uranium and low concentrations of nitroaromatic compounds from the contaminated sediment.

Soil removal was in two phases: 1997 through 1998, and in 1999. A total of 1,931 cubic yards (1,476 cubic meters) was excavated in the first phase, and about 22.5 cubic yards (17.2 cubic meters) was excavated in the second phase.

Post-remediation soil sampling was conducted at Southeast Drainage locations after the soil was excavated. The purpose of this sampling was to determine the remaining concentrations of radionuclides within the soil and sediment and to calculate the risk reduction achieved from soil removal. Sampling was conducted in accordance with the *Post-Remediation Sampling Plan for the Southeast Drainage* (DOE 1997e). All post-remediation data results were used by Argonne National Laboratory to calculate risk reduction achieved by the removal action.

Complete details of the remediation as well as the post-cleanup risk assessment of the Southeast Drainage are in the *Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7* (DOE 1999a).

The Southeast Drainage post-cleanup risk assessment is detailed in the above document, which states that the remediation met the post-cleanup risk assessment for the hypothetical child. The hypothetical child is based on the future land-use scenario that a home would be built in the vicinity of the drainage, allowing a child to access the drainage for use as a play area. The post-cleanup risk assessment also states that the results indicate the removal action accomplished the goals presented in the Decision Document for the Southeast Drainage (DOE 1996).

4.5.3 Southeast Drainage System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in Section 4.1 (CPOU) also apply to the Southeast Drainage. This includes the LTS&M Plan, inspections, and ICs. Institutional controls for the Southeast Drainage are discussed in Section 6.5.1 and Section 7.1.5.

4.6 Post-ROD Changes

CERCLA contains provisions for addressing changes to a remedy that occur after the ROD is signed. No changes were made to the RODs during this Five-Year Review period.

5.0 Progress Since Last Review

Since the second Five-Year Review, remedial activities at the Chemical Plant and the Quarry have been completed with the exception of long-term groundwater monitoring at both locations. Since the site has reached physical completion, the LTS&M activities have become the main focus of the project. Major activities for the project include revising the LTS&M Plan (DOE 2008c), monitoring the groundwater, monitoring erosion activity, making progress on the establishment of ICs, conducting annual surveillance inspections, upgrading the Interpretive Center, and establishing Howell Prairie.

The issues noted in the previous five-year review and a discussion of each is included below:

Table 14. Status of Issues from Third Five-Year Review

Issue	Recommendations and Follow-Up Actions	Status
Erosion areas have been identified on the Chemical Plant Property	Have repaired erosion areas identified in past inspections. Will continue to inspect for erosion and repair as needed.	See Sections 4.1.3.5 and 6.5.14 for a complete discussion and update on Erosion issues.
Small depressions and bulges have been identified on the disposal cell	These types of areas are not unexpected for a disposal cell of this type and are not a cause for concern. DOE will continue to monitor the area.	As stated the areas are not considered a cause for concern and DOE continues to monitor annually. No new depression or bulges have been found that would be a cause for concern.
Erosion issues were identified at the Highway 94 and Highway D culverts	Notified MoDOT of the issues. MoDOT repaired these areas in Fall 2005. DOE will continue to monitor the areas during the annual inspections.	DOE continues to monitor the culvert areas during the annual inspections. See Section 4.1.3.7 for an update on the culverts.

The protectiveness statements in the last Five-Year Review stated that the remedies are expected to be protective of human health and the environment upon completion. The Protectiveness Section in the last Five-Year Review also provided discussion about the need and plans for the long-term maintenance and surveillance of the site and ICs. The progress in attaining these objectives is detailed in Sections 6.0, 7.0, and 8.0 of this document.

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6.0 Five-Year Review Process

6.1 Administrative Components of the Five-Year Review Process

The Five-Year Review process for the Weldon Spring Site began in October 2010 and continued through September 2011. The Five-Year Review process included notifying regulatory agencies, the community, and other interested parties of the start of the Five-Year Review; reviewing relevant documents and data; conducting site inspections; conducting site interviews; and developing and reviewing this fourth Five-Year Review Report. Each of these elements is discussed below.

The EPA and MDNR were formally notified that the Five-Year Review process had begun in a letter dated September 17, 2010. The letter, which is included in Appendix A, notified them that the annual LTS&M inspection was to take place from October 26 through 28, 2010, and stated that the Five-Year Review would be a topic of discussion during the inspection period. During the annual inspection, the Five-Year Review was discussed with all participants, including Jane Powell and Vijendra Kothari of DOE; Terri Uhlmeyer, Becky Cato, Yvonne Deyo, and Randy Thompson of Stoller; Hoai Tran of EPA-Region 7; and Patrick Anderson of MDNR. Other contributors to the development of the Five-Year Review included Laura Cummins of Stoller.

6.2 Community Notification and Involvement

Activities to involve the community in the Five-Year Review were initiated in October 2010. On October 13, 2010, DOE sent a letter to its distribution list, which includes many members of the public. The letter notified the recipients that DOE had initiated the fourth Five-Year Review, discussed the purpose of the Five Year Review, stated that community involvement is an integral part of the Five-Year Review process, and requested input or suggestions, via a survey that DOE posted online. The survey included questions that EPA had suggested for community interviews in the Five Year Review guidance. Appendix A includes a copy of the letter and survey questions. On October 22, 2010, the *St. Louis Post Dispatch* published an additional announcement from DOE that the Five-Year Review process would be initiated. The announcement discussed the purpose of the Five-Year Review, the history of the Weldon Spring Site, the remedy, and COCs. The announcement also included information on the Administrative Record and the collection of records housed at the Middendorf-Kredell Library in O'Fallon, Missouri. Website and contact information were included, and the online survey was discussed. A copy of the public notice is included in Appendix A. Two individuals responded to the online survey, and their responses are included in Appendix A. Also during the annual inspection, several stakeholders are contacted regarding the inspection and to inquire if there are any concerns or questions about the project.

The stakeholder contacted included:

- St. Charles County Sheriff
- Cottleville Fire District
- Francis Howell High School
- Simplex-Grinnel Alarm System
- St. Charles County

The IC contacts also were notified in regard to the inspection and to maintain annual contact with the representatives relevant to ICs. In the future, when ICs are established, this annual contact will be used to verify that each representative is knowledgeable of the ICs, requirements, and restrictions. The following representatives were contacted:

- John Vogel, MDC
- Joel Porath, MDC
- Doyle Brown, MDC
- Mary Bryan, MDNR Division of State Parks
- Quinn Kellner, MDNR Division of State Parks
- Marsha Miller, Army
- Tom Blair, MoDOT
- Jim Gremaud, MoDOT
- Kevin Wideman, MoDOT

The stakeholders listed above were notified of the upcoming Five-Year Review, and several were asked questions recommended by the Five-Year Review guidance. The interview forms are included in Appendix D. The general questions asked from the five-year review guidance are listed as follows:

- What is your overall impression of the project (general sentiment)?
- What effects have site operations had on the surrounding community?
- Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
- Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency response from local authorities? If so, please give details.
- Do you feel well informed about the site’s activities and progress?
- Do you have any comments, suggestions, or recommendations regarding the site’s management or operation?

There were no negative concerns expressed by any of the interviews. An additional interview was conducted during the five-year review process with a representative from the MDNR – Hazardous Waste Program.

The Five-Year Review was also discussed in the 2010 annual public meeting. Beginning in October 2010, a display notifying the public that the Five-Year Review was taking place was exhibited at the Interpretive Center.

6.3 Document Review

The following sections list the documents assessed as part of this Five-Year Review.

6.3.1 Basis for Response Actions

The documents listed in Table 15 identify the background and goals of the remedies and any changes in laws and regulations that may affect the response action. These documents also provide background information on the remedial actions, basis for action, cleanup levels, and applicable or relevant and appropriate requirements (ARARs), and address community concerns and preferences.

6.3.2 Implementation of the Response

The documents listed in Table 16 furnish information about design assumptions, design plans or modifications, and documentation of the response at the site.

Table 15. Documents Supporting Basis for Response Actions at the Site

Document	Purpose	Use for Review
Feasibility Study for Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri (DOE 1990c)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Remedial Investigation for Quarry Bulk Wastes (DOE 1989)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Baseline Risk Assessment for Exposure to Bulk Wastes at the Weldon Spring Quarry (DOE 1990d)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Record of Decision for the Management of the Bulk Wastes at the Weldon Spring Quarry (DOE 1990a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site (DOE 1992d)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Feasibility Study for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site (DOE 1992b)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Remedial Investigation for the Chemical Plant of the Weldon Spring Site (DOE 1992a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs

Table 15 (continued). Documents Supporting Basis for Response Actions at the Site

Document	Purpose	Use for Review
Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site (DOE 1993)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri (DOE 1996)	Record removal action decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri (DOE 1998b)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri (DOE 1997b)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri (DOE 1998d)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Record of Decision for the Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri (DOE 1998a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site (DOE 1997c)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site, Weldon Spring, Missouri (DOE 1997a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site, Weldon Spring, Missouri (DOE 1998c)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site (DOE 1999d)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs

Table 15 (continued). Documents Supporting Basis for Response Actions at the Site

Document	Purpose	Use for Review
Supporting Evaluation for the Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site (DOE 2003e)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site (DOE 2000a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site (DOE 2004a)	Record selected remedial decision	Remediation goals Background Basis for action Community concerns Cleanup levels ARARs
Explanation of Significant Differences, Weldon Spring Site (DOE 2005c)	Records significant changes from the original remedy	Remediation goals

Table 16. Documents Supporting Implementation of the Response at the Site

Document	Purpose	Use for Review
Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7 (DOE 1999a)	Documents removal action completion	History Chronology Whether cleanup levels were met
Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit (DOE 2000b)	Documents planned remedial design and activities	Background Remediation goals Remedial activities
Completion Report for Radon Flux Monitoring of the WSSRAP Disposal Facility (DOE 2001)	Documents results of monitoring	Monitoring results
*Quarry Bulk Waste Excavation Remedial Action Report (*DOE 1997d)	Documents that construction activities are complete	History Chronology Effectiveness of remedial action
Conceptual Design Report for Remedial Action at the Chemical Plant Area of the Weldon Spring Site (DOE 1994)	Documents planned remedial design and activities	Background Remediation goals Remedial activities
Chemical Plant Operable Unit Remedial Action Report (DOE 2004b)	Documents that construction activities are complete	History Chronology Effectiveness of remedial action
Quarry Residuals Operable Unit Interim Remedial Action Report (DOE 2003a)	Documents that construction activities are complete	History Chronology Effectiveness of remedial action
Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site (DOE 2004f)	Documents planned remedial design and activities	Background Remediation goals Remedial activities

6.3.3 Operation and Maintenance

The operation and maintenance documents listed in Table 17 describe the ongoing measures at the site to ensure that the remedy remains protective. They provide the structure for operation and maintenance at the site and confirm that operation and maintenance are proceeding as planned.

Table 17. Documents Supporting Operations and Maintenance at the Site

Document	Purpose	Use for Review
Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy, Weldon Spring, Missouri, Site, (DOE 2008c)	Contains technical information necessary to operate and maintain the remedy	History Operation and maintenance requirements

6.3.4 Remedy Performance

The monitoring data, progress reports, post-remediation risk assessments, and performance evaluation reports listed in Table 18 provide information that can be used to determine whether the remedial actions continue to operate and function as designed and have achieved, or are expected to achieve, cleanup levels and are protective.

Table 18. Documents Supporting Remedy Performance at the Site

Document	Purpose	Use for Review
Weldon Spring Site Remedial Action Project Second Five-Year Review (DOE 2001b)	Records status and protectiveness of remedies	History Update status
Post-Remediation Risk Assessment for the Chemical Plant Operable Unit Weldon Spring Site St. Charles, Missouri (DOE 2002d)	To document risk estimates	Site status Monitoring Results
Weldon Spring Site Cell Groundwater Monitoring Demonstration Report for the December 2004 Sampling Event (DOE 2005b)	Document sampling results and explanation for exceedances. Includes plan of action	Site status Monitoring results Required actions
Weldon Spring Site Remedial Action Project Third Five-Year Review (DOE 2006c)	Records status and protectiveness of remedies	History Update status
2006 Annual Inspection Report for the Weldon Spring Site, St. Charles, Missouri (DOE 2007a)	Document results of annual inspection of LTS&M activities and IC status	Status of LTS&M activities and IC status
Weldon Spring Site Environmental Report for Calendar Year 2006 (DOE 2007b)	Summarize activities and monitoring data annually	Site status Monitoring results
2007 Annual Inspection Report for the Weldon Spring, Missouri, Site (DOE 2008a)	Document results of annual inspection of LTS&M activities and IC status	Status of LTS&M activities and IC status
Baseline Concentrations of the Chemical Plant Operable Unit Monitored Natural Attenuation Network at the Weldon Spring, Missouri, Site (DOE 2008d)	Summarize environmental data	Site status Monitoring results Required actions
Weldon Spring Site Environmental Report for Calendar Year 2007 (DOE 2008b)	Summarize activities and monitoring data annually	Site status Monitoring results
2008 Annual Inspection Report for the Weldon Spring, Missouri, Site (DOE 2009a)	Document results of annual inspection of LTS&M activities and IC status	Status of LTS&M activities and IC status
Weldon Spring Site Environmental Report for Calendar Year 2008 (DOE 2009b)	Summarize activities and monitoring data annually	Site status Monitoring results
2009 Annual Inspection Report for the Weldon Spring, Missouri, Site (DOE 2010a)	Document results of annual inspection of LTS&M activities and IC status	Status of LTS&M activities and IC status
Weldon Spring Site Environmental Report for Calendar Year 2009 (DOE 2010b)	Summarize activities and monitoring data annually	Site status Monitoring results
2010 Annual Inspection Report for the Weldon Spring, Missouri, Site (DOE 2011)	Document results of annual inspection of LTS&M activities and IC status	Status of LTS&M activities and IC status

6.3.5 Legal Documentation

The legal documentation listed in Table 19 includes information pertinent to the site that specified responsibilities for conducting remedial action, implementing institutional and access controls, and activities.

Table 19. Documents Supporting Legal Standards Regarding Remedial Action at the Site

Document	Purpose	Use for Review
Federal Facility Agreement	Commitments and agreements regarding implementation and operation of the remedies, conduct of studies, and responsibilities of other agencies	Site status Required actions Roles of different agencies
Institutional Control documentation	Access agreements, easements, and restrictions	Status and requirements of ICs

6.4 Data Review

Monitoring data is provided annually in the site environmental reports. Historical water quality and water level data for existing wells can be found on the DOE Office of Legacy Management website: www.lm.doe.gov. Photographs, maps, and physical features can also be viewed on this website.

The monitoring programs at the Weldon Spring Site include the sampling and analysis of water collected from wells at the Chemical Plant, the Quarry, adjacent properties, and selected springs in the vicinity of the Chemical Plant. The groundwater monitoring programs are formally defined in the LTS&M Plan (DOE 2008c).

Testing for temporal trends was performed on the following data sets:

- Uranium, nitrate, TCE, and nitroaromatic compounds for the GWOU using data collected between 2006 and 2010, as required in the Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site (DOE 2004f). Results for the trending analysis are reported for the Objective 2 wells and the Objective 5 springs because these locations monitor the area of groundwater impact and the discharge points.
- Total uranium and 2,4-DNT data from the Quarry collected between 2006 and 2010. Results for the trending analysis for uranium and 2,4-DNT are reported for wells in Lines 1 and 2 of the Quarry monitoring network, as these wells monitor the area of groundwater impact.

The Mann-Kendall test is used for temporal trend identification because it can easily facilitate missing data and does not require the data to conform to a particular distribution (such as a normal or log-normal distribution). The nonparametric method is valid for scenarios where there are a high number of non-detect data points. Data reported as trace concentrations or less than the detection limit can be used by assigning them a common value that is smaller than the smallest measured value in the data set (i.e., one-half the specified detection limit). This approach is valid because only the relative magnitudes of the data, rather than their measured values, are used in the method. A possible consequence of this approach is that the test can produce biased results if a large fraction of data within a given time series are non-detects and if detection limits change between sampling events. One-half the specified detection limit (on the date of analysis) was used in place of all concentrations reported at or below the detection limit.

The maximum contaminant level (MCL) for uranium in groundwater is 30 μg/L, which are mass units. Uranium data for the Weldon Spring Site has consistently been reported in activity (pCi/L). The activity to mass conversion factor that was adopted for the Weldon Spring Site is 0.68 pCi/μg. Using this conversion factor, the MCL is 20.4 pCi/L.

6.4.1 Groundwater Operable Unit

Contaminated groundwater remains beneath the Chemical Plant. Contaminants include uranium, nitrate, TCE, and nitroaromatic compounds. Contamination in groundwater is generally confined to the shallow, weathered portion of the Burlington-Keokuk Limestone. Some contamination exists in the deeper, unweathered portion of the bedrock, primarily beneath the former Raffinate Pits. The groundwater at the Chemical Plant has been contaminated by past operations that resulted in multiple source areas. Remediation activities have eliminated the sources for the groundwater contamination beneath the site. The distribution of contaminants in the shallow aquifer at the site is controlled by bedrock topography that influences groundwater flow and several processes, such as transformation, adsorption, desorption, dilution, or dispersion; the primary attenuation mechanisms are dilution and dispersion.

6.4.1.1 Hydrogeologic Description

The Chemical Plant site is in a physiographic transitional area between the Dissected Till Plains of the Central Lowlands province to the north and the Salem Plateau of the Ozark Plateaus province to the south. Subsurface flow and transport in the Chemical Plant area occurs primarily in the carbonate bedrock. The unconsolidated surficial materials are clay-rich, mostly glacially derived units, which are generally unsaturated beneath the site. These materials become saturated to the north and influence groundwater flow. The thickness of the unconsolidated materials ranges from 20 to 50 ft (DOE 1992).

A groundwater divide is located along the southern boundary of the site. Groundwater north of the divide flows north toward Dardenne Creek and ultimately to the Mississippi River, and groundwater south of the divide flows south to the Missouri River. Localized flow is controlled largely by bedrock topography. Groundwater movement is by generally diffuse flow with localized zones of discrete fracture-controlled flow.

The aquifer of concern beneath the Chemical Plant is the shallow bedrock aquifer comprised of Mississippian Burlington-Keokuk Limestone (the uppermost bedrock unit) and the underlying Fern Glen Formation. The Burlington-Keokuk Limestone is described as having two different lithologic zones, a shallow, weathered zone and an underlying unweathered zone. The weathered portion of this formation is highly fractured and exhibits solution voids and enlarged fractures. These features may also be present on a limited scale in the unweathered zone, particularly in the vicinity of buried preglacial stream channels (paleochannels). Localized aquifer properties are controlled by fracture spacing, solution voids, and preglacial weathering, including structural troughs along the bedrock–overburden interface. The unweathered portion of the Burlington-Keokuk Limestone is thinly to massively bedded. Fracture densities are significantly less in the unweathered zone than in the weathered zone.

All monitoring wells at the Chemical Plant are completed in the Burlington-Keokuk Limestone. Most of the wells are completed in the weathered zone of the bedrock where groundwater has the greatest potential to be contaminated. Some wells screened in the unweathered zone of the Burlington-Keokuk Limestone are used to assess the vertical migration of contaminants. Monitoring wells within the boundaries of the Chemical Plant are located near historical contaminant sources and preferential flow pathways (paleochannels) to assess the movement of contaminated groundwater in the shallow aquifer. Additional wells are located outside the Chemical Plant boundary to detect and evaluate the potential off-site migration of contaminants (Figure 8).

Numerous springs, a common feature in carbonate terrains, are present in the vicinity of the site. Four springs that are monitored routinely (Figure 9) have been historically influenced by Chemical Plant discharge water or groundwater that contained one or more of the contaminants of concern.

The presence of elevated total uranium and nitrate levels at Burgermeister Spring (SP 6301), which is 1.2 miles north of the site, indicates that discrete subsurface flow paths are present in the vicinity of the site. Groundwater tracer tests performed in 1995 (DOE 1997a) confirmed that a discrete and rapid subsurface hydraulic connection exists between the northern portion of the Chemical Plant and Burgermeister Spring. These flow paths are associated with the preglacial stream channels (paleochannels) present beneath the site.

6.4.1.2 Contaminants of Interest

The Raffinate Pits were the primary historical source of uranium contamination in groundwater. Uranium entered the shallow aquifer via infiltration through the thin overburden beneath the pits. The extent of uranium in groundwater was limited because uranium is partially sorbed to the clays in the overburden materials and bedrock fractures. At locations where uranium contaminated water migrated beneath the overburden, it entered the limestone conduit system and subsequently discharged to springs north of the site. The oxidizing conditions of the shallow aquifer are not favorable for the precipitation of uranium from solution. Uranium contaminated sediments were also discharged off site during past operations. These sediments accumulated in subsurface cracks and fissures in the losing stream segments and act as residual sources to groundwater and springs.

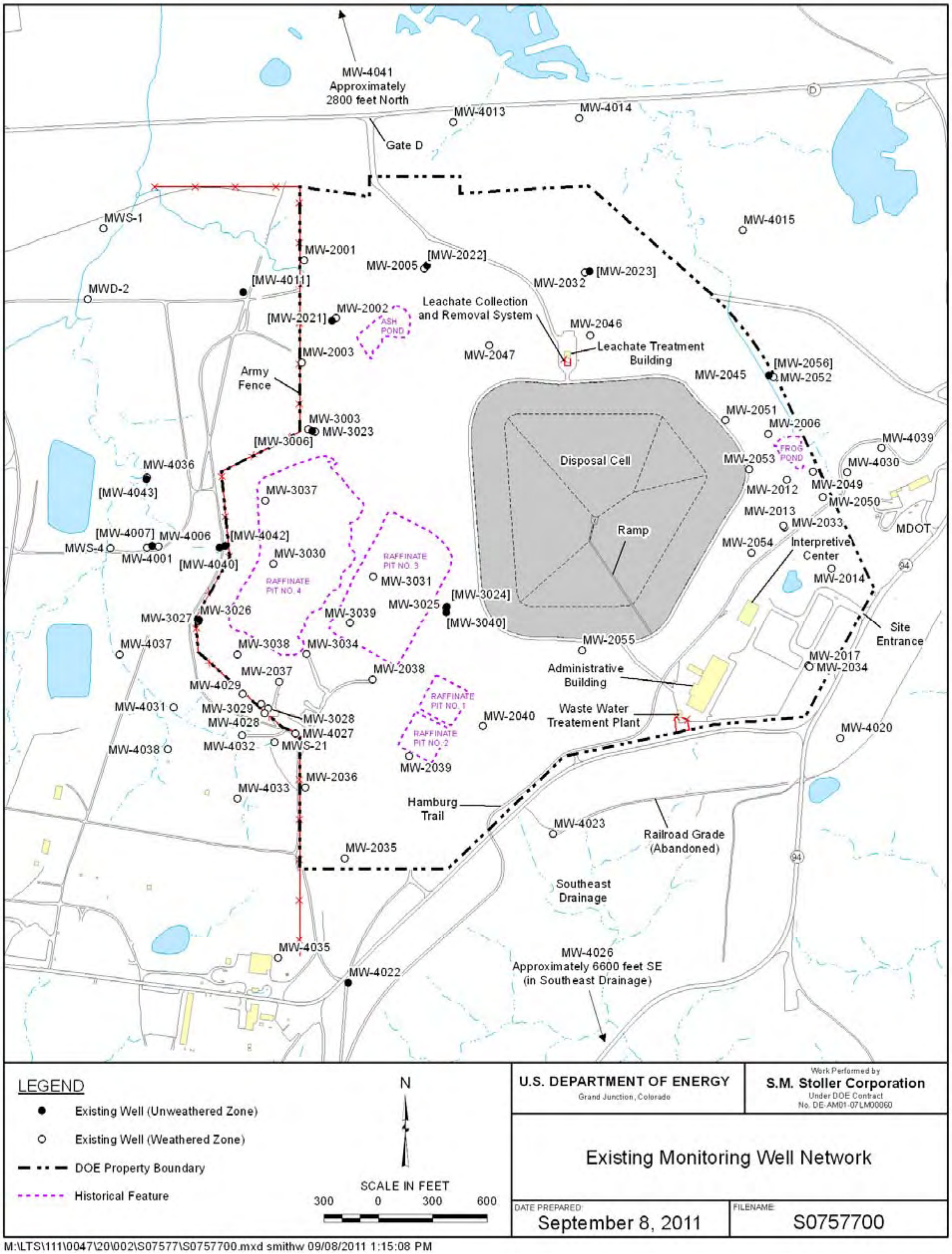

Figure 8. Existing Monitoring Well Network

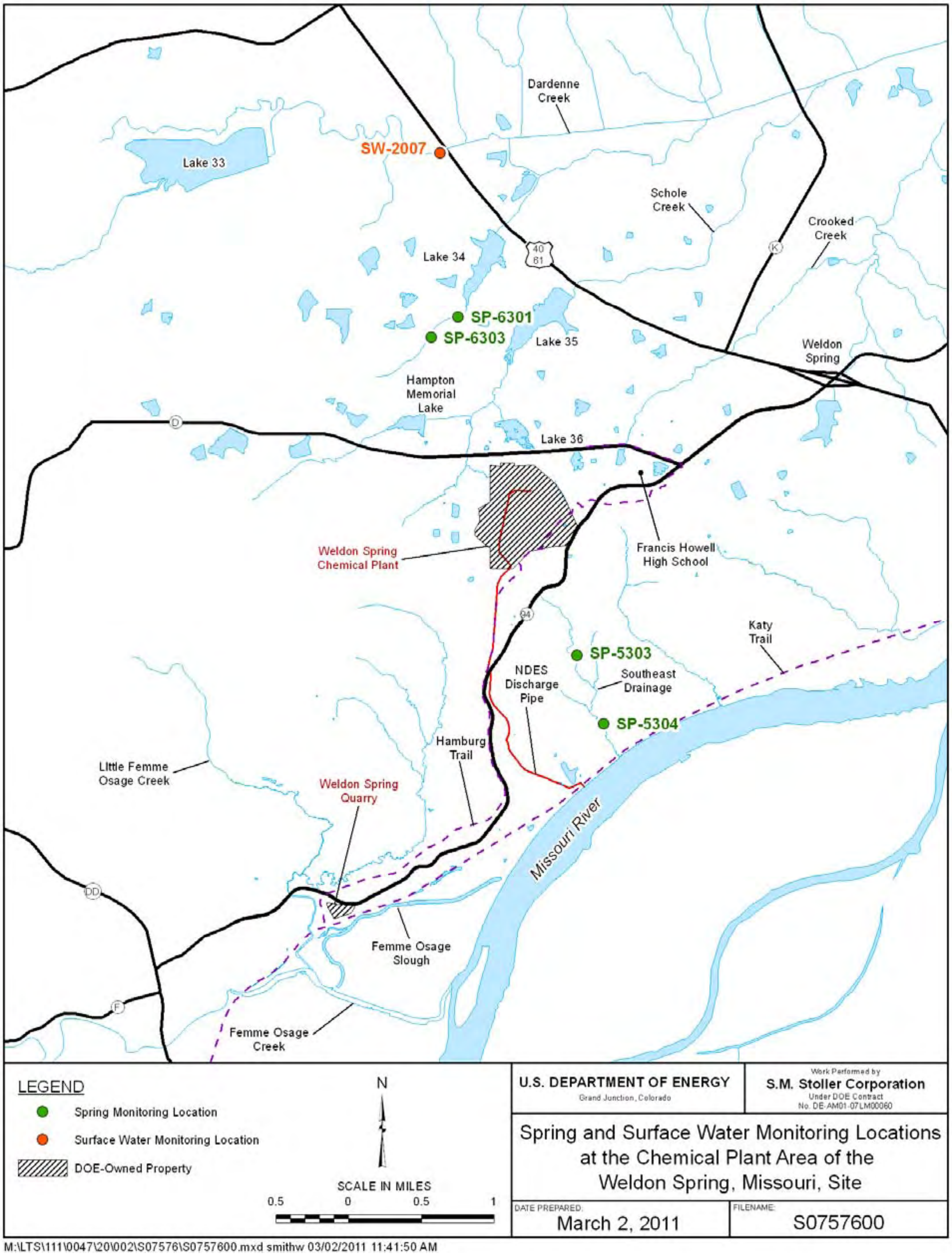

Figure 9. Spring and Surface Water Monitoring Locations at the Chemical Plant Area of the Weldon Spring, Missouri, Site

Nitrate is present in the groundwater near the former Raffinate Pits area and the Ash Pond area, which are the historical sources of this contaminant. Nitrate is mobile in the shallow groundwater system, as it is not readily sorbed to subsurface materials. Conditions for natural denitrification have not been identified in the shallow aquifer, so nitrate persists in groundwater, enters the limestone conduit system, and subsequently discharges to springs north of the site.

Groundwater contaminated with TCE is localized in the weathered portion of the bedrock aquifer in the vicinity of Raffinate Pit 4. The source of TCE contamination was drums that were disposed of in Raffinate Pit 4. The oxidizing conditions in the shallow bedrock aquifer do not promote the biodegradation of organic compounds.

Nitroaromatic compounds (1,3-dinitrobenzene [DNB]; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene) in the groundwater system coincide with former production line locations. The presence of nitroaromatic compounds in groundwater is a result of leakage from former TNT process lines, discharges from water lines, and leaching from contaminated soils and waste lagoons. The mobility of nitroaromatic compounds in the bedrock aquifer is high due to little sorption to the bedrock materials. Microorganisms indigenous to the soils and the shallow aquifer have the ability to transform and degrade TNT and DNT.

6.4.1.3 GWOU Monitoring Program

The monitoring network is designed to provide data either to show that natural attenuation processes are acting as predicted or to trigger the implementation of contingencies when these processes are not acting as predicted (e.g., unexpected expansion of the plume or sustained increases in concentrations within the area of impact). The locations and the objectives they satisfy are summarized in Table 13 and are depicted in Figure 6. The data analysis and interpretation will satisfy the following:

- Baseline conditions (Objective 1) have remained unchanged.
- Performance monitoring locations (Objective 2) indicate that concentrations within the area of impact are decreasing or remaining stable, as expected.
- Detection monitoring locations (Objectives 3, 4, and 5) indicate when a trigger has been exceeded, indicating unacceptable expansion of the area of impact.
- Hydrogeologic monitoring locations (Objectives 1, 2, 3, 4, and 6) indicate any changes in groundwater flow that might affect the protectiveness of the MNA remedy at the site over time.

Data are evaluated as outlined in the Baseline Concentrations Report (DOE 2008d). The evaluation of data was established to satisfy the monitoring objectives for the MNA remedy.

Trigger levels were set for each contaminant at the performance and detection monitoring locations in the event that unexpected increases occur. There are two trigger levels for each contaminant (Table 20). The first trigger level is set at what would be considered a statistically significant increase of a contaminant at a location and is defined as the mean plus 3 standard deviations for the previous eight data points. The second trigger level was established as a fixed concentration that indicates unacceptable increases within the area of impact (Objective 2), outside the area of impact (Objectives 3 and 4), or at discharge points (Objective 5). Contingency actions are defined in Appendix M of the LTS&M Plan.

Table 20. Trigger Levels for Performance and Detection Monitoring for the GWOU

Analyte	Cleanup Standard	Objective 2	Objective 3 (Near)	Objective 3 (Far)	Objective 4	Objective 5
Nitrate (mg/L)	10	1,350	30	10	20	20
Uranium (pCi/L)	20	100	50	20	40	150
TCE (μg/L)	5	1,000	15	5	10	5
2,4-DNT (μg/L) – FP	0.11	2,300	1.1	0.11	0.22	0.22
2,4-DNT (μg/L) – RP		5	0.55			
2,6-DNT (μg/L)	1.3	2,000	13	1.3	2.6	1.3
2,4,6-TNT (μg/L)	2.8	500	11.2	2.8	5.6	2.8
1,3-DNB (μg/L)	1.0	20	4	1	2	1
NB (μg/L)	17	50	34	17	17	17

Abbreviations:
DNB = dinitrobenzene
DNT = dinitrotoluene
FP = Frog Pond
μg/L = micrograms per liter
mg/L = milligrams per liter
NB = nitrobenzene
pCi/L = picocuries per liter
RP = Raffinate Pits
TNT = trinitrotoluene

Groundwater data from the upgradient locations are compared with the previously collected data from each respective location. If a statistically significant increase (mean plus 3 standard deviations for the previous eight data points) is measured, then the value is evaluated for its validity. For those locations that are "nondetect," a statistically significant increase is considered to be the respective cleanup standard measured for two consecutive sampling periods. Contingency actions are defined in Appendix M of the LTS&M Plan.

Baseline Monitoring Results for the GWOU

Baseline conditions are monitored in four upgradient wells to determine if possible changes in downgradient areas of impact are the result of upgradient conditions. The objective of this monitoring is to determine if baseline conditions have remained unchanged.

Each of the upgradient wells was sampled semiannually during the period from 2006 through 2008 and annually in 2009 and 2010. The concentration for each parameter is presented in Table 21. The concentrations measured in from 2006 through 2010 are similar and indicate no change in upgradient groundwater quality.

Table 21. Baseline Monitoring for the GWOU MNA Remedy (2006–2010)—Averages

Location	MW-2017	MW-2035	MW-4022	MW-4023
	Weathered	Weathered	Unweathered	Weathered
Parameters				
Uranium (pCi/L)	NR	0.48	4.0	1.7
Nitrate (as N) (mg/L)	NR	0.52	0.29	0.93
TCE (μg/L)	NR	< 1	NR	NR
1,3-DNB (μg/L)	ND (< 0.04)	ND (< 0.05)	NR	NR
2,4,6-TNT (μg/L)	ND (< 0.05)	ND (< 0.05)	NR	NR
2,4-DNT (μg/L)	ND (< 0.05)	ND (< 0.05)	NR	NR
2,6-DNT (μg/L)	ND (< 0.07)	ND (< 0.07)	NR	NR
Nitrobenzene (μg/L)	ND (< 0.06)	ND (< 0.06)	NR	NR

Abbreviations:
DNB = dinitrobenzene
DNT = dinitrotoluene
μg/L = micrograms per liter
mg/L = milligrams per liter
ND = analyte not detected above the reporting limit indicated in parentheses
NR = analyte not required
pCi/L = picocuries per liter
TNT = trinitrotoluene

Performance Monitoring Results for the GWOU

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells. Objective 2 wells are within the areas of impact and monitor both the weathered and unweathered units of the Burlington-Keokuk Limestone. Objective 2 of the MNA strategy is to verify that contaminant concentrations are declining or remaining stable as expected and that cleanup standards will be met in a reasonable time frame.

Contaminant concentrations are monitored using 20 wells within the areas of highest impact of each contaminant in groundwater at the site. These wells were sampled at least semiannually during the period of 2006 through 2010.

Performance of the remedy is gauged against long-term trend analysis as outlined in the MNA Baseline Concentrations Report (DOE 2008d) and the LTS&M Plan. Some locations are expected to show temporary upward trends due to ongoing dispersion, analytical variability, or other factors; however, concentrations are not expected to exceed historical maximums. Concentration-versus-time graphs serve as visual indicators of MNA progress.

Uranium

The area of uranium impact is in the former Raffinate Pits area in the western portion of the site. Uranium levels exceed the MCL of 20 pCi/L in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the uranium values for the period from 2006 through 2010 is presented in Table 22.

Table 22. Uranium Data from GWOU Objective 2 Wells (2006–2010)

Location	Uranium (pCi/L)				
	2006	2007	2008	2009	2010
Weathered Unit					
MW-3003	5.3	3.8	4.2	5.6	3.3
MW-3030	40.3	40.4	39.0	46.6	31.3
Unweathered Unit					
MW-3024	71.8	91.0	114	132	105
MW-3040	93.6	91.8	100	119	95.1
MW-4040	255	264	354	373	296

pCi/L = picocuries per liter

Uranium impact in the weathered unit is monitored in two wells. The highest uranium levels in this unit are measured in MW-3030 (Figure 10), installed beneath the former Raffinate Pits area. The Objective 2 wells screened in the weathered unit have generally shown gradually decreasing uranium levels since the removal of the pits. The levels in MW-3003 have consistently been less than the MCL since 2000.

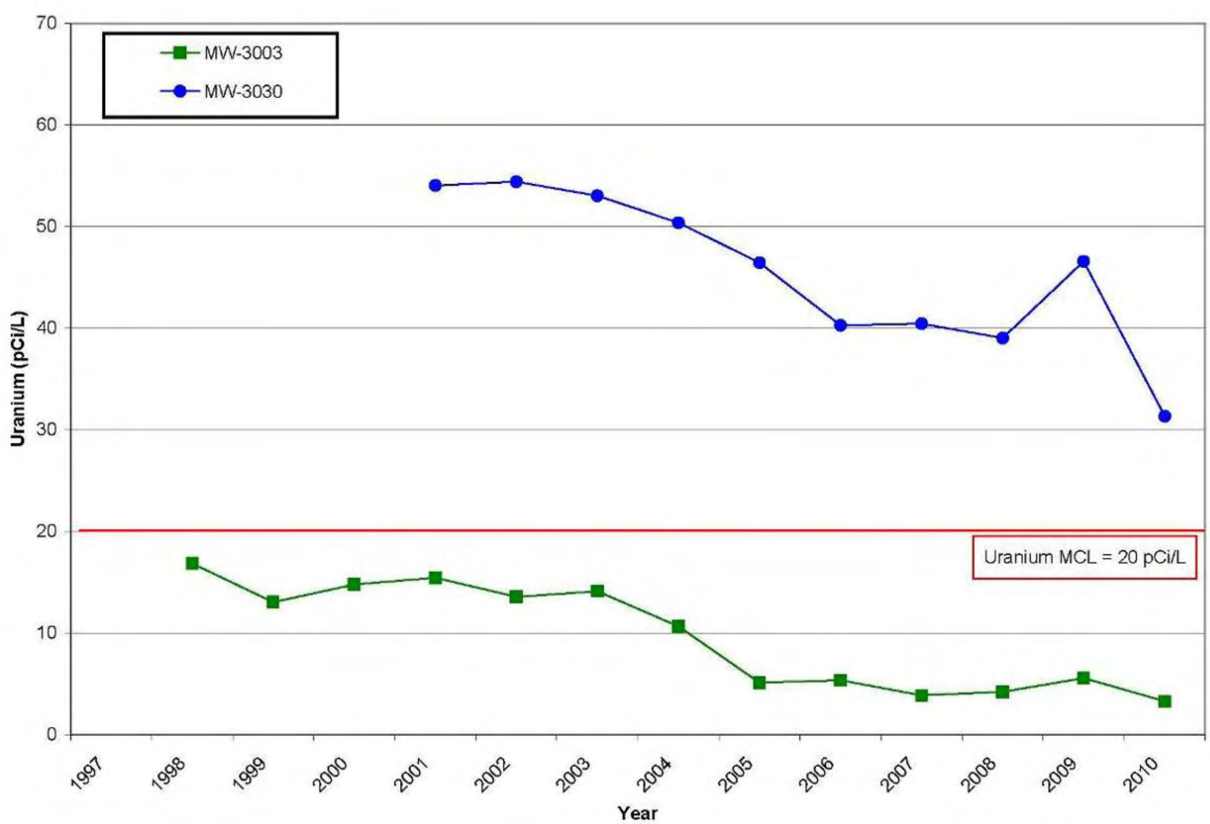

Figure 10. Average Uranium Levels in Objective 2 Wells Screened in the Weathered Unit (1997–2010)

Results for trend analysis of uranium data from the weathered unit wells (Table 23) indicate that uranium levels for the past 5 years have been decreasing, as indicated by negative slopes. A downward trend was determined for MW-3030. If the current decrease in uranium continues in MW-3030, it is estimated that the MCL of 20 pCi/L could be reached by 2019, using an exponential curve model. The estimated cleanup time frame for uranium in the weathered unit is 56 years. Well MW-3003 has been less than the MCL since 2000.

Table 23. Trending Analysis for Uranium in Objective 2 MNA Weathered Unit Wells (2006–2010)

Location	Monitored Unit	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
					Lower	Upper
MW-3003	Weathered	14	None	–0.39	–0.75	0.13
MW-3030	Weathered	14	**Down**	–2.6	–3.5	–1.3

pCi/L/yr = picocuries per liter per year

Uranium impact is greatest in the wells that are screened in the unweathered unit beneath and immediately downgradient of the former Raffinate Pits (Figure 11). Wells MW-3040 and MW 4040 were installed in 2004 to provide uranium data for the unweathered unit in this area. These two wells were designated as Objective 2 wells for the area of uranium impact in the unweathered unit in 2005 (DOE 2005e). Uranium levels in MW-4040 have consistently been greater than the Objective 2 trigger of 100 pCi/L since the well was installed. Wells MW-3024 and MW-3040 began having uranium levels greater than the trigger level starting in 2008.

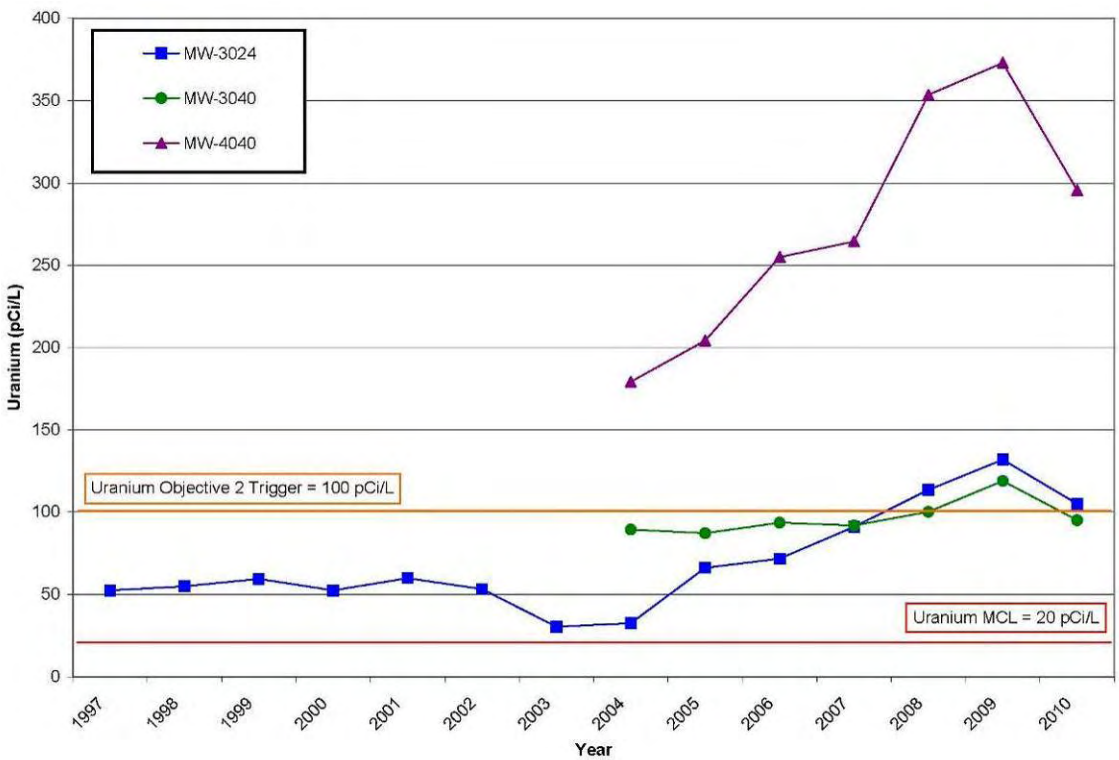

Figure 11. Average Uranium Levels in Objective 2 Wells Screened in the Unweathered Unit (1997−2008)

The increased uranium levels in MW-3024 and MW-3040 have been part of a special study started in 2008. As part of this study, MW-3024 and MW-3040 have been sampled quarterly for uranium. Data from these wells and other nearby wells are summarized in Table 24. The study indicates that the reduction in infiltration has limited dilution of the impacted groundwater in the unweathered unit and has resulted in little flushing of the system due to the low amount of recharge through the system. Increased uranium levels are the result of desorption of residual uranium from contaminated materials that were forced deeper into the bedrock by the hydraulic head of the Raffinate Pits. Since there is little infiltration to flush this impacted groundwater through the bedrock aquifer, changes will likely be slow.

As of August 2010, well MW-3024 had seven consecutive data points greater than 100 pCi/L. The GWOU contingency action decision trees included in the LTS&M Plan (Figure M–3) indicates that after six consecutive events with trigger level exceedences, the average contaminant concentration within the cleanup standard contour should be calculated and if necessary, the distribution of uranium reevaluated. The average uranium level within the 20 pCi/L contour (which contains only MW-3024) is 118 pCi/L (using the 8 most recent data points). The initial concentration for estimation of the original cleanup time frame of this area was 54 pCi/L and was based on data from only MW-3024. In the Baseline Concentrations Report (DOE 2008d), the initial concentration for MW-3024 was determined to be 62 pCi/L. The average uranium level in the contour in question is 113 pCi/L (using the eight most recent data points from MW-3024 and MW-3040) and is approximately twice the value used to estimate the cleanup time frame of 4 years.

Table 24. Uranium Data from Special Study for MW-3024 and MW-3040

Date	Uranium Levels (pCi/L)		
	MW-3024	MW-3040	MW-4040
March 2008		94.1	313
April 2008	125		
May 2008		95.5	378
July 2008	109	107	360
August 2008	120	106	370
September 2008			
October 2008	100	98.2	347
February 2009	99.5	98.8	332
April 2009	110	105	
May 2009			296
August 2009	118	105	339
November 2009	200	167	530
February 2010	102	95.9	303
April 2010	108	88.0	305
June 2010	102	94.5	284
August 2010	108	102	291
October 2010	108	102	305
December 2010	115	109	311

pCi/L = picocuries per liter

The distribution of uranium was evaluated in 2008 as part of the special study (Figure 12). This distribution was compared to the areal distribution used in the MNA time frame calculations to evaluate whether significant expansion of the uranium in groundwater had occurred. This figure depicts one area of uranium impact in the weathered unit and two discrete areas of uranium impact for the unweathered unit beneath the Raffinate Pits area. The distribution of uranium in the weathered unit has expanded along the western side of the Raffinate Pits area, as indicated by the increased average values in MW-4036 measured since 2008. The contour for MW-3024/MW-3040 has remained unchanged based on recent data; however, it has been determined that this well now represents impact in the unweathered unit. Another area of impact in the unweathered unit is present along the western edge of the Chemical Plant site as indicated by data from well MW-4040. It can be concluded that the distribution of uranium in the unweathered unit to the west is larger than that depicted from the 2008 data by the addition of MW-4043.

Results from the trend analyses for uranium in the unweathered unit (Table 25) indicate increasing uranium levels in the three Objective 2 wells screened in the unweathered unit, as indicated by positive slopes. Statistically upward trends were calculated for wells MW-3024 and MW-3040 using data from the past 5 years. Analysis of the uranium data from MW-4040 indicates no trend, either upward or downward. No cleanup time frames were determined for uranium impact in the unweathered unit, as this impact was identified after implementation of the MNA remedy.

Table 25. Trending Analysis for Uranium in Objective 2 MNA Unweathered Unit Wells (2006–2010)

Location	Monitored Unit	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
					Lower	Upper
MW-3024	Unweathered	18	**Up**	6.6	0	11.6
MW-3040	Unweathered	22	**Up**	2.8	0.34	5.2
MW-4040	Unweathered	22	None	12.0	–11.0	24.7

pCi/L/yr = picocuries per liter per year

Overall, uranium impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Uranium levels in the weathered unit are decreasing as a result of source removal and natural attenuation (dilution and dispersion). The MCL for uranium could be attained in this portion of the shallow aquifer by 2019 if decreases continue at the current rate. Uranium levels within the less-permeable unweathered unit are increasing due to desorption of uranium from residual materials as a result of reduced recharge deeper into the aquifer system that has limited flushing. Recharge that does enter the system is more likely to move horizontally through the weathered unit than vertically into the unweathered unit due to greater conductivity in the horizontal direction and the lack of a vertical driving force to move the groundwater downward as was previously exerted by water in the Raffinate Pits.

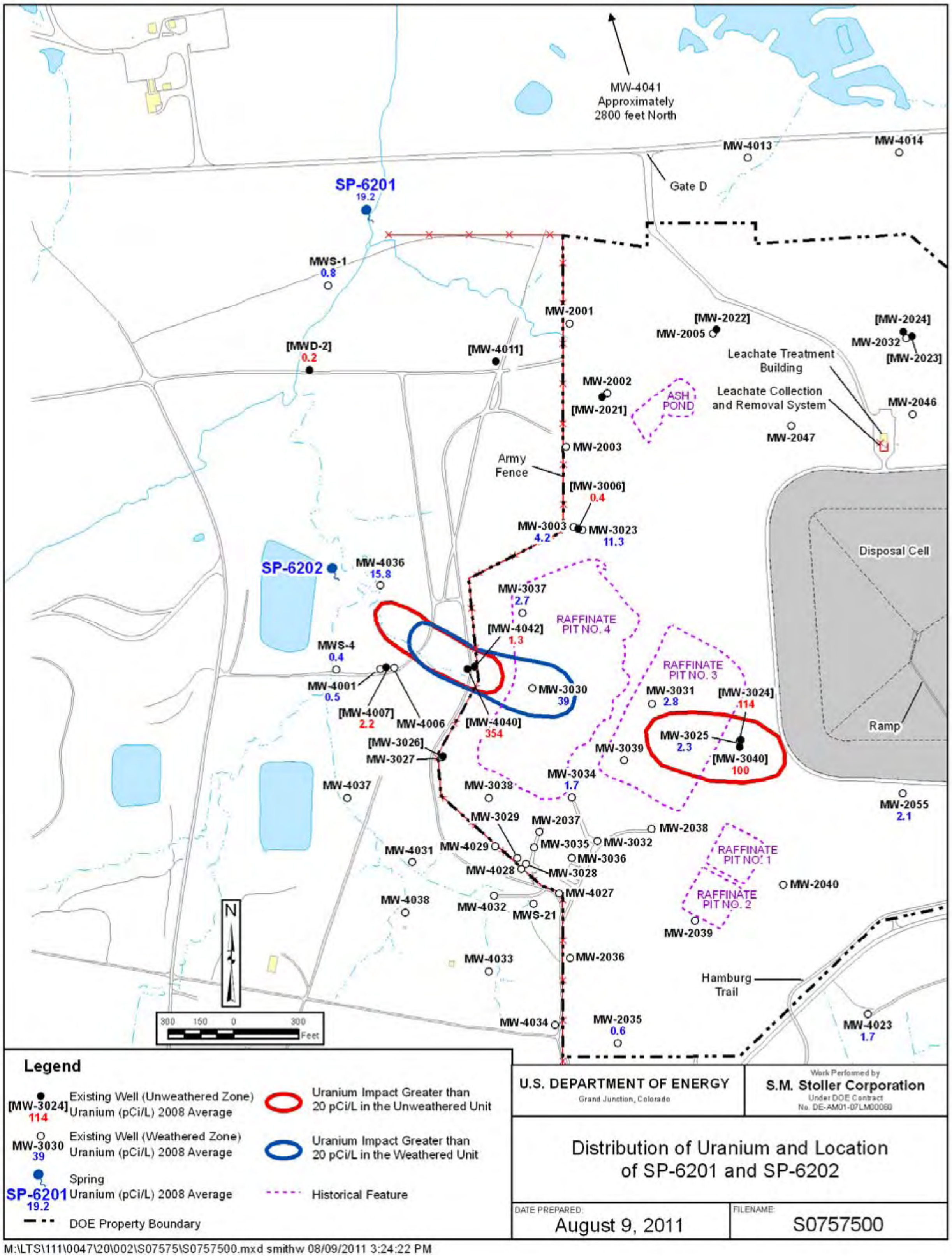

Figure 12. Uranium Distribution in the Weathered and Unweathered Units in 2008

Nitrate (as N)

The highest concentrations of nitrate have been measured in the former Raffinate Pits area. Elevated nitrate concentrations are also present in the former Ash Pond area. Both are historical sources of this contaminant. The higher mobility of nitrate, as compared to other contaminants at the site, has resulted in a larger distribution of this contaminant in the shallow aquifer. Nitrate levels exceed the MCL of 10 milligrams per liter (mg/L) (for nitrate as N) in all of the Objective 2 wells in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the nitrate data for the period from 2006 through 2010 is presented in Table 26.

Nitrate concentrations are highest in the weathered unit of the Burlington-Keokuk Limestone and are measured in wells that are in the former Raffinate Pits area (MW-2038, MW-3003, and MW-4029) (Figure 13). Recent data show decreasing nitrate concentrations in all of the wells except MW-3003 and MW-4036. The decrease of the concentrations is the result of source removal in the Raffinate Pits and Ash Pond areas.

Monitoring well MW-4036 is on the downgradient edge of the nitrate plume in the Raffinate Pits area. Nitrate concentrations have varied at this location, and recent data support an upward trend in concentrations. Monitoring well is located within the preferential flow path that extends north from Raffinate Pit 4. The concentration of nitrate at this location is significantly less than the Objective 2 trigger. Short-term upward trends were anticipated along the migration pathway where these wells are located.

Results of trend analysis of nitrate data from the weathered unit collected from 2006 through 2010 indicate decreasing levels in all of the wells, except MW-4036, as indicated by negative slopes (Table 27). Statistically downward trends were calculated for MW-3034 and MW-4029, both located in the Raffinate Pits area. If the current decreases in nitrate concentrations continue in these wells, it is estimated that the MCL of 10 mg/L (for nitrate as N) could be reached by 2026 in MW-3034 and by 2056 in MW-4029, using an exponential curve model. The estimated cleanup time frame for nitrate is 63 years for wells located in the Raffinate Pits area. A statistically upward trend was calculated for MW-4036, which is along the leading edge of the nitrate impact in the weathered unit. Increases in Objective 3 near wells were anticipated during the design and implementation of the MNA remedy and the triggers took this occurrence into account.

Table 26. Nitrate Data from GWOU Objective 2 Wells (2006–2010)

Location	Nitrate (as N) Concentration (mg/L)				
	2006	**2007**	**2008**	**2009**	**2010**
Weathered Unit					
MW-2038	252	540	466	564	480
MW-2040	93.6	106	97.4	84.2	3.8
MW-3003	378	682	437	441	477
MW-3034	236	248	199	178	170
MW-4013	88.0	82.4	79.2	80.1	84.0
MW-4029	552	683	545	436	410
MW-4031	155	158	167	166	150
MW-4036	4.6	42.8	19.7	25.0	24.0
Unweathered Unit					
MW-3040	194	385	143	128	124
MW-4040	111	95.1	180	132	122

mg/L = milligrams per liter

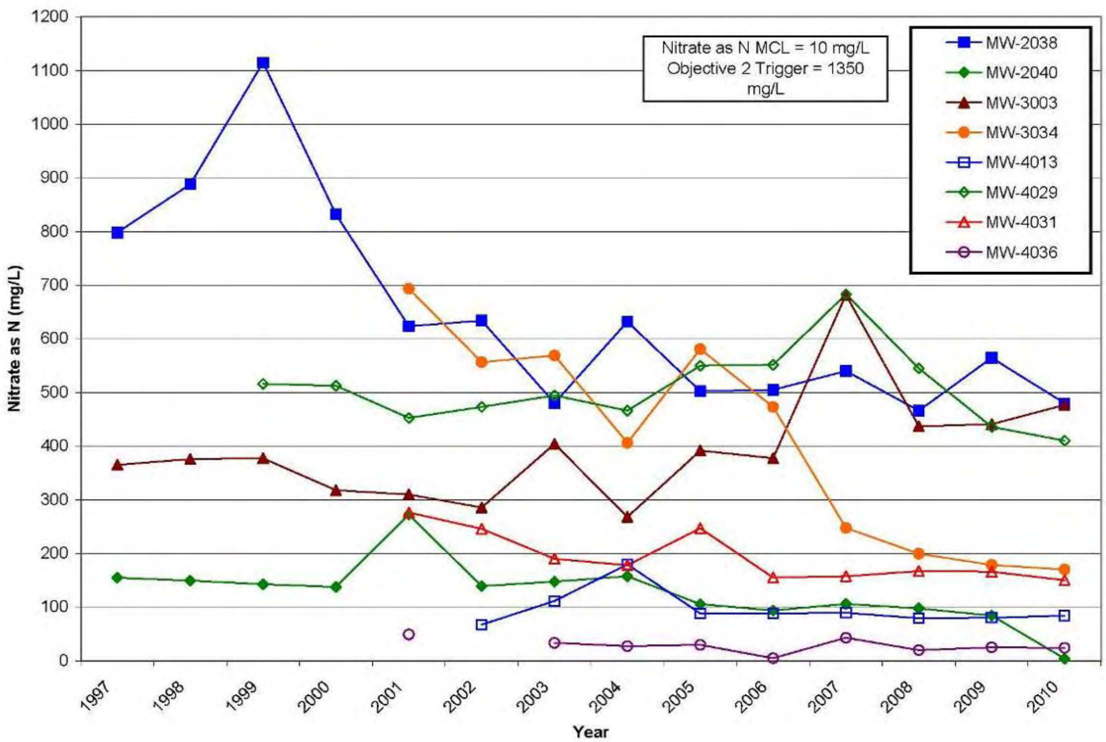

Figure 13. Average Nitrate Concentrations in Objective 2 Wells Screened in the Weathered Unit (1997−2010)

Table 27. Trending Analysis for Nitrate (as N) in Objective 2 MNA Weathered Unit Wells (2006–2010)

Location	Monitored Unit	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
					Lower	Upper
MW-2038	Weathered	9	None	–5.7	–43.5	49.7
MW-2040	Weathered	10	None	–7.1	–23.8	9.5
MW-3003	Weathered	14	None	–14.0	–40.6	45.1
MW-3034	Weathered	10	**Down**	–33.0	–68.2	–10.3
MW-4013	Weathered	8	None	–1.7	–5.6	2.6
MW-4029	Weathered	10	**Down**	–28.3	–100	–2.9
MW-4031	Weathered	10	None	–0.44	–20.0	20.8
MW-4036	Weathered	19	**Up**	4.7	0.48	8.8

mg/L/yr = milligrams per liter per year

Nitrate concentrations in the unweathered unit exceed the MCL only in the Raffinate Pits area. The nitrate concentrations in MW-3040 have decreased since installation of the well (Figure 14). Nitrate concentrations in MW-4040 increased in 2008; however, the concentrations have since declined. Well MW-4040 is downgradient of MW-3040, and the increases observed in MW-4040 are likely the eventual migration of groundwater with higher nitrate concentrations that were measured at MW-3040.

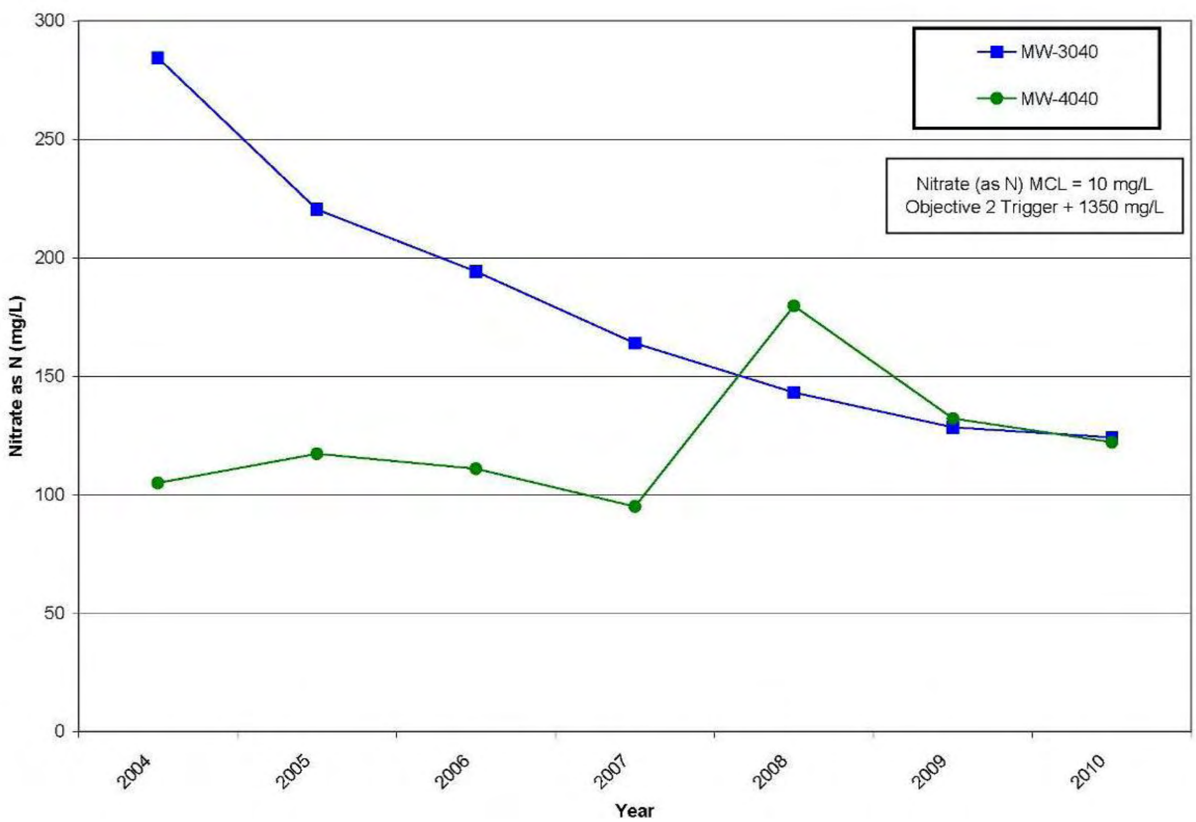

Figure 14. Average Nitrate Concentrations in Objective 2 Wells Screened in the Unweathered Unit (2004−2010)

Results of trend analysis indicate decreasing concentrations over the past 5 years, as indicated by negative slopes (Table 28). A statistically downward trend was calculated for MW-3040. If the current decreases in nitrate concentrations continue in MW-3040, it is estimated that the MCL of 10 mg/L (for nitrate as N) could be reached by 2032, using an exponential curve model. No cleanup time frames were determined for nitrate impact in the unweathered unit, as this impact was identified after implementation of the MNA remedy

Table 28. Trending Analysis for Nitrate (as N) in Objective 2 MNA Unweathered Unit Wells (2006–2010)

Location	Monitored Unit	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
					Lower	Upper
MW-3040	Unweathered	21	**Down**	–16.0	–20.0	–12.4
MW-4040	Unweathered	22	None	–2.8	–15.8	13.5

mg/L/yr = milligrams per liter per year

Overall, nitrate impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Nitrate concentrations in the weathered and unweathered units are decreasing except along the leading edge of the area of impact in the weathered unit. Some locations were expected to show temporary upward trends due to ongoing dispersion; however, concentrations are not expected to exceed historical maximums seen within the areas of highest impact. The MCL for nitrate could be attained by 2056 in the weathered unit and by 2032 in the unweathered unit if decreases continue at the current rate. The higher mobility of nitrate, as compared to other contaminants at the site, has resulted in quicker flushing of this contaminant from the aquifer system.

Trichloroethylene

TCE contamination in the shallow groundwater is located in the vicinity of former Raffinate Pit 4, where drums containing TCE are suspected to have been discarded. TCE impact is detected in only the weathered unit of the Burlington-Keokuk Limestone. A summary of the TCE data for the period from 2006 through 2010 is presented in Table 29.

Table 29. TCE Data from GWOU Objective 2 Wells (2006–2010)

Location	TCE Concentration (µg/L)				
	2006	2007	2008	2009	2010
MW-3030	395	350	250	270	270
MW-3034	430	213	175	165	120
MW-4029	600	763	510	455	370

µg/L = micrograms per liter

TCE impact is highest in MW-4029, along a preferential flow pathway in the area. The TCE concentrations in MW-3030 and MW-3034 have varied over time (Figure 15); however, some changes are a result of rebound from field studies performed in 2001 and 2002. Data from recent years indicate decreases in TCE concentrations in these three wells. Concentrations of TCE in all of the Objective 2 wells continue to exceed the MCL.

Low levels of the TCE breakdown product *cis*-1,2-dichloroethene (DCE) is measured in the three Objective 2 wells and the concentrations are significantly less than the MCL of 70 μg/L. Estimated detections of *trans*-1,2-DCE less than 1 μg/L are reported in the three Objective 2 wells. No detectable concentrations of vinyl chloride were reported in any of the Objective 2 wells. The geochemistry of the groundwater at the Chemical Plant is oxidize; therefore, reductive dechlorination of TCE is limited. Dilution and dispersion are the primary attenuation mechanisms for TCE in groundwater.

Results of the trend analysis for the Objective 2 TCE wells indicate that concentrations in groundwater have begun to decrease, as indicated by negative slopes. Downward trends were calculated for MW-3034 and MW-4029 using the data collected from 2006 through 2010. If the current decreases in TCE concentrations continue in MW-3034 and MW-4029, it is estimated that the MCL of 5 μg/L could be reached by 2023 in MW-3034 and by 2033 in MW-4029, using an exponential curve model. The estimated cleanup time frame for TCE is 101 years.

Overall, TCE impact is confined to a discrete area of the Chemical Plant site and is limited to the weathered unit of the Burlington-Keokuk Limestone. TCE concentrations in the weathered unit are decreasing in the area of impact. The MCL for TCE could be attained by 2033 if decreases continue at the current rate.

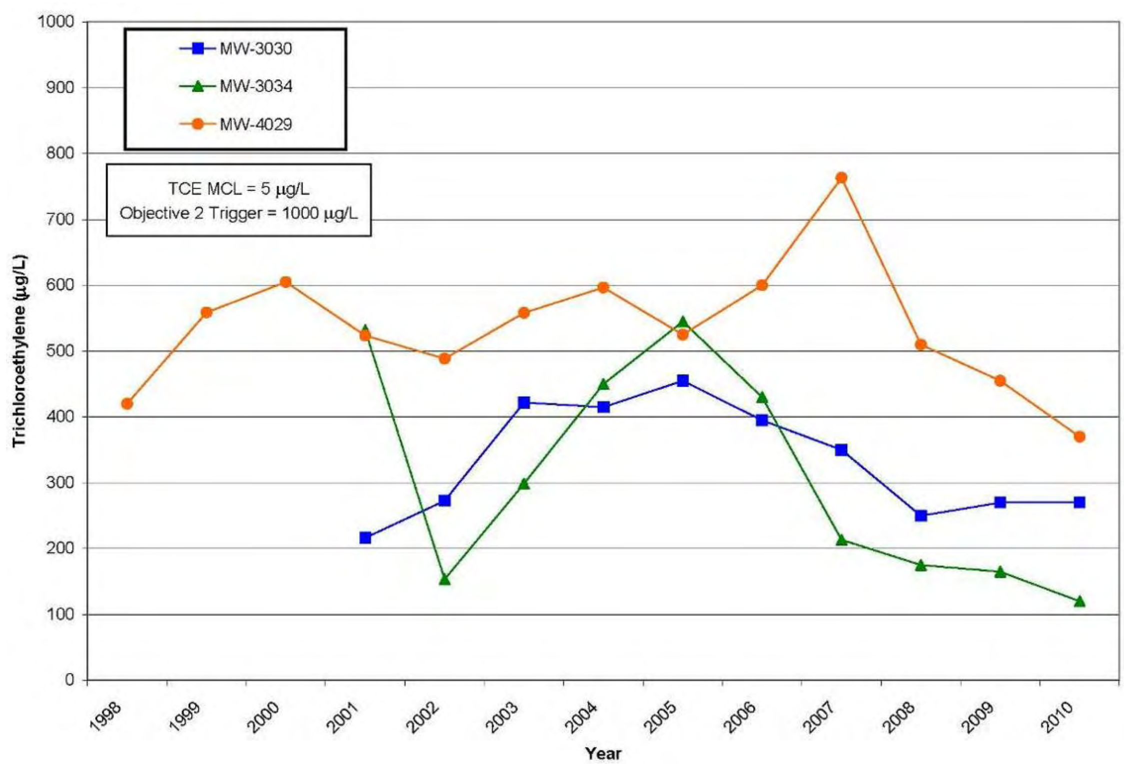

Figure 15. Average TCE Concentrations in Objective 2 Wells (1998−2010)

Nitroaromatic Compounds—Former Frog Pond Area

The area of greater nitroaromatic compound groundwater impact at the site is in the former Frog Pond area and is limited to the weathered unit of the Burlington-Keokuk Limestone. Groundwater in this area has historically shown impact above the cleanup standards for 1,3-DNT; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene (NB). Concentrations of nitroaromatic compounds increased in this area starting in 1997. Recent data have indicated that several Objective 2 wells have concentrations less than cleanup standards for some compounds.

The distribution of nitroaromatic compounds suggests that the primary source area is Production Line 1, most notably the wash house (T-13) and the wastewater settling tank (T-16). Some contribution to the nitroaromatic contamination originates from Army Lagoon 1. The preferential flow path in the vicinity of Frog Pond has been identified from the bedrock topography, and the contaminant distribution is controlled somewhat by the topography. Nitroaromatic compound impact in the former Frog Pond area is isolated to the weathered unit of the Burlington-Keokuk Limestone.

In recent years, nitroaromatic compound concentrations, primarily the DNTs, have varied in the former Frog Pond area. Starting in 1997, increases in concentrations were reported, and concentrations increased dramatically during and after the completion of soil excavation in this area and remedial activities performed by the U.S. Army Corps of Engineers in nearby Army Lagoon 1. Also during this time frame, groundwater elevations steadily decreased, likely in response to the removal of Frog Pond and redirection of surface water runoff, both of which reduced the amount of infiltration into the groundwater system. Nitroaromatic compound concentrations in several wells in this area dramatically decreased in 2004. The suspected cause was the infiltration of surface water runoff into the groundwater system through a subsidence feature that formed near MW-2012. The continued influence of surface water infiltration is indicated by the fluctuation of groundwater elevations in several Objective 2 wells near the preferential flow pathway in the area (Figure 16). Large fluctuations in groundwater elevations occurred historically when Frog Pond and surface water drainage features were present. In recent years, groundwater elevations have generally increased in wells along the preferential pathway, most notable MW-2012 and MW-2052. This increase is likely attributed to surface water contribution in a natural drainage channel that is beginning to establish in this area.

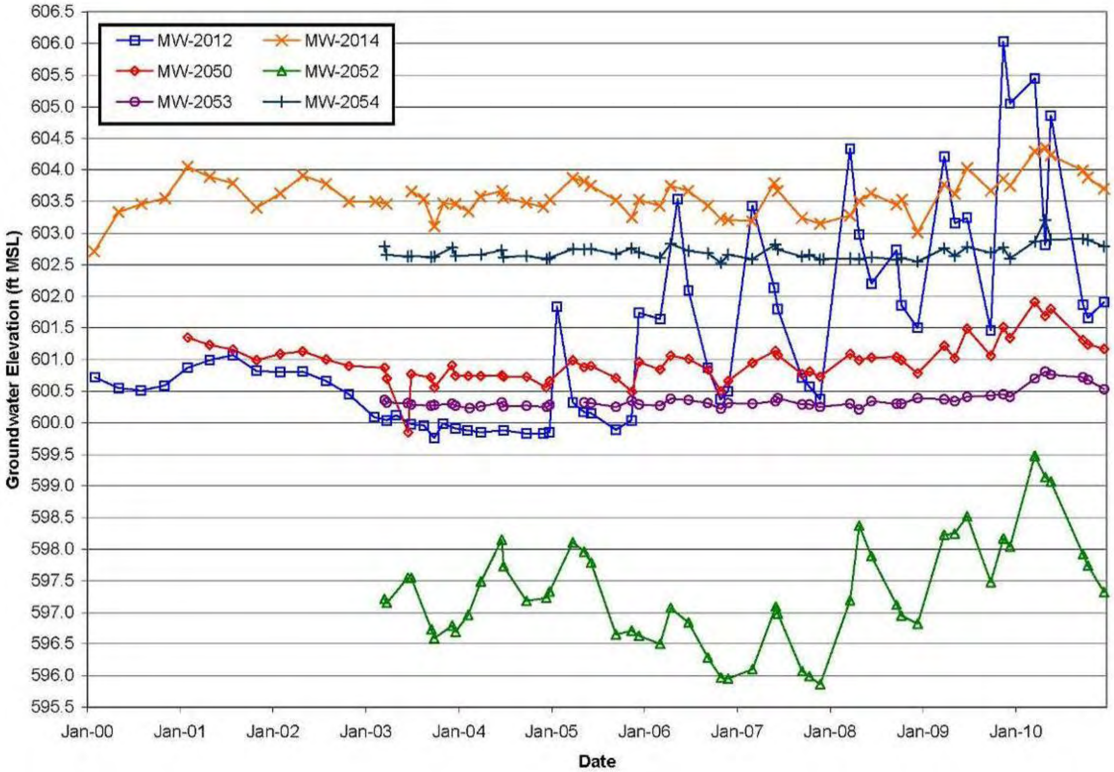

Figure 16. Groundwater Elevations in Frog Pond Area Objective 2 Wells

Concentrations of 1,3-DNB have varied in well MW-2012 (Figure 17). Starting in 2006, the average concentration decreased below the cleanup standard of 1.0 µg/L (Table 30). Decreases in 1,3-DNB are expected, as this nitroaromatic compound is a photodegradation breakdown product of 2,4-DNT. Increases in concentration of this compound began during the period that 2,4-DNT impacted soils were being excavated in this area. Exposure of impacted soil likely resulted in some photodegradation and subsequent infiltration into the aquifer system.

Table 30. 1,3-DNB Data from GWOU Objective 2 Wells (2006–2010)

Location	1,3-DNB Concentration (µg/L)				
	2006	2007	2008	2009	2010
MW-2012	0.09	0.16	0.05	0.02	0.05

µg/L = micrograms per liter

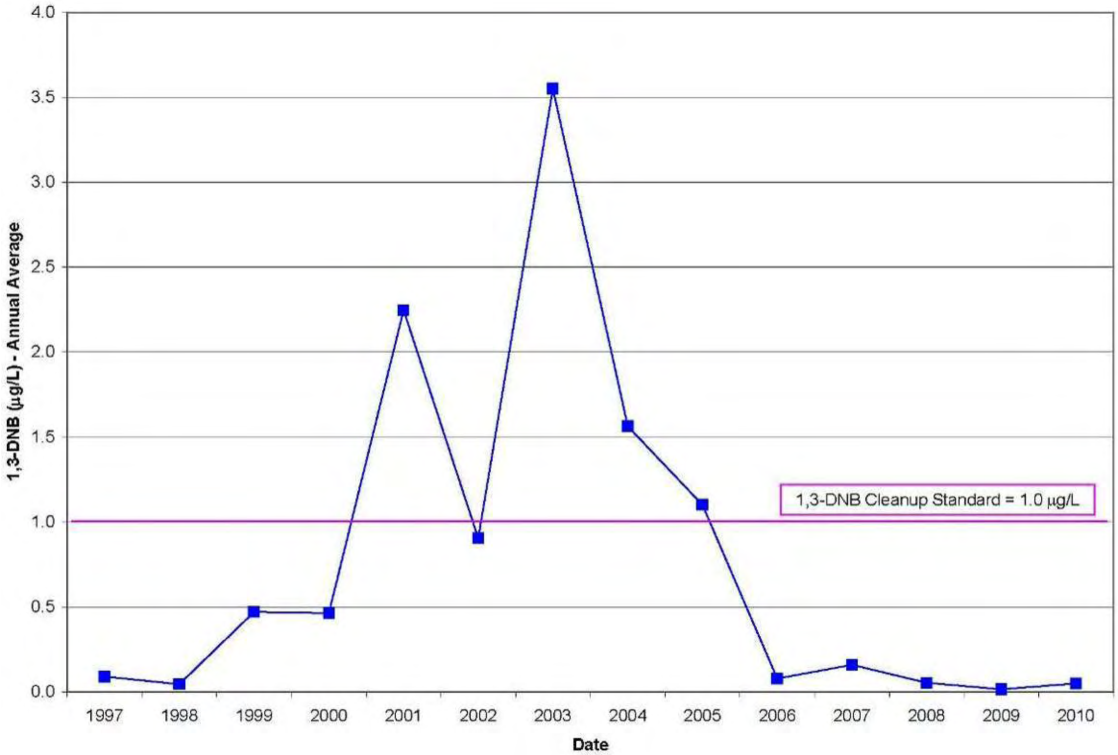

Figure 17. Annual Average 1,3-DNB Concentrations in MW-2012 (1997–2010)

Results of the trend analyses for 1,3-DNB (Table 31) indicated decreasing concentrations, as indicated by the negative slope in the Objective 2 well in the former Frog Pond area. Analysis of the data for MW-2012 indicates no trend either upward or downward; however, concentrations for the past 5 years can be regarded as stable due to the small slope and confidence intervals.

Table 31. Trending Analysis for 1,3-DNB in Objective 2 MNA Wells (2006–2010)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	9	None	–0.007	–0.037	0.013

µg/L/yr = micrograms per liter per year

The highest 2,4,6-TNT concentrations continue to be monitored in MW-2053, which is close to where TNT-production buildings once stood (Table 32). Concentrations of TNT have generally decreased in the Frog Pond area (Figure 18), with the largest decrease in MW 2012. Well MW-2046 monitors a discrete area of TNT impact in the north-central portion of the site. Substantial decreases in concentrations were reported in all of the Objective 2 wells in 2005. The annual average TNT concentrations in all of the Objective 2 wells were less than the cleanup standard of 2.8 µg/L in 2009 and 2010.

Table 32. 2,4,6-TNT Data from GWOU Objective 2 Wells (2006–2010)

Location	2,4,6-TNT Concentration (μg/L)				
	2006	2007	2008	2009	2010
MW-2012	12.7	21.0	3.4	0.56	1.4
MW-2046	3.0	5.2	3.3	0.75	0.50
MW-2053	0.06	7.2	8.5	1.4	2.1

μg/L = micrograms per liter

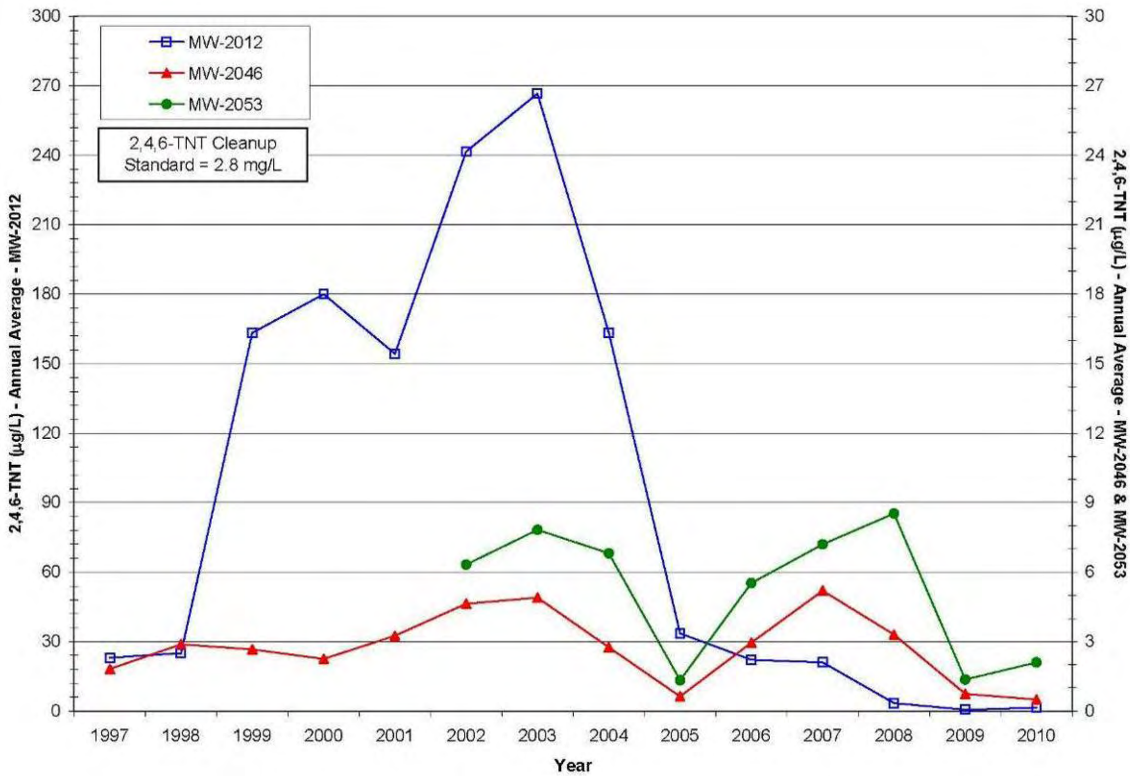

Figure 18. Annual Average 2,4,6-TNT Concentrations in Objective 2 Wells (1997–2010)

Trend analysis of 2,4,6-TNT data collected from 2006 through 2010 indicates decreasing concentrations in all of the Objective 2 wells, as indicated by negative slopes (Table 33). A statistically downward trend was calculated for MW-2046. Analysis of the data from the remainder of the locations indicated no trend, either upward or downward.

Table 33. Trending Analysis for 2,4,6-TNT in Objective 2 MNA Wells (2006–2010)

Location	No. of Samples	Trend	Slope (μg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	10	None	–2.7	–6.8	0.06
MW-2046	9	**Down**	–0.96	–1.7	–0.12
MW-2053	8	None	–0.65	–6.1	2.9

μg/L/yr = micrograms per liter per year

The nitroaromatic compounds 2,4-DNT and 2,6-DNT are the most persistent in groundwater at the site. Data from the last few years indicate that concentrations of DNT have varied in most of the Objective 2 wells (Table 34 and Table 35). The variability in 2,4-DNT and 2,6-DNT concentrations in the Objective 2 wells can be attributed to the introduction of surface water into the groundwater system. Concentrations of these compounds are typically higher during periods of low groundwater elevations and decrease as groundwater elevations rise. The introduction of surface water infiltration temporarily dilutes the concentrations in groundwater.

Table 34. 2,4-DNT Data from GWOU Objective 2 Wells in the Frog Pond Area (2006–2010)

Location	2,4-DNT Concentration (μg/L)				
	2006	2007	2008	2009	2010
MW-2012	157	200	0.52	0.23	6.5
MW-2014	0.15	0.57	0.11	0.38	0.09
MW-2050	42.5	33.0	45.5	30.0	27.5
MW-2052	0.07	0.06	0.93	0.08	0.06
MW-2053	0.3	No data	0.19	0.01	73.5
MW-2054	0.83	0.27	0.16	0.04	0.11

μg/L = micrograms per liter

Table 35. 2,6-DNT Data from GWOU Objective 2 Wells (2006–2010)

Location	2,6-DNT Concentration (μg/L)				
	2006	2007	2008	2009	2010
MW-2012	168	222	6.2	0.82	21.6
MW-2014	0.53	0.94	0.56	0.31	0.42
MW-2050	48.5	54.5	49.0	35.0	30.5
MW-2052	0.16	0.64	0.95	0.14	0.15
MW-2053	5.0	10.0	10.9	8.5	165
MW-2054	13.0	4.0	1.2	1.1	0.18

μg/L = micrograms per liter

The changes in 2,4-DNT and 2,6-DNT concentrations in the former Frog Pond area are generally similar in each well. The highest concentrations of 2,4-DNT and 2,6-DNT are reported in MW-2012, MW-2050, and MW-2053 (Figure 19, Figure 20, and Figure 21), which are downgradient of the TNT-production buildings and Army Lagoon 1. During previous years, the highest concentrations of these two compounds were reported in MW-2012; however, concentrations of DNT, as well as the other nitroaromatic compounds, have decreased substantially at this location. Increases were observed in MW-2012 and MW-2053 in 2010 as compared to previous years. Limited data are available to evaluate the cause for the increases measured in these two wells during 2010. The concentrations measured in MW-2012 are similar to those measured prior to 2007; however, the concentration in MW-2053 are new highs. Well MW-2053 is downgradient from the location of Production Line 1 and likely represents the downgradient migration of impacted groundwater from the former source area. Annual average concentrations of 2,4-DNT and 2,6-DNT in MW-2014, MW-2052, and MW-2054 were less than or equal to the cleanup standards of 0.11 μg/L and1.3 μg/L, respectively, in 2010 (Figure 22).

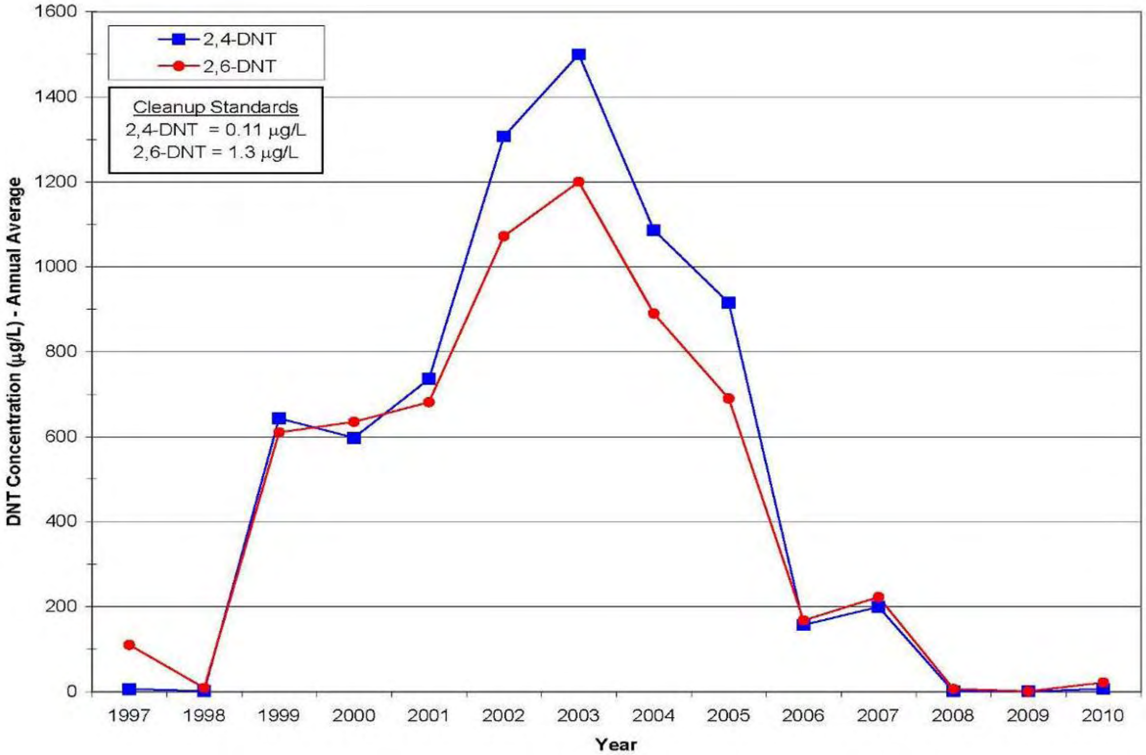

Figure 19. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2012 (1997–2010)

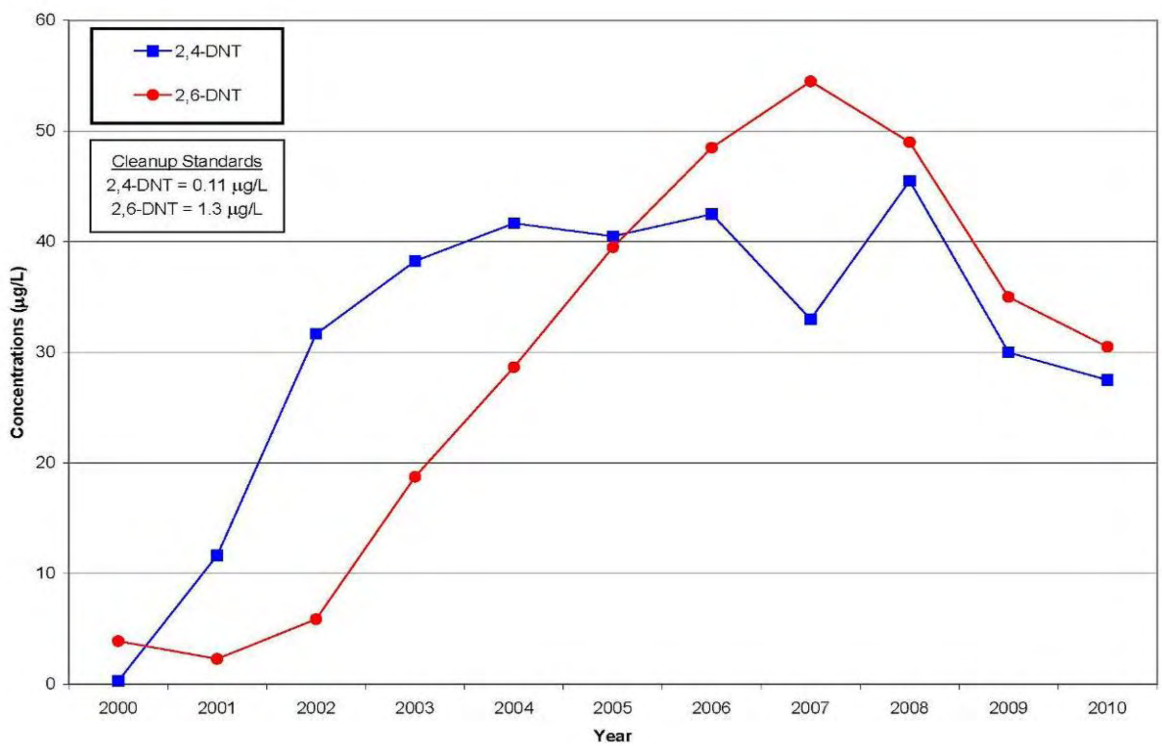

Figure 20. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2050 (2000–2010)

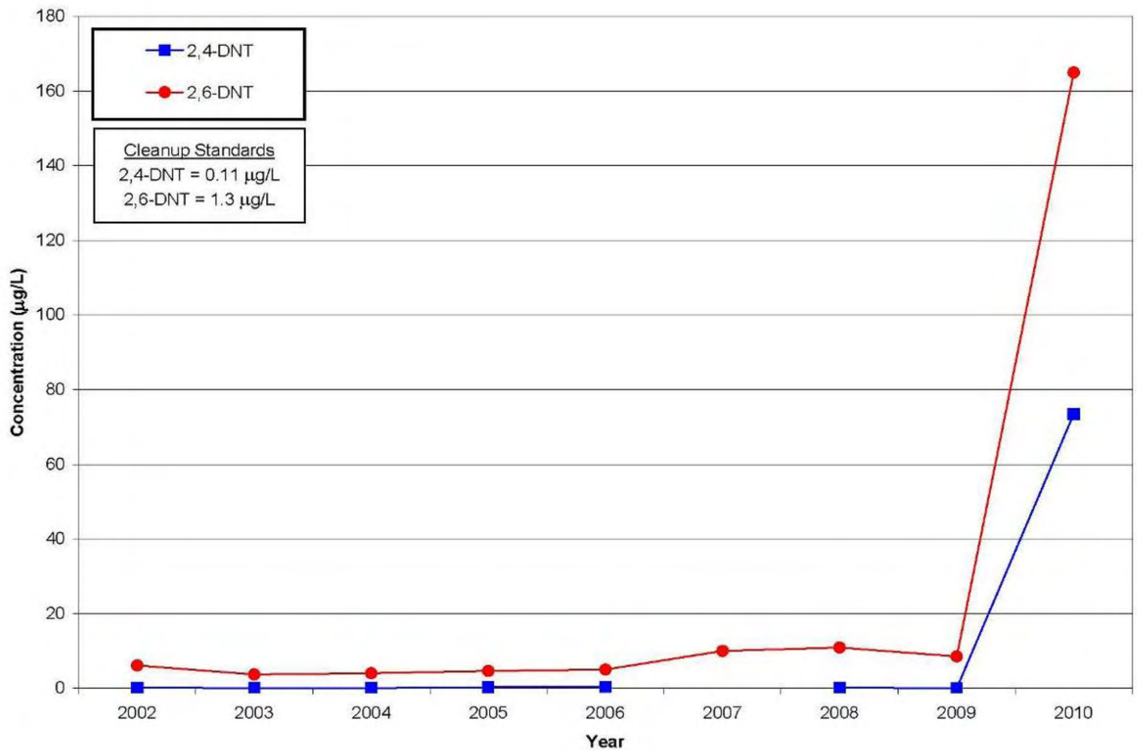

Figure 21. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2053 (2002–2010)

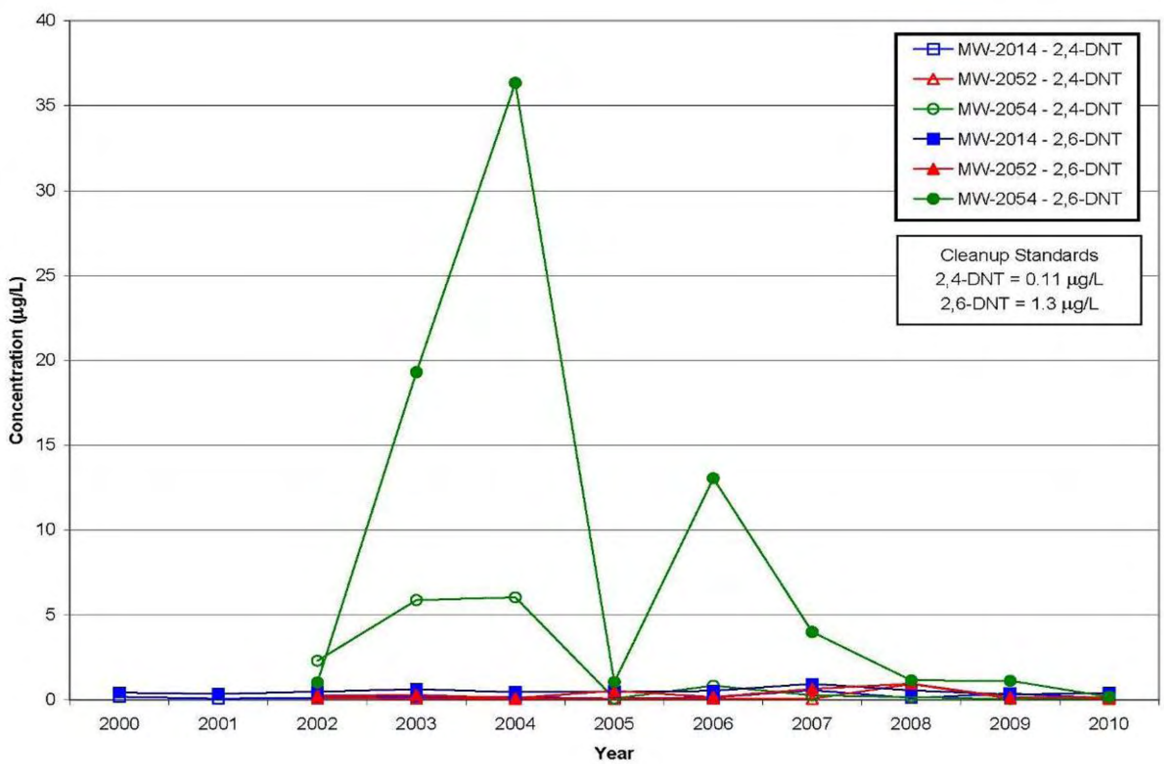

Figure 22. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2014, MW-2052, and MW-2054 (2000–2010)

Trend analysis of 2,4-DNT data indicates decreasing concentrations in MW-2012, MW-2050, and MW-2054, using the data from 2006 through 2010, as indicated by negative slopes (Table 36). Analysis of the data for 2,4-DNT in the Frog Pond area indicated no statistical trend, either upward or downward. A review of the trend data suggests that concentrations of 2,4-DNT are relatively stable in wells MW-2014, MW-2052, and MW-2054, where slopes and confidence intervals are small.

Table 36. Trending Analysis for 2,4-DNT in Objective 2 MNA Wells in the Frog Pond Area (2006–2010)

Location	Area	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
					Lower	Upper
MW-2012	Frog Pond	11	None	–1.8	–47.0	0.06
MW-2014	Frog Pond	10	None	0	–0.16	0.09
MW-2050	Frog Pond	10	None	–3.7	–8.4	1.5
MW-2052	Frog Pond	9	None	0	–0.03	0.01
MW-2053	Frog Pond	7	None	4.1	–0.10	65.1
MW-2054	Frog Pond	10	None	–0.02	–0.36	0.02

µg/L/yr = micrograms per liter per year

Trend analysis of 2,6-DNT data indicates decreasing concentrations in MW-2012, MW-2014, MW-2050, and MW-2054, using the data from 2006 through 2010, as indicated by negative slopes (Table 37). Statistical downward trends were calculated for wells MW-2050 and MW-2054. A review of the trend data suggests that concentrations of 2,6-DNT are relatively stable in wells MW-2014 and MW-2052, where slopes and confidence intervals are small. If the current decreases in 2,6-DNT concentrations continue in MW-2050, it is estimated that the cleanup standard of 1.3 µg/L could be reached by 2034, using an exponential curve model. Concentrations in well MW-2054 have been less than the cleanup standard since 2008. The estimated cleanup time frame for 2,6-DNT is 53 years.

Table 37. Trending Analysis for 2,6-DNT in Objective 2 MNA Wells (2006–2010)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	11	None	–15.1	–85.2	5.1
MW-2014	10	None	–0.05	–0.26	0.04
MW-2050	10	**Down**	–5.2	–9.8	–2.1
MW-2052	10	None	0	–0.08	0.05
MW-2053	10	None	3.9	–0.39	51.0
MW-2054	10	**Down**	–0.02	–4.3	0.05

µg/L/yr = micrograms per liter per year

Well MW-2012 is the only location where NB is monitored. NB has not been detected at this location since 2002, when a one-time detection of 69 µg/L was reported. The cleanup standard for NB is 17 µg/L.

Overall, nitroaromatic compound impact in the former Frog Pond area is confined to the weathered unit of the Burlington-Keokuk Limestone. The concentrations of 2,4-DNT and 2,6-DNT continue to vary; however, only a few locations exhibit increasing concentrations, based on data from the past 5 years. Concentrations of 1,3-DNB and 2,4,6-TNT are generally decreasing in this area, as indicated by trend analysis. The cleanup standard for 2,6-DNT in MW-2050 could be attained by 2034 if decreases continue at the current rate. The concentrations of 2,4,6-TNT in the north-central portion of the site are decreasing, and concentrations are below the cleanup standard.

Nitroaromatic Compounds—Former Raffinate Pits Area

The other area of nitroaromatic compound impact at the Chemical Plant site is in the former Raffinate Pits area where portions of TNT-production lines 3 and 4 were located. Groundwater in this area is impacted by 2,4-DNT in concentrations that exceed the cleanup standard of 0.11 µg/L. Nitroaromatic compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 2,4-DNT data from the former Raffinate Pits area for the period of 2006 through 2010 is presented in Table 38.

Table 38. 2,4-DNT Data from GWOU Objective 2 Wells in the Raffinate Pits Area (2006–2010)

Location	2,4-DNT Concentration (µg /L)				
	2006	2007	2008	2009	2010
MW-2038	0.25	0.61	0.06	0.22	0.17
MW-3030	0.93	1.4	1.3	0.85	0.55
MW-3034	0.20	No data	0.06	0.11	0.07
MW-3039	0.40	0.58	0.06	0.24	0.19

µg/L = micrograms per liter

The highest concentrations of 2,4-DNT continue to be monitored in MW-3030 (Figure 23). Concentrations in wells MW-2038, MW-3034, and MW-3039 decreased substantially in 2008 but rebounded to some extent during 2009. The annual average concentrations of 2,4-DNT in MW-3034 have been less than or equal to the cleanup standard of 0.11 µg/L since 2008.

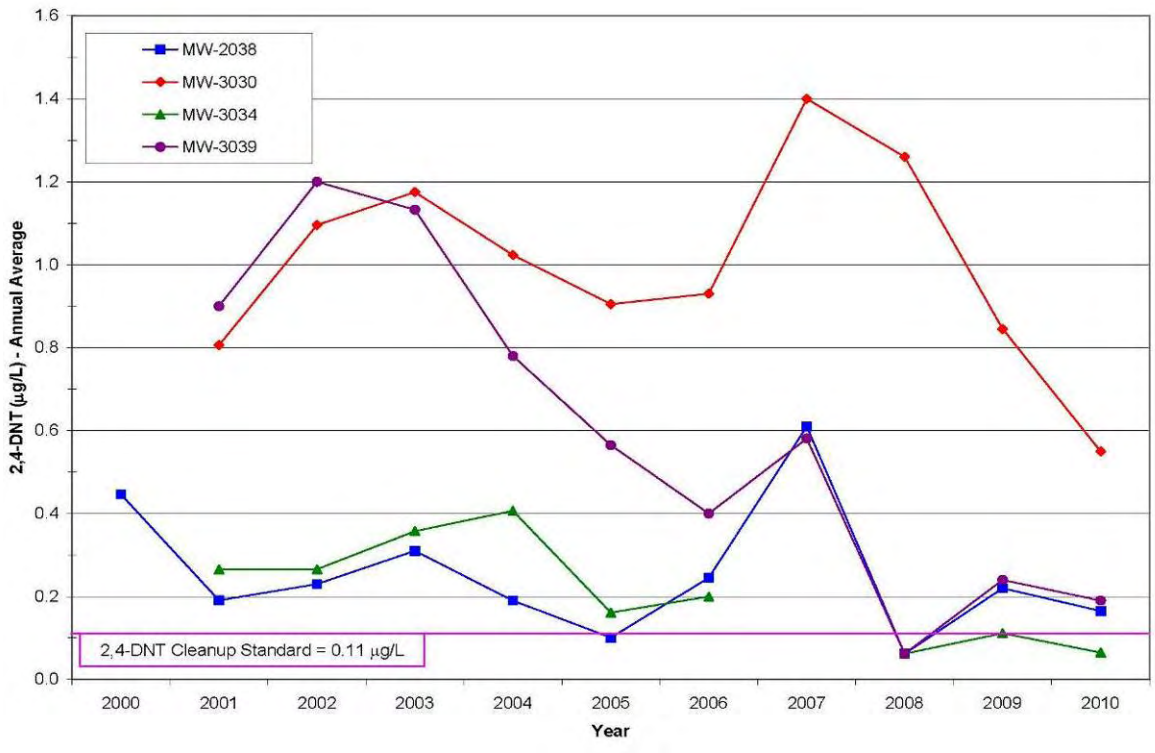

Figure 23. Annual Average 2,4-DNT Concentrations in Objective 2 Wells in the Former Raffinate Pits Area (1997–2010)

Trend analysis based on the data from 2006 through 2010 indicates that 2,4-DNT concentrations in the former Raffinate Pits area are decreasing, as indicated by negative slopes (Table 39). Statistical downward trends were calculated for wells MW-3030 and MW-3034. A review of the trend data suggests that concentrations of 2,4-DNT are relatively stable in wells MW-2038 and MW-3039, where slopes and confidence intervals are small. If the current decreases in 2,4-DNT concentrations continue in MW-3030, it is estimated that the cleanup standard of 0.11 µg/L could be reached by 2021, using an exponential curve model. The estimated cleanup time frame for 2,4-DNT in the Raffinate Pits area is 79 years.

Table 39. Trending Analysis for 2,4-DNT in Objective 2 MNA Wells in the Raffinate Pits Area (2006–2010)

Location	Area	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
					Lower	Upper
MW-2038	Raffinate Pits	10	None	–0.02	–0.10	0.04
MW-3030	Raffinate Pits	10	**Down**	–0.13	–0.38	–0.01
MW-3034	Raffinate Pits	8	**Down**	–0.03	–0.06	0
MW-3039	Raffinate Pits	10	None	–0.04	–0.17	0.06

µg/L/yr = micrograms per liter per year

Overall, nitroaromatic compound impact in the former Raffinate Pits area is confined to the weathered unit of the Burlington-Keokuk Limestone. The concentrations of 2,4-DNT, although variable, are decreasing. The cleanup standard for 2,4-DNT could be attained in MW-3030 by 2021 if decreases continue at the current rate.

Detection Monitoring Results for the GWOU

Detection monitoring consists of sampling to fulfill Objectives 3, 4, and 5 of the MNA strategy. Wells along the fringes and downgradient (both laterally and vertically) of the areas of impact are monitored to ensure that lateral and vertical migration remains within the current area of impact and that expected lateral downgradient migration (due to dispersion) within the paleochannels is minimal or nonexistent. Springs and a surface water location on Dardenne Creek are also monitored as part of this program, as these are the closest groundwater discharge points for the shallow aquifer in the vicinity of the Chemical Plant. These locations are monitored to ensure that concentrations remain protective of human health and the environment and that water quality continues to improve in the springs.

Contaminant concentrations are monitored using 21 wells, 4 springs, and 1 surface water location situated along the fringes or downgradient of the areas of highest impact of the different contaminant plumes at the site. The monitoring well locations were sampled semiannually from 2006 through 2008 and then annually in 2009 and 2010, and the springs were sampled quarterly during the review period, unless noted. The data are discussed in the following sections.

Uranium

Data from the detection monitoring network indicate that uranium is migrating along the preferential flow pathways (paleochannels), as expected. Average uranium levels higher than the MCL of 20 pCi/L were reported in MW-4036 in 2006 and 2007. The uranium levels in the remainder of the wells screened in either the weathered or unweathered unit have been stable over the past 5 years. A summary of the average uranium values for 2006 through 2010 is presented in Table 40.

Uranium levels in MW-4036 have varied (Figure 24), ranging from 1.3 to 85.0 pCi/L. This well has exceeded the MCL of 20 pCi/L eight times since it was installed in 2001. Since the MNA monitoring program began in 2004, this well has exceeded the trigger level of 50 pCi/L twice. Review of the data indicates that the uranium levels vary seasonally. Generally, uranium levels are higher in spring and lower in summer.

Table 40. Uranium Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Unit/Location	Uranium (pCi/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-3031	Fringe	2.5	2.4	2.8	3.2	2.4
MW-3037	Fringe	1.5	2.4	2.6	3.2	2.0
MW-4026	Southeast Drainage (alluvium)	ND	ND	0.5	0.8	0.05
MW-4036	Downgradient	**23.2**	**28.0**	15.8	14.1	9.8
MW-4041	Downgradient	1.6	1.5	2.0	1.6	1.6
MWS-1	Downgradient	0.8	0.7	0.8	0.8	0.7
MWS-4	Downgradient	0.4	0.4	0.4	0.3	0.4
Unweathered Unit						
MW-3006	Fringe	3.4	0.68	0.4	0.6	0.4
MW-4042	Downgradient			1.3	0.6	0.4
MWD-2	Downgradient	1.2	0.9	0.2	0.1	0.2
Springs and Surface Water						
SP-5303	Southeast Drainage	**64.4**	**63.8**	**60.7**	**65.0**	**56.8**
SP-5304	Southeast Drainage	**61.4**	**59.8**	**59.7**	**68.8**	**72.1**
SP-6301	Burgermeister Spring Branch	**55.9**	**47.9**	**50.7**	**30.4**	**38.1**
SP-6303	Burgermeister Spring Branch	0.8	Dry	1.5	1.3	0.8
SW-2007	Dardenne Creek	0.8	0.7	0.7	0.5	0.6

Values in **bold** exceed the MCL of 20 pCi/L.
ND = not detected
pCi/L = picocuries per liter

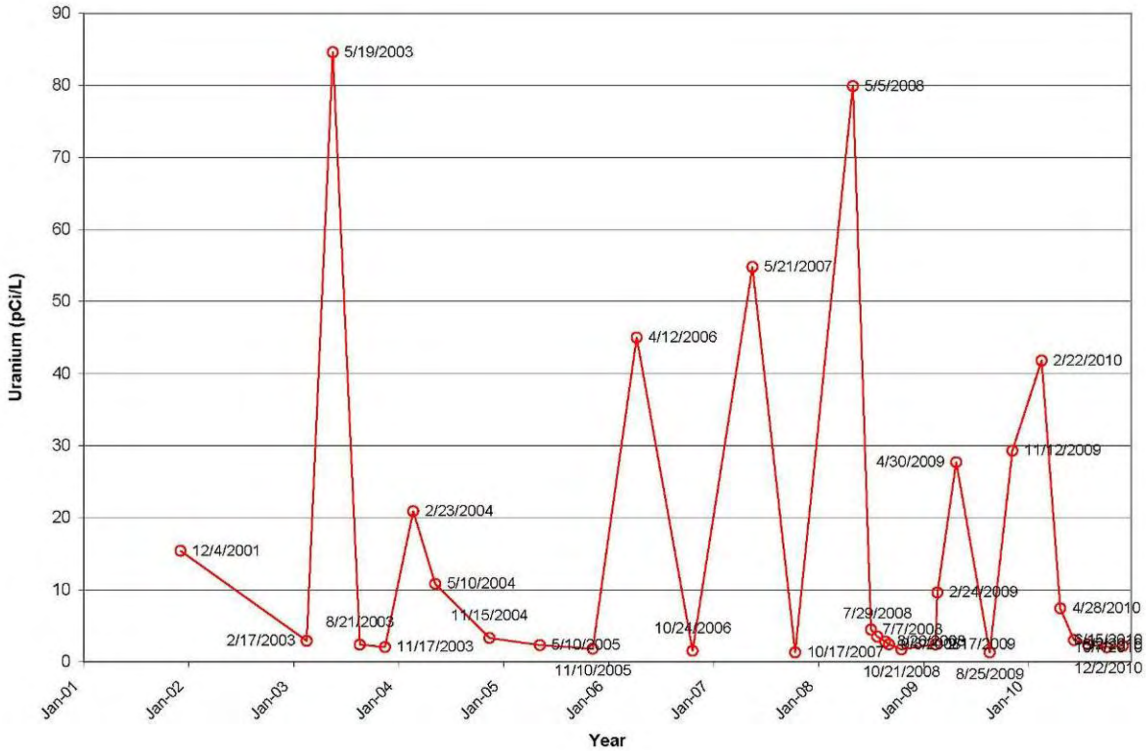

Figure 24. Uranium Levels in MW-4036 (2001–2010)

In response to the periodic high uranium levels in MW-4036 and the increased uranium levels in MW-3024 and MW-3040, a special study was initiated in 2008. The following actions were undertaken to evaluate the possible changes in conditions and to better understand the mechanisms causing the increases in uranium levels:

- Quarterly sampling of MW-4036 and other nearby wells for uranium.
- Sampling of SP-6201 on the neighboring Army property and Burgermeister Spring.
- Evaluation of groundwater levels and precipitation events.
- Installation of a new well (MW-4043) screened in the unweathered unit adjacent to MW-4036.

Comparison of uranium levels and groundwater elevations in MW-4036 indicates that changes in both are correlated. (Figure 25). Uranium levels increase or decrease as groundwater elevations increase or decrease. However, groundwater elevations in MW-4036 do not respond to precipitation events.

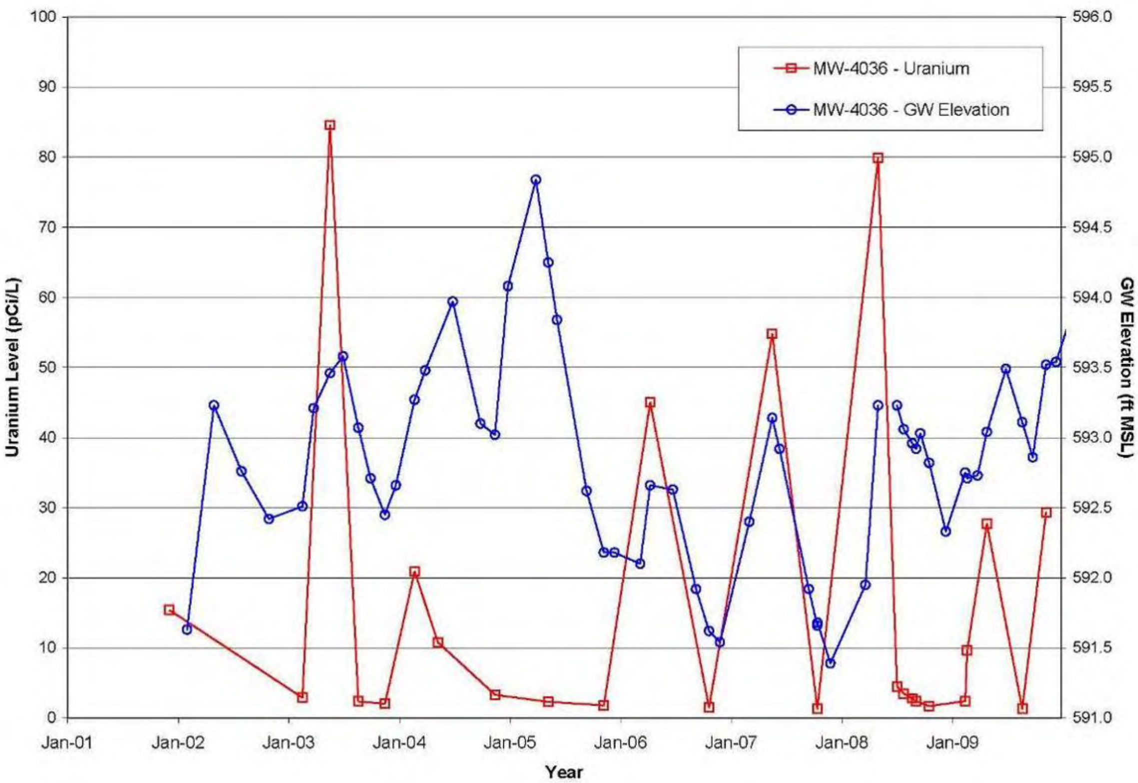

Figure 25. Groundwater Elevations and Uranium Levels in MW-4036

Data from the new well MW-4043 provide better delineation of the extent of uranium impact in the unweathered unit west of the former Raffinate Pits area. The elevated uranium level in this well supports the interpretation that groundwater with higher uranium levels in the unweathered unit periodically contributes uranium mass to the weathered unit near MW-4036. However, the mechanism that causes the periodic contribution of uranium into the weathered unit has not been identified.

In general, the distribution of uranium has expanded along the western side of the Raffinate Pits area, as indicated by the variable uranium values reported in MW-4036 and the elevated uranium levels measured in MW-4043. The presence of uranium in a downgradient spring SP-6201, at an average value of 19.4 pCi/L, also supports the conclusion of downgradient migration of uranium. Downgradient migration is expected, as the attenuation mechanisms for uranium are dilution and dispersion, which lead to some downgradient migration. Triggers for “Objective 3–near” wells were set to take into account the migration of contaminants in the paleochannels.

Uranium impact is contained within the paleochannel located within the upper portion of the shallow aquifer (weathered and unweathered units of the Burlington-Keokuk Limestone). A cross section was constructed along the preferential flow pathway in the former Raffinate Pits area; it included updated information from well MW-4043 (Figure 26). This graphic illustrates the geology in the former Raffinate Pits area and areas within the shallow aquifer where uranium levels are greater than 20 pCi/L.

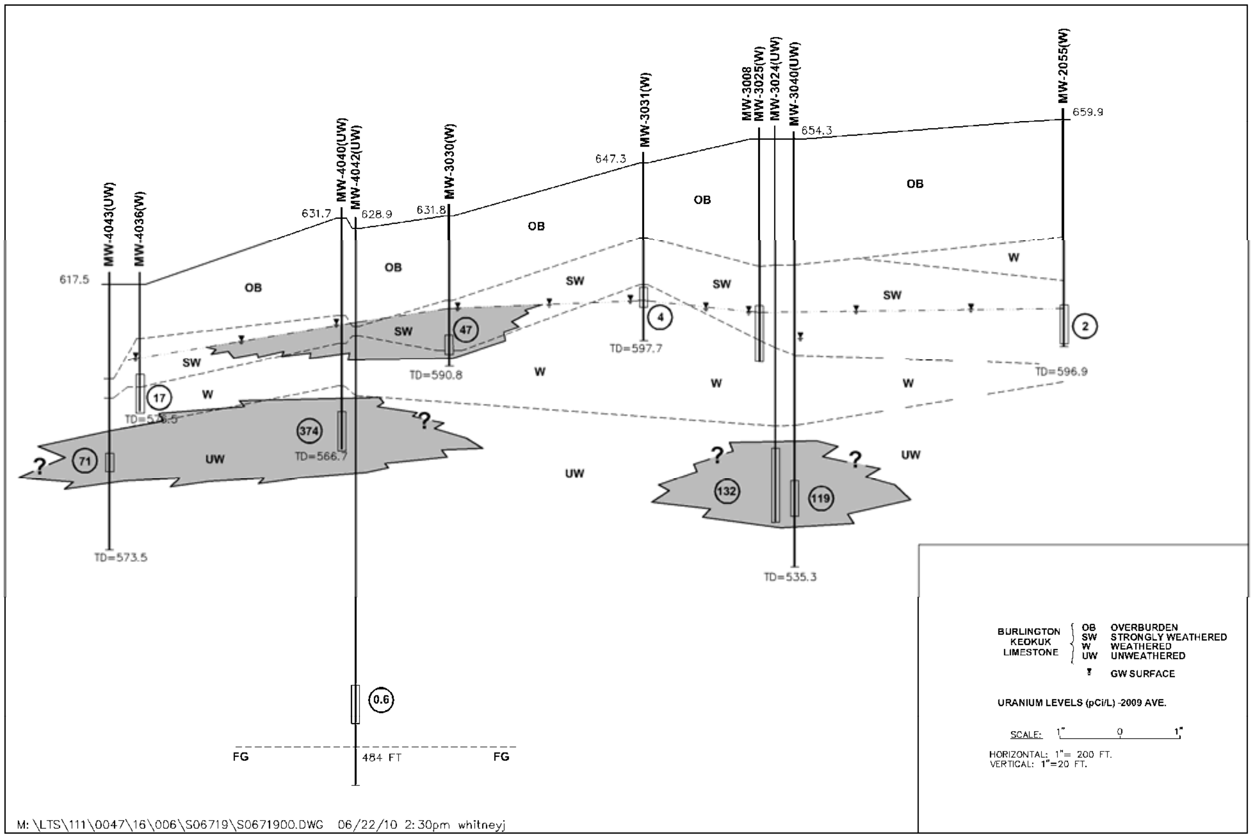

Figure 26. Cross Section of Uranium Impact Area

Uranium levels in Burgermeister Spring have varied but have remained within historical ranges and well below the trigger level of 150 pCi/L (Figure 27). Uranium levels increased in 2005 and have shown a general decline since then. Periodic increases in Burgermeister Spring may be related to the infrequent increases that occur in groundwater in the Raffinate Pits area. Uranium levels in SP-6303 remain low and are consistent with historical data. The uranium levels in Burgermeister Spring and SP-6303 are not correlated and indicate that the source contribution to SP-6303 is less than the contribution to Burgermeister Spring. Uranium levels in Dardenne Creek have been low since monitoring resumed at location SW-2007 in 2001.

Periodic uranium increases in Burgermeister Spring may be related to the infrequent increases that occur in MW-4036 (Figure 28). It appears that when uranium levels increase in MW-4036, a similar increase occurs during the same sampling period or slightly later in Burgermeister Spring. Concurrent increases are possible because groundwater travel times from the site to Burgermeister Spring are on the order of 2 to 9 days, as determined from dye tracing (DOE 1997a).

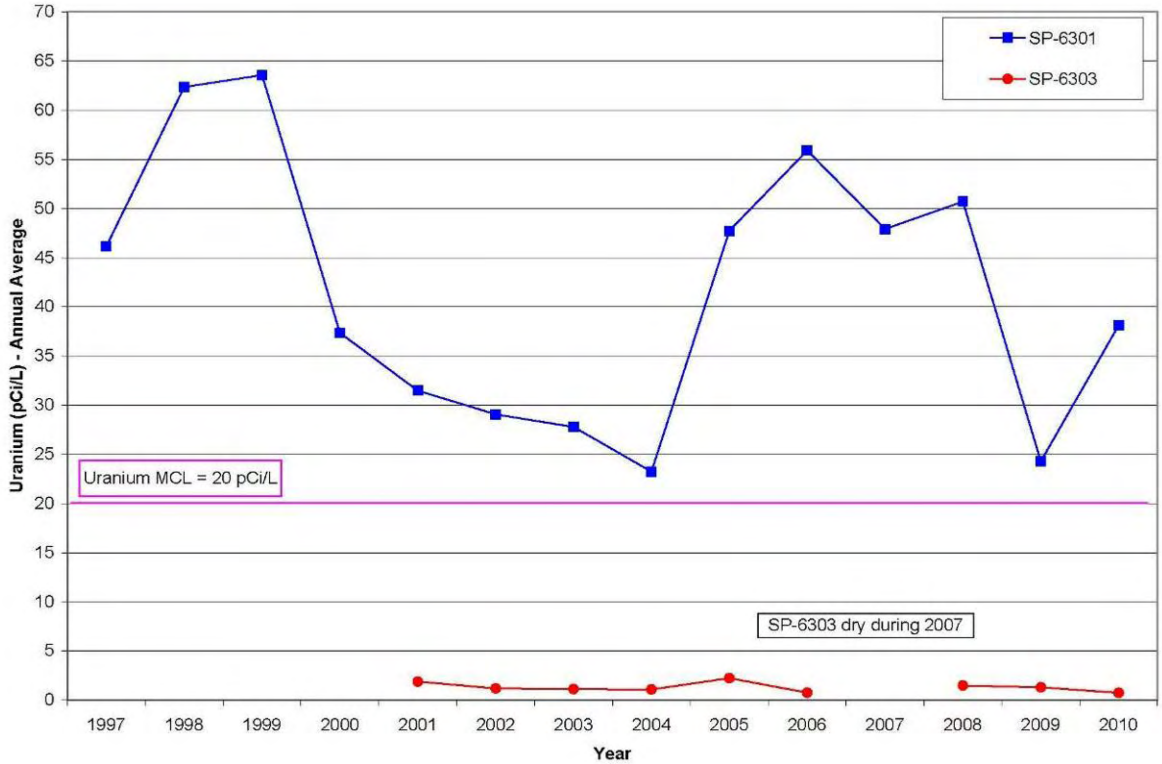

Figure 27. Annual Average Uranium Levels in Burgermeister Spring and SP-6303 (1997–2010)

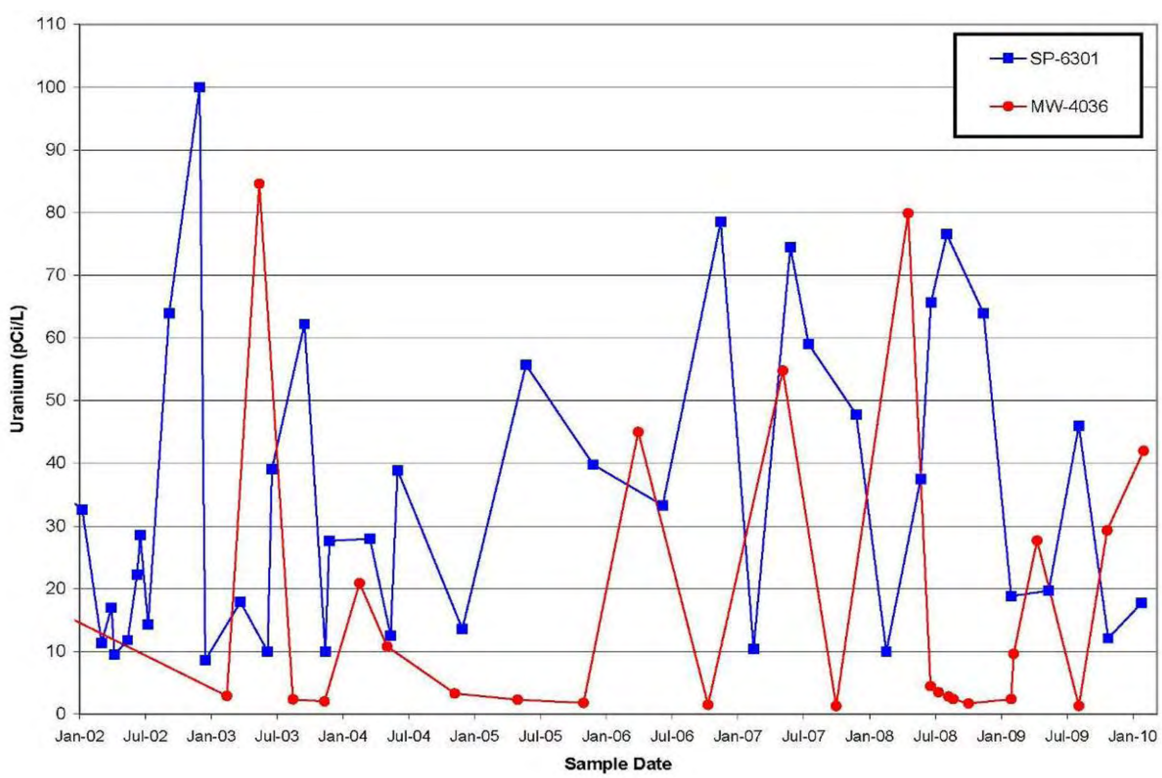

Figure 28. Uranium Levels in SP-6301 and MW-4036

Results of the trend analysis for Burgermeister Spring (SP-6301) and SP-6303 indicate that uranium levels have begun to decrease, as indicated by negative slopes (Table 41). Analysis of the data collected from 2006 through 2010 indicated no statistical trends, either upward or downward, for these two springs. If the current decreases in uranium levels continue in Burgermeister Spring, it is estimated that the MCL of 20 pCi/L could be reached by 2017, using an exponential curve model.

Table 41. Trending Analysis for Uranium in SP-6301 and SP-6303 (2006−2010)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
SP-6301	25	None	–2.8	–8.8	4.2
SP-6303	14	None	–0.10	–0.41	0.11

pCi/L/yr = picocuries per liter per year

Uranium impact in the Southeast Drainage is the result of historical discharges to this drainage during plant operation that resulted in contaminated soil and sediment within this drainage. Uranium impact in the two springs is sourced by residually contaminated sediments within the bedrock fracture system. The uranium levels in the two Southeast Drainage springs monitored under this program have been less variable in the past few years (Figure 29), and uranium behaves similarly in both springs. Uranium levels in both springs exceed the MCL but are less than the trigger level of 150 pCi/L. Uranium levels in MW-4026, a monitoring well downgradient of the two springs, were within background ranges.

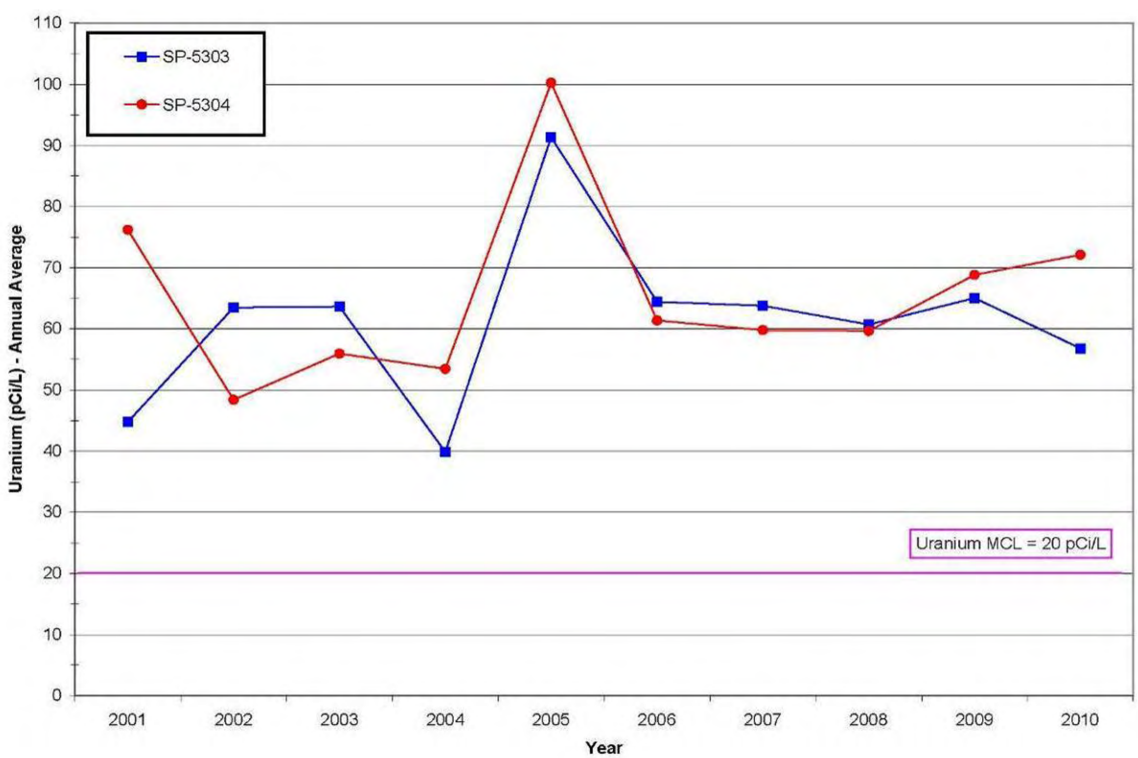

Figure 29. Annual Average Uranium Levels in Southeast Drainage Springs (2001–2010)

Results of the trend analysis for SP-5303 and SP-5304 indicate that uranium levels have begun to decrease in SP-5303, as indicated by negative slopes (Table 42). Uranium levels in SP-5304 are increasing slightly, as indicated by the small positive slope. Analysis of the data collected from 2006 through 2010 indicated no statistical trends for these two springs.

Table 42. Trending Analysis for Uranium in SP-5303 and SP-5304 (2006−2010)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
SP-5303	17	None	–3.4	–9.3	1.4
SP-5304	17	None	1.6	–4.0	6.8

pCi/L/yr = picocuries per liter per year

While uranium levels in the Raffinate Pits area have changed since the implementation of the MNA remedy for uranium, overall, the remedy remains protective. Groundwater flow directions are unchanged in the Raffinate Pits area. Impacted groundwater is contained within the paleochannel in this area and is migrating along the expected pathways. Uranium levels are decreasing in the weathered unit due to dilution and dispersion. Uranium levels are not trending downward in the unweathered unit; the reduction in infiltration has limited the amount of flushing in the aquifer, and increased uranium levels are the result of desorption of residual uranium from contaminated materials in this portion of the shallow aquifer. Discharge from the unweathered unit into the weathered unit is monitored at MW-4036. Uranium levels in "Objective 3–far" wells remain low, and levels in Burgermeister Spring, while variable, are declining.

Nitrate (as N)

The nitrate concentrations in the detection monitoring wells indicate that the movement of the area of impact is behaving as expected. Average concentrations of nitrate in well MWS-1 has exceeded the MCL for nitrate (as N) since 2007, but all data were less than the trigger level of 30 mg/L set for this location. The uranium levels in the remainder of the wells screened in either the weathered or unweathered unit have been stable over the past 5 years. Nitrate data reported in the springs were consistent with historical data. A summary of the data is presented in Table 43.

The nitrate concentrations in Burgermeister Spring ranged from 0.6 to 3.0 mg/L—less than the MCL of 10 mg/L. The annual average nitrate concentrations in Burgermeister Spring have been less than the MCL since 2002 (Figure 30). Nitrate concentrations in SP-6303 have been less than the MCL since monitoring resumed in 2001.

Table 43. Nitrate (as N) Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Unit/Location	Nitrate (as N) (mg/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-4014	Fringe	4.4	2.8	1.2	3.1	7.2
MW-4041	Downgradient	0.2	0.3	0.3	0.2	0.2
MWS-1	Downgradient	9.4	14.2	11.7	15.1	17.0
MWS-4	Downgradient	2.2	2.9	2.4	1.2	1.5
Unweathered Unit						
MW-2021	Vertical Extent	ND	ND	ND	ND	ND
MW-2022	Vertical Extent	ND	ND	ND	ND	ND
MW-3006	Fringe	ND	ND	0.02	ND	ND
MW-4007	Downgradient	ND	ND	0.08	0.07	0.08
MW-4042	Downgradient			0.01	ND	
MWD-2	Downgradient	ND	ND	0.01	ND	ND
Springs and Surface Water						
SP-6301	Burgermeister Spring Branch	2.7	4.2	3.3	1.3	2.6
SP-6303	Burgermeister Spring Branch	0.3	Dry	4.1	1.6	0.6

mg/L = milligrams per liter
ND = not detected above the reporting limit

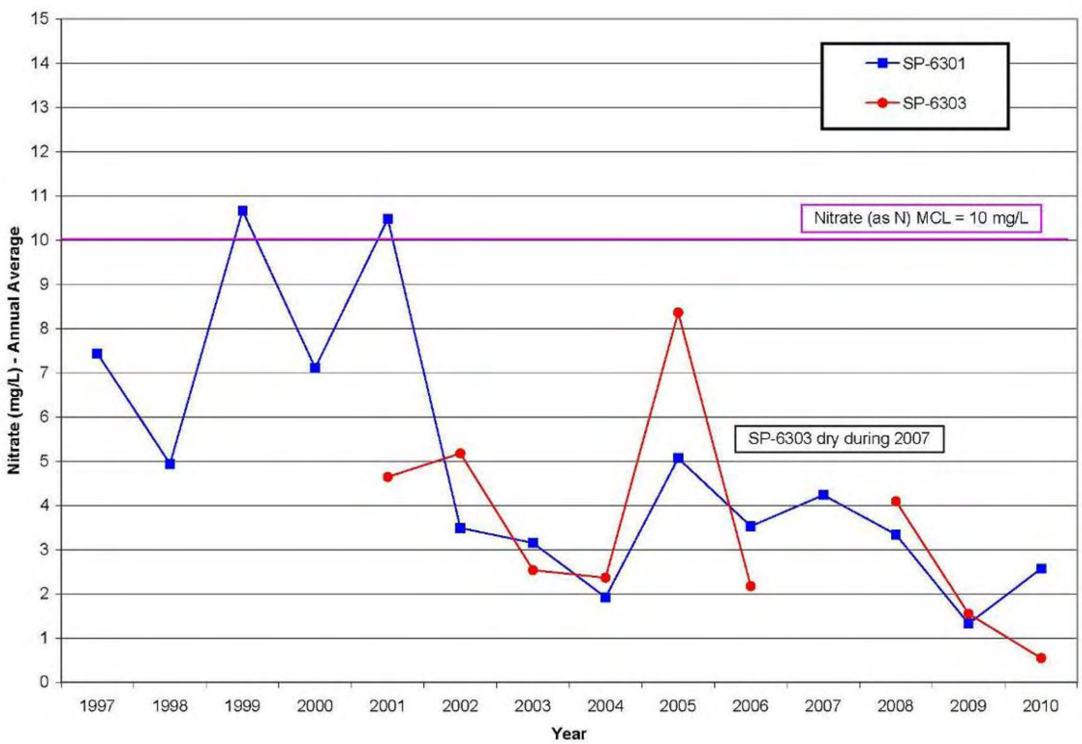

Figure 30. Annual Average Nitrate Concentrations in Burgermeister Spring and SP-6303 (1997–2010)

Results of the trend analysis for Burgermeister Spring (SP-6301) and SP-6303 indicate that nitrate concentrations are decreasing, as indicated by negative slopes (Table 44). Analysis of the data collected from 2006 through 2010 indicated no statistical trends for these two springs.

Table 44. Trending Analysis for Nitrate (as N) in SP-6301 and SP-6303 (2006−2010)

Location	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
				Lower	Upper
SP-6301	22	None	–0.24	–0.90	0.48
SP-6303	12	None	–0.65	–2.0	0.31

mg/L/yr = milligrams per liter per year

Trichloroethylene

Detections of TCE were not reported in the detection monitoring wells; however, estimated values less than 1 μg/L were reported in several locations. Estimated values are concentrations reported less than the quantification limit and may indicate the presence of TCE. The data from the past 5 years indicate that the area of TCE impact has not expanded, either laterally or vertically. Low detectable concentrations of TCE were reported at Burgermeister Spring and SP-6303 during this period. No detectable concentrations of the breakdown products *cis*-1,2-DCE, *trans*-1,2-DCE, or vinyl chloride were reported in any of the detection monitoring locations. A summary of the TCE data is presented in Table 45.

Table 45. TCE Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Unit/Location	TCE (μg/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-3031	Fringe	ND	ND	0.4 (J)	0.6 (J)	0.2 (J)
MW-3037	Fringe	ND	0.3 (J)	0.4 (J)	0.5 (J)	0.2 (J)
MW-4036	Downgradient	ND	0.2 (J)	ND	0.8 (J)	ND
MW-4041	Downgradient	ND	ND	0.5 (J)	0.2 (J)	0.4 (J)
MWS-1	Downgradient	ND	0.2 (J)	0.2 (J)	ND	ND
MWS-4	Downgradient	ND	0.2 (J)	0.3 (J)	0.1 (J)	ND
Unweathered Unit						
MW-3006	Fringe	ND	ND	ND	ND	ND
MW-4007	Downgradient	ND	ND	0.3 (J)	0.2 (J)	ND
MW-4040	Vertical Extent	ND	0.3 (J)	ND	0.3 (J)	ND
MW-4042	Vertical Extent		0.3 (J)	0.4 (J)	0.2 (J)	ND
Springs and Surface Water						
SP-6301	Burgermeister Spring Branch	ND	ND	ND	0.1 (J)	ND
SP-6303	Burgermeister Spring Branch	0.6 (J)	Dry	0.2 (J)	0.8 (J)	0.4 (J)

J = estimated value less than the reporting limit
μg/L = micrograms per liter
ND = not detected above the reporting limit

Nitroaromatic Compounds

Detection monitoring results for 1,3-DNB show that no downgradient migration of impacted groundwater has occurred from the area of known impact within the weathered unit (Table 46). Fringe location MW-2051 has low concentrations of 1,3-DNB, and these concentrations are consistent with historical data. The data from the unweathered unit wells indicate that the impacted groundwater in the overlying weathered unit has not moved downward. The concentrations reported in SP-6303 are negligible and consistent with historical data. None of the concentrations reported exceeded the triggers levels set for the Objective 3 or 4 wells or the Objective 5 springs.

The concentrations of 2,4,6-TNT reported in the detection monitoring wells in the weathered unit indicate that no downgradient migration of impacted water has occurred beyond the area of known impact (Table 47). Two fringe locations have low concentrations of 2,4,6-TNT; these concentrations are consistent with historical data. No detectable concentrations of 2,4,6-TNT were reported in the wells in the unweathered unit. However, an estimated detection was reported in MW-2022 in 2009. The concentrations reported in Burgermeister Spring and SP-6303 are negligible and consistent with historical data. None of the concentrations reported exceeded the trigger levels set for the Objective 3 or 4 wells or the Objective 5 springs.

Table 46. 1,3-DNB Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Location	1,3-DNB (μg/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-2032	Fringe	ND	ND	ND	ND	ND
MW-2051	Fringe	0.08	ND	ND	0.034 (J)	0.04 (J)
MW-4014	Downgradient	ND	ND	ND	ND	ND
MW-4039	Fringe	ND	ND	ND	ND	ND
MW-4041	Downgradient - Far	ND	ND	ND	ND	ND
Unweathered Unit						
MW-2022	Vertical Extent	ND	ND	ND	ND	ND
MW-2023	Vertical Extent	ND	ND	ND	ND	ND
MW-2056	Vertical Extent	ND	ND	ND	ND	ND
Springs						
SP-6301	Burgermeister Spring	ND	ND	ND	ND	ND
SP-6303	Burgermeister Spring Branch	ND	Dry	0.07	0.026 (J)	ND

J = estimated value less than reporting limit
ND = nondetect above method detection limit

Table 47. 2,4,6-TNT Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Location	2,4,6-TNT (µg/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-2032	Fringe	ND	ND	ND	0.005 (J)	ND
MW-2051	Fringe	0.11	0.10	0.12	0.087 (J)	0.07 (J)
MW-4014	Downgradient	ND	ND	ND	ND	ND
MW-4039	Fringe	ND	ND	ND	ND	ND
MW-4041	Downgradient - Far	ND	ND	ND	ND	ND
Unweathered Unit						
MW-2022	Vertical Extent	ND	ND	ND	0.007 (J)	ND
MW-2023	Vertical Extent	ND	ND	ND	ND	ND
MW-2056	Vertical Extent	ND	ND	ND	ND	ND
Springs						
SP-6301	Burgermeister Spring	ND	ND	ND	0.010 (J)	ND
SP-6303	Burgermeister Spring Branch	ND	Dry	0.21	0.034	ND

FP = Frog Pond area; J = estimated value less than reporting limit
NDL = nondetect not detected above the method detection limit indicated in parentheses; RP = Raffinate Pits area

Detection monitoring results for the area of 2,4-DNT impact in the Frog Pond area indicate that some migration from this area continues (Table 48); however, none of the concentrations reported exceeded the trigger levels set for the Objective 3 wells. The data from the unweathered unit wells indicate that the impacted groundwater in the overlying weathered unit has not moved downward. The concentrations reported in Burgermeister Spring and SP-6303 are negligible and consistent with historical data. None of the concentrations reported exceeded the trigger levels set for the Objective 5 springs.

Detection monitoring results for the area of 2,4-DNT impact in the Raffinate Pits area show that minimal migration from this area has occurred (Table 48). Detections of 2,4-DNT in wells MW-4036 and MWS-1 may be sourced by impact on the Chemical Plant site, impact on the Army property, or both. None of the concentrations reported exceeded the trigger levels set for the Objective 3 wells. The data from the unweathered unit wells verify that the impacted groundwater in the overlying weathered unit has not migrated downward.

Continued downgradient migration of 2,6-DNT impacted groundwater from the Frog Pond area is monitored by the Objective 3 wells (Table 49). Concentrations in these downgradient wells have decreased slightly during the review period. Concentrations are consistent with historical data. No detectable concentrations of 2,6-DNT were reported in the wells in the unweathered unit. However, an estimated detection was reported in MW-2023 in 2009. The concentrations reported in Burgermeister Spring and SP-6303 are low and consistent with historical data. None of the concentrations reported exceeded the trigger levels set for the Objective 3 or 4 wells or the Objective 5 springs.

The nitroaromatic compound NB has not been detected in any of the Objective 3, 4, or 5 monitoring locations since the MNA program began in 2004.

Table 48. 2,4-DNT Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Location	2,4-DNT (μg/L)				
		2006	2007	2008	2009	2010
Weathered Unit						
MW-2032	Fringe – FP	ND	ND	ND	0.028 (J)	ND
MW-2051	Fringe – FP	0.05	0.07	ND	0.083 (J)	0.05 (J)
MW-3037	Fringe – RP	ND	ND	ND	ND	ND
MW-4013	Downgradient – FP	ND	ND	ND	0.32	ND
MW-4014	Downgradient – FP	ND	ND	ND	0.063 (J)	ND
MW-4015	Downgradient – FP	0.06	0.11	0.09	0.35	ND
MW-4036	Downgradient – RP	ND	0.09	ND	0.12	0.06 (J)
MW-4039	Fringe – FP	ND	ND	ND	ND	ND
MW-4041	Downgradient - Far	ND	ND	ND	ND	ND
MWS-1	Downgradient - RP	ND	ND	ND	0.010 (J)	ND
Unweathered Unit						
MW-2023	Vertical Extent – FP	ND	ND	ND	ND	ND
MW-2056	Vertical Extent – FP	ND	ND	ND	ND	ND
MW-3006	Vertical Extent – RP	ND	ND	ND	ND	ND
MW-4040	Vertical Extent – RP	ND	ND	ND	ND	ND
Springs						
SP-6301	Burgermeister Spring	ND	ND	ND	0.024	ND
SP-6303	Burgermeister Spring Branch	0.13	Dry	0.07	0.092	ND

Abbreviations:
FP = Frog Pond area
J = estimated value less than reporting limit
μg/L = micrograms per liter
NDL = nondetect not detected above the method detection limit indicated in parentheses
RP = Raffinate Pits area

Chemical Plant Hydrogeologic Data Analysis

Hydrogeologic conditions at the site are being monitored using all of the wells included in the MNA network (Objectives 1, 2, 3, and 4 wells) and additional wells (Objective 6 wells) that were selected to provide adequate coverage to identify changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater levels of the monitoring network are measured to establish that groundwater flow is not changing significantly and causing shifts in contaminant migration.

The average groundwater elevations measured in 2010 were used to construct a potentiometric surface map of the shallow aquifer using the available wells at the Chemical Plant (Figure 31). The configuration of the potentiometric surface has remained relatively unchanged. However, groundwater elevations have decreased in several portions of the site. Even though the groundwater elevations have changed, the groundwater flow direction continues to be generally to the north. A groundwater divide is present along the southern boundary of the Chemical Plant site. Troughs in the groundwater surface occur where paleochannels are located.

Table 49. 2,6-DNT Data for GWOU Objective 3, 4, and 5 Locations (2006–2010)

Sample ID	Location	2,6-DNT (μg/L)				
		2006	**2007**	**2008**	**2009**	**2010**
Weathered Unit						
MW-2032	Fringe – FP	ND	ND	ND	0.013 (J)	0.02 (J)
MW-2051	Fringe – FP	0.07	ND	ND	0.042 (J)	0.03 (J)
MW-4013	Downgradient – FP	0.61	0.53	0.64	0.40	0.53
MW-4014	Downgradient – FP	ND	ND	ND	0.074	0.10
MW-4015	Downgradient – FP	0.80	1.02	0.64	0.70	0.79
MW-4039	Fringe – FP	ND	ND	ND	ND	ND
MW-4041	Downgradient – Far	ND	ND	ND	ND	ND
Unweathered Unit						
MW-2023	Vertical Extent – FP	ND	ND	ND	0.004 (J)	ND
MW-2056	Vertical Extent – FP	ND	ND	ND	ND	ND
Springs						
SP-6301	Burgermeister Spring	ND	0.10	ND	0.043	0.07 (J)
SP-6303	Burgermeister Spring Branch	0.15	Dry	0.35	0.285	0.03 (J)

Abbreviations:
FP = Frog Pond area
J = estimated value less than reporting limit
μg/L = micrograms per liter
NDL = not detected above the method detection limit
RP = Raffinate Pits area; FP = Frog Pond area; J = estimated value less than reporting limit;
ND = nondetect above method detection limit indicated in parentheses; RP = Raffinate Pits area

Groundwater elevations have shown a general decrease in the weathered unit of the Burlington-Keokuk Limestone (Figure 32). Groundwater elevations in the weathered unit in the Frog Pond area show influence of surface water infiltration. Decreases in groundwater elevations in the unweathered unit have occurred in the Raffinate Pits area (Figure 33). The decreases in both units are likely due to the removal of large surface water impoundments, such as the Raffinate Pits, during site remediation.

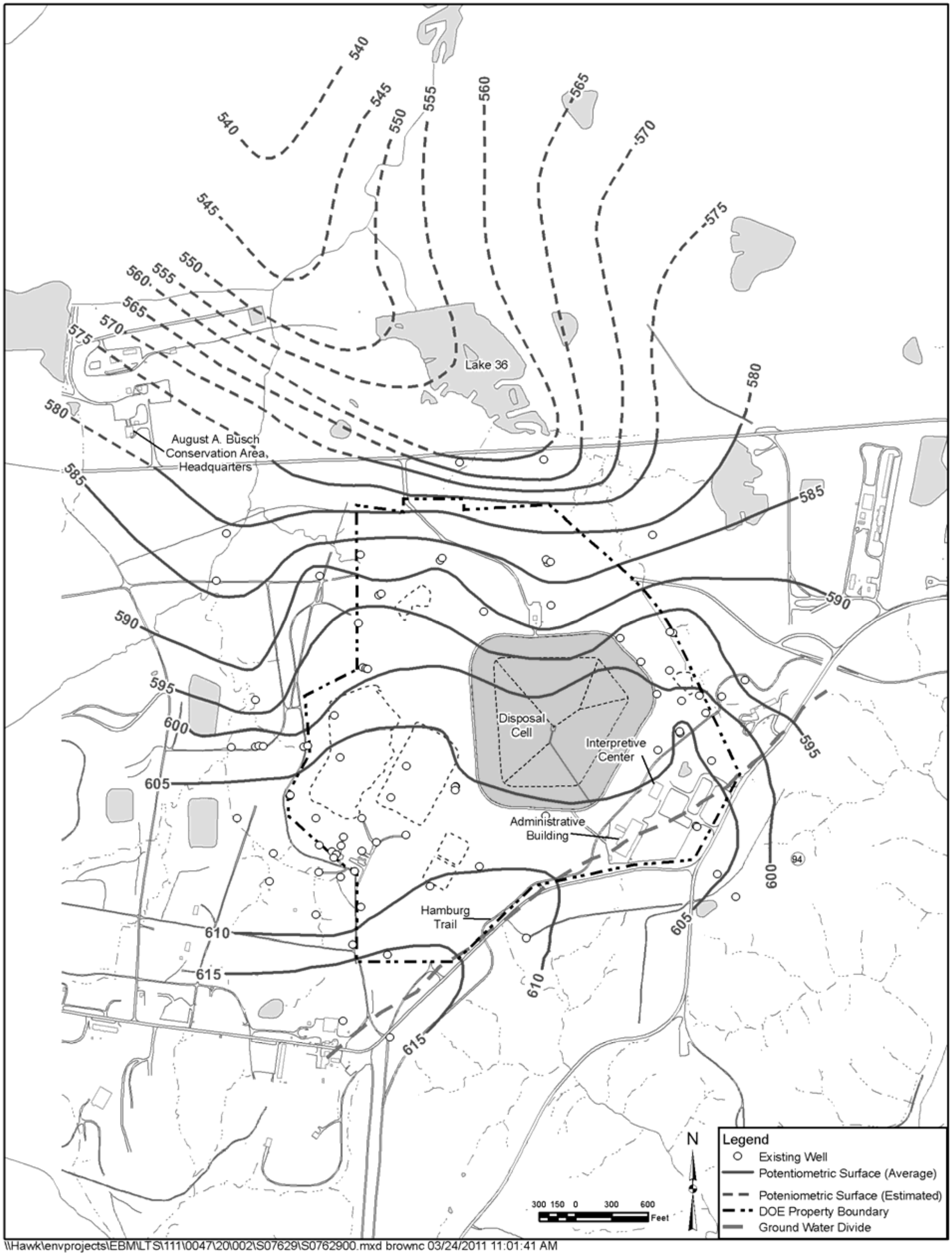

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Figure 31. Groundwater Surface at the Weldon Spring Quarry

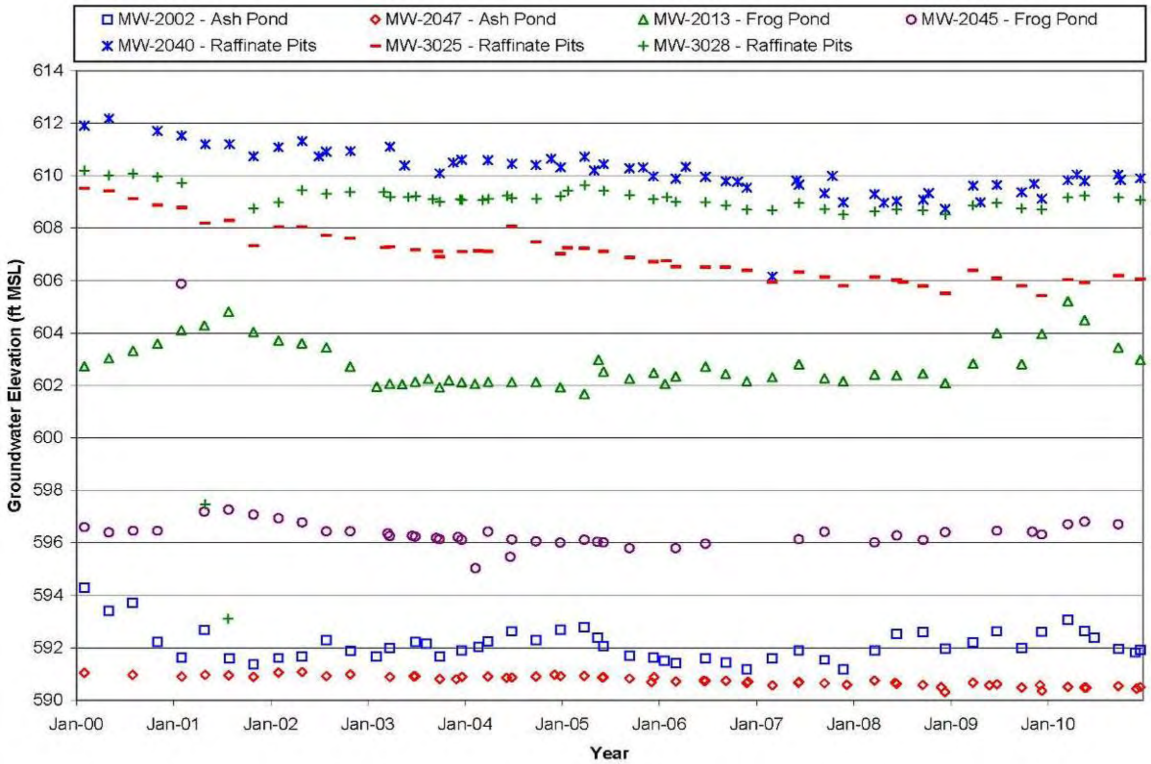

Figure 32. Groundwater Elevations in the Weathered Unit

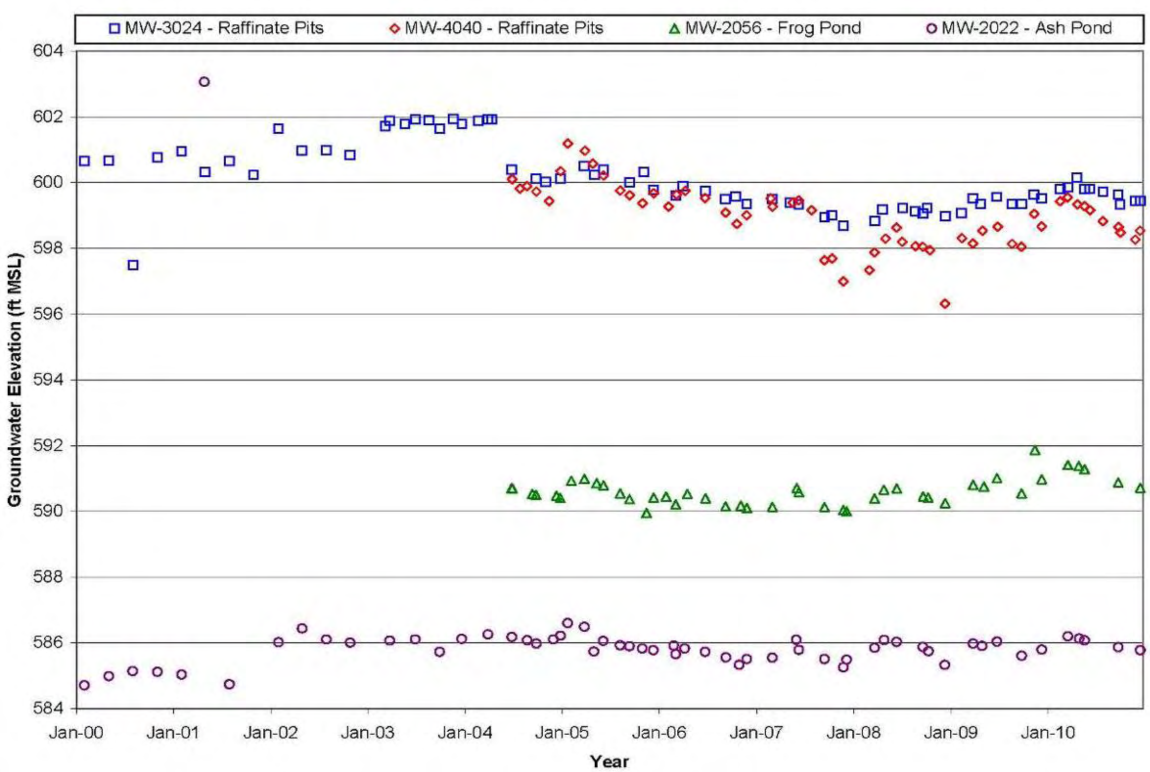

Figure 33. Groundwater Elevations in the Unweathered Unit

6.4.2 Quarry Residuals Operable Unit

EPA signed the QROU ROD (DOE 1998a) on September 30, 1998. The QROU ROD specified long-term groundwater monitoring and ICs to limit groundwater use during the monitoring period. Groundwater north of the Femme Osage Slough will be monitored until a target level of 300 pCi/L for uranium is attained. In addition, groundwater south of the slough will be monitored to ensure protection of human health and the environment.

In 2000, DOE initiated a long-term monitoring program as outlined in the *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit* (DOE 2000b). This network was modified to add wells upgradient of the Quarry (MW-1012), downgradient of the area of impact (MW-1028), and within the area of highest uranium impact (MW-1051 and MW 1052).

6.4.2.1 Hydrogeologic Description

The geology of the Quarry Area is separated into three units: upland overburden, Missouri River alluvium, and bedrock. The unconsolidated upland material overlying the bedrock consists of up to 30 ft of silty clay soil and loess deposits and is not saturated (DOE 1989). Three Ordovician formations constitute the bedrock: the Kimmswick Limestone, the limestone and shale of the Decorah Group, and the Plattin Limestone. The alluvium associated with the Missouri River consists of clays, silts, sands, and gravels above the bedrock. The alluvium thickness increases with distance from the edge of the river floodplain toward the river, where the maximum thickness is approximately 100 ft.

Alluvium at the Quarry is truncated by an erosional contact with the Ordovician bedrock bluff consisting of Kimmswick, Decorah, and Plattin Formations. These formations also form the rim wall of the Quarry. The bedrock unit underlying alluvial materials north of Femme Osage Slough is the Decorah Group. Primary sediments between the bluff and the slough are intermixed and inter-layered clays, silts, and sands. Organic material is intermixed throughout the sediments.

The area between the bedrock bluff and the Femme Osage Slough contains a naturally occurring oxidation-reduction front, which acts as a barrier to the migration of dissolved uranium in groundwater by inducing its precipitation. This reduction zone is the primary mechanism controlling the distribution south of the Quarry.

The uppermost groundwater flow systems at the Quarry are composed of alluvial and bedrock aquifers. Water levels in the alluvial aquifer are primarily controlled by surface water levels in the Missouri River and the infiltration of precipitation and overland runoff that recharges the bedrock aquifer.

Eight monitoring wells in the Darst Bottom area were used to study the water quality of the Missouri River alluvium upgradient of the Quarry and provide a reference for background values of uranium. Several other bedrock wells were installed north of the Quarry to provide background values for uranium in the bedrock units. A summary of the uranium background values is provided in Table 50 (DOE 1998a).

Table 50. Background Uranium Levels for Units at the Quarry

Unit	Uranium (pCi/L)	
	Background Value (UCL_{95})	Background Range
Alluvium[a]	2.77	0.1−16
Kimmswick-Decorah[b]	3.41	0.5−8.5
Plattin[c]	3.78[d]	1.2−5.1

Notes:
[a] Based on data from Darst Bottom wells (U.S. Geological Survey and DOE)
[b] Based on data from MW-1034 and MW-1043 (DOE)
[c] Based on data from MW-1042 (DOE)
[d] This background value is lower than previously published as a result of recent data evaluation (DOE 1998b).

Abbreviations:
pCi/L = picocuries per liter
UCL_{95} = 95th percentile upper confidence limit of the mean concentration

6.4.2.2 Contaminants of Interest

Uranium and nitroaromatic compounds that leached from wastes in the Quarry proper contaminated the groundwater beneath and downgradient of the Quarry. Contaminant levels have decreased since the removal of the wastes from the Quarry. The remaining source of groundwater contamination is residual material in the fractures and uranium that has precipitated or sorbed onto the alluvial materials north of the Femme Osage Slough.

Uranium entered the shallow aquifer via migration through bedrock fractures in the Kimmswick Limestone and Decorah Formation that constitute the Quarry. The extent of uranium in groundwater was limited to the area north of the slough through precipitation by a naturally occurring chemical reduction process and adsorption onto aquifer materials.

Nitroaromatic compounds, primarily 2,4-DNT, in the groundwater system coincide with where these wastes were disposed of in the Quarry proper. Nitroaromatic compounds entered the shallow aquifer via migration through bedrock fractures of the Quarry. The mobility of nitroaromatic compounds in the bedrock aquifer is high because these compounds have little sorptive affinity for the bedrock materials. Some microorganism activity may be able to transform and degrade TNT and DNT in the alluvial materials north of the slough.

6.4.2.3 QROU Monitoring Program

Long-term monitoring at the Quarry is designed to (1) monitor uranium levels south of the slough to ensure that they remain protective of human health and the environment, and (2) monitor uranium and 2,4-DNT levels within the area of groundwater impact north of the slough until they attain target levels that have been identified as having a negligible impact on the groundwater south of the slough (DOE 2000a). To implement these two monitoring objectives, the wells were categorized into monitoring lines (Figure 34). Each line provides specific information relevant to long-term goals at the Quarry.

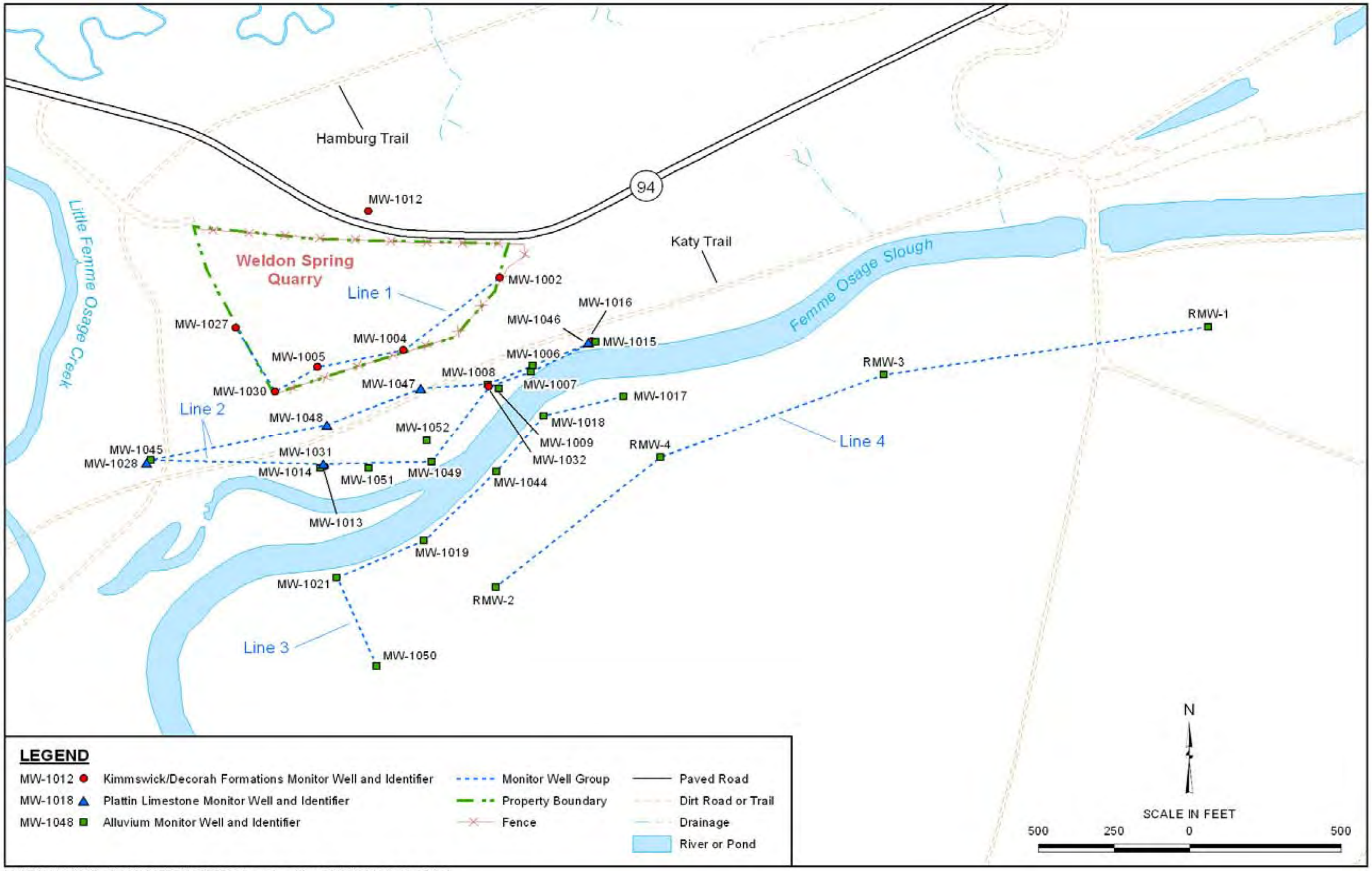

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Figure 34. QROU Monitoring Network

The sampling frequency for each location was selected to provide adequate reaction time on the basis of travel times from the residual sources and areas of impact to potential receptors. Monitoring wells on the Quarry rim were sampled semiannually starting in 2009 due to declining uranium levels. Monitoring wells between the Quarry and the Femme Osage Slough, the area of highest impact, are sampled quarterly. Locations south of the slough are sampled semiannually or annually. All locations in the Quarry Area were sampled for uranium, sulfate, and dissolved iron. A selected group of wells north of the slough was sampled for nitroaromatic compounds.

Monitoring Results for Groundwater in the Area of Impact at the Quarry

Contaminant concentrations are monitored using 24 wells screened in either the bedrock or alluvial materials in the area of uranium and 2,4-DNT impact, which is north of the Femme Osage Slough. The contaminant and geochemical data are discussed in the following sections.

Uranium

Uranium is monitored in both the bedrock and the adjoining alluvial materials north of the Femme Osage Slough. These wells are monitored to determine when the area of groundwater impact north of the slough will have a negligible impact on the groundwater south of the slough.

Levels of uranium in the Line 1 wells along the Quarry rim continue to be high. The annual averages for total uranium from 2006 through 2010 are summarized in Table 51. In 2010, two of these locations had uranium levels that exceeded the target level of 300 pCi/L. Uranium levels in the Line 1 wells have shown a general decrease (Figure 35). Since 2006, the annual average levels of uranium in MW-1002, MW-1027, and MW-1030 have been less than the target level of 300 pCi/L established for groundwater north of the Femme Osage Slough. Uranium levels in MW-1002 and MW-1030 have consistently been less than the MCL of 20 pCi/L since 2001.

Table 51. Average Total Uranium in the QROU Line 1 Wells (2006–2010)

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2006	2007	2008	2009	2010
MW-1002	1	Kimmswick-Decorah	3.7	3.6	3.4	3.0	2.9
MW-1004	1	Kimmswick-Decorah	**772**	**789**	**711**	**622**	**576**
MW-1005	1	Kimmswick-Decorah	**718**	**556**	**493**	**383**	**376**
MW-1012	1[b]	Kimmswick-Decorah	2.1	1.8	2.1	2.3	2.1
MW-1027	1	Kimmswick-Decorah	212	176	108	116	30.0
MW-1030	1	Kimmswick-Decorah	7.2	5.4	7.0	6.4	5.6

[a] Concentrations in **bold** exceed the target level of 300 pCi/L.
[b] Upgradient location.
pCi/L = picocuries per liter

The results of trend analysis for the Line 1 wells (Table 52) indicate that uranium concentrations in recent years have been decreasing in most of the wells, as indicated by negative slopes. Statistically downward trends have been calculated for MW-1002, MW-1004, MW-1005, and MW-1027. If the current decreases in uranium continue in these wells, it is estimated that the target level of 300 pCi/L could be reached by 2019, using an exponential curve model. Uranium levels in MW-1030 are stable, based on the small slope and confidence intervals.

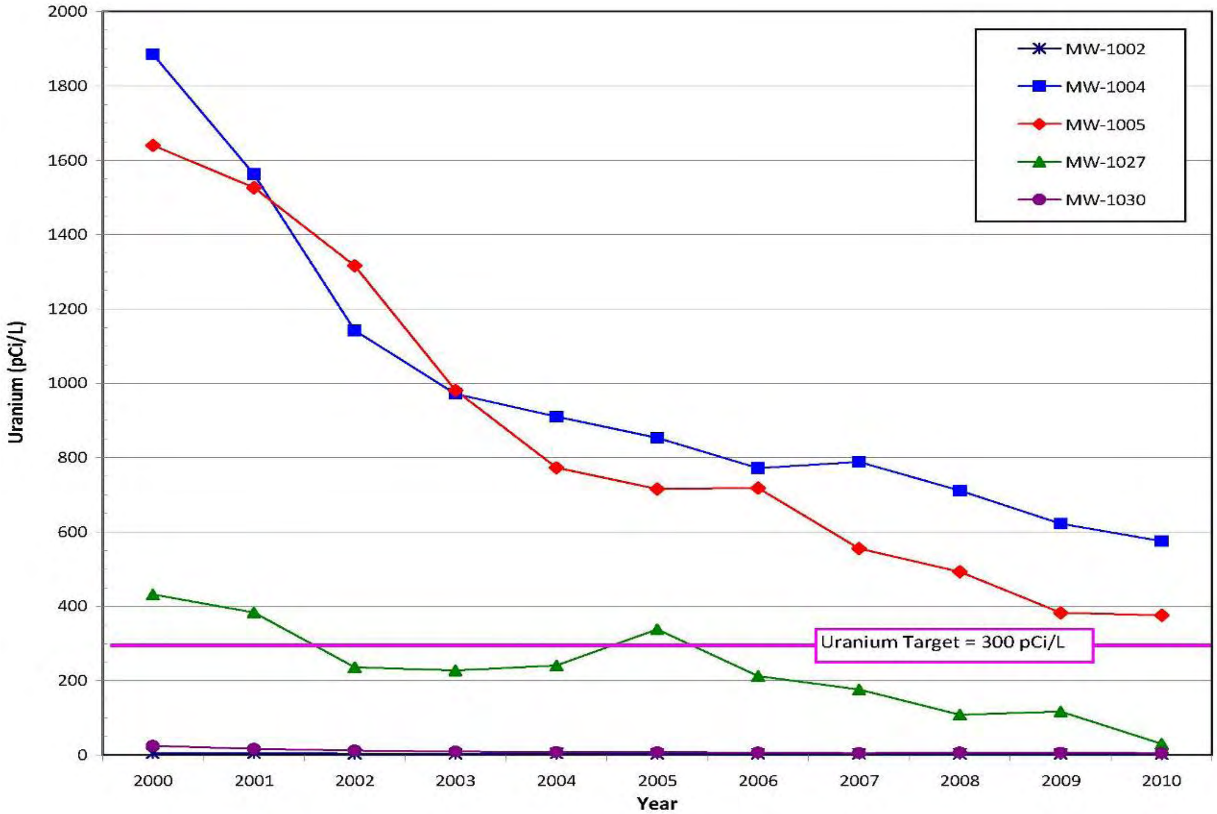

Figure 35. Average Uranium in Line 1 Monitoring Wells

Table 52. Trending Analysis for Uranium in Line 1 Groundwater Monitoring Wells (2006–2010)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
MW-1002	16	**Down**	–0.24	–0.36	–0.09
MW-1004	16	**Down**	–59.3	–84.7	2.2
MW-1005	16	**Down**	–85.3	–135	–52.3
MW-1027	16	**Down**	–38.5	–65.2	–8.4
MW-1030	16	None	0.09	–0.67	0.40

pCi/L/yr = picocuries per liter per year

Bedrock wells located between the Quarry rim and Femme Osage Slough continue to have elevated uranium levels. The annual averages for uranium from 2006 through 2010 are summarized in Table 53. In 2010, uranium levels in only one of these bedrock wells exceeded the target level of 300 pCi/L. Uranium levels in the Line 2 bedrock wells have generally decreased since 2000 (Figure 36). The highest levels of uranium are in MW-1032, which is beneath the area of highest uranium impact in the overlying alluvium. The average levels of uranium in MW-1015, MW-1028, MW-1031, MW-1046, MW-1047, and MW-1048 have been less than the target level of 300 pCi/L since 2009.

Table 53. Average Total Uranium in QROU Line 2 Bedrock Wells (2006–2010)

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2006	2007	2008	2009	2010
MW-1013	2	Kimmswick-Decorah	**350**	286	**308**	239	290
MW-1015	2	Kimmswick-Decorah	170	134	124	152	117
MW-1028	2	Plattin	1.6	1.8	1.7	2.2	1.8
MW-1031	2	Plattin	12.4	11.4	11.0	11.1	10.1
MW-1032	2	Kimmswick-Decorah	**933**	**838**	**1029**	**686**	**633**
MW-1046	2	Plattin	1.4	2.2	2.0	1.6	1.4
MW-1047	2	Plattin	1.2	0.93	1.2	0.92	0.75
MW-1048	2	Plattin	**319**	**320**	293	234	165

[a] Concentrations in **bold** exceed the target level of 300 pCi/L.
pCi/L = picocuries per liter

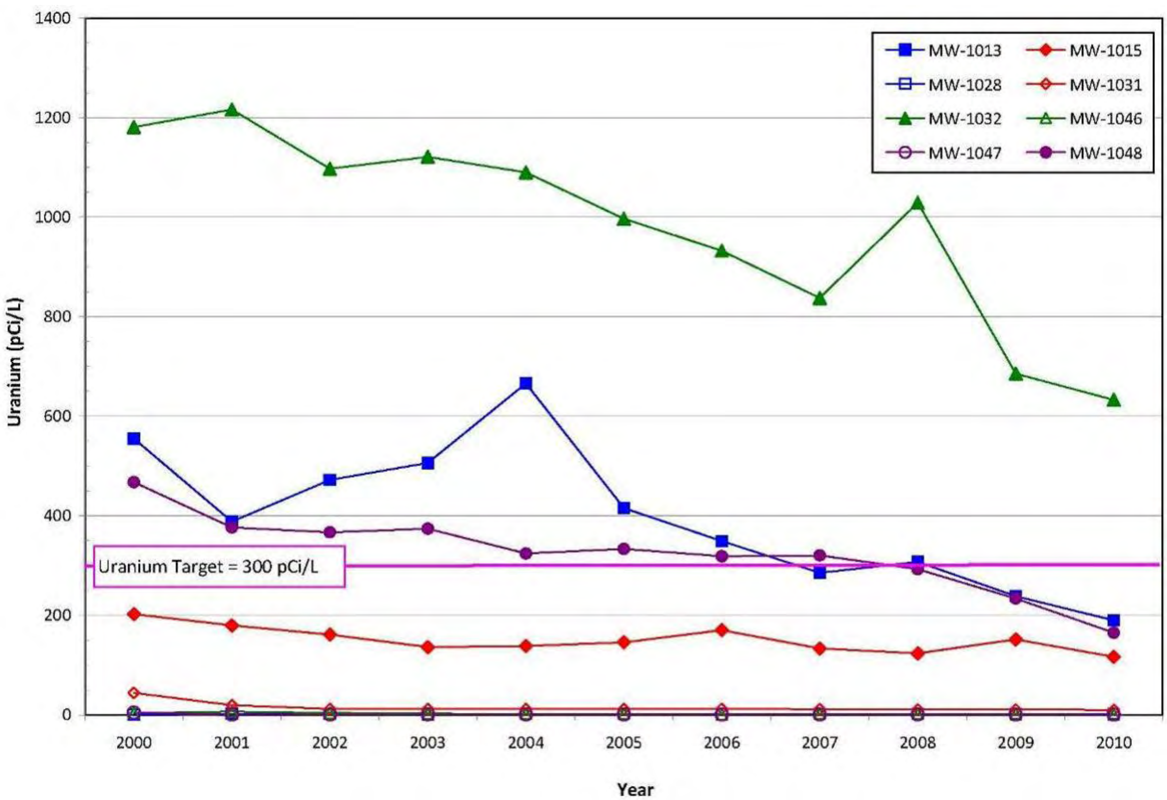

Figure 36. Average Uranium in Line 2 Bedrock Wells

Results continue to indicate that the highest levels of uranium in groundwater are in the alluvial materials between the Quarry rim and Femme Osage Slough. The annual averages for uranium in the alluvial wells from 2006 through 2010 are summarized in Table 54. Uranium levels in the Line 2 alluvial wells rebounded after a significant decrease was observed in this area in 2006 (Figure 37). From 2006 through 2010, levels have varied at most locations; however, levels in 2009 and 2010 were similar to those measured in 2005. In 2010, five of these locations had uranium levels that exceeded the target level of 300 pCi/L. These wells are in the center of the area of uranium impact. The average levels of uranium in MW-1009, MW-1045, and MW-1049 have remained low during the review period and represent the limits of uranium impact in the groundwater.

Table 54. Average Total Uranium in QROU Line 2 Alluvial Wells (2006–2010)

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2006	2007	2008	2009	2010
MW-1006	2	Alluvium	**793**	**1,337**	**1,704**	**1,322**	**1,134**
MW-1007	2	Alluvium	**46.5**	**1,872**	**1,284**	**406**	128
MW-1008	2	Alluvium	**1,607**	**3,486**	**2,358**	**3,178**	**2,097**
MW-1009	2	Alluvium	0.73	3.2	2.6	1.5	1.3
MW-1014	2	Alluvium	**571**	**802**	**823**	**1,197**	**1,061**
MW-1016	2	Alluvium	79.3	100	92.0	114	147
MW-1045	2	Alluvium	8.3	6.2	2.6	2.3	2.1
MW-1049	2	Alluvium	0.46	0.14	0.21	0.09	0.06
MW-1051	2	Alluvium	**304**	**688**	**912**	**1,114**	**834**
MW-1052	2	Alluvium	**76.5**	**333**	**664**	**1,812**	**1,095**

[a] Concentrations in **bold** exceed the target level of 300 pCi/L.
pCi/L = picocuries per liter

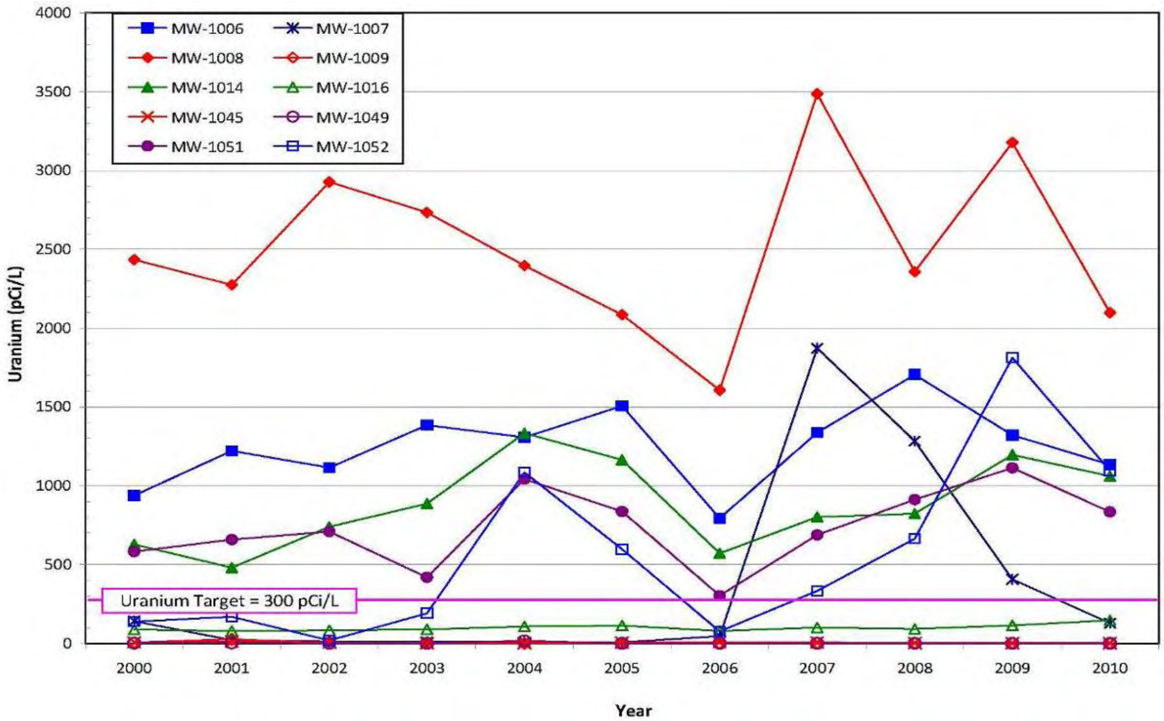

Figure 37. Average Uranium in Line 2 Alluvial Wells

Increasing uranium levels were reported in alluvial wells MW-1006, MW-1008, MW-1014, MW-1051, and MW-1052 starting in 2007. These alluvial wells are screened primarily in the oxidized portion of the groundwater where changes in groundwater elevations have typically affected the uranium levels measured in the wells (Figure 38). Prior to 2006, this correlation between uranium levels and groundwater levels was generally consistent. In 2006, water levels were extremely low due to drought conditions in the Quarry Area that continued into early 2008. Uranium levels have varied since 2007, with a significant increase in uranium levels after a large increase in groundwater levels in 2007 and another increase in 2008. Geochemical data from these wells support the presence of dissolved uranium in the groundwater. The geochemistry of the groundwater in this area exhibits high oxidation-reduction potential (ORP) values and sulfate concentrations and low dissolved iron concentrations, indicators of an oxidizing environment. Sulfate concentrations in wells MW-1051 and MW-1052 have increased over recent years.

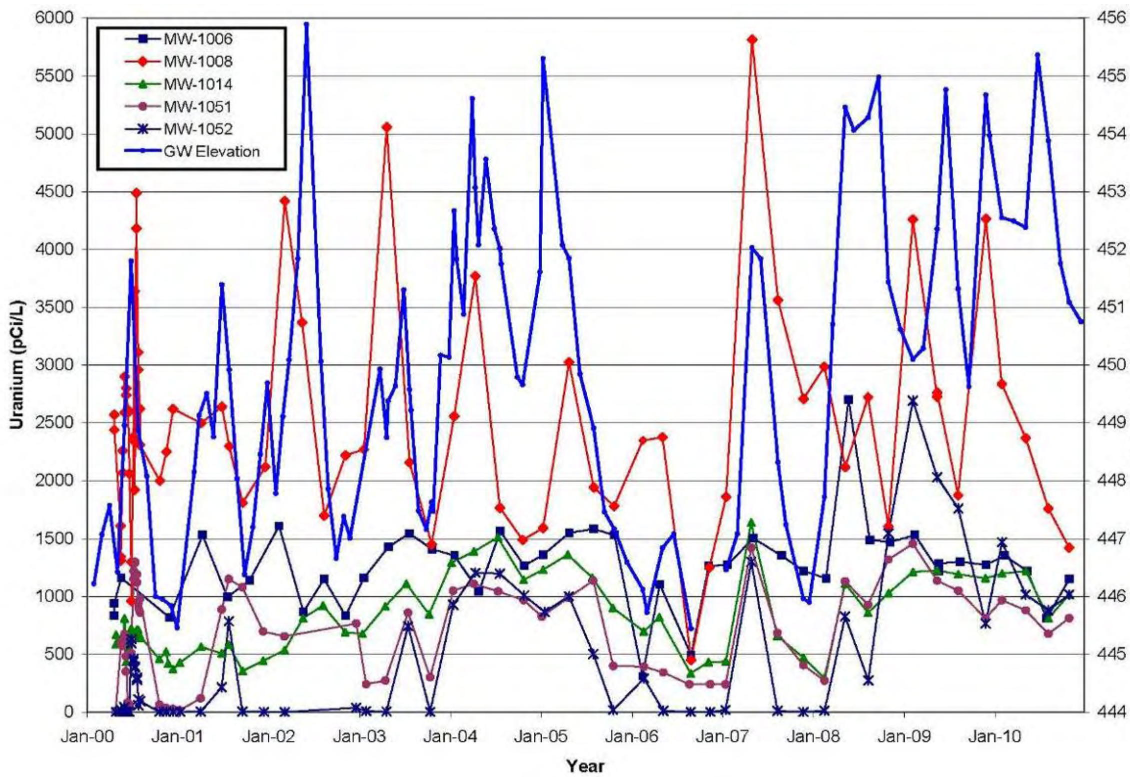

Figure 38. Uranium Levels MW-1006, MW-1008, MW-1014, MW-1051, and MW-1052 and Groundwater Levels

The significant uranium increase in alluvial well MW-1007, which is screened in the reduced portion of the groundwater north of the slough, was evaluated. During 2007 and 2008, uranium levels in this well became remarkably high, coinciding with significant increases in groundwater levels. Changes in groundwater elevation historically have not affected the uranium levels measured in this well because the reducing conditions are more prevalent. The geochemical data from MW-1007 do not support the presence of elevated uranium in groundwater. The geochemistry in this well exhibits high dissolved iron concentrations and low ORP values, indicators of a reducing environment. However, sulfate concentrations, which are typically low in reducing environments, increased coincident with the increases in uranium levels. The evaluation of filtered and unfiltered data indicated no significant difference between the filtered and unfiltered samples, even though the turbidity in the well had increased. Well MW-1007 was redeveloped in August 2009 because of continued high turbidity; however, subsequent data were not different from previous data. Overall, data from 2009 and 2010 indicate a decrease in both uranium levels and sulfate concentrations in this well. Although elevated uranium levels are reported along the northern boundary of the reduction zone, Line 3 data indicate no migration of uranium south of the Femme Osage Slough into the Missouri River alluvium.

Trending results for the Line 2 wells (Table 55), which are screened in the saturated alluvium or bedrock between the Quarry rim and the Femme Osage Slough, show decreases in uranium levels in this area, as indicated by negative slopes. Downward trends were identified in all of the bedrock wells in Line 2. Well MW-1032 is the only bedrock well with uranium levels above the target level of 300 pCi/L. If the current decreases continue in MW-1032, it is estimated that the target level could be reached by 2017, using an exponential curve model.

Increasing uranium levels are reported in alluvial wells MW-1006, MW-1008, MW-1014, MW-1016, MW-1051, and MW-1052, as indicated by positive slopes. Statistically upward trends were calculated for MW-1014, MW-1016, and MW-1052. Decreasing or stable uranium levels and no statistical trends in the data were calculated for MW-1007, MW-1009, and MW 1049, all screened in the reduced portion of the aquifer which is not conducive to the presence of uranium.

The attainment objective for the long-term monitoring of uranium in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 300 pCi/L (DOE 2000b). The average uranium levels in eight wells north of the slough exceeded the target level in 2010. The 90th percentile associated with the data from the Line 1 and 2 wells was 1,193 pCi/L. This value is slightly lower than those determined for 2007, 2008, and 2009, which were higher than in previous years (Figure 39). Looking at the 90th percentile for Lines 1 and 2 separately indicates that the increased metric was the result of changes in uranium levels in the Line 2 wells, primarily the uranium levels measured in the Line 2 alluvial wells. The changes in the Line 2 bedrock wells mirror those seen in the Line 1 wells. In general, the levels in Line 1 and the Line 2 bedrock have decreased, whereas the levels in the Line 2 alluvium have increased.

Table 55. Trending Analysis for Uranium in Line 2 Groundwater Monitoring Wells (2006–2010)

Location	Unit	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
					Lower	Upper
MW-1006	Alluvium	21	None	10.5	–83.1	110
MW-1007	Alluvium	21	None	–133	–364	66.3
MW-1008	Alluvium	21	None	13.6	–369	341
MW-1009	Alluvium	21	None	0	–0.48	0.28
MW-1013	Bedrock	20	**Down**	–41.4	–61.7	–16.5
MW-1014	Alluvium	20	**Up**	126	29.9	239
MW-1015	Bedrock	20	**Down**	–9.6	–14.0	–6.7
MW-1016	Alluvium	20	**Up**	15.8	8.2	20.8
MW-1028	Bedrock	14	None	0.05	–0.15	0.21
MW-1031	Bedrock	20	**Down**	–0.57	–1.1	–0.07
MW-1032	Bedrock	20	**Down**	–90.6	–109	–61.3
MW-1045	Alluvium	20	**Down**	–0.52	–1.8	–0.14
MW-1046	Bedrock	20	**Down**	–0.10	–0.22	0
MW-1047	Bedrock	20	**Down**	–0.08	–0.17	–0.02
MW-1048	Bedrock	20	**Down**	–39.8	–56.2	–26.2
MW-1049	Alluvium	20	None	–0.02	–0.04	0
MW-1051	Alluvium	20	None	127	–53.6	240
MW-1052	Alluvium	20	**Up**	258	11.3	432

pCi/L = picocuries per liter

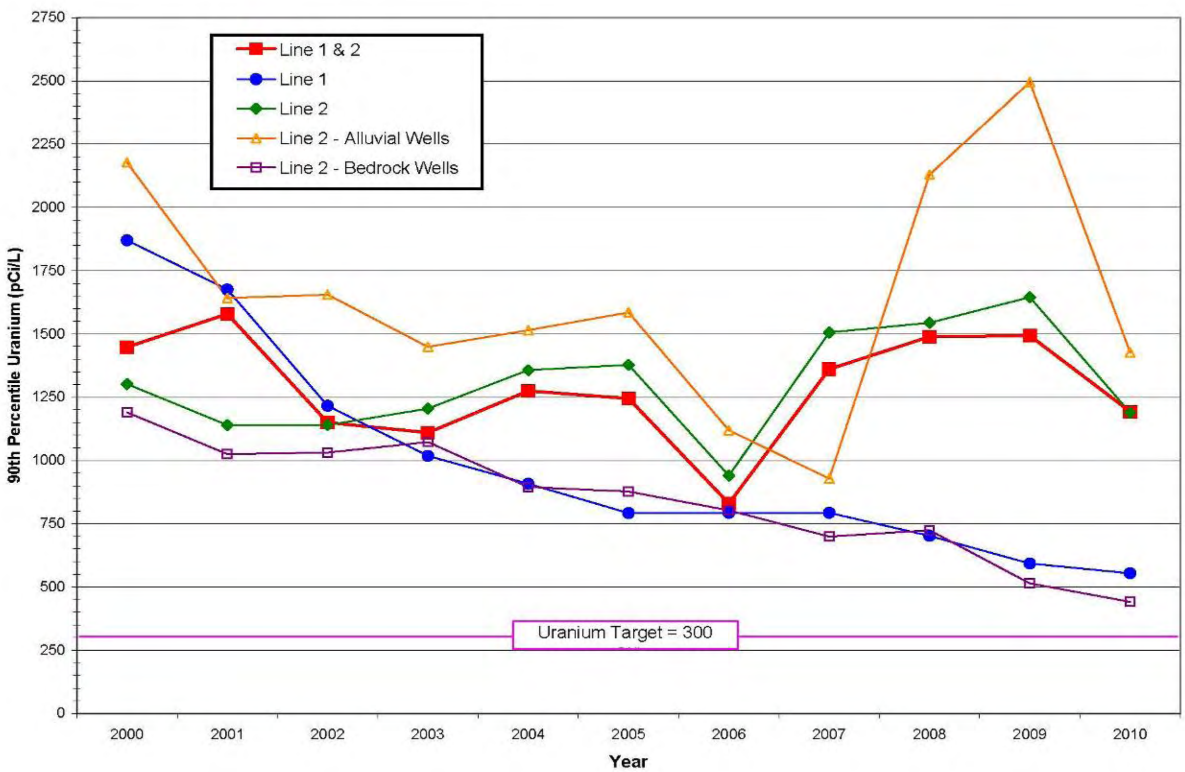

Figure 39. 90th Percentile of Uranium in Line 1 and 2 Wells (2000–2010)

Overall, the decreasing uranium levels in the Quarry rim and area north of the Femme Osage Slough are the result of bulk waste removal and restoration activities in the Quarry proper. Remedial activities in the Quarry have reduced and possibly prevented infiltration of precipitation and storm water into the residually contaminated fracture system in the Quarry proper. Uranium does not bind as readily to the bedrock as it does to the alluvial materials; therefore, decreases should occur more readily in the bedrock as groundwater flushes through the system. The distribution of uranium in groundwater is still predominantly controlled by the precipitation of uranium along the oxidizing-reducing front north of the Femme Osage Slough. Although uranium levels have increased in some of the alluvial wells north of the slough, levels are far below historical highs. Monitoring in wells screened in the reducing portion of the area north of the slough indicate that uranium levels continue to remain low.

Nitroaromatic Compounds

Samples from eight monitoring wells were analyzed for the nitroaromatic compound 2,4-DNT. Two of these monitoring wells have historically been impacted by nitroaromatic compounds, and the remainder monitor upgradient and downgradient water quality along the Quarry rim or between the Quarry and Femme Osage Slough. Average concentrations of 2,4-DNT for the eight long-term locations from 2006 through 2010 are presented in Table 56. Detectable concentrations were reported in only MW-1006 and MW-1027 during the period from 2006 through 2010, and the average concentrations were above the Missouri Water Quality Standard of 0.11 μg/L.

Table 56. Average Concentrations of 2,4-DNT at the Weldon Spring Quarry (2006–2010)

Location	Line	Geologic Unit	Average 2,4-DNT (μg/L)				
			2006	2007	2008	2009	2010
MW-1002	1	Kimmswick-Decorah	ND	ND	ND	ND	ND
MW-1004	1	Kimmswick-Decorah	ND	ND	ND	0.02 (J)	ND
MW-1005	1	Kimmswick-Decorah	ND	ND	ND	ND	ND
MW-1006	2	Alluvium	0.06	**0.43**	**0.21**	**0.43**	ND
MW-1027	1	Kimmswick-Decorah	**2.62**	**9.31**	ND	0.04	**0.42**
MW-1032	2	Kimmswick-Decorah	ND	ND	ND	ND	ND
MW-1045	2	Alluvium	ND	ND	ND	ND	ND
MW-1049	2	Alluvium	ND	ND	ND	ND	ND

[a] Concentrations in **bold** exceed the Missouri Water Quality Standard of 0.11 μg/L for 2,4-dinitrotoluene.
J = estimated values less than the reporting limit
μg/L = micrograms per liter
ND = analyte not detected above the method detection limit

The concentration of 2,4-DNT has varied in the Quarry Area (Figure 40). Increased concentrations were observed in wells MW-1006 and MW-1027 during 2005, and the concentrations have fluctuated significantly after that time. A correlation between water level and 2,4-DNT concentration has not been determined. No detectable concentrations have historically been reported in MW-1045 and MW-1049, which are the downgradient-most wells in the vicinity of wells MW-1006 and MW-1027.

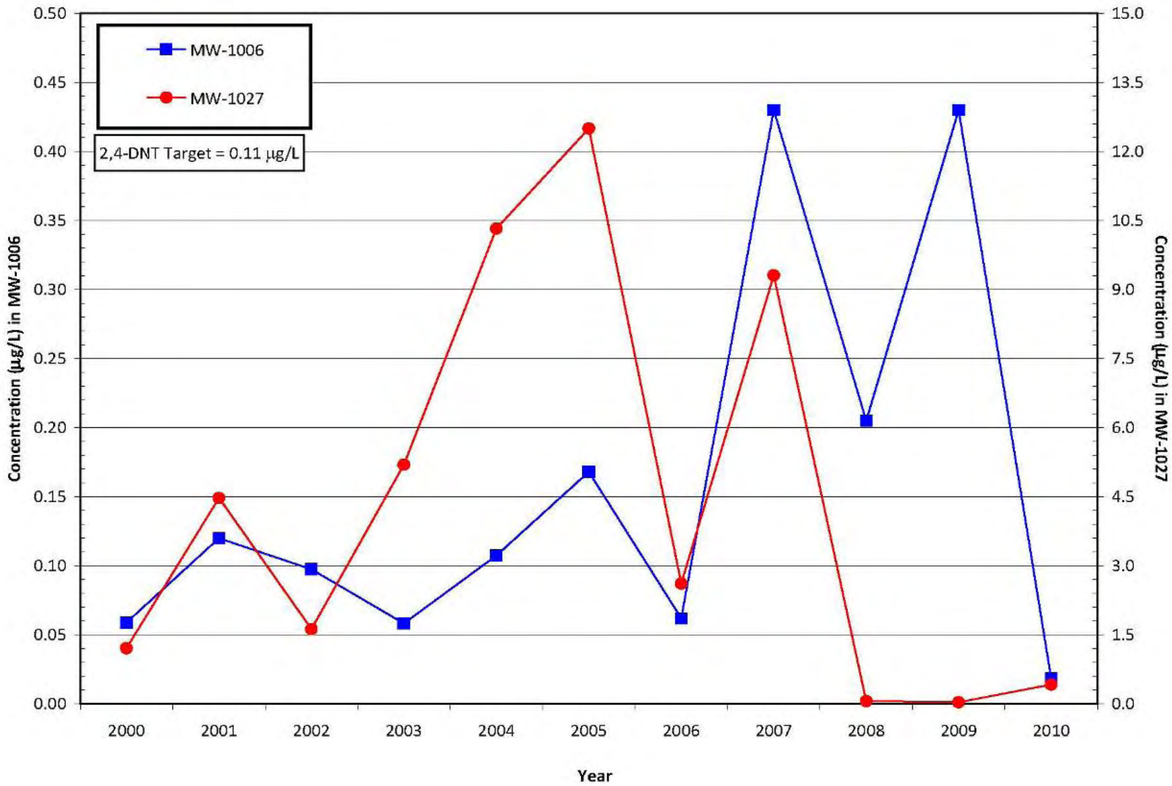

Figure 40. Average 2,4-DNT in MW-1006 and MW-1027

Trend analyses for 2,4-DNT were performed for wells MW-1006 and MW-1027 (Table 57), as these are the only locations that had detectable concentrations of 2,4-DNT in the last 5 years. Overall, the concentrations of 2,4-DNT are decreasing at these two locations, as indicated by negative slopes. No statistical trends were calculated for either well using data from 2006 through 2010.

Table 57. Trending Analysis for 2,4-DNT in Selected Quarry Groundwater Monitoring Wells (2006–2010)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-1006	16	None	–0.046	–0.134	0.049
MW-1027	16	None	–0.099	–1.29	0

µg/L/yr = micrograms per liter per year

The attainment objective for the long-term monitoring of 2,4-DNT in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 0.11 µg/L (DOE 2000b). The eight monitoring wells that have been selected for continued long-term monitoring were used to calculate this metric. The 90th percentile associated with the data from the eight wells was 0.02 µg/L using data collected in 2010. This value is significantly lower than those measured in previous years (Figure 41).

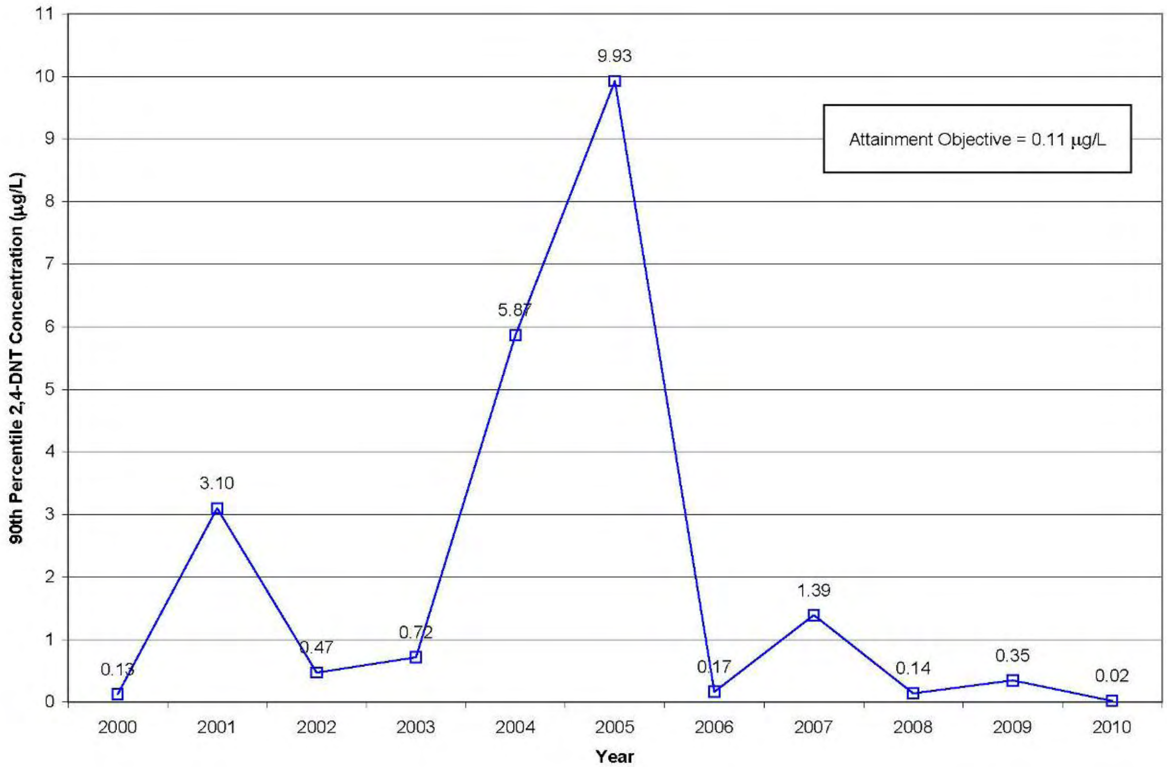

Figure 41. 90th Percentile of 2,4-DNT in Long-Term Monitoring Wells (2000–2010)

Overall, 2,4-DNT impact in groundwater is within two discrete areas. Concentrations, although variable, have generally decreased since removal of the bulk wastes in the Quarry. Present concentrations in groundwater pose little potential impact to the groundwater in the Missouri River alluvium.

Geochemical Parameters

The geochemistry of the shallow aquifer is monitored to verify the presence of the reduction zone and to confirm that the reduction zone is capable of the ongoing attenuation of uranium in groundwater. Groundwater is analyzed for sulfate, dissolved iron, ferrous iron, and Eh. Sulfate is monitored as an indicator of redox conditions in the groundwater in the vicinity of the Quarry. Higher sulfate concentrations are generally observed in an oxidizing environment. Iron (total dissolved and ferrous) is also monitored as an indicator of oxidation-reduction conditions in the groundwater. Iron concentrations typically increase in a reducing environment. These results generally correlate with observed uranium concentrations upgradient and downgradient of the reduction zone, as uranium is typically more mobile in an oxidizing environment and precipitates in a reducing environment. Summaries of the geochemical parameters for each monitoring location are presented in Table 58 through Table 60.

Table 58. Average Values for Sulfate at the Weldon Spring Quarry (2006–2010)

Location	Line	Geologic Unit	Sulfate (mg/L)				
			2006	2007	2008	2009	2010
MW-1002	1	Kimmswick-Decorah	104	105	91.3	86.0	85.5
MW-1004	1	Kimmswick-Decorah	85.6	116	110	112	110
MW-1005	1	Kimmswick-Decorah	220	192	115	69.8	81.5
MW-1012	1	Kimmswick-Decorah	35.1	34.6	36.9	37.9	41.0
MW-1027	1	Kimmswick-Decorah	71.4	58.6	55.0	69.2	72.5
MW-1030	1	Kimmswick-Decorah	96.0	127	106	94.2	86.0
MW-1006	2	Alluvium	51.4	83.7	94.7	92.8	55.5
MW-1007	2	Alluvium	28.1	395	534	96.6	29.6
MW-1008	2	Alluvium	112	102	75.1	100	79.5
MW-1009	2	Alluvium	25.3	8.0	10.0	37.2	33.6
MW-1013	2	Kimmswick-Decorah	81.9	77.5	80.6	73.6	68.9
MW-1014	2	Alluvium	110	120	105	126	96.8
MW-1015	2	Kimmswick-Decorah	101	90.6	69.5	73.9	64.6
MW-1016	2	Alluvium	104	92.4	80.3	73.0	87.9
MW-1028	2	Plattin	55.3	40.4	35.8	37.5	22.0
MW-1031	2	Alluvium	25.3	33.2	34.1	33.2	32.8
MW-1032	2	Kimmswick-Decorah	120	110	112	115	104
MW-1045	2	Alluvium	42.2	36.8	23.4	24.4	25.8
MW-1046	2	Plattin	51.2	62.2	63.7	62.8	69.9
MW-1047	2	Plattin	83.8	81.7	78.9	77.7	83.3
MW-1048	2	Plattin	63.6	68.1	60.2	58.1	66.6
MW-1049	2	Alluvium	0.10	0.57	0.44	1.22	0.31
MW-1051	2	Alluvium	25.0	73.1	124	130	100
MW-1052	2	Alluvium	0.33	47.6	59.9	126	63.1

mg/L = milligrams per liter

Table 59. Average Values for Dissolved Iron at the Weldon Spring Quarry (2006–2010)

Location	Line	Geologic Unit	Dissolved Iron (µg/L)				
			2006	2007	2008	2009	2010
MW-1002	1	Kimmswick-Decorah	26.0	47.1	113	46.8	ND
MW-1004	1	Kimmswick-Decorah	53.1	41.1	62.0	600	605
MW-1005	1	Kimmswick-Decorah	3,626	2,095	42,180	48.7	53.0
MW-1012	1	Kimmswick-Decorah	59.1	33.0	37.3	40.0	ND
MW-1027	1	Kimmswick-Decorah	102	308	7,115	157	23.5
MW-1030	1	Kimmswick-Decorah	7,150	6,010	6,968	8,625	6,650
MW-1006	2	Alluvium	1,405	50.8	228	363	1,488
MW-1007	2	Alluvium	45,000	33,800	41,700	36,400	52,650
MW-1008	2	Alluvium	23.1	86.7	48.5	52.4	ND
MW-1009	2	Alluvium	21,520	12,257	21,225	21,600	24,050
MW-1013	2	Kimmswick-Decorah	3,822	3,712	3,855	3,835	3,322
MW-1014	2	Alluvium	2,387	306	92.0	129	294
MW-1015	2	Kimmswick-Decorah	30.6	55.5	41.2	69.7	46.9
MW-1016	2	Alluvium	25.6	150	755	37.1	ND
MW-1028	2	Plattin	775	150	ND	39.0	ND
MW-1031	2	Alluvium	38.4	23.0	ND	32.7	ND
MW-1032	2	Kimmswick-Decorah	37.8	29.2	315	80.2	192
MW-1045	2	Alluvium	ND	44.2	39.9	38.4	23.8
MW-1046	2	Plattin	386	110	ND	52.7	24.0
MW-1047	2	Plattin	131	25.8	ND	29.9	ND
MW-1048	2	Plattin	1144	1,105	1,074	1,076	858
MW-1049	2	Alluvium	56,625	54,425	48,275	48,200	50,750
MW-1051	2	Alluvium	3,745	3,337	1,134	192	448
MW-1052	2	Alluvium	38,900	35,950	17,952	4,248	4,695

[a] Convert oxidation-reduction potential to Eh by adding 200 mV to the ORP value.
mg/L = milligrams per liter; mV = millivolts; µg/L = micrograms per liter; ORP = oxidation-reduction potential

Table 60. Average Values for Oxidation-Reduction Potential at the Weldon Spring Quarry (2006–2010)

Location	Line	Geologic Unit	Oxidation-Reduction Potential (mV)[a]				
			2006	2007	2008	2009	2010
MW-1002	1	Kimmswick-Decorah	160	172	170	135	164
MW-1004	1	Kimmswick-Decorah	175	147	85	20	41
MW-1005	1	Kimmswick-Decorah	29	45	70	7	101
MW-1012	1	Kimmswick-Decorah	195	158	140	152	193
MW-1027	1	Kimmswick-Decorah	4	146	60	38	128
MW-1030	1	Kimmswick-Decorah	183	-27	97	-51	-56
MW-1006	2	Alluvium	-15	41	75	24	18
MW-1007	2	Alluvium	-111	-29	-14	-96	-129
MW-1008	2	Alluvium	81	151	135	130	99
MW-1009	2	Alluvium	-83	-34	-38	-37	-109
MW-1013	2	Kimmswick-Decorah	-29	-26	88	20	-38
MW-1014	2	Alluvium	30	124	139	96	46
MW-1015	2	Kimmswick-Decorah	76	108	130	49	84
MW-1016	2	Alluvium	186	137	72	71	134
MW-1028	2	Plattin	27	76	84	100	92
MW-1031	2	Alluvium	174	154	120	118	126
MW-1032	2	Kimmswick-Decorah	104	104	31	76	40
MW-1045	2	Alluvium	145	104	57	76	103
MW-1046	2	Plattin	-26	157	134	83	165
MW-1047	2	Plattin	90	123	133	118	100
MW-1048	2	Plattin	-25	-8	110	35	17
MW-1049	2	Alluvium	-113	-129	-84	-153	-150
MW-1051	2	Alluvium	12	32	110	95	60
MW-1052	2	Alluvium	-91	-93	74	11	-39

[a] Convert oxidation-reduction potential to Eh by adding 200 mV to the ORP value.
mV = millivolts

A review of the geochemical data indicates that although the area of highest impact has an oxidizing environment, reducing conditions are prevalent along the northern edge of the slough, as shown by data in wells MW-1007, MW-1009, and MW-1049. This is consistent with the uranium data where low levels are detected, especially in MW-1049 where very low sulfate and high dissolved iron concentrations are also observed. The location of this reduction area was consistent during the review period, and the attenuation of uranium in this area continues.

Monitoring Results for the Missouri River Alluvium

Groundwater quality in the Missouri River alluvium is monitored using 10 wells screened in the alluvial materials. These wells are sampled for uranium and geochemical parameters to ensure that water quality remains protective of human health.

Uranium

The six monitoring wells immediately south of the slough (Line 3) and the four RMW series wells (Line 4) were sampled for uranium during the review period (Table 61) to verify that levels remain within the range of its natural variation in Missouri River alluvium. The results indicate that the average uranium levels were less than the statistical background value in the alluvium (Table 50). None of the locations south of the slough have uranium levels that exceed the drinking water standard of 20 pCi/L.

Table 61. Values for Total Uranium in the Missouri River Alluvial Aquifer (2006–2010)

Location	Line	Uranium (pCi/L)				
		2006	2007	2008	2009	2010
MW-1017	3	ND	ND	ND	0.21	0.12
MW-1018	3	ND	ND	ND	0.14	0.07
MW-1019	3	ND	ND	ND	0.10	0.03
MW-1021	3	ND	ND	ND	ND	0.03
MW-1044	3	ND	ND	ND	0.16	0.03
MW-1050	3	ND	ND	ND	0.17	0.07
RMW-1	4	0.95	0.66	0.8	1.1	1.4
RMW-2	4	5.4	2.4	0.9	2.9	4.3
RMW-3	4	0.52	0.35	ND	0.67	0.96
RMW-4	4	0.47	1.1	0.6	2.2	1.0

ND = analyte not detected above the method detection limit
pCi/L = picocuries per liter

Geochemical Parameters

The monitoring wells south of the slough were sampled for sulfate and dissolved iron, and ORP, for the purpose of assessing oxidation-reduction conditions in the Missouri River alluvium downgradient of the area of uranium impact (Table 62 through Table 64). The data continue to indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough, as shown by high dissolved iron concentrations, low sulfate concentrations, and low ORP values. This environment is not favorable for the migration of uranium, if it were to pass beyond the reduction zone north of the slough. Data from the review period were consistent for all locations, except MW-1044.

Increased sulfate concentrations were reported in MW-1044 beginning in late 2008 and have continued through 2010. High iron concentrations and low Eh values indicate that a reducing environment is still prevalent in this area. Uranium levels remain low at this location and the remainder of the locations along the southern edge of the Femme Osage Slough.

Table 62. Average Values for Sulfate in the Missouri River Alluvial Aquifer (2006–2010)

Location	Line	Sulfate (mg/L)				
		2006	2007	2008	2009	2010
MW-1017	3	0.1	0.2	0.1	0.6	0.8
MW-1018	3	7.2	3.0	0.2	0.3	3.4
MW-1019	3	0.2	0.2	0.1	0.1	0.4
MW-1021	3	0.2	0.4	0.6	0.4	30.0
MW-1044	3	ND	0.2	97.8	340	255
MW-1050	3	12.1	12.2	0.4	3.2	22.9
RMW-1	4	45.1	39.1	NAL	38.5	57.0
RMW-2	4	12.7	7.5	NAL	15.1	48.9
RMW-3	4	24.7	19.1	NAL	20.4	45.3
RMW-4	4	8.8	14.1	NAL	14.3	5.2

mg/L = milligrams per liter
NAL = not analyzed
ND = not detected

Table 63. Average Values for Dissolved Iron in the Missouri River Alluvial Aquifer (2006–2010)

Location	Line	Dissolved Iron (μg/L)				
		2006	2007	2008	2009	2010
MW-1017	3	31,400	25,050	22,350	20,400	19,350
MW-1018	3	24,400	33,100	33,300	28,400	30,450
MW-1019	3	22,650	15,350	14,800	13,850	13,100
MW-1021	3	16,200	16,500	17,900	17,850	15,750
MW-1044	3	20,700	24,600	21,850	44,800	32,950
MW-1050	3	14,700	17,300	17,550	18,250	13,650
RMW-1	4	9,730	10,700	NAL	9,050	4,400
RMW-2	4	8,540	10,700	NAL	9,230	6,030
RMW-3	4	16,000	14,600	NAL	15,200	13,200
RMW-4	4	17,200	4,200	NAL	2,060	7,910

μg/L = micrograms per liter
NAL = not analyzed

Table 64. Average Values for Oxidation-Reduction Potential in the Missouri River Alluvial Aquifer (2006–2010)

Location	Line	Oxidation-Reduction Potential (mV)				
		2006	2007	2008	2009	2010
MW-1017	3	-139	-137	-127	-96	-158
MW-1018	3	-140	-148	-125	-134	-161
MW-1019	3	-137	-130	-98	-140	-137
MW-1021	3	-119	-124	-113	-96	-143
MW-1044	3	-131	-153	-146	-173	-178
MW-1050	3	-132	-138	-108	-138	-148
RMW-1	4	-104	-80	NAL	-89	-26
RMW-2	4	-105	-103	NAL	-67	-104
RMW-3	4	-168	-132	NAL	-155	-133
RMW-4	4	-159	-47	NA	-33	-94

[a] Convert oxidation-reduction potential to Eh by adding 200 mV to the oxidation-reduction value.
mV = millivolts
NAL = not analyzed

Quarry Hydrogeologic Data Analysis

Groundwater flow at the Quarry is monitored using all of the wells in the long-term monitoring network. The static groundwater levels of the monitoring network are measured at least quarterly to establish that groundwater flow has not changed significantly and resulted in shifts in potential contaminant migration. The average groundwater elevations measured in 2010 were used to construct a groundwater surface map of the shallow bedrock and alluvium at the Quarry (Figure 42). Groundwater flow is parallel to the bedrock bluff of the Quarry as it moves south beneath the Femme Osage Slough. The configuration of the shallow groundwater surface has remained relatively unchanged from previous years.

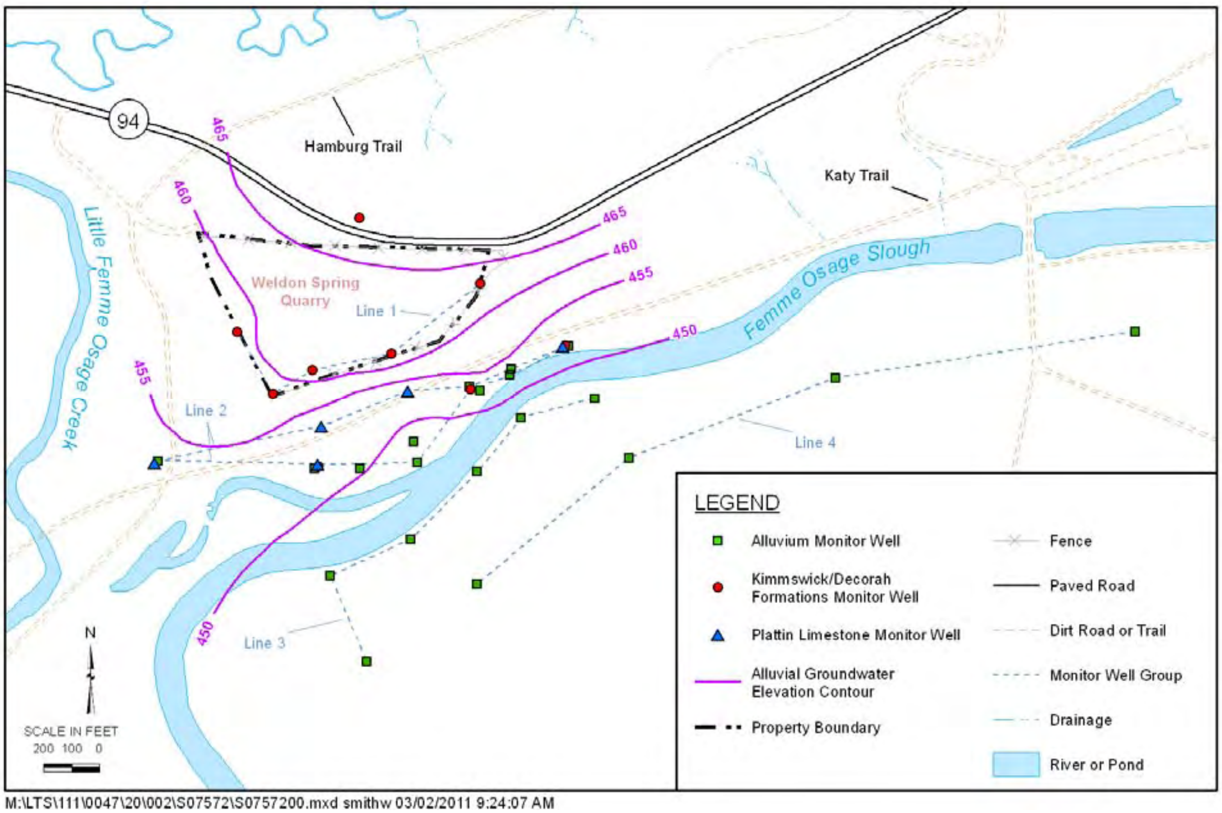

Figure 42. Groundwater Surface at the Weldon Spring Quarry

Groundwater elevations in the Quarry Area fluctuate significantly (Figure 43), primarily in response to the level of the Missouri River. The level in the Missouri River does not influence bedrock wells along the Quarry rim (Line 1) as much as it does the wells in the Missouri River alluvium (Lines 2, 3 and 4). In 2006, water levels were extremely low due to drought conditions in the Quarry Area, and continued into early 2008. Water levels have generally increased in the Quarry Area since that time.

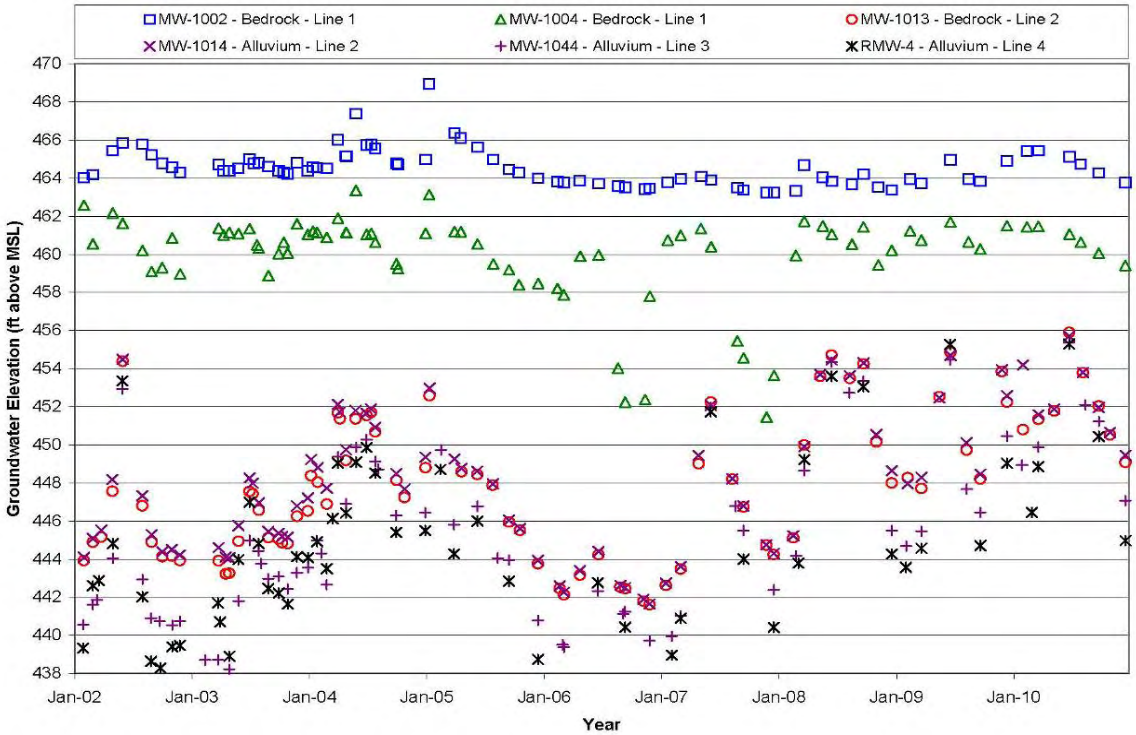

Figure 43. Groundwater Elevations in the Quarry Area

6.4.3 Disposal Cell Monitoring Program

The disposal cell groundwater detection monitoring network consists of one upgradient well (MW-2055), four downgradient wells (MW-2032, MW-2046, MW-2047, and MW-2051), one downgradient spring (SP-6301), and the disposal cell leachate. Semiannual detection monitoring began in mid-1998, after cell construction and waste placement activities had begun.

Under the monitoring program for the disposal cell, the monitoring wells, spring, and leachate are sampled semiannually (in June and December). Groundwater and surface water samples are analyzed for the analytes listed in Table 65. Leachate was analyzed for the analytes listed in Table 66. Sampling was performed as specified in Appendix K of the LTS&M Plan (DOE 2008c). The present modified program is a result of a review of the leachate and groundwater data. The rationale for modification of the program is contained in Appendix K of the LTS&M Plan.

The performance of the disposal cell is gauged on the concentrations of signature parameters in the groundwater. Signature parameters are those constituents present in the leachate at concentrations that are at least 1 order of magnitude greater than in the underlying groundwater. Initially, barium, iron, manganese, and uranium were identified as signature parameters for the leachate. In 2008, the list was reduced to include only barium and uranium. Under the monitoring program, signature parameter data from each monitoring event are compared to the BTLs to trace general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. Tolerance limits for signature parameters have been calculated using the data set from 1997 through 2002, using 95 percent confidence limits.

Table 65. Disposal Cell Detection Monitoring—Groundwater and Surface Water Analyte List

Radiological	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Arsenic Barium Chromium Lead Manganese Nickel Selenium Thallium Uranium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT NB	PCBs PAHs	pH Temperature Specific conductance

Abbreviations:
DNB = dinitrobenzene
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TNB = trinitrobenzene
TNT = trinitrotoluene

Table 66. Disposal Cell Detection Monitoring—Leachate Analyte List

Radiological	Inorganic Ions	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Chloride Fluoride Nitrate (as N) Sulfate	Arsenic Barium Chromium Cobalt Iron Lead Manganese Nickel Selenium Thallium Uranium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT NB	PCBs PAHs	pH Temperature Specific conductance COD TDS TOC Turbidity

Abbreviations:
COD = chemical oxygen demand
DNB = dinitrobenzene
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TDS = total dissolved solids
TNB = trinitrobenzene
TNT = trinitrotoluene
TOC = total organic carbon

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if there are changes in the groundwater system. Data are compared to the 3 most recent years of data to determine if statistically significant changes in concentrations are present. A measured concentration is considered statistically significant if it is greater than the arithmetic mean plus 3 times the standard deviation for a given location.

Wells with data showing statistically significant increases or decreases are re-sampled to confirm the exceedance. If the results of the re-sampling confirm the exceedance, historical leachate analytical data and volumes are evaluated to assess the integrity of the disposal cell. If the leachate data do not indicate that the exceedance could be the result of leakage from the cell, the analytical data are assessed, and site-wide monitoring data are reviewed. If the exceeding parameter is a COC for the GWOU, this information is evaluated under the monitoring program for that OU.

6.4.3.1 Disposal Cell Monitoring Results

The monitoring results for the signature parameters collected from 2006 through 2009 are presented in Table 67 along with applicable BTLs. The results were less than the applicable BTLs, which indicates that there is no statistical evidence of leakage into the groundwater beneath the disposal cell. The general groundwater quality in the detection monitoring wells and springs during this period were consistent with historical data.

The monitoring results for the disposal cell leachate are presented in Table 11. The LCRS is sampled semiannually, and the data are used for comparison with corresponding concentrations in wells if elevated levels of constituents are identified in the groundwater. In general, the composition of the leachate has remained stable over the past 5 years, with the exception of iron, manganese, and uranium. These three constituents have shown a general decline.

6.4.3.2 Groundwater Flow

Groundwater flow rate and direction are evaluated annually as specified in Appendix K of the LTS&M Plan (DOE 2008c). The groundwater flow direction was determined by constructing a potentiometric surface map of the shallow aquifer using the available wells at the Chemical Plant (Figure 31). The configuration of the potentiometric surface has remained relatively unchanged since the construction of the disposal cell. The groundwater flow direction is generally to the north. A groundwater divide is present along the southern boundary of the site.

The average groundwater flow rate (average linear velocity) is calculated using the following equation:

$$v = -Ki/n_e$$

Where: v = velocity
K = average hydraulic conductivity
i = hydraulic gradient
n_e = effective porosity

The average hydraulic conductivity (K) using data from the cell monitoring wells is 7×10^{-3} centimeters per second. An effective porosity (n_e) of 0.10 was selected to estimate the maximum groundwater flow rate in this area. The hydraulic gradient (i) in the disposal cell area is 0.011 foot per feet and is based on data from MW-2032 and MW-2055, located 2,100 ft apart. This approach is consistent with the calculations presented in Appendix K of the LTS&M Plan. The average flow rate for 2010 was 2.2 ft per day, which is the same as the average flow rate calculated since 2005.

Table 67. Signature Parameter Results and Associated BTLs at Disposal Cell Monitoring Locations (2006–2010)

Parameter	Location	BTL	Results									
			June 2006	Dec 2006	June 2007	Dec 2007	June 2008	Dec 2008	June 2009	Dec 2009	June 2010	Dec 2010
Barium (µg/L)	MW-2032	337	186	155	135	165	222	145	220	195	152	201
	MW-2046	277	217	214	204	205	229	180	201	189	185	179
	MW-2047	471	403	373	344	329	396	363	359	334	323	354
	MW-2051	285	201	200	187	190	248	240	235	237	226	239
	MW-2055	98	19.1	19.6	17.7	18.3	20.9	18.4	18.9	18.4	17.4	18.1
	SP-6301	180	130	140	131	125	104	144	98.4	103	104	113
Uranium (pCi/L)	MW-2032	6.4	2.5	4.2	4.2	2.4	2.5	2.7	2.6	2.8	2.5	2.3
	MW-2046	1.8	1.2	1.0	1.2	1.0	1.4	1.2	1.3	1.3	1.0	1.1
	MW-2047	2.7	1.3	1.2	1.3	1.2	1.2	1.2	1.3	1.2	1.1	1.2
	MW-2051	4.5	1.2	1.3	1.3	1.2	1.5	1.4	1.5	1.4	1.1	1.2
	MW-2055	7.5	2.1	1.8	2.5	1.9	2.1	2.1	2.1	1.9	1.7	1.7
	SP-6301	159	33.3	78.5	74.5	47.8	37.5	63.9	19.7	24.9	30.1	26.9
Iron (mg/L)	MW-2032	1,125	ND	ND	ND	ND						
	MW-2046	1,578	80.6	ND	373	414						
	MW-2047	1,485	ND	ND	27.3	ND						
	MW-2051	2,896	ND	ND	ND	ND						
	MW-2055	10,579	30.2	ND	ND	46.5						
	SP-6301	2,608	299	228	28.7	197						
Manganese (mg/L)	MW-2032	57	9.7	4.6	ND	ND						
	MW-2046	187	5.2	5.3	24.5	27.5						
	MW-2047	171	ND	4.4	6.2	ND						
	MW-2051	265	ND	1.3	ND	ND						
	MW-2055	179	2.5	2.8	ND	ND						
	SP-6301	88	3.5	5.0	ND	4.6						

BTL = baseline tolerance limits; µg/L = micrograms per liter; mg/L = millgrams per liter; ND = not detected; pCi/L = picocuries per liter

6.5 Site Inspection

The Weldon Spring Site, located in St. Charles, Missouri, was inspected October 26-28, 2010. The inspection was conducted in accordance with the *LTS&M Plan for the Weldon Spring, Missouri, Site* (DOE 2008c), and the updated inspection checklist. Representatives from DOE, the DOE contractor S.M. Stoller, EPA, and MDNR participated in the inspection. Representatives from MoDOT, MDC, and St. Charles County participated in portions of the inspection. The Weldon Spring Site is a CERCLA site. This inspection also served as the five-year review inspection to support the site's CERCLA Five-Year Review Report.

The main areas inspected at the site were areas where future ICs will be established, the Quarry, the disposal cell, LCRS, monitoring wells, and assorted general features.

The IC areas were inspected to ensure that pending restrictions such as excavating soil, groundwater withdrawal, residential use, etc., were not being violated. Each area was inspected and no indications of violations of future restrictions were observed.

An aerial survey of the disposal cell was flown in May 2010. This survey is required by the LTS&M Plan and checklist to be conducted every five years in conjunction with the 5-year review inspection. The previous aerial survey was conducted in 2005 in conjunction with the previous five-year review and in 2003 in conjunction with the first annual LTS&M inspection. The survey results were discussed during the inspection

The disposal cell was inspected by walking ten transects over the cell and around the cell perimeter. Hand-held GPS equipment was used to navigate the ten transects. Five areas of the cell which had been marked and located by GPS survey equipment during the 2003 annual inspection were located and observed for any signs of rock degradation. The LCRS was also inspected and found to be in good condition. Sixty-nine of the 124 groundwater-monitoring wells were inspected and generally were in good condition. Other site features including the prairie, site markers, and roads also were inspected.

As preparation for the Five-Year Review, the LTS&M requires that DOE contact MDNR to determine if well registrations were issued for the groundwater restricted area. The Wellhead Section of MDNR was contacted and in response to this request they sent a letter stating that there were no wells of record (other than monitoring wells associated with the site) drilled within this area since January 2004. The letter is attached in Appendix C.

At the time of the inspection nine personnel from S.M. Stoller Corporation (Stoller), the Technical Assistance Contractor at the U.S. Department of Energy (DOE) office in Grand Junction, Colorado, were employed full-time at the site. Some of these employees also support other Legacy Management sites around the nation. Also employed at the site were nine part-time contractor and subcontractor employees

This report presents the results of the DOE annual inspection of the Weldon Spring Site. The following personnel from Stoller were the lead inspectors during the inspection:

Terri Uhlmeyer, Weldon Spring Site
Randy Thompson, Weldon Spring Site

The following support personnel from Stoller participated in the inspection:

Tom Welton, Weldon Spring Site
Tim Zirbes, Weldon Spring Site
Becky Cato, Weldon Spring Site

The following personnel observed the inspection and provided oversight:

Vijendra Kothari (DOE)
Jane Powell – DOE
Hoai Tran – EPA, Region VII
Patrick Anderson – MDNR
Hannah Humphrey – MDNR
Kevin Wideman – MoDOT
John Vogel – MDC
Pieter Sheehan – St. Charles County Health
Ryan Tilley – St. Charles County Health
Yvonne Deyo – Stoller

The inspection was conducted in accordance with the *LTS&M Plan for the Weldon Spring, Missouri, Site* (DOE 2008c). The inspection checklist, which is from Appendix H to the LTS&M Plan, is included in Appendix B. The checklist was derived from the checklist included in the EPA CERCLA Five-Year Review guidance.

The inspection base maps, which include the location of the photographs, are included as Figure 44 and Figure 45. The inspection photos are included in Appendix B.

6.5.1 Institutional Controls

Section 2.3.4 of the LTS&M Plan states "DOE will conduct a formal annual inspection of the physical locations addressed by ICs. DOE also will evaluate whether the ICs remain effective in protecting human health and the environment and, in coordination with EPA and MDNR, will take appropriate action if evidence indicates the controls are not effective."

The Weldon Spring Site has made progress on the attainment of the instruments for institutional controls, although some are still pending and not yet formally in place. The institutional controls attained during 2009 were the signed revised Memorandum of Understanding (MOU) with the Army to specify the groundwater use restrictions contained in the Explanation of Significant Difference (ESD) and to further enhance DOE's access for the purpose of environmental monitoring and for surveillance of the restricted area and an easement on the MDNR-Parks property to implement the groundwater use restriction on that property. The institutional controls that are in place prior to 2009 include a Notation of Land Ownership on the Chemical Plant and Quarry Property which is filed with St. Charles County; the interpretive center; a license granting DOE permission to abandon or install and operate groundwater wells and perform sampling; and a license granting DOE continued operation and maintenance of the effluent discharge pipeline that runs from DOE property to the Missouri River and through the Katy Trail. The "Special Use Area" under the Missouri Well Code was finalized in the Missouri regulations in August 2007.

This is a special regulation that designated the DOE and Army's groundwater restricted areas as special areas that require additional drilling protocols and construction specifications to be imposed by MDNR on any future domestic wells. The final LTS&M also lists the following additional ICs that DOE has been pursuing:

> DOE will negotiate with the surrounding affected State agency property owners (Missouri Department of Conservation and Missouri Department of Transportation) to acquire easements that implement the groundwater and land use restrictions contained in the ESD, and to further enhance DOE's access for the purpose of environmental monitoring and for surveillance of the restricted area.

During the inspection, the final and pending institutional control areas were inspected in accordance with the current information in the LTS&M Plan. Figure 46 and Figure 47 are the institutional control location maps from the LTS&M Plan.

The institutional control areas are listed below as they are stated in the inspection checklist.

6.5.2 Land and Shallow Groundwater Use within the Site Proper Boundary (Outside Disposal Cell Buffer Zone)

Inspect for indications of excavations into soil or bedrock and groundwater withdrawal or use in restricted areas. If any party has been granted use of portions of the Chemical Plant area, inspect to ensure that land use is in compliance with the terms of the restrictions within the notation.

Inspection Results: This area was inspected and no indications of excavations into soil or bedrock, groundwater withdrawal, or use were observed. Lindenwood University has been granted use of the Administration Building and its use is consistent with the agreement. Current land use remains consistent with the planned institutional controls.

6.5.3 Land and Shallow Groundwater Use at DOE Site Proper Disposal Cell and Buffer Zone

Inspect for indications of excavations into soils and bedrock, and for residential use of the shallow groundwater within the buffer zone. Inspect to ensure that the land use continues to be in compliance with the terms of the restrictions within the notation.

Inspection Results: This area was inspected and no indications of excavations into soils and bedrock, and no residential use of the shallow groundwater within the buffer zone were observed. Current land use remains consistent with planned institutional controls.

6.5.4 Groundwater Use in Areas Surrounding the Chemical Plant

Groundwater use will be restricted in this area. Inspect affected areas for evidence of groundwater or spring water use (Burgermeister Spring and Spring 6303). Inspect to ensure that land use continues to be in compliance with the terms of the license, easement, or permit and the restrictions contained therein.

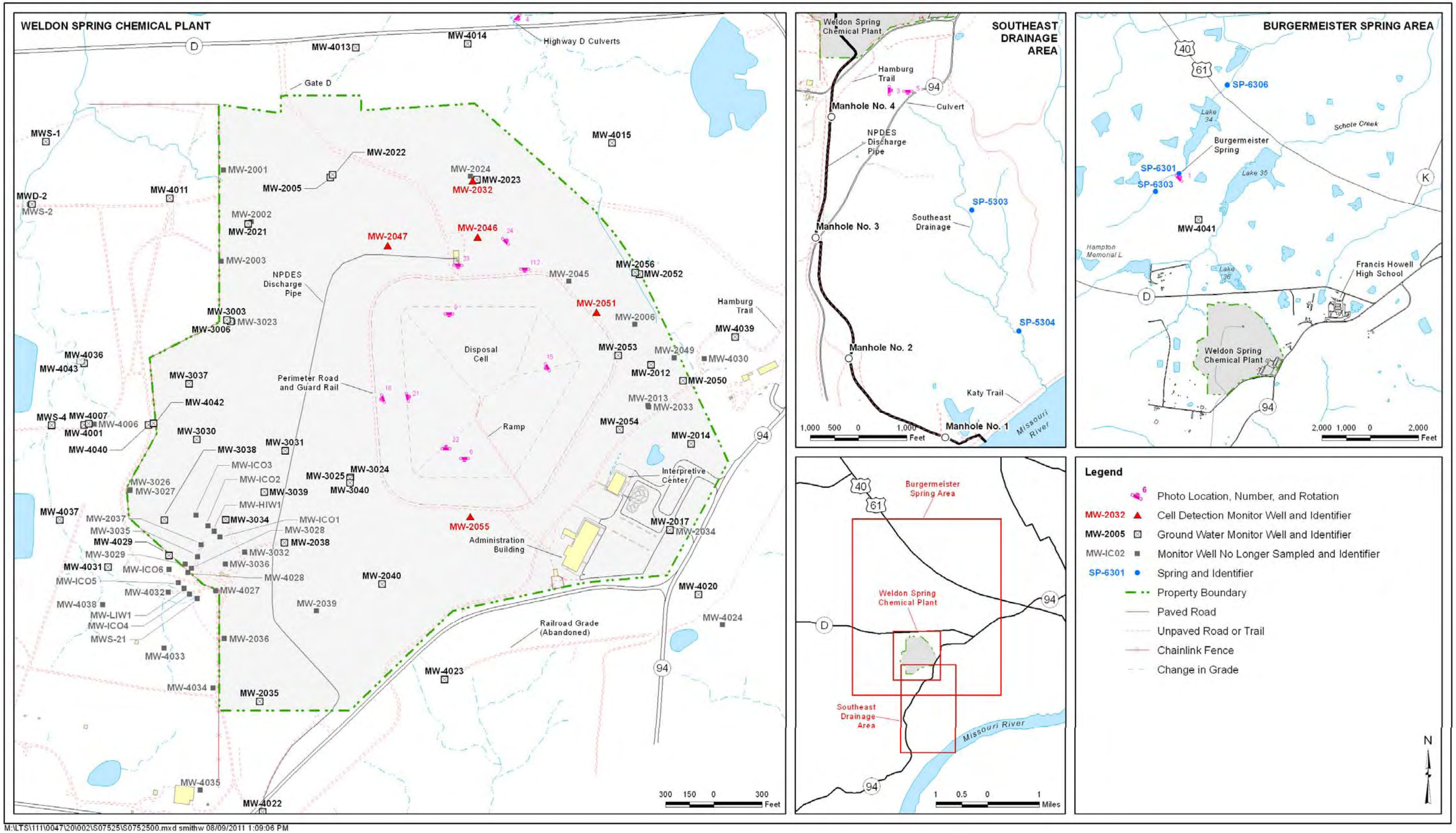

Figure 44. 2010 Inspection Map for the Chemical Plant Area of the Weldon Spring, Missouri, Site

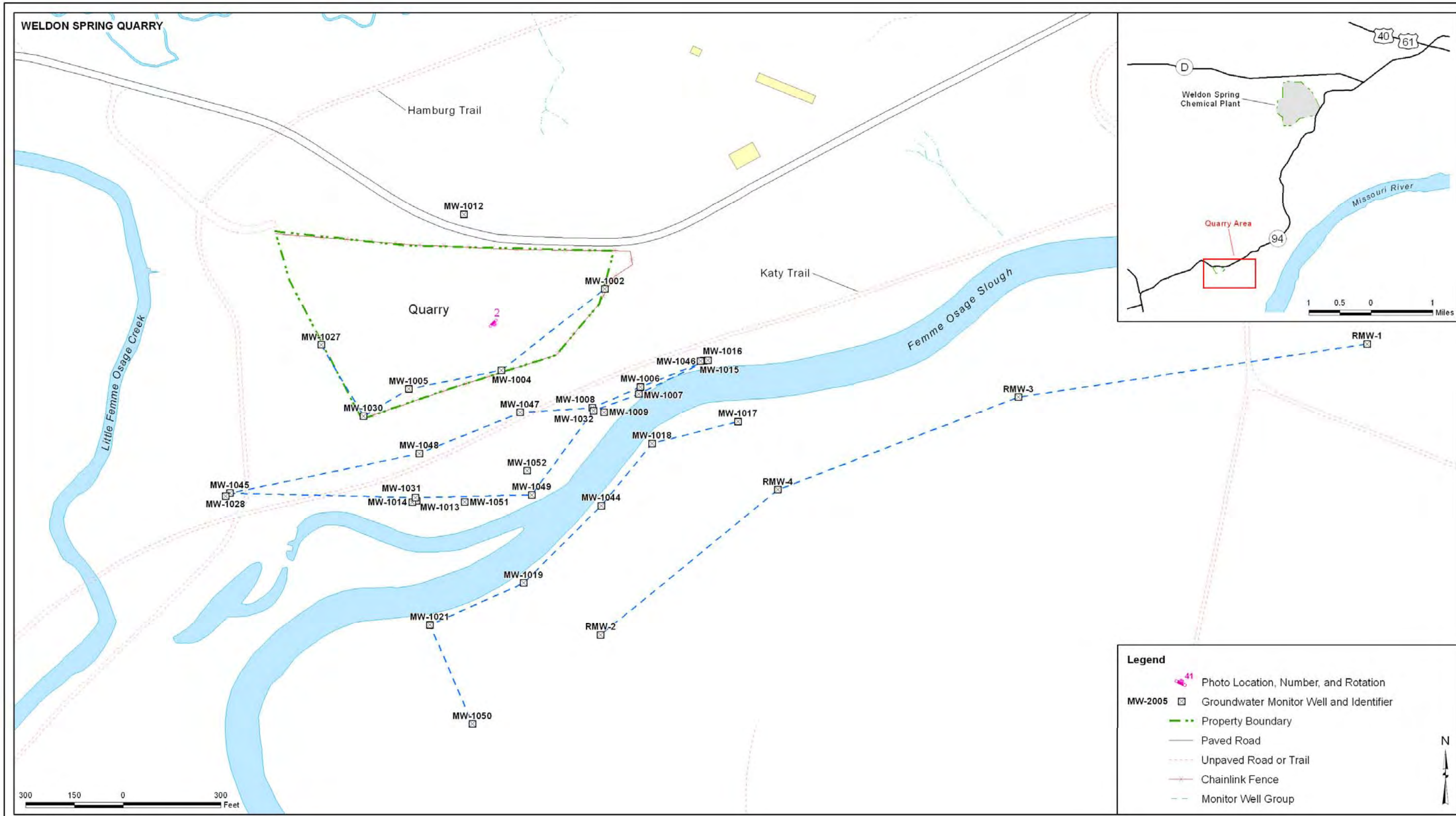

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Figure 45. Inspection Map for the Quarry Area of the Weldon Spring, Missouri, Site

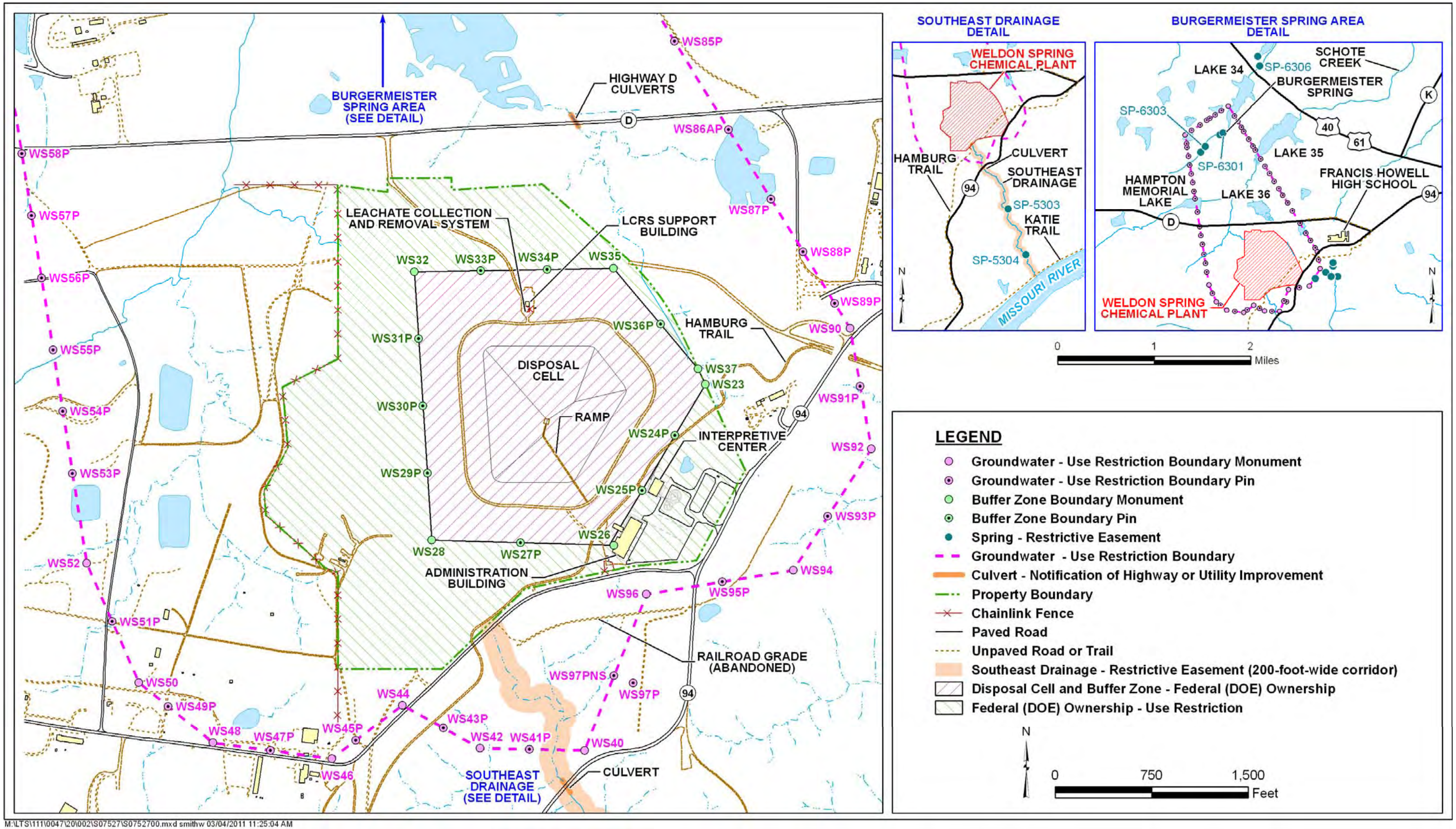

Figure 46. Institutional Controls Location Map for the Chemical Plant Area

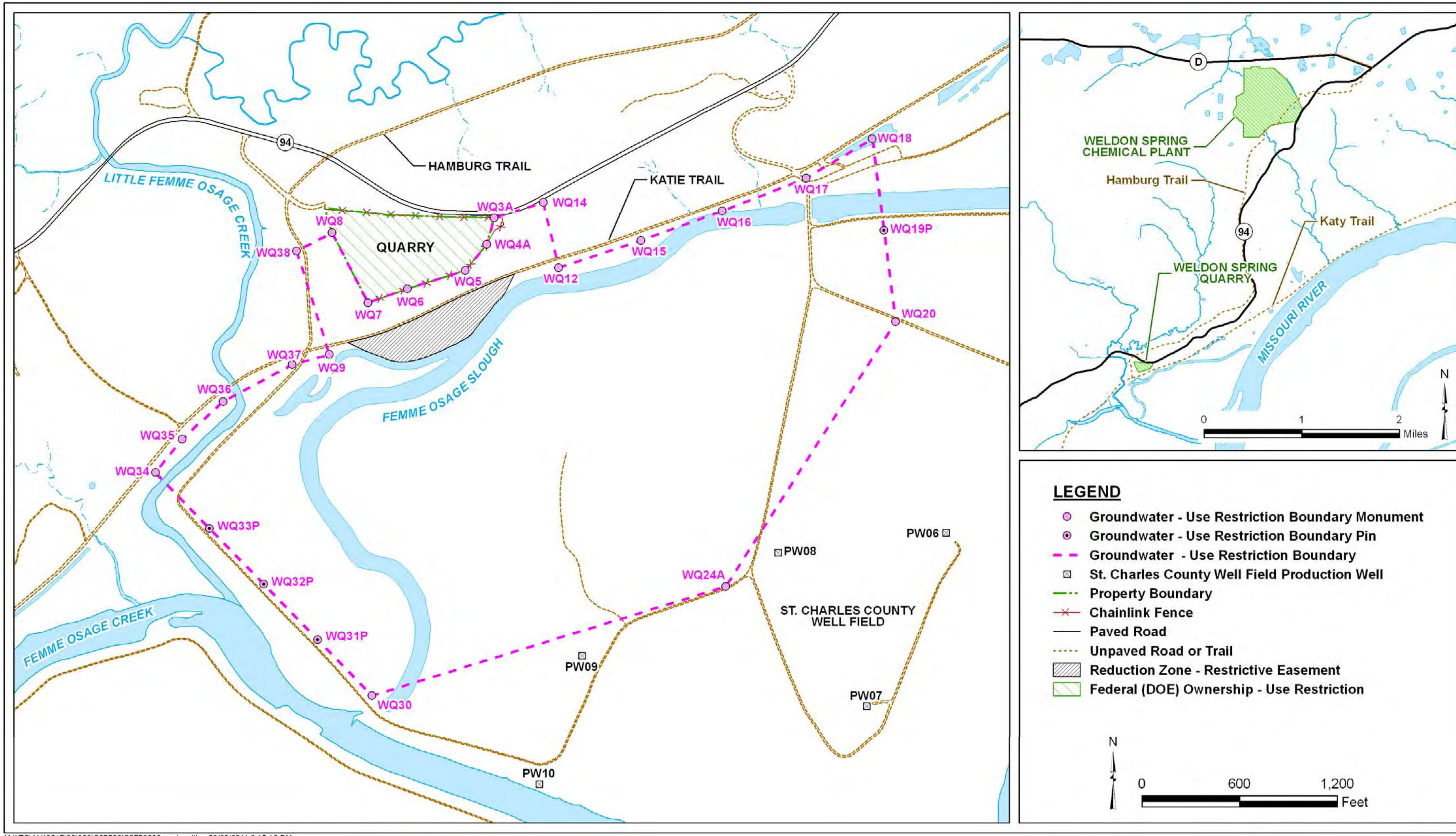

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Figure 47. Institutional Controls Location Map for the Quarry Area

Inspection Results: The surrounding area where groundwater use will be restricted was inspected. This includes property owned by MDC and the Army. No evidence of groundwater use was observed and current land use remains consistent with planned institutional controls on both properties. Burgermeister Spring 6301 (Photo 1) and Spring 6303 on MDC property were inspected and there were no indications of spring water use. Spring 6303 was not flowing. On the Army property, survey monument WS46, was inspected. The Chemical Plant groundwater restriction area boundary monuments are shown in Figure 46. All the monitoring wells inspected were locked. There were some monitoring wells that needed the contact label replaced and some that needed painting. One well had two bollards that were loose. The Army is constructing a new reserve center outside it's fenceline and has plans to build a larger center inside the fence in the next few years. The boundary monument WS90 was located and it was noted that it had been broken and needs repaired.

6.5.5 Land and Shallow Groundwater Use on the DOE Quarry Property

Inspect for indications of excavations into soil or bedrock and groundwater withdrawal or use in restricted areas. If any party had been granted use of portions of the Quarry Area, inspect to ensure that land use is in compliance with the terms of the restrictions within the notation.

Inspection Results: The Quarry Property was inspected and no indications of excavation into soil or bedrock, groundwater withdrawal, or use were observed. Also, no party has been granted use of portions of the Quarry Area. Quarry backfill continues to provide positive drainage from the Quarry to the Little Femme Osage Creek and vegetative cover remains well established (Photo 2). Current land use remains consistent with planned institutional controls.

6.5.6 Groundwater (Quarry)

Groundwater use is restricted in certain areas. Inspect affected areas for evidence of groundwater withdrawal or use in the area of impact. Inspect to ensure that land use continues to be in compliance with the terms of the license and the restrictions contained therein.

Inspection Results: The groundwater-restricted area was inspected and no evidence of groundwater withdrawal or use in the area was observed. The Quarry groundwater restriction area boundary survey monuments are shown in Figure 47. The following survey monuments were located during the inspection: WQ7, WQ8, WQ10, WQ11, and WQ12. It was noted that WQ12 needs to be restamped.

6.5.7 Land Use in Quarry Area Reduction Zone

A naturally occurring reduction zone exists in soil south of the Katy Trail and north of the Femme Osage Slough. Inspect for indications of excavations into soils and bedrock in the uranium reduction zone. Inspect to ensure that land use continues to be in compliance with the terms of the easement and the restrictions contained therein.

Inspection Results: The Quarry reduction zone area was inspected and no indications of excavation into soils and bedrock were observed. As required by the final LTS&M Plan, information signage and contact numbers were posted on monitoring wells at the Quarry Area reduction zone. The labels indicate no digging is allowed in this area and include contact numbers for DOE and MDC. Land use remains consistent with planned institutional controls.

6.5.8 Southeast Drainage

Check for indications of residential use or construction in the Southeast Drainage (200-foot-wide-corridor), or other activity that would indicate non-recreational use of the area. Check Springs 5303 and 5304 for residential, commercial, or agricultural use of spring water.

Inspection Results: The inspectors walked down the entire Southeast Drainage 9 (Photo 3) and no indications of residential use, construction, or any other activity that would indicate non recreational use of the area were observed. The springs also were inspected and no indications of residential, commercial, or agricultural use of the springs were observed. Both of the springs were observed to be flowing. Current land use remains consistent with planned institutional controls.

6.5.9 Highway D Culvert

Check for signs of disturbance of the affected region where the Frog Pond outlet culverts pass beneath Highway D and in the utility rights-of-way in the affected area.

Inspection Results: The Highway D culverts were inspected (Photo 4). No disturbance or changes were noted. It was noted that MoDOT plans to widen the shoulders on Highway D next spring, therefore, DOE has agreed to work with MoDOT and assist in removing the contaminated culverts and soil in this area. Coordination is underway regarding this activity.

6.5.10 State Route 94 Culvert

Check for signs of disturbance of the affected region where the culvert passes beneath State Route 94 and in the utility rights-of-way in the affected area.

Inspection Results: The State Route 94 culvert was inspected and it was noted that Stoller representatives had cut off a portion of the culvert (Photo 5) in August 2010 at the request of MoDOT. The culvert pieces that were removed are stored in a container in a Conex box behind the LCRS building.

6.5.11 Pipeline from LCRS to Missouri River

Inspect the entire length of the pipeline and outfall for any disturbance or maintenance needs.

Inspection Results: The pipeline was inspected. GPS surveying equipment was used to find the locations of the manholes and cleanouts. A map of the pipeline, indicating the manhole locations, is shown in Figure 7. It was noted that there were no on-site disturbances of the pipeline and there were no apparent disturbances in the area of the pipeline or manholes in the off-site areas.

6.5.12 Disposal Cell

The disposal cell was inspected in accordance with the LTS&M Plan (Photo 6) and the annual inspection checklist. The cell was divided into ten transects (Figure 48). The inspectors separated into two groups and walked five transects each. The inspectors looked for depressions, shifts of cell plane vertices, and other indications of settlement. Other items for inspection were vegetation, wet areas, apron drains, guardrail, and the stairs. A GPS unit was used during the 2003 inspection to map five areas chosen for rock degradation review (Figure 48). The inspectors took photographs of these and compared them to photographs from the previous inspection of the same areas and observed no rock degradation. These areas are shown from the original inspection in 2003, last year, and this year for comparison in Photos 7 through 21. It was noted that some rocks had been removed from the Test Plot #5. Rocks had also been displaced along Transect 5 to make a small hole (Photo 22). It was recommended during the inspection that the site place signs on the disposal cell stating that video surveillance is being conducted.

In accordance with the checklist the inspectors also checked for wet areas or water drainage and observed that none were present. The toe and apron drains were inspected and found to be functioning as designed. The guardrail and stairs were in good condition. No vegetation was found on the disposal cell during the inspection. It has been observed the past two years that much of the rock is darker than in previous years and is assumed to be due to weathering. The darkened rock is not an issue that could compromise the disposal cell, just an observation of a changed condition.

Aerial surveys are required by the LTS&M Plan to be performed in conjunction with the CERCLA five-year reviews. The survey is required to be conducted with a vertical resolution no less precise than 0.5 feet and map and survey data to be produced with the cell surface represented by 1.0-foot contour intervals. The data are reviewed for indications of possible settlement. The first survey was performed in 2003 as a baseline and subsequent surveys were performed in 2005 and 2010, in conjunction with the CERCLA Five-Year reviews.

A comparison on the baseline topography from 2003 to the 2010 topography indicates general uniform settlement in the cell no more than 2 ft (Figure 49). The side slopes are stable showing no evidence bulging or slumping.

6.5.13 Leachate Collection and Removal System

Operations of the LCRS were discussed with site personnel and the system was inspected (Photo 23). The fences and doors were locked and in good condition. The system was functioning as designed. The LCRS data and documentation were reviewed during the document review period of the inspection and the following information was checked and verified that it was available: sampling data, LCRS flow rates, action leakage rate information, “burrito” system flow rates, and leachate data. The leachate data and information are discussed in Section 4.1.2.1.

The DOE continues to exercise its pretreatment contingency process equipment by pretreating the leachate through a system of cartridge filters and ion exchange media that is selective for uranium. The leachate is sampled and continues to be well below the limit for uranium. The leachate will continue to be managed in this manner until the leachate is consistently below the 20 pCi/L level for uranium.

The ion exchange vessel has been labeled as “Potential Internal Contamination” based on the potential for uranium to accumulate in the resin.

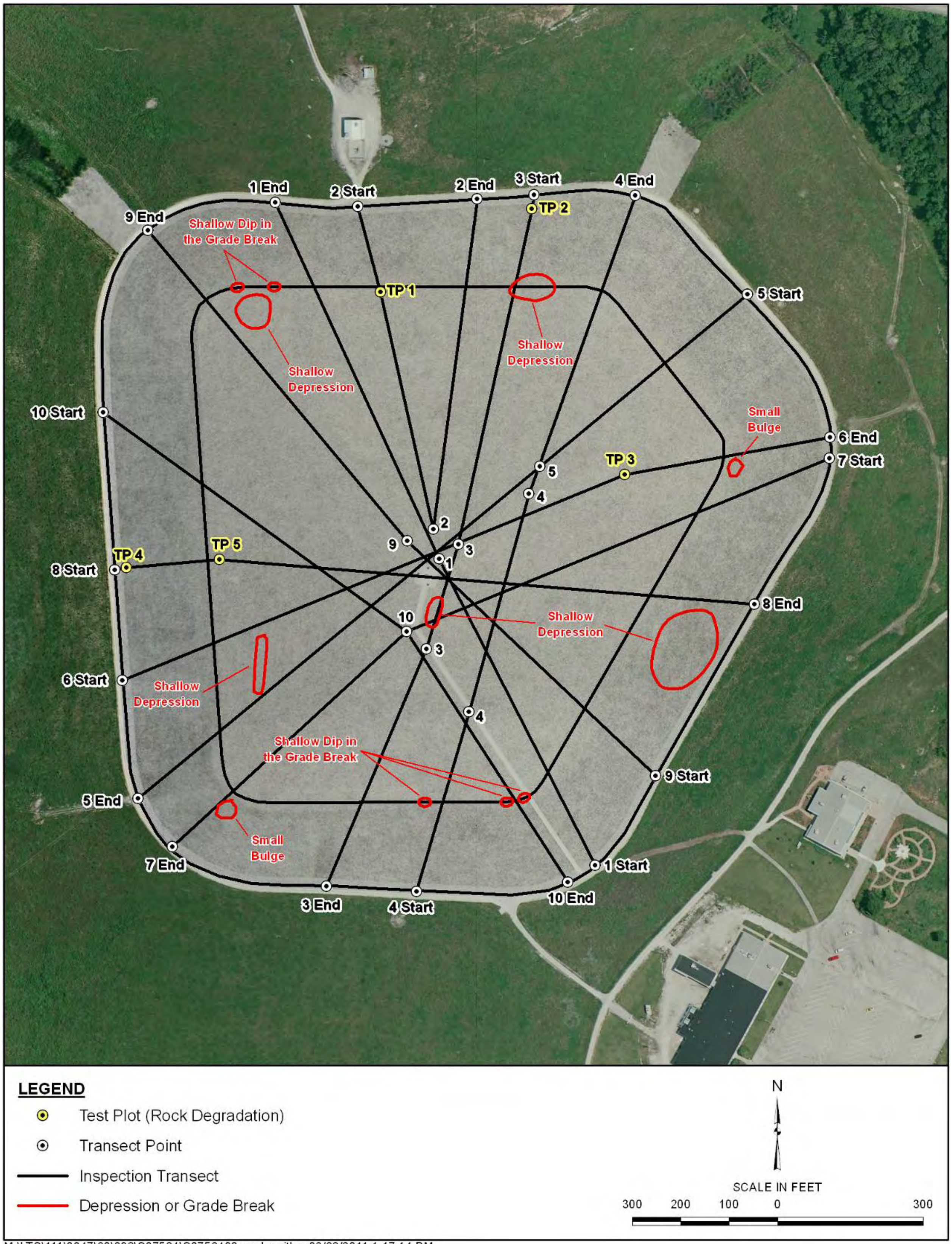

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Figure 48. Disposal Cell Inspection Transects and Rock Test Plot Locations at the Weldon Spring, Missouri, Site

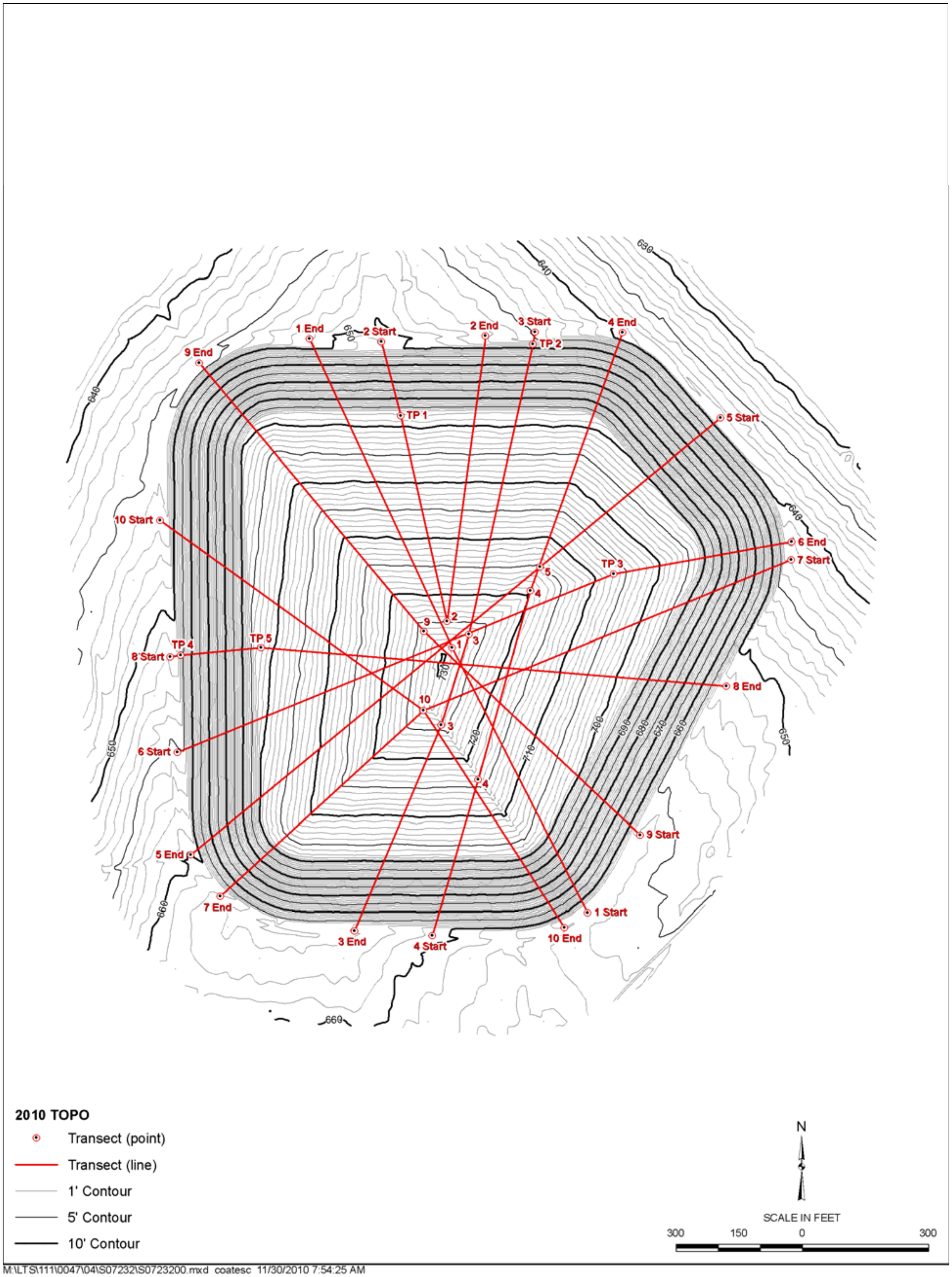

Figure 49. Aerial Survey

6.5.14 Erosion

6.5.14.1 Chemical Plant Area

Areas of erosion in the prairie were identified during the 2006 inspection and it was recommended that the prairie be inspected more thoroughly, the erosion areas be located and mapped by GPS, and that erosion areas be repaired. Erosion channels within the entire prairie were mapped with GPS in August 2007 and again in June 2008, June 2009, and May 2010 (Figure 50). The resulting information will be used to track the nature and extent of erosion in the future.

A field survey to evaluate erosion issues in the prairie was performed on August 2, 2007. The following individuals participated in the survey: Yvonne Deyo (Stoller, Weldon Spring Project Manager), Marilyn Kastens (Stoller soil reclamation specialist), Ben Moore (MDNR), Raymond Franson (MDNR), Frank Oberle (Pure Air Native Seed), and Jon Wingo (DJM Ecological Services). It was determined that existing erosion was temporary, typical of a newly reclaimed site in the process of stabilizing. It was recommended to monitor erosion channels and evaluate the other possible soil amendment and/or vegetation management strategies. Soil disturbance of any kind was not recommended at this time. The report that was prepared to document this trip was reviewed by the inspection participants during the 2007 inspection and included in the 2007 report.

In September 2009, a group of Legacy Management Support subject matter expert personnel met to discuss the current status of site erosion. It was determined that existing erosion continued to be fairly typical for a reclaimed site and no channels were currently a threat to the integrity of the disposal cell. The group agreed that continued monitoring of erosion would be prudent. The erosion will continue to be monitored and another mapping and evaluation is scheduled for the spring/early summer 2011.

It was noted during the 2010 inspection that vegetation had taken over some of the worst erosion areas located on the north side of the disposal cell considerably (Photo 24).

Quarry Area

No erosion areas were noted during the inspection of the Quarry Area.

6.5.15 General Site Conditions

General site conditions as listed in the checklist were inspected and are discussed below.

6.5.15.1 Roads

The roads consist of asphalt roads leading into the property and a gravel road that extends around the disposal cell and to Gate D. The roads were in good condition.

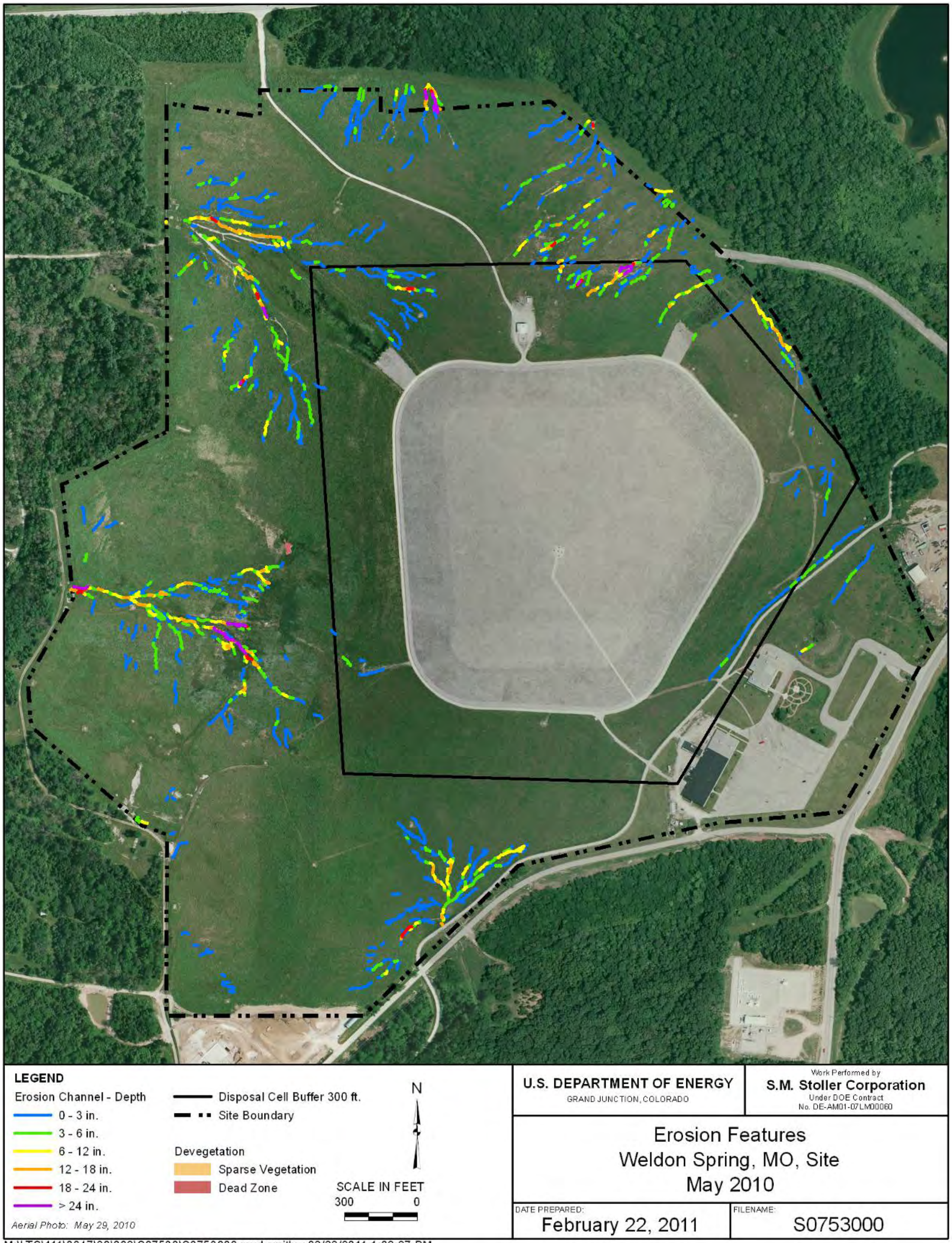

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Figure 50. Erosion Features

6.5.15.2 Vandalism

Although the site is publicly accessible, signs are clearly posted at the disposal cell that the viewing platform is open during daylight hours only. Increasing evidence of nighttime access of the viewing platform has been noted. Public use of the site continues to rise. Because of on-going issues associated with this use (e.g., littering at various locations throughout the site including at the top of the disposal cell, occasional discovery of illegal drug paraphernalia, etc.), a private security firm has been hired to provide seasonal patrol coverage of the site during the evening hours. These patrols, along with the upgraded safety-oriented security system have dramatically curtailed the degree of undesirable activities at the site.

The disposal cell monument plaques were observed to have been vandalized during 2010. The corners of the plaques have been bent down by the use of excessive force. The plaques are still functional and nothing further will be done at this time.

6.5.15.3 Personal Injury Risks

No personal injury risks were observed.

6.5.15.4 Site Markers

The four information plaques on top of the cell were generally in good condition (See Section 6.5.15.2.). There was vandalism noted to the plaques in that the corners had been bent down from the use of excessive force as noted above. The historical markers were inspected and were in good condition.

The plan also states that signs are posted on the LCRS fence to inform the public that trespassing is forbidden and that persons may call the DOE 24-hour security telephone number (970-248-6070 or 877-695-5322) for information. During the 2010 inspection, it was noted that these signs were posted on the LCRS fence.

6.5.16 Monitoring Wells

Monitoring wells in the Disposal Cell Monitoring Well Network, Chemical Plant Monitoring Well Network, and Quarry Monitoring Well Network were inspected. The inspection checklist required all the disposal cell wells to be inspected, and greater than 10 percent of the Chemical Plant and Quarry wells to be inspected. The checklist required the wells to be inspected to ensure they are properly secured and locked, in good condition, and to check if they need maintenance and have the proper ID number on the well. All of the wells that were inspected met the majority of these requirements. There were some wells that required some type of maintenance.

- Need new contact label: MW-4020, 4031, 4006, 4007, 4002, 2014, 2017, 2034, 4041, 205, 3003.
- Need new well numbers: MW-2055, 3024, 3025, 3037
- Need painted: MW-1052, 2017, 2034, 4041
- Loose ballards: MW-1049, 2023, 4029

It should be noted that each well is inspected at least quarterly during the year when static water levels are recorded and that well maintenance and painting is ongoing. The wells are listed below for identification purposes.

At the time of the inspection it was discussed that abandonment of 16 wells was to begin during the week of November 1, 2010. These wells are listed below:

MW-2034, 2045, 3032, 3035, 3036, 4002, 4024, 4034, HIW1, LIW1, ICO1, ICO2, ICO3, ICO4, ICO5, ICO6.

It was determined that MW-4035 would be transferred to the Army.

6.5.16.1 Disposal Cell Monitoring Well Network

Each well in the disposal cell network was inspected and is listed below:

MW-2032, 2046, 2047, 2051, 2055.

6.5.16.2 Chemical Plant Area Monitoring Well Network

The inspection checklist requires at least 10 percent of the wells be inspected from the Chemical Plant monitoring well network. The monitoring well network consists of 85 wells owned by DOE and 4 wells owned by the Army. This number does not include the 5 disposal cell wells, although some of those wells are monitored for the groundwater remedy. Forty-nine wells were inspected (58%). Only fifty wells are monitored for the groundwater remedy of monitored natural attenuation. The remaining wells are monitored quarterly for static water levels only. The wells that were inspected are listed below:

MW–2006, 2012, 2013, 2104, 2017, 2023, 2024, 2033, 2034, 2045, 2046, 2049, 2050, 2053, 3003, 3006, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3031, 3037, 3040, 4001, 4002, 4006, 4007, 4020, 4027, 4028, 4029, 4030, 4031, 4034, 4035, 4035, 4036, 4039, 4040, 4041, 4042, 4043, ICO4, ICO5, ICO6, LIWI.

6.5.16.3 Quarry Monitoring Well Network

The inspection checklist requires greater than 10 percent of the wells in the Quarry monitoring well network be inspected. The monitoring well network consists of 34 wells. Fifteen wells were inspected (44%). The wells that were inspected are listed below:

MW–1002, 1004, 1005, 1006, 1007, 1008, 1009, 1013, 1014, 1027, 1030, 1031, 1032, 1049, 1052.

6.5.17 On-Site Document and Record Verification

The following on-site documents and records were verified:

- Surveillance and Maintenance Plan: (*Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri, Site*, December 2008c)
- Maintenance log (Plan of the Day/Week forms)

- NPDES permit(s): #MO–0107701, revised
- Metropolitan St. Louis Sewer District (MSD) agreement and records
- Groundwater monitoring records
- Leachate records
- Interpretive Center sign-in logs
- Telecons and interview records

6.5.18 Contacts

Several stakeholders were notified prior to the inspection in accordance with the checklist. These included:

- St. Charles County Sheriff
- Cottleville Fire District
- Francis Howell High School
- Simplex-Grinnel Alarm System
- St. Charles County

The institutional control contacts also were notified in regard to the inspection and to maintain annual contact with the representatives relevant to institutional controls. In the future, when institutional controls are established, this annual contact will be used to verify cognizance of the institutional controls and the requirements and/or restrictions with each representative. The representatives contacted are listed below.

- John Vogel – Missouri Department of Conservation
- Joel Porath – Missouri Department of Conservation
- Doyle Brown – Missouri Department of Conservation
- Mary Bryan – Missouri Department of Natural Resources – Parks
- Quinn Kellner – Missouri Department of Natural Resources – Parks
- Marsha Miller – Army
- Tom Blair – Missouri Department of Transportation
- Jim Gremaud - Missouri Department of Transportation
- Kevin Wideman - Missouri Department of Transportation

The St. Charles Planning and Zoning Department also was contacted and they verified that no planning and zoning activities were currently taking place within one-quarter mile of the Chemical Plant and Quarry Property. The Notation of Land Ownership was verified to be filed and present at the St. Charles Recorder of Deeds office by checking the county website at www.sccmo.org. It was noted that the county website had changed and this will be corrected in the next annual inspection checklist.

The Stoller Project Manager, Yvonne Deyo, and Environmental Data Manager, Randy Thompson, were interviewed as required by the inspection checklist.

All conversations and interviews were recorded on an Interview Record form from the EPA *Comprehensive Five-Year Review Guidance.* The forms for each of these contacts and interviews are attached as Appendix D.

6.5.19 Findings and Recommendations

1. Recommendation: Wells that required some type of maintenance.

Need new contact label: MW-4020, 4031, 4006, 4007, 4002, 2014, 2017, 2034, 4041, 205, 3003.

Need new well numbers: MW-2055, 3024, 3025, 3037

Need painted: MW-1052, 2017, 2034, 4041

Loose bollards: MW-1049, 2023, 4029

Action: Apply the required maintenance to these wells.

Target Date: June 2011

2. Recommendation: Restamp Survey Monument WQ12

Action: Restamp Survey Monument WQ12

Target Date: The Survey Monument was restamped on November 9, 2010.

3. Recommendation: Place a new rock degradation test plot on the south side of the disposal cell.

Action: Place a new rock degradation test plot on the south side of the disposal cell.

Target Date: July 2011

4. Recommendation: Place signs on the disposal cell stating that video surveillance is in use or similar type action. This is in response to vandalism on the disposal cell, including disturbance of Test Plot #5.

Action: Place signs on the disposal cell stating that video surveillance is in use or similar type action.

Target Date: July 2011

5. Recommendation: Repair Survey Monument WS90 which was broke.

Action: Repair Survey Monument WS90.

Target Date: September 2011

6. Recommendation: Continue to monitor and evaluate erosion on the Chemical Plant Site.

Action: Continue to monitor and evaluate erosion on the Chemical Plant Site.

Target Date: Ongoing.

7.0 Technical Assessment

7.1 Chemical Plant Operable Unit

Question A: Is the remedy functioning as intended by the decision documents?

Answer A: Yes, the remedy is functioning as intended by the decision documents.

7.1.1 Remedial Action Performance

The review of documents and environmental monitoring data and the results of the annual and Five-Year Review inspections indicate that the remedy for the CPOU, which consisted of controlling contaminant sources at the Chemical Plant and disposing of contaminated materials in an engineered on-site disposal facility, is functioning as intended. The disposal cell has remained stable and is in good condition. and based on annual inspections, and groundwater and leachate monitoring is performing as intended.

7.1.2 System Operation and Maintenance

The LTS&M Plan includes system operation and operation-and-maintenance information for the site. DOE also performs annual inspections of site features, systems, and activities, such as the disposal cell, the LCRS, environmental monitoring, and ICs, and has found these areas to be functioning as intended.

7.1.3 Opportunities for Optimization

Several opportunities for optimization have been implemented at the site during the past five-year period:

Leachate level and flow rates are now being uploaded electronically into SOARS. SOARS makes it possible to monitor and track these data remotely instead of having to download the data at the LCRS. The remote data transfer equipment was installed in April 2007 and has been downloading data since then. SOARS records and tracks the leachate sump level and the secondary volumetric containers. Data are transferred via a land-connected phone line several times a day.

Low-flow sampling was implemented at the site, saving time and reducing purge water volumes. The reduced purge water volume resulted in less treatment required.

A level monitor was installed in the primary effluent tank in the LCRS building. This allowed the level in the tank to be more closely monitored without climbing a ladder to look in the top. The new monitor also provides a more accurate measurement than a site tube did.

The purchase and use of a snowblower and deicer spreader has made the site safer during snowy and icy weather. A problem with parking lot drainage causes icy areas to persist. This equipment allows the ice to be addressed first thing in the morning before most of the staff members arrive for work.

Erosion areas in the prairie have been evaluated and determined to be typical for a newly reclaimed site. However, to help increase plant establishment in a noninvasive and cost-effective manner, seeds from prairie species in the native plant garden have been harvested each year. In the fall and winter, these seeds are hand-sown in erosion areas that have the fewest established plants. Targeted seeding in this manner will improve vegetation density over time in the erosion areas.

Invasive weed control in the prairie is handled primarily through spot-spraying individual plants at the optimal time in the growing season. However, due to the highly detailed nature of this process, plants can be inadvertently overlooked. These plants flower profusely late in the season, making them particularly noticeable. Although late in the growing season is one of the least effective times to eradicate this species, the vegetative portion of the plant is targeted for removal in order to prevent large quantities of seed from germinating the following spring.

7.1.4 Early Indicators of Potential Issues

There are no early indicators of potential issues that could affect the protectiveness of the remedy.

7.1.5 Implementation of ICs and Other Measures

The information in this section is extracted from Section 3.0 of the LTS&M Plan (DOE 2008c).

This section summarizes information pertinent to the implementation of ICs to meet objectives of the use restrictions described in the ESD issued in February 2005 (DOE 2005c). The ESD clarified use restrictions necessary for the remedial actions specified in the CPOU, GWOU, and QROU RODs to remain protective over the long term. The areas requiring use restrictions are shown on Figure 51 and Figure 52.

7.1.5.1 Use Restrictions

The ESD prepared for the Weldon Spring Site presents use restrictions for specific areas. The areas are on either federally owned or state-owned properties. No privately owned property is affected by the use restrictions. The use restrictions for the Chemical Plant property are described below:

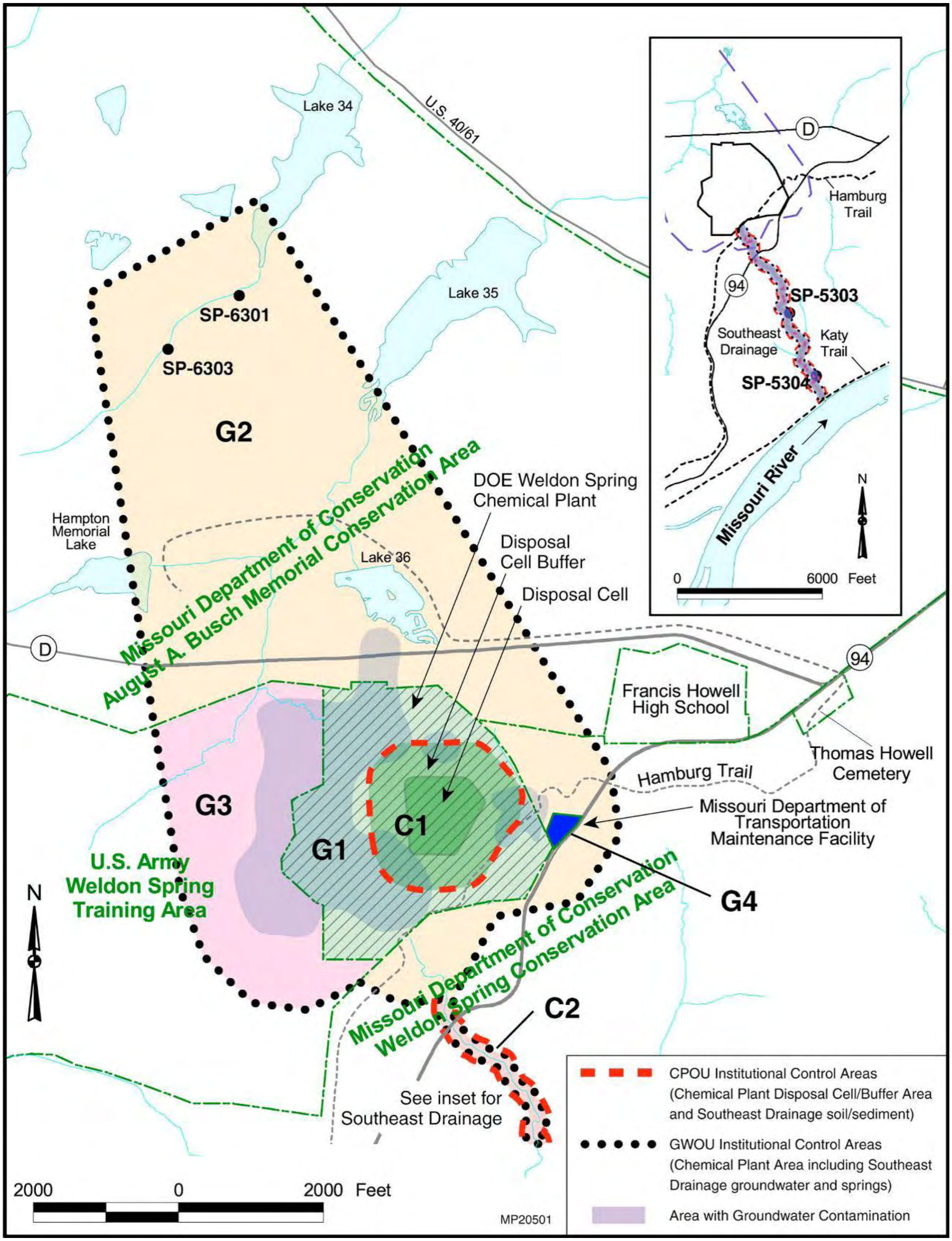

Figure 51. Institutional Control Areas for the Chemical Plant and Groundwater Operable Units

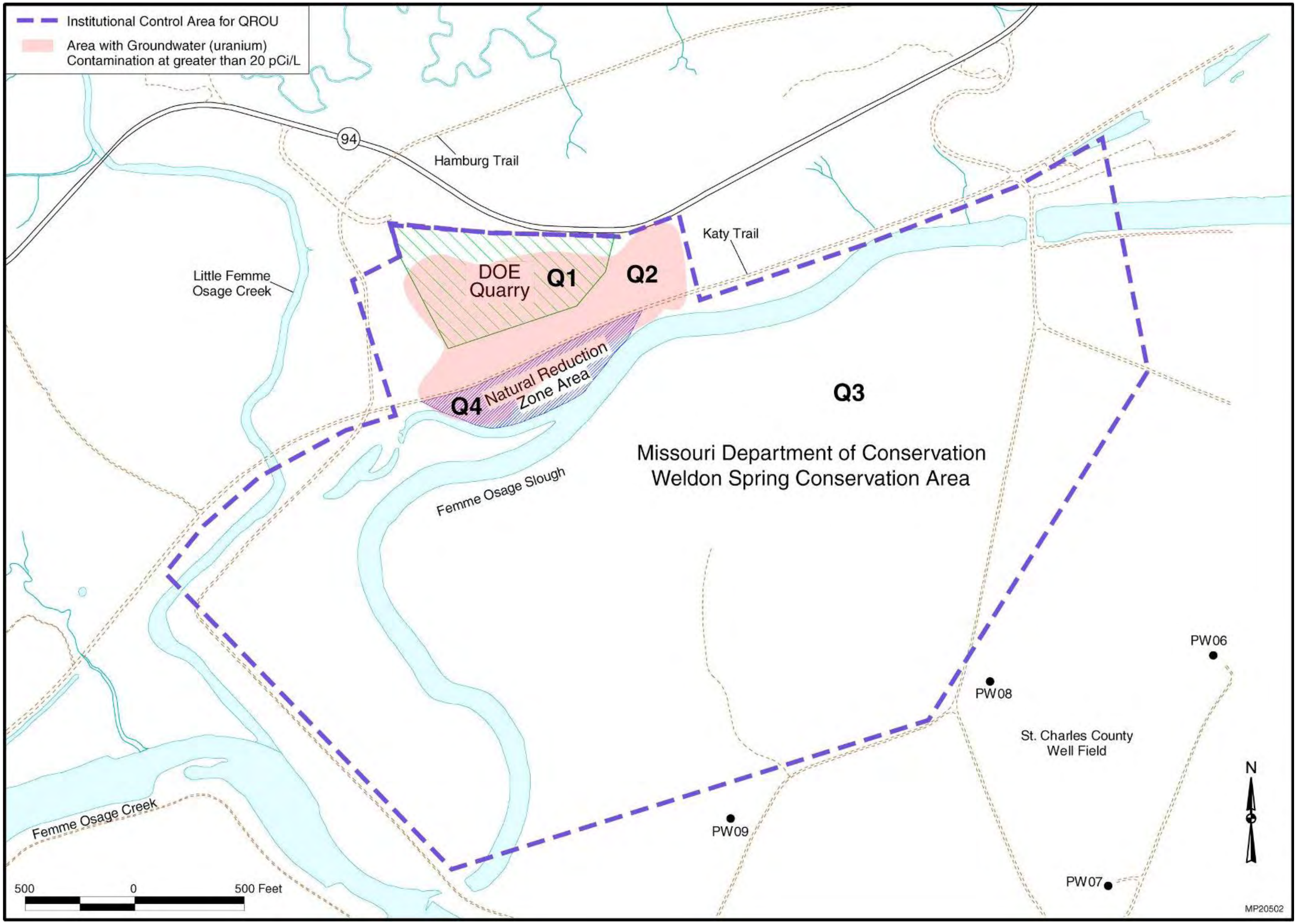

Figure 52. Institutional Control Areas for the Quarry Residuals Operable Unit

Disposal Cell and Buffer Area

The use restrictions listed below must be met throughout the disposal cell area, including its surrounding 300-ft buffer zone. This area is under federal DOE jurisdictional control. The use restrictions listed below shall be maintained until the remaining hazardous substances are at levels allowing for unlimited use and unrestricted exposure (UUUE). Due to the extremely long-lived nature of the radioactive constituents in the disposal cell, these restrictions are expected to be necessary for essentially as long as the disposal cell remains in place. The objectives of the controls or restrictions are as follows:

1. Prevent activities on the disposal cell, such as the use of recreational vehicles, that could compromise the integrity of the cell cover (e.g., result in the removal or disturbance of the riprap).
2. Prevent activities in the buffer zone, such as drilling, boring, or digging, that could disturb the vegetation, disrupt the grading pattern, or cause erosion.
3. Retain access to the buffer area for continued maintenance, monitoring, and routine inspections of the cell and buffer area.
4. Prevent construction of any type of residential dwelling or facility for human occupancy on the disposal cell and buffer area, other than facilities to be occupied for activities associated with performing environmental investigation or the restoration and expansion of the existing Interpretive Center.
5. Maintain the integrity of any current or future remedies or monitoring systems.

Southeast Drainage Soil or Sediment

The use restrictions listed below must be met at the approximately 37-acre area covering the 200 ft corridor along the length of the Southeast Drainage: The restricted area is located on property that is owned by state entities. These restrictions will need to be maintained until the remaining hazardous substances are at levels allowing for UUUE, which is anticipated to be a period of decades or longer.

- Prevent the development and use of the Southeast Drainage property for residential housing, schools, childcare facilities, and playgrounds.

7.1.5.2 Types of ICs

Specific IC mechanisms have been identified to implement the use restrictions presented for each area. The ICs generally fall into one of the four categories identified by EPA guidance (EPA 2000). Multiple mechanisms are being used to provide “layering” for additional durability.

The EPA IC categories are as follows.

1. **Proprietary controls:** Are based on real property law and generally create legal property interests; include easements and covenants.
2. **Governmental controls:** Are generally implemented and enforced by state or local governments; include zoning restrictions, well drilling regulations, building permits, ordinances, and similar mechanisms that restrict land or resource use.

3. **Enforcement and permit tools with ICs components:** Can be used to enforce or restrict site activities; include CERCLA FFAs, CERCLA Unilateral Administrative Orders, and Administrative Orders on Consent.

4. **Informational devices:** Provide information that a site contains residual or capped contamination; include state registries, deed notices, information centers, markers, and advisories.

7.1.5.3 Summary of ICs Currently in Place

The following ICs are in place for the Weldon Spring Site:

1. DOE has exclusive jurisdictional control over the Chemical Plant and the Quarry. Federal ownership provides inherent authority for DOE to control land use based on its legislative jurisdiction and take action against unapproved uses, but also entails statutory and regulatory obligations. Numerous requirements are placed on federal agencies that manage land to ensure the protection of human health and the environment. Per DOE Order 430.1B, *Real Property Asset Management*, DOE is required to provide an inventory of the specific ICs implemented to restrict use of the property in DOE's Facilities Information Management System (FIMS). The maintenance of a real property asset inventory system is designed to communicate the presence of land use restrictions to current federal management personnel and to ensure that this information is readily available to possible future users of the land. As part of the protocol for maintaining this database, FIMS data must be (a) maintained as complete and current throughout the life cycle of real property assets, including real- property related ICs; and (b) archived after disposal of real property assets) with those necessary for long-term maintenance and surveillance identified, reviewed, and retained accordingly.

   CERCLA Section 120(h) (3) requires for property transfers to be accompanied by a covenant warranting that "all remedial action necessary to protect human health and the environment with respect to any such substance remaining on the property has been taken before the date of transfer" and that "any additional remedial action found to be necessary after the date of transfer shall be conducted by the United States." Upon transfer, the deed or other agreement governing the transfer must contain clauses that indicate the following information: (a) necessary restrictions on the use of the property to ensure protection of human health and the environment (e.g., maintenance of ICs), and (b) restrictions on the use necessary to ensure that the required remedial investigations, response actions (e.g., monitoring, implementation of ICs), and oversight activities (e.g., LTS&M activities) will not be disrupted.

2. DOE has committed to perpetual care of the disposal cell and buffer zone as specified in the Chemical Plant ROD, which is enforceable under the FFA.

3. A notation has been entered on the ownership record filed at the St. Charles County Recorder's Office (deed notice). The notation explains the restrictions on groundwater use and residential development of the Chemical Plant and Quarry Areas. The notice acts as an informational device in the event ownership is transferred at some point in the future.

4. The Interpretive Center serves as a community information resource, which depicts the history of the area and details the progression of the cleanup process. Information is available on the construction of the engineered disposal cell and the residual groundwater contamination.

5. Historical markers have been placed along the Hamburg Trail, and informational plaques are accessible at the top of the engineered disposal cell. The historical markers depict significant events and locations along the trail related to the displacement of the population during the early 1940s to accommodate the federal government's World War II efforts. The markers also note significant events at their respective locations related to DOE cleanup efforts and encourage the reader to learn more by visiting the DOE Interpretive Center. Similarly, the plaques at the top of the disposal cell contain information regarding the surroundings and the history of St. Charles, as well as information regarding the cleanup and waste materials buried within the disposal cell.

6. Missouri regulates the construction of wells pursuant to 10 CSR Chapter 3, "Well Construction Code," Section 3.010(1)(A)4, which states that "a well shall be constructed so as to maintain existing natural protection against pollution of water-bearing formations and to exclude all known sources of contamination from the well including sources of contamination from adjacent property." 10 CSR 3.030(2) says, "Minimum Protective Depths of Well Casing. All wells shall be watertight to such depths as may be necessary to exclude contaminants. A well shall be constructed so as to seal off formations that are likely to pose a threat to the aquifer or human health." Well Construction Code 10 CSR 3.090(1)(A) says, "All persons engaged in drilling domestic wells in Area 1, a limestone or dolomite area shall set no less than 80 ft of casing, extending not less than 30 ft into bedrock. Example: if 60 ft of residual (weathered rock) material is encountered in drilling before bedrock, then 90 ft of casing must be set." These regulations combine to have the effect of preventing the construction of wells that would allow for consumption of contaminated groundwater by preventing the well from drawing water from groundwater from a depth less than 80 ft, which includes the surficial contaminated zone.

7. DOE has real estate licenses with MDC that allow access for the purpose of monitoring and maintaining groundwater wells, drilling and plugging wells, usage of the effluent water pipeline, and entering through the north gate.

8. DOE has real estate licenses with MDNR that allow access along portions of the Katy Trail for the purpose of monitoring and maintaining groundwater wells, drilling and plugging wells, using the effluent water pipeline, and collecting samples along portions of the Katy Trail.

9. An MOU with the Army regarding cooperation with DOE's remedy implementation is in place. The MOU gives DOE permission to access Army property for the purpose of implementing remedial actions, which includes monitoring and maintaining groundwater wells, drilling and plugging wells, and inspecting for consequential land or resource use changes. The revised MOU, signed in 2009 by both parties, is also specific with respect to the necessary groundwater use restrictions for property under Army control.

10. A "Special Use Area" Designation Under the State Well Drillers' Act was finalized in the Missouri regulations and became effective in August 2007 (10 CSR 23-3.100[8]). This is a special regulation that DOE and the Army pursued. It designated DOE and the Army's groundwater restricted areas as special areas that require additional drilling protocols and construction specifications, imposed by MDNR, on any future domestic wells.

11. An easement with the MDNR Division of State Parks restricts the use of groundwater on areas of their property along the Katy Trail and grants right of access to DOE for purposes of monitoring and characterization.

12. An easement with MDC (which was finalized in July 2011) restricting use of the contaminated groundwater and the hydraulic buffer zone on MDC property, and also to restrict land use in the Southeast Drainage and at the Quarry reduction zone
13. The use restrictions and the ICs identified in the LTS&M Plan are enforceable under the FFA.

Copies of existing IC agreements are included in Appendix E of the LTS&M Plan.

7.1.5.4 Implementation of Additional ICs

In addition to ICs that are already in place, as discussed above, DOE is in the process of implementing the additional IC identified below. The ICs were identified based on research findings and positions developed by EPA and DOE (EPA 2005a, EPA 2005b, DOE 2005c, DOE 2005d) and now consists of just one easement with a state agency, MoDOT. DOE obtained the Special Area Designation under the Missouri Well Drillers' Act in 2007, and the MOU with the Army was signed by both parties in 2009. DOE and the MDNR Division of State Parks (a third state agency) finalized and signed the easement regarding the MDNR Division of State Parks property in September 2009. The easement with MDC was signed by MDC on June 24, 2011, and by DOE on July 25, 2011. The proposed easement with MoDOT will be reevaluated. It was reported to DOE by MoDOT during the 2011 public meeting that this MoDOT facility is slated for closure and the future property owner is not known.

Easements

DOE has finalized easements with two of the surrounding affected state-agency landowners for implementing the use restrictions required on state properties. DOE also is in the process of negotiating an easement with a third state-agency landowner and, as stated above, the future landowner is in question regarding that property. It is currently owned by MoDOT, but DOE had been informed by MoDOT that that facility is slated for closure and the future landowner is unknown. An easement is a real property interest that conveys certain rights from the grantor (fee simple land owner) to the grantee. In the case of the Weldon Spring Site, DOE has finalized easements for the purpose of restricting use of the contaminated groundwater and the hydraulic buffer zone, and also to restrict land use in the Southeast Drainage and at the Quarry reduction zone. The easements will also ensure DOE access to monitoring locations for sampling and maintenance and, where applicable, provide that DOE is notified of use inconsistent with the terms of the easements. These easements supersede and replace the current real estate licenses described above.

DOE has acquired the easements in accordance with DOE policy and procedures. The completed easements would be appropriate for recordation with St. Charles County and effective in the state of Missouri.

DOE has completed the following activities toward acquiring the easements:

1. Obtained legal descriptions and surveyed the affected properties. The legal descriptions of the properties affected by the use restrictions are presented in Appendix D of the LTS&M Plan.

2. Conducted a title search for the affected properties. DOE conducted a title search (Investors Title Search Company 2004) to identify "less than fee simple" owners within the wider area originally comprising the Weldon Spring Ordnance Works to investigate real property interests, easements, or rights-of-way (ROWs) in these areas.

3. Obtained preliminary title commitment. A follow-up title search was conducted (Investors Title Search Company, March 2005) to provide sufficient ownership information to proceed with negotiations. The information obtained from these title searches is summarized in the LTS&M Plan. All of the "less than fee simple" ownership in the properties identified for use restrictions is expected to be unaffected by the restrictions (that is, any utility ROW would not be impaired by the implementation of DOE's use restrictions). Conversely, DOE has examined the existing ROWs and concluded that none of these interfere with or invalidate any of the use restrictions, including any of the prospective easements.

4. Issued initial letters, dated October 12, 2005, to the surrounding state agency property owners. The letters were intended to initiate discussions regarding the proposed easements. DOE, through its realty section and its interagency agreement with the U.S. Army Corps of Engineers (Omaha Office), sent a draft easement and offer letter to MDC in May 2006. The letters were issued to the MDNR Division of State Parks and MoDOT in September 2006. DOE received a response from the MDNR Division of State Parks dated May 10, 2007. DOE issued additional letters to the three state agencies in August 2007. These letters included copies of the original offer letters and draft easements. The purpose of these letters was to attempt to revitalize the easement negotiations. DOE met with the MDNR Division of State Parks on October 22, 2007, and prepared meeting minutes from the meeting. The agencies are working towards resolution of issues. Appendix E, *Institutional Control Documentation*, included language that was agreed on by DOE and the MDNR Division of State Parks for contamination questions that may arise during any construction in the MDNR Division of State Parks easement areas along the Katy Trail. DOE issued additional letters to MDC and MoDOT in December 2007, in another attempt to revitalize negotiations. DOE received a response from MoDOT in January 2008. The response stated that they are working on the issue with the other state agencies. DOE coordinated and communicated with the state agencies extensively throughout 2009 and 2010, resulting in the finalization of the easement with the MDNR Division of State Parks and MDC and a draft easement with MoDOT.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?

Answer: Yes, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy are still valid.

<u>Human Health</u>

The contaminated soil and other wastes generated from the CPOU cleanup are now permanently disposed of at an engineered disposal cell constructed at the Chemical Plant. Wastes generated from cleanup of the Quarry Area have likewise been disposed of in the disposal cell. At the time of its closure, the cell contained approximately 1.13 million cubic meters (1.48 million cubic yards) of waste.

The following is excerpted from the ESD (DOE 2005c), which is discussed in Section 6.5.1 and was issued in February 2005:

> "The 1993 CPOU ROD specifies that "perpetual care be taken of the committed land within the disposal cell footprint because waste would retain its toxicity for thousands of years." It stipulates that the cell cover be inspected and that the groundwater be monitored. This ROD also specified that "following completion of the site cleanup activities, an assessment of the residual risks based on actual site conditions will be performed to determine the need for any future land use restrictions. This assessment would consider the presence of the on-site disposal cell, the buffer zone, the adjacent Army site, and any other relevant factors necessary to ensure that appropriate measure are taken to protect human health and the environment for the long term.
>
> As part of the remedy selected for the CPOU, soil contamination was cleaned up by removing to depth and disposing of contaminated soils in the on-site disposal cell. Soil cleanup goals were established in the CPOU ROD that were intended to be as low as reasonably achievable given the design limitations pertaining to safe field excavation techniques and field survey capabilities. Recreational use was considered to be the reasonably anticipated future land use. A standard conservative recreational visitor scenario as defined in the CPOU Baseline Risk Assessment (DOE 1992d was considered to be representative of recreational use. The exposure assumptions used were consistent with those recommended for a recreational scenario in EPA Risk Assessment Guidance for Superfund (RAGS). Risk calculations based on the soil cleanup goals showed cumulative risk to the recreational visitor was within the acceptable risk range. Recognizing that the actual post cleanup condition might be different than what was anticipated by the cleanup goals, the ROD specified that a post-remediation risk assessment would be performed following cleanup and that a final decision on the need for any future land use restrictions would be based on the actual residual condition.
>
> The soil excavations were conservatively designed to remove contamination to depth to achieve the established cleanup goals or better. The post-remediation risk assessment (DOE 2002d) used post cleanup confirmation data to evaluate the cumulative risk posed by exposure to soil from all contaminants. The assessment is believed to overestimate risks because it did not take into consideration the backfilling and reworking of the soils following excavation. The assessment confirmed that the potential risks to recreational visitors are within the acceptable risk range.
>
> The post-remediation risk assessment also evaluated the risk to a suburban resident. A standard conservative suburban residential scenario as defined in the CPOU Baseline Risk Assessment was used. Following recommendations in EPA guidance (RAGS, Exposure Factors Handbook), the exposure assumptions (e.g., contact rate, exposure frequency and duration variables) used as input to this estimate were based on statistical data representing the 95th or, if not available, the 90th percentile value for these variables. This approach provides risk estimates for reasonable maximum exposure (RME) to a resident receptor. The calculated risk to the suburban resident was generally greater than 1×10^{-4} but less than 1×10^{-3} and therefore slightly exceeds the acceptable

risk range. However, the risk to the suburban resident from exposure to naturally occurring background concentrations of radionuclides in soils is 5.3×10^{-4} or essentially the same risk posed by residual concentrations in the remediated areas. In other words, there is no significant incremental increase in risk from exposure to the remediated areas for a suburban resident. For purposes of this site and this ESD, the standard conservative suburban residential scenario is considered representative of unlimited use and unrestricted exposure (UUUE), the EPA policy threshold for determining whether ICs are appropriate.

These calculated risks are cumulative of all contaminants; however, the risks are primarily due to the radionuclides associated with the uranium ores. The CPOU ROD considered the standards for residual Ra-226 found in 40 CFR 192, Subpart B to be relevant and appropriate (RAR) to the cleanup of these radionuclides. The ROD was issued in 1993 prior to the issuance of EPA Directive 9200.4-25, Use of Soil Cleanup Criteria *[in]* 40 CFR 192 as Remediation Goals for CERCLA Sites. A review of the expectations set forth by EPA in this guidance confirms 1) these standards would be considered RAR were the decision to be made today, i.e., the contamination and its distribution was consistent with the outlined expectations; and 2) the actual residual concentrations for radium and thorium combined are much less than the concentrations identified in the guidance as meeting the health-based standard."

Table 68 lists the constituents of concern in soils at the CPOU. Toxicity values for many of the constituents have changed since the time of the CPOU ROD (DOE 1993). However, risks associated with the site after completion of remediation were assessed using updated values (DOE 2002d), which are included in Table 68. Recent toxicity values are also provided.

Only two toxicity values are different from those used in the post-remediation assessment and would not affect post-remediation risk estimates. Since the time of that assessment, EPA has also issued supplemental guidance for conducting inhalation risk assessments for chemical constituents (EPA 2009). However, as external exposure to radiological constituents is the main risk driver at the site, this revised methodology will not impact the remedy protectiveness. The inhalation pathway was not considered important for the recreational visitor scenario. Exposure assumptions are still valid and site conditions remain protective.

EPA is currently soliciting input on whether to review and potentially revise the standards found in 40 CFR 192, including the soil standard for radium-226. However, because soils associated with the CPOU are at levels comparable to background, changes to the soil standards (which are expressed as concentrations above background) would not affect the protectiveness of the remedy. Likewise, though exposure assumptions and toxicity data used in the baseline and post-remediation risk assessments remain valid, the fact that the cleanup achieved background levels essentially renders the risk assessments irrelevant as they do not form the basis for establishing cleanup levels.

For the above reasons, DOE concluded in the ESD that there is no need to restrict land use in the Chemical Plant Area based on exposure to soils. This conclusion still remains valid based on updated information. This assessment applies to land use only. This assessment does not apply to the soils and sediments in the Southeast Drainage.

Table 68. Chemical Plant OU

Constituent	Pathway	C or N	Post-Remed. Toxicity Values	Current Toxicity Values	Source	Change
Radionuclides						
Radium-226+D	Ingestion	C	7.5E-10[f]	7.3E-10	HEAST	Lower
	External	C	8.49E-06[a]	8.49E-06	HEAST	None
	Inhalation	C	1.16E-08[f]	1.16E-08	HEAST	None
Radium-228+D	Ingestion	C	2.29E-09[f]	2.29E-09	HEAST	None
	External	C	4.53E-06[a]	4.53E-06	HEAST	None
	Inhalation	C	5.23E-09[f]	5.23E-09	HEAST	None
Thorium-230	Ingestion	C	2.02E-10[f]	2.02E-10	HEAST	None
	External	C	8.19E-10[a]	8.19E-10	HEAST	None
	Inhalation	C	2.85E-08[f]	2.85E-08	HEAST	None
Thorium-232	Ingestion	C	2.31E-10[f]	2.31E-10	HEAST	None
	External	C	3.42E-10[a]	3.42E-10	HEAST	None
	Inhalation	C	4.33E-08[f]	4.33E-08	HEAST	None
Uranium-238+D	Ingestion	C	2.10E-10[f]	2.10E-10	HEAST	None
	External	C	1.14E-07[a]	1.14E-07	HEAST	None
	Inhalation	C	9.35E-09[f]	9.35E-09	HEAST	None
Chemicals						
Arsenic	Ingestion	C	1.5[b]	1.5	IRIS	None
	Inhalation	C	0.0043[d]	0.0043	IRIS	None
	Ingestion	N	0.0003[c]	0.0003	IRIS	None
Chromium III	Ingestion	N	1.5[c]	1.5	IRIS	None
Chromium VI	Inhalation	C	0.012[d]	0.084	RSL	Higher
	Ingestion	N	.003[c]	0.003	IRIS	None
Thallium	Ingestion	N	0.00008[c]	0.00001	PPRTV	None
PAHs	Ingestion	C	7.3[b,e]	7.3	ECAO	None
PCBs	Ingestion	C	2.0[b]	2.0	RSL	None
2,4,6-TNT	Ingestion	C	0.03[b]	0.03	IRIS	None

Notes:
[a] risk/yr per pCi/g
[b] slope factor; $(mg/kg\text{-}d)^{-1}$
[c] reference dose (mg/kg-d)
[d] unit risk $(\mu g/m^3)^{-1}$
[e] slope factor for benzo*[a]*pyrene used for all B2 PAHs
[f] risk/pCi

Abbreviations:
$\mu g/m^3$ = micrograms per cubic meter
mg/kg-d = millgrams per kilogram per day
pCi/g = picocuries per gram
C or N = carcinogenic or noncarcinogenic
HEAST = Health Effects Assessment Summary Tables
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer-Reviewed Toxicity Value
RSL = Regional Screening Level Summary Table
ECAO = Environmental Criteria and Assessment Office

Section 1.5, *Current Regulatory Requirements*, of the LTS&M Plan discusses the ARARs that apply to the post-remediation aspect of the project, and states the following:

> "The disposal cell contents are not regulated under the Resource Conservation and Recovery Act (RCRA), but RCRA postclosure disposal cell monitoring and maintenance requirements are ARARs. The RCRA groundwater protection standard (40 CFR 264 Subpart F) sets forth the general groundwater monitoring requirements for the disposal cell. Generally, the disposal cell groundwater monitoring program must provide representative samples of background water quality, as well as groundwater passing the point of compliance. For a more complete description, see the Disposal Cell Groundwater Monitoring Plan (Appendix K) which was developed to address these requirements. Additional postclosure requirements for the cell are identified in 40 CFR 264 Subpart N and include action leakage rate and leachate collection and removal requirements. These requirements are addressed in Sections 2.7.4, 2.9.2, and Appendixes I and J. Subpart N also includes requirements to maintain the integrity of the final cover, including making repairs as necessary, which is addressed in Section 2.6."

The ARARs for the Chemical Plan are listed in Table 69.

Table 69. Chemical Plant ARARs

ARAR/Citation	Description	Status	Comments
RCRA Subtitle F and N; 40 CFR 264	Regulates groundwater monitoring and post-closure care	Relevant to post-closure care	Groundwater monitoring, leachate collection being conducted in accordance with these requirements

The Southeast Drainage is narrow and wooded with limited access. One of the objectives of the cleanup was to limit ecological damage to the drainage. It was determined that the soil cleanup goals developed for the CPOU, described above, were not appropriate for cleanup of this area. Risk-based cleanup goals were developed for the drainage that were designed to be protective for recreational use and for a modified residential scenario involving a child living near the drainage and using it periodically for play activities. Post-cleanup soil and sediment sampling was conducted, and a post-cleanup risk assessment was performed to confirm that the drainage is protective for these uses and, therefore, protective for any reasonably anticipated land use. However, residual soil and sediment contamination remains in some locations within the drainage at levels exceeding those that would support UUUE as represented in this case by a standard conservative suburban residential exposure scenario described above. Therefore, land use restrictions are needed in the drainage to prevent residential use or other uses inconsistent with recreational use. As noted above, the Southeast Drainage is located on property owned by state entities.

Risk-based cleanup criteria for the Southeast Drainage were based on achieving a risk level of 1×10^{-5} for recreational use of the area by a recreation visitor (child/hunter). Risk drivers were radionuclides. The toxicity values used in the post-remediation risk assessment are provided in Table 70 along with current values. [Note: The post-remediation risk assessment (ANL 1999) did not actually list the values used in the calculations, but just referenced sources for the values in place at the time (Health Effects Summary Tables [HEAST], Integrated Risk Information System [IRIS]). However, another risk assessment completed in the same time frame (DOE 1997b) actually listed the referenced toxicity values that were used. It is assumed that these same values were used in the Southeast Drainage post remediation risk assessment]. Nearly all of the current slope factors are slightly higher for both pathways, leading to the question of whether these changes could significantly affect estimates of post-remediation risks.

Table 70. Comparison of Slope Factors Used in Southeast Drainage Risk Assessment with Current Values

Constituent	Pathway	C or N[c]	Post-Cleanup Slope Factors	Current Slope Factors[d]	Change
Radionuclides (pCi/g)					
Radium-226+D	Ingestion[a]	C	2.96E-10	7.3E-10	Increase
	External[b]	C	6.74E-06	8.49E-06	Increase
	Inhalation[a]	C	2.75E-09	1.16E-08	Increase
Radium-228+D	Ingestion	C	2.48E-10	2.29E-09	Increase
	External	C	3.28E-06	4.53E-06	Increase
	inhalation	C	9.94E-10	5.23E-09	Increase
Thorium-230	Ingestion	C	3.75E-11	2.02E-10	Increase
	External	C	4.40E-11	8.19E-10	Increase
	inhalation	C	1.72E-08	2.85E-08	Increase
Thorium-232	Ingestion	C	3.28E-11	2.31E-10	Increase
	External	C	1.97E-11	3.42E-10	Increase
	inhalation	C	1.93E-08	4.33E-08	Increase
Uranium-238+D	Ingestion	C	6.20E-11	2.10E-10	Increase
	External	C	6.57E-08	1.14E-07	Increase
	inhalation	C	1.24E-08	9.35E-09	Decrease

[a] risk/pCi
[b] risk/yr per pCi/g
[c] N or C = noncarcinogenic or carcinogenic risks
[d] data from Health Effects Assessment Summary Tables

Ingestion of soil and external gamma exposure to soils contaminated with radionuclides were the primary pathways of concern. These pathways are still valid. Using the same assumptions as the CPOU post-remediation risk assessment (DOE 2002d) for a “recreational visitor” (combination of childhood and adult exposures), risks were recalculated for the four segments of the Southeast Drainage using both old and new slope factors and the 95th percentile upper confidence limit of the mean concentration (UCL_{95}) values for each segment presented in the original post-remediation risk assessment (ANL 1999). These results are presented in Table 71.

As expected with increases in slope factors, recalculated risks are slightly higher for both the inhalation and external exposure pathways. External exposure to radium-226 is still the main risk driver; recalculated risks for this pathway have increased only marginally and are still within the acceptable risk range. The updated toxicity data does not affect the protectiveness of the remedy.

The exposure assumptions and toxicity data used in the EE/CA (DOE 1996) and post-remediation risk assessment (DOE 2002d) of the Southeast Drainage are still valid as are the corresponding cleanup levels and remedial objectives. Contaminants addressed in the Southeast Drainage are primarily radium-226, radium-228, thorium-230, and uranium-238. Pathways include soil ingestion and direct gamma exposure. Because contaminant concentrations remain above levels that would permit UUUE, the most important assumption for protectiveness in the

Southeast Drainage is land use. As long as this area remains undeveloped and receives only recreational use, residual contaminant levels should be protective.

Table 71. Southeast Drainage Recalculated Residual Risks

Constituent	Concentration (UCL_{95})	Inhalation Risk—Old	Inhalation Risk—New	External Risk—Old	External Risk—New
	Southeast Drainage, Segment A				
U-238+D	74	3.30E-07	1.12E-06	1.33E-06	2.31E-06
Ra-226+D	22	4.69E-07	1.16E-06	4.06E-05	5.12E-05
Ra-228+D	2.3	4.11E-08	3.79E-07	2.07E-06	2.85E-06
Th-230	17	4.59E-08	2.47E-07	2.05E-10	3.81E-09
	Total risk	8.86E-07	2.90E-06	4.40E-05	5.63E-05
	Southeast Drainage, Segment B				
U-238+D	24	1.07E-07	3.63E-07	4.32E-07	7.50E-07
Ra-226+D	25	5.33E-07	1.31E-06	4.62E-05	5.82E-05
Ra-228+D	1.8	3.21E-08	2.97E-07	1.62E-06	2.23E-06
Th-230	15	4.05E-08	2.18E-07	1.81E-10	3.37E-09
	Total risk	7.13E-07	2.19E-06	4.82E-05	6.11E-05
	Southeast Drainage, Segment C				
U-238+D	21	9.37E-08	3.18E-07	3.78E-07	6.56E-07
Ra-226+D	12	2.56E-07	6.31E-07	2.22E-05	2.79E-05
Ra-228+D	2	3.57E-08	3.30E-07	1.80E-06	2.48E-06
Th-230	11	2.97E-08	1.60E-07	1.33E-10	2.47E-09
	Total risk	4.15E-07	1.44E-06	2.43E-05	3.11E-05
	Southeast Drainage, Segment D				
U-238+D	16	7.14E-08	2.42E-07	2.88E-07	5.00E-07
Ra-226+D	7.6	1.62E-07	3.99E-07	1.40E-05	1.77E-05
Ra-228+D	1.9	3.39E-08	3.13E-07	1.71E-06	2.36E-06
Th-230	23	6.21E-08	3.35E-07	2.77E-10	5.16E-09
		3.29E-07	1.29E-06	1.60E-05	2.05E-05

UCL_{95} = 95th percentile upper confidence limit of the mean concentration

Ecological Risk

Numerous ecological investigations have been conducted at the Weldon Spring site. A 1995 report (DOE 1995a) summarized studies that took place from 1987 until that time; a later letter report included a summary of more recent studies (ANL 2004). Generally speaking, the investigations included sampling and analysis of various contaminated media and comparison against "safe" benchmark values. Quantitative and qualitative biological surveys were also conducted and included sampling and examination of plants, reptiles, birds, and small mammals to determine if any adverse effects could be observed. Mammals and fish were collected for tissue sampling, and toxicity testing was conducted to determine the potential for effects on aquatic life.

Site-wide biouptake studies were conducted to determine the potential effects of area fish and game consumption on an "avid sportsman" (DOE 1995a). Biouptake modeling was conducted using uptake factors and assumptions from the literature. In addition, fish, small mammals, and waterfowl were sampled to see how modeled tissue concentrations (based on concentrations of contaminated media and literature uptake factors) compared to actual observations. Results revealed that modeled dose estimates were greater than measured dose estimates by factors from

3 to 10—indicating the conservatism of model assumptions. Risks to humans calculated using modeled values were within EPA's acceptable risk range. It was determined that further biota monitoring was not needed to assure protectiveness (with the exception of some limited fish sampling in area lakes and the Femme Osage Slough; it appears this was subsequently discontinued in the late 1990s).

The baseline (preremediation) risk assessment for the CPOU (DOE 1992d) indicated that concentrations of some site-related constituents were present at levels that could potentially cause adverse effects in ecological receptors. However, no such adverse effects were actually observed in the fauna that were sampled, with the possible exception of the former raffinate ponds area (DOE 1992b); those ponds were subsequently remediated and exposures were eliminated.

Maximum surface water concentrations observed in the Southeast Drainage exceeded benchmarks and were further evaluated for ecological risks through toxicity testing (DOE 1996); limited toxicity was found at one location. Surveys of terrestrial wildlife indicated diverse communities and no adverse impacts. While aquatic communities were more limited, this was attributed to the intermittent nature of the drainage as opposed to site-related contamination. Uranium concentrations as high as 1,800 µg/L (about 1,200 pCi/L based on a site-specific conversion factor) were reported in the past in the Southeast Drainage—exceeding levels at which toxic effects have been observed (DOE 1992b). However, since that time uranium concentrations have declined. The most recent sampling results indicate that concentrations are less than 100 pCi/L (Table 30).

There have been no significant changes in exposure assumptions, toxicity, or ecological risk assessment methodology that would call into question the protectiveness of the CPOU remedy (including the Southeast Drainage) from an ecological risk perspective. Concentrations in relevant media have been reduced through the remediation that has taken place.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

7.2 Groundwater Operable Unit

Question A: **Is the remedy functioning as intended by the decision documents?**

Answer A: Yes, the remedy is functioning as intended by the decision documents

7.2.1 Remedial Action Performance

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells. Objective 2 wells are within the areas of impact and monitor both the weathered and unweathered units of the Burlington-Keokuk Limestone. Objective 2 of the MNA strategy is to verify that contaminant concentrations are declining or remaining stable as expected and that cleanup standards will be met in a reasonable time frame.

Detection monitoring consists of sampling to fulfill Objectives 3, 4, and 5 of the MNA strategy. Wells along the fringes and downgradient (both laterally and vertically) of the areas of impact are monitored to ensure that lateral and vertical migration remains within the current area of impact and that expected lateral downgradient migration (due to dispersion) within the paleochannels is minimal or nonexistent. Springs and a surface water location on Dardenne Creek are also monitored as part of this program, as these are the closest groundwater discharge points for the shallow aquifer in the vicinity of the Chemical Plant. These locations are monitored to ensure that concentrations remain protective of human health and the environment and that water quality continues to improve in the springs.

7.2.1.1 Contaminant Trending Summary

Overall, groundwater impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Decreases are attributed to source removal and attenuation mechanisms. Uranium, nitrate, TCE, and nitroaromatic compounds are decreasing in the vast majority of the Objective 2 wells in the weathered unit. Statistical downward trends indicate that cleanup objectives will likely be attained in the weathered unit within the estimated time frames in the remedial design documents and the revised Baseline Concentrations Report (DOE 2008d). Locations that exhibit increasing concentrations are generally located along the leading edge of the area of impact. Some locations were expected to show temporary increases due to ongoing dispersion; however, concentrations are not expected to exceed historical maximums previously seen in the areas of highest impact.

Detection monitoring indicates that impacted groundwater is remaining within the paleochannels and is migrating along expected flow pathways. The levels of COCs in the springs are decreasing and are less than the cleanup objectives in Burgermeister Spring and SP-6303, except for uranium in Burgermeister Spring. This spring is the primary discharge point for groundwater from the Chemical Plant site, and while it continues to exceed the cleanup objective for uranium, levels are decreasing.

Uranium levels in the Southeast Drainage springs continue to exceed the cleanup objective. These springs are not sourced by impacted groundwater from the Chemical Plant site, but rather the flushing of uranium from residually contaminated sediments within the bedrock fractures by surface water lost to the stream channel.

7.2.1.2 Uranium Levels in the Raffinate Pits Area

Uranium levels within the less-permeable unweathered unit are increasing due to desorption of uranium from residual materials as a result of reduced recharge deeper into the aquifer system that has limited flushing. Recharge that does enter the system is more likely to move horizontally through the weathered unit than vertically into the unweathered unit due to greater conductivity in the horizontal direction and the lack of a vertical driving force to move the groundwater downward as was previously exerted by water in the Raffinate Pits.

While uranium levels in the Raffinate Pits area have changed since implementation of the MNA remedy for uranium, overall, the remedy remains protective. Groundwater flow directions are unchanged in the Raffinate Pits area. Impacted groundwater is contained within the paleochannel in this area and is migrating along the expected pathways. Uranium levels are decreasing in the weathered unit due to dilution and dispersion. Uranium levels are not trending downward in the unweathered unit; the reduction in infiltration has limited the amount of flushing in the aquifer and increased uranium levels are the result of desorption of residual uranium from contaminated materials in this portion of the shallow aquifer. Discharge from the unweathered unit into the weathered unit is monitored at MW-4036. Uranium levels in “Objective 3–far” wells remain low, and levels in Burgermeister Spring, while variable, are declining.

7.2.1.3 Evaluation of Baseline Concentrations and Data Assessment Methods

The Baseline Concentrations Report (DOE 2008d) was updated and revised in July 2008. The primary objective of the report was to evaluate monitoring data collected from July 2004 through May 2006 to establish baseline concentrations for the COCs for each well and spring in the MNA network. Baseline monitoring was performed to acquire a comprehensive set of data to reevaluate the MNA remediation time frames developed in 2002 during the remedial design phase of the GWOU and assess the long-term monitoring program. Also, this report presented the methodology for review and evaluation of future MNA data.

A comparison of the initial concentrations used in 2002 and the baseline concentrations indicates that the values were relatively similar for most of the COCs. A review of the contaminant distribution in the shallow groundwater at the Chemical Plant from 2002 and the baseline period (2004 through 2006) shows that the areal distribution of the COCs is essentially unchanged. The modeling performed in 2002 to evaluate MNA (DOE 2003c), were not revised, and the projected cleanup times resulting from that earlier evaluation were considered applicable. The projected time to clean up the GWOU remains approximately 100 years.

It was determined in the Baseline Concentrations Report that additional data were needed to establish better baseline concentrations for nitrate and uranium in wells MW-3040 and MW-4040, screened in the unweathered unit below the Raffinate Pits area. Data from these wells was not used in the reevaluation of MNA remediation time frames.

The monitoring network was designed to provide data to show that natural attenuation processes are acting as predicted or to trigger the implementation of contingencies. Methods to review and interpret data that will satisfy the monitoring objectives were defined in the revised Baseline Concentrations Report. Performance of the MNA remedy will be gauged against long-term trends in the Objective 2 wells. This progress will be reviewed and documented every 5 years in conjunction with the CERCLA Five-Year Review. This review includes trending analysis for the past 5 years of data.

7.2.2 System Operation and Maintenance

The operation and maintenance activities for the Weldon Spring Site are specified in the LTS&M Plan, which was revised in December 2008. Environmental monitoring and evaluation of data are performed in accordance with the procedures and methods outlined in the LTS&M Plan. DOE also performs annual inspections of LTS&M activities, environmental monitoring, and ICs, and has found these activities to be functioning as intended.

7.2.3 Opportunities for Optimization

7.2.3.1 Modification of Sampling Frequencies

As part of the Baseline Concentrations Report (DOE 2008d), an evaluation was performed to determine the appropriateness of the network to fulfill the intended objectives and the adequacy of the sampling frequencies that were initially specified for the MNA monitoring program. The following changes were recommended in the Baseline Concentrations Report and implemented through the LTS&M Plan in 2009. A summary of the modifications are as follows:

- **Objective 1:** Reduced the sampling frequency to annual because concentrations in these upgradient wells were stable.
- **Objective 2:** Maintained semiannual sampling in the Objective 2 wells due to continued variability in the data.
- **Objective 3:** Reduced the sampling frequency to annual because concentrations have been behaving as expected.
- **Objective 4:** Reduced the sampling frequency to annual because concentrations have been behaving as expected.
- **Objective 5:** Increased the sampling frequency to quarterly due to variability in the springs and in some Objective 2 wells.

A review of remediation technologies relevant to the existing contamination at the GWOU was performed as part of the Five-Year Review process. This review was conducted to determine whether new technologies that may be more effective than the MNA remedy currently implemented have been introduced since the publication of the Feasibility Study (DOE 1998c) and the issuance of the GWOU ROD (DOE 2004a). The technology review consisted of a current literature search and evaluation of the latest information from the Federal Remediation Technologies Roundtable, the Environmental Security Technology Certification Program, Hazardous Waste Clean-Up Information, and the Groundwater Remediation Technologies Analysis Center. These programs are summarized in Table 72. At this time, no new viable remediation technologies have become available for addressing TCE, nitrate, nitroaromatic compounds, and uranium present in groundwater at the Chemical Plant area. The limitations to extract groundwater from the shallow aquifer or introduce chemical or materials into the aquifer still reduce the effectiveness of any of the technologies reviewed. Thus, the selected remedy of MNA with ICs as implemented is still the optimum remedy for the GWOU.

7.2.4 Early Indicators of Potential Issues

There are no early indicators of potential issues.

7.2.5 Implementation of ICs and Other Measures

The following are the use restriction listed in the LTS&M Plan for the GWOU. The ICs that are in place and planned for the Weldon Spring Site are discussed under the CPOU section above. The ICs that specifically apply to the GWOU are the Missouri Well Installation Special Area designation rulemaking; the easements with MDC, MoDOT, and the MDNR Division of State Parks; and the new MOU with the Army.

Table 72. Remediation Technology Programs Reviewed

Program	Agency Sponsors	Web Site	Comments
Federal Remediation Technologies Roundtable (FRTR)	U.S. Department of Defense U.S. Environmental Protection Agency U.S. Department of Energy U.S. Department of the Interior National Aeronautics and Space Administration	www.frtr.gov	Covers in-situ and ex-situ technologies for all contaminant types in soil and groundwater.
Environmental Security Technology Certification Program (ESTCP)	U.S. Department of Defense	www.estcp.org	Focuses on in-situ and ex-situ remediation technologies for organic compounds and explosives, including TCE and nitroaromatic compounds in soil and groundwater.
Hazardous Waste Clean-Up Information (CLU-IN) Web Site	U.S. Environmental Protection Agency	www.clu-in.org	A public service of EPA's Technology Innovation Program under the Office of Superfund Remediation and Technology Innovation. Contains information on in-situ and ex-situ treatment technologies for inorganic and organic contaminants in soil and groundwater.
Groundwater Remediation Technologies Analysis Center (GWRTAC)	U.S. Environmental Protection Agency U.S. Department of Energy U.S. Department of Defense	www.gwrtac.org	Contains information on in-situ and ex-situ treatment technologies for inorganic and organic contaminants in groundwater.

The use restrictions listed below must be met in the entire area of approximately 1,140 acres shown in Figure 12, where groundwater use needs to be restricted until concentrations of the COCs meet drinking water or risk-based standards that allow for UUUE. The period of time necessary for contaminants to attenuate to these levels has been estimated at approximately 100 years. The size of the restricted area includes a 1,000 ft buffer area that accounts for the groundwater gradient and flow conditions at the site. The restricted area includes properties under federal jurisdictional control (DOE and the Army) as well as properties owned by state entities.

The objectives of the controls or restrictions are as follows:

1. Prevent the use of the contaminated shallow groundwater and spring water for drinking water purposes. The contaminated shallow groundwater occurs in the weathered and unweathered portions of the upper limestone unit (Burlington-Keokuk). The contaminated groundwater and spring water system occurs within the limits of the hydraulic buffer zone identified in Figure 12. The springs are identified in the figure as SP-6301, SP-6303, SP-5303, and SP-5304. This restriction will need to be maintained over a period of decades or longer.

2. Limit the use of all groundwater within the outlined restricted area to investigative monitoring only. The boundary of the restricted area extends beyond the area of contamination and is intended to provide a buffer against potential hydraulic influences on

the area of contamination by preventing such things as pumping wells being located in the proximity of the contaminated area. This restriction includes the shallow groundwater system and also extends vertically to all groundwater systems that underlie the contaminated groundwater. This restriction will need to be maintained over a period of decades or longer.

3. Retain access to the area for continued monitoring and maintenance of groundwater wells and springs.
4. Maintain the integrity of any current or future remedies or monitoring systems.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection still valid?

Answer B: Yes, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection are still valid.

7.2.6 RAOs—Uranium Monitoring in the Unweathered Unit

The MNA monitoring network established in the *Remedial Design/Remedial Action Work Plan* (DOE 2004f) and later modified in the *Interim Remedial Action Report* (DOE 2005e) focused on impact in the weathered unit of the Burlington-Keokuk Limestone. It was not until 2004, when wells were installed within the footprint of the Raffinate Pits that definitive data were acquired that supported uranium and nitrate impact greater than the MCLs in the deeper unweathered unit. These wells were installed with the intention that they would be Objective 4 wells, monitoring the unweathered unit beneath the known are of uranium and nitrate impact in the weathered unit. These wells were reclassified as Objective 2 wells for the unweathered unit in 2005 as they had sufficiently high uranium and nitrate values.

Uranium levels in MW-4040 have consistently been greater than the Objective 2 trigger of 100 pCi/L since it was installed. The Objective 2 triggers were set at or near historical maximums. The 100 pCi/L trigger is applicable to the maximums observed in the weathered unit. Wells MW-3040 and MW-4040 have had uranium levels greater than the trigger level since being installed.

Uranium increases in the Raffinate Pits area have been the focus of a special study ongoing since 2008. Levels have increased in Objective 2 wells screened in the unweathered unit beneath the Raffinate Pits area and one downgradient Objective 3 well screened in the weathered unit. It has been concluded from the study thus far that the reduction in infiltration has limited dilution of the impacted groundwater in the unweathered unit and has resulted in little flushing of the system due to the low amount of recharge through the system. Increased uranium levels are the result of desorption of residual uranium from contaminated materials that were forced deeper into the bedrock by the hydraulic head of the Raffinate Pits. Since there is little infiltration to flush this impacted groundwater through the bedrock aquifer, changes will likely be slow.

A comparison of uranium levels and groundwater elevations in the Objective 3 well indicates that changes in both are correlated; uranium levels increase and decrease as groundwater elevations also increase and decrease. However, groundwater elevations in this well do not respond to precipitation events. In the area of this well, uranium levels are higher in the unweathered unit than in the weathered unit. It has been theorized that groundwater with higher uranium levels in the unweathered unit periodically contributes uranium mass to the weathered unit near this Objective 3 well. However, the mechanism that causes the periodic contribution of uranium from the unweathered unit into the weathered unit has not been identified.

DOE recommends that after completion of additional groundwater sampling and evaluation of vertical gradients under this special study, the MNA program regarding the uranium impact in the unweathered unit be evaluated and possibly modified, which could include new trigger values and additional monitoring locations. This topic was discussed with the regulators in the Five-Year Review kick-off meeting on October 28, 2010.

7.2.7 Exposure Assumptions, Toxicity Data, and Cleanup Levels

Human Health

A review of assumptions incorporated into the risk assessments documented in the *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri* (DOE 1997a) and *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri* (DOE 1998c) was also performed. The review included the following risk assessment aspects: risk assessment methodology, exposure scenarios, exposure assessment input parameters, and toxicity values.

EPA has published vapor intrusion pathway guidance as well as supplemental guidance for conducting inhalation risk assessments since documentation of the GWOU was developed (EPA 2002). The guidance recommends evaluating the vapor intrusion pathway where plumes are within 100 ft of a habitable structure. At the GWOU there are no habitable structures within 1,000 ft of the organic groundwater plume so the vapor intrusion pathway is not applicable. In addition, engineering controls prevent the construction of buildings in areas where the vapor intrusion pathway could be of concern.

The inhalation pathway is also considered to be an inconsequential contributor to risk for the recreational visitor scenario. The baseline risk assessment for the Quarry Residuals Operable Unit (DOE 1997) assessed risks associated with ingestion and inhalation of PCBs and PAHs in a recreational scenario (i.e., exposures to surface water and sediment); ingestion risks were 3 or more orders of magnitude higher than inhalation risks and inhalation risks were not considered further. There have been no new developments with respect to these groups of constituents to suggest that potential inhalation risks should be of increased concern for a recreational visitor; this pathway is not reevaluated. The recreational visitor scenario and exposure assessment input parameters are also still valid as land uses assumed in the risk assessment documents are still representative of current and expected future land uses. In addition, ICs have been identified and are currently being implemented to ensure that current land uses are maintained (see Sections 7.1.5 and 7.2.5 for additional discussion of ICs being implemented).

The EPA toxicity values used to characterize risks for the COCs for the GWOU (TCE, uranium, nitrate as N, 2,4-DNT, 2,6-DNT, 2,4,6-TNT, 1,3-DNB, and NB) were also reviewed. All values (except for TCE, uranium, and nitrobenzene) have remained unchanged since the Baseline Risk Assessment was issued. The toxicity value (i.e., the slope factor for carcinogenicity) for TCE has since been withdrawn from EPA's Integrated Risk Information System (IRIS) database until further EPA evaluations are completed; in the meantime, the California Environmental Protection Agency (Cal/EPA) value is use for assessing protectiveness per EPA guidance (OWSER Directive 9285.7-53; EPA 2003). Risks calculated with this slope factor would be lower than those previously calculated. The uranium slope factors for radionuclide toxicity were revised by EPA and are about a two-fold increase from that used in the Baseline Risk Assessment. The decision presented in the ROD accounted for both TCE and uranium as COCs with MCLs for both used as the RAOs. Therefore, the change in toxicity values does not affect the remedial action or the remedial design that is being implemented. The toxicity value for nitrobenzene was increased in 2009 and does not affect the remedial action. Table 73 is a compilation of the toxicity values used in the preparation of the RI/FS-ROD and their current status.

Table 73. Review of Toxicity Values Used in Risk Assessments for the GWOU and QROU

Constituents of Concern[a]	Toxicity Values In Baseline Risk Assessment	IRIS/HEAST Data Accessed January 2011	Status of Toxicity Value
Uranium(chemical) Uranium (radiological) U-234 U-235+D U-238+D	0.003 mg/kg-d 4.4E-11/pCi 4.5E-11/pCi 6.2E-11/pCi	0.003 mg/kg-d 7.1E-11/pCi 7.2E-11/pCi 8.7E-11/pCi	Unchanged Revised (increased) Revised (increased) Revised (increased)
Nitrate	1.6 mg/kg-d	1.6 mg/kg-d	Unchanged
Trichloroethylene	0.011 [(mg/kg-d)$^{-1}$]	0.0059 [(mg/kg-d)$^{-1}$][b]	Withdrawn
2,4-DNT	0.002 mg/kg-d 0.68 [(mg/kg-d)$^{-1}$]	0.002 mg/kg-d 0.68 [(mg/kg-d)$^{-1}$][c]	Unchanged Unchanged
2,6-DNT	0.001 mg/kg-d 0.68 [(mg/kg-d)$^{-1}$]	0.001 mg/kg-d 0.68 [(mg/kg-d)$^{-1}$][c]	Unchanged Unchanged
2,4,6-trinitrotoluene	0.0005 mg/kg-d 0.03 [(mg/kg-d)$^{-1}$]	0.0005 mg/kg-d 0.03 [(mg/kg-d)$^{-1}$]	Unchanged Unchanged
1,3-DNB	0.0001 mg/kg-d	0.0001 mg/kg-d	Unchanged
Nitrobenzene	0.0005 mg/kg-d	0.002 mg/kg-d	Revised (increased)

Notes:

[a] 1,3,5-trinitrobenzene (1,3,5-TNB) was included in the RI/FS evaluations but was deleted from the list of COCs presented in the GWOU ROD because the site concentrations were no longer of concern when evaluated against the revised reference dose for this compound. The EPA revised the reference dose for 1,3,5-TNB from 0.00005 to 0.03 (i.e., determined to be a thousand-fold less toxic).

[b] Current slope factor is from Cal/EPA database pending EPA evaluation

[c] Slope factor for these constituents is IRIS slope factor for 2,4- and 2,6-DNT mixture; Cal/EPA slope factor for 2,4-DNT is 0.31 (mg/kg-d)$^{-1}$

Abbreviations:

mg/kg-d = milligrams per kilogram per day
pCi = picocuries

The following slope factors for the ingestion pathway for uranium were used in the Baseline Risk Assessment to evaluate its radiological effects: uranium-234, 4.4E-11/pCi; uranium-235 +D, 4.5E-11/pCi; and uranium-238+D, 6.2E-11/pCi. The “+D” designation indicates that the risks from associated short-lived decay products (i.e., with radioactive half-lives less than or equal to 6 months) are also included. These values were taken from EPA’s HEAST of 1995. Since then an update of radionuclide toxicity values was posted by EPA in April of 2001. This update of the HEAST for radionuclides incorporates all new values, based on Federal Guidance Report No. 13, which was developed by EPA's Office of Radiation and Indoor Air. Federal Guidance Report No. 13 incorporates state-of-the-art models and methods that take into account age- and gender-dependence of radionuclide intake, metabolism, dosimetry, radiogenic cancer risk, and competing risks. Major differences between the risk coefficients of Federal Guidance Report No. 13, as incorporated into the current radionuclide slope factors, and the preceding generation of radionuclide slope factors (published in the November 1995 HEAST) include the following:

- Consideration of revised dosimetric models, including a revised lung model and age-dependent biokinetic models and GI-absorption factors for internal dose estimates and revised external dose coefficients for external dose estimates.
- Consideration of age- and gender-dependent inhalation and ingestion rates.
- Incorporation of updated vital statistics and baseline cancer mortality data.
- Specification of separate values for ingestion of water, food products, and soil, based on the different *age-dependent intake rate functions for these materials, instead of the single ingestion value for each radionuclide presented previously.*

Section 7.2.5 indicates that controls are intended to prevent the use of shallow groundwater and spring water for drinking water purposes. While groundwater use can be prevented by putting well drilling restrictions in place, it is much more difficult to prevent the use of surface water, particularly in areas that do not receive heavy use. Under current site conditions, the only potentially complete exposure pathway to groundwater is that of a recreational visitor to the Weldon Spring Conservation Area possibly coming into contact with spring water in the Southeast Drainage. The 2009 Annual Site Environmental Report (DOE 2010b) included an estimated total effective dose equivalent (TEDE) to a hypothetical individual assumed to frequent the Southeast Drainage of the Weldon Spring Conservation Area. The calculation of dose equivalent is based on a recreational user of the Conservation Area who drank from spring location SP-5303 (maximum observed concentration in 2009) 20 times per year during 2009.

The exposure scenario assumptions particular to this dose calculation include the following: (1) the reasonably maximally exposed individual drank 1 cup (0.2 liter [L]) of water from the spring 20 times per year (equivalent to 1.05 gallons [4.0 L] of water for the year); and (2) the maximum uranium concentration in water samples taken from spring locations during 2009 was at SP-5303 in the Southeast Drainage (79.9 pCi/L). This concentration was assumed to be present in all of the water ingested by the reasonably maximally exposed individual. The calculations resulted in a TEDE of 0.18 millirem (mrem). This value represents less than 0.18 percent of the DOE standard of 100 mrem TEDE above background. In comparison, the annual average exposure to natural background radiation in the United States results in a TEDE of approximately 300 mrem (BEIR 1990).

Using these same exposure assumptions, recent maximum uranium concentrations observed in 2010 (88 pCi/L and 0.110 mg/L at location SP-5304), and the updated toxicity data from Table 73 results in an added risk of approximately 3×10^{-8} per year of exposure and a hazard quotient of 0.0057. These results indicate that likely exposures to spring water are protective.

Table 74 lists the water quality standards for the Chemical Plant area GWOU, which are the contaminant-specific ARARs that apply to the GWOU.

Table 74. Federal and State Water Quality Standards for the Chemical Plant GWOU

Constituent	Standard	Citation
Nitrate (as N)	10 mg/L	40 CFR 141.62
Total Uranium	20 pCi/L[a]	40 CFR 141
1,3-DNB	1.0 µg/L	10 CSR 20-7[b]
2,4-DNT	0.11 µg/L	10 CSR 20-7[b]
NB	17 µg/L	10 CSR 20-7[b]
TCE	5 µg/L	40 CFR 141.61
2,6-DNT	1.3 µg/L	Risk-based[c]
2,4,6-TNT	2.8 µg/L	Risk-based[d]

Notes:
[a] Based on site-specific conversion factor; equivalent to 30 µg/L standard
[b] Missouri Groundwater Quality Standard.
[c] Risk-based concentration equivalent to 10^{-5} for a resident scenario
[d] Risk-based concentration equivalent to 10^{-6} for a resident scenario

Abbreviations:
DNB = dinitrobenzene
DNT = dinitrotoluene
µg/L = micrograms per liter
mg/L = milligrams per liter
NB = nitrobenzene
pCi/L = picocuries per liter
TCE = trichloroethylene

Federal and state water quality standards have not changed. Toxicity data for risk-based standards are the same as when the standards were established. (Note: The risk-based value calculated for 2,6-DNT using the IRIS slope factor for the 2,4- and 2-6-DNT mixture is more conservative than a risk-based value using the 2,6-DNT reference dose.)

From the above discussion, it can be concluded that under the current exposure scenario the remedy remains protective of human health and that the remediation objectives are still valid. Institutional controls play a key role in maintaining protectiveness until final remedial objectives for groundwater can be met.

Ecological Risks

It was previously noted that numerous ecological studies have been conducted across the Weldon Spring site (DOE 1995a, ANL 2004). Specific to the GWOU, sediment and surface water at Burgermeister Spring exhibited some elevated concentrations, prompting toxicity testing with those media (DOE 1997c). Toxicity was detected for some samples based on reduced survival of test organisms; however, no spatial relationship was observed between toxicity gradients and the spring. It was concluded that the toxicity could be due to some other source. Biotic surveys indicated no ill effects on invertebrate, fish, and amphibian communities and it was suggested that the communities have adapted and are tolerant of any contamination in the area. Uptake modeling indicated no risks to terrestrial receptors. The ecological risk assessment conducted as part of the GWOU baseline risk assessment concluded that groundwater associated with the Chemical Plant does not pose an unacceptable risk to aquatic or terrestrial biota, particularly due to the small and temporal nature of most of the springs.

There have been no changes in exposure assumptions, toxicity, or risk assessment methodology that would call into question the protectiveness of the remedy from an ecological risk perspective. Concentrations in relevant media have been reduced through the remediation that has taken place. Uranium concentrations remain elevated, but observations at the site suggest this is not having an adverse impact on the ecological communities at the site.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

7.3 Quarry Residuals Operable Unit

Question A: Is the remedy functioning as intended by the decision documents?

Answer A: Yes, the remedy is functioning as intended by the decision documents.

7.3.1 Remedial Action Performance

Long-term monitoring at the Quarry is designed to (1) monitor uranium levels south of the slough to ensure that they remain protective of human health and the environment, and (2) monitor uranium and 2,4-DNT levels within the area of groundwater impact north of the slough until they attain target levels that have been identified as having a negligible impact on the groundwater south of the slough (DOE 2000a). Groundwater north of the Femme Osage Slough will be monitored until a target level of 300 pCi/L for uranium is attained. In addition, groundwater south of the slough will be monitored to ensure protection of human health and the environment.

7.3.1.1 Missouri River Alluvium

Monitoring results from the Missouri River alluvial groundwater indicate that the average uranium levels were less than the statistical background value in the alluvium. The geochemical data continue to indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough, as shown by high dissolved iron concentrations, low sulfate concentrations, and low ORP values. This environment is not favorable for the migration of uranium, if it were to pass beyond the reduction zone north of the slough.

7.3.1.2 Area of Uranium and 2,4-DNT Impact

Uranium levels within the area of impact are decreasing in the bedrock wells along the Quarry rim and in some wells north of the Femme Osage Slough. These decreases are the result of bulk waste removal and restoration activities in the Quarry proper that reduced and possibly prevented infiltration of precipitation and storm water into the residually contaminated fracture system in the Quarry proper. The distribution of uranium in groundwater is still predominantly controlled by the precipitation of uranium along the oxidizing–reducing front north of the Femme Osage Slough. Although uranium levels have increased in some of the alluvial wells north of the slough, levels are far below historical highs. Monitoring in wells screened in the reducing portion of the area north of the slough indicate that uranium levels continue to remain low.

The attainment objective for the long-term monitoring of uranium in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 300 pCi/L (DOE 2000b). The 90th percentile associated with the data from the Line 1 and 2 wells was 1,193 pCi/L. This metric is strongly influenced by the uranium levels in the Line 2 alluvial wells, which have increased in the past 5 years. Uranium impact in this area still poses a potential impact to the groundwater quality in the Missouri River Alluvium south of the Femme Osage Slough.

Only two discrete areas in the Quarry Area exhibit 2,4-DNT impact in groundwater. Concentrations, although variable, have generally decreased since removal of the bulk wastes in the Quarry. Present concentrations in groundwater pose little potential impact on the groundwater in the Missouri River Alluvium.

The attainment objective for the long-term monitoring of 2,4-DNT in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 0.11 µg/L (DOE 2000b). The 90th percentile associated with the data from the 2,4-DNT monitoring network was 0.02 µg/L, which is significantly lower than those measured in previous years.

A review of the geochemical data north of the slough indicates that although the area of highest impact has an oxidizing environment, reducing conditions are prevalent along the northern edge of the slough. This is consistent with the uranium data where low levels are detected, especially along the edge of the slough where very low sulfate and high dissolved iron concentrations are also observed. The location of this reduction area was consistent during the review period, and the attenuation of uranium in this area continues.

7.3.2 System Operation and Maintenance

DOE has finalized the LTS&M Plan, which includes system operation and operation and maintenance information for LTS&M. DOE also performs annual inspections of LTS&M activities, environmental monitoring, and ICs, and found these activities to be functioning as intended.

7.3.3 Opportunities for Optimization

A review of remediation technologies relevant to the existing contamination associated with the QROU was performed as part of the Five-Year Review process. This review was conducted to determine whether new technologies that may be more effective than the long-term monitoring currently implemented and the methodologies evaluated in the supporting field studies have been introduced since the publication of the *Feasibility Study for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri* (DOE 1998d) and the issuance of the QROU ROD (DOE 1998d). The technology review consisted of a current literature search and evaluation of the latest information from the Federal Remediation Technologies Roundtable, the Environmental Security Technology Certification Program, and Hazardous Waste Clean-Up Information. These programs are summarized in Table 72. At this time, no new viable remediation technologies have become available for addressing uranium and nitroaromatic compounds present in groundwater at the Quarry and surrounding area. The limitations to extract groundwater from the shallow aquifer still reduces the effectiveness of any of the technologies reviewed. Thus, the selected remedy of long-term monitoring with ICs as implemented is still the optimum remedy for the QROU.

7.3.4 Early Indicators of Potential Issues

There are no early indicators of potential issues.

7.3.5 Implementation of ICs and Other Measures

The following are the use restriction listed in the LTS&M Plan (DOE 2008c) for the QROU. The ICs that are in place and planned for the Weldon Spring Site are discussed under the CPOU section above. The ICs that specifically apply to the QROU are the Missouri Well Installation Special Area designation rulemaking and the easements with MDC and the MDNR Division of State Parks.

The use restrictions listed below must be met at the specific areas shown in Figure 10. The use restrictions must be maintained until the remaining hazardous substances are at levels allowing for UUUE.

1. Prevent the development and use of the Quarry for residential housing, schools, childcare facilities, and playgrounds. Prevent drilling, boring, digging, or other activities in the Quarry proper that disturb the vegetation, disrupt the grade, expose the Quarry walls, or cause erosion of the clean fill that was used to restore the Quarry. This restriction should be maintained for the long term. The 9-acre Quarry is under DOE jurisdictional control.
2. Prevent the use of the contaminated shallow groundwater for drinking water purposes. The contaminated shallow groundwater underlies the Quarry and extends to the marginal alluvium north of the slough as indicated in Figure 13. This restriction will need to be maintained over a period of decades or longer.
3. Limit the use of all groundwater within the outlined restricted area shown in Figure 13 to investigative monitoring only. The boundary of the restricted area extends beyond the area of contamination and is intended to provide a buffer against potential hydraulic influences on the area of contamination by preventing such things as pumping wells being located in the proximity of the contaminated area. This restriction includes the shallow groundwater system and also extends vertically to all groundwater systems that underlie the contaminated groundwater. This restriction will need to be maintained over a period of decades or longer, until uranium concentrations in Quarry groundwater north of the slough are at 300 pCi/L or lower. With the exception of the 9-acre Quarry, this restricted area is owned by state entities. This area covers approximately 202 acres.
4. Prevent drilling, boring, digging, construction, earth moving, or other activities in the location identified as the Quarry natural reduction zone area that could result in disturbing the soils at this location or exposing subsurface soils (i.e., soils deeper than [about] 5 ft below the surface). The soil in this area at a depth of 5 ft or greater contains geochemical properties that allow reduction processes to naturally occur, resulting in the precipitation of uranium from Quarry groundwater north of the Femme Osage Slough and thereby minimizing uranium migration to the well field. The restrictions must be maintained over a

period of decades or longer, until uranium concentrations in Quarry groundwater north of the slough are 300 pCi/L or lower. This area is located on property owned by a state entity and is approximately 4.7 acres in size.

5. Retain access to the area for continued monitoring and maintenance of groundwater wells.
6. Maintain the integrity of any current or future remedies or monitoring systems.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection still valid?

Answer B: Yes, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection are still valid.

Human Health

A review of assumptions incorporated into the risk assessments documented in the *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri (1998b)* and the *Feasibility Study for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri* (1998d) was also performed. The review included the following risk assessment aspects: risk assessment methodology, exposure scenarios, exposure assessment input parameters, and toxicity values. The remediation and ICs have resulted in the severing of all exposure pathways.

A post-remediation risk assessment was conducted for the QROU (ANL 2003) to estimate risks associated with residual contamination at the site and compare it to preremediation risks estimated in the baseline risk assessment. Risks were calculated for exposures at Femme Osage Slough, the Quarry proper, and soils outside the Quarry for both a recreational visitor and a resident using assumptions from the original baseline risk assessment (DOE 1997b). Toxicity data were not provided in the post-remediation risk assessment, but it is assumed that data were the same as those used in the CPOU post-remediation risk assessment (DOE 2002; Table 73) and that data and calculations remain valid. The calculations indicated that risks to recreational visitors and residents are acceptable (resident risks were comparable to background; recreational visitor risks were lower). Risks were dominated by external exposure to radium-226 and -228.

No changes to the risk assessment methodology recommended by EPA for CERCLA sites have occurred since the publication of the QROU documentation that would significantly affect the conclusions of the post-remediation risk assessment. Exposure scenarios and exposure assessment input parameters are also still valid as land uses assumed for the risk assessments are still representative of current and expected future land use (i.e., recreational visitor scenario). In addition, as for the GWOU, ICs are also being implemented to ensure that current land uses remain unchanged.

Section 1.5, *Current Regulatory Requirements,* in the LTS&M Plan discusses the ARARs that apply to the post-remediation aspect of the project, and it states the following:

> "The 30 µg/L standard for uranium in groundwater outlined in 40 CFR 192.02 was considered as a potential ARAR for the quarry groundwater during development of the Feasibility Study (DOE 1998a) and Proposed Plan (DOE 1998b). The groundwater north of the slough is impacted; however, it is not considered to be a usable groundwater

> source. Conversely, the Missouri River alluvium south of the slough is currently not impacted and is presently being used as a potable water source. Because groundwater north of the slough is not a useable source, 40 CFR 192.02 is not considered an ARAR for that groundwater. However, 40 CFR 192.02 would likely be an ARAR for any remedial action considered for the useable groundwater source south of the slough in the unlikely event of contaminant migration from north of the slough. The Missouri Water Quality Standard for 2,4-DNT (0.11 µg/L) is also a chemical-specific ARAR for quarry groundwater."

<u>Ecological Risk</u>

It was previously noted that numerous ecological studies have been conducted across the Weldon Spring site (DOE 1995a, ANL 2004). Specific to the QROU, the baseline (preremediation) risk assessment indicated that some contaminants were present at levels above "safe" values for ecological receptors (DOE 1997b). However, no such adverse effects were actually observed in the fauna that were sampled; furthermore, most of the QROU was determined to not provide good habitat for ecological receptors based on its physical characteristics. The exceptions are Femme Osage Slough and Little Femme Osage Creek. Radionuclides in tissues of small mammals collected from the Quarry were comparable to those from the reference areas. Internal and external examinations of small mammals did not show any sign of abnormalities that could be attributed to site contamination. Fish sampling was conducted every two years in Femme Osage Slough and area lakes for a number of years in the 1990s and did not detect any abnormal results. Sampling was discontinued in the late 1990s.

Remediation has addressed most of the potential ecological risks associated with the QROU. There have been no changes in exposure assumptions, toxicity, or risk assessment methodology that would call into question the protectiveness of the remedy from an ecological risk perspective. Concentrations in relevant media have been reduced through the remediation that has taken place.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

8.0 Issues

Table 75. Issues

Issue	OU Affected	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Erosion areas have been identified on the Chemical Plant property.	CPOU	N	N
Small depressions and bulges have been identified on the disposal cell.	CPOU	N	N
Uranium levels in the GWOU Objective 2 wells screened in the unweathered unit have been greater than the trigger of 100 pCi/L since installation. A specific monitoring program for COCs in the unweathered unit has not been established as this impact was identified after design and implementation of the MNA remedy.	GWOU	N	N
Vandalism issues exist.	CPOU	N	N
DOE is working to obtain an easement with MoDOT.	GWOU	N	N

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9.0 Recommendations and Follow-Up Actions

Table 76. Recommendations and Follow-Up Actions

Issue	Recommendations and Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness	
					Current	Futures
Erosion areas have been identified on the Chemical Plant property.	It has been determined that existing erosion continues to be fairly typical for a reclaimed site and that no channels are currently a threat to the integrity of the disposal cell. Continued monitoring of erosion would be prudent. The erosion will continue to be monitored, and another mapping and evaluation is scheduled for the spring and early summer 2011.	DOE	EPA MDNR	Ongoing	N	N
Small depressions and bulges have been identified on the disposal cell.	These types of areas are not unexpected for a disposal cell of this type and are not a cause for concern. DOE will continue to monitor the area.	DOE	EPA MDNR	Ongoing	N	N
Uranium levels in the GWOU Objective 2 wells screened in the unweathered unit have been greater than the trigger of 100 pCi/L since installation. A specific monitoring program for COCs in the unweathered unit has not been established as this impact was identified after design and implementation of the MNA remedy.	The MNA program regarding the uranium impact in the unweathered unit should be evaluated and possibly modified, which could include new trigger values and additional monitoring locations.	DOE	EPA MDNR	Ongoing N/A	N	N
Vandalism issues exist.	Continue security patrols. Place signs on the disposal cell stating that the video surveillance is in use (or a similar type of action).	DOE	EPA MDNR	Ongoing N/A	N	N
DOE is working to obtain an easement with MoDOT.	Work with MDNR and MoDOT to resolve landowner and other issues. Reevaluate whether IC is necessary.	DOE	EPA MDNR	9/2014	N	N

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10.0 Protectiveness Statements

This five-year review found the remedy for the entire site to be protective of human health and the environment for all the operable units.

10.1 Chemical Plant Operable Unit

The remedy that has been implemented at the CPOU is protective of human health and the environment. Contaminant sources are contained in an on-site disposal facility at the Chemical Plant. The environmental monitoring data and annual inspections continue to verify that the disposal cell is functioning as intended.

The remedy that has been implemented at the Southeast Drainage is protective of human health and the environment. The remedy consisted of removing contaminated soils and sediment to levels that are protective under the current land use. The drainage has recovered from the removal activities and is stable. ICs will be used to maintain appropriate land and resource use and ensure that the remedy remains protective over the long term.

10.2 Groundwater Operable Unit

The remedy for the GWOU will be protective of human health and the environment upon attainment of groundwater cleanup goals, through MNA, which is expected to require approximately 100 years to achieve. In the interim, exposure pathways that could result in unacceptable risks are being controlled and ICs are in place to prevent the groundwater from being used in the restricted area.

10.3 Quarry Bulk Waste Operable Unit

The remedy for the QBWOU is protective of human health and the environment. The action consisted of excavating the bulk wastes from the Quarry and placing them in controlled temporary storage pending final placement in the on-site disposal cell at the Chemical Plant. Excavating the wastes from the Quarry eliminated the potential for direct contact with the waste material and removed the source of ongoing contaminant migration to groundwater.

10.4 Quarry Residuals Operable Unit

The remedy for the QROU is protective of human health and the environment through long-term monitoring with ICs. The remedy consists of long-term groundwater monitoring and ICs to maintain appropriate land and resource use and ensure that the remedy remains protective over the long-term.

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11.0 Next Review

This is the fourth statutory Five-Year Review for this site. The next Five-Year Review for the Weldon Spring Site is required five years from the signature date of this review.

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12.0 References

40 CFR 141. U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations," *Code of Federal Regulations,* July 1, 2005.

40 CFR 192. U.S. Environmental Protection Agency, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations,* July 1, 2005.

40 CFR 264. U.S. Environmental Protection Agency, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations,* July 1, 2005.

10 CSR 20-7.031. *Missouri Code of State Regulations,* Title 10, "Department of Natural Resources," Division 20, "Clean Water Commission," Chapter 7.031, "Water Quality Standards."

10 CSR 25-7.264. *Missouri Code of State Regulations,* Title 10, "Department of Natural Resources," Division 25, "Hazardous Waste Management Commission," Chapter 7.264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities."

ANL (Argonne National Laboratory), 1999. *Postcleanup Risk Assessment for the Southeast Drainage*, letter report from Mary Picel to Tom Pauling, September 14.

ANL (Argonne National Laboratory), 2003. *An Evaluation of the Residual Risk Status for the Quarry Residuals Operable Unit*, letter report from Mary Picel to Tom Pauling, April 30.

ANL (Argonne National Laboratory), 2004. *NRDA and Ecological Risk Assessments at the Weldon Spring Site Remedial Action Project (WSSRAP), Weldon Spring, MO,* letter report from Mary Picel to Tom Pauling, January 30.

BEIR V (Committee on the Biological Effects of Ionizing Radiation), National Research Council. Health Effects of Exposure to Low Levels of Ionizing Radiation. Washington, DC: National Academy Press, 1990.

DOE Orders: 430.1B, *Real Property Asset Management*
5400.5, *Radiation Protection of the Public and the Environment*

DOE (U.S. Department of Energy), 1989. *Remedial Investigation for Quarry Bulk Wastes,* Rev. 1, DOE/OR/21548-066, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 1990a. *Proposed Plan for the Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri*, Rev. 0, DOE/OR/21548-105, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1990b. *Record of Decision for the Management of the Bulk Wastes at the Weldon Spring Quarry*, Rev. 0, DOE/OR/21548-317, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1990c. *Feasibility Study for Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri*, DOE/OR/21548-104, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1990d. *Baseline Risk Evaluation for Exposure to Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri*, DOE/OR/21548-065, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 1992a. *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-074, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 1992b. *Feasibility Study for the Chemical Plant Area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-148, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 1992c. *Agricultural Sampling Plan*, Rev. 1., DOE/OR/21548-229, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 1992d. *Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site*, DOE/OR/21548-091, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 1992e. *Biological Assessment for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site,* ANL/EAIS/TM-80, November.

DOE (U.S. Department of Energy), 1992f. *Proposed Plan for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-160, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 1993. *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-376, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1994. *Conceptual Design Report for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-411, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 1995a. *Radiological and Chemical Uptake in Game Species at the Weldon Spring Site,* DOE/OR/21548-426, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1995b. *Remedial Action Work Plan for the Chemical Plant area of the Weldon Spring Site*, Rev. 0, DOE/OR/21548-529, U.S. Department of Energy Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 1996. *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548-584, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 1997a. *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri*, DOE/OR/21548-571, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1997b. *Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri*, DOE/OR/21548-594, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1997c. *Baseline Risk Assessment for the Remedial Action for the Groundwater Operable Units at the Chemical Plant and Ordnance Works, Weldon Spring, Missouri*, DOE/OR/21548-568, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1997d. *Quarry Bulk Waste Excavation Remedial Action Report*, DOE/OR/21548-642, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, March.

DOE (U.S. Department of Energy), 1997e. *Post-Remediation Sampling Plan for the Southeast Drainage*, DOE/OR/21548-616, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1998a. *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548-725, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1998b. *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri*, Rev. 2 (Final), DOE/OR/21548-587, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1998c. *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri*, DOE/OR/21548-569, U.S. Department of Energy Oak Ridge Operations Office and U.S. Department of the Army Corps of Engineers, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, March.

DOE (U.S. Department of Energy), 1998d. *Feasibility Study for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri*, Rev. 2 (Final), DOE/OR/21548-587, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1998e. *Proposed Plan for Remedial Action at the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri*, Rev. 2 (Final), DOE/OR/21548-724, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, March.

DOE (U.S. Department of Energy), 1999a. *Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7*, Rev. 0, DOE/OR/21548-772, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1999b. *Technical Guidance for the Long-Term Monitoring of Natural Attenuation Remedies at Department of Energy Sites*, October.

DOE (U.S. Department of Energy), 1999c. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, OSWER 9200.4-178, April.

DOE (U.S. Department of Energy), 1999d. *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri*, Rev. 0, DOE/OR/21548-783, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, June.

DOE (U.S. Department of Energy), 1999e. *Proposed Plan for the Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri*, Rev. 0, DOE/OR/21548-733, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, June.

DOE (U.S. Department of Energy), 2000a. *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site*, DOE/OR/21548-798, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 2000b. *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit*, DOE/OR/21548-787, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2000c. *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups*, EPA 540-F-00-005, September.

DOE (U.S. Department of Energy), 2001a. *Comprehensive Five-Year Review Guidance*, OSWER 9355.7–03B–P, October.

DOE (U.S. Department of Energy), 2001b. *Weldon Spring Site Remedial Action Project Second Five-Year Review*, DOE/OR/21548-891, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 2001c. *Completion Report for Radon Flux Monitoring of the WSSRAP Disposal Facility*, DOE/OR/21548-876, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2002a. *Completion Report for the Geochemical Characterization Performed in Support of the QROU Field Studies,* DOE/OR/21548-919, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, April.

DOE (U.S. Department of Energy), 2002b. *Weldon Spring Site Environmental Report for Calendar Year 2001,* Rev. 0, DOE/OR/21548-917, U.S. Department of Energy Oak Ridge Operations Office, St. Charles, Missouri.

DOE (U.S. Department of Energy), 2002c. *Completion Report for the Additional Groundwater Field Studies in Support of the Groundwater Operable Unit*, Rev. 0, DOE/OR/21548-920, U.S. Department of Energy Oak Ridge Operations Office, July.

DOE (U.S. Department of Energy), 2002d. *Post-Remediation Risk Assessment for the Chemical Plant Operable Unit Weldon Spring Site St. Charles, Missouri*, Rev. 1, DOE/OR/21548-910, U.S. Department of Energy Oak Ridge Operations Office, March.

DOE (U.S. Department of Energy), 2003a. *Quarry Residuals Operable Unit Interim Remedial Action Report,* DOE/OR/21548-927, U.S. Department of Energy Oak Ridge Operations Office Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri.

DOE (U.S. Department of Energy), 2003b. *Evaluation of the Performance of the Interceptor Trench Field Study*, Draft, DOE/OR/21548-916, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri.

DOE (U.S. Department of Energy), 2003c. *Weldon Spring Site Environmental Report for Calendar Year 2002,* Rev. 0, DOE/OR/21548-931, U.S. Department of Energy Oak Ridge Operations Office, St. Charles, Missouri.

DOE (U.S. Department of Energy), 2003d. *Environmental Monitoring Plan*, Rev. 11, DOE/OR/21548–424, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2003e. *Supporting Evaluation for the Proposed Plan for the Final Remediation Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site*, DOE/GJ/79491-934, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 2003f. *Proposed Plan for Final Remediation Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site*, DOE/GJ/79491-932, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 2004a. *Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site,* DOE/GJ/79491-936a, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2004b. *Chemical Plant Operable Unit Remedial Action Report*, DOE/GJ/79491–909, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2004c. *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan.* Rev 2, DOE/GJ/79491-646, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, March.

DOE (U.S. Department of Energy), 2004d. *Institutional Controls Evaluation (ICE) Report: Summary of Supporting Information for the Identification and Evaluation of Institutional Controls for the Weldon Spring Site*, U.S. Department of Energy Office of Legacy Management, October.

DOE (U.S. Department of Energy), 2004e. *2003 Annual Inspection Report for the Weldon Spring Site, St. Charles, Missouri.* Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 2004f. *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site,* DOE/GJ/79491-943, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 2004g. *Weldon Spring Site Environmental Report for Calendar Year 2003,* U.S. Department of Energy Office of Legacy Management, DOE/GJ/79491-944.

DOE (U.S. Department of Energy), 2004h. *Completion Report for the Groundwater Sampling Performed in Support of the Pilot Phase ICO Project,* DOE/GJ/79491-939, U.S. Department of Energy Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2005a. *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri Site*, DOE-LM/GJ885-2005, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 2005b. *Weldon Spring Site Cell Groundwater Monitoring Demonstration Report for the December 2004 Sampling Event,* DOE-LM/GJ893-2005, U.S. Department of Energy Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2005c. *Explanation of Significant Differences, Weldon Spring Site,* U.S. Department of Energy Office of Legacy Management, February.

DOE (U.S. Department of Energy), 2005d. *2004 Annual Inspection Report for the Weldon Spring, Missouri, Site*, DOE-LM/GJ778-2005, U.S. Department of Energy Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2005e. *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site,* DOE/GJ/79491-952, U.S. Department of Energy Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2005f. *Weldon Spring Site Environmental Report for Calendar Year 2004,* DOE-LM/GJ879-2005, U.S. Department of Energy Office of Legacy Management, July.

DOE (U.S. Department of Energy), 2006a. *2005 Annual Inspection Report for the Weldon Spring, Missouri, Site*, DOE-LM/GJ1137-2005, U.S. Department of Energy Office of Legacy Management, February.

DOE (U.S. Department of Energy), 2006b. *Weldon Spring Site Environmental Report for Calendar Year 2005,* DOE-LM/GJ1213-2006, U.S. Department of Energy Office of Legacy Management, July.

DOE (U.S. Department of Energy), 2006c. *Weldon Spring Site Third Five-Year Review*, DOE-LM/GJ1158-2006, U.S. Department of Energy Office of Legacy Management, September.

DOE (U.S. Department of Energy), 2007a. *2006 Annual Inspection Report for the Weldon Spring, Missouri, Site*, DOE-LM/1425/2007, U.S. Department of Energy Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2007b. *Weldon Spring Site Environmental Report for Calendar Year 2006*, DOE-LM/GJ1486-2007, U.S. Department of Energy Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2008a. *2007 Annual Inspection Report for the Weldon Spring, Missouri, Site*, DOE-LM/GJ1561-2007, U.S. Department of Energy Office of Legacy Management, December.

DOE (U.S. Department of Energy), 2008b. *Weldon Spring Site Environmental Report for Calendar Year 2007*, LMS/WEL/S04501, U.S. Department of Energy Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2008c. *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri Site*, DOE-LMS/WEL/S0079-1.0, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 2008d. *Baseline Concentrations of the Chemical Plant Groundwater Operable Unit Monitored Natural Attenuation Network at the Weldon Spring Site*, DOE-LMS/WEL/S02589, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 2009a. *2008 Annual Inspection Report for the Weldon Spring, Missouri, Site*, LMS/WEL/S05038, U.S. Department of Energy Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2009b. *Weldon Spring Site Environmental Report for Calendar Year 2008*, LMS/WEL/S05532, U.S. Department of Energy Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2010a. *2009 Annual Inspection Report for the Weldon Spring, Missouri, Site*, LMS/WEL/S06063, U.S. Department of Energy Office of Legacy Management, January

DOE (U.S. Department of Energy), 2010b. *Weldon Spring Site Environmental Report for Calendar Year 2009*, LMS/WEL/S06713, U.S. Department of Energy Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2011. *2010 Annual Inspection Report for the Weldon Spring, Missouri, Site*, LMS/WEL/S07299, U.S. Department of Energy Office of Legacy Management, January.

EPA (U.S. Environmental Protection Agency), 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, OSWER 9200.4-178, April.

EPA (U.S. Environmental Protection Agency), 2000. *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups*, EPA 540-F-00-005, September.

EPA (U.S. Environmental Protection Agency), 2001. *Comprehensive Five-Year Review Guidance*, OSWER 9355.7–03B–P, October.

EPA (U.S. Environmental Protection Agency), 2002. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), EPA530-D-02-004, November.

EPA (U.S. Environmental Protection Agency), 2005a. *Institutional Controls Research−Missouri*. Prepared for U.S. Environmental Protection Agency Region VII, Superfund Division, and Office of Regional Counsel by DPRA Incorporated, Manhattan, Kansas, April 8.

EPA (U.S. Environmental Protection Agency), 2005b. Transmittal Letter from U.S. Environmental Protection Agency Region VII, Superfund Division to U.S. Department of Energy, Office of Legacy Management (transmitting attachment with recommendations for institutional controls for the Weldon Spring site), April 22.

EPA (U.S. Environmental Protection Agency), 2009. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment, Final, EPA-540-R-070-002, OSWER 9285.7-82, January.

Kleeschulte, M.J., L.F. Emmett, and J.H. Barks, 1986. *Hydrologic Data for the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles, County, Missouri – 1984-1986*, U.S. Geologic Survey Open-File Report 86-488, Rolla, Missouri.

Layne Wester Company, Inc., 1986. *Groundwater Hydrology Investigation,* Weldon Spring, Missouri, Vol. 1, Hydrology Division, Kansas City, January.

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