United States
Environmental Protection
Agency

EPA 542-R-14-010
Office of Solid Waste and Emergency Response
Office of Superfund Remediation and
Technology Innovation

Optimization Review
Lockwood Operable Unit 2 – Soco/Brenntag Source Area

Billings, Montana

www.clu-in.org/optimization | www.epa.gov/superfund/cleanup/postconstruction/optimize.htm

OPTIMIZATION REVIEW

LOCKWOOD OPERABLE UNIT 2 - SOCO/BRENNTAG SOURCE AREA

BILLINGS, MONTANA

Report of the Optimization Review

Conducted at Lockwood Solvent Groundwater Plume Site

FINAL REPORT

September 19, 2014

EXECUTIVE SUMMARY

Optimization Background

The U.S. Environmental Protection Agency (EPA) defines optimization as the following:

> *"Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness. Contractors, states, tribes, the public, and PRPs* [potentially responsible parties] *are also encouraged to put forth opportunities for the Agency to consider."*(1)

An optimization review considers the goals of the remedy, available site data, the conceptual site model (CSM), remedy performance, protectiveness, cost-effectiveness and the closure strategy. A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, optimization now routinely considers green remediation and environmental footprint reduction during optimization reviews.

An optimization review includes reviewing site documents, interviewing site stakeholders, potentially visiting the site for 1 day, and compiling a report that includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site completion
- Environmental footprint reduction

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed before the recommendation can be implemented. Note that the recommendations are based on an independent review and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the State of Montana, the Region, and other site stakeholders. Also note that while the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans (QAPP).

Site-Specific Background

The Lockwood Solvent Groundwater Plume Site (LSGPS) is located on the outskirts of Billings, Montana, in EPA Region 8. The site is managed as two operable units (OUs). OU1 consists of

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[1] U.S. Environmental Protection Agency (EPA). 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

contaminated soils and a plume of chlorinated solvents in groundwater associated with the Beall Source Area (Area B), and OU2 consists of affected media associated with the Brenntag (Soco; Area A) Source Area. This optimization review addressed remedial components planned for affected soil and groundwater in OU2. OU1 is addressed under a separate optimization review report.

The source area for OU2 is a former chemical storage, re-packaging, and distribution facility operated under the Brenntag and Dyce Chemical corporate names. The facility began operations in 1972. The property is currently under new ownership, with no on-going commercial activity. Built structures have been demolished. Remediation of affected soil and groundwater is currently being conducted under the Superfund program as a PRP-lead project.

In 1986, Lockwood Water and Sewer District (LWSD) personnel identified benzene and chlorinated solvents in Lockwood area water supply wells, leading to a number of investigations by the Montana Department of Environmental Quality (DEQ). In June 1998, DEQ performed an integrated site assessment in cooperation with the EPA. The LSGPS was added to the National Priorities List (NPL) in 2000 (CERCLIS ID# MT0007623052).

In 2002, the DEQ conducted a Remedial Investigation (RI) that included surface and subsurface soil sampling, monitoring well construction and groundwater sampling, aquifer testing, surface water sampling, sediment sampling and soil vapor sampling. Based on the RI results, the EPA and DEQ evaluated remedial alternatives as part of a Feasibility Study (FS) and Proposed Plan completed in July 2004. The site-wide LSGPS Record of Decision (ROD) was issued in 2005. The 2005 ROD selected the following components for the OU2 remedial action:

- Soil excavation of accessible vadose zone soils in the source area
- Ex situ thermal treatment of excavated soils
- Soil vapor extraction (SVE)/ozone sparging of inaccessible vadose zone soils in the source area
- In situ chemical oxidation (ISCO) of inaccessbible saturated zone soils
- In situ bioremediation (ISB) treatment of groundwater source and plume
- Permeable reactive barrier (PRB) of source groundwater
- Risk mitigation for groundwater and subsurface soils including monitoring potable water supplies, mitigation (providing municipal water) for affected private water supply wells, and indoor air monitoring and mitigation as needed
- Institutional controls to prohibit excavation and drilling in affected subsurface areas
- Groundwater monitoring of the alluvial aquifer
- Five-year reviews.

The remedial design (RD) process is under way at OU2, with the goal of addressing contamination associated with the Soco Source Area.

The LSGPS was nominated for an optimization review by the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) at the request of the Region 8 Remedial Project Manager (RPM) in September 2012. The review of remedy design considerations for the selected remedy options for the LSGPS OU2 is intended to optimize the remedial response to address contamination in soil and groundwater, to achieve maximum protectiveness while improving remedy cost and energy efficiency and to minimize time required to achieve cleanup goals.

Summary of Conceptual Site Model and Key Findings

Several primary sources of contamination have been identified within the former chemical handling facility at OU2. Site data suggest that contamination was released at different times and by different mechanisms at several locations around the facility. The priority contaminant of concern (COC) and parent constituent on site is tetrachloroethene (PCE), but several other hydrocarbon compounds are also present in shallow soils. PCE in the shallow subsurface has undergone anaerobic degradation, resulting in formation of the decay products, trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride. PCE and its degradation products have been detected at concentrations above EPA Maximum Contaminant Levels (MCLs) in groundwater.

Site surface soil and shallow subsurface soils are composed of highly heterogeneous, interbedded sands and gravels, silty sands, clays and silts. PCE and other chlorinated volatile organic compounds (cVOCs) released from the diverse primary sources have migrated to the saturated zone (located at approximately 10 feet below ground surface). Source area soils show both vertical and horizontal heterogeneity and discontinuous concentrations of the primary COCs. The distributed nature of source materials and contamination adds complexity to selecting effective remedial approaches. High concentrations of cVOCs in soils imply the presence of non-aqueous phase liquids (NAPL). Because of the heterogeneity of soil textures, the majority of the contamination that remains is likely present in the relatively impermeable silt layers, possibly serving as a long-term secondary source of contamination.

A saturated silt, sand and gravel shallow alluvial aquifer is present between 15 and 30 feet below ground surface. A sandstone and shale bedrock layer (Eagle Sandstone) lies below 30 feet depth. Groundwater in the bedrock aquifer does not appear to be contaminated. A groundwater plume in the shallow alluvial aquifer extends to the northwest from the OU2 source area, ultimately discharging to the Yellowstone River approximately 2,000 feet downgradient of the OU2 source area. Centerline concentrations of PCE in the alluvial plume are in the range of 300 to 2,000 micrograms per liter (µg/L). Groundwater flow direction is to the north-northwest with relatively flat gradients. Historical activities in the flood plain, such as dewatering in the gravel pit north of the source area may have influenced the shape of the contaminant plume.

Historical water supply wells may have pulled contaminated groundwater to the west. Shallow supply wells in the area have been abandoned and area residents supplied with municipal water. The change in pumping regime may cause the plume to migrate more toward the north/northeast in the future.

The average saturated thickness in the shallow aquifer is about 20 feet. Groundwater seepage velocities are in the range of 2.75 feet per year (for low permeability saturated zones) to 654 feet per year (in the saturated gravel zones). The precise distribution of contamination in the saturated zone is currently difficult to quantify because well screens at many locations are 20 feet long.

The highest dissolved contaminant concentrations in groundwater were detected at wells installed to monitor the Northwest Source Area and the pilot-scale SVE/ozone sparging system. Wells in this area show stable to decreasing concentration trends for PCE by the Mann-Kendall statistical test for trend, indicating that the SVE/ozone sparging system tested in the area was effective at removing contaminant mass.

Potentially complete exposure pathways associated with OU2 include ingestion of, and direct contact with, contaminated groundwater, and vapor intrusion in nearby residences and commercial operations and on-site exposure to contaminated soils. Shallow, private water supply wells in the area have been abandoned and area residents have been supplied with municipal water. Residential indoor air sampling was conducted in 1999 and 2000 by the Superfund Technical Assessment and Response Team (START) to evaluate health risks from vapor intrusion of chlorinated solvents into area residences. Mitigation of risks related to contaminated groundwater and indoor air exposure are on-going. Plume discharge to the Yellowstone River is not considered to cause excess ecological risk.

Summary of Recommendations

Optimization review team recommendations were developed to support an adaptive management strategy for long-term remediation of soil and groundwater at OU2. The following sequence of activities is recommended to optimize the RD process and long-term remedy performance at LSGPS OU2:

- Additional groundwater wells are recommended for the source and immediate downgradient plume. Wells are recommended to be installed in clusters of three depths using Rotosonic drilling and 5-foot screened intervals. (Note: this recommendation has largely been accomplished.) Perform depth-discreet groundwater sampling to identify the intervals of highest contamination at sampling locations with long screens in the downgradient plume. Identifying the areas of highest contamination will support locating remedies for optimal mass removal.
- Use existing data to prepare highly detailed, OU2-specific cross sections that highlight low-permeability seams and areas of highest contaminant mass. Use detailed source-area data to refine the RD.
- Reactivate and expand the SVE/ozone sparging remedy for the Northwest Source Area and other nearby highly contaminated primary source areas. Expand the *ex situ* SVE/ozone sparging system to treat excavated soils.
- Excavate and treat highly contaminated, low-permeability, shallow soil (above 20 feet below ground surface) with *ex situ* SVE/ozone sparging. The time and efficacy benefit of excavation may outweigh the added cost of excavation. On-site treatment with the SVE/ozone sparging system already in place will reduce costs and improve efficiency.
- Implement ISB treatment in the source area. Placement of the ISB remedy should be based on the interpretation of data from the additional site characterization recommended above. Add the ISB amendment at the base of the excavations (if implemented) to treat deeper areas of contamination at and below the water table in the source area.
- Conduct performance monitoring for the source remedy for 3 to 5 years after implementation.
- Prioritize source area remediation. Delay implementation of an ISB remedy in the dissolved leading edge of the groundwater plume until 3 to 5 years of source area remedy performance data have been collected and analyzed. Given the high rate of groundwater flow, the success of the source remedy should be apparent in downgradient alluvial aquifer wells (for example, MW-007, MW-122, and MW-009) relatively rapidly. Strongly decreasing concentration trends and a reduced or altered plume footprint in response to source treatment may influence the location and extent of the downgradient ISB plume remedy.
- Carefully monitor the northern and eastern edges of the plume near well MW-006, where concentrations may be increasing because groundwater flow is no longer influenced by pumping from historical operations at the gravel pit. If concentrations increase above MCLs at well MW-006, consider installing an additional monitoring well to delineate the plume to the northeast.

Improving effectiveness –

Recommendations to improve remedy effectiveness include addressing data gaps through additional site characterization. Data acquired from additional sampling can be used to scale and position remedial components for maximum efficacy. Remedy effectiveness should be improved through adaptive site management following the sequence of activities outlined above. The optimization review team recommends a combination of expanded SVE/ozone sparging, excavation and *ex situ* soil treatment with *ex situ* SVE/ozone sparging, followed by ISB for source area contamination. Targeted excavation of highly contaminated, low-permeability soils followed by *ex situ* SVE/ozone sparging treatment on site should reduce the potential for long-term back diffusion. ISB treatment at the base of the excavations will stimulate anaerobic degradation of the residual cVOC constituents.

Reducing cost –

No specific recommendations are provided in this category at this time. The adaptive site management approach, where decisions are made based on the data gathered during implementation of the optimization recommendations, should provide long-term reduction in cost. Expanding the existing SVE/ozone sparging system to treat shallow contamination and excavated soils should be cost efficient relative to other potential remedies considered.

Delaying the decision on the scale or necessity of ISB treatment for the downgradient plume may result in long-term cost savings by scaling and positioning the ISB remedy for maximum efficacy.

Technical improvement –

Recommendations for technical improvement are the largely same as those for improved efficacy. Additional site characterization and sequencing of remedial approaches should improve the performance of selected remedies. Specific recommendations for remedy performance monitoring will indicate when remedies are not functioning as anticipated. Underperforming remedies can be modified or terminated, based on accumulated data.

Site closure –

Specific recommendations are provided for short- and long-term remedy performance monitoring. Acquisition of statistically significant datasets to evaluate remedy performance will support decisions on termination of active remedies and site redevelopment.

Green remediation –

Addressing data gaps through further source characterization should support the design of more efficient remedy scale and placement, thus reducing the overall footprint of the remedy. Expanding the existing pilot-scale SVE/ozone sparging system to treat excavated soils should reduce the carbon footprint of the overall remedy, especially compared with the thermal treatment option considered.

NOTICE AND DISCLAIMER

Work described herein was performed by Tetra Tech, Inc. (Tetra Tech) for the U.S. Environmental Protection Agency (EPA). GSI Environmental performed work under a subcontract to Tetra Tech. Work conducted by Tetra Tech, including preparation of this report, was performed under Work Assignment 2-58 of EPA contract EP-W-07-078 with Tetra Tech. The report was approved for release as an EPA document, following the Agency's administrative and expert review process.

This optimization review is an independent study funded by the EPA that focuses on protectiveness, cost-effectiveness, site closure, technical improvements and green remediation. Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Recommendations are based on an independent evaluation of existing site information, represent the technical views of the optimization review team and are intended to help the site team identify opportunities for improvements in the current site remediation strategy. These recommendations do not constitute requirements for future action; rather, they are provided for consideration by the State of Montana, EPA Region and other site stakeholders.

While certain recommendations may provide specific details to consider during implementation, these recommendations are not meant to supersede other, more comprehensive, planning documents such as work plans, sampling plans and quality assurance project plans (QAPP); nor are they intended to override applicable or relevant and appropriate requirements (ARARs). Further analysis of recommendations, including review of EPA policy may be needed prior to implementation.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization from remedial investigation to site completion implemented by the U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI)[2]. The project contacts are as follows:

Organization	Key Contact	Contact Information
U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI)	Kirby Biggs	EPA OSRTI Technology Innovation and Field Services Division (TIFSD) 2777 Crystal Drive Arlington, VA 22202 biggs.kirby@epa.gov phone: 703-823-3081
Tetra Tech (Contractor to EPA)	Jody Edwards, P.G.	Tetra Tech, Inc. 45610 Woodland Road Suite 400 Sterling, VA 20166 jody.edwards@tetratech.com phone: 802-288-9485
GSI Environmental (Contractor to EPA)	Mindy Vanderford, Ph.D.	GSI Environmental, Inc. 2211 Norfolk Suite 1000 Houston, TX 77098 mvanderford@gsi-net.com phone: 713-522-6300 x 186

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[2] U.S. Environmental Protection Agency (EPA). 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

LIST OF ACRONYMS AND ABBREVIATIONS

μg/kg	Micrograms per Kilogram
μg/L	Micrograms per Liter
ATC	Advanced Technologies, Inc.
bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-Dichloroethene
COC	Contaminant of Concern
CSM	Conceptual Site Model
cVOC	Chlorinated Volatile Organic Compound
cy	Cubic yards
DEQ	Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
FYR	Five-Year Review
GAC	Granular Activated Carbon
GIS	Geographic Information System
ISB	*In situ* Bioremediation
IC	Institutional Control
ISCO	*In situ* Chemical Oxidation
LSGPS	Lockwood Solvent Groundwater Plume Site
LWSD	Lockwood Water and Sewer District
MAROS	Monitoring and Remediation Optimization System Software
MCL	Maximum Contaminant Level
mg/kg	Milligrams per Kilogram
MW	Monitoring Well
N/A	Not Applicable
NAPL	Non-Aqueous Phase Liquid
NI	Not Identified
NPL	National Priorities List
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
OU2	Operable Unit 2, Soco West source area (formerly known as Brenntag)
PCE	Tetrachloroethene
PDB	Permeable diffusion bag
PRB	Permeable Reactive Barrier
PRP	Potentially Responsible Party
PWT	Pacific Western Technologies, Ltd.
QAPP	Quality Assurance Project Plan
RAC	Remedial Action Contractor

RACER	Remedial Action Cost Engineering and Requirements System
RAO	Remedial Action Objective
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
START	Superfund Technical Assessment and Response Team
SVE	Soil Vapor Extraction
TCE	Trichloroethene
VOC	Volatile Organic Compound

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1.0 OBJECTIVES OF OPTIMIZATION REVIEW

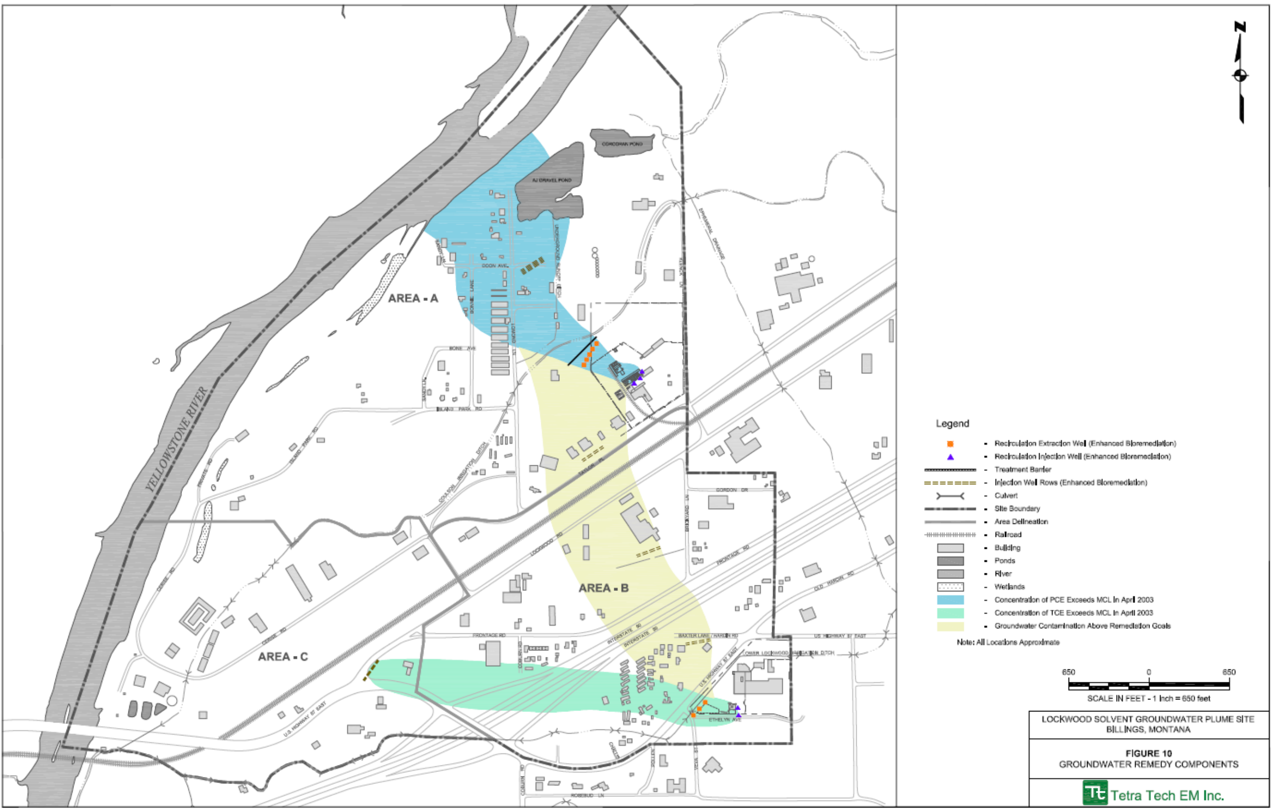
This section describes the objectives of the optimization review, composition of the optimization review team, documents and data reviewed, and quality assurance.

1.1 Objectives of the Remedial Design Optimization

The Lockwood Solvent Groundwater Plume Site (LSGPS) occupies approximately 580 acres on the outskirts of Billings, Montana, in U.S. Environmental Protection Agency (EPA) Region 8. The site is managed as two operable units (OUs). OU1 consists of contaminated soils and the plume of chlorinated solvents in groundwater associated with the Beall Source Area (Area B). OU2 consists of affected media associated with the Brenntag (Soco; Area A) Source Area. Additional land is included in the greater LSGPS (Area C, see Figure 1 below or Attachment A for a full size version), but this area contains no known primary sources of contamination and low-to non-detectable levels of contaminants.

This optimization review addresses remedial components planned for affected soil and groundwater in OU2. The remedial design (RD) for OU1 is addressed under a separate optimization report.

Figure 1: Lockwood Solvent Groundwater Plume Site



Source: Figure 10 from OU1 ROD; EPA 2005.

For more than a decade, the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) has provided technical support to the EPA regional offices through the use of independent (third-party) optimization reviews at Superfund sites. The LSGPS was nominated for an optimization review at the request of the Region 8 Remedial Project Manager (RPM) in September 2012. This review of the remedy design proposed for LSGPS OU2 is intended to optimize the remedial response to address contamination in soil and groundwater to achieve maximum protectiveness while improving remedy cost and energy efficiency and minimizing time required to meet cleanup goals.

An optimization review team (described below) was assembled and met with regulatory stakeholders and consultants in Billings, Montana, and at the site in February 2013 to review site data, remediation goals, logistics and time frames to implement the remedy. This report presents the findings and recommendations for OU2 based on a review of site documents, the site visit and meetings with stakeholders.

Objectives of the RD optimization review team included:

- Review of the conceptual site model (CSM)
- Review of Remedial Action Objectives (RAOs)
- Review of selected remedy options and associated costs
- Recommendations for remedial strategy, including:
  - Addressing and prioritizing significant data gaps in the CSM
  - Recommending remedy improvements
  - Prioritizing and sequencing remedial components
  - Identifying decision points for contingent responses
  - Performance monitoring for recommended remedies
  - Remediation and data collection to support an exit strategy.

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed before the recommendation can be implemented. Note that the recommendations are based on an independent evaluation and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the State of Montana, the Region and other site stakeholders. Also note that while the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans and quality assurance project plans (QAPP).

The National Optimization Strategy includes a system for tracking consideration and implementation of the optimization review recommendations. It includes a provision for follow-up technical assistance from the optimization review team as mutually agreed on by the site management team and EPA OSRTI.

1.2 Team Composition

The LSGPS optimization review team included the following individuals:

Table 1: Optimization Review Team

Name	Affiliation	Phone	Email
Doug Sutton	Tetra Tech		
Mindy Vanderford	GSI Environmental, Inc.	713-522-6300	mvanderford@gsi-net.com

In addition to the optimization review team listed above, the individuals listed below also attended the site visit or contributed to the site data review process:

Table 2: Site Visit and Review Participants

Name	Affiliation	Title or Role	Email Address
Kirby Biggs	EPA OSRTI	Optimization Review Lead	biggs.kirby@epa.gov
Tillman McAdams	EPA Region 8	RPM for OU1	
Andrew Schmidt	EPA Region 8	Hydrologist, Technical Support	
John Podolinsky	Montana Department of Environmental Quality	State lead for OU2	
Catherine LeCours	Pacific Western Technologies, Inc.	RAC Contractor for OU2	
Roger Hoogerheide	EPA Region 8	RPM for OU2	Hoogerheide.Roger@epamail.epa.gov
Jim Sullivan	Cardno Advanced Technologies, Inc.	PRP Contractor for OU2	

Notes: EPA OSRTI = U.S. Environmental Agency Office of Superfund Remediation Technology Innovation; RPM = Remedial Project Manager; OU = Operable Unit; RAC = Remedial Action Contractor; PRP = potentially responsible party.

Email contact information is provided for the site managers only. Communication with other participants can be coordinated through the site managers.

The site visit including the individuals listed in Tables 1 and 2 was conducted on February 28, 2013.

1.3 Documents and Data Reviewed

The following documents were reviewed to support the optimization review.

ATC, (2003). Ozone Sparging/Soil Vapor Extraction Pilot Test Report Brenntag West, Advanced Technologies, Inc. for the Brown Law Firm.

ATC (2005). Soil Vapor Extraction Interim Pilot Test Report. Billings, MT, Prepared for Brenntag West, Inc. by ATC Associates.

ATC (2012). Remedial Design Assessment Quality Asssurance Project Plan Operable Unit 2; Lockwood Solvent Groundwater Plume Site. Billings, MT, ATC Associates. Prepared for EPA Region 8 and Montana Department of Environmental Quality.

ATC (2012). Remedial Design Assessment Work Plan Sampling and Analysis Plan and Field Sampling Plan Operable Unit 2 Lockwood Solvent Groundwater Plume Site. Billings, MT, ATC Associates Prepared for US EPA Region 8 and Montana Department of Environmental Quality.

CardnoATC (2012a). Monthly Progress Report #5 - October 2012 Operable Unit 2 Lockwood Solvent Groundwater Plume Site. Billings, Montana, Prepared for the EPA Region 8, Montana Department of Environmental Quality.

Cardno ATC (2012b). Monthly Progress Report #6 - November 2012 Operable Unit 2 Lockwood Solvent Groundwater Plume Site. Billings, Montana, Prepared for the EPA Region 8, Montana Department of Environmental Quality.

Cardno ATC (2012c). Vapor Intrusion Assessment Work Plan Operable Unit 2 Lockwood Solvent Groundwater Plume Site Billings, MT. Billings, MT, Prepared for EPA Region 8 and Montana Department of Environmental Quality Remediation Division by Cardno ATC.

Department of Justice (2011). Remedial Design/ Remedial Action Consent Decree. Case 1:22-cv-00088-RFC. E. E. S. U.S. Department of Justice. U.S. District Court, District of Montana, Billings, MT.

MSE-HKM (1998). Final Billings Lockwood Pumping Test and Groundwater Monitoring Report. Helena, MT. Prepared for Montana Department of Environmental Quality.

Tetra Tech (2003). Remedial Investigation Report: Lockwood Solvent Groundwater Plume Site. Helena, MT. Prepared for Montana Department of Environmental Quality Remediation Division.

Tetra Tech (2004). Final Feasibility Study Report: Lockwood Solvent Groundwater Plume Site. Helena, MT. Prepared for Montana Department of Environmental Quality.

EPA (2005). Record of Decision: Lockwood Solvent Ground Water Plume OU1. Billings, MT. Environmental Protection Agency Region 8.

Site soil and groundwater monitoring data, lithologic data, and Geographic Information System (GIS) files were received from the site contractor (Cardno Advanced Technologies, Inc. [ATC] and Pacific Western Technologies, Ltd. [PWT]), January 2013.

1.4 Quality Assurance

The optimization review team reviewed existing environmental data to interpret the CSM, evaluate potential remedy performance and make recommendations to improve the remedy. The quality of existing data was evaluated by the optimization review team before the data were used for these purposes. The evaluation for data quality included a brief review of how the data were collected and managed (where practical, the site QAPP is considered), the consistency of the data with other site data, and the use of the data in the optimization review. Data that were of suspect quality were either not used as part of the optimization review or were used with the quality concerns noted. Where appropriate, this report provides recommendations to improve data quality.

2.0 CONCEPTUAL SITE MODEL

This section presents information on the site background, source areas, and the surface water, soil, subsurface unsaturated soil and groundwater media.

2.1 Site Background

The source area for OU2 is a former chemical storage, re-packaging and distribution facility operated under the Brenntag and Dyce Chemical corporate names. The facility began operations in 1972. The property is currently under new ownership, with no on-going commercial activity. Built structures have been largely demolished. Remediation of affected soil and groundwater is currently being conducted under the Superfund program as a Potentially Responsible Party (PRP)-lead project.

In 1986, Lockwood Water and Sewer District (LWSD) personnel identified benzene and chlorinated solvents in Lockwood area water supply wells, leading to a number of investigations by the Montana Department of Environmental Quality (DEQ). In June 1998, DEQ performed an integrated site assessment in cooperation with the EPA. The assessment identified the former Brenntag West property (formerly the Dyce Chemical property and now the Soco West property, OU2) as a potential source of tetrachloroethene (PCE) and its breakdown byproducts in the groundwater. The investigation also identified the upgradient Beall property (OU1) as a potential source of trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride. In December 2000, the EPA placed LSPGS on the National Priorities List (NPL).

Land use within and around the LSGPS is categorized as light industrial, commercial and residential. The commercial and light industrial facilities include trucking, vehicle repair, truck tank manufacturing, chemical repackaging, petroleum pipelines, machine shops and auto salvage. The former Comet Oil Site, proposed for the NPL in 1988, is located on the east and northeast border of the LSGPS, upgradient of the OU2 source. There are 81 commercial and light industrial businesses, and there are an estimated 75 residential single-family residences, two trailer parks, and one apartment complex located within the LSGPS boundary. LSGPS is bordered by the Yellowstone River on the west and northwest; some wetlands and ponds are included in the LSGPS area.

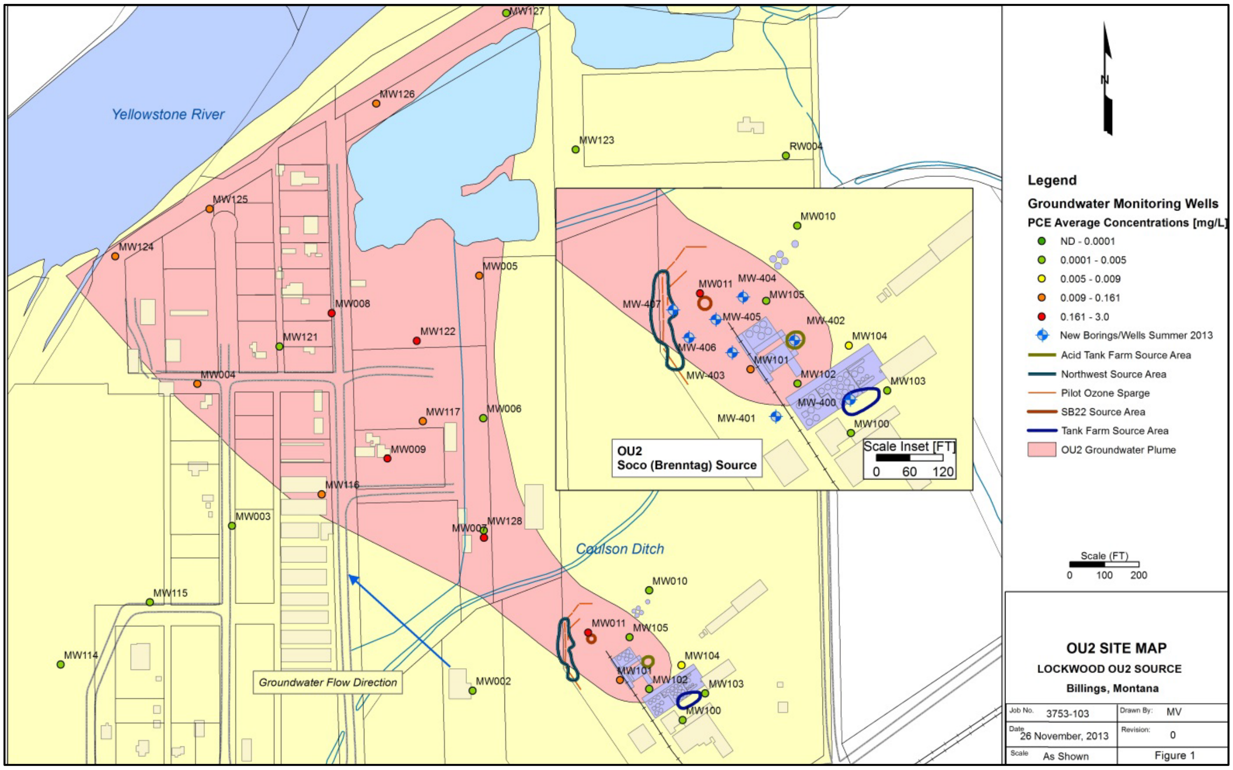
In 2002, the DEQ conducted a remedial investigation (RI) that included surface and subsurface soil sampling, monitoring well construction and groundwater sampling, aquifer testing, surface water and sediment sampling and soil vapor sampling in the LSGPS area. Based on the RI results, the EPA and DEQ evaluated remedial alternatives, as documented in the July 2004 Proposed Plan. The November 2004 Plan detailed the human health risks, past activities and the preferred remedial actions for the site. Based on the public meeting and comment period, the EPA and DEQ selected a final remedy, as documented in the 2005 LSGPS site-wide Record of Decision (ROD). The 2011 Remedial Design/ Remedial Action Consent Decree (DOJ 2011) identified OU1 in the area of the Beall source and OU2 in the Brenntag/Soco source area.

The RD process is under way at OU2, with the goal of addressing contamination associated with the Soco West source area and affected groundwater under adjacent properties. Site characterization has continued in the period between publication of the ROD and the present. This optimization review considered both historical and more recent data to develop recommendations.

2.2 Source Areas

Several source areas have been identified within the former chemical handling facility at OU2. Site data suggest that contamination was released at different times and by different mechanisms in several smaller source areas. The priority contaminant of concern (COC) and parent constituent on site is PCE. PCE in the shallow subsurface has undergone anaerobic degradation stimulated by releases of petroleum hydrocarbons, including benzene, toluene, ethylbenzene, and xylenes (BTEX) serving as carbon sources for anaerobic processes. Anaerobic decay products of PCE include, TCE, cis-1,2-DCE and vinyl chloride. PCE and its degradation products TCE, cis-1,2-DCE, and vinyl chloride have been detected at concentrations above EPA Maximum Contaminant Levels (MCLs) in groundwater. The primary source areas thought to be contributing contaminant mass to the groundwater plume are listed below and shown on Figure 2.

Figure 2: Lockwood OU2 Groundwater Plume



Note: Groundwater monitoring locations indicated on the map show average PCE concentration for 2000 to 2012. The inset map shows locations of new borings and groundwater wells installed in Summer 2013. Wells in the vicinity of the soil vapor extraction (SVE)/ozone sparging system pilot test in the Northwest Source Area are not shown for visual clarity.

Source: GSI, 2014 from data provided by Cardo ATC, 2013.

The primary source areas are the:

- Former Tank Farm Area (farthest upgradient)
- Former Acid Tank Farm
- Northwest Source Area
- SB22 Area

The Former Tank Farm Area is located on the upgradient, southeastern portion of the property near where chemicals were unloaded and stored. Groundwater in the Former Tank Farm Area has high concentrations of PCE and its breakdown products as well as significant BTEX. Recent samples in this area (MW-400) indicate high concentrations of cis-1,2-DCE, toluene and PCE in shallow zones. What appear to be minor source areas are located at the Former Acid Tank Farm (near MP-105), the SB22 (near DP063) Area and perhaps an additional area around the former rail line in the center of the property (near new well MW-

403). The Former Acid Tank Farm area shows high concentrations of PCE in the deeper saturated zone (MW-402). The Northwest Source Area is located along the northwest boundary of the property, upgradient of Coulson Ditch in a topographic low area. The Northwest Source Area is adjacent to the Keller Transport property, where access for site characterization has been limited. PCE contamination is found in the shallow zone, indicating a primary release, rather than transport from an upgradient source. A pilot-scale soil vapor extraction (SVE)/ozone sparging system was installed in the Northwest Source Area in 2003.

The hydrostratigraphy of the OU2 source area consists of the following:

- From 0 to15 feet below ground surface (bgs) – surficial clay/silt, saturated below roughly 10 feet bgs
- From 15 to 30 feet bgs — saturated sand/gravel
- Below 30 feet - sandstone and shale bedrock (Eagle Sandstone).

The water table is at approximately 10 feet bgs, with saturation in both the silty/clay unit and in the sand/gravel unit. Attachment A includes cross-section and example boring logs from the RI.

2.3 Surface Water, Soils and the Unsaturated Subsurface

Surface water features located in Lockwood OU2 (Area A) include the Coulson Irrigation Ditch, the AJ Gravel Pond and the Yellowstone River. Analytical results for surface water have not shown concentrations that exceed human health or ecological screening levels for the primary site COCs.

Site surface soil and shallow subsurface soils are composed of highly heterogeneous, interbedded sands and gravels, silty sands, clays and silts. Soil contamination has been evaluated based on discrete soil samples collected from multiple depth intervals in the vicinity of OU2 during site investigations. PCE and other chlorinated volatile organic compounds (cVOCs) released from the diverse primary sources have migrated to the saturated zone (located at approximately 10 feet bgs). Source area soils show both vertical and horizontal heterogeneity and discontinuous concentrations of the primary COCs. The distributed nature of source materials adds complexity to evaluating and selecting remedial strategies. High concentrations of PCE were detected in soils in the area of PT-02 (2,404 milligrams per kilogram [mg/kg] at 6 to 8 feet bgs). Higher concentrations of cis-1,2-DCE are detected in soils located upgradient, especially near boring BH M (12,000 mg/kg at 9 to 11 feet bgs), most likely caused by oxygen depletion resulting from high BTEX in the Former Tank Farm Area. These high concentrations of cVOCs imply the presence of non-aqueous phase liquids (NAPL). Because of the heterogeneity of soil textures, the majority of the contamination that remains is likely present in the relatively impermeable silt layers, possibly serving as a long-term secondary source of contamination.

2.4 Groundwater

A groundwater plume in the alluvial aquifer extends to the northwest from the OU2 source area, ultimately discharging to the Yellowstone River approximately 2,000 feet downgradient of the OU2 source area. Groundwater in the bedrock aquifer does not appear to be affected above MCLs based on concentrations at bedrock well MW-128. There have been intermittent detections of cVOCs below MCLs at MW-128, but recent sample results have shown no detections

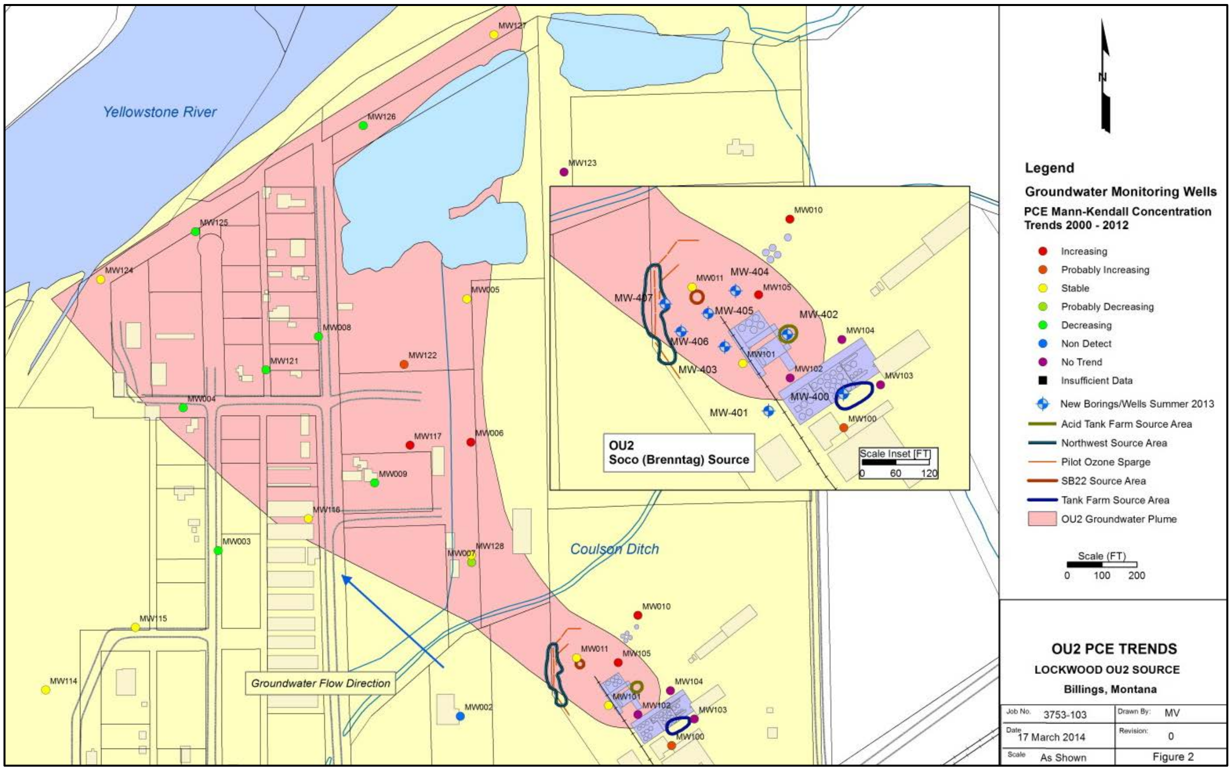
Centerline concentrations of PCE in the alluvial plume are in the range of 300 to 2,000 micrograms per liter (µg/L). The plume broadens downgradient of Coulson Ditch with an approximate width of 1,200 feet at discharge. The bottom of Coulson Ditch intercepts groundwater and the ditch can be either "gaining" (receiving groundwater) or "losing" (discharging to groundwater), depending on weather conditions. Water elevations in the gravel mining ponds downgradient of the source area are coincident with the water table, indicating that they may be a local sink for groundwater flow, pulling the plume to the north.

Alluvial aquifer characteristics include a gradient of 0.0064 foot per foot and an estimated hydraulic conductivity between 0.295 feet per day and 70 feet per day (Tetra Tech 2003). The average saturated thickness in the OU2 area is about 20 feet. Using a porosity value of 0.25, groundwater seepage velocity would be in the range of 2.75 feet per year (for low permeability saturated zones) to 654 feet per year (in the saturated gravel zones).

Groundwater in the OU2 area has been monitored via sampling and analysis of up to 48 wells and piezometers between 1998 and 2012. Groundwater concentration trends and distribution of mass in OU2 groundwater were evaluated using the Monitoring and Remediation Optimization System (MAROS) software for the optimization review. The highest dissolved contaminant concentrations were detected at wells installed to monitor the SVE/ozone sparging system pilot test (PT-02, PT-05 and PT-06) in the Northwest Source Area. For the time period of 2000 to 2012, wells PT-02, PT-05 and PT-06 show stable to decreasing concentration trends for PCE by the Mann-Kendall statistical test for trend.

Figure 3 shows groundwater concentration trends for the downgradient plume based on statistical analysis using MAROS for groundwater data for individual wells. Several well locations within or near the western part of the plume show decreasing concentration trends (indicated by green icons at wells MW-003, MW-009, MW-121, MW-008, MW-004, MW-125 and MW-126). In particular, well MW-009, which had historically high concentrations of PCE and based on the MAROS results is located near the estimated center of mass for the plume, shows a strongly decreasing trend for PCE. Increasing trends are evident along the eastern edge of the plume at wells MW-010, MW-006, MW-122 and MW-117. Increasing trends to the east may indicate plume migration to the east and northeast.

Figure 3: Lockwood OU2 PCE Concentration Trends



Note: Mann-Kendall statistical concentration trends for PCE are shown for data collected 2000 to 2012. (Note: Wells in the vicinity of the SVE/ozone sparging pilot test are not shown for visual clarity.).

Source: GSI, 2014 from data provided by Cardo ATC, 2013.

Groundwater data analysis using the MAROS software indicates that the total dissolved mass of PCE shows neither an increasing nor a decreasing statistical trend plume-wide (see MAROS reports, Attachment C), indicating largely stable contaminant mass. Estimates of total dissolved mass indicate that approximately 20 percent of dissolved PCE is still in the source area, with about half the estimated dissolved source mass in the Northwest Source Area. No estimates are available for the amount of contaminant mass in the source area soils. The center of dissolved mass in the plume is near well MW-009.

3.0 REMEDIAL ACTION OBJECTIVES AND SELECTED REMEDY OPTIONS

This section discusses the remedial action objectives from the 2005 ROD and describes the components of the selected remedy options for OU2.

3.1 Remedial Action Objectives and Affected Media

The ROD identifies the following RAOs for the LSGPS for groundwater, surface water and soil (EPA 2005):

- Prevent exposure of humans to groundwater and surface water contaminants in concentrations above regulatory standards.
- Reduce contaminant concentrations in the alluvial aquifer and surface water to below regulatory standards.
- Prevent or minimize further migration of the contaminant plume.
- Prevent or minimize further migration of contaminants from source materials (soil) to groundwater.

The ROD identifies the principal threat waste as chlorinated solvent contamination found in the vadose zone soil and saturated soils.

Table 3 shows the groundwater cleanup standards and the soil cleanup levels for the LSGPS. The soil cleanup levels were established based on modeling conducted by the site team during the Feasibility Study (FS); the modeling was implemented to identify concentrations of COCs that would protect groundwater from contamination leaching from soil. Table 4 summarizes the affected media on site and the composition and potential receptor exposure or migration pathways associated with each medium.

Table 3: Contaminants of Concern and Cleanup Levels

Contaminant of Concern	Groundwater Cleanup Standard (µg/L)	Soil Cleanup Standards for OU 2 (µg/kg)
Trichloroethene (TCE)	5	720
Tetrachloroethene (PCE)	5	654
Cis-1,2,-dichloroethene (cis-1,2-DCE)	70	4,898
Vinyl chloride	2	157

Notes: µg/kg = micrograms per kilogram; µg/L = micrograms per liter.

Table 4: Affected or Potentially Affected Media on Site

Medium	Location	Composition	Potential Exposure / Migration Pathways
Surface soil (vadose and saturated at depth)	Ground surface to 10 to15 feet bgs	• Silt, silty clay with sand lenses, highly heterogeneous • Can be saturated below 10 feet bgs	• Discharge to alluvial groundwater • Direct exposure by excavation
Alluvial aquifer	15 to 30 feet bgs	Alluvial sand and gravel aquifer, some cobbles	• Drinking water wells historically located in this unit • Transport to downgradient surface water
Siltstone/sandstone bedrock	Below 30 feet bgs	• Eagle Sandstone with some shale • Groundwater in interconnected fractures	• Not currently affected • Potential for transport from alluvial and discharge to bedrock aquifer (deeper groundwater)

Notes: bgs = below ground surface.

3.2 Selected Remedy Options

The remedy options selected for OU2 are described in the ROD (EPA 2005) and summarized in Table 5. The ROD specifies thermal treatment of excavated soils for the Soco Source Area (*ex situ* thermal treatment), SVE, and *in situ* chemical oxidation (ISCO) for affected soils. A permeable reactive barrier (PRB) and *in situ* bioremediation (ISB) were selected for source groundwater, with the location and design of the remedy to be determined after pilot testing. ISB was selected for site-wide groundwater and was anticipated to include injection of a chemical reductant to stimulate anaerobic biodegradation of cVOCs.

Site-wide elements of the remedy include long-term groundwater monitoring, five-year reviews (FYR) and institutional controls (IC), including restrictions on groundwater use. The selected remedy also includes risk mitigation for potential exposures arising from drinking water sources and indoor vapor intrusion. Risk mitigation includes monitoring potable water supply wells, and eliminating exposure through means such as extending the municipal supply line.

Table 5: Remedy Options Selected in the ROD

Remedy	Target Medium	Description
Soil Excavation	Accessible vadose zone soils in source	Excavation and removal of soils
Ex Situ Thermal Treatment	Accessible vadose zone soils in source area	Thermal treatment of mixed excavated soils
SVE/Ozone Sparging	Inaccessible, vadose zone in source area	Apply SVE/ozone sparging (pilot test conducted in Northwest Source Area, design in progress)

Remedy	Target Medium	Description
In Situ Chemical Oxidation (ISCO)	Inaccessible saturated zone soils	Addition of chemical oxidant to affected soil to catalyze conversion to carbon dioxide (CO_2)
In Situ Bioremediation Treatment	Groundwater source and plume	Treatment of groundwater with reductants *in situ* to stimulate anaerobic degradation – amendments to be chosen based on treatability studies; design in progress
Permeable Reactive Barrier (PRB)	Source groundwater	Emplacement of reactive materials such that dissolved contaminants flowing through the system react with materials forming non-toxic by-products
Risk Mitigation	Groundwater and subsurface soils	Continue monitoring potable water supply wells, mitigation (such as providing municipal water) for residences and commercial property with affected private water supply wells, Indoor air monitoring and mitigation where needed.
Institutional Controls (IC)	Commercial property, affected groundwater	Restrictions on excavation or drilling into affected subsurface areas
Groundwater monitoring	Alluvial aquifer	Collection of contaminant concentration data to assess remedy performance, progress toward remedial goals and protectiveness
Five-Year Reviews	All site media	Documentation of remedy performance and protectiveness every 5 years

4.0 FINDINGS

This section outlines the major findings of the optimization review team.

4.1 CSM Implications for Remedial Strategy

The CSM described in Section 2 has the following potential implications for a remedial strategy:

- There were multiple historical releases of contaminants within the Soco West source area. Delineation and characterization of these sources is complex. Uncertainty about the distribution of primary sources and contaminant mass remaining in the vadose zone may reduce remedial efficacy, particularly for remedies such as ISCO and excavation that rely on precise identification of contamination.
- Geochemical conditions in source soils may vary due to the presence of residual co-contaminants (such as petroleum hydrocarbons) as well as variability in lithology.
- Increasing PCE concentration trends are evident along the eastern edge of the plume at wells MW-010, MW-105, MW-006, MW-122 and MW-117 while strongly decreasing trends are evident at center wells MW-009, MW-008, and MW-121 and wells to the west MW-004 and MW003 of the plume. Concentration trends may indicate plume migration or dilute expansion of the plume footprint to the north-northeast of the source.
- Groundwater flushes through the site's gravel aquifer at a velocity up to 600 feet per year, indicating that significant source removal may be apparent in downgradient groundwater monitoring well concentrations, particularly at locations monitoring transmissive zones with current high concentrations or decreasing trends, within 5 years.
- Site groundwater monitoring wells have screened intervals that are long (10 to 20 feet). The long interval can introduce sampling-induced variability in analytical results and may obscure the zone of maximum concentrations. The long screens traverse the fine-grained saturated zone as well as the coarse-grained alluvial aquifer, introducing uncertainty in evaluating long-term desorption and remedy efficacy for the two different strata.
- High concentrations of cis-1,2-DCE and other PCE degradation products in site groundwater, particularly in upgradient source areas, indicate that anaerobic biodegradation is an ongoing process and that the microbial community is highly adapted to consume cVOCs. This observation supports the choice of an ISB remedy to address source groundwater contamination.
- Access to adjoining properties is limited by lack of cooperation from property owners. Access issues complicate further site characterization and may complicate installation of remedy components in the plume.
- Matrix or back-diffusion from silty layers in both the upper saturated and unsaturated zones may provide a long-term secondary source of contamination.
- The vertical distribution of contamination below the water table, which is currently unknown, will affect the design and performance of the groundwater remedy.
- Overall, several groundwater monitoring wells (MW-004, MW-121, MW-008, MW-009, MW-125 and MW-126) indicate decreasing concentration trends, particularly in the Northwest Source Area (PT-01, PT-02, and PT-06) and the downgradient plume along the western edge. Total dissolved mass estimates for the plume indicate largely stable values, indicating that mass discharge from the source is balanced by mass discharge to surface water and natural attenuation mechanisms.

4.2 Data Gaps

Several key data gaps and uncertainties in the LSGPS OU2 Site CSM were identified during the site meeting and based on document review.

Preliminary recommendations to address OU2 data gaps were provided in March 2013 by memorandum and through a short web-based presentation of preliminary findings (see Attachment B). To support RD, the optimization review team recommended additional depth-discreet data collection. The primary data gap in designing the remedial response for OU2 is uncertainty about the distribution and magnitude of historical releases within the former chemical facility. Several primary source areas have been identified, such as the Former Tank Farm Area and the Northwest Source Area. A detailed history of site operations and releases is not available, introducing uncertainty into the efficient design of source remedies.

Recommendations for additional characterization are summarized in Table 6 and discussed Section 5.1.

Table 6: Identified Data Gaps

Medium	Data Gap	Recommendation
Unsaturated Soil (Vadose)	• Vertical and horizontal source areas and extent of highest contamination • Distribution of PCE degradation products • Effect of heterogeneity in soils on SVE/ozone sparging/ISB/excavation remedies	• Detailed delineation of down- and cross-gradient extent of contamination (proposed sampling locations are detailed in Section 5.1) • Detailed delineation of fine-grained versus coarse-grained material to assess back diffusion
Alluvial aquifer	• Vertical and lateral characterization of high mass zones • Possible presence of secondary sources in low permeability soils below water table	• Additional depth discreet groundwater wells with short screens (5 feet) • Depth discreet groundwater sampling with multiple PDBs in existing wells (Section 5.1) • Continue area-wide comprehensive groundwater level monitoring for five-year reviews
Siltstone/sandstone bedrock	Extent of contamination	Currently appears unaffected, continue sampling from bedrock intervals at existing wells

Notes: PCE = tetrachlorethene; SVE = soil vapor extraction; ISB = *in situ* bioremediation; PDB = passive diffusion bag.

4.3 Considerations for the Remedial Strategy

A phased remedial approach is recommended for LSGPS OU2. Optimization review team recommendations for the site's remediation include aggressive source treatment, which is anticipated to reduce cVOC discharge to the downgradient plume, resulting in decreasing concentration trends and plume footprints. As the efficacy of source treatment is monitored, additional contingent remedies (for example, ISB) may be installed as needed in the downgradient gravel aquifer to attain site cleanup goals.

Remedial priorities and decision points are summarized in this section and described in more detail in Section 5. The relative merits of implementing various remedies for source soils are discussed in detail below and summarized in Section 5.

Implementation costs for several remedial technologies to address source soils were evaluated using Remedial Action Cost Engineering and Requirements (RACER) System version 10.4.0. Table 7 presents the results of this evaluation. The cost estimates are based on Montana state average costs. Also, the unit cost of shallow (above 10 feet bgs) and deep soil excavation (10 to30 feet bgs) are nearly equivalent and, therefore, costs for soil excavation with *ex situ* vapor extraction and land farming were evaluated only for shallow soil. In the case of SVE/ozone sparging, no precise costs were available to compare the cost of installing and maintaining the ozone sparging system. Cost estimates for SVE with granular activated carbon (GAC) treatment were substituted, with the understanding that this cost estimate may be higher than the actual costs for ozone sparging.

The levels of certainty for the cost estimates provided are comparable to those typically prepared for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) FS reports (-30 to+50 percent), and are considered rough estimates for planning purposes.

The optimization review team considers excavation and SVE/ ozone sparging as the two primary, and potentially complementary, remedial options for soil remediation. The remedial approaches considered for cost evaluation include:

(1) Excavation and disposal of Shallow Soil (vadose zone, 0 to 10 feet bgs): excavated soil will remain as bulk and be disposed of as hazardous waste.
(2) Excavation and disposal of Shallow Soil (vadose zone, 0 to 10 feet bgs): excavated soil will be placed in containers and be disposed of off-site as hazardous waste.
(3) Excavation and disposal of Deep Soil (vadose zone, 0 to 10 feet bgs plus saturated zone 10 to 30 feet bgs): excavated soil will remain as bulk and be disposed of off site as hazardous waste.
(4) Excavation and disposal of Deep Soil (vadose zone, 0 to 10 feet bgs plus saturated zone 10 to 30 feet bgs): excavated soil will be placed in containers and be disposed of off site as hazardous waste.
(5) Excavation of Shallow Soil (vadose zone, 0 to 10 feet bgs): excavated soil will be treated on site with *ex situ* SVE/ozone sparging.
(6) Excavation of Shallow Soil (vadose zone, 0 to 10 feet bgs): excavated soil will be treated on site with *ex situ* land farming.
(7) SVE/ozone sparging (approximated cost estimates using published data for a GAC system) treatment: install new wells for an area approximately equivalent to the Northwest Source Area and implement SVE/ozone sparging.
(8) SVE/ozone sparging (approximated costs estimated using published data for a GAC system): use of existing wells (for example, PT-01 through PT-07) with implementation of SVE/ozone sparging.
(9) ISB: implement ISB for source soils.
(10) On-site thermal desorption support by the existing SVE/ozone sparging system to treat off-gases.

Table 7 presents the estimated total and unit costs for the remedial alternatives listed above:

Table 7: Cost Estimates for Remedial Alternatives

Remediation Alternative	Total Cost ($)	Unit Cost ($ / cy)
Excavation – Shallow – Bulk – Hazardous Waste	2,890,000	309
Excavation – Shallow – Container – Hazardous Waste	5,490,000	590
Excavation – Deep – Bulk – Hazardous Waste	2,200,000	351

Remediation Alternative	Total Cost ($)	Unit Cost ($ / cy)
Excavation – Deep – Container – Hazardous Waste	4,060,000	649
Excavation – Shallow – *ex situ* Vapor Extraction	1,370,000	146
Excavation – Shallow – *ex situ* Land Farming	1,620,000	174
SVE/Ozone Sparging – Using New Wells (approximated based on GAC costs)	680,000	60
SVE/Ozone Sparging – Using Existing Wells (approximated based on GAC costs)	455,000	32
ISB	820,000	73
On-site thermal desorption – Existing SVE – ozone	1,630,000	144

Notes: total costs are based on different areas and/or volumes. Unit costs should be used for comparison purposes. SVE = soil vapor extraction; GAC = granular activated carbon; cy = cubic yards.

Excavation

The primary technical and logistical advantages of excavation include (1) the certainty that targeted soil will be remediated, (2) the ability to effectively remediate contamination in tightly bound (low-permeability) soils, and (3) remediation can occur in a timely fashion once initiated. The technical and logistical disadvantages of this approach are (1) costs for excavation and disposal of soil as hazardous waste are high, (2) excavation to 30 feet bgs poses engineering challenges and requires a large site area, and (3) primary sources are numerous and dispersed through the site.

SVE/Ozone Sparging

SVE/ozone sparging has been pilot tested in the Northwest Source Area. Shallow groundwater wells in this location have shown decreasing concentration trends in response to the remedy (for example, at monitoring locations PT-06, PT-02 and PT-01). The primary technical and logistical advantages of SVE/ozone sparging are: (1) a system using SVE/ozone sparging has already been pilot tested and shown to be effective, and existing wells can be used as part of the final system, (2) the target treatment volume does not need to be as precisely defined as for excavation, and (3) unit costs are low. Advantages of oxidation technologies such as ozone include the potential for rapid and complete destruction of chemical contaminants without generating a waste stream that is expensive to treat or dispose of. The technical and logistical disadvantages of this approach are that (1) SVE/ozone sparging still requires delineation of the most affected soils, so there is less certainty in removing soil contamination that can cause long-term groundwater contamination relative to more diffuse technologies such as ISB, (2) remediation will likely need to continue for 2 or more years, (3) there are challenges in removing contaminant mass from low-permeability materials and (4) oxidation in the subsurface may inhibit natural attenuation through anaerobic biodegradation. In the case of SVE/ozone sparging, no precise costs were available to compare the cost of installing and maintaining the ozone sparging system with other remedies. Costs for SVE with GAC were substituted, with the understanding that this cost estimate may be higher than the actual costs for ozone sparging.

Thermal Treatment

The ROD includes thermal treatment of excavated soils as a selected remedy option. While the cost estimate for thermal treatment in the ROD indicates that the cost would be comparable to excavation and disposal, the optimization review team believes that these costs are underestimates due to the current cost of providing energy for thermal treatment technologies and the size and distribution of contaminated soils on site. The combination of excavation and thermal treatment (*ex situ* treatment) is cost competitive, but the successful demonstration of SVE and the cost savings associated with expanding the existing SVE system make this option more practical.

ISCO

ISCO is a selected remedy option in the ROD for inaccessible saturated soils. The SVE/ozone sparging remedy piloted in the Northwest source area is a form of oxidative treatment that has been shown to be effective on site in areas of known high contamination. Advantages and disadvantages of other ISCO technologies (for example, peroxide/Fenton’s reagent) are similar to those discussed for SVE/ozone sparging. Other ISCO technologies can cause precipitates to form reducing the permeability of the formation. As with other forms of oxidation/reduction treatment, metals can sometimes be mobilized during and after treatment. For the purposes of this report, the SVE/ozone sparging system will be considered rather than other ISCO technologies as its efficacy has already been demonstrated. Other forms of ISCO treatment may be considered by the site team, but pilot tests should be performed before selecting from the variety of oxidants available

PRB

The ROD includes PRB treatment of groundwater as a selected remedy option. The optimization review team believes that this technology is not cost-effective and may not be capable of achieving remedy objectives. Therefore, no detailed review was performed for this technology.

5.0 RECOMMENDATIONS

This section provides several recommendations related to remedy effectiveness, cost control, technical improvement and site completion strategy. Note that while the recommendations provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans and QAPPs.

The optimization review recommendations focus on resolving uncertainty with regard to the CSM. General recommendations on remedial strategy and decision points are also included, but because they have been developed based on available data and there are data gaps for the CSM, specific recommendations for further refinements to the RD must be made after data gaps in the extent of contamination and initial performance of soil remedies have been addressed.

The costs presented do not include potential costs associated with community or public relations activities that may be conducted before field activities. The estimated costs of these remedial alternatives are summarized in Table 7.

5.1 Recommendations to Sequence Remedial Approach

A phased remedial approach consistent with an adaptive management strategy is recommended for OU2. Optimization review team recommendations for the site include additional source area characterization to refine the RD to target the location of treatment and refine the scale of the remedial components. The source area remedies are anticipated to include SVE/ozone sparging, with possible excavation in high concentration areas and ISB treatment for source groundwater. Source treatment is anticipated to reduce cVOC discharge to the dilute downgradient plume. Monitoring of the downgradient plume is recommended for a period of 2 to 3 years to assess the effects of source treatment. Additional remedies for the downgradient plume may be implemented after the effects of source treatment are evaluated.

The following sequence of activities is recommended to optimize RD and future performance at LSGPS OU2:

- Additional groundwater wells are recommended for the source and immediate downgradient plume. Wells are recommended to be installed at different depths in clusters of three depths using Rotosonic drilling and 5-foot screened intervals. (Note: this recommendation was largely been accomplished by the time this report was finalized.)
- Sampling with multiple passive diffusion bags (PDBs) in existing wells with long-screen-interval wells to provide greater vertical characterization at multiple intervals.
- Identifying the areas of highest contamination will support locating remedies for optimal mass removal.
- Use existing and new data to prepare highly detailed, OU2-specific cross sections with low-permeability seams and areas of highest contaminant mass highlighted. Use detailed source-area data to refine the RD.
- Reactivate and expand the SVE/ozone sparging remedy for the Northwest Source Area. The existing SVE/ozone sparging system may be extended to other, well-defined source areas. Expand the SVE system to treat excavated soils.
- Excavate highly contaminated, low permeability, shallow soil (above 20 feet bgs) and treat *ex situ* by expansion of the existing SVE/ozone sparging system. The time and efficacy benefit of

excavation may outweigh the added cost of excavation. On-site treatment with an SVE/ozone sparging system already in place will reduce costs and improve efficiency.

- Implement ISB treatment in the source area. Placement of the ISB remedy should be based on the interpretation of data from the additional site characterization recommended above as well as additional information obtained by expanding the SVE/ozone sparging system. Add the ISB amendment at the base of the excavations (if implemented) to treat deeper areas of contamination outside of the SVE/ozone sparging treatment area, at and below the water table in the source area.
- Conduct performance monitoring for the source remedy for 3 to 5 years after implementation.
- Prioritize source area remediation. Delay implementation of an ISB remedy in the dissolved leading edge of the groundwater plume until 3 to 5 years of source area remedy performance data have been collected and analyzed. Given the high rate of groundwater flow, the success of the source remedy should be apparent in downgradient gravel aquifer wells (for example, MW-007, MW-122, and MW-009) relatively rapidly. Strongly decreasing concentration trends, and a reduced or altered plume footprint in response to source treatment may influence the location and extent of the downgradient plume remedy (ISB).
- Carefully monitor the northern and eastern edges of the plume near MW-006, where concentrations may be increasing because groundwater flow is no longer influenced by pumping from water supply wells located west of the plume. If concentrations increase past MCLs at well MW-006, consider installing an additional monitoring well to delineate the plume to the northeast.

5.2 Recommendations to Characterize the Source Area for Remedy Design Refinement

A more accurate assessment of the location and magnitude of contaminant mass in the dissolved phase will guide development and implementation of the proposed groundwater remedy. The goals of the recommendations in the previous section are to (1) identify the general vadose and saturated target treatment zones, and (2) estimate mass flux from the various source areas. Several of Section 5.1's recommendations were provided to the site team in March 2013. For the most part, the recommendations were implemented during the summer of 2013 and are included here for completeness.

Recommendation 5.2.1: In a communication of March 2013, groundwater wells were recommended to be installed in clusters of three using Rotosonic drilling with 5-foot screened intervals at various locations in the source and near downgradient zone. Based on communication with the site team, many of these wells were installed and sampled in the summer of 2013.

Benefits of Implementing Section 5.2 Recommendations

- Additional well locations will characterize the lateral extent of contaminant sources, reducing uncertainty for remedy placement.
- Vertical characterization of affected groundwater will help target remedial activities and assess remedy performance.
- Recommendations optimize efficiency of groundwater monitoring to track performance of the source remedy.

The optimization review team recommended OU2 source area wells for three discreet depths:

- *A-Depth*: Based on lithologic interpretation of the Rotosonic cores, the upper well should be placed in the most permeable portion of the silty/low-permeability saturated unit.
- *B-Depth*: Based on lithologic interpretation of the Rotosonic cores, the middle interval well should be placed in a shallow transmissive section of the upper sand/gravel aquifer.

- *C-Depth*: The bottom screen interval should be placed at the bottom of the sand/gravel aquifer near the contact with bedrock. It is expected that the C-Depth well for each cluster will be installed first so that the intervals for the A-Depth and B-Depth wells can be identified from the C-Depth Rotosonic core.

The suggested locations for the well clusters are provided in Attachment B. The optimization review team understands that there are challenges to conducting characterization in off-site areas because of access agreements. Lithologic interpretations of the Rotosonic cores in these areas will provide important information with regard to stratigraphy. Monitoring wells in each of the three depth intervals suggested will help determine the chemical signature, distribution and mass flux of contamination at the locations suggested. Water level measurements from discrete interval monitoring wells will also provide improved information regarding vertical hydraulic gradients.

- One well cluster should be placed in, or immediately downgradient of, the upgradient Tank Farm Source area near borings MP104 and BHM. Contamination in this area appears to be deeper and more degraded than in other areas of the source. Existing deep sample data in this location exhibit high concentrations of the PCE degradation product cis-1,2-DCE. This well cluster will provide the above-mentioned information for the most upgradient source area in OU2.
- One well cluster is recommended be installed downgradient from the Former Tank Farm Area near historical soil boring BHF, west of the Former Acid Tank Farm Area’s source area. Comparing the analytical results from this well cluster with the results from the upgradient well cluster may help determine if additional sources downgradient of the Former Tank Farm Area source are contributing contaminant mass to this location.
- The optimization review team recommends that a transect of well clusters be installed perpendicular to groundwater flow near soil borings BHA, BHB and BHC. This transect would be downgradient from both the Former Acid Tank Farm and the Former Tank Farm Areas, but upgradient of the Northwest Source Area and the SB22 Area source. Wells in this area will characterize the depth and composition of contamination entering the Northwest Source Area. Quantifying mass entering the Northwest Source Area will support allocation of remedial effort to each of the sources and will help evaluate the performance of remedies both upgradient and downgradient of this transect.
- The optimization review team recommends that one well cluster be installed for the area downgradient of the Northwest Source Area and upgradient of Coulson Ditch. The wells in this area will quantify mass exported from the Northwest Source Area and support remedy performance evaluations.
- The optimization review team recommends that a transect of well clusters be installed for the area north of Coulson Ditch and south and southeast of monitoring well MW-007. This transect of wells will provide data to evaluate source-remedy performance and will help estimate mass discharge downgradient.

Recommendation 5.2.2: The optimization review team suggests sampling with multiple passive diffusion bags (PDB) in existing long-screen-interval wells to provide greater vertical characterization at multiple intervals at key wells in the body of the plume such as MW-117, MW-121, MW-122 (20-foot screens) and MW-007, MW-009, MW-008, and MW-005 (10-foot well screens). PDB analytical results will help better characterize the water quality within the saturated depth, which includes two distinct lithologies. Characterization at discrete depths may also help reduce some of the variability in analytical results seen in the trend analysis (See MAROS Reports Attachment C, Note PCE results for MW-122). Determining the optimal sampling depth for long-term monitoring will improve the performance evaluations of the remedy.

PDBs are often deployed in 2-foot intervals within each well. The recommendation is to deploy two (10-foot screens) or three (20-foot screens) PDBs per well with one located near the bottom of the screened interval and the others in the middle or towards the top of the screen. Once the area of highest concentration is identified, long-term monitoring can be performed using low-flow methods from that interval. Selection of final low-flow sampling locations may be aided by in-well borehole flow monitoring to confirm flow characteristics across the screen lengths.

The optimization review team estimates the cost of sampling with PDBs at the specified wells as about $20,000 for one event. This cost includes an addendum to the QAPP and field sampling plan for two to three PDBs per well, including purchase, deployment, retrieval, laboratory analysis, and preliminary data interpretation.

Recommendation 5.2.3: The optimization review team recommends preparation of highly detailed cross-sections and maps of high concentration areas as well as heterogeneity within saturated units based on the sampling described above. Detailed site visualization and analysis are essential to refining the CSM to support RD.

High-resolution cross-sections and maps can be used to target remediation and assess remedial performance in areas of highest contaminant mass. The purpose of the detailed cross-sections and maps is to identify areas of shallow soil contamination with high concentrations and low porosity to optimize excavations.

5.3 Recommendations for Source Area Soil Remediation

This sections provides recommendations for source area soil remediation based on optimization review findings.

Recommendation 5.3.1: Given the success of the pilot SVE/ozone sparging system and the low relative cost, the optimization review team recommends expanding the existing pilot-scale SVE/ozone sparging system to include the full Northwest Source Area and perhaps the adjacent SB22 Area source. Expansion of the SVE/ozone sparging system should occur prior to extensive excavation and prior to ISB applications. The SVE/ozone sparging system should be expanded to treat soils excavated from other source areas. If needed, a GAC unit can be installed to treat cVOC vapors. The operational status of the pilot SVE/ozone sparging system was not known at the time of the optimization review, but reactivation and expansion of the system will most likely not exceed $500,000. Performance of the system can be evaluated by comparing the vapor phase mass removed to the operating costs. The SVE/ozone sparging remedy should be terminated when mass recoveries are low relative to operating costs and fuel inputs. Contingent remedies for SVE/ozone sparging include excavation and ISB treatments. Additional oxidation technologies (for example, ISCO) may be considered, but pilot tests and monitoring for undesirable changes in the subsurface (for example changes in porosity, mobilization of metals or sterilization of microbial communities) should be conducted prior to full-scale implementation.

- SVE/ozone sparging has been shown to be both an effective and cost efficient remedial alternative for this site.
- Excavation with on-site SVE/ozone sparging treatment is time and cost efficient and may eliminate the potential for long-term back diffusion of contaminants from fine-grained sediments.
- ISB treatment can be used at the base of excavations to stimulate biodegradation of contaminants in the saturated zone.
- Source area staging of SVE/ozone sparging/excavation/ISB may dramatically reduce mass flux to leading edge of plumes.

Recommendation 5.3.2: The optimization review team recommends excavation for shallow, low-permeability soils with high residual (above 1,000 mg/kg) cVOC concentrations. Soils in the Former Tank Farm Area are recommended for excavation. The decision on where SVE/ozone sparging alone or excavation with SVE/ozone sparging is most appropriate should be made based on more detailed soil concentration data, relative permeability and relative cost assessments. Low-permeability and high concentration soils should be prioritized for excavation. Excavated soils should be managed on-site and treated *ex situ* through expansion of the SVE/ozone sparging system. Based on estimated unit costs of $146 per cubic yard and a rough estimate of 3,000 cubic yards, the cost would be approximately $400,000.

Recommendation 5.3.3: Emulsified vegetable oil (ISB) treatment can be placed at the bottom of the excavations to treat deeper saturated soils not treated by the SVE/ozone sparging system.

Based on a cumulative excavation area of approximately 5,000 square feet and a target treatment thickness of 5 feet below the floor of the excavation, approximately 11,000 pounds of emulsified vegetable oil might be applied as a 5 percent solution (approximately 25,000 gallons of water) followed by an additional 25,000 gallons of water. Some contamination may mobilize in the short term, but given the current extent of the plume and the demonstrated capacity for biodegradation, the mobilized contamination would not be expected to increase the size of the plume. Recommendations for remedy performance and plume stability monitoring are provided in Section 5.5. The design for application of water and vegetable oil to the base of the excavations should be carefully conveyed to the geotechnical engineer designing the excavation so that it can be considered in the design of the excavation side walls. The optimization review team anticipates that this recommendation might cost $75,000 to implement.

5.4 Recommendations for Groundwater Remediation

Based on the results of sampling of new wells installed in summer 2013 in the general source area, groundwater contamination in the source at the Former Tank Farm Area is primarily in the shallow A-zone. Results show high concentrations of cis-1,2-DCE, indicating strong anaerobic dechlorination processes most likely the result anaerobic conditions resulting from metabolism of BTEX co-contaminants. The shallow A-zone sediments are clay/silt, potentially providing a long-term source of contamination to groundwater because of back or matrix diffusion. A similar pattern is seen at location MW-403 and to a lesser degree at MW-401 and 402. Very high concentrations of TCE were detected at the shallow MW-403 interval. Overall, cVOC contamination in the upgradient source area is characterized by highly degraded PCE sources. Contamination was detected at deeper levels at MW-404, indicating it may have migrated from upgradient sources.

Analytical results from the Northwest Source Area show shallow, less degraded sources of PCE. Concentrations of PCE are fairly high at the MW-407 shallow zone, with cis-1,2-DCE seen at higher relative concentrations in the deeper aquifer. Strong cis-1,2-DCE signals are seen at the line of monitoring wells upgradient from the Northwest Source Area, indicating that cis-1,2-DCE may be migrating from upgradient sources into the Northwest Source Area and perhaps beyond.

Recommendation 5.4.1: As an initial measure, the optimization review team recommends SVE/ozone sparging treatment, excavation and limited ISB applied to excavation areas for shallow vadose and saturated deposits in the source area. Groundwater monitoring during active SVE/ozone sparging and 2 years post-remedy should indicate the extent of

Benefits of Implementing Section 5.4 Recommendations

- Source area treatment may reduce the scale of or eliminate the need for downgradient remedies.
- Combination of ISB with excavation in the source area will result in cost effective removal of residual contamination from low-permeability saturated zones that may function as long term sources of contamination to downgradient groundwater.

reduction of source groundwater concentrations. Groundwater flows quickly at the site (up to 600 feet per year in the most transmissive zones), and the optimization review team finds it likely that quantifiable indications of performance of source area remediation will be realized at downgradient locations (for example, MW-007, MW-009 and MW-117) in less than 3 years.

Monitoring of source area groundwater wells, during and after the excavation/SVE/ozone sparging treatment, including those recommended above, will indicate reductions in mass flux from treated areas. Failure to see a response in source area groundwater wells may indicate that smaller, unidentified sources have not been fully characterized.

The decision on the need for and the location and scale of groundwater treatment should be made after the performance of the soil remedy has been evaluated. The optimization review team would not recommend the use of ISB to address concentrations below 10 µg/L. Source area excavation and SVE/ozone sparging should be performed before additional ISB treatments (excluding the ISB in excavations) in source and downgradient groundwater. Rapid remediation of residual soil sources, especially through excavation, could have a beneficial effect on remediation of groundwater by removing the source of contamination to groundwater.

Recommendation 5.4.2: If groundwater monitoring suggests that significant contaminant mass remains in the source areas, an expanded ISB remedy can be considered for both source and downgradient groundwater. Triggers for further source and plume ISB would be continued high concentrations of PCE at center line wells (for example, MW-009) or strongly increasing trends at wells indicating plume migration (for example, MW-006). Application of emulsified vegetable oil would be appropriate through injection wells for the saturated zone. Given the volumes of water needed to disperse the vegetable oil throughout the target areas, extracted groundwater would be a reasonable source of water for blending and injection the emulsified vegetable oil.

The appropriate location and number of injection wells can be selected after analysis of post-SVE/ozone sparging remedy soil and groundwater data to determine the distribution of remaining mass. Long-term sources of contamination may remain in the fine-grained saturated zone. Lack of access to the neighboring property may influence the location of injection and extraction wells.

The optimization review team anticipates that design, implementation and reporting of this injection event (including well installation) might cost up to $1 million. A repeat event for the same volume, likely needed, would cost less because design, planning and well drilling would have already occurred. The cost for this remedial approach can be substantially reduced if source soil remediation is effective.

Additional costs would be incurred for remedy performance monitoring as described in the following section.

5.5 Recommendations for Remedial Performance Monitoring

Historically, more than 40 groundwater wells have been installed in LSGPS Area A for characterization of groundwater. Many of these wells are installed outside of the PCE plume and can be eliminated from routine monitoring (although they may be retained for periodic groundwater elevation measurements).

Remedial performance monitoring will be required for groundwater for all of the remedies proposed, including excavation, SVE/ozone sparging and ISB.

Benefits of Implementing Section 5.5 Recommendations

- Remedy performance can be evaluated more effectively.
- Quantitative metrics demonstrate performance to stakeholders.
- Remedy performance monitoring can prevent operating remedies past their effective life span.

Recommendation 5.5.1: A preliminary remedy performance monitoring matrix is included as Table 9. Approximately 95 groundwater samples per year are recommended for the 3 to 5 years of active source remediation and post-response action monitoring. Costs for monitoring during active remediation are anticipated to be approximately $75,000 per year, including sample plan development, sample analysis, data management and data analysis and reporting. After the excavation/SVE/ozone sparging remedy performance monitoring period has been completed, groundwater monitoring can be reduced both in terms of the number wells and frequency of sampling.

Recommended groundwater monitoring wells are listed for various monitoring objectives, including remediation of the various source areas. Sampling frequencies are recommended for each well group as well as potential data analysis techniques to support each monitoring objective.

After the PDB sampling and analysis recommended in Section 5.2 above has been completed, sampling should be conducted with low-flow sampling technology from the interval with the highest concentration indicated from the PDB sampling. Selection of final low-flow sampling locations may be aided by in-well borehole flow monitoring to confirm flow characteristics across the screen lengths.

Groundwater samples collected using low-flow sampling methods should be analyzed for typical field stabilization parameters (including oxidation reduction potential, turbidity and pH), as well as cVOCs analytes. During the ISB remedy, if implemented, metals and geochemical indicators should be included in the monitoring program to support assessment of the strength of biodegradation processes, including ferrous iron, nitrate, sulfate, dissolved organic carbon and alkalinity. Metals should be evaluated to ensure that oxidation/reduction manipulation does not mobilize constituents such as arsenic and manganese.

Additional data analyses to evaluate remedy performance may include estimates of total mass in each medium and estimated trends and reduction of total mass as well as mass flux estimates. Concentration trends for PCE and cis-1,2-DCE at downgradient wells (MW-007, MW-122 and MW-009) should show statistical decreases after 3 to 5 years.

All area wells should be monitored at least once during a FYR cycle. Data should be evaluated routinely to determine if a follow-up downgradient plume remedy is required and if the dilute areas of the plume are being restored in a timely manner. The sampling frequency can be revisited after 3 years of quarterly sampling.

Particular attention should be paid to future sampling results from MW-006, which delineates the plume’s eastern edge of the northern segment of the plume. With the cessation of groundwater pumping at the gravel pit and changes in historical extraction due to ICs and abandonment of private supply wells, the plume footprint may expand laterally in the northeast direction upgradient of the gravel ponds. MW-006 shows increasing trends for PCE, TCE, cis-1,2-DCE and vinyl chloride, although concentrations are still below cleanup goals, concentration increases may indicate an expansion of the plume footprint. No new wells are recommended at this time, but may be considered if MW-006 shows continued increases in COC concentrations.

5.6 Recommendations Related to Green Remediation

No specific recommendations are provided at this time in this category. Green remediation best practices and environmental footprint analysis can be revisited after characterization activities have been completed and the site team is developing a more targeted RD. In general:

- The additional characterization suggested should help target the precise location of media to be remediated and, therefore, reduce the footprint of the final remedy;
- Cost savings for the recommended combination of excavation, on-site treatment and SVE should reduce the project footprint by minimizing soil transport and disposal;
- The recommended remedy performance monitoring plan should help reduce the likelihood that the remedies will be run longer than is cost effective. Performance monitoring will also help identify underperforming remedies earlier in the remediation process so they can be modified or replaced, thus saving costly time and material expenditures; and
- The proposed, staged remedial response (source remedy followed by monitoring) may prevent installation of unnecessary remedy components to treat the downgradient plume.

Table 8 summarizes the optimization review recommendations. Table 9 summarizes the recommended groundwater performance monitoring program.

Table 8: Recommendations Summary

Recommendation	**Effectiveness**	**Cost Reduction**	**Technical Improvement**	**Site Closure**	**Environmental Footprint Reduction**	**Capital Cost**	**Change in Annual Cost**
5.2.1 Additional groundwater wells installed using Rotosonic drilling to characterize groundwater and vadose zone	◆		◆		◆	(Already installed)	N/A
5.2.2 Groundwater sampling using PDBs for vertical delineation of contaminants	◆		◆			$20,000	N/A
5.2.3 Detailed cross-sections	◆	◆	◆	◆		$10,000	N/A
5.3.1 Scale up of pilot SVE/ozone sparging system for source soils	◆	◆	◆	◆		$500,000	N/A
5.3.2 Excavation and *ex situ* treatment of low permeability, shallow contaminated soil	◆	◆	◆	◆	◆	$400,000	N/A
5.3.3 ISB remedy at base of excavation	◆		◆	◆		$75,000	N/A
5.4.1 Delay decision on source groundwater treatment until performance of soil remedy has been evaluated		◆				$0	N/A
5.4.2 ISB for source and downgradient plume, if source remedy alone does not shrink plume	◆		◆	◆		$1,000,000	N/A
5.5.1 Remedy performance monitoring for source soil treatment and downgradient groundwater response (3 years)			◆	◆		$225,000	Cost increase of ~30%

Notes: PDB = passive diffusion bag; SVE = soil vapor extraction; ISB = *in situ* bioremediation; N/A = not applicable

Table 9: Recommended Groundwater Performance Monitoring Program
LSGPS OU2

Well Name	Unit	Objective	Parameters & Frequency*	Analyses
MW-011	Source Area	Evaluate response to Excavation/ SVE and ISB treatment	VOCs semi-annually for 2 years after excavation/ SVE (and metals if ISB used with excavation) annually after active remedies discontinued	Concentration trend evaluation, mass discharge downgradient mass removal vs. cost of remedy
MW-101				
MW-102				
MW-103				
MW-105				
MW-400(S, I, D)	Source Area	Delineate depth of contamination, evaluate remedy performance	VOCs semi-annually from highest concentration interval, annual from all intervals during active remedy	Concentration trend evaluation, mass discharge downgradient mass removal vs. cost of remedy
MW-401(S, I, D)				
MW-402(S, I, D)				
MW-403(S, I, D)				
MW-404(S, I, D)				
MW-405(S, I, D)				
MW-406(S, I, D)				
MW-407(S, I, D)				
MW-411(S, I, D)				
PT-01	Northwest Source Area	SVE Remedy Performance	VOCs semi-annually for duration of SVE, annually thereafter	Concentration Trend
PT-02				
PT-03				
PT-04				
PT-05				
PT-06				
PT-07				
MW-408(S, I, D)	Downgradient of Source	Remedy Performance	VOCs semi-annually from highest concentration interval, annual from all intervals during active remedy	Concentration trend evaluation, mass discharge downgradient,
MW-409(S, I, D)				
MW-410(S, I, D)				
MW-412(S, I, D)				
MW-413(S, I, D)				
MW-128	Bedrock	Delineation	Every 2 years	Delineation vertical extent of affected groundwater

Well Name	Unit	Objective	Parameters & Frequency*	Analyses
MW-007	Centerline Wells	Remedy Performance – high concentration tail wells	VOCs semi-annually during active remediation	Concentration Trend evaluation, mass discharge downgradient, mass removal vs. cost of remedy
MW-008				
MW-009				
MW-117				
MW-122				
MW-004	Plume Tail Wells	Remedy Performance	VOCs Annual	Concentration trend evaluation, plume stability
MW-005				
MW-006				
MW-116				
MW-121				
MW-001	Upgradient and Cross Gradient Delineation	Delineation upgradient extent of OU2 plume/mixing with OU1 plume	cVOCs for 5-Year Review	Compare to detection limits and cleanup standards—Monitor for plume expansion
MW-002				
MW-003				
MW-010				
MW-100				
MW-103				
MW-104				
MW-110				
MW-123				
MW-124	Delineate toward River	Evaluate plume stability	VOCs Annual	Compare with detection limits and cleanup standards—Monitor for discharge to river
MW-125				
MW-126				
MW-127				
Additional area wells	Outside of OU2 Plume	Groundwater elevation/ flow direction	5-Year Review	Groundwater elevation measure
SVE extraction wells (vapor)	Source area	Mass removal	Photoionization detector monthly and cVOCs quarterly from key wells for comparison	Mass removal rate

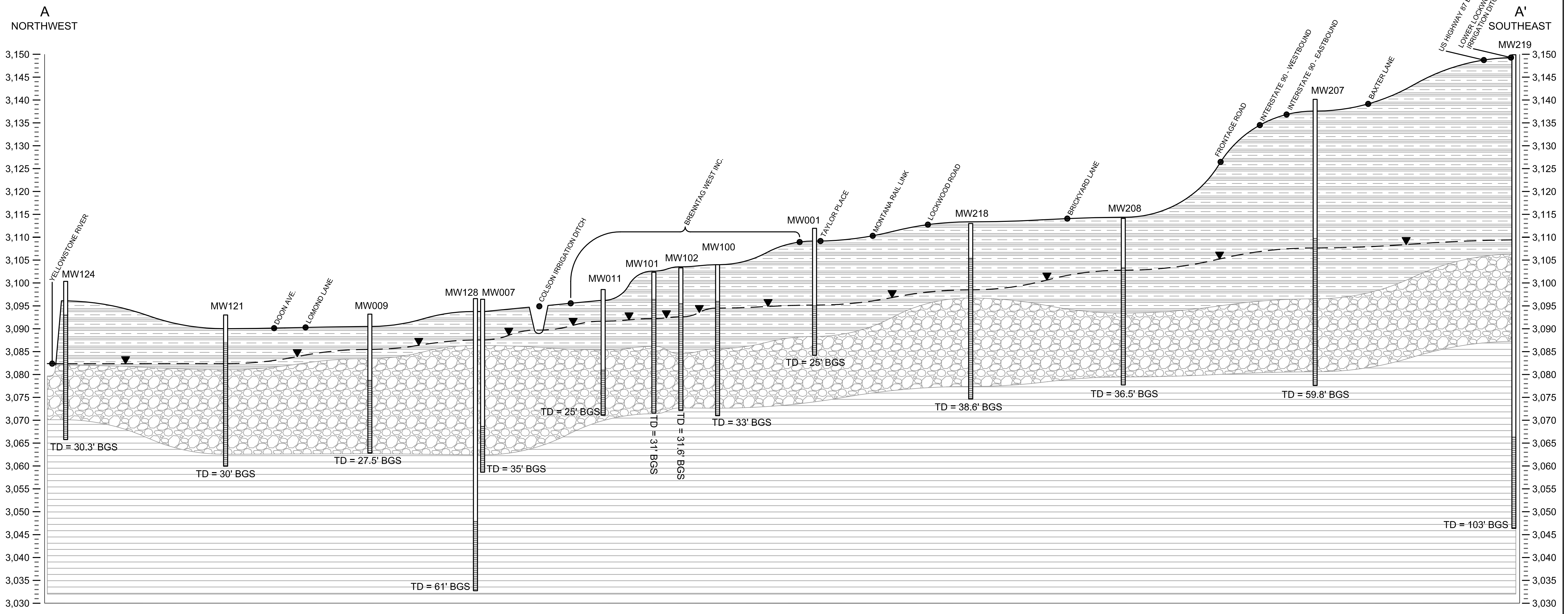
Notes: MW = monitoring well; SVE = soil vapor extraction; ISB = *in situ* bioremediation; N/A = not applicable; VOC = volatile organic compounds; cVOCs = chlorinated volatile organic compounds.

ATTACHMENT A
FIGURES FROM EXISTING SITE REPORTS

Attachment A
Figures Excerpted from Site Documents

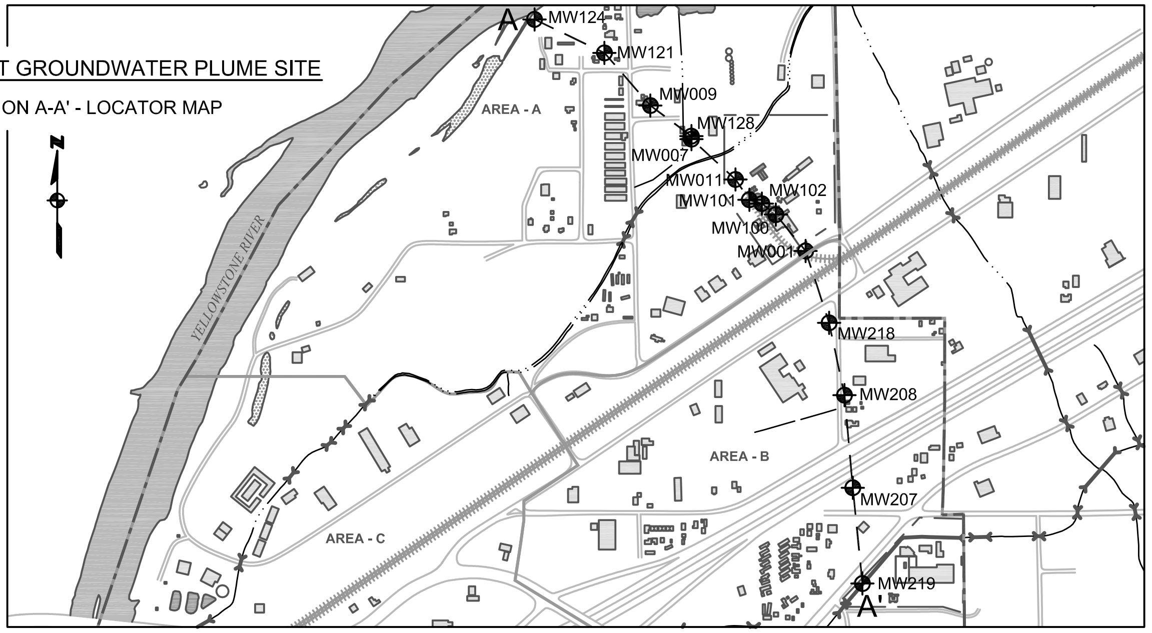
Figures from RI Report

Figure 3-3
Log of Borehole MW007
Log of Borehole MW011
Log of Borehole MW102



LOCKWOOD SOLVENT GROUNDWATER PLUME SITE

CROSS SECTION A-A' - LOCATOR MAP

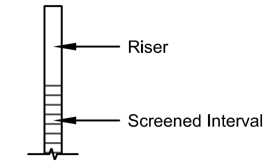


Legend

MW - Monitoring Well Locations
TD - Total Depth
BGS - Below Ground Surface
▼ - Groundwater Level
▤ - Silty Clay / Silt / Fine Sand
▨ - Gravels With Sand
☰ - Bedrock

Elevations Listed In Feet Above Mean Sea Level

Well Detail



325 0 325 650

SCALE IN FEET - 1 inch = 325 feet
VERTICAL SCALE EXAGGERATED 15X

LOCKWOOD SOLVENT GROUNDWATER PLUME SITE
BILLINGS, MONTANA

FIGURE 3-3
GEOLOGIC CROSS SECTION
A-A'

Tetra Tech EM Inc.

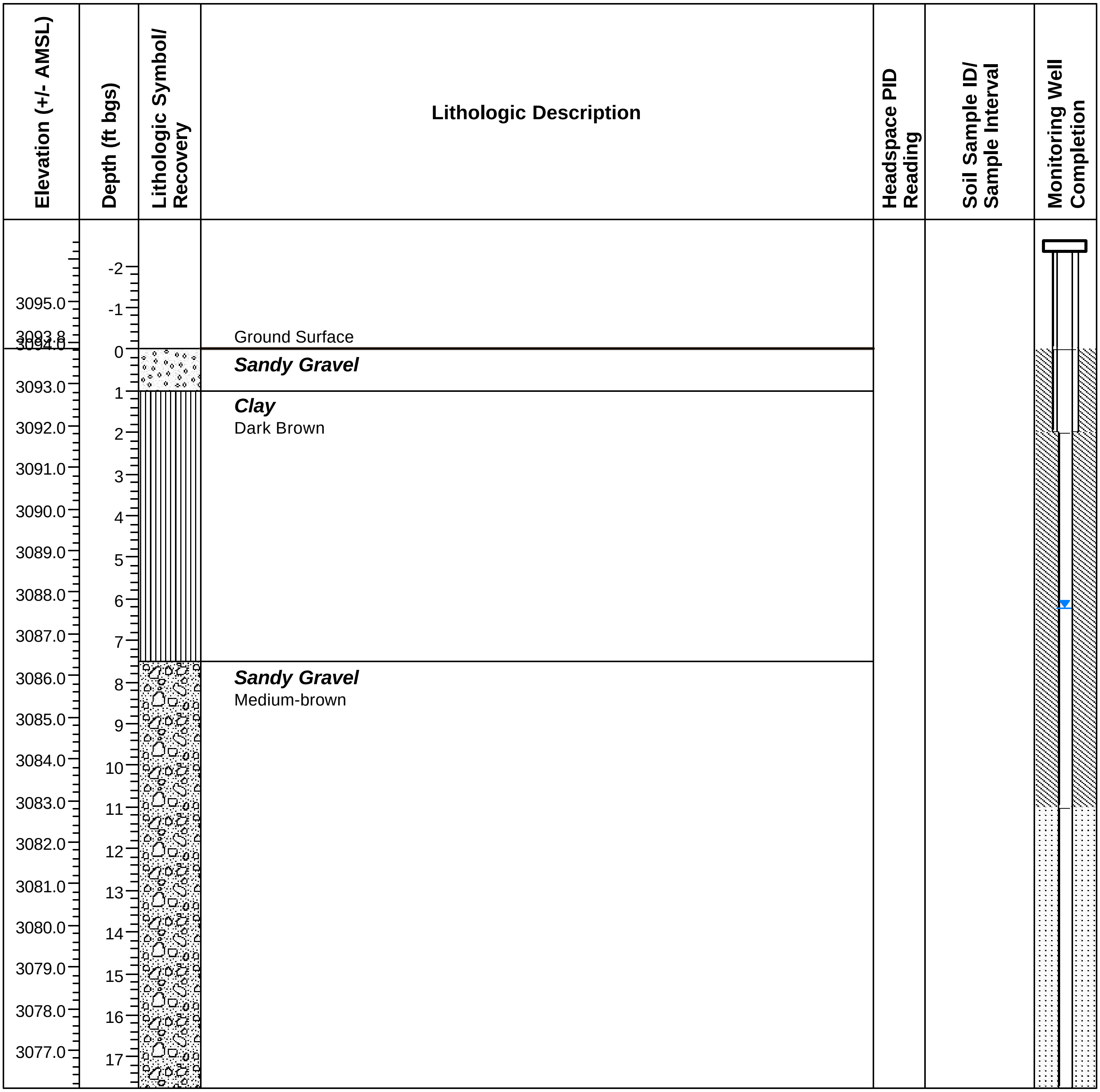
x-sect base map - DWH - 05/29/2003 - S1176-10-RIRPRT

LOCKWOOD SOLVENT
GROUNDWATER PLUME SITE

YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: ***MW007***



Ground Surface

Sandy Gravel

Clay
Dark Brown

Sandy Gravel
Medium-brown

DRILLING DATE: 9-29-99
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs): 35
TOTAL WELL DEPTH (ft btoc): 31.45
LOGGED BY: P. Bray
CLIENT: MDEQ
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.5
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3096.44
GROUND ELEVATION (ft AMSL): 3093.84
DRILLING CO.: Maxim
WATER LEVEL (ft btoc): 8.81
GROUNDWATER ELEV (ft AMSL).: 3087.63

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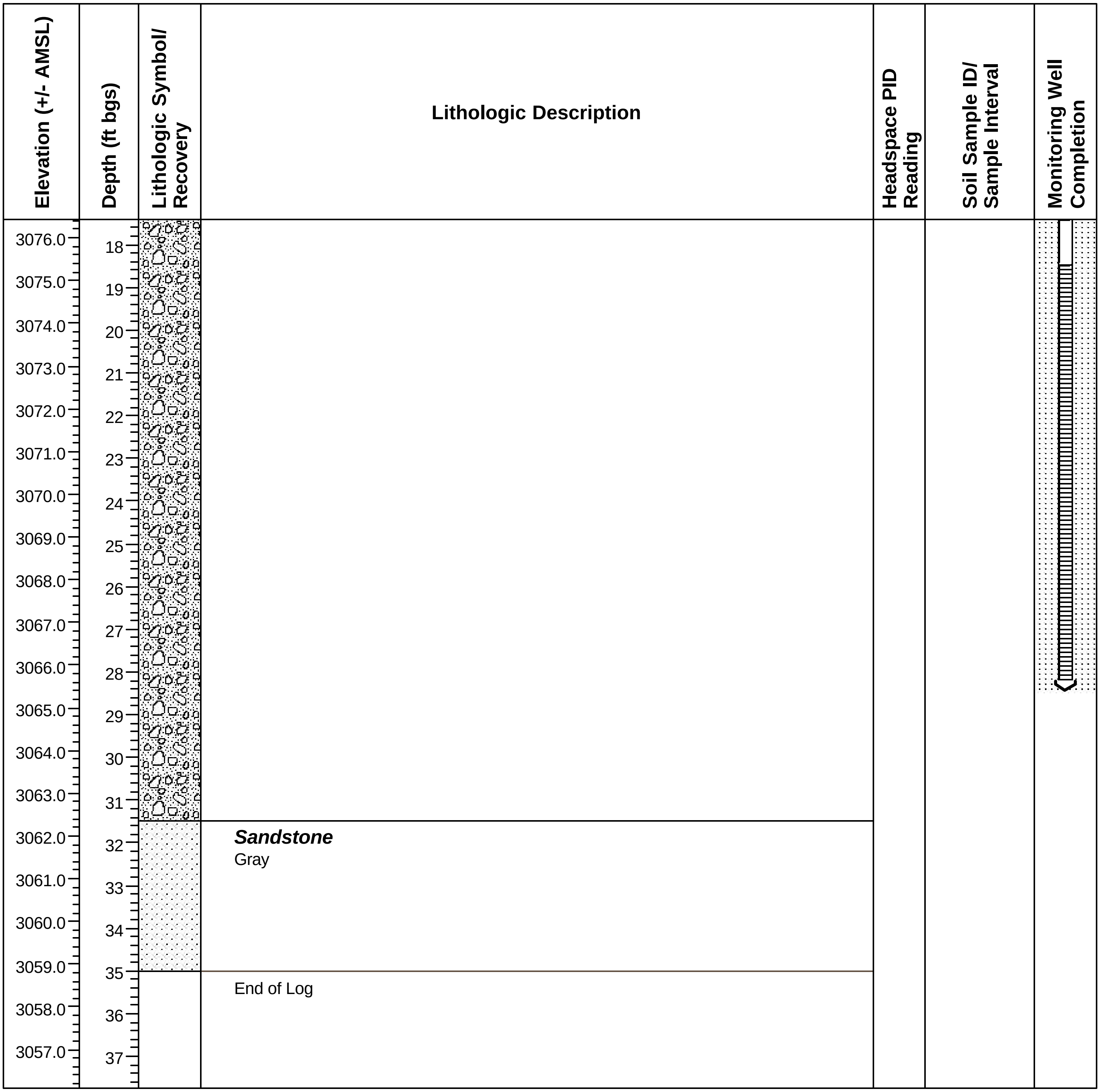
YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: MW007



Sandstone
Gray

End of Log

DRILLING DATE: 9-29-99
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs): 35
TOTAL WELL DEPTH (ft btoc): 31.45
LOGGED BY: P. Bray
CLIENT: MDEQ
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.5
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3096.44
GROUND ELEVATION (ft AMSL): 3093.84
DRILLING CO.: Maxim
WATER LEVEL (ft btoc): 8.81
GROUNDWATER ELEV (ft AMSL).: 3087.63

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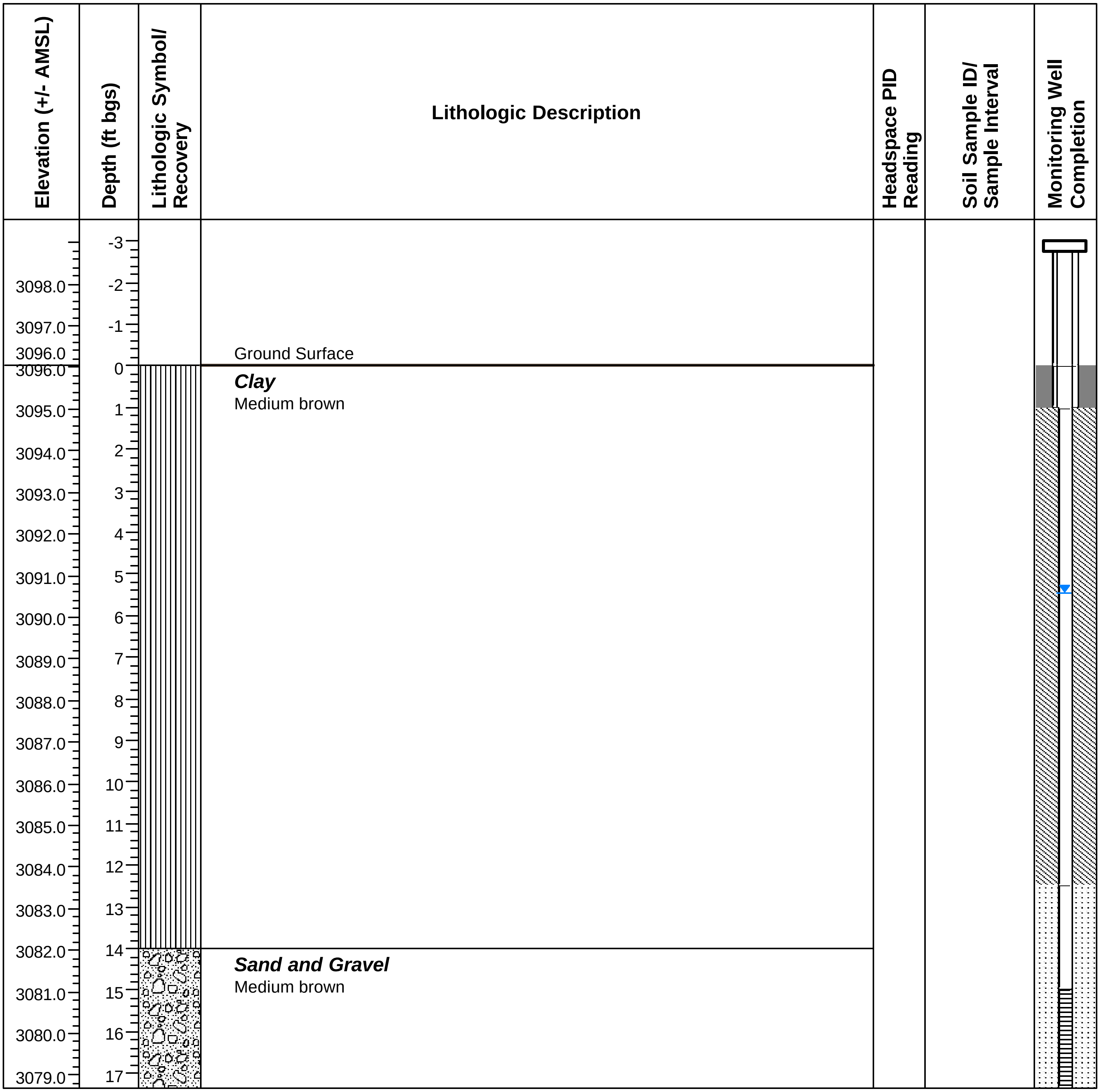
YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: ***MW011***



Ground Surface

Clay
Medium brown

Sand and Gravel
Medium brown

DRILLING DATE: 9-30-99
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs):
TOTAL WELL DEPTH (ft btoc):
LOGGED BY: P. Bray
CLIENT: MDEQ EPA
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.5
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3153.39
GROUND ELEVATION (ft AMSL): 3096.04
DRILLING CO.: Maxim
WATER LEVEL (ft btoc): 7.88
GROUNDWATER ELEV (ft AMSL).: 3113.90

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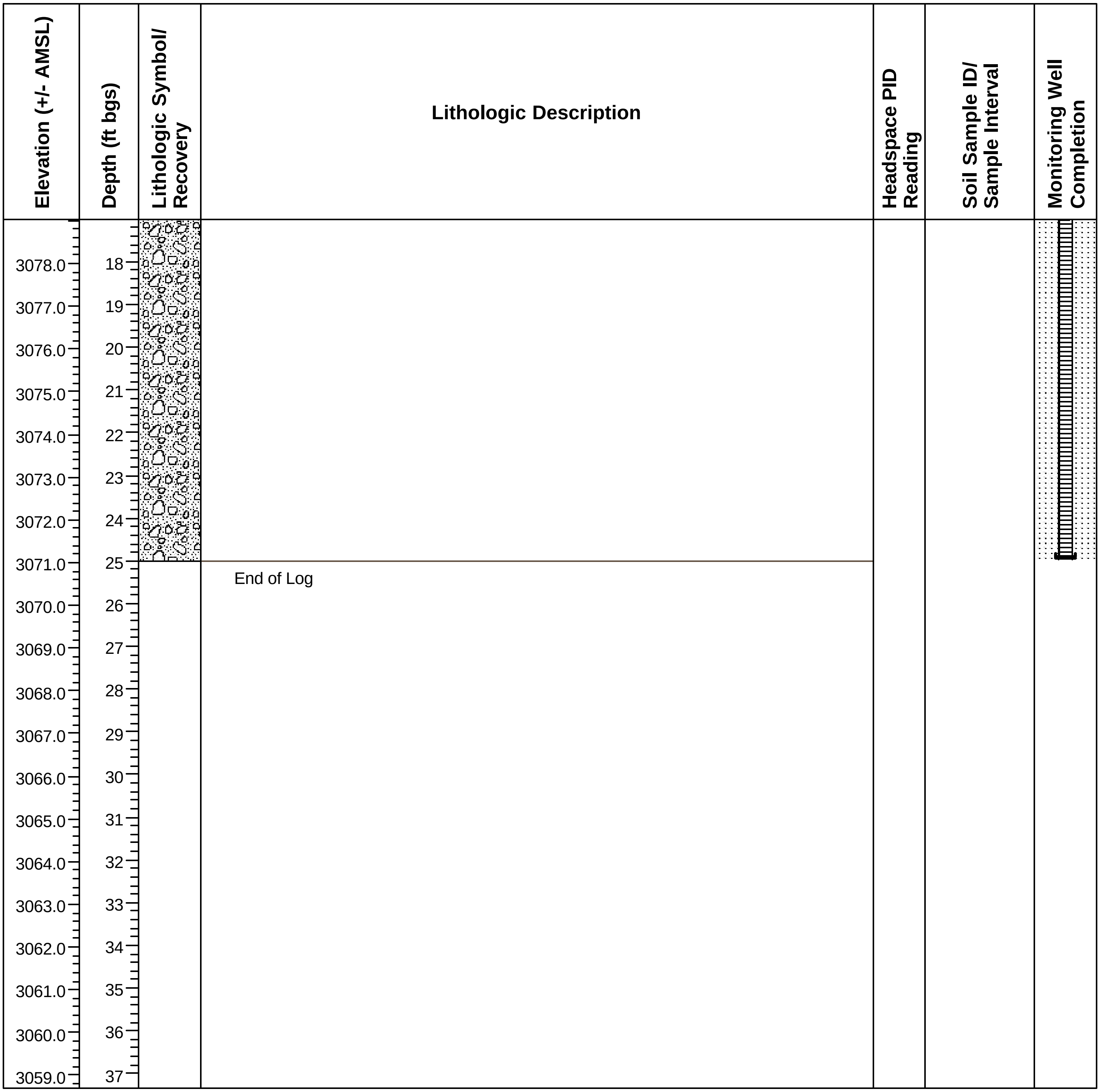
GROUNDWATER PLUME SITE

YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: ***MW011***



DRILLING DATE: 9-30-99
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs):
TOTAL WELL DEPTH (ft btoc):
LOGGED BY: P. Bray
CLIENT: MDEQ EPA
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.5
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3153.39
GROUND ELEVATION (ft AMSL): 3096.04
DRILLING CO.: Maxim
WATER LEVEL (ft btoc): 7.88
GROUNDWATER ELEV (ft AMSL).: 3113.90

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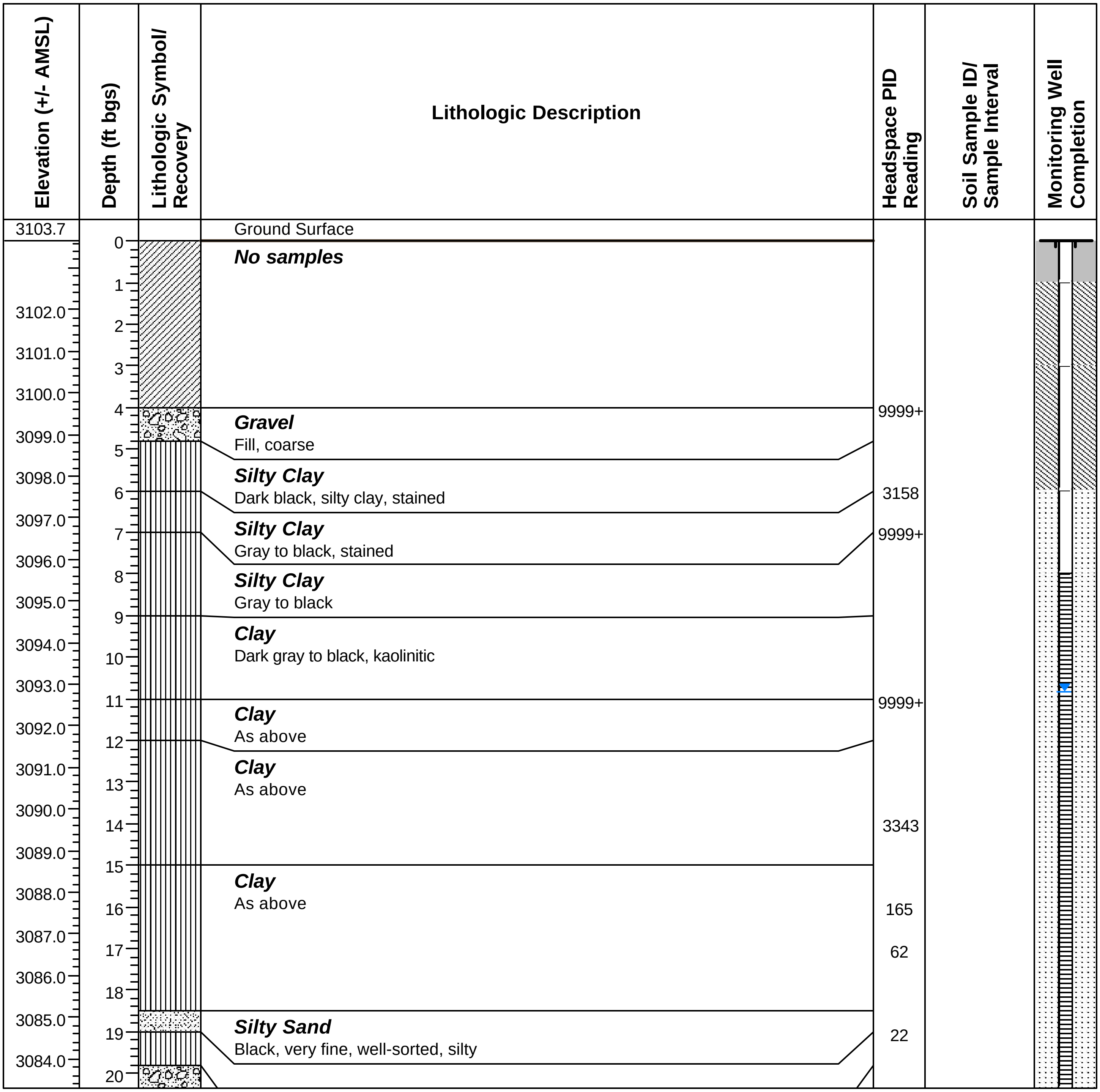
LOCKWOOD SOLVENT
GROUNDWATER PLUME SITE

YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: MW102



Ground Surface

No samples

Gravel
Fill, coarse

Silty Clay
Dark black, silty clay, stained

Silty Clay
Gray to black, stained

Silty Clay
Gray to black

Clay
Dark gray to black, kaolinitic

Clay
As above

Clay
As above

Clay
As above

Silty Sand
Black, very fine, well-sorted, silty

DRILLING DATE: 6-20-02
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs): 33
TOTAL WELL DEPTH (ft btoc): 33
LOGGED BY: J. Faubion
CLIENT: MDEQ
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.25
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3103.28
GROUND ELEVATION (ft AMSL): 3103.65
DRILLING CO.: SK Geotechnical
WATER LEVEL (ft btoc): 10.42 (10/28/02)
GROUNDWATER ELEV (ft AMSL).: 3092.86

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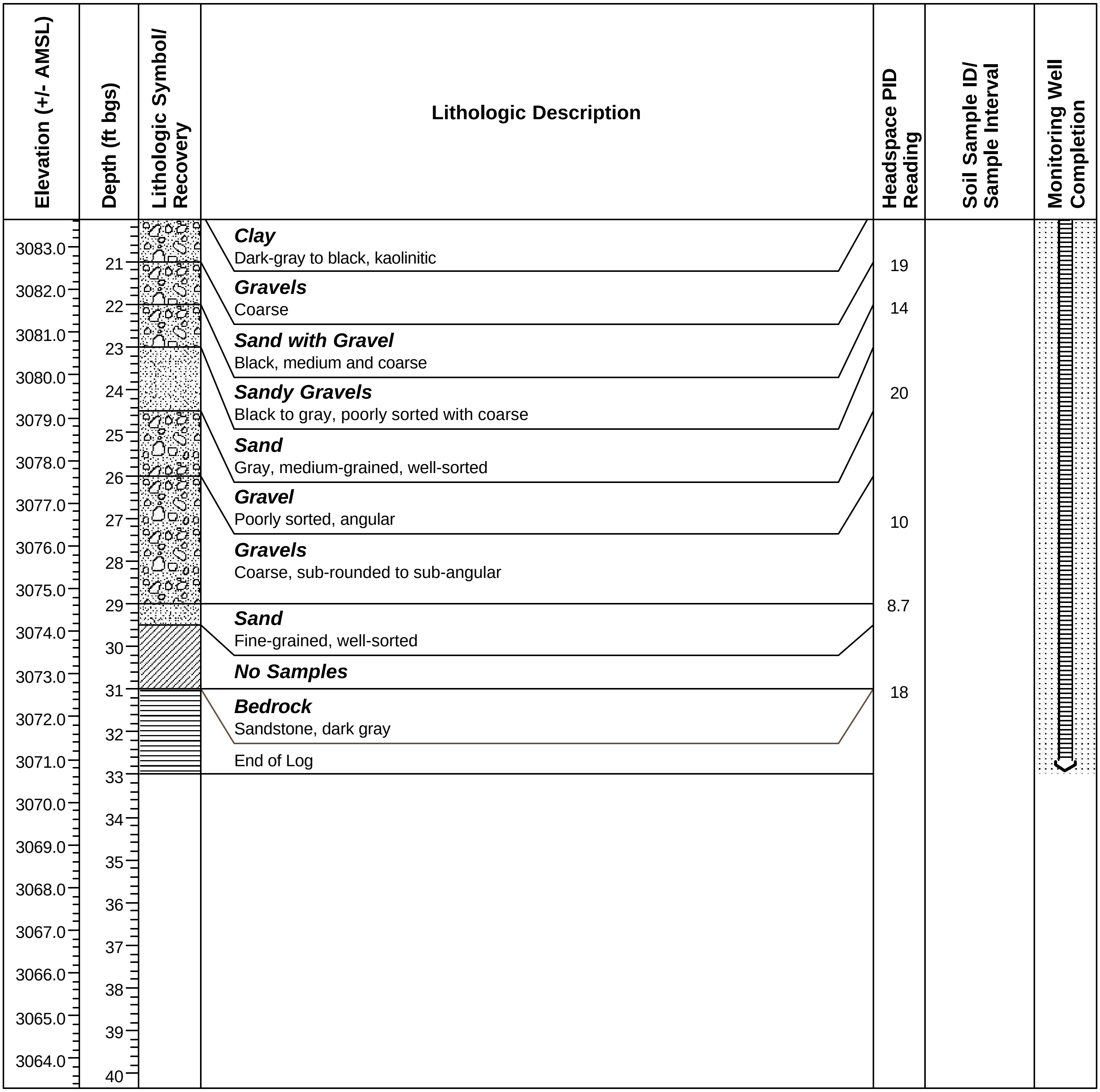
GROUNDWATER PLUME SITE

YELLOWSTONE COUNTY
MONTANA

LOG OF BOREHOLE

Borehole/Well ID: ***MW102***



Clay
Dark-gray to black, kaolinitic

Gravels
Coarse

Sand with Gravel
Black, medium and coarse

Sandy Gravels
Black to gray, poorly sorted with coarse

Sand
Gray, medium-grained, well-sorted

Gravel
Poorly sorted, angular

Gravels
Coarse, sub-rounded to sub-angular

Sand
Fine-grained, well-sorted

No Samples

Bedrock
Sandstone, dark gray

End of Log

DRILLING DATE: 6-20-02
DRILLING METHOD: HSA
BOREHOLE DEPTH (ft bgs): 33
TOTAL WELL DEPTH (ft btoc): 33
LOGGED BY: J. Faubion
CLIENT: MDEQ
PROJECT NO.: S1176-10RIRPRT

BOREHOLE DIAMETER (in.): 8.25
WELL CASING DIAMETER (in.): 2.0
TOC ELEVATION (ft AMSL): 3103.28
GROUND ELEVATION (ft AMSL): 3103.65
DRILLING CO.: SK Geotechnical
WATER LEVEL (ft btoc): 10.42 (10/28/02)
GROUNDWATER ELEV (ft AMSL).: 3092.86

Tetra Tech EM Inc.
7 West 6th Avenue, Suite 612
Helena, Montana
(406)442-5588

ATTACHMENT B
INTERIM OPTIMIZATION MEMORANDUM AND PRESENTATION FROM MARCH 2013

Attachment B
Interim Optimization Memorandum and Presentation

OU2 Memorandum: Preliminary Well Location Recommendations

OU2 Presentation: Optimization Review Interim Update

March 15, 2013

MEMORANDUM

TO: **Kirby Biggs, USEPA TIFSD**

FROM: Mindy Vanderford
Doug Sutton

RE: **Lockwood Solvent Groundwater Plume Site, OU2**
Preliminary Well Location Recommendations

USEPA TIFSD is supporting remedial design stage optimization activities at the Lockwood Solvent Groundwater Plume Site (LSGPS) near Billings, Montana, USEPA Region 8. As part of remedial design optimization, the review team has been tasked with evaluating potential groundwater well locations for OU2 to 1) improve source area characterization and 2) provide performance monitoring for future remedial actions.

The following preliminary recommendations are based on a review of existing OU2 groundwater and soil data, cross-sections, site reports and a site visit conducted February 28, 2013. Preliminary recommendations are being provided prior to the final optimization report to help scope and budget well installation activities. These preliminary recommendations are representative of our current interpretation, and the recommendations may change as data are further interpreted over the next few weeks.

The overall source area of LSGPS OU2 consists of a number of smaller potential sources of contamination. Site data suggest that contamination was released at different times and by different mechanisms in each source area. The primary areas thought to be contributing contaminant mass to the groundwater plume are listed below and shown on Figure 1.

- Tank Farm Source
- Acid Tank Farm Source
- Northwest Source
- SB22 Source

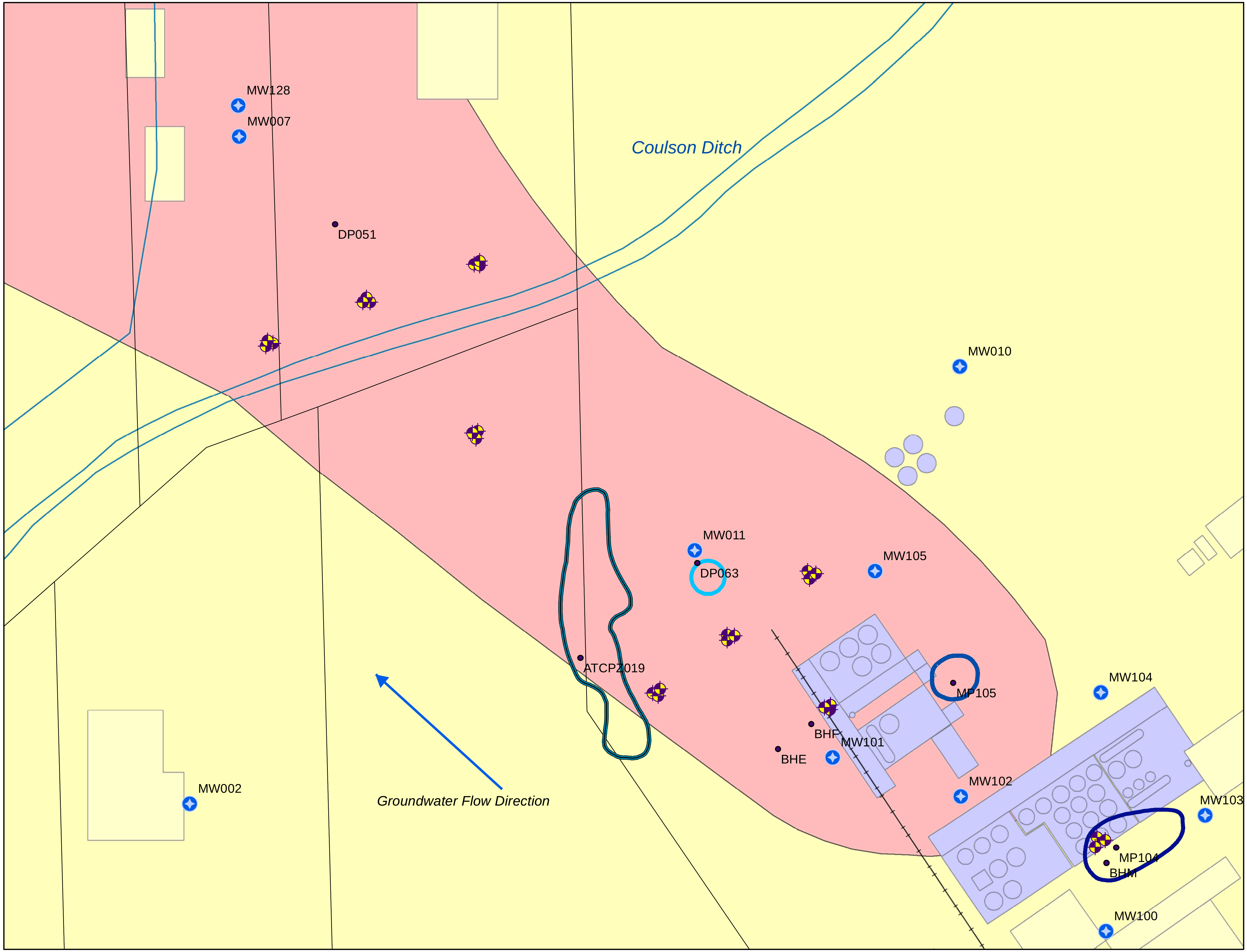
The shallow subsurface of the source zone consists of a surficial silt/clay/sand layer extending to approximately 15 feet below ground surface (bgs). The silty upper layer is underlain by a sand/gravel unit extending to the sandstone bedrock at approximately 30 ft bgs. Both the silt/sand and the sand/gravel units are saturated. Monitoring wells installed in the source are screened across both the low and high-porosity layers.

In order to choose between different remedial options and optimize remedial response, the optimization team recommends that additional depth-discreet data should be collected in the source area and that the input or mass flux from each of the smaller sources should be quantified. To this end, preliminary well installation recommendations are detailed below and shown on Figure 1.

- Wells are recommended to be installed in clusters of three using rotosonic drilling and the following 5-ft screened intervals.
    - *A- Depth*: Based on interpretation of the rotosonic core, the upper well should be placed in the most permeable portion of the silty/low-permeability saturated unit.

  - *B-Depth*: Based on interpretation of the rotosonic core, the middle interval well should be placed in a shallow transmissive section of the upper sand/gravel aquifer.
  - *C-Depth*: The bottom interval well should be placed at the bottom of the sand/gravel aquifer near the contact with bedrock. It is expected that the C-Depth well for each cluster will be installed first so that the intervals for the A-Depth and B-Depth wells can be determined from the C-Depth rotosonic core.
- The suggested locations for the well clusters are provided below. Interpreting the rotosonic cores in these areas will provide important information with regard to stratigraphy. Monitoring wells in each of the three suggested depth intervals will help determine the chemical signature, distribution and mass flux of contamination at the suggested locations. Water level measurements from discrete interval monitoring wells will also provide improved information regarding vertical hydraulic gradients.
  - One well cluster should be placed in or immediately downgradient of the upgradient Tank Farm Source area near borings MP104 and BHM. Contamination in this area appears to be deeper and more degraded than in other areas of the source. Existing deep sample data in this location are characterized by high quantities of the chlorinated solvent degradation product DCE. This well cluster will provide the above-mentioned information for the most upgradient source area in OU2.
  - One well cluster is recommended downgradient from the Tank Farm area near historic soil boring BHF, west of the Acid Tank Farm source area. Comparing the sampling results from this well cluster with the sampling results from the upgradient well cluster may help determine if additional sources downgradient of the Tank Farm Source are contributing contaminant mass to this location.
  - A transect of well clusters is recommended for a line perpendicular to groundwater flow near soil borings BHA, BHB and BHC. This transect is downgradient from both the Acid Tank Farm and the Tank Farm but upgradient of the Northwest Source and the SB22 Source. Wells in this area will characterize the depth and composition of contamination entering the Northwest Source Area. Quantifying mass entering the Northwest Source area will support allocation of remedial effort to each of the sources and will help evaluate the performance of remedies both upgradient and downgradient of this transect.
  - One well cluster is recommended for the area downgradient of the Northwest Source and upgradient of Coulson Ditch. The wells in this area will quantify mass exported from the Northwest Source area and support remedy performance evaluations.
  - A transect of well clusters is recommended from the area north of Coulson Ditch and south/southeast of monitoring well MW-007. This transect of wells will provide data to evaluate source-remedy performance and will help estimate mass discharge downgradient.

Additional shallow soil and groundwater investigations will likely be recommended to delineate individual source areas that are net yet fully delineated. It is likely that the investigations will involve direct-push technology and real-time field measurement supported by confirmatory soil samples. The scope of these investigations will likely be informed to some degree by the data collected from the installation and sampling of the above monitoring wells. For that reason, it is recommended that the shallow soil and groundwater investigation take place after the above wells have been installed, developed, surveyed, gauged, and sampled at least once.



PRELIMINARY WELL LOCATION RECOMMENDATIONS

LOCKWOOD OU2 SOURCE

Billings, Montana

Job No.	3753-103	Drawn By:	MV
Date	15 March, 2013	Revision:	0
Scale	As Shown		Figure 1

Lockwood Solvent Groundwater Plume Site

Optimization Review Interim Update

Doug Sutton / Tetra Tech
Mindy Vanderford / GSI

USEPA TIFSD

April 15, 2013

Optimization Review Interim Update

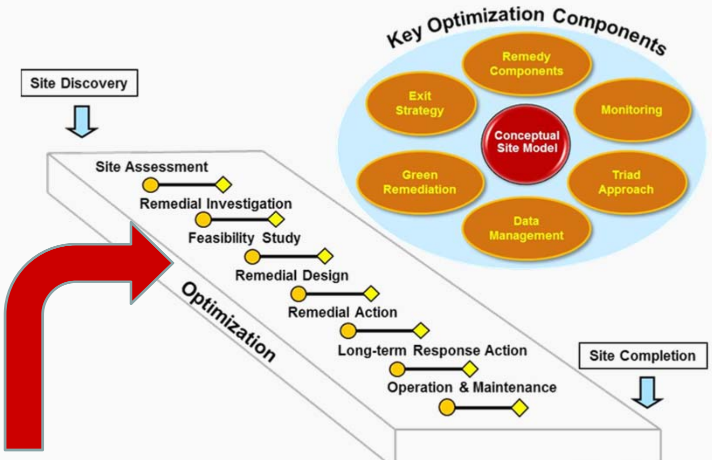
- ***US EPA National Optimization Strategy***
- ***LSGPS Goals and Objectives***
- ***OU1 – Beall Source Area***
  - ***CSM Review***
  - ***OU1 Recommendations***
- ***OU2 – Soco Source Area***
  - ***CSM Review***
  - ***OU2 Recommendations***

EPA's Definition of Optimization

Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion.

To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness.

From: National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion, September 2012



Key Optimization Components

Remedy Components

Exit Strategy

Monitoring

Conceptual Site Model

Green Remediation

Triad Approach

Data Management

Site Discovery

Site Assessment

Remedial Investigation

Feasibility Study

Remedial Design

Remedial Action

Long-term Response Action

Operation & Maintenance

Optimization

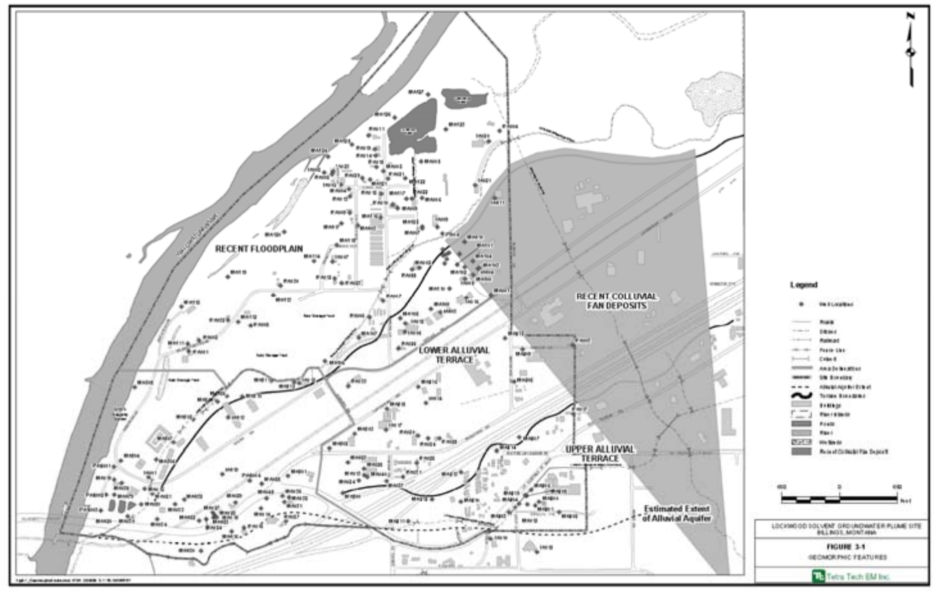
Site Completion

You Are Here

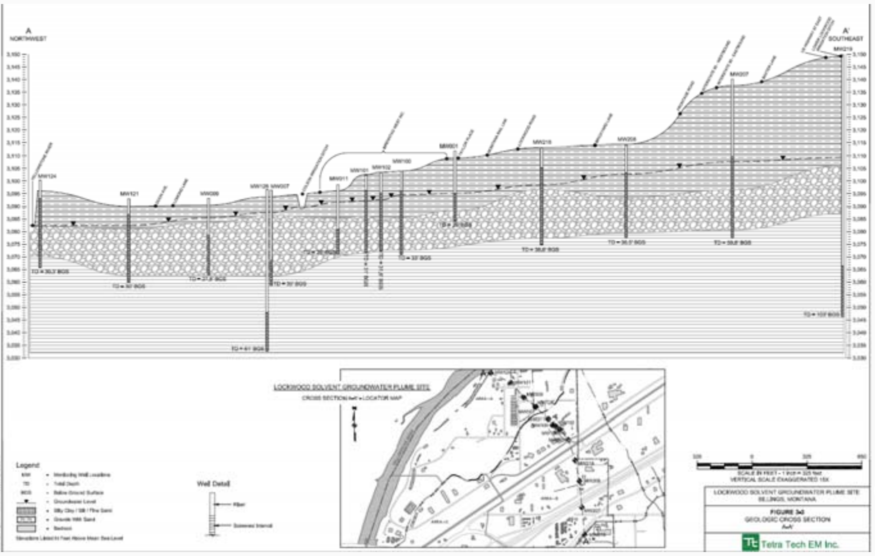
LSGPS Project Goals

- Remedial Design for OU1 and OU2
  - Review CSM for data gaps
  - Recommend additional characterization
  - Support choice of remedial components that are protective and maximize cleanup while minimizing effort/cost/risk
    - Source Treatment
    - Plume Treatment and Management
    - Remedial Performance Monitoring

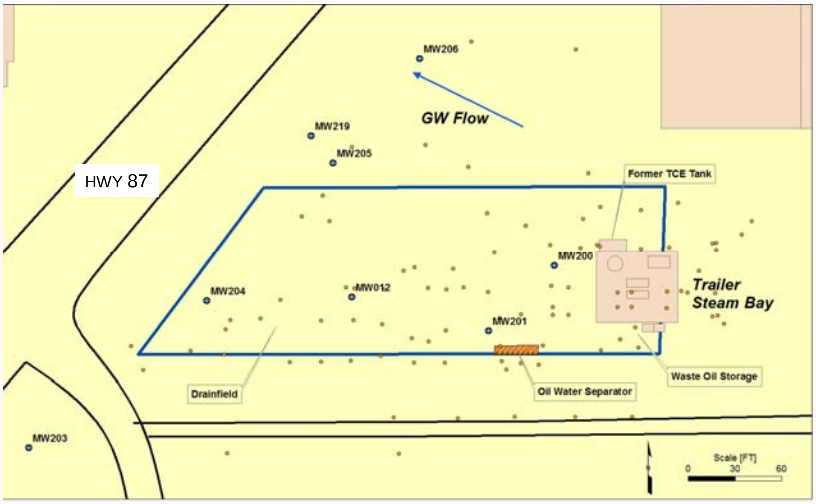
LSGPS Region



LSGPS Cross-Section



OU1 – Beall Trailers Source

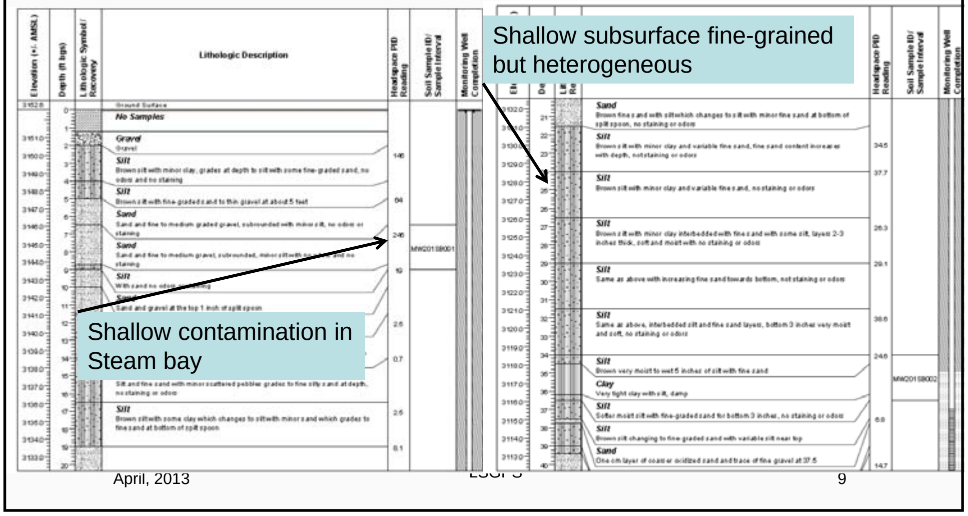


OU1 – Beall Area

- Historic Trailer Washing
  - TCE Tank and Oil/Water separator
- Property Redevelopment will retain function
- GW flow to N/NW – Historic municipal well to West
- Upper Terrace – Fine-grained zone thicker than at OU2
- Proposed Remedies –
  - SVE or Excavation?
  - Enhanced Bioremediation
  - MNA

OU1 Subsurface Observations

MW-201

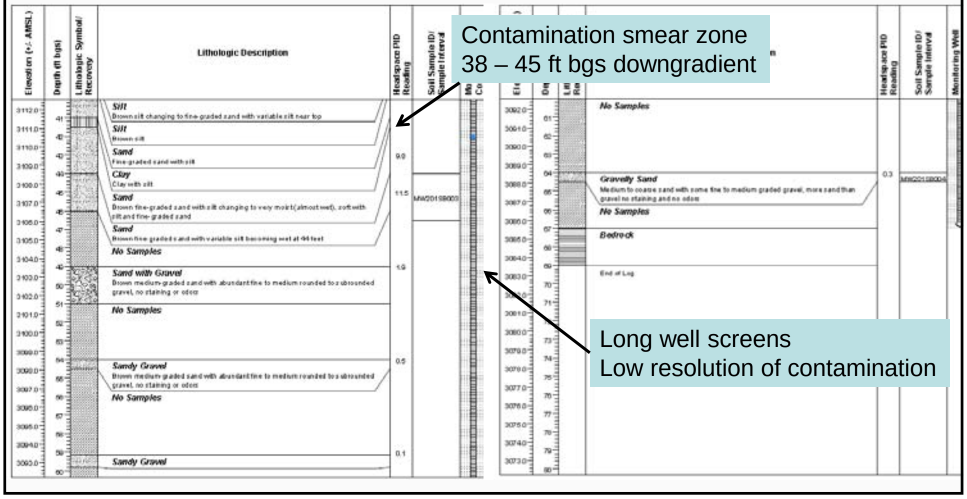


Shallow subsurface fine-grained but heterogeneous

Shallow contamination in Steam bay

OU1 Subsurface Observations

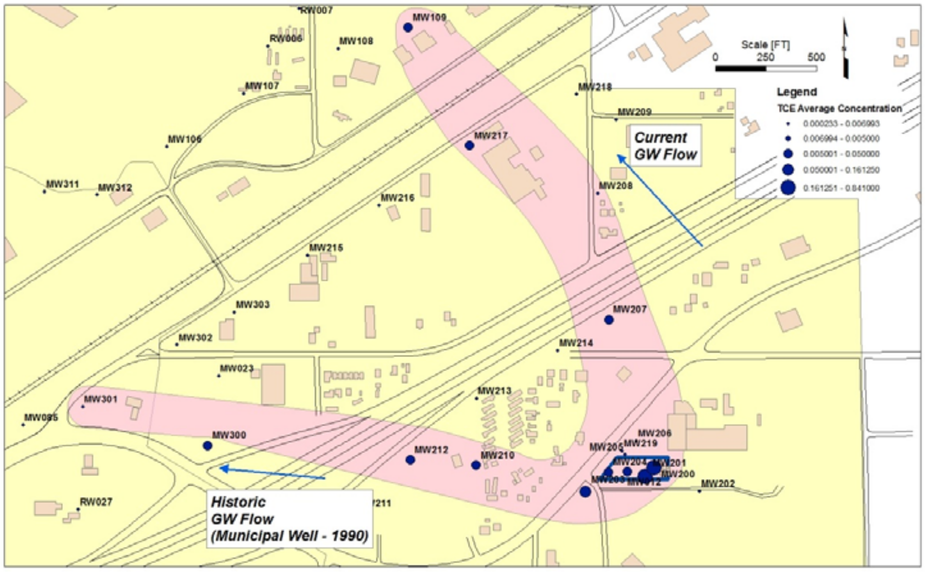
MW-201



Contamination smear zone
38 – 45 ft bgs downgradient

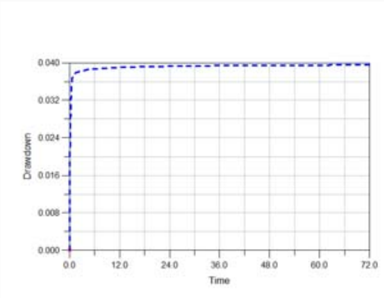
Long well screens
Low resolution of contamination

OU1 – Groundwater Plume



OU1 Hydraulic Conductivity

- Simulated hydrograph generated with following parameters:
    - Flow rate: 3 gpm
    - Observation well distance: 15 ft
    - Hydraulic conductivity: 300 ft/day
    - Saturated thickness: 24 ft
- Very, very small response, easily masked by minor trend in regional water level
- Best explanation of result is high hydraulic conductivity



OU1 Uncertainties

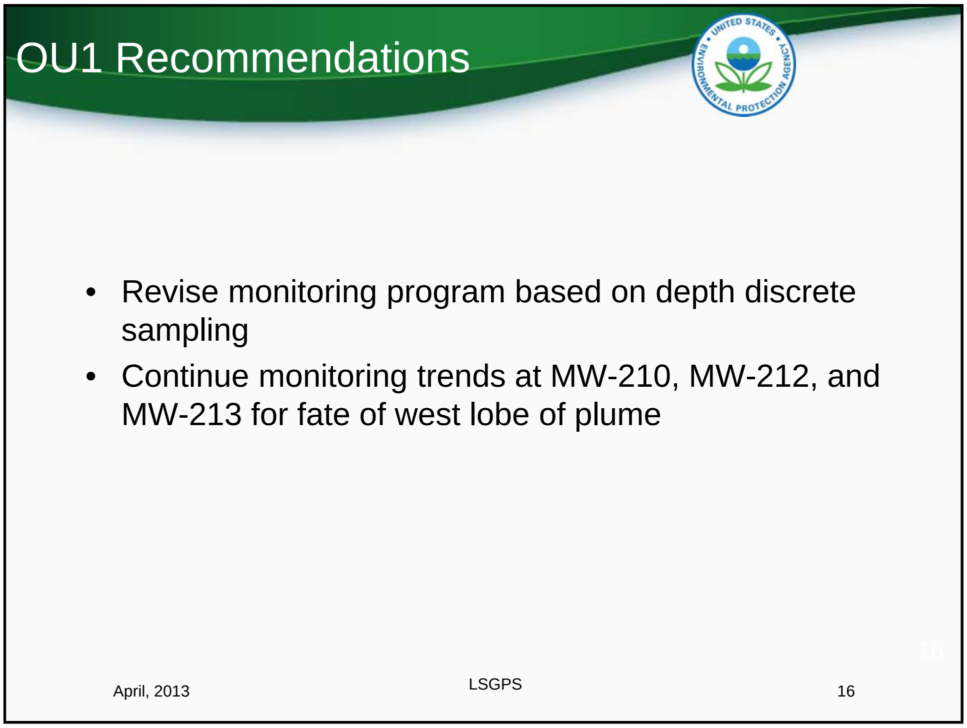
- Need to better understand vertical distribution of contamination in saturated zone
    - To fully delineate affected groundwater and soil
    - To optimize treatment
- How did contamination migrate vertically to top of bedrock?
    - Vertical infiltration or deeper 2nd source?
    - Former lines and drain field?

OU1 Uncertainties

- Groundwater long well screens – do not resolve areas of high contamination
- Why are concentrations still high in west lobe?
  - MW-203, MW-210, MW-212
  - Will west lobe plume migrate north?
- SVE or Excavation?

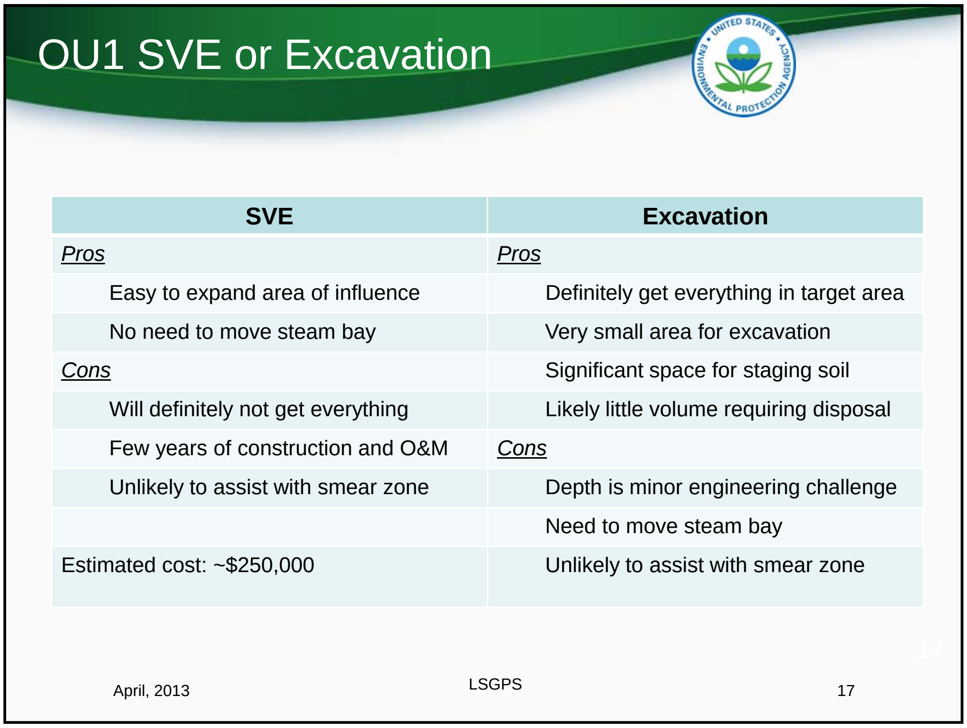
OU1 Recommendations

- Vertical contaminant resolution in source area, west lobe of plume, and northwest lobe of plume
  - Permeable Diffusion Bags at multiple intervals at key wells: MW-200, MW-201, MW-203 to MW-207, MW-210, MW-211, to MW-214
  - Hydraulic profiling of smear zone and saturated zone to better understand vertical variability in horizontal flow parameters
  - Based on above results, additional vertical saturated soil samples will be appropriate
  - Based on above results, wells with smaller screen intervals may be needed



OU1 Recommendations

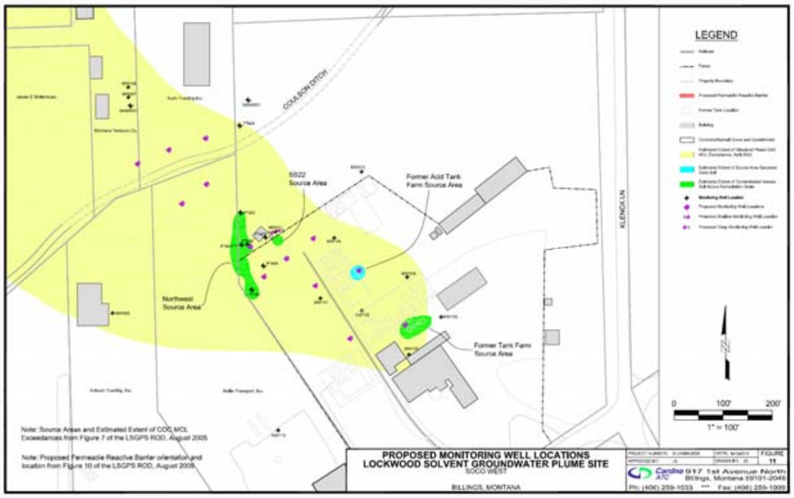
- Revise monitoring program based on depth discrete sampling
- Continue monitoring trends at MW-210, MW-212, and MW-213 for fate of west lobe of plume



OU1 SVE or Excavation

SVE	Excavation
Pros	*Pros*
Easy to expand area of influence	Definitely get everything in target area
No need to move steam bay	Very small area for excavation
Cons	Significant space for staging soil
Will definitely not get everything	Likely little volume requiring disposal
Few years of construction and O&M	*Cons*
Unlikely to assist with smear zone	Depth is minor engineering challenge
	Need to move steam bay
Estimated cost: ~$250,000	Unlikely to assist with smear zone

OU2 Soco West Source Area



OU2 Soco Area

- Historic chemical storage and distribution
- PCE source – plume extends to Yellowstone River
  - Source area more complex than OU1
- Anaerobic degradation products
  - Oxygen depleted aquifer – from co-contaminants or off-site petroleum site?
- Shallow fine-grained zone (15 ft bgs), deeper gravel aquifer to 30 ft. Both saturated.

OU2 Soco Area

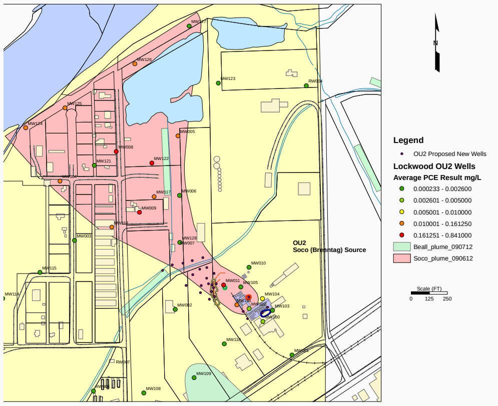
- Proposed Remedies
  - SVE, ozone sparging (piloted)
  - Excavation
  - Enhanced *in situ* bioremediation → MNA
  - Chemical oxidation
- Sequence of remedies

OU2 Source Uncertainties

- Source Areas
  - Tank Farm Source
  - Acid Tank Farm Source
  - Northwest Source
  - SB22
  - Other? BH-F?
- Vertical distribution
- Soil heterogeneity

OU2 Source Uncertainties

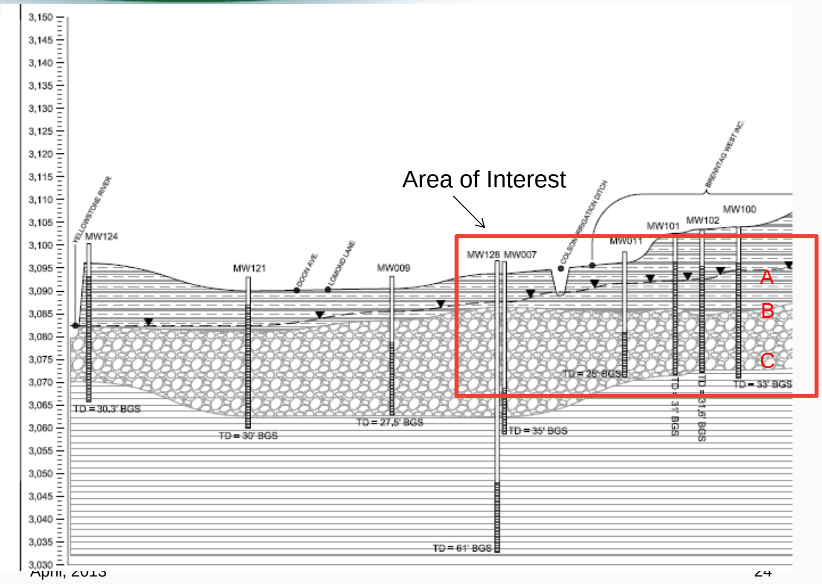
- Dissolved Plume
  - Vertical characterization
    - 20 ft well screens
  - Vapor Intrusion- residential buildings
  - Pumping wells to the west ceased- migration toward pond?
  - Sewer installation



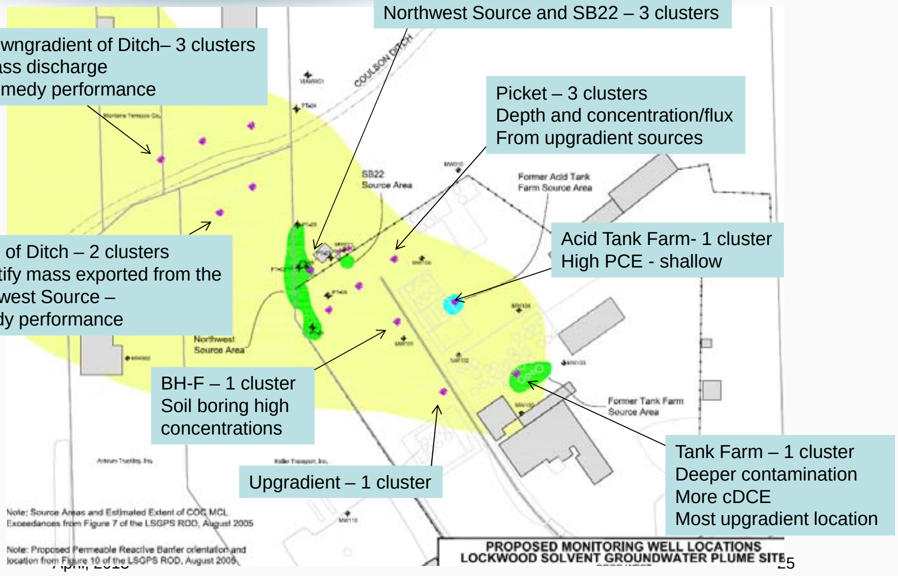
OU2 Recommendations

- New wells in source area
  - Rotosonic drilling for better cores
  - Clusters of wells with short screens at:
    - A-Depth – shallow, in most permeable part of silty zone
    - B-Depth – upper sand/gravel aquifer
    - C-Depth – near bottom of sand/gravel aquifer and bedrock

OU2 Recommendations



OU2 Recommendations



Northwest Source and SB22 – 3 clusters

Downgradient of Ditch– 3 clusters
Mass discharge
Remedy performance

Picket – 3 clusters
Depth and concentration/flux
From upgradient sources

South of Ditch – 2 clusters
Quantify mass exported from the
Northwest Source –
remedy performance

Acid Tank Farm- 1 cluster
High PCE - shallow

BH-F – 1 cluster
Soil boring high
concentrations

Upgradient – 1 cluster

Tank Farm – 1 cluster
Deeper contamination
More cDCE
Most upgradient location

OU2 Recommendations

- New wells in source area
  - Detailed cross-sections of source
  - Identify magnitude, identity (PCE or *cis*-DCE) and depth of contamination
  - Wells to be used for performance monitoring of remedy
- Monitor downgradient plume for stability
- Continue vapor profile for residences

OU2 Recommendations

- Follow up
  - MIP to delineate shallow sources – fine-grained zone
  - Data to guide excavation of shallow sources
- Future Remedy Components
  - Dependent on results of site characterization

Conclusions

- OU1
  - Vertical characterization of soil/groundwater
    - PDBs in long screens
    - Hydraulic profiling
    - Additional soil samples from saturated zone
  - Monitor west lobe for migration north/east
- OU2
  - Rotosonic drilling to produce improved cross-sections
  - Additional shallow well clusters in source area

Questions?

ATTACHMENT C
MONITORING AND REMEDIATION OPTIMIZATION SYSTEM REPORTS

DOJ (2011). Remedial Design/ Remedial Action Consent Decree. Case 1:22-cv-00088-RFC. E. E. S. U.S. Department of Justice. U.S. District Court, District of Montana, Billings, MT.

Attachment C
MAROS Software Reports

Individual Well Reports

Mann-Kendall Individual Well Trend Analysis
MK PCE Trend Well MW-006
MK PCE Trend Well MW-007
MK PCE Trend Well MW-009
MK PCE Trend Well MW-122
MK PCE Trend Well MW-126
MK PCE Trend Well PT-02
MK PCE Trend Well PT-06
MK cDCE Trend Well PT-05
MK cDCE Trend Well MW102
MK cDCE Trend Well MW117

Plume Level Analyses

Moment Summary
Zeroth Moment PCE
Zeroth Moment Vinyl Chloride
PCE Percent Mass by Well

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

Time Period: 9/22/1998 **to** 11/1/2012
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
MW002	T	27	24	0.33	-150	99.9%	No	D
MW003	T	27	26	1.09	-223	100.0%	No	D
MW004	S	28	28	0.68	-254	100.0%	No	D
MW005	S	28	28	1.19	-69	91.0%	No	PD
MW006	T	28	28	0.88	250	100.0%	No	I
MW007	T	28	28	0.48	-85	95.1%	No	D
MW008	T	27	27	0.46	-125	99.6%	No	D
MW009	T	28	28	0.38	-64	89.2%	No	S
MW010	T	28	24	0.48	91	96.3%	No	I
MW011	S	26	26	0.58	-119	99.6%	No	D
MW017	T	6	5	0.45	-7	86.4%	No	S
MW100	S	22	21	1.69	13	63.1%	No	NT
MW101	S	22	22	0.65	-7	56.6%	No	S
MW102	S	23	23	1.21	1	50.0%	No	NT
MW103	S	24	23	1.65	40	83.1%	No	NT
MW104	S	22	20	1.82	-155	100.0%	No	D
MW105	S	21	21	0.66	-26	77.2%	No	S
MW115	T	7	1	0.09	-2	55.7%	No	S
MW116	T	22	22	0.66	-90	99.5%	No	D
MW117	T	22	22	0.67	42	87.5%	No	NT
MW121	T	22	22	0.44	-58	94.6%	No	PD
MW122	T	22	22	0.44	33	81.4%	No	NT
MW123	T	22	2	2.17	-30	79.1%	No	NT
MW124	T	20	20	0.58	-65	98.2%	No	D
MW125	T	9	9	0.33	8	76.2%	No	NT
MW126	T	22	22	0.47	-63	96.0%	No	D

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

cis-1,2-DICHLOROETHYLENE

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
MW127	T	20	20	0.85	106	100.0%	No	I
MW128	T	22	2	0.85	-7	56.6%	No	S
PT-01	S	5	5	0.95	0	40.8%	No	S
PT-02	S	10	10	0.36	-11	81.0%	No	S
PT-03	S	8	8	0.37	2	54.8%	No	NT
PT-04	S	4	4	0.70	-6	95.8%	No	D
PT-05	S	7	7	0.67	-15	98.5%	No	D
PT-06	S	10	10	1.35	-19	94.6%	No	PD
PT-07	S	7	7	0.42	-11	93.2%	No	PD
MW002	T	27	0	0.00	0	49.2%	Yes	ND
MW003	T	27	26	0.50	-181	100.0%	No	D
MW004	S	28	28	0.44	-247	100.0%	No	D
MW005	S	28	27	0.84	-18	63.0%	No	S
MW006	T	28	25	1.39	251	100.0%	No	I
MW007	T	28	28	0.34	-69	91.0%	No	PD
MW008	T	27	27	0.34	-94	97.4%	No	D
MW009	T	28	28	0.41	-123	99.3%	No	D
MW010	T	28	27	0.29	97	97.2%	No	I
MW011	S	27	27	0.84	-41	79.6%	No	S
MW017	T	6	6	0.68	-6	81.5%	No	S
MW100	S	22	17	2.24	47	90.1%	No	PI
MW101	S	22	22	0.71	-19	69.2%	No	S
MW102	S	23	13	1.11	44	87.1%	No	NT
MW103	S	24	12	1.70	-7	55.9%	No	NT
MW104	S	22	4	1.31	-30	79.1%	No	NT
MW105	S	22	19	1.68	96	99.7%	No	I
MW115	T	7	1	0.03	-2	55.7%	No	S
MW116	T	22	22	0.65	-46	89.6%	No	S
MW117	T	22	22	0.81	139	100.0%	No	I
MW121	T	22	18	1.30	-141	100.0%	No	D
MW122	T	22	22	0.39	59	94.9%	No	PI
MW123	T	22	2	1.33	-32	80.7%	No	NT

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

TETRACHLOROETHYLENE(PCE)

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
MW124	T	20	20	0.47	-11	62.6%	No	S
MW125	T	9	9	0.63	-19	97.0%	No	D
MW126	T	22	22	0.83	-133	100.0%	No	D
MW127	T	20	15	0.74	-4	53.8%	No	S
MW128	T	22	1	0.78	-9	58.8%	No	S
PT-01	S	5	5	1.05	-8	95.8%	No	D
PT-02	S	10	10	1.63	-29	99.5%	No	D
PT-03	S	8	8	0.28	10	86.2%	No	NT
PT-04	S	4	4	1.41	-4	83.3%	No	NT
PT-05	S	7	7	0.99	-7	80.9%	No	S
PT-06	S	10	10	1.32	-31	99.8%	No	D
PT-07	S	7	7	0.89	-9	88.1%	No	S

MW002	T	27	26	0.38	-197	100.0%	No	D
MW003	T	27	27	0.17	-218	100.0%	No	D
MW004	S	28	28	0.32	-260	100.0%	No	D
MW005	S	28	28	0.80	-92	96.4%	No	D
MW006	T	28	20	0.92	233	100.0%	No	I
MW007	T	28	28	0.34	-43	79.5%	No	S
MW008	T	27	27	0.41	-185	100.0%	No	D
MW009	T	28	27	0.34	-126	99.4%	No	D
MW010	T	28	23	0.28	136	99.7%	No	I
MW011	S	27	27	0.78	-41	79.6%	No	S
MW017	T	6	6	0.55	-6	81.5%	No	S
MW100	S	22	21	0.57	134	100.0%	No	I
MW101	S	22	22	0.62	-8	57.7%	No	S
MW102	S	23	22	1.86	-11	60.3%	No	NT
MW103	S	24	20	1.42	-14	62.5%	No	NT
MW104	S	22	16	2.06	-83	99.0%	No	D
MW105	S	22	22	1.36	19	69.2%	No	NT
MW115	T	7	0	0.00	0	43.7%	Yes	ND
MW116	T	22	22	0.71	-178	100.0%	No	D
MW117	T	22	22	0.66	111	99.9%	No	I

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

TRICHLOROETHYLENE (TCE)

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
MW121	T	22	20	1.08	-157	100.0%	No	D
MW122	T	22	22	0.31	29	78.3%	No	NT
MW123	T	22	1	1.37	17	67.2%	No	NT
MW124	T	20	20	0.41	-61	97.5%	No	D
MW125	T	9	9	0.51	0	46.0%	No	S
MW126	T	22	22	0.48	-79	98.7%	No	D
MW127	T	20	17	0.71	44	91.8%	No	PI
MW128	T	22	2	1.26	-24	73.9%	No	NT
PT-01	S	5	5	0.58	-3	67.5%	No	S
PT-02	S	10	9	0.94	-23	97.7%	No	D
PT-03	S	8	8	0.43	6	72.6%	No	NT
PT-04	S	4	4	0.36	-4	83.3%	No	S
PT-05	S	7	7	1.06	-19	99.9%	No	D
PT-06	S	10	10	2.32	-35	100.0%	No	D
PT-07	S	7	7	0.89	-15	98.5%	No	D
MW002	T	27	0	0.05	-48	83.5%	Yes	ND
MW003	T	26	3	0.45	-68	93.0%	No	PD
MW004	S	28	8	1.07	-159	99.9%	No	D
MW005	S	28	18	2.50	-116	98.9%	No	D
MW006	T	28	16	1.46	95	96.9%	No	I
MW007	T	28	27	0.77	-113	98.7%	No	D
MW008	T	27	25	0.90	-153	99.9%	No	D
MW009	T	28	27	0.93	-170	100.0%	No	D
MW010	T	28	0	0.05	-52	84.2%	Yes	ND
MW011	S	27	27	1.11	-93	97.3%	No	D
MW017	T	6	0	0.00	0	42.3%	Yes	ND
MW100	S	22	14	1.82	-57	94.2%	No	PD
MW101	S	22	22	0.95	-21	71.1%	No	S
MW102	S	23	22	1.20	-5	54.2%	No	NT
MW103	S	24	13	1.91	19	67.1%	No	NT
MW104	S	22	14	1.60	-143	100.0%	No	D
MW105	S	22	22	1.01	-30	79.1%	No	NT

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

VINYL CHLORIDE

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
MW115	T	7	0	0.00	0	43.7%	Yes	ND
MW116	T	22	20	0.87	-82	99.0%	No	D
MW117	T	22	19	1.07	-13	63.1%	No	NT
MW121	T	22	5	0.95	-43	88.0%	No	S
MW122	T	22	22	0.76	-32	80.7%	No	S
MW123	T	22	0	1.38	-37	84.3%	Yes	ND
MW124	T	20	0	1.40	-17	69.6%	Yes	ND
MW125	T	9	2	1.25	6	69.4%	No	NT
MW126	T	22	22	0.65	-107	99.9%	No	D
MW127	T	20	19	0.67	85	99.8%	No	I
MW128	T	22	0	0.81	-37	84.3%	Yes	ND
PT-01	S	5	1	0.88	-8	95.8%	No	D
PT-02	S	10	9	0.84	15	89.2%	No	NT
PT-03	S	8	8	0.51	-8	80.1%	No	S
PT-04	S	4	3	0.87	-6	95.8%	No	D
PT-05	S	7	7	0.80	-7	80.9%	No	S
PT-06	S	10	4	2.89	-9	75.8%	No	NT
PT-07	S	7	7	0.64	-3	61.4%	No	S

MAROS Mann-Kendall Statistics Summary

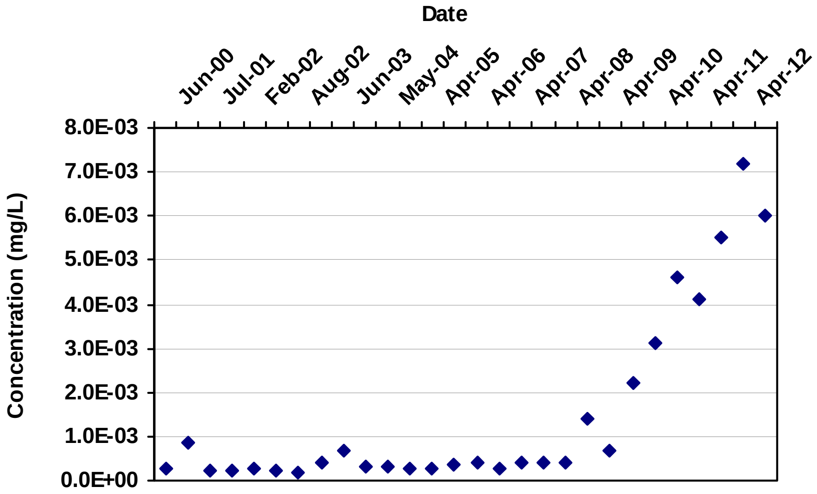
Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well:	MW006	**Time Period:**	9/22/1998 **to** 11/1/2012
Well Type:	T	**Consolidation Period:**	No Time Consolidation
COC:	TETRACHLOROETHYLENE(PCE)	**Duplicate Consolidation:**	Median
		Consolidation Type:	Average
		ND Values:	1/2 Detection Limit
		J Flag Values :	Actual Value



Mann Kendall S Statistic:

251

Confidence in Trend:

100.0%

Coefficient of Variation:

1.39

Mann Kendall Concentration Trend: (See Note)

I

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW006	T	6/2/2000	TETRACHLOROETHY	2.5E-04	ND	1	0
MW006	T	11/16/2000	TETRACHLOROETHY	8.8E-04		2	2
MW006	T	7/25/2001	TETRACHLOROETHY	2.1E-04		1	1
MW006	T	10/24/2001	TETRACHLOROETHY	2.3E-04		1	1
MW006	T	2/6/2002	TETRACHLOROETHY	2.5E-04	ND	1	0
MW006	T	5/1/2002	TETRACHLOROETHY	2.2E-04		1	1
MW006	T	8/16/2002	TETRACHLOROETHY	2.0E-04		1	1
MW006	T	10/31/2002	TETRACHLOROETHY	4.1E-04		1	1
MW006	T	6/13/2003	TETRACHLOROETHY	6.8E-04		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW006	T	11/12/2003	TETRACHLOROETHY	3.1E-04		2	2
MW006	T	5/26/2004	TETRACHLOROETHY	3.1E-04		1	1
MW006	T	10/15/2004	TETRACHLOROETHY	2.6E-04		1	1
MW006	T	4/28/2005	TETRACHLOROETHY	2.9E-04		1	1
MW006	T	10/27/2005	TETRACHLOROETHY	3.8E-04		1	1
MW006	T	4/6/2006	TETRACHLOROETHY	4.2E-04		1	1
MW006	T	10/27/2006	TETRACHLOROETHY	2.5E-04	ND	1	0
MW006	T	4/4/2007	TETRACHLOROETHY	3.9E-04		1	1
MW006	T	10/4/2007	TETRACHLOROETHY	4.0E-04		1	1
MW006	T	4/17/2008	TETRACHLOROETHY	4.2E-04		2	2
MW006	T	10/16/2008	TETRACHLOROETHY	1.4E-03		1	1
MW006	T	4/15/2009	TETRACHLOROETHY	6.8E-04		1	1
MW006	T	10/8/2009	TETRACHLOROETHY	2.2E-03		1	1
MW006	T	4/14/2010	TETRACHLOROETHY	3.1E-03		1	1
MW006	T	10/14/2010	TETRACHLOROETHY	4.6E-03		1	1
MW006	T	4/13/2011	TETRACHLOROETHY	4.1E-03		1	1
MW006	T	10/13/2011	TETRACHLOROETHY	5.5E-03		2	2
MW006	T	4/20/2012	TETRACHLOROETHY	7.2E-03		1	1
MW006	T	11/1/2012	TETRACHLOROETHY	6.0E-03		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well: MW007

Well Type: T

COC: TETRACHLOROETHYLENE(PCE)

Time Period: 9/22/1998 **to** 11/1/2012

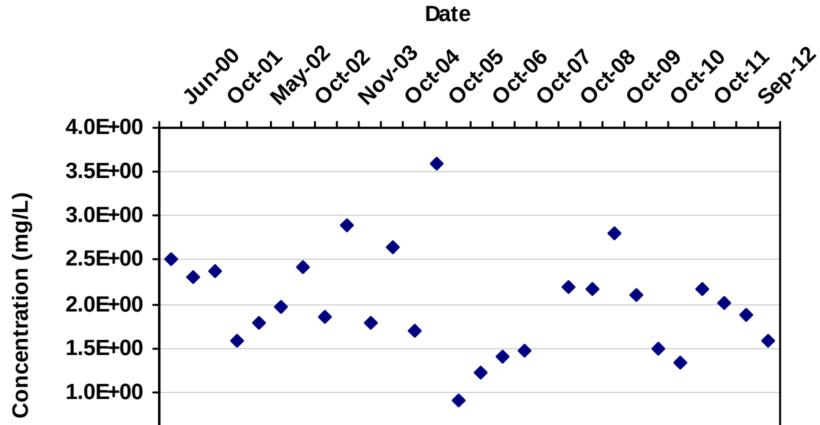
Consolidation Period: No Time Consolidation

Duplicate Consolidation: Median

Consolidation Type: Average

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value



Mann Kendall S Statistic:

-69

Confidence in Trend:

91.0%

Coefficient of Variation:

0.34

Mann Kendall Concentration Trend: (See Note)

PD

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW007	T	6/2/2000	TETRACHLOROETHY	2.5E+00		1	1
MW007	T	11/16/2000	TETRACHLOROETHY	2.3E+00		1	1
MW007	T	10/24/2001	TETRACHLOROETHY	2.4E+00		1	1
MW007	T	2/6/2002	TETRACHLOROETHY	1.6E+00		1	1
MW007	T	5/1/2002	TETRACHLOROETHY	1.8E+00		1	1
MW007	T	8/16/2002	TETRACHLOROETHY	2.0E+00		2	2
MW007	T	10/31/2002	TETRACHLOROETHY	2.4E+00		1	1
MW007	T	6/13/2003	TETRACHLOROETHY	1.9E+00		1	1
MW007	T	11/12/2003	TETRACHLOROETHY	2.9E+00		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW007	T	5/26/2004	TETRACHLOROETHY	1.8E+00		1	1
MW007	T	10/15/2004	TETRACHLOROETHY	2.6E+00		1	1
MW007	T	4/28/2005	TETRACHLOROETHY	1.7E+00		2	2
MW007	T	10/27/2005	TETRACHLOROETHY	3.6E+00		1	1
MW007	T	4/6/2006	TETRACHLOROETHY	9.0E-01		1	1
MW007	T	10/27/2006	TETRACHLOROETHY	1.2E+00		1	1
MW007	T	4/4/2007	TETRACHLOROETHY	1.4E+00		1	1
MW007	T	10/4/2007	TETRACHLOROETHY	1.5E+00		1	1
MW007	T	4/17/2008	TETRACHLOROETHY	2.1E-01		2	1
MW007	T	10/16/2008	TETRACHLOROETHY	2.2E+00		1	1
MW007	T	4/15/2009	TETRACHLOROETHY	2.2E+00		1	1
MW007	T	10/8/2009	TETRACHLOROETHY	2.8E+00		1	1
MW007	T	4/14/2010	TETRACHLOROETHY	2.1E+00		1	1
MW007	T	10/14/2010	TETRACHLOROETHY	1.5E+00		1	1
MW007	T	4/13/2011	TETRACHLOROETHY	1.3E+00		2	2
MW007	T	10/13/2011	TETRACHLOROETHY	2.2E+00		2	2
MW007	T	4/20/2012	TETRACHLOROETHY	2.0E+00		1	1
MW007	T	9/7/2012	TETRACHLOROETHY	1.9E+00		3	3
MW007	T	11/1/2012	TETRACHLOROETHY	1.6E+00		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well: MW009

Well Type: T

COC: TETRACHLOROETHYLENE(PCE)

Time Period: 9/22/1998 **to** 11/1/2012

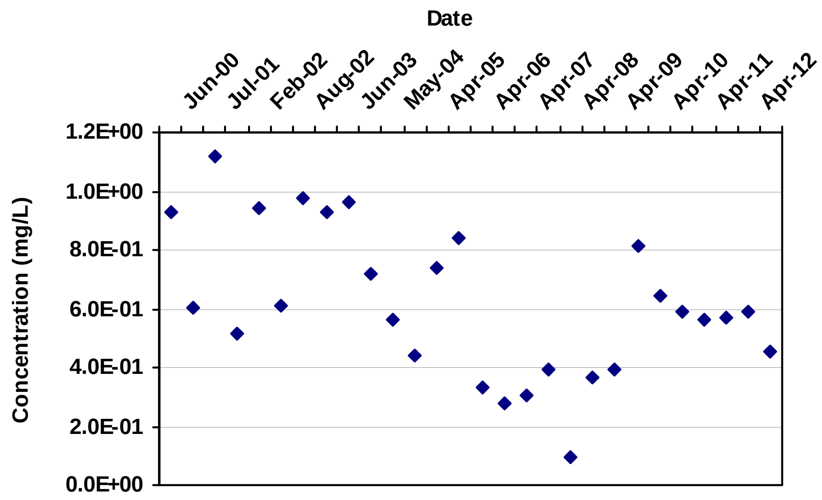
Consolidation Period: No Time Consolidation

Duplicate Consolidation: Median

Consolidation Type: Average

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value



Mann Kendall S Statistic:

-123

Confidence in Trend:

99.3%

Coefficient of Variation:

0.41

Mann Kendall Concentration Trend: (See Note)

D

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW009	T	6/2/2000	TETRACHLOROETHY	9.3E-01		1	1
MW009	T	11/16/2000	TETRACHLOROETHY	6.0E-01		1	1
MW009	T	7/25/2001	TETRACHLOROETHY	1.1E+00		1	1
MW009	T	10/24/2001	TETRACHLOROETHY	5.2E-01		1	1
MW009	T	2/6/2002	TETRACHLOROETHY	9.4E-01		1	1
MW009	T	5/1/2002	TETRACHLOROETHY	6.1E-01		1	1
MW009	T	8/16/2002	TETRACHLOROETHY	9.8E-01		1	1
MW009	T	10/31/2002	TETRACHLOROETHY	9.3E-01		1	1
MW009	T	6/13/2003	TETRACHLOROETHY	9.6E-01		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

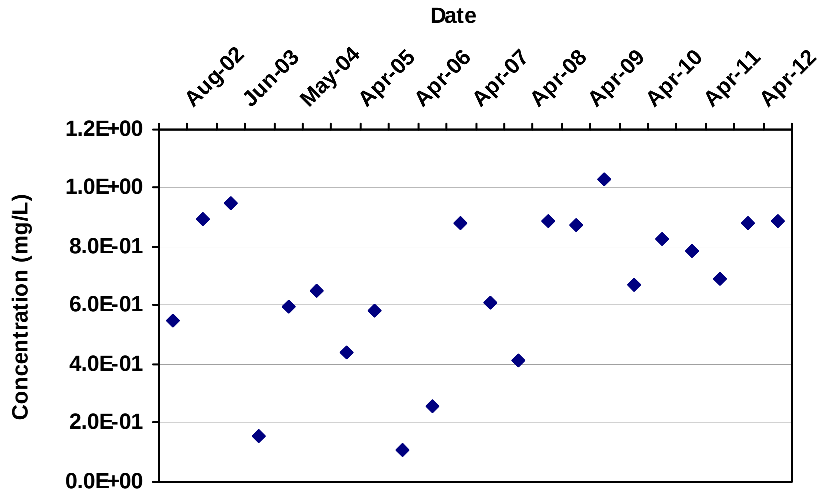
Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW009	T	11/12/2003	TETRACHLOROETHY	7.2E-01		1	1
MW009	T	5/26/2004	TETRACHLOROETHY	5.6E-01		1	1
MW009	T	10/15/2004	TETRACHLOROETHY	4.4E-01		1	1
MW009	T	4/28/2005	TETRACHLOROETHY	7.4E-01		2	2
MW009	T	10/27/2005	TETRACHLOROETHY	8.4E-01		1	1
MW009	T	4/6/2006	TETRACHLOROETHY	3.3E-01		1	1
MW009	T	10/27/2006	TETRACHLOROETHY	2.8E-01		1	1
MW009	T	4/4/2007	TETRACHLOROETHY	3.1E-01		1	1
MW009	T	10/4/2007	TETRACHLOROETHY	3.9E-01		1	1
MW009	T	4/17/2008	TETRACHLOROETHY	9.6E-02		1	1
MW009	T	10/16/2008	TETRACHLOROETHY	3.7E-01		1	1
MW009	T	4/15/2009	TETRACHLOROETHY	3.9E-01		1	1
MW009	T	10/8/2009	TETRACHLOROETHY	8.2E-01		1	1
MW009	T	4/14/2010	TETRACHLOROETHY	6.4E-01		2	2
MW009	T	10/14/2010	TETRACHLOROETHY	5.9E-01		1	1
MW009	T	4/13/2011	TETRACHLOROETHY	5.6E-01		1	1
MW009	T	10/13/2011	TETRACHLOROETHY	5.7E-01		1	1
MW009	T	4/20/2012	TETRACHLOROETHY	5.9E-01		2	2
MW009	T	11/1/2012	TETRACHLOROETHY	4.5E-01		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu   **User Name:** MV

Location: OU2   **State:** Montana

Well:	MW122	**Time Period:**	9/22/1998 **to** 11/1/2012
Well Type:	T	**Consolidation Period:**	No Time Consolidation
COC:	TETRACHLOROETHYLENE(PCE)	**Duplicate Consolidation:**	Median
		Consolidation Type:	Average
		ND Values:	1/2 Detection Limit
		J Flag Values :	Actual Value



Mann Kendall S Statistic:

59

Confidence in Trend:

94.9%

Coefficient of Variation:

0.39

Mann Kendall Concentration Trend: (See Note)

PI

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW122	T	8/16/2002	TETRACHLOROETHY	5.5E-01		1	1
MW122	T	10/31/2002	TETRACHLOROETHY	9.0E-01		1	1
MW122	T	6/13/2003	TETRACHLOROETHY	9.5E-01		1	1
MW122	T	11/12/2003	TETRACHLOROETHY	1.6E-01		1	1
MW122	T	5/26/2004	TETRACHLOROETHY	6.0E-01		1	1
MW122	T	10/15/2004	TETRACHLOROETHY	6.5E-01		1	1
MW122	T	4/28/2005	TETRACHLOROETHY	4.4E-01		1	1
MW122	T	10/27/2005	TETRACHLOROETHY	5.8E-01		1	1
MW122	T	4/6/2006	TETRACHLOROETHY	1.1E-01		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW122	T	10/27/2006	TETRACHLOROETHY	2.6E-01		1	1
MW122	T	4/4/2007	TETRACHLOROETHY	8.8E-01		1	1
MW122	T	10/4/2007	TETRACHLOROETHY	6.1E-01		1	1
MW122	T	4/17/2008	TETRACHLOROETHY	4.1E-01		1	1
MW122	T	10/16/2008	TETRACHLOROETHY	8.9E-01		1	1
MW122	T	4/15/2009	TETRACHLOROETHY	8.7E-01		1	1
MW122	T	10/8/2009	TETRACHLOROETHY	1.0E+00		1	1
MW122	T	4/14/2010	TETRACHLOROETHY	6.7E-01		2	2
MW122	T	10/14/2010	TETRACHLOROETHY	8.3E-01		1	1
MW122	T	4/13/2011	TETRACHLOROETHY	7.8E-01		1	1
MW122	T	10/13/2011	TETRACHLOROETHY	6.9E-01		2	2
MW122	T	4/20/2012	TETRACHLOROETHY	8.8E-01		1	1
MW122	T	11/1/2012	TETRACHLOROETHY	8.9E-01		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well: MW126

Well Type: T

COC: TETRACHLOROETHYLENE(PCE)

Time Period: 9/22/1998 **to** 11/1/2012

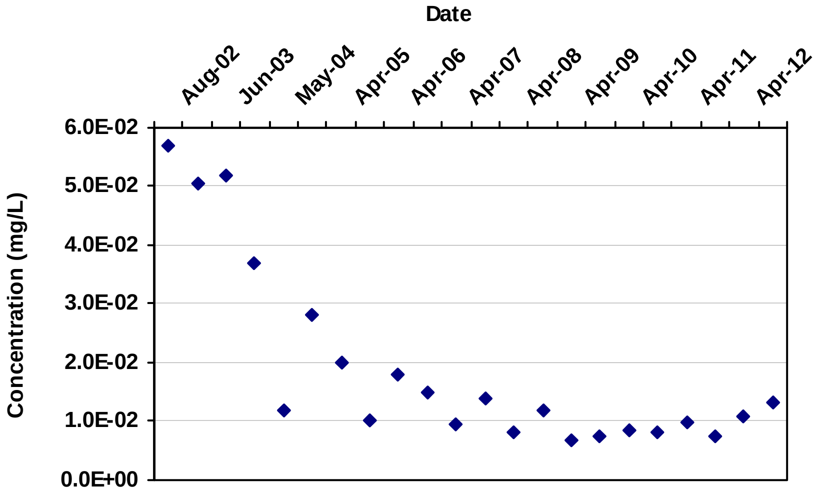
Consolidation Period: No Time Consolidation

Duplicate Consolidation: Median

Consolidation Type: Average

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value



Mann Kendall S Statistic:

-133

Confidence in Trend:

100.0%

Coefficient of Variation:

0.83

Mann Kendall Concentration Trend: (See Note)

D

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW126	T	8/16/2002	TETRACHLOROETHY	5.7E-02		1	1
MW126	T	10/31/2002	TETRACHLOROETHY	5.1E-02		2	2
MW126	T	6/13/2003	TETRACHLOROETHY	5.2E-02		1	1
MW126	T	11/12/2003	TETRACHLOROETHY	3.7E-02		1	1
MW126	T	5/26/2004	TETRACHLOROETHY	1.2E-02		1	1
MW126	T	10/15/2004	TETRACHLOROETHY	2.8E-02		1	1
MW126	T	4/28/2005	TETRACHLOROETHY	2.0E-02		1	1
MW126	T	10/27/2005	TETRACHLOROETHY	1.0E-02		1	1
MW126	T	4/6/2006	TETRACHLOROETHY	1.8E-02		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu
User Name: MV

Location: OU2
State: Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW126	T	10/27/2006	TETRACHLOROETHY	1.5E-02		1	1
MW126	T	4/4/2007	TETRACHLOROETHY	9.4E-03		2	2
MW126	T	10/4/2007	TETRACHLOROETHY	1.4E-02		1	1
MW126	T	4/17/2008	TETRACHLOROETHY	8.1E-03		2	1
MW126	T	10/16/2008	TETRACHLOROETHY	1.2E-02		1	1
MW126	T	4/15/2009	TETRACHLOROETHY	6.9E-03		1	1
MW126	T	10/8/2009	TETRACHLOROETHY	7.3E-03		1	1
MW126	T	4/14/2010	TETRACHLOROETHY	8.4E-03		1	1
MW126	T	10/14/2010	TETRACHLOROETHY	8.2E-03		1	1
MW126	T	4/13/2011	TETRACHLOROETHY	9.8E-03		1	1
MW126	T	10/13/2011	TETRACHLOROETHY	7.3E-03		1	1
MW126	T	4/20/2012	TETRACHLOROETHY	1.1E-02		1	1
MW126	T	11/1/2012	TETRACHLOROETHY	1.3E-02		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well: PT-02

Well Type: S

COC: TETRACHLOROETHYLENE(PCE)

Time Period: 9/22/1998 **to** 11/1/2012

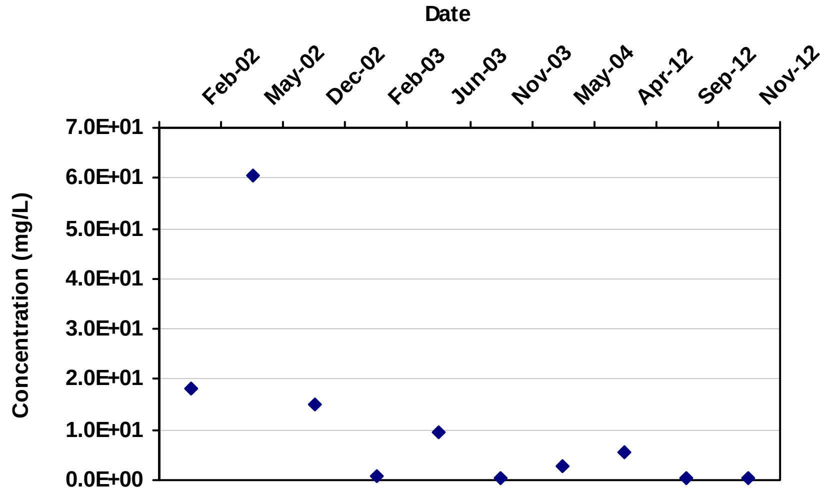
Consolidation Period: No Time Consolidation

Duplicate Consolidation: Median

Consolidation Type: Average

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value



Mann Kendall S Statistic:

-29

Confidence in Trend:

99.5%

Coefficient of Variation:

1.63

Mann Kendall Concentration Trend: (See Note)

D

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
PT-02	S	2/6/2002	TETRACHLOROETHY	1.8E+01		1	1
PT-02	S	5/1/2002	TETRACHLOROETHY	6.1E+01		2	2
PT-02	S	12/20/2002	TETRACHLOROETHY	1.5E+01		1	1
PT-02	S	2/26/2003	TETRACHLOROETHY	7.7E-01		5	5
PT-02	S	6/13/2003	TETRACHLOROETHY	9.3E+00		2	2
PT-02	S	11/12/2003	TETRACHLOROETHY	4.6E-01		2	2
PT-02	S	5/26/2004	TETRACHLOROETHY	2.8E+00		1	1
PT-02	S	4/20/2012	TETRACHLOROETHY	5.4E+00		1	1
PT-02	S	9/7/2012	TETRACHLOROETHY	4.8E-01		3	3

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

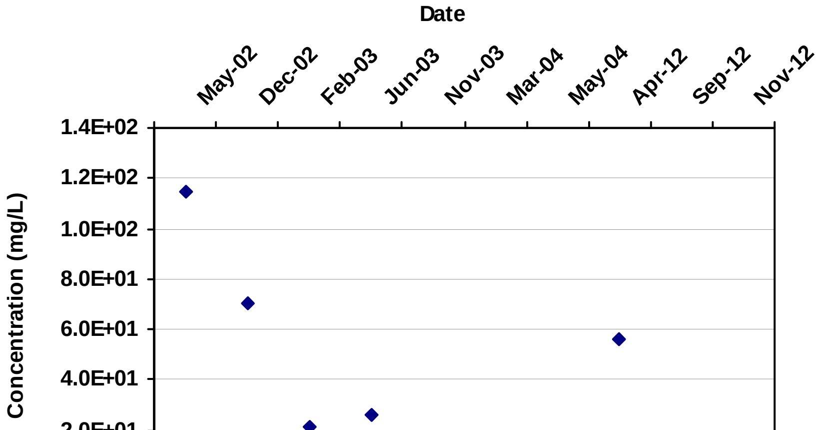
Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
PT-02	S	11/1/2012	TETRACHLOROETHY	3.6E-01		2	2

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

Well:	PT-06	**Time Period:**	9/22/1998 **to** 11/1/2012
Well Type:	S	**Consolidation Period:**	No Time Consolidation
COC:	TETRACHLOROETHYLENE(PCE)	**Duplicate Consolidation:**	Median
		Consolidation Type:	Average
		ND Values:	1/2 Detection Limit
		J Flag Values :	Actual Value



Mann Kendall S Statistic:

-31

Confidence in Trend:

99.8%

Coefficient of Variation:

1.32

Mann Kendall Concentration Trend: (See Note)

D

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
PT-06	S	5/1/2002	TETRACHLOROETHY	1.2E+02		2	2
PT-06	S	12/20/2002	TETRACHLOROETHY	7.0E+01		1	1
PT-06	S	2/26/2003	TETRACHLOROETHY	2.1E+01		4	4
PT-06	S	6/13/2003	TETRACHLOROETHY	2.6E+01		3	3
PT-06	S	11/12/2003	TETRACHLOROETHY	3.3E+00		2	2
PT-06	S	3/1/2004	TETRACHLOROETHY	1.3E+00		1	1
PT-06	S	5/26/2004	TETRACHLOROETHY	1.3E+00		1	1
PT-06	S	4/20/2012	TETRACHLOROETHY	5.6E+01		1	1
PT-06	S	9/7/2012	TETRACHLOROETHY	4.5E-01		6	6

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
PT-06	S	11/1/2012	TETRACHLOROETHY	9.7E-02		1	1

MAROS Mann-Kendall Statistics Summary

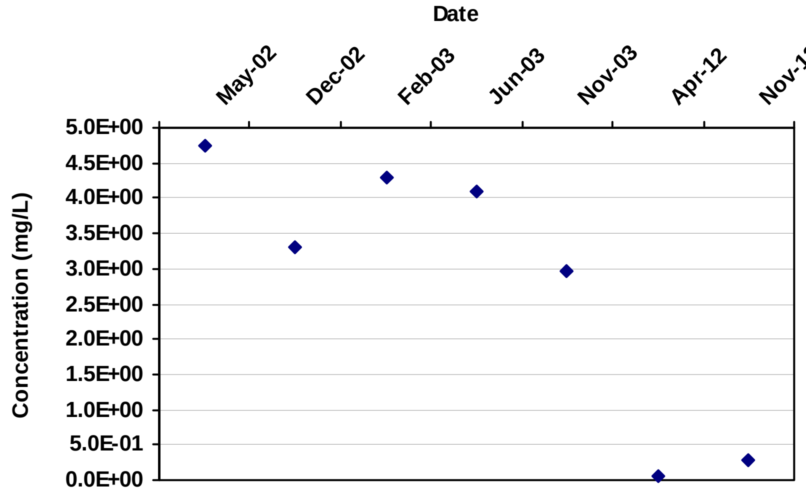
Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well:	PT-05	**Time Period:**	9/22/1998 **to** 11/1/2012
Well Type:	S	**Consolidation Period:**	No Time Consolidation
COC:	cis-1,2-DICHLOROETHYLENE	**Duplicate Consolidation:**	Median
		Consolidation Type:	Average
		ND Values:	1/2 Detection Limit
		J Flag Values :	Actual Value



Mann Kendall S Statistic:

-15

Confidence in Trend:

98.5%

Coefficient of Variation:

0.67

Mann Kendall Concentration Trend: (See Note)

D

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
PT-05	S	5/1/2002	cis-1,2-DICHLOROET	4.8E+00		2	2
PT-05	S	12/20/2002	cis-1,2-DICHLOROET	3.3E+00		1	1
PT-05	S	2/26/2003	cis-1,2-DICHLOROET	4.3E+00		4	4
PT-05	S	6/13/2003	cis-1,2-DICHLOROET	4.1E+00		3	3
PT-05	S	11/12/2003	cis-1,2-DICHLOROET	3.0E+00		2	2
PT-05	S	4/20/2012	cis-1,2-DICHLOROET	6.7E-02		1	1
PT-05	S	11/1/2012	cis-1,2-DICHLOROET	2.9E-01		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects

MAROS Mann-Kendall Statistics Summary

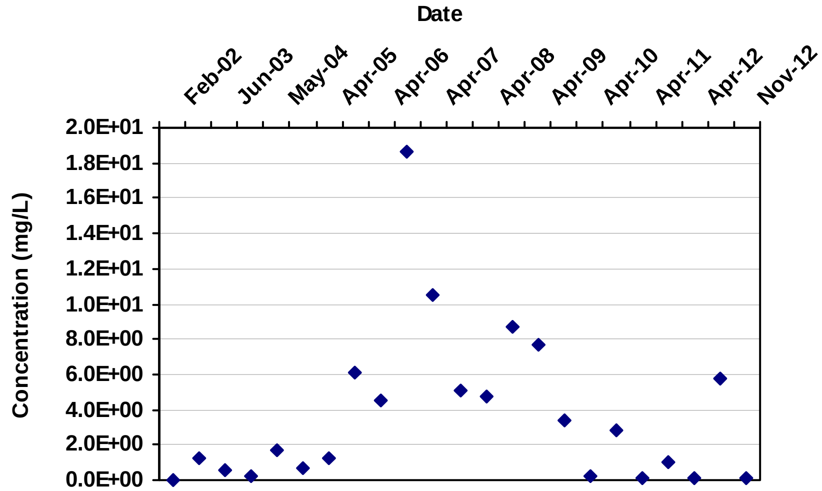
Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well:	MW102	**Time Period:**	9/22/1998 **to** 11/1/2012
Well Type:	S	**Consolidation Period:**	No Time Consolidation
COC:	cis-1,2-DICHLOROETHYLENE	**Duplicate Consolidation:**	Median
		Consolidation Type:	Average
		ND Values:	1/2 Detection Limit
		J Flag Values :	Actual Value



Mann Kendall S Statistic:

1

Confidence in Trend:

50.0%

Coefficient of Variation:

1.21

Mann Kendall Concentration Trend: (See Note)

NT

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW102	S	2/6/2002	cis-1,2-DICHLOROET	2.4E-02		1	1
MW102	S	8/16/2002	cis-1,2-DICHLOROET	1.3E+00		1	1
MW102	S	6/13/2003	cis-1,2-DICHLOROET	5.1E-01		1	1
MW102	S	11/12/2003	cis-1,2-DICHLOROET	2.2E-01		1	1
MW102	S	5/26/2004	cis-1,2-DICHLOROET	1.7E+00		1	1
MW102	S	10/15/2004	cis-1,2-DICHLOROET	6.4E-01		1	1
MW102	S	4/28/2005	cis-1,2-DICHLOROET	1.2E+00		1	1
MW102	S	10/27/2005	cis-1,2-DICHLOROET	6.1E+00		1	1
MW102	S	4/6/2006	cis-1,2-DICHLOROET	4.5E+00		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW102	S	10/27/2006	cis-1,2-DICHLOROET	1.9E+01		1	1
MW102	S	4/4/2007	cis-1,2-DICHLOROET	1.1E+01		1	1
MW102	S	10/4/2007	cis-1,2-DICHLOROET	5.1E+00		1	1
MW102	S	4/17/2008	cis-1,2-DICHLOROET	4.8E+00		1	1
MW102	S	10/16/2008	cis-1,2-DICHLOROET	8.7E+00		1	1
MW102	S	4/15/2009	cis-1,2-DICHLOROET	7.7E+00		1	1
MW102	S	10/8/2009	cis-1,2-DICHLOROET	3.4E+00		1	1
MW102	S	4/14/2010	cis-1,2-DICHLOROET	2.5E-01		1	1
MW102	S	10/14/2010	cis-1,2-DICHLOROET	2.8E+00		1	1
MW102	S	4/13/2011	cis-1,2-DICHLOROET	1.1E-01		1	1
MW102	S	10/13/2011	cis-1,2-DICHLOROET	9.8E-01		1	1
MW102	S	4/20/2012	cis-1,2-DICHLOROET	1.4E-01		1	1
MW102	S	9/7/2012	cis-1,2-DICHLOROET	5.8E+00		7	7
MW102	S	11/1/2012	cis-1,2-DICHLOROET	1.1E-01		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well: MW117

Well Type: T

COC: cis-1,2-DICHLOROETHYLENE

Time Period: 1/1/2000 **to** 11/1/2012

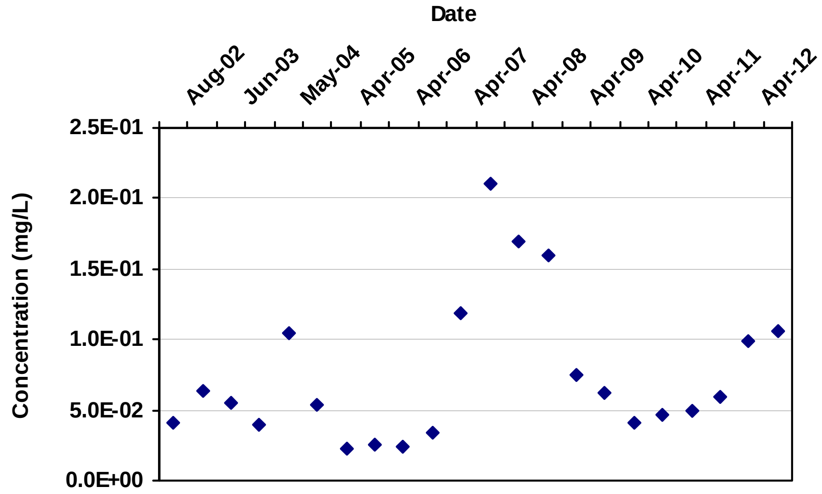
Consolidation Period: No Time Consolidation

Duplicate Consolidation: Median

Consolidation Type: Average

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value



Mann Kendall S Statistic:

42

Confidence in Trend:

87.5%

Coefficient of Variation:

0.67

Mann Kendall Concentration Trend: (See Note)

NT

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW117	T	8/16/2002	cis-1,2-DICHLOROET	4.1E-02		1	1
MW117	T	10/31/2002	cis-1,2-DICHLOROET	6.3E-02		1	1
MW117	T	6/13/2003	cis-1,2-DICHLOROET	5.5E-02		1	1
MW117	T	11/12/2003	cis-1,2-DICHLOROET	4.0E-02		1	1
MW117	T	5/26/2004	cis-1,2-DICHLOROET	1.0E-01		1	1
MW117	T	10/15/2004	cis-1,2-DICHLOROET	5.4E-02		1	1
MW117	T	4/28/2005	cis-1,2-DICHLOROET	2.2E-02		1	1
MW117	T	10/27/2005	cis-1,2-DICHLOROET	2.6E-02		1	1
MW117	T	4/6/2006	cis-1,2-DICHLOROET	2.4E-02		1	1

MAROS Mann-Kendall Statistics Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW117	T	10/27/2006	cis-1,2-DICHLOROET	3.4E-02		1	1
MW117	T	4/4/2007	cis-1,2-DICHLOROET	1.2E-01		1	1
MW117	T	10/4/2007	cis-1,2-DICHLOROET	2.1E-01		1	1
MW117	T	4/17/2008	cis-1,2-DICHLOROET	1.7E-01		1	1
MW117	T	10/16/2008	cis-1,2-DICHLOROET	1.6E-01		1	1
MW117	T	4/15/2009	cis-1,2-DICHLOROET	7.5E-02		1	1
MW117	T	10/8/2009	cis-1,2-DICHLOROET	6.2E-02		1	1
MW117	T	4/14/2010	cis-1,2-DICHLOROET	4.1E-02		1	1
MW117	T	10/14/2010	cis-1,2-DICHLOROET	4.6E-02		1	1
MW117	T	4/13/2011	cis-1,2-DICHLOROET	5.0E-02		1	1
MW117	T	10/13/2011	cis-1,2-DICHLOROET	6.0E-02		3	3
MW117	T	4/20/2012	cis-1,2-DICHLOROET	9.9E-02		1	1
MW117	T	11/1/2012	cis-1,2-DICHLOROET	1.1E-01		1	1

MAROS Spatial Moment Analysis Summary

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

	0th Moment	1st Moment (Center of Mass)			2nd Moment (Spread)		
Effective Date	Estimated Mass (Kg)	Xc (ft)	Yc (ft)	Source Distance	Sigma XX (sq ft)	Sigma YY (sq ft)	Number of Wells
7/1/2000	4.4E-01	681,191	173,460	305	6,050	5,985	10
7/1/2001	5.8E-01	681,196	173,452	296	6,282	6,015	11
7/1/2002	1.6E+00	681,243	173,455	264	11,497	19,214	34
7/1/2003	1.6E+00	681,229	173,467	282	11,842	19,690	32
7/1/2004	1.2E+00	681,226	173,474	288	11,892	18,367	32
7/1/2005	9.5E-01	681,224	173,469	287	12,825	18,992	27
7/1/2006	9.1E-01	681,255	173,452	252	16,834	22,772	26
7/1/2007	9.2E-01	681,241	173,474	279	11,832	19,667	25
7/1/2008	7.7E-01	681,245	173,463	268	11,218	18,803	25
7/1/2009	9.9E-01	681,234	173,462	274	11,167	17,522	25
7/1/2010	9.6E-01	681,224	173,475	291	10,878	17,454	25
7/1/2011	9.5E-01	681,230	173,471	283	9,943	17,357	25
7/1/2012	9.8E-01	681,212	173,511	326	7,617	15,907	32
7/1/2000	7.6E-01	681,181	173,467	316	5,394	5,000	10
7/1/2001	8.2E-01	681,187	173,454	304	6,378	5,440	11
7/1/2002	1.8E+00	681,213	173,482	304	7,293	16,312	34
7/1/2003	1.4E+00	681,196	173,504	331	5,444	14,620	32
7/1/2004	1.0E+00	681,205	173,489	314	5,026	13,200	32
7/1/2005	9.6E-01	681,197	173,492	321	4,424	11,275	27
7/1/2006	6.7E-01	681,195	173,510	337	5,667	13,675	26
7/1/2007	8.5E-01	681,210	173,502	320	5,130	12,963	25
7/1/2008	8.0E-01	681,210	173,501	319	5,362	12,466	25
7/1/2009	9.4E-01	681,212	173,492	312	4,017	10,323	25
7/1/2010	9.8E-01	681,206	173,499	321	3,844	10,696	25
7/1/2011	1.1E+00	681,212	173,494	313	3,933	10,687	25
7/1/2012	1.3E+00	681,211	173,505	322	3,623	11,656	32
7/1/2000	1.8E-01	681,183	173,449	304	5,444	6,194	10
7/1/2001	2.8E-01	681,207	173,423	269	6,439	6,598	11
7/1/2002	5.1E-01	681,203	173,471	303	7,367	15,891	34
7/1/2003	5.1E-01	681,198	173,476	310	7,034	16,752	32

MAROS Spatial Moment Analysis Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

	0th Moment	1st Moment (Center of Mass)			2nd Moment (Spread)		
Effective Date	Estimated Mass (Kg)	Xc (ft)	Yc (ft)	Source Distance	Sigma XX (sq ft)	Sigma YY (sq ft)	Number of Wells
TRICHLOROETHYLENE (TCE)							
7/1/2004	4.1E-01	681,192	173,487	322	6,938	15,862	32
7/1/2005	3.6E-01	681,199	173,471	306	8,238	15,644	27
7/1/2006	2.7E-01	681,201	173,481	311	8,536	16,497	26
7/1/2007	3.2E-01	681,224	173,465	284	7,661	17,134	25
7/1/2008	2.7E-01	681,220	173,464	286	7,951	16,331	25
7/1/2009	2.4E-01	681,216	173,468	291	6,673	15,472	25
7/1/2010	2.6E-01	681,217	173,470	293	7,196	17,031	25
7/1/2011	2.3E-01	681,230	173,468	282	8,625	18,313	25
7/1/2012	2.7E-01	681,214	173,493	311	5,910	17,096	32
7/1/2000	7.4E-02	681,237	173,427	248	6,388	7,095	10
7/1/2001	1.1E-01	681,233	173,424	249	7,303	6,769	11
7/1/2002	1.6E-01	681,258	173,443	244	8,886	17,330	34
7/1/2003	1.1E-01	681,277	173,425	218	11,847	20,165	32
7/1/2004	8.9E-02	681,312	173,394	172	13,114	20,294	32
7/1/2005	6.4E-02	681,287	173,408	199	13,110	20,716	27
7/1/2006	6.9E-02	681,315	173,384	163	11,492	17,091	26
7/1/2007	1.1E-01	681,310	173,405	182	10,804	20,005	25
7/1/2008	8.4E-02	681,283	173,429	217	9,372	18,759	25
7/1/2009	9.8E-02	681,284	173,403	198	10,328	16,619	25
7/1/2010	8.2E-02	681,289	173,420	207	12,461	23,799	25
7/1/2011	9.5E-02	681,299	173,395	181	9,094	17,723	25
7/1/2012	5.2E-02	681,278	173,439	228	8,544	20,480	32

MAROS Spatial Moment Analysis Summary

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana

Moment Type	Constituent	Coefficient of Variation	Mann-Kendall S Statistic	Confidence in Trend	Moment Trend
0th Moment	cis-1,2-DICHLOROETHYLENE	0.35	6	61.7%	NT
0th Moment	TETRACHLOROETHYLENE(P	0.29	12	74.5%	NT
0th Moment	TRICHLOROETHYLENE (TCE)	0.33	-30	96.2%	D
0th Moment	VINYL CHLORIDE	0.30	-18	84.7%	S
First Moment	cis-1,2-DICHLOROETHYLENE	0.07	-2	52.4%	S
First Moment	TETRACHLOROETHYLENE(P	0.03	12	74.5%	NT
First Moment	TRICHLOROETHYLENE (TCE)	0.05	-4	57.1%	S
First Moment	VINYL CHLORIDE	0.14	-24	91.8%	PD
Second Moment X	cis-1,2-DICHLOROETHYLENE	0.27	-10	70.5%	S
Second Moment X	TETRACHLOROETHYLENE(P	0.21	-50	99.9%	D
Second Moment X	TRICHLOROETHYLENE (TCE)	0.13	18	84.7%	NT
Second Moment X	VINYL CHLORIDE	0.21	2	52.4%	NT
Second Moment Y	cis-1,2-DICHLOROETHYLENE	0.30	-12	74.5%	S
Second Moment Y	TETRACHLOROETHYLENE(P	0.28	-12	74.5%	S
Second Moment Y	TRICHLOROETHYLENE (TCE)	0.26	40	99.3%	I
Second Moment Y	VINYL CHLORIDE	0.29	24	91.8%	PI

Note: The Sigma XX and Sigma YY components are estimated using the given field coordinate system and then rotated to align with the estimated groundwater flow direction. Moments are not calculated for sample events with less than 6 wells.

MAROS Zeroth Moment Analysis

Project: Lockwood Groundwater Solvent Plu

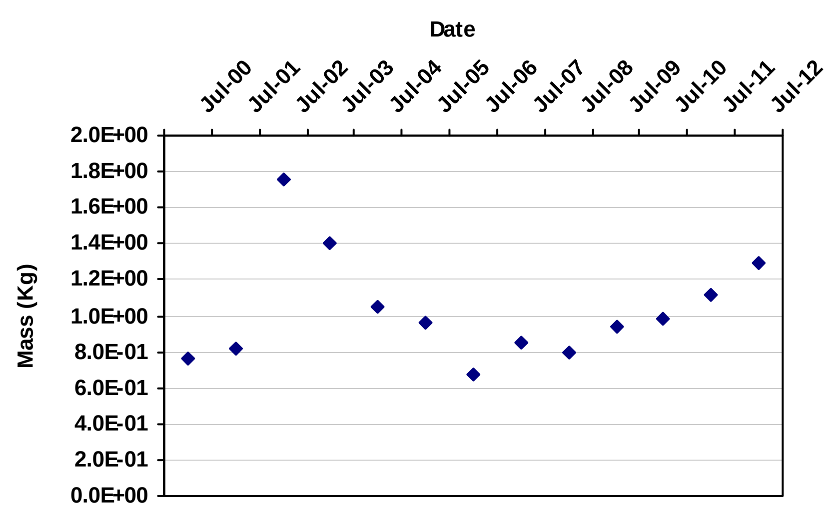
User Name: MV

Location: OU2

State: Montana

Change in Dissolved Mass Over Time

COC: TETRACHLOROETHYLENE(PCE)



Porosity: 0.25

Saturated Thickness:

Uniform: 20 ft

Mann-Kendall S Statistic:

12

Confidence in Trend:

74.5%

Coefficient of Variation:

0.29

Zeroth Moment Trend:

NT

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	TETRACHLOROETHYLENE(PCE)	7.6E-01	10
7/1/2001	TETRACHLOROETHYLENE(PCE)	8.2E-01	11
7/1/2002	TETRACHLOROETHYLENE(PCE)	1.8E+00	34
7/1/2003	TETRACHLOROETHYLENE(PCE)	1.4E+00	32
7/1/2004	TETRACHLOROETHYLENE(PCE)	1.0E+00	32
7/1/2005	TETRACHLOROETHYLENE(PCE)	9.6E-01	27
7/1/2006	TETRACHLOROETHYLENE(PCE)	6.7E-01	26
7/1/2007	TETRACHLOROETHYLENE(PCE)	8.5E-01	25
7/1/2008	TETRACHLOROETHYLENE(PCE)	8.0E-01	25
7/1/2009	TETRACHLOROETHYLENE(PCE)	9.4E-01	25
7/1/2010	TETRACHLOROETHYLENE(PCE)	9.8E-01	25
7/1/2011	TETRACHLOROETHYLENE(PCE)	1.1E+00	25
7/1/2012	TETRACHLOROETHYLENE(PCE)	1.3E+00	32

MAROS Zeroth Moment Analysis

Project: Lockwood Groundwater Solvent Plu

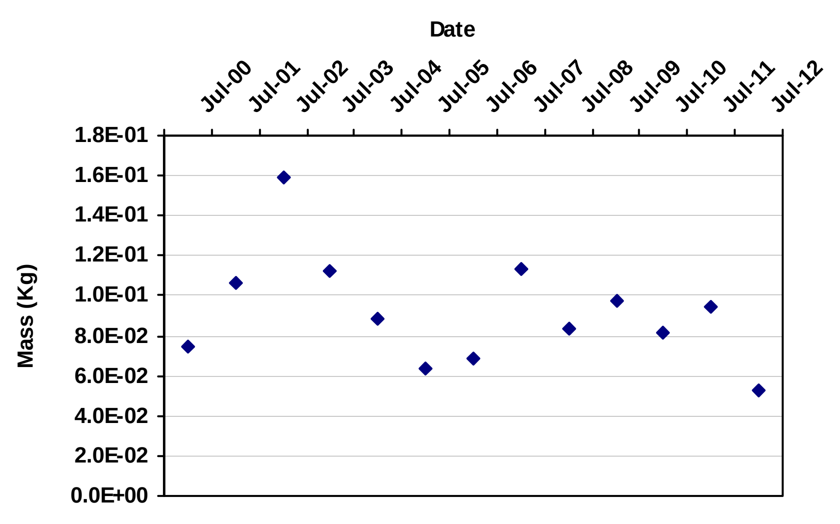
User Name: MV

Location: OU2

State: Montana

Change in Dissolved Mass Over Time

COC: VINYL CHLORIDE



Porosity: 0.25

Saturated Thickness:

Uniform: 20 ft

Mann-Kendall S Statistic:

-18

Confidence in Trend:

84.7%

Coefficient of Variation:

0.30

Zeroth Moment Trend:

S

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	VINYL CHLORIDE	7.4E-02	10
7/1/2001	VINYL CHLORIDE	1.1E-01	11
7/1/2002	VINYL CHLORIDE	1.6E-01	34
7/1/2003	VINYL CHLORIDE	1.1E-01	32
7/1/2004	VINYL CHLORIDE	8.9E-02	32
7/1/2005	VINYL CHLORIDE	6.4E-02	27
7/1/2006	VINYL CHLORIDE	6.9E-02	26
7/1/2007	VINYL CHLORIDE	1.1E-01	25
7/1/2008	VINYL CHLORIDE	8.4E-02	25
7/1/2009	VINYL CHLORIDE	9.8E-02	25
7/1/2010	VINYL CHLORIDE	8.2E-02	25
7/1/2011	VINYL CHLORIDE	9.5E-02	25
7/1/2012	VINYL CHLORIDE	5.2E-02	32

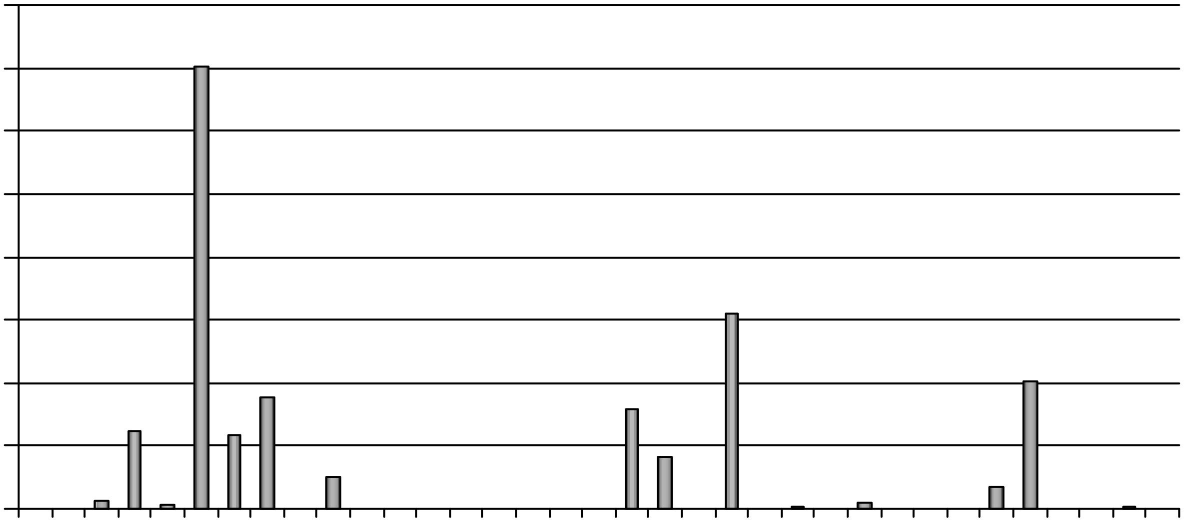
MAROS Percent of Mass by Well

Project: Lockwood Groundwater Solvent Plu

User Name: MV

Location: OU2

State: Montana



MW002	5,645.55	0.25	0.00	2.69
MW003	11,391.98	3.89	0.06	5.43
MW004	12,075.99	42.74	0.62	5.75
MW005	19,665.29	430.69	6.20	9.37
MW006	15,763.45	18.21	0.26	7.51
MW007	7,413.01	2,438.88	35.10	3.53
MW008	11,096.51	406.83	5.86	5.29
MW009	6,746.82	613.96	8.84	3.21
MW010	5,572.92	0.83	0.01	2.65
MW011	1,117.38	175.20	2.52	0.53
MW017	5,445.13	0.95	0.01	2.59
MW100	445.41	0.02	0.00	0.21
MW101	1,523.14	2.89	0.04	0.73
MW102	1,322.97	0.93	0.01	0.63

MAROS Percent of Mass by Well

Project: Lockwood Groundwater Solvent Plu **User Name:** MV

Location: OU2 **State:** Montana

MW103	359.64	0.02	0.00	0.17
MW104	1,647.18	0.07	0.00	0.78
MW105	1,847.46	1.83	0.03	0.88
MW115	3,610.29	0.63	0.01	1.72
MW116	13,555.68	551.55	7.94	6.46
MW117	4,302.66	286.50	4.12	2.05
MW121	8,891.86	0.39	0.01	4.24
MW122	6,957.79	1,078.20	15.52	3.31
MW123	9,535.07	0.42	0.01	4.54
MW124	4,006.43	8.27	0.12	1.91
MW125	9,498.19	1.66	0.02	4.52
MW126	13,612.55	28.94	0.42	6.48
MW127	4,201.57	0.45	0.01	2.00
MW128	5,049.15	0.22	0.00	2.41
PT-01	2,060.15	0.96	0.01	0.98
PT-02	1,423.88	120.19	1.73	0.68
PT-03	2,871.11	708.45	10.20	1.37
PT-04	10,335.75	3.26	0.05	4.92
PT-05	579.46	5.18	0.07	0.28
PT-06	141.04	11.15	0.16	0.07
PT-07	202.56	3.03	0.04	0.10