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Flint Hills Resources Alaska, LLC

Fourth Quarter 2013 Groundwater Monitoring Report

North Pole Refinery
North Pole, Alaska
DEC File Number: 100.38.090

January 31, 2014

ARCADIS

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ARCADIS

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Acronyms and Abbreviations

ADEC	Alaska Department of Environmental Conservation
AHL	Arctic Home Living
ALS	ALS Environmental Laboratory
ARCADIS	ARCADIS U.S., Inc.
AS	air sparge
ASTM	ASTM International
Barr	Barr Engineering Company
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CCV	continuing calibration verification
city	North Pole, Alaska
COC	constituent of concern
COPC	constituent of potential concern
DNR	Alaska Department of Natural Resources
DO	dissolved oxygen
DPE	dual-phase extraction
DQO	data quality objective
ERI	electrical resistivity imaging
FDEM	frequency domain electromagnetic induction
FHRA	Flint Hills Resources Alaska, LLC
ft/ft	foot per foot
g/day	grams per day
GAC	granular activated carbon
GC/MS	gas chromatography/mass spectrometry
gpm	gallons per minute

GVEA	Golden Valley Electric Association
IRAP	Interim Removal Action Plan
lb/day	pound per day
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LNAPL	light nonaqueous phase liquid
LOD	limit of detection
LOQ	limit of quantitation
MAROS	Monitoring and Remediation Optimization System
monitoring plan	Deep Private Well Groundwater Monitoring Plan
MS	matrix spike
MSD	matrix spike duplicate
NPB	North Property Boundary
NPR	North Pole Refinery
Offsite SCR – 2013	Offsite Site Characterization Report – 2013 Addendum
Offsite SCWP	Revised 2013 Offsite Site Characterization Work Plan
Onsite SCR – 2013	Onsite Site Characterization Report –2013 Addendum
Onsite SCWP	Revised 2013 Onsite Site Characterization Work Plan
ORP	oxidation-reduction potential
Pace	Pace Analytical Services, Inc.
PAH	polyaromatic hydrocarbon
PIANO	paraffin, isoparaffin, aromatic, naphthene, or olefin
POE	point of entry
POE SAP	Point-of-Entry Sampling and Analysis Plan
power plant	electrical generating facility

QA	quality assurance
QC	quality control
report	Fourth Quarter 2013 Groundwater Monitoring Report
reporting period	fourth quarter 2013
Revised IRAP Addendum	Revised Interim Remedial Action Plan Addendum
RPD	relative percent difference
RSAP	Revised Sampling and Analysis Plan
SCR – 2011	Site Characterization Report Through 2011
SGS	SGS Laboratories
site	Flint Hills Resources Alaska, LLC North Pole Refinery, located on H and H Lane in North Pole, Alaska
SOP	standard operating procedure
Startup Aquifer Testing Report	Evaluation of Recovery Well Replacement, Start-up Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring Report
SWI	Shannon & Wilson, Inc.
Toolkit	Mass Flux Toolkit
TPT	Technical Project Team
TWUP	temporary water use permit
UAF	University of Alaska – Fairbanks
USEPA	United States Environmental Protection Agency
VPT	vertical profiling transect
WO	work order
WWTP	wastewater treatment plant
µg/L	micrograms per liter
°C	degrees Celsius

1. Introduction

On behalf of Flint Hills Resources Alaska, LLC (FHRA), ARCADIS U.S., Inc. (ARCADIS) prepared this Fourth Quarter 2013 Groundwater Monitoring Report (report) for the FHRA North Pole Refinery (NPR), an active petroleum refinery located on H and H Lane in North Pole, Alaska (Site). This report summarizes field activities completed during the fourth quarter 2013 (reporting period) as described in Sections 1.1, 1.2 and 3. Table 1-1 summarizes the field activities completed during the reporting period. In addition, at the Alaska Department of Environmental Conservation’s (ADEC’s) request, FHRA’s consultants obtained groundwater samples and provided these samples to ADEC’s designated contractors for further testing and analysis.

The data, analyses, and conclusions in this report are the product of a collaborative effort among FHRA’s consulting team members. That team includes qualified professionals in a variety of technical disciplines from four environmental consulting firms; ARCADIS, Shannon & Wilson, Inc. (SWI), Barr Engineering Company (Barr), and Geomega, Inc. (Geomega). FHRA has engaged these consulting firms to perform various tasks on the project. Pursuant to 18 AAC75.335, this groundwater monitoring report has been prepared and submitted by a Qualified Person. The sampling plan for this report was prepared by a Qualified Person, and those plans were approved by ADEC. The reports, and the samples taken for use in those reports are conducted under 18 AAC 75.355(c). The Arctic Home Living (AHL) work is supervised by FHRA and its consultants and the resulting sampling data are reviewed and used in reports prepared by qualified persons.

Onsite and offsite site characterization activities were completed during 2013 as proposed in the Revised 2013 Onsite Site Characterization Work Plan (Onsite SCWP; ARCADIS 2013a) and the Revised 2013 Offsite Site Characterization Work Plan (Offsite SCWP; ARCADIS 2013b), respectively, and additional work agreed to in electronic communication with ADEC. This section summarizes the characterization activities completed during the reporting period. Onsite and offsite data collected prior to November 20, 2013 and technical analyses based on these data are presented in the Onsite Site Characterization Report – 2013 Addendum (Onsite SCR – 2013; ARCADIS 2013c) and Offsite Site Characterization Report – 2013 Addendum (Offsite SCR – 2013; ARCADIS 2013d), respectively. Data collected after November 20, 2013 as part of these activities are summarized in this report (Section 4.11).

1.1 2013 Onsite Site Characterization Activities

The following onsite characterization field activities were completed during the reporting period:

- Ground-based frequency domain electromagnetic induction (FDEM) and electrical resistivity imaging (ERI) data collection and down-hole geophysical evaluation.
- Installation of Phase 8 monitoring, observation, and recovery wells; soil sampling and initial benzene, toluene, ethylbenzene and total xylenes (BTEX) and sulfolane groundwater sampling.
- Hydraulic conductivity and grain-size sampling and analysis of soil from Phase 8 borings.
- Advancement of soil borings and soil sample collection for sulfolane, BTEX, petroleum hydrocarbons, polyaromatic hydrocarbons (PAHs), 1,3,5- trimethylbenzene, and total organic carbon.
- Advancement of Hydropunch borings for grab groundwater sampling for sulfolane and BTEX.
- North Gravel Pit surface water and sediment sampling.
- Tracer injection and data collection.
- Light nonaqueous phase liquid investigation (LNAPL) investigation, including LNAPL transmissivity and compositional testing.
- In-situ respiration testing at monitoring point SG-05.

Table 1-1 summarizes the onsite characterization activities completed during the reporting period.

1.2 2013 Offsite Site Characterization Activities

Offsite characterization field activities completed during the reporting period are listed below:

- Ground-based FDEM and ERI data collection and down-hole geophysical evaluation.
- Installation of Phase 8 monitoring, observation, and recovery wells; soil sampling and initial sulfolane groundwater sampling.
- Hydraulic conductivity and grain-size sampling and analysis of soil from Phase 8 borings.

Table 1-1 summarizes the offsite characterization activities completed during the reporting period.

2. Site Setting

This section describes the site and the site's physical setting, and summarizes the current groundwater monitoring program at the site.

2.1 Site Description

The 240-acre site is located inside the city limits of North Pole, Alaska (the city). The city is located approximately 13 miles southeast of Fairbanks, Alaska, within Fairbanks North Star Borough (Figure 2-1). NPR is an active petroleum refinery that receives crude oil feedstock from the Trans-Alaska Pipeline.

Three crude oil processing units are located in the southern portion of the site, making up the process area. Only one of the processing units is currently operating. Tank farms are located in the central portion of the site. Truck-loading racks are located immediately north of the tank farms and a railcar-loading rack is located west of the tank farms. Wastewater treatment lagoons, storage areas, and two flooded gravel pits (North and South Gravel pits) are located in the western portion of the site. Rail lines and access roads are located in the northernmost portion of the site.

Along the southern site boundary, partially surrounded by the NPR, is an electrical generating facility (power plant) operated by Golden Valley Electric Association (GVEA). FHRA representatives indicated that the power plant burns heavy aromatic gas oil (diesel 4) or other fuels produced at the site. The property south of the site and the GVEA power plant is occupied by the Petro Star, Inc. Refinery. Site features are presented on Figure 2-2.

North of the site are residential properties and the city's wastewater treatment plant (WWTP). The North Pole High School is located immediately north and west of the WWTP and the residential properties. An undeveloped parcel of property, owned by the Alaska Department of Natural Resources (DNR), lies between the site and the WWTP. The Tanana River is located to the south and west, flowing in a northwesterly direction toward Fairbanks. East of the site and crossing the offsite area running southeast to northwest are the Old Richardson Highway and the Alaska Railroad right-of-way. An onsite site plan is presented on Figure 2-3 and an offsite site plan is presented on Figure 2-4.

2.2 Physical Setting

The site and the surrounding North Pole area are located on a relatively flat-lying alluvial plain that is situated between the Tanana River and Chena River. The site is located on the Tanana River Floodplain. Up to 2 feet of organic soil is typically found in the undeveloped portions of the site. Silt and silty sand layers varying in thickness from 0 to 10 feet typically occur beneath the organic soil. Alluvial sand and gravel associated with the Tanana River are present below the organic soil and silty layers. Depth to bedrock has been estimated at 400 to 600 feet below ground surface (bgs).

The city is located within an area of Alaska characterized by discontinuous permafrost (Ferrians 1965). Permafrost tends to act as a confining unit, impeding and redirecting the flow direction of groundwater (Glass et al. 1996). Based on regional information (Williams 1970, Miller et al. 1999), permafrost is assumed to be absent beneath the Tanana River.

The aquifer beneath the alluvial plain between the Tanana and Chena rivers consists of highly transmissive sands and gravels under water table conditions (Cederstrom 1963, Glass et al. 1996). The Tanana River has a drainage area of approximately 20,000 square miles upstream of Fairbanks (Glass et al. 1996). Near the site, this aquifer is reportedly greater than 600 feet thick (at least 616 feet thick near Moose Creek Dam) (Glass et al. 1996). Beyond the zones of influence of the site groundwater recovery system, groundwater flow directions are controlled by discharge from the Tanana River to the aquifer and from the aquifer to the Chena River, as described by Glass et al. (1996). Variations in river stage through time are believed to be the primary cause of variations in groundwater flow direction in the aquifer between the rivers (Lilly et al. 1996, Nakanishi and Lilly 1998). Based on data from U.S. Geological Survey water table wells, the flow direction varies from a north-northwesterly direction to a few degrees east of north. The flow direction trends to the north-northwest in spring and more northerly in the summer and fall (Glass et al. 1996).

2.3 Conceptual Site Model

The Conceptual Site Model (CSM) was presented as Appendix A in both the Onsite SCR – 2013 and Offsite SCR – 2013 (ARCADIS 2013c and d, respectively). The CSM summarizes how chemicals were historically released to the environment at the NPR, how chemicals released move through the environment, how those chemicals affect living organisms, and ongoing efforts to protect people from exposure to those chemicals. The CSM is based on extensive environmental assessment activities that have been conducted at the NPR during the past 26 years, with the majority of field activities occurring since 2009. The assessment included a thorough review of historical chemical use at the NPR, collection and analysis of water and soil samples from the surface and subsurface, monitoring of groundwater data over time, hydrologic studies of groundwater gradients and movement, geophysical studies of permafrost in the area, and computer-based simulations of the movement of sulfolane in groundwater. The CSM will support evaluation of potential remedial technologies in a future feasibility study and development of the final cleanup plan for the site. The extensive LNAPL, soil, groundwater, and soil-gas data collected to date and the CSM are sufficient to support a risk-based evaluation of appropriate remedial alternatives for the site.

3. Current Groundwater Monitoring Program and Methods

The current onsite and offsite groundwater monitoring programs were originally proposed in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011), and were subsequently revised in several iterations of site characterization reports. A revised monitoring plan was submitted to ADEC on October 14, 2013, and ADEC approval and comments were received in an email correspondence on October 21, 2013. The approved changes to the monitoring networks and frequencies, including recommendations for further changes received in the October 21, 2013 ADEC email, have been documented in the Revised Sampling and Analysis Plan (RSAP, Version 6, Appendix A). The RSAP is an update to the SAP which was initially presented in Appendix M of the Site Characterization Work Plan (Barr 2010a). The RSAP will be implemented as approved during the second quarter 2014 sampling event. Table 3-1 summarizes well construction details. Tables 3-2, 3-3, 3-4, 3-5, 3-6a, 3-6b, and 3-7 summarize the groundwater elevation monitoring well network, LNAPL thickness monitoring well network, LNAPL migration monitoring well network, BTEX monitoring well network, sulfolane monitoring well network (including both onsite and offsite wells), and deployed transducer network. Well locations are shown on Figures 2-3 and 2-4.

Routine quarterly groundwater monitoring and sampling was performed as part of the ongoing operations to characterize onsite LNAPL, dissolved-phase benzene and total xylenes, and onsite and offsite dissolved-phase sulfolane impacts. Methods used for nonroutine analyses are described or referenced in corresponding sections. Fourth quarter 2013 private well samples, including deep private well data, are included in this report.

Groundwater monitoring was completed according to the procedures summarized in the RSAP. The RSAP is updated on a continuous basis and submitted periodically; updates are tracked in Appendix A of the RSAP. Revisions and updates are incorporated into Version 6, which is included as Appendix A of this report.

Groundwater monitoring data are used to assess changes in COC concentration and trends, and also to assess the efficacy of the onsite groundwater recovery system. A statistical analysis of BTEX and sulfolane concentration trends was originally presented in the Site Characterization Report – Through 2011 (SCR – 2011; Barr 2012) and updated annually in the fourth quarter groundwater monitoring reports. A statistical analysis of historical groundwater analytical data from April 1987 through September 2013 was completed for benzene and xylenes at onsite wells screened at or near the water table for the LNAPL assessment presented in the Onsite SCR – 2013 (ARCADIS 2013c). Section 4.9 discusses the results of the 2013 statistical analysis of site constituents of concern (COCs) per the Revised Draft Final Human Health Risk Assessment (Draft Final HHRA; ARCADIS 2012a) including benzene, total xylenes, and sulfolane concentration trends.

3.1 Groundwater Elevation and Light Nonaqueous Phase Liquid Monitoring

The comprehensive quarterly groundwater elevation monitoring event was conducted on September 30 and October 1 and 2, 2013 from an extensive network of onsite and offsite wells. Two additional groundwater elevation monitoring events were completed during the reporting period to monitor the hydraulics of the North Gravel Pit (NGP) and hydraulic capture of the groundwater recovery system and) as discussed in Sections 4.3 and 5.4.2, respectively. A third additional groundwater monitoring event was scheduled during November of the reporting period but was not completed due to issues related to the treatment system operation, as discussed in Section 5.3.3, which resulted in FHRA temporarily suspending operation of five of the seven recovery wells.

The LNAPL monitoring network was expanded and measurements were collected to determine the LNAPL thickness and potential migration to confirm the stability of the LNAPL plume (as described in the SCR – 2011 (Barr 2012). During this reporting period, LNAPL thickness and migration measurements were collected monthly from monitoring wells on October 22 and 29; November 19, 25, and 26; and December 18 and 20, 2013.

Depth to water and LNAPL thickness measurements were completed according to the RSAP. Measurements were collected from site monitoring wells with an oil/water interface probe. If present, LNAPL thickness was calculated based on depth to groundwater and LNAPL measurements. Groundwater elevation was calculated using the previously surveyed top of casing elevation and the depth to water. Where LNAPL was present, the groundwater elevation was corrected for the thickness of LNAPL using the appropriate LNAPL-specific gravity value presented in the SCR – 2011 (Barr 2012). One hundred thirty-four onsite and offsite wells were resurveyed in March, June, July, August, and September 2013 to account for frost-jacking and settling of monitoring well casings due to seasonally variable soil and weather conditions (Table 3-1). Section 5.4.2 summarizes monthly groundwater elevation monitoring and a top of well casing survey completed during the reporting period to evaluate the recovery system hydraulic capture. This includes the Phase 8 wells that were surveyed from August through December 2013.

In addition to manual water-level measurements, automated measurements were collected from a network of wells using vented Global WL-16 automated water-level loggers, vented In-Situ Level Troll 500 loggers, or unvented In-Situ Rugged Troll 100 loggers. A list of wells with deployed pressure transducers is provided in the RSAP (Appendix A). Each Global WL-16 is a combined pressure transducer and data logger with automatic barometric pressure and temperature compensation. One Barotroll® logs the barometric pressure for the In-Situ Level Troll 500 loggers. Each logger provides an elevation reading below the top of casing and is programmed to measure water levels on an hourly basis. A total of 72 transducers are currently deployed in 24 onsite wells and 48 offsite wells to observe hydrogeological conditions between wells screened at various depths within the suprapermafrost aquifer.

Groundwater elevation measurements were downloaded from the deployed transducers on December 9, 10, 11, 18, 19, 20, and 30, 2013. The standard operating procedure (SOP) for groundwater elevation monitoring submitted to ADEC on August 27, 2013 (SWI 2013) was used to evaluate vertical hydraulic gradients within well nests and horizontal hydraulic gradients and groundwater flow directions between groups of wells. The fourth quarter 2013 hydrographs contain errors bars in accordance with the technical memorandum included as an attachment to the SOP.

3.2 Light Nonaqueous Phase Liquid Transmissivity Testing

Several methods were applied to calculate LNAPL transmissivity using data generated during data collection, and from ongoing LNAPL recovery system operations. LNAPL recoverability can be evaluated based on LNAPL transmissivity calculations.

LNAPL transmissivity is calculated from the following field tests and datasets:

- LNAPL manual skimming tests
- LNAPL baildown tests
- Water-enhanced recovery (dual-phase extraction [DPE])
- LNAPL pneumatic skimming tests

The methodologies used to calculate the fraction of recoverable LNAPL are included in Appendix O of the SCR – 2011 (Barr 2012). The methodology for LNAPL transmissivity data and collection and analysis are consistent with the ASTM International (ASTM) Standard Guide for Estimation of LNAPL Transmissivity, E2856-12 (ASTM 2012).

LNAPL baildown testing is currently performed semiannually during hydrogeologic cycle minima, typically in March and late October, to characterize LNAPL transmissivity at the site. Results of baildown testing completed during the reporting period are discussed in Section 4.5. The LNAPL transmissivity results will be used to quantify relative LNAPL recoverability to focus LNAPL recovery efforts in areas that have higher recovery potential and to establish practical limits of recovery.

3.3 Groundwater Sampling Priorities

In response to several quarterly sampling events during which inclement weather reduced the opportunity to collect samples from all wells within each monitoring well network, well networks were evaluated and each well was assigned a priority (one through four). Sampling is conducted in order of priority to assure that the most valuable data are collected during each sampling event. Tables 3-5, 3-6a, and 3-6b summarize the priority levels assigned to each well in the BTEX and sulfolane monitoring networks, respectively. A priority level of two was assigned to Phase 8 wells. Priority levels for each monitoring well network were also updated in the RSAP.

During the reporting period, seven wells (MW-172A-15, MW-172B-150, MW-182A-15, MW-189A-15, MW-189B-60, MW-308-30, MW-335-41) in the sulfolane monitoring network and one well (S-50) in the BTEX monitoring network were not sampled because the wells were frozen. Two well channels (MW-304-CMT-10 and MW-305-CMT-8) were dry and were not sampled. Wells that were initially frozen were checked periodically throughout the quarter to determine if the wells had thawed so that a sample could be collected. Wells that were not sampled are indicated in the sulfolane and BTEX result tables (Tables 4-10 and 4-11).

3.4 Groundwater Sampling Methods

Groundwater samples collected during the reporting period were sampled in accordance with Version 5 (March 2013) of the RSAP. Groundwater was purged from each sampled well using dedicated or portable pumps. Purging was conducted until geochemical parameters stabilized or three well volumes of groundwater were pumped from the well. A YSI ProPlus multiprobe or equivalent was used to monitor geochemical parameters, including temperature, conductivity, dissolved oxygen (DO), pH, and oxidation-reduction potential (ORP).

3.5 Groundwater Monitoring Analytical Methods

Upon collection, quarterly groundwater samples were stored in iced coolers and submitted to SGS Laboratories (SGS) of Anchorage, Alaska under proper chain of custody procedures. Groundwater analytical samples were submitted for the following quarterly analyses:

- BTEX by United States Environmental Protection Agency (USEPA) Method 8260B
- Sulfolane by modified USEPA Method 1625B with isotope dilution gas chromatography/mass spectrometry (GC/MS)

Sample analysis by modified USEPA Method 1625B/8270D with isotope dilution GC/MS was conducted in accordance with the Updated Key Elements document prepared by the Chemistry Subgroup in July 2013. Revised Laboratory Standard Operating Procedures (SOPs) were submitted to ADEC on January 21, 2014.

3.6 Geochemical Parameter Monitoring

As proposed in the Offsite SCWP (ARCADIS 2013b), geochemical parameter monitoring is performed annually during the third quarter to characterize the potential for natural attenuation of sulfolane at the site. Geochemical parameter monitoring will resume during third quarter 2014.

Field geochemical parameters such as temperature, conductivity, DO, pH, and ORP were collected from wells within the BTEX and sulfolane network and are discussed in Section 4.10.

3.7 Private Well Sampling

A door-to-door survey was conducted downgradient from the site to identify private water-supply wells in Search Areas 1 through 10 (Search Area 10 is shown on Figure 3-1; Search Areas 1 through 9 were provided in previous groundwater monitoring reports). Site characterization activities began offsite in 2009. Since that time, permanent buildings within the search areas were visited and residents were surveyed to determine the presence of wells on the properties. If a well was identified, information regarding well construction details and water usage was requested. If a drinking-water well was present on a property, permission to collect a groundwater sample for sulfolane analysis was requested. The overall search area was expanded until sulfolane was not detected in private well water samples. Private well sampling locations are shown on the figure included as Appendix B.

During the reporting period, FHRA continued annual sampling of the wells near the edge of the plume that did not contain detectable concentrations of sulfolane during previous sampling events (buffer zone). Six wells were sampled during the reporting period (through December 13, 2013), including one deep private well and one location with a point of entry (POE) treatment system. To date, a total of 195 of the 214 wells scheduled were resampled during 2013. Nineteen wells scheduled to be resampled in 2013 were unable to be sampled before the end of the year for the following reasons:

- 9 locations were unresponsive to contact attempts;
- 3 locations were unresponsive to contact attempts, but appear to be vacant;
- 2 locations refused to participate;
- 4 locations had wells that were no longer functioning; and
- 1 location shares a well with another home that was already resampled in 2013 and set up with a POE treatment system due to a detection in the 2013 sample.

Samples collected during the reporting period include:

- Four wells near the edge or within the plume boundary that did not contain detectable concentrations of sulfolane during previous sampling events.

- Two city fire wells.

During the reporting period, FHRA also collected initial groundwater samples from 13 private wells, including the following:

- Five “call-in” samples (PW-0239, PW-0690, PW-0828, PW-1893, and PW-1894) from outside the search areas.

- One call-in sample from inside the search areas (PW-1494) was collected prior to demolition of the structure. The homeowner plans to rebuild in the same location.

- Four “one-time only” samples (PW-0669, PW-1038, PW-0342, PW-1340) from deep private wells northeast to east of the sulfolane plume.

- Three samples (PW-1493, PW-1891, and PW-1892) from locations within the search areas. FHRA continued to revisit locations within the search areas that were previously noted as “unable to be contacted,” “contacted but not sampled,” or “appear uninhabited.” Two of the three locations visited during the reporting period were outside of the sulfolane plume (confirmed by samples; see Section 4.7.2). One location inside the plume had been vacant until recently. The new resident has been provided with bottled water until a permanent alternative water solution can be established.

To date (between November 11, 2009 and December 16, 2013), FHRA has sampled and received results for 640 wells within the search areas, with many locations sampled several times as part of the annual resampling events or the Deep Private Well Groundwater Monitoring Plan (monitoring plan; ARCADIS 2012b) . In addition, 173 private well samples were collected from outside the search areas at locations near the defined search areas or where FHRA was contacted (by a landowner, resident, or a real estate agent) with requests for testing.

Each well location sampled was assigned a four-digit private well identification number (PW-ID); these identification numbers are shown on the figure included as Appendix B. In cases where a property contains more than one well that was sampled, each sampled well on the property was assigned a separate identification number. In addition, wells discovered during review of ADEC septic records were assigned an identification number, although many of these are outside search areas and have not been sampled. Identification numbers were assigned to protect the privacy of the private well owners.

3.7.1 Garden Well Search

During the reporting period, FHRA continued to survey locations within the plume that are also within the city-water distribution area. The initial search of this area was conducted prior to the garden sampling project included in the SCR – 2011 (Barr 2012). The purpose of the 2013 survey was to confirm that the property owners and residents living at these locations were aware of the State of Alaska Department of Health and Social Services (ADHSS) recommendation for well water use within the plume area. If a garden well was present on the property, collection of a groundwater sample was offered to the property owner. Additionally, properties identified as having a sulfolane-impacted well were offered an outside hose spigot connected to the property's city-water system for gardening or other potable water activities. At these locations, FHRA contractors also attached placards next to each outside hose spigot, identifying them as either potable or nonpotable water sources.

As of December 17, 2013, 294 locations were contacted and 46 auxiliary and 37 inactive wells were found. Letters will be mailed to owners where door-to-door visits and phone calls were not successful in establishing contact. Each property with a well has been connected to city water services except one, which is provided bottled water on a regular basis until a permanent city connection or alternative water solution can be established. No private well samples were collected for the garden well search during this reporting period.

3.7.2 Point of Entry Sampling

FHRA continued to import POE system maintenance sulfolane sample results for raw-water samples ("A" samples) into the database to further inform the site characterization. In addition, FHRA imported the associated sample-port data (i.e., "C," "C1," "C2," and "D" samples) for historical and fourth quarter 2013 POE system results; associated POE data will continue to be imported to the analytical database. Sixty-eight laboratory packets for the reporting period were received from Pace Analytical Services, Inc. (Pace) as of December 16, 2013 and were imported into the database during the reporting period. One data packet (Pace 10250804) includes results for the POE system at the warehouse, which is used to treat rinsate water collected during maintenance activities.

AHL personnel are completing sample collection under the supervision of FHRA and its consultants and the resulting sampling data are reviewed by qualified persons. POE system maintenance samples are submitted to Pace and analyzed in accordance with a Key Elements document prepared by the TPT Chemistry Subgroup (updated in July 2013). Laboratory SOPs were approved by ADEC via email on May 18, 2011. Updated SOPs have been submitted for ADEC approval on January 21, 2014.

On September 16, 2013, AHL began implementing the Point-of-Entry Sampling and Analysis Plan (POE SAP, which was included in the Final Alternative Water Solutions

Program – Management Plan (Barr 2013b). The POE SAP was prepared for sampling and validation of data collected during maintenance of the POE systems. Sampling results presented on Figure 3-1 are designated with a different symbol than well samples that do not have a POE treatment system.

3.8 Deep Private Well Monitoring

The Deep Private Well Monitoring Plan (ARCADIS 2012b) was submitted to ADEC on June 20, 2012 and an updated monitoring plan was submitted in the Offsite SCWP (ARCADIS 2013d). The monitoring plan proposed quarterly collection of sulfolane and geochemical data from a larger network of deep private wells for two years. The objectives of the monitoring plan were to:

- Establish a groundwater monitoring network of deep private wells with intake intervals reported to be in the subpermafrost aquifer.
- Establish a baseline dataset of sulfolane concentrations and geochemical conditions at the deep private well groundwater monitoring network.
- Monitor sulfolane concentrations and geochemical conditions quarterly for 2 years at deep private wells in areas where sulfolane has previously been detected.

The monitoring plan identified private well locations inside the detectable sulfolane groundwater plume (internal plume locations), and along the perimeter of the sulfolane groundwater plume (perimeter locations). The candidate deep private wells had intake intervals reported to be in the subpermafrost aquifer. Subsequently, it was determined that shallow (suprapermafrost) private wells also existed on the same properties as two deep private wells.

The monitoring plan presented a two-phase implementation approach. The objective of Phase I was to select candidate wells and obtain access agreements for sampling the selected wells. The objective of Phase II was to sample the selected wells, with access agreements in place, quarterly for two years. Phase II was initiated during the first quarter 2013 and is in progress.

A third phase of deep private well monitoring was proposed to evaluate the connectivity of, and vertical gradients between, suprapermafrost and subpermafrost water-bearing zones. The Phase III activities included a down-hole camera inspection that was conducted in a private well (PW-1230) on April 5, 2013 to verify the well construction information detailed on a boring log discovered in the ADEC septic record files. Additional camera verification work is planned as part of Phase III. Two additional locations within the deep private well network are being pursued for camera verification. The results will be provided to ADEC if that work can be completed.

FHRA obtained access for 20 private wells on 18 properties. Eighteen of these wells have intake intervals reported at depths below permafrost (based on installation logs), with total depths between approximately 89 and 305 feet bgs, while two wells have reportedly shallow intake intervals at approximately 24 and 30 feet bgs and are located on the same properties as deep wells.

Analytical results for groundwater samples collected during third quarter 2013 were finalized after the submittal date for the third quarter groundwater monitoring report and were included in the Offsite SCR – 2013 (ARCADIS 2013d). During the third quarter 2013, FHRA collected groundwater samples from 18 of the 20 private wells from September 5 through 26, 2013. FHRA collected groundwater samples from 18 of the 20 private wells during the reporting period from October 16 through December 17, 2013. FHRA has agreements in place with the private well owners to collect water samples on a quarterly basis. However, FHRA was unable to sample one well during third quarter (PW-0259) and two wells during the fourth quarter reporting period (PW-0259 and PW-1458). Samples were most recently collected from PW-0259 in June and PW-1458 in September. A one-time sample was collected from PW-1626 in October 2013.

Deep residential sampling results from third and fourth quarters are discussed in Section 4.7.3.

4. Groundwater Monitoring Results

Groundwater impacts have been, and continue to be, characterized through the analysis of gauging data and groundwater samples collected from onsite and offsite monitoring wells. This section presents results of gauging data and groundwater analyses of onsite well samples (analyzed for BTEX and/or sulfolane), offsite well samples (analyzed for sulfolane), private well samples (analyzed for sulfolane), and nonroutine samples collected during the reporting period. Groundwater field parameters, groundwater elevations, NGP hydraulic gradients, LNAPL thickness measurements, LNAPL migration measurements, LNAPL transmissivity testing results, BTEX analytical results, sulfolane analytical results, sulfolane mass flux results, private well initial sampling and resampling results, and deep private well results are presented in Tables 4-1 through 4-16. Historical groundwater elevation and LNAPL thickness measurements, BTEX analytical results, sulfolane analytical results, geochemical analytical results, and private well analytical results are included as Appendix C. Laboratory analytical reports and ADEC review checklists are included as Appendices D and E, respectively. Field data sheets are included as Appendix F.

4.1 Groundwater Elevation

Depth to water measurements were collected from monitoring wells on September 30 and October 1 and 2, 2013. Additional depth to water measurements used for hydraulic capture evaluation of the groundwater recovery system are discussed in Section 5. During the reporting period, the general direction of the horizontal hydraulic gradient was interpreted to be to the north-northwest, which is consistent with historical groundwater data. However, in areas where no permafrost is believed to exist at depth, hydraulic head data from deep monitoring wells MW- 181C-150 and MW-332-150 and deep private well PW-1230 were used to infer flow directions in the subpermafrost aquifer. The inset image on Figure 4-6 suggests that flows in the subpermafrost aquifer may have been more northerly than the flows in the suprapermafrost aquifer. In future quarterly reports, grouping of deep wells may be modified on groundwater contour maps. Groundwater elevations and depth to LNAPL measurements are summarized in Table 4-2. Potentiometric maps are included for each monitoring zone: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table (Figures 4-1 through 4-6). Onsite, the magnitudes of the horizontal hydraulic gradients at the water table were calculated at approximately 0.0015 foot per foot (ft/ft) during the reporting period. The magnitude of offsite horizontal hydraulic gradients at the water table and onsite and offsite hydraulic gradients at 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table were calculated to be 0.0009 ft/ft.

In addition to manual water-level measurements, automated measurements were collected with transducers from 72 wells, including 21 well nests. Data from well nests were used to measure differences in groundwater elevations between wells screened at various depths within the suprapermafrost aquifer. Groundwater elevation hydrographs were prepared in accordance with the SOP (SWI 2013) using the most recent survey data. Error ranges, calculated in accordance with the method outlined in the SOP (SWI 2013) and presented as Appendix G, are shown on the well nest hydrographs.

Thirteen pressure transducer data logs were incomplete for the reporting period due to reasons outlined in the table below.

Monitoring Well	Reason for Omitted Data	Comments
MW-166A	Water-level data have not been received from University of Alaska – Fairbanks (UAF).	Data will be imported once they are received.
MW-167A	Water-level data have not been received from UAF.	Data will be imported once they are received.
MW-168A	Water-level data have not been received from UAF.	Data will be imported once they are received.
MW-170A	The data logger suspension cable broke on October 9, 2013, and the data logger was at the bottom of the well until October 14, 2013.	The data from October 9 to 14, 2013 have been marked invalid, and do not appear on the hydrograph.
MW-171A	Water-level data have not been received from UAF.	Data will be imported once they are received.
MW-172A	The well was frozen. Data logger could not be accessed.	Data will be downloaded once the logger can be accessed.
MW-172B	The well was frozen. Data logger could not be accessed.	Data will be downloaded once the logger can be accessed.
MW-182A	The well was frozen. Data logger could not be accessed.	Data will be downloaded once the logger can be accessed.
MW-185A-15	Water-level data have not been received from UAF.	Data will be imported once they are received.
MW-186A-15	The procedure for adjusting data to account for LNAPL in the well hasn't been established.	No data have been imported into the database.
MW-187-15	Water-level data have not been received from UAF.	Data will be imported once they are received.
MW-189-15	The well was frozen. Data logger could not be accessed.	Data will be downloaded once the logger can be accessed.

Monitoring Well	Reason for Omitted Data	Comments
MW-334-15	The procedure for adjusting data to account for LNAPL in the well has not been established.	No data have been imported into the database.

A detailed evaluation of transducer data and hydraulic gradients is provided in Appendix 6-B to the Onsite SCR – 2013 (ARCADIS 2013c) and Appendix 5-A to the Offsite SCR – 2013 (ARCADIS 2013d).

4.2 Onsite Surface Water Elevation

Measurements were recorded from gauging points located at the North and South Gravel pits on October 1, 2013. The NGP measurement was taken from a surveyed mark on an I-beam above a grate in the fire pump house that sits over the water on the southeast end of the pit. The South Gravel Pit measurement was taken from a 12-foot staff gauge in the pit. The North and South Gravel pits were measured during the reporting period at elevations of 484.30 and 491.31 feet above mean sea level, respectively. Data are summarized in Table 4-2 and presented on Figure 4-1. Historical gauging data are summarized in Appendix C.

Measurements were recorded from nine offsite culverts on October 3, 2013 and November 2, 2013; icy road conditions and snow buildup precluded measurements in December 2013. Culvert locations are shown on Figure 2-4 and measurements collected during the comprehensive event (October 2013) are summarized in Table 4-2; measurements collected in November 2013 are included on historical tables provided in Appendix C.

4.3 North Gravel Pit Hydraulic Gradient Analysis

On August 26, 2013, FHRA submitted the Work Plan for Additional Site Monitoring Activities During Construction Dewatering (ARCADIS 2013i) which summarizes groundwater and surface water monitoring during the proposed replacement of an existing transfer line that carries water from the South Gravel Pit to the NGP. The project was postponed and subsequently a portion of the proposed investigation activities were postponed including deployment of pressure transducers to monitor surface water and groundwater elevation fluctuations during the project. Despite the postponement of the project and monitoring, the proposed piezometers were installed, surveyed, and made available for groundwater elevation monitoring. FHRA is collecting preliminary monthly groundwater elevation data from the piezometers to inform the eventual groundwater monitoring activities proposed during the transfer line replacement. During the reporting period, depth to water measurements were collected from monitoring wells around the perimeter and in vicinity of the NGP on November 25 and December 19, 2013.

Potentiometric maps showing the data collected on November 25, 2013 are included for NGP area-specific monitoring zones: water table, 10 to 20 feet below the water table, 20 to 40 feet below the water table, and 40 to 70 feet below the water table (Figures 4-7 through 4-10, respectively). Consistent with historical data, horizontal hydraulic gradients were in the north-northwest direction with magnitudes for each monitoring zone averaging approximately 0.0007 ft/ft during the reporting period. Due to the preliminary nature of this evaluation, only one monthly dataset and horizontal gradients were evaluated. A complete evaluation of monthly data and data collected during the transfer line project will be presented in a summary report. Depth to water measurements and groundwater elevation data are summarized in Table 4-3.

4.4 Light Nonaqueous Phase Liquid Monitoring Results

Observation wells were installed to better define LNAPL occurrence at the site. LNAPL thickness data from those wells are included in Section 4.4 of this report. LNAPL thickness measurements were collected on October 22 and 29; November 19, 25, and 26; and December 18 and 20, 2013 from a network of monitoring, observation, and recovery wells screened across the water table. An apparent LNAPL thickness was measured in 37 wells during October 2013, in 30 wells during November 2013, and in 31 wells during December 2013. A visible sheen or trace (not measureable in the field) was recorded in one well during October 2013, in five wells during November 2013, and in two wells during December 2013. On October 29, 2013, a maximum LNAPL thickness of 3.12 feet was measured in monitoring well MW-176A-15 (Figure 4-11).

4.4.1 Light Nonaqueous Phase Liquid Extent

LNAPL migration measurements were collected from wells along the perimeter of the LNAPL plume on October 22 and 29; November 19, 25, and 26; and December 18 and 20, 2013. LNAPL was not measured in any of the LNAPL migration monitoring wells during the reporting period.

4.4.2 Light Nonaqueous Phase Liquid Thickness

LNAPL thicknesses and the LNAPL footprint observed during the reporting period are similar to historical footprints. LNAPL thickness and migration data are summarized in Tables 4-4 and 4-5, respectively, and maximum thickness data from the reporting period are presented on Figure 4-11.

4.5 Light Nonaqueous Phase Liquid Transmissivity

4.5.1 Light Nonaqueous Phase Liquid Baildown Test Data

FHRA completed LNAPL baildown tests in October 2013 at seven monitoring wells in which LNAPL was observed (MW-176A, O-27, O-31, O-33, O-34, S-21, and S-39). One test was completed per well with the exception of wells O-34 and S-21, where two tests were completed. LNAPL recovery in wells after test completion ranged from 3 to 105 percent of the initial LNAPL thickness for the wells. A percent recovery greater than 100 can occur when the well is not in equilibrium when the test is initiated or due to fluctuating water table conditions. Transmissivity data collected through fourth quarter 2014 are presented in Table 4-6 and shown on Figure 4-12.

LNAPL baildown testing and data analysis was conducted according to procedures outlined in the RSAP. Appendix 7-C of the Onsite SCR – 2013 (ARCADIS 2013c) presents the LNAPL baildown test input data.

4.5.2 Light Nonaqueous Phase Liquid Manual Skimming Test Data

Although not proposed in the Onsite SCWP (ARCADIS 2013a) or RSAP, FHRA completed a manual skimming test at MW-334-15 in October 2013 as part of the onsite characterization activities. Monitoring well MW-334-15 was slated for LNAPL baildown testing as part of the site-wide baildown test program. However, when the test was attempted, the observed LNAPL discharge into the well was high and LNAPL could not be effectively purged to initiate the test. Based on this observation and consultation with ARCADIS experts, the field staff discontinued the baildown test and instead conducted a manual skimming test at MW-334-15.

Forty-eight gallons of LNAPL were removed during the 3-hour manual skimming test. An LNAPL recovery rate was calculated for each LNAPL removal step, which was in turn used to calculate the transmissivity for that period. Results from the manual skimming test for MW-334-15 are presented in Table 4-7 and shown on Figure 4-12. The data used in the LNAPL transmissivity calculations are presented in Appendix 7-B of the Onsite SCR – 2013 (ARCADIS 2013c).

Well MW-334-15 was originally constructed using a two-inch PVC casing. A replacement well was installed using a four-inch steel casing during the reporting period. An additional 9 gallons of LNAPL were recovered from well MW-334-15 between October 31 and November 19, 2013, resulting in a total of 66 gallons of LNAPL recovered from this well.

4.5.3 Water-Enhanced Recovery

FHRA updated LNAPL transmissivity calculations for recovery well R-21 using remediation system data collected from October through December 2013. As discussed above, groundwater transmissivity is a required input calculation of LNAPL transmissivity from a groundwater and LNAPL recovery system. Average groundwater transmissivity values for the recovery wells were calculated from hydrogeologic analyses presented in the Evaluation of Recovery Well Replacement, Startup Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring Report (Barr 2013a).

Groundwater transmissivity values were based on groundwater pump tests conducted at the Site. The groundwater transmissivity values used for the LNAPL transmissivity calculations were chosen based on the spatial location of wells in relation to each other, screen intervals, and similar geology. Groundwater transmissivity values from R-43 and R-44 were averaged and used for LNAPL transmissivity calculations for R-21 (13,600 square feet per day). LNAPL/water density ratios were calculated for R-21 from laboratory fluid physical properties discussed in the SCR – 2011 (Barr 2012).

LNAPL and groundwater drawdowns are also required input values for the LNAPL transmissivity calculation. Ideally, these drawdown values would be based on a difference between fluid levels under non-pumping, equilibrium conditions. However, the fluid-level data were collected while the DPE systems were running because routine recovery system shutdown and equilibration are not feasible. Therefore, two simplifying assumptions were made to facilitate the LNAPL transmissivity calculations:

1. LNAPL drawdown used in the calculations was based on the observed thickness of LNAPL in the well during gauging and system data collection.

2. Groundwater drawdown can reasonably be calculated for R-21 by pairing the recovery well with a monitoring well outside the zone of capture.

These assumptions introduce a small degree of error into the calculation, but the results are representative of the magnitude of LNAPL transmissivity.

Recovery well R-21 was paired with O-5 to complete the calculation. Groundwater drawdown was calculated for this location based on fluid gauging data from the quarterly reports. Data collected from each well along with calculated groundwater drawdown is presented in Appendix H Table 1. LNAPL transmissivity results from the water-enhanced recovery are summarized in Tables 4-9a and 4-9b. Time series plots for water-enhanced LNAPL recovery at R-21 and R-40 are included as Figures 4-13A and 4-13B, respectively.

4.5.4 Light Nonaqueous Phase Liquid Pneumatic Skimming

LNAPL transmissivity can be calculated from an LNAPL skimming system if periodic LNAPL drawdown and volume recovery rate data are collected from each test well. Longer term automated LNAPL skimming transmissivity calculations were completed for two wells (MW-138 and R-20R) from January 2010 to December 2013. Results from the LNAPL pneumatic skimming for R-20R are presented in Table 4-8. The data collected during the reporting period for use in LNAPL transmissivity calculations are presented in Appendix H-2.

4.6 Onsite Monitoring Well Sampling

Most BTEX data are collected semiannually during the second and fourth quarters. Groundwater samples were collected during the reporting period for BTEX analysis from 78 wells, including:

- Sixty-six wells sampled as part of semiannual BTEX monitoring and semiannual groundwater extraction and recovery system performance monitoring. This included 53 wells screened in the water table zone, eight wells screened 10 to 55 feet below the water table, four wells screened 55 to 90 feet below the water table, and one well screened 90 to 160 feet below the water table.

- Newly installed Phase 8 wells (12 samples), including three wells screened within the water table zone and nine wells screened 10 to 55 feet below the water table.

BTEX results for the reporting period are summarized in Table 4-10. Analytical results for benzene and total xylenes are presented on Figures 4-14 through 4-17, which show the inferred extent of the dissolved-phase benzene distribution at the site at the following depth intervals: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table. Results for benzene and total xylenes are discussed in Section 4.6.1. Historical BTEX analytical results are included as Appendix C.

Sulfolane data were collected from wells that are on a quarterly monitoring schedule and a quarterly performance monitoring schedule for the groundwater extraction and recovery system (Table 3-6a). Additionally, samples from newly installed Phase 8 wells were submitted for sulfolane analysis. Groundwater samples collected from 219 onsite wells during the reporting period were submitted for sulfolane analysis. This included:

- One hundred and sixty-seven wells onsite sampled as part of quarterly sulfolane monitoring and groundwater extraction and recovery system performance monitoring, including 69 wells screened across the water table, 51 wells screened 10 to 55 feet below the water table, 26 wells screened 55 to 90 feet below the water table, and 21 wells screened 90 to 160 feet below the water table.

- Fifty-two samples from newly installed onsite Phase 8 wells, including 17 wells screened across the water table, 23 wells screened 10 to 55 feet below the water table, five wells screened 55 to 90 feet below the water table, and seven wells screened 90 to 160 feet below the water table.

Sulfolane analytical results are summarized in Table 4-11 and shown on Figures 4-18 through 4-21. The estimated extent of the onsite dissolved-phase sulfolane plume is presented at the following depth intervals: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table. Results for onsite sulfolane analytical results are discussed in Sections 4.6.2.1 through 4.6.2.4.

A total of 55 samples were collected from the vertical profiling transect (VPT), which includes well clusters MW-301 through MW-306. Groundwater samples were analyzed for sulfolane and results are described in Section 4.6.2.5.

Data are summarized in Table 4-12 and presented on Figure 4-22. Sulfolane concentrations for VPT wells in each groundwater zone are also presented on Figures 4-18 through 4-21. Historical sulfolane analytical results are included as Appendix C.

4.6.1 Benzene and Total Xylenes

4.6.1.1 *Water Table*

During the reporting period, in water table zone monitoring wells sampled for hydrocarbon analytical parameters, benzene was not detected in samples collected from 31 wells. In remaining sampling locations within the water table zone benzene concentrations ranged from 0.69 µg/L (duplicate sample from MW-180A-15) to 14,900 µg/L (MW-336-15). Total xylenes were not detected in 40 samples collected from the water table zone. Total xylenes detections ranged from 1.04 J µg/L (MW-179A-15) to 8,350 µg/L (MW-336-15).

Benzene concentrations detected in groundwater samples collected from well O-2 and total xylenes concentrations detected in groundwater samples from wells MW-124-25, MW-132-20, MW-134-20, MW-140-25, MW-179A-15, MW-180A-15, MW-345-15, O-4, O-12, and O-32 were flagged as estimated, as described in Section 6. The estimated extent of benzene and total xylenes within the water table zone is identified as isopleths based on benzene concentrations on Figure 4-14.

4.6.1.2 *10 to 55 Feet Below the Water Table*

During the reporting period, in the 10 to 55 feet below the water table zone monitoring wells sampled for hydrocarbon analytical parameters, benzene was not detected in groundwater samples collected from 16 wells. In the remaining three sampling locations, benzene concentrations ranged from 1.09 µg/L (MW-336-55) to 15,300 µg/L (MW-336-20). Total xylenes were also not detected above the detection limit in groundwater samples collected from 16 wells within the 10 to 55 feet below the water table zone. Total xylenes detections in the remaining three wells ranged from 5.09 µg/L (MW-336-35) to 4,720 µg/L (MW-336-20). The estimated extent of the benzene and total xylenes in the 10 to 55 feet below the water table zone is identified as isopleths based on benzene concentrations on Figure 4-15.

4.6.1.3 *55 to 90 Feet Below the Water Table*

During the reporting period, in the 55 to 90 feet below the water table zone monitoring wells sampled for hydrocarbon analytical parameters, benzene and total xylenes were not detected in groundwater samples collected from three monitoring wells. Benzene and total xylenes were detected in sample collected from one well screened within the 55 to 90 feet below the water table zone at 0.720 µg/L and 2.05 J, respectively (MW-186E-75). The total xylenes concentration detected in groundwater sample collected from well MW-186E-75 was flagged as estimated, as described in Section 6. Benzene and total xylenes concentrations in wells screened at 55 to 90 feet below water table are presented on Figure 4-16.

4.6.1.4 *90 to 160 Feet Below the Water Table*

Benzene and total xylenes were not detected in the one groundwater sample collected from within the 90 to 160 feet below the water table zone (MW-199-150). Benzene and total xylenes analytical results at this depth zone are presented on Figure 4-17.

4.6.2 Sulfolane

4.6.2.1 *Water Table*

Sulfolane was not detected in 30 samples collected from onsite monitoring and observation wells screened within the water table zone. Sulfolane was detected in groundwater samples from the remaining 55 samples collected from onsite monitoring and observation wells screened within the water table zone at concentrations ranging from 3.43 J µg/L (O-24) to 17,600 µg/L (MW-336-15). Sulfolane concentrations detected in groundwater samples collected from wells O-1, O-24, O-34, O-35, O-36, O-37, MW-131-25, MW-176A-15, MW-179A-15, MW-355-15 (October 10 and November 25 samples), S-21, and S-43 were flagged as estimated. The sulfolane concentration for the sample collected from well O-31 was rejected due to hydrocarbon interference as discussed in Section 6. Sulfolane concentration isopleths within the water table zone are presented on Figure 4-18.

4.6.2.2 *10 to 55 Feet Below the Water Table*

Sulfolane was not detected in 37 samples collected from onsite monitoring and observation wells screened within the 10 to 55 feet below the water table zone. Sulfolane was detected in the remaining 37 samples collected from onsite wells at concentrations ranging from 3.61 J µg/L (MW-176B-50) to 34,800 µg/L (MW-336-20).

Sulfolane concentrations detected in the groundwater samples collected from wells MW-142-65, MW-174A-50, MW-176B-50, MW-179B-50, MW-301-60, MW-303-CMT-59, MW-305-CMT-18, MW-305-CMT-28, MW-336-55, MW-348-65, MW-364-65 (November 18 and 22, 2013), and O-27-65 were flagged as estimated, as described in Section 6. The estimated extent of the sulfolane plume in the 10 to 55 below water table zone is identified on Figure 4-19. The sulfolane isopleth near MW-310-65 and MW-330-65 takes into consideration data from hydropunch sampling completed in this area as presented in the Onsite SCR – 2013 (ARCADIS 2013c).

4.6.2.3 *55 to 90 Feet Below the Water Table*

Sulfolane was not detected in 21 samples collected from onsite monitoring wells screened within the 55 to 90 feet below the water table zone. In the remaining samples collected from this depth zone, sulfolane was detected in ten samples at concentrations ranging from 3.85 J µg/L (MW-362-80) to 26.8 µg/L (duplicate sample from MW-154B-95). Sulfolane concentrations detected in groundwater samples collected from wells MW-154A-75, MW-186E-75, MW-301-70, MW-303-70, MW-345-75, MW-360-80, and MW-362-80 were flagged as estimated, as described in Section 6. The estimated extent of the sulfolane plume in this zone is shown on Figure 4-20.

4.6.2.4 *90 to 160 Feet Below the Water Table*

Sulfolane was not detected in groundwater samples collected from onsite monitoring wells screened 90 to 160 feet below the water table. Sulfolane analytical results from samples collected from monitoring wells screened within this depth zone are presented on Figure 4-21.

4.6.2.5 *Vertical Profiling Transect*

Groundwater sampling was conducted at the VPT wells to evaluate the vertical distribution of sulfolane concentrations. Sulfolane results for the VPT wells are summarized in Table

4-12 and shown on Figure 4-22. Additionally, Figures 4-18 through 4-21 show sulfolane concentrations for the VPT cluster locations at depths appropriate for each figure.

At the MW-301 well cluster, sulfolane was not detected in the samples collected from 10, 20, 30, 40, and 50 feet bgs. Estimated concentrations of sulfolane in groundwater were detected at 3.73 J µg/L and 5.63 J µg/L in samples collected from the 60- and 70-foot bgs depth intervals, respectively. The 70-foot bgs interval is the deepest well installed at this location because permafrost was encountered at 70 feet bgs.

At the MW-302 well cluster, sulfolane in groundwater was detected at a maximum concentration of 52.7 µg/L in the sample collected from the 20-foot bgs depth interval. From this depth interval, detectable sulfolane concentrations decreased with depth to 14.7 µg/L in the sample collected at 80 feet bgs. Sulfolane concentrations were not detected in the samples collected from 95 and 110 feet bgs. The well installed at 110 feet bgs is the deepest well installed at this location because permafrost was encountered at this depth.

At the MW-303 well cluster sulfolane was not detected in groundwater in the sample collected at the water table. Sulfolane was detected at a maximum concentration of 51.2 µg/L in the groundwater sample collected at 29 feet bgs. Sulfolane decreases with depth to an estimated detection of 5.5 J µg/L in the sample collected at 70 feet bgs. Sulfolane concentrations were not detected in samples collected at 80, 95, and 130 feet bgs. The well installed at 130 feet bgs is the deepest well installed at this location because permafrost was encountered at this depth.

At the MW-304 cluster, the maximum sulfolane detection in groundwater was 352 µg/L in the duplicate sample collected at 15 feet bgs, but decreased with depth to 40 feet bgs (25.4 µg/L). Sulfolane concentrations were not detected in the groundwater samples collected at 50, 60, 70, 80, 95, 125, and 150 feet bgs. The well installed at 150 feet bgs is the total depth sampled in MW-304.

At the MW-305 cluster, only estimated sulfolane concentrations of 3.80 J and 6.71 J µg/L were detected in samples collected from the 18- and 28-foot depth intervals, respectively. Sulfolane concentrations were not detected in the samples collected from 38, 48, 58, 70, 80, and 100 feet bgs. The well installed at 100 feet bgs is the deepest well installed at this location because permafrost was encountered at 110 feet bgs. No groundwater was present at the 8-foot depth interval.

At the MW-306 cluster, sulfolane was not detected in any of the groundwater samples collected to the total depth of 150 feet bgs.

4.6.3 Sulfolane Mass Flux

A quarterly analysis of mass flux using analytical data collected across the VPT was recommended in the Fourth Quarter 2012 Groundwater Monitoring Report (ARCADIS 2013f). Methods to calculate mass flux and site-specific geologic input data are included as Appendix I. The Mass Flux Toolkit (Toolkit) developed by GSI Environmental for the Department of Defense Environmental Security Technology Certification Program (Farhat et al. 2006) was used to calculate sulfolane mass flux across the VPT.

Sulfolane mass flux across the VPT was first calculated with this method from data collected in November 2011 and was reported in the SCR – 2011 (Barr 2012). Mass flux in November 2011 was estimated at approximately 86 grams per day (g/day; or 0.19 pound per day [lb/day]). A sulfolane mass flux of approximately 43 g/day (0.095 lb/day) was calculated for the reporting period, which is approximately one-half of the initial flux calculated based on samples collected in November 2011. Mass flux increased slightly from third quarter (35 g/day) and may be attributed to rebounding near the AS pilot system. Mass flux rates across the VPT are decreasing and are presented on Figure 4-23. The zones where the majority of mass flux is occurring are summarized in Table 4-13. These zones are consistent with observations from the rest of 2013.

During the reporting period, 95 percent of the total sulfolane mass flux was discharged across the VPT occurred near MW-302 (water table to approximately 90 feet bgs), MW-303 (water table to approximately 70 feet bgs), and MW-304 (water table to approximately 42 feet bgs zone; Figure 4-23). In addition, the sample concentrations within the 60- and 70-foot intervals at MW-301; the 59- and 70-foot intervals at MW-303; and the 18- and 28-foot intervals at MW-305 were flagged as estimated by the laboratory (J-flags). This estimation may skew the mass discharge distribution, reducing the relative magnitude of the total contribution to flux of the zones of the transect where sulfolane was actually detected with greater analytical certainty.

During the reporting period, sample intervals for VPT well clusters MW-301 and MW-305 indicated low mass discharge and no mass discharge, respectively. There is likely no significant mass flux of sulfolane at the lateral edges of the plume at these locations. The Toolkit (Farhat et al. 2006) assumes a concentration boundary of zero at each end of the transect. Because no detections were reported in MW-305 or the deep intervals from well clusters MW-303 and MW-305, these sampling points act as a boundary and therefore were assigned values equal to zero rather than one-half of the detection limit.

4.7 Sulfolane Distribution in Offsite Groundwater

FHRA installed a total of 165 offsite monitoring wells including 43 new monitoring wells during 2013 (Phase 8 monitoring wells; see Figure 2-4) to characterize the nature and extent of sulfolane impacts and permafrost depths offsite (ARCADIS 2013d). In addition, FHRA compiled data from an extensive review of available private well logs, collected information regarding construction of private wells from property owners, and had discussions with well drillers regarding private well depths and the depths to both the top and bottom of permafrost. A total of 45 private wells have been identified as having been installed beneath permafrost and are located throughout the detectable sulfolane plume, depths ranging from 30 to 353 feet bgs. This list of wells includes deep private wells identified in the monitoring plan (ARCADIS 2012b) that are sampled quarterly as described in Section 3.8.

During this reporting period, groundwater samples were collected from 139 offsite monitoring wells, including 22 newly installed Phase 8 wells, and 37 offsite private wells, and were submitted for sulfolane analysis. The offsite monitoring well data are presented in Table 4-11. Results from private wells sampled for the first time during the reporting period are presented in Table 4-14, while results from the private well resampling event are provided in Table 4-15. Results from the deep private well monitoring network for 2013 are presented in Table 4-16. Offsite sulfolane distribution is shown on Figures 4-24 through 4-26. Historical sulfolane analytical results are included in Appendix C.

4.7.1 Private Well Sampling Results

As stated in Section 3.7, sampling of private wells was conducted from November 11, 2009 through December 16, 2013; results received as of December 16, 2013 are included in this report. Since November 2009, groundwater samples have been collected from 640 private wells located within the search areas and analyzed for sulfolane. Samples collected through May 11, 2011 were analyzed for sulfolane using USEPA Method 8270D. Subsequent samples were analyzed using USEPA Method 1625B with isotope dilution. Private wells sampled for the first time during this reporting period were analyzed for sulfolane using USEPA Method 1625B with isotope dilution and are presented in Table 4-14. In addition, private wells that were resampled during the reporting period were also analyzed for sulfolane using USEPA Method 1625B with isotope dilution and are presented in Table 4-15.

During the reporting period, 13 initial samples were collected from private wells inside and outside of search areas. Of these 13 initial samples, only two samples, from private wells located inside of the search areas, contained detectable concentrations of sulfolane (PW-1493 at 12.8 µg/L and PW-1494 at 100 µg/L), as indicated on Figure 3-1. Well locations are shown on the figure in Appendix B. Initial samples collected during the reporting period are indicated using a halo on Figure 3-1.

During this reporting period, four resamples were collected from private wells near the plume edge that previously did not contain detectable concentrations of sulfolane. None of the resampled private wells had sulfolane detections. Two resamples were collected from two city fire wells (Section 3.7). No sulfolane was detected in one fire water well and the other fire water well (PW-1491) only had an estimated concentration of sulfolane at 4.66 J µg/L (Table 4-15).

The most recent data for each residential data point are shown on Figure 3-1 with color gradation to indicate the concentration. In addition, 85 raw water samples collected at location with a POE treatment system ("A" samples; excludes warehouse sample not in plume) were collected during the reporting period were merged into the residential sulfolane database to further develop the hydrogeologic conceptual site model and evaluate analytical trends. Raw water data for locations with a POE treatment system are included in the dataset shown on Figure 3-1.

Historical private well data, including historical POE treatment system data for raw water samples, are presented in Appendix C. Laboratory reports and associated ADEC data review checklists reviewed during the reporting period are presented in Appendices D and E, respectively. Data were evaluated for potential sulfolane concentration trends and results are discussed in Section 4.9.3 and included in Appendix J.

4.7.2 Deep Private Monitoring Results

Third quarter groundwater samples were collected from September 5 through 26, 2013 from 18 private wells. Groundwater samples collected during fourth quarter were collected from November 19 through December 17, 2013 from 18 private wells. Deep private well results are summarized in Table 4-16 and shown on Figure 4-27. Laboratory analytical results from groundwater samples collected during the reporting period are included as Appendix D. Field data sheets for deep private well monitoring are provided in Appendix F.

Sulfolane was detected at a concentration of 652 µg/L in the groundwater samples collected from deep private well PW-1230 during the third quarter 2013, and at concentrations of 639 and 657 µg/L in the original and duplicate fourth quarter samples, respectively. Consistent with 2013 data, well PW-1230 contains the highest offsite sulfolane concentration.

4.7.3 Subpermafrost and Suprapermafrost Aquifers

Permafrost is present under much of the offsite area as a relatively continuous mass that extends beyond the northern and western extents of the NPR boundary as defined in the Offsite SCR – 2013 (ARCADIS 2013d). Permafrost is absent under the Tanana River and is truncated on a portion of the eastern edge of the sulfolane plume by a thawed zone beneath Badger Slough. The permafrost body appears to extend beneath Badger Slough near the northern limit of the plume and possibly near Hurst Road.

Wells installed within the suprapermafrost aquifer include offsite monitoring wells and private wells with reliable information indicating the intake is within the suprapermafrost. A total of 45 private wells have been identified as installed beneath permafrost. There are no offsite monitoring wells installed beneath permafrost.

Figure 4-24 shows the cumulative sulfolane analytical results from offsite monitoring wells along with private wells in both the suprapermafrost and subpermafrost aquifers. This includes private wells that do not have available or reliable well construction information and, therefore, cannot be designated to either the suprapermafrost or subpermafrost aquifer. The following sections present the analytical data collected from offsite groundwater monitoring wells and private wells during the reporting period.

4.7.3.1 *Offsite Sulfolane Distribution in the Suprapermafrost Aquifer*

Offsite monitoring wells were sampled during the reporting period on October 2 through 5, 7, 8, 9, and 11, 12, 15, 21 and 31; and November 12, 2013. Additionally, groundwater results from newly installed Phase 8 monitoring wells sampled on September 25, 26, 27, and 30, 2013 (after the third quarter data cut-off) are included in this report. A total of 139 offsite monitoring wells were sampled and analyzed for sulfolane. Private wells are sampled on an ongoing basis through annual Alternative Water Solution monitoring, POE system maintenance monitoring, and the quarterly deep private well monitoring program. Private wells installed to a depth of 40 feet bgs or shallower were assumed to be installed above permafrost and are used to evaluate the distribution of sulfolane in the suprapermafrost aquifer.

Based on offsite data collected during the reporting period, which includes initial samples from newly installed monitoring wells and private wells, sulfolane was not detected above the detection limit in samples collected from 58 monitoring wells, 11 initial private wells and five resampled private wells. Sulfolane was detected in the suprapermafrost aquifer at concentrations ranging from 3.38 J µg/L (MW-316-15) to 230 µg/L (MW-332-150). However, based on the results of the geophysical surveys and preliminary data reported by UAF, monitoring wells MW-332-110 (25.7 µg/L), MW-332-150 (230 µg/L), MW-346-15 (7.19 J µg/L), MW-346-65 (22.7 µg/L), and MW-346-150 (<6.20 µg/L) appear to be installed in an area just beyond the edge of a large permafrost body. Sulfolane concentrations in these wells may be indicative of a “mixing zone” between the sub- and suprapermafrost aquifers, as shown on Figures 4-24 and 4-25.These results are presented in Tables 4-11, 4-14, and 4-15 and on Figure 4-25.

Figure 4-25 presents the detectable sulfolane suprapermafrost plume. The detectable sulfolane plume is currently delineated by offsite monitoring wells and shallow private wells. The detectable sulfolane plume in the suprapermafrost aquifer extends beyond the site boundary to approximately 3.6 miles downgradient. At the North Property Boundary (NPB), the detectable sulfolane plume is estimated to be approximately 1,000 feet wide. Due to the local hydrogeology (i.e., presence of permafrost and seasonal hydrogeologic cycles), the width of the sulfolane plume increases to approximately 1.5 miles (7.900 feet) at the distal end, likely due to the presence of shallow permafrost and seasonal fluctuations in groundwater flow directions.

4.7.3.2 *Offsite Sulfolane Distribution in the Subpermafrost Aquifer*

Of the 13 private wells sampled for the first time during the reporting period, only well PW-1493 was identified to be installed beneath permafrost. Sulfolane was detected at a concentration of 12.8 µg/L at this location. Figure 4-26 presents the most recent sulfolane data collected from the last 12 months from private wells identified as reportedly installed beneath permafrost. This includes samples collected quarterly as part of the deep private well monitoring network.

The highest sulfolane concentrations measured at private wells known to be within the subpermafrost aquifer were measured at private well PW-1230 (657 µg/L), located approximately one mile northwest of the NPB. Private well PW-1230 has a total depth of approximately 231 feet bgs.

Sulfolane was not present above the laboratory detection limits of 6.20 to 6.74 µg/L during 2013 in samples collected from perimeter private well locations PW-0972, PW-0259, PW 1343, and PW-0332. The detectable subpermafrost sulfolane plume is shown on Figure 4-26. In some cases, wells with no detectable concentrations are near those with detectable concentrations, and therefore are included within the non-detect contour line.

4.8 **Constituent of Potential Concern Analysis**

Constituent of potential concern (COPC) analysis was initiated during the third quarter 2011 reporting period and COPCs were evaluated in the SCR – 2011 (Barr 2012), which recommended discontinuation of the sampling for additional COPCs other than sulfolane and BTEX. However, per ADEC email correspondence dated July 20, 2012, continued analysis of iron was required. The SCR – 2011 (Barr 2012) recommended continued annual sampling of gasoline range organics, diesel range organics, and iron, to be conducted during the second quarter of each year. The revised COPC program will resume in second quarter 2014. Historical COPC data are summarized in Appendix C.

4.9 **Statistical Analysis of Benzene, Total Xylenes, and Sulfolane Data**

The Mann-Kendall Trend Analysis is a nonparametric statistical method for determining trends for concentrations of a given constituent at a given monitoring well. The protocol described in the Monitoring and Remediation Optimization System (MAROS) will be used to complete the Mann-Kendall Trend analysis for sulfolane in select groundwater monitoring wells. MAROS is a decision support tool developed by the Air Force Center for Engineering and the Environment in order to use statistical methods based on site-specific data. The use of MAROS for Mann-Kendall analysis was applied to groundwater monitoring data collected since 2006 from monitoring wells, observation wells, recovery wells and air sparge pilot monitoring wells. Wells with LNAPL historically present were excluded from the evaluation of benzene and total xylene concentration trends. The analysis trends are expressed as probably increasing, increasing, probably decreasing, decreasing, stable, or no trend.

A statistical and graphical evaluation of benzene, total xylenes and sulfolane concentration trends at monitoring wells is used to evaluate plume migration and stability, interim remedial action effectiveness, and to identify relationships between dissolved-phase concentrations, groundwater elevations, and flow directions. Sulfolane results for private wells were also evaluated during this reporting period.

Analyte	All Results Non Detect	Insufficient Data Points	Probably Decreasing	Decreasing	Probably Increasing	Increasing	Stable	No Trend
Benzene	63	24	2	7	1	1	4	13
Total Xylenes	75	19	2	1	1	0	5	12
Sulfolane (Monitoring Wells)	187	71	19	80	1	11	35	26
Sulfolane (Private Wells)	457	211	1	12	5	47	29	53

4.9.1 Benzene and Total Xylenes Statistical Evaluation

Benzene and total xylenes trend data from 115 wells were reviewed, some of which had data from up to 63 sampling events. Wells with LNAPL accumulation during the reporting period were not included in the statistical evaluation for benzene and total xylenes. Results of the trend analyses for benzene are presented in Table 1 and Figures 1 and 2 of Appendix J, Results for the total xylenes trend analyses are presented in Table 2 and Figure 2 of Appendix J. Time series plots of these analytes are included as an attachment to Appendix J. Benzene and total xylenes data trends are reported as “insufficient” for 24 and 19 wells, respectively, and are not discussed further.

4.9.1.1 *Nondetects, Decreasing, or Stable Trends*

As shown in Table 1 (Appendix J), no analytes detected, decreasing, probably decreasing, or stable trends for benzene were identified at 76 wells. Benzene was not detected in several of the wells outside the onsite process areas (MW-105A-25, MW-106-25, MW-131-25, MW-141-20) or at wells screened at depths well below the water table (MW-101-60, MW-102-70, MW-104-65, MW-105-65, MW-118-45, MW-129-40, MW-153B-55, and MW-186B-60) for the entire data set used in the evaluation . Other wells where benzene was not detected include wells MW-101A-25, MW-105A-25, MW-133-20, MW-134-20, MW-355-15, O-1, O-8, O-14, O-15, O-17 and O-28 which delineate the benzene plume. Additionally, BTEX has not been detected in groundwater collected from several well locations (MW-146A-15, MW-147A-15, MW-148A-15, MW-148B-30, MW-149A-15, MW-149B-20, and MW-153A-15) at or near the north property boundary.

Decreasing or probably decreasing benzene concentration trends were identified in groundwater from eight wells. This includes wells MW-110-20 and MW-139-25 located west of the NPR's rail spur, wells MW-124-25, MW-125-25, MW-136-20, MW-137-20 and active or formerly active recovery well R-42 located near the truck-loading rack. A decreasing benzene trend was also observed in groundwater from well MW-130-25 located west of recovery well R-35R and wells MW-115-15 located near the crude extraction units. At the wells where decreasing benzene concentrations were identified by MAROS, total xylenes were either "decreasing" or "stable" where a trend was able to be analyzed.

Stable benzene concentration trends were identified in groundwater from four wells: MW-116-15 located near the crude extraction units and wells MW-140-25, MW-334-65, and active recovery well R-43 located near the truck-loading rack.

4.9.1.2 *Increasing Trends*

The statistical analysis indicated increasing or probably increasing benzene concentration trends for two wells, which includes well S-9 and active recovery well R-46. These two wells are located near the truck loading rack. Total xylenes exhibit a probably increasing trend in well MW-132-20, located in the former bolted tank area. A statistical trend was not resolved for benzene with the given data set.

Benzene and total xylenes concentrations in groundwater from well S-9 were not detected from second quarter 2012 until third quarter 2013, when benzene and total xylenes were first detected. These detections following several years with nondetect concentrations resulted in MAROS characterizing these analytes' long-term concentration trends as "probably increasing." Benzene concentrations at recovery well R-46 ranged from 0.0364 to 0.0699 µg/L in the MAROS dataset. Total xylenes trend in well MW-132-20 located near the northwest corner of Containment Area 8 and northwest of Tank 110, is characterized as "probably increasing." Benzene and total xylenes concentrations in groundwater from this well were near or below the laboratory reporting limit from 1999 until April 2010, when they exhibited an apparently short-term concentration spike but both compounds have been on a decreasing trend since April 2011.This short-term spike in benzene and total xylenes concentrations following several years with relatively low concentrations caused the MAROS evaluation to characterize these analytes' long-term concentration trends as "probably increasing."

4.9.1.3 *No Trend*

No trend was identified for benzene in groundwater from 13 wells. This includes wells MW-109-15, MW-111-15, and MW-113-15 located west of the rail spur at the NPR. Well MW-111-15 will not be included in future evaluations because it was destroyed and was replaced by MW-174-15 (ARCADIS 2013a). This well is located near the western edge of the BTEX plume, and the absence of a clear concentration trend likely reflects fluctuating concentrations in that area. Data are summarized in Table 1 of Appendix J. Well locations are presented on Figure 2-3.

There was also no clear concentration trend for benzene in groundwater from wells MW-126-25 and MW-127-25 located near the truck-loading rack. Benzene has limited detections in groundwater from well MW-126-25, with some detections greater than 100 µg/L before 1993 and few detections since 1993. Benzene and total xylenes have not been detected in this well since fourth quarter 2010. The benzene concentration in groundwater from well MW-127-25 increased from below the reporting limit in 1997 to a maximum of 500 µg/L in 2001; the concentration decreased from that maximum to below the reporting limit in 2005, with some occasional detections since 2005. The latest benzene result at that location was 54.6 µg/L. Total xylenes concentration also exhibits no trend at well MW-127-25.

Benzene and total xylenes have not been detected in wells MW-142-20, MW-143-20, MW-144A-25, and MW-145-20 since, 2011, 2009, 2009 and 2011, respectively so no trend was identified. These wells are located at or near the northern extent of the benzene and total xylenes plumes. While benzene was historically detected in groundwater from these wells, the detections were infrequent. Benzene was detected in groundwater from wells MW-144A-25 and MW-145-20 twice between 2006 and 2011, and was also detected at low concentrations (0.931 to 2.21 µg/L) during 2009 in groundwater from well MW-143-20. Benzene was detected in groundwater from MW-142-20 periodically between 2002 and 2005, and again at relatively low concentrations in 2008, 2009, and 2011. Benzene and total xylenes concentrations in groundwater at these locations have remained below their detection limits for a minimum of two consecutive years.

Lastly, wells MW-154A-75, MW-154B-95, and O-12 also exhibit no concentration trends. Benzene concentrations in wells MW-154A-75 and MW-154B-95 have been below the detection limits except for low detections (below 1 µg/L) in 2013. Benzene was detected twice in groundwater from well O-12, with the latest detection in 2013 at 16.9 µg/L.

4.9.2 Monitoring Well Sulfolane Statistical Evaluation

Sulfolane trend data from 430 wells were reviewed, some of which had data from up to 67 sampling events. Well locations with insufficient data points were included in the analysis presented in Appendix J, but were reported as "insufficient" and trends were not identifiable. Concentration trends for 71 wells are reported as “insufficient” and are not discussed further.

Results of the trend analyses for sulfolane are presented in Table 3 of Appendix J and discussed below. Figures 3 through 6 show the sulfolane trends for onsite wells and Figure 7 shows the sulfolane trends for offsite wells. Concentration plots of sulfolane through time are included in Appendix J. The Fourth Quarter 2012 Groundwater Monitoring Report (ARCADIS 2013f) included trends calculated from sulfolane concentrations analyzed by both laboratory methods and trends calculated using only sulfolane concentrations analyzed by method USEPA Method 1625B. The fourth quarter 2013 statistical analysis for sulfolane was completed using a dataset that includes data from both sulfolane analytical methods. Sulfolane samples were analyzed by modified USEPA Method 1625B with isotope dilution starting May 11, 2011; USEPA Method 8270D was used prior to this date. This switch is indicated on the sulfolane trend charts included as an attachment to Appendix J.

4.9.2.1 *Nondetects, Decreasing, or Stable Trends*

As shown in Table 3 (Appendix J), 187 wells have not yielded samples containing detectable sulfolane since 2006 or the first monitoring event (if the well was installed or monitoring was initiated after 2006). The MAROS trend evaluation indicated that sulfolane concentrations in groundwater at 99 wells are decreasing or likely decreasing, and concentrations in groundwater at 35 wells are stable (Table 3).

Decreasing or likely decreasing trends were also exhibited by most of the onsite water table wells including MW101A-25, MW-109-15, MW-110-20, MW-111-15, MW-115-15, MW-127-25, MW-130-25, MW-131-25, MW-134-20, MW-139-25, MW-142-20, MW-143-20, MW-149A-15/B-20, MW-176A-15, MW-178A-15, MW-179A-15, MW-186A-15, MW-309-15, MW-310-15, MW-321-15, and MW-334-15 and some wells screened from 10 to 55 feet below the water table located within the sulfolane plume (MW-101-60, MW-174A-50, MW-186B-60, MW-309-66 (Figures 2-3 and 2-4). These wells are mostly located near the NPR’s rail spur and crude extraction units. Wells MW-116-15, MW-186E-75, MW-334-65 and R-35R located within the sulfolane plume resulted in stable trends. Twenty-five of the 59 VPT wells showed decreasing or stable concentration trends. Decreasing concentration trends in the VPT wells are consistent with the lower sulfolane mass flux recorded across the VPT since November 2011.

In the offsite area, decreasing trends were observed in monitoring wells screened at a range of depths. Wells MW-148B-30/C-55, MW-150A-10/B-25, MW-151A-15/B-25/C-60, MW-152B-25/C-65, MW-153A-15, MW-154A-75, MW-155A-15, MW- 156A-15/ B-50, MW-157A-15, MW-158A-15/B-60, MW-159B-45/C-70, MW-160B-90, MW-162A-15/B-65, MW-163B-40, MW-164B-50/ C-60, MW-193A-15/ B-60, MW-317-15/71, MW-329-15/66. These locations are located in the southern and central portion of the offsite sulfolane plume, with the exception of well MW-329-15/66, which is located near the downgradient edge of the plume.

Groundwater from wells exhibiting decreasing or stable concentrations include all AS monitoring wells with the exception of well AS-MW-1, where a trend was not resolved. The trends in these wells will be evaluated as sulfolane concentrations rebound in the treatment zone post-shutdown.

4.9.2.2 *Increasing Trend*

Using the data from 2006 through the current reporting period, groundwater concentrations from 12 wells (MW-153B-55, MW-161A-15, MW-166A-15, MW-166B-30, MW-167A-15, MW-167B-35, MW-168A-15, MW-168B-50, MW-187-15, MW-308-15, MW-321-65 and MW-332-150) were found to have increasing or likely increasing sulfolane trends. Most of these wells are located at or near the leading edge of the offsite sulfolane plume, except wells MW-321-65 (west of the NPR’s rail), MW-153B-55 (near the northern site boundary) and MW-332-150 (in the eastern portion of the offsite plume). The maximum sulfolane concentrations were detected at wells MW-161A-15 (226 µg/L) and MW-332-150 (236 µg/L) during third quarter 2013.

4.9.2.3 *No Trend*

The MAROS evaluation using the sulfolane dataset from 2006 through the reporting period characterized the groundwater concentrations from 26 wells as having no trend. Some of these wells have a relatively small sample set, with four to nine samples each.

Wells MW-178B-50 and MW-179B-50 are located within the sulfolane plume onsite, north of the Crude Unit #2 Extraction Unit area. Sulfolane concentrations in groundwater from well MW-178B-50 have varied from less than 100 µg/L to approximately 300 µg/L, while sulfolane concentrations in groundwater from well MW-179B-50 have either been below the detection limit or estimated below the limit of quantitation (LOQ). Wells MW-183A-15 and MW-194B-40 are located near the northwestern plume boundary. Both locations exhibit fluctuating concentrations of sulfolane of up to approximately 100 µg/L.

Well MW-105-25 is located upgradient from the site and sulfolane concentrations in this well have been below the detection limit, except for one detection in third quarter 2012 (155 µg/L). Sulfolane has not been detected at this location for the last four quarters.

Well MW-176B-50 is located within the southern portion of the onsite plume and has been below the detection limit until the current reporting period, when sulfolane was detected at a concentration of 3.21 J µg/L.

Wells MW-303-CMT-9 and MW-304-96 are located along the VPT and have had fluctuating sulfolane concentrations ranging up to 10 µg/L in the MAROS dataset.

Observation wells O-4, O-6, and O-19 have fluctuating concentrations without a discernible trend.

4.9.3 Private Wells and Point of Entry Treatment System Sulfolane Statistical Evaluation

Sulfolane trend data from 815 private wells, including locations with POE treatment systems samples, were reviewed, some of which had data from up to 46 sampling events. Results of the trend analyses for sulfolane are presented in Table 4 and on Figures 7 and 8 of Appendix J and discussed below. Concentration plots of sulfolane in private wells through time are included in Appendix J.

Well locations with insufficient data points were included in the analysis presented in Appendix J, but were reported as "insufficient." Datasets for 211 wells are reported as “insufficient” and these wells are not discussed further. This includes private wells that were sampled for the first time during fourth quarter 2013.

The fourth quarter 2013 statistical analysis for sulfolane was completed using a dataset that includes data from both sulfolane analytical methods. Sulfolane samples were analyzed by modified USEPA Method 1625B with isotope dilution starting May 11, 2011; USEPA Method 1625B was employed prior to this date. This switch is indicated on the sulfolane trend charts included in Appendix J.

4.9.3.1 *Nondetects, Decreasing, or Stable Trends*

As shown in Appendix J Table 4, 457 locations have not yielded samples containing detectable sulfolane. Further, MAROS trend evaluation indicated that sulfolane concentrations in groundwater at 17 wells are decreasing or likely decreasing, and concentrations in groundwater at 29 wells are stable. The trends for sulfolane for private well samples are shown on Figures 7 and 8 in Appendix J. The majority of nondetect, stable, decreasing, and likely decreasing trends are located along the fringes of the offsite plume and near the southern boundary of the offsite plume, as shown on Figures 7 and 8 in Appendix J.

4.9.3.2 *Increasing Trend*

Using the data from 2006 through the current reporting period, groundwater concentrations from 52 private wells were found to have increasing or likely increasing trends. This includes eight wells from the deep private well monitoring network (PW-0463, PW-0464, PW-0466, PW-0658, PW-0932, PW-0943, PW-1109, and PW-1155). As presented on Figures 7 and 8 in Appendix J, locations with increasing or likely increasing trends are primarily located along the leading edge of the offsite sulfolane plume. The highest detections were observed at wells PW-1096 and PW-1230. Sulfolane results at well PW-1096 ranged from 288 µg/L (September 20, 2014) to 463J* µg/L (November 27, 2012). Well PW-1230 ranged from 517 µg/L (March 28, 2013) to 657 µg/L (December 2, 2013). Trend analyses completed on the datasets from these two wells resulted in “no trend.” However, both wells PW-1096 and PW-1230 have relatively small sample sets (6 and 5 samples, respectively). In addition, well PW-1230 was only sampled during 2013. These limited datasets are not sufficient to identify seasonal concentration fluctuations and the results of the trend analysis should be considered with respect to both the limited number of samples and the limited monitoring period for PW-1230. Therefore, the trends calculated should not be considered long-term trends until additional data are collected for these wells.

4.9.3.3 *No Trend*

Using the data from 2006 through the current reporting period, the MAROS evaluation characterized the sulfolane concentrations as having no trend in groundwater from 53 wells. All of these wells have small sample sets with four to 10 samples and varying concentrations. As shown on the historical sulfolane chart for this well (Appendix J), an increasing or decreasing trend is not evident due to several alternating cycles of rising and falling concentrations.

4.10 **Geochemical Parameters**

As proposed in the Offsite SCWP (ARCADIS 2013b), geochemical parameter monitoring is performed annually during the third quarter of each year to characterize the potential for natural attenuation of sulfolane at the site. Geochemical parameter monitoring will resume during third quarter 2014.

Field geochemical parameters collected from sulfolane and BTEX monitoring networks during the reporting period are consistent with historical data collected at the site and are included in Table 4-1. Field data sheets are included as Appendix F. Historical geochemical data are summarized in Appendix C.

4.11 Nonroutine Activities

Nonroutine activities completed during the reporting period include air sparge (AS) pilot test post-shutdown monitoring and site characterization activities completed after the Onsite SCR – 2013 (ARCADIS 2013c) cutoff date of November 20, 2013.

4.11.1 Air Sparging Pilot Test Post-Shutdown Monitoring

Sulfolane monitoring results from the Gallery Pond and bench-scale testing results indicated that sulfolane removal is potentially associated with aeration of recovered groundwater. Therefore, FHRA commenced an air sparge pilot test in 2012 to evaluate whether aeration of the aquifer via AS could create conditions for in-situ sulfolane removal. A technical memorandum describing the pilot test startup, monitoring results and data evaluation was included as an appendix to the Interim Remedial Action Plan Addendum (ARCADIS 2013e). An updated technical memorandum was included as Appendix 14-A of the Onsite SCR – 2013 (ARCADIS 2013c). Actions taken during the reporting period are summarized below.

The AS pilot test was conducted from 2012 until the system was shut down on July 10, 2013, after 70 weeks of operation. Following system shutdown, monitoring was continued to evaluate the longevity of DO in the aquifer and the timing of the rebound in sulfolane concentrations. During the reporting period, monitoring was completed biweekly with events occurring 12 to 24 weeks post-shutdown.

As shown in Table 4-17, at the end of the injection period and prior to system shutdown, the AS monitoring wells did not contain detectable concentrations of sulfolane, except AS-MW-1 and AS-MW-8. As shown on Figure 4-28, AS-MW-1 is located on the perimeter of the AS injection area and AS-MW-8 is upgradient from the system. Post-shutdown monitoring results show a slow decrease in DO concentrations and correspondingly slow rebound of sulfolane concentrations in the downgradient monitoring wells, except in AS-MW-5. At location AS-MW-5, which is located directly downgradient from the injection points, sulfolane has not been detected in any of the post-shutdown samples through the end of the reporting period (24 week post-shutdown).

FHRA intends to continue post-shutdown monitoring during the first quarter 2014.

4.11.2 Light Nonaqueous Phase Liquid Composition Sampling

On October 16 and 17, 2013, two LNAPL samples were collected from observation wells O-31 and O-34 and sent to Friedman and Bruya, Inc. for compositional analysis. Paraffin, isoparaffin, aromatic, naphthene, or olefin (PIANO) bar charts from the FHRA-provided refined product samples were used to evaluate sample composition. PIANO bar charts for the refined product samples are provided on Figure 4-29. PIANO results for the refined product samples are summarized below:

- The gasoline-R and gasoline-P samples have similar PIANO bar charts, with hydrocarbons in the C4 to C8 range dominating the PIANO compound pool. The PIANO bar charts show higher relative proportions of paraffins and naphthenes in the gasoline-R sample compared to the gasoline-P sample, reflecting the difference in grade.

- The naphtha sample shows a similar distribution to gasoline, although it is slightly heavier and contains a greater proportion of paraffins and naphthenes, and lower proportion of aromatics than gasoline.

- The Jet A PIANO data are characterized by a broader and heavier range of hydrocarbons (C6 to C15) respective to gasoline (C4 to C10). Jet A is dominated by paraffins and aromatics.

- Diesel fuel is the heaviest of the FHRA-provided refined product samples; aromatics and paraffins were the dominant classes detected in the PIANO analysis (note that isoparaffins are not measured above the C10 range). The relative contribution of paraffins to the total PIANO pool increases with increasing carbon class, a trend that is indicative of a diesel-type product.

PIANO bar charts for 2013 LNAPL samples are provided on Figure 4-30. Based on the PIANO results, the LNAPL sample from well O-31 is a Jet A/naphtha mixture due to the distribution of paraffins, isoparaffins, aromatics, and naphthenes in the C6 to C9 range, with a higher contribution of paraffins in the heavier hydrocarbon range (C10 to C13). Jet A is the dominant fuel type in well O-34 as the sample predominantly comprising paraffins and aromatics in the C9 to C13 range, with minor contributions of paraffins in the C6 to C8 range. The fourth quarter PIANO data are consistent with the data presented in the Onsite SCR – 2013 (ARCADIS 2013c). Well O-31 is located in the northern portion of the site, where LNAPL composition varies between Jet-A dominated and naptha dominated product types. Well O-31 is located east of well O-13, where the LNAPL is Jet-A dominated. Well O-34 is located in the vicinity of wells R-32 and S-22 that have Jet-A dominated LNAPL.

PIANO laboratory reports for 2013 LNAPL samples are provided in Appendix D.

4.11.3 Tracer Injection Test

Two tracer tests were performed at the site during October and November 2013 as part of the onsite characterization activities. The tracer tests were conducted to collect data necessary to more thoroughly characterize the hydrogeologic and fate and transport properties of the suprapermafrost water-bearing zone and support risk assessments and remedial evaluations associated with the site. Two tracer tests were performed in two areas of the site (Tracer Test Area 1 and Tracer Test Area 2), in accordance with the Tracer Test Field Implementation Plan (ARCADIS 2013g). Data collected through November 20, 2013 are presented in the Onsite SCR – 2013 (ARCADIS 2013c). Data collection is ongoing to further confirm the conclusions drawn through evaluation of the early data.

4.11.4 Soil Analytical Results

Seven soil samples were collected from Phase 8 well installation locations on October 31; November 19 and 26; and December 3, 5 and 20, 2013. Two samples were analyzed for sulfolane and BTEX, while fiver samples were analyzed for sulfolane only. Analytical results are presented in Table 4-18. Sulfolane, benzene, and total xylenes results are presented on Figure 4-31.

The well ID for the sulfolane soil sample collected from well MW-368-15 at 7.7 to 7.8 feet bgs was mislabeled as MW-358-15 on the chain-of-custody. Well MW-358-15 was not sampled for sulfolane, but a sample was collected directly above the water table at well MW-358-60.

5. Remediation System Results and Evaluation

This section summarizes and evaluates the operating results for the existing onsite groundwater remediation system for the reporting period and annually for 2013. This section also provides an update on implementation of the interim corrective actions described in the Interim Remedial Action Plan (IRAP; Barr 2010b), SCR – 2011 (Barr 2012), and Revised Interim Remedial Action Plan Addendum (Revised IRAP Addendum; ARCADIS 2013g).

5.1 Remediation System Overview

Ongoing remediation efforts at the site include groundwater recovery and treatment for sulfolane and BTEX, and LNAPL recovery and recycling, as described in Sections 5.3 and 5.5, respectively. The main components of the remediation systems operated during the reporting period are as follows:

- Groundwater recovery from seven recovery wells (R-21, R-35R, R-42, R-43, R-44, R-45, and R-46). The locations of the wells are shown on Figure 5-1. Wells R-39 and R-40 were removed from service and replaced by R-45 and R-46 during second quarter 2013.

- The recovered groundwater passes through a prefilter for solids removal, a coalescer for LNAPL removal, and four air strippers for removal of volatile organic compounds, and then flows into the Gallery Pond. Groundwater from the Gallery Pond is then pumped through sand filters and a four-vessel granular activated carbon (GAC) system, which were added as part of the IRAP implementation in 2011. The sand filters were added to remove suspended solids, and the GAC system was added to remove sulfolane and other COCs. Treated groundwater is discharged to the South Gravel Pit. The layout of the groundwater recovery and treatment system is shown on Figure 5-1 and a process flow diagram of the system is shown on Figure 5-2.

- Pneumatic LNAPL recovery systems are operated when recoverable LNAPL is present in wells MW-138, R-20R, R-21, R-35R, R-40, R-45, and S-50 (Figure 5-1). FHRA uses a hand-held LNAPL recovery pump or vacuum truck at other locations (R-18, R-22, R-32, R-32R, O-10, MW-176A-15, and MW-334-15) if LNAPL is present and recovery is possible. Recovery wells R-43, R-44, and R-46 also have the capability for pneumatic recovery system operation; however, enough LNAPL for operation of pneumatic recovery systems was not present at these locations during the reporting period or anytime during 2013, with the exception of well R-20R. LNAPL was recovered from additional locations in 2013 during baildown testing, as described in Section 4.5.1 (MW-176A, O-10, O-11, O-27, O-31, O-33, O-34, R-14A, S-21, S-22, S-39, S-44, S-50 and S-51). A manual skimming test was completed at well MW-334-15 due to apparent high transmissivity.

5.2 Associated Permits

As previously discussed, operation of the groundwater pump and treat system currently involves groundwater recovery from seven recovery wells (R-21, R-35R, R-42, R-43, R-44, R-45, and R-46). Recovery well R-42 began operation on July 26, 2011 upon issuance of an amended temporary water use permit (TWUP A2011-48) from the DNR. An additional amendment to TWUP A2011-48 was received on October 3, 2012, which allows increased groundwater withdrawal volume plus withdrawal from more recently installed recovery wells R-43, R-44, R-45, and R-46. Treated groundwater is discharged at the South Gravel Pit in accordance with wastewater disposal permit 2005-DB0012, issued by ADEC. Additional monitoring has been conducted to evaluate the performance of the sand filters and the GAC filter system following startup on June 9, 2011. ADEC approved monitoring to evaluate performance of the GAC filter system prior to establishing a discharge limit for sulfolane. A copy of the amended temporary water use permit is included in Appendix K.

5.3 Groundwater Recovery

The objectives of the recovery well system operation are to remediate sulfolane- and BTEX-impacted groundwater, provide hydraulic control of the dissolved-phase sulfolane and BTEX plumes, and enhance LNAPL recovery.

5.3.1 Reporting Period

Throughout the reporting period, the groundwater recovery rate for the system averaged 347 gallons per minute (gpm), as measured at the treatment system outlet. The groundwater recovery rate for the system averaged 382 gpm during 2013. The system flowrate was reduced during the reporting period due to issues with the treatment system performance as described below in Section 5.3.3, which resulted in the temporary shutdown of five recovery wells. Overall, the groundwater recovery volume in 2013 increased compared to past years, as presented in Section 5.3.2

Pumping rates for the individual recovery wells are measured weekly. The average rates (when active) and the total and percent run times for the reporting period and 2013 are shown in the tables below.

Location	Fourth Quarter 2013 Average Flow Rate	Fourth Quarter 2013 Runtime	Percent Runtime
R-21	48 gpm	1759.9 hours	79.7%
R-35R	51 gpm	1759.3 hours	79.7%
R-42	80 gpm	2,207.0 hours	99.9%
R-43	57 gpm	1,759.9 hours	79.7%
R-44	75 gpm	1,754.6 hours	79.5%
R-45	52 gpm	1,757.8 hours	79.6%
R-46	33 gpm	2,206.6 hours	97.4%

Location	2013 Average Flow Rate	2013 Runtime	Percent Runtime
R-21	48 gpm	8,003.7 hours	91.3%
R-35R	61 gpm	7,988.6 hours	91.2%
R-39	86 gpm	2,900.0 hours	95.6% (prior to shutdown on 5/7/13)
R-40	49 gpm	2,900.5 hours	96.4% (prior to shutdown on 5/6/13)
R-42	94 gpm	8,449.4 hours	96.4%
R-43	72 gpm	5,211.6 hours	88.4% (following startup on 4/30/13)
R-44	64 gpm	5,206.3 hours	88.3% (following startup on 4/30/13)
R-45	57 gpm	5,067.2 hours	88.5% (following startup on 5/7/13)
R-46	36 gpm	5,353.6 hours	94.7% (following startup on 5/10/13)

5.3.2 Cumulative Groundwater Recovery

Table 5-1 summarizes the volume and rate of groundwater recovered monthly from 2009 through the reporting period. Annual groundwater recovery totals, as measured at the final effluent of the treatment system, are summarized below:

- 2009: 69,200,000 gallons

- 2010: 107,100,000 gallons
- 2011: 136,900,000 gallons
- 2012: 188,300,000 gallons
- 2013: 200,815,291 gallons

5.3.3 Groundwater Treatment Performance Evaluation

In accordance with the wastewater disposal permit described in Section 5.2, FHRA conducted monthly monitoring of the treatment system during the reporting period; results are summarized in Table 5-2. Additional monitoring was conducted in November as described below; these results are also included in Table 5-2. Analytical laboratory reports are provided in Appendix D.

As shown in Table 5-2, the sulfolane concentration in the final effluent was below the detection limit during each monitoring event, showing effective removal of sulfolane from the recovered groundwater. For the majority of the reporting period, Vessel A was the lead vessel followed by Vessel B in series, which was followed by Vessels C and D in parallel. However, during a portion of the reporting period, Vessels A and B were operated in parallel to maintain the necessary treatment rate, followed by Vessels C and D in parallel. Additionally, the GAC in Vessels A and B was changed out during the reporting period, and during this time Vessels C and D operated in parallel.

BTEX and PAH concentrations were below detection limits at the final effluent during the October and December monitoring events (Table 5-2); however, during the November monitoring event, the reported BTEX and PAH concentrations were elevated and greater than the wastewater disposal permit limits for benzene, total aromatic hydrocarbon, and total aqueous hydrocarbon. Details of the events leading to the elevated concentrations were provided to ADEC in the Discharge Monitoring Report and are summarized below:

- During the November 14, 2013 sampling event, the technician collecting the samples noticed a petroleum odor in the GAC vessel effluent and notified FHRA. FHRA investigated the odor and determinedLNAPL was accumulating near the gallery pond intake. The triggering event occurred when, after a power outage in the early morning, a bypass valve was opened during change-out of the prefilter cartridges. The open valve created a reduction in the system backpressure leading to an increase in the pumping volume from the recovery wells. The increased pumping volume at the recovery wells lowered the water levels and allowedLNAPL to become entrained into the extraction stream. The volume ofLNAPL was greater than what the coalescer is designed to manage effectively, which then allowedLNAPL to reach the gallery pond.

- FHRA personnel responded and removed the accumulatedLNAPL from the gallery pond on November 14, 2013. The system was then observed to return to normal operating conditions after these response actions were taken.

- The results from the November 14, 2013 sampling event were received on November 20, 2013 and indicated elevated BTEX concentrations in the treatment system effluent (Table 5-2). FHRA promptly notified ADEC of a discharge permit exceedance.

- On November 20, 2013, FHRA began preparing to shut down the system (shutdown was completed on November 21, 2013); however, extreme cold weather and the potential for freezing pipes due to operational limitations with the glycol heat-tracing system prevented a complete shutdown. FHRA reduced the system flowrate from 450 to 80 gpm until successful treatment could be verified. FHRA collected one sample from the treatment system effluent on November 20, 2013; all parameters were below detection limits and in compliance with the discharge permit (Table 5-2).

- FHRA continued to operate the recovery system at a reduced flowrate to allow change-out of the GAC in Vessels A and B. On November 24, 2013, FHRA resampled the treatment system outlet; all parameters were below detection limits and in compliance with the discharge permit (Table 5-2).

- On November 26, 2013, FHRA sampled the treatment system outlet with the Vessels A and B offline for change-out of the GAC to confirm successful operation with only Vessels C and D. All parameters were below detection limits and in compliance with the discharge permit (Table 5-2)

- On December 10, 2013, FHRA completed change-out of the GAC in Vessels A and B and began increasing groundwater extraction rates at the recovery wells. The daily average pumping rate of the recovery wells ranged from 380 to 440 gpm and averaged 405 gpm from December 10 until the end of the reporting period.

5.4 Groundwater Capture Evaluation

As proposed in the Revised IRAP Addendum (ARCADIS 2013g), performance monitoring was conducted to confirm the continued effectiveness of the groundwater extraction and recovery system. This monitoring is currently being completed monthly. Evaluations have been reported previously for June 6, 2013 (Barr 2013a), August 1, 2013 (Barr 2013a, ARCADIS 2013k), and September 30, 2013 (ARCADIS 2013k). Hydraulic capture of the sulfolane and BTEX plumes was assessed using groundwater elevation and groundwater quality data as described below.

5.4.1 Handheld Groundwater Elevation Measurements

Manual groundwater-level measurements were completed concurrently with a top of well casing survey in a subset of site monitoring and observation wells to provide the most accurate groundwater elevation data for delineation of the capture zone of the groundwater recovery system. These measurements were recorded on October 22 and December 18, 2013 and presented in Appendix L. The recovery system was pumping at average rates of 411 and 432 gpm during these measurement events, respectively. No measurements were taken in November. The November measurement event was scheduled, but issues related to performance of the treatment system resulted in FHRA suspending operation of five of the seven recovery wells from November 21 through December 10, 2013.

The interpolated water table contours and the estimated capture zone at the water table for measurements recorded on October 22, 2013 are presented in Appendix L (Figure L-1). The capture zone was also evaluated in cross section at two locations (A-A' and B-B' shown in Appendix L [Figure L-1]). Figure L-2 in Appendix L shows the estimated capture zone on Cross Section A-A' and Figure L-3 in Appendix L shows the estimated capture zone on Cross Section B-B'. These capture zones are similar in depth to those estimated for August 1, 2013. The procedures used to estimate the capture zones in plan view and cross section are described in the Startup Aquifer Testing Report (Barr 2013a) and Third Quarter 2013 Groundwater Monitoring Report (ARCADIS 2013k). In the email transmitting their comments on the Startup Aquifer Testing Report (Barr 2013a), ADEC indicated their agreement that the capture zone evaluations suggest good capture by the groundwater recovery system (Cardona 2013).

The interpolated water table contours and the estimated capture zone at the water table for measurements recorded on December 18, 2013 are presented on Figure L-4 in Appendix L. The capture zone was also evaluated in cross section at two locations (A-A' and B-B' shown in Appendix L [Figure L-1]). Figure L-5 in Appendix L shows the estimated capture zone on Cross Section A-A' and Figure L-6 in Appendix J shows the estimated capture zone on Cross Section B-B'. These capture zones are similar in depth to those estimated in prior months and extend below the screens of wells with detectable concentrations of sulfolane near the recovery wells.

As with the capture zone evaluation for September 30, 2013, the October 22 and December 18, 2013 capture zone evaluations include a measurement of the NGP stage. A series of control points along the shoreline of the pit were used with the estimated elevation shown on Figures 1 and 4 in Appendix L. This approach assumes that the NGP stage is the water table elevation (there is no loss of head from the NGP to the suprapermafrost aquifer).

Additional wells were included in the October 22 and December 18, 2013 measurement events, which allowed an expanded evaluation compared to the September 30, 2013 event. Unlike the estimate for September 30, 2013 (ARCADIS 2013k), the estimated capture zone for October 22, 2013 does not extend to the NGP. This is consistent with groundwater capture zone modeling during design of the recovery system expansion (ARCADIS 2013g). The estimated capture zone for December 18, 2013 extends to the NGP. The addition of new monitoring wells near the NGP in 2014 will aid in determining the western extent of the capture zone.

5.4.2 Capture Zone Summary

With implementation of the IRAP improvements in January 2010, FHRA began to increase the overall groundwater recovery rate. Groundwater recovery rates further increased in July 2011 following the installation of R-42, and again in June 2013 following implementation of the Revised IRAP Addendum and the installation of wells R-43, R-44, R-45, and R-46 (ARCADIS 2013e). The effects of these improvements and additions demonstrated in the hydraulic capture zone analysis (Barr 2013a) and the monthly measurement events since August 2013, indicate that the groundwater recovery system is attaining hydraulic control at the water table from east of MW-137-20 westward to the MW-309 nest (Appendix L [Figure L-1]). The groundwater recovery system pumping rates at the times of the capture zone evaluations were 486, 402, 411, and 432 gpm on August 1, September 30, October 22, and December 18, 2013, respectively. The capture zone at the water table encompasses the benzene and total xylenes plumes. The capture zone at the water table also encompasses the sulfolane plume with the exception of its western limit, which is the target of the recovery system expansion (ARCADIS 2013g). The estimated capture zone extends vertically to depths up to 80 feet bgs, below the known extent of detectable sulfolane concentrations in this area.

5.5 Light Nonaqueous Phase Liquid

5.5.1 Volumetric Recovery Rates

During the reporting period, FHRA performed LNAPL recovery via skimmer systems when adequate LNAPL thickness was present at wells R-20R, R-21, R-45, and S-50 (Figure 5-1). During 2013, skimmer systems were also used at wells MW-138 and R-40. Additionally, manual LNAPL recovery was completed during the reporting period with a vacuum truck or portable LNAPL pump at wells MW-334-15, O-10, R-18, R-32, and R-34. The coalescer also removed LNAPL that was recovered by the groundwater extraction and recovery system. The recovered LNAPL from the skimmer systems and manual recovery activities is recycled within a refinery process unit.

LNAPL recovery during the reporting period is summarized in Table 5-3. During this period, 400 gallons of LNAPL were recovered, the majority of which was from wells MW-334-15, R-20R, R-21, R-32, and R-45. In 2013, 804 gallons of LNAPL were recovered.

Table 5-4 summarizes LNAPL recovery at the site since 1986. From 1986 to present, approximately 394,400 gallons of LNAPL have been recovered.

5.5.2 Transmissivity

As mentioned in Section 3.2, LNAPL transmissivity results will be used to quantify relative LNAPL recoverability to focus LNAPL recovery efforts in areas that have higher recovery potential and to establish practical limits of recovery. LNAPL baildown testing is currently performed twice a year targeting the hydrogeologic minima as proposed in the 2013 Onsite SCWP (ARCADIS 2013a).

5.6 **Benzene, Toluene, Ethylbenzene, and Total Xylenes Mass Capture**

FHRA monitored the cumulative BTEX concentrations in recovered groundwater on a monthly basis to calculate mass removal rates (Table 5-5). The rates were calculated from BTEX concentrations measured in the treatment system influent during the reporting period. Based on the monthly monitoring results, BTEX mass removal averaged 1.94 lb/day and totaled approximately 175 pounds during the reporting period. For 2013, the treatment system removed approximately 403 pounds of BTEX.

5.7 **Sulfolane Mass Capture**

5.7.1 Per Well

FHRA monitored the sulfolane concentration in recovered groundwater at each active recovery well on a monthly basis; mass recovery rates for each well are summarized in Tables 5-6a through 5-6g. During the reporting period, the highest mass recovery rate was measured at well R-21 (0.18 lb/day; Table 5-6g). Well R-46 had no measurable recovery of sulfolane and is considered to be outside the sulfolane plume (Table 5-6a). However, groundwater recovery continues at well R-46 to maintain capture of the BTEX plume in this area.

5.7.2 Cumulative

Table 5-7 summarizes the sulfolane mass removal rates for the overall groundwater recovery system. The rates were calculated from sulfolane concentrations measured monthly in the treatment system influent. Approximately 45,900,000 gallons of sulfolane-impacted groundwater were remediated during the reporting period. Sulfolane mass removal averaged 0.37 lb/day and totaled approximately 34 pounds during the reporting period. For 2013, the groundwater extraction and recovery system removed approximately 142 pounds of sulfolane.

5.8 Sulfolane Concentration Trend Evaluation

5.8.1 Monitoring Wells

FHRA monitors sulfolane concentrations quarterly and BTEX concentrations semiannually to determine trends in order to evaluate the performance of the groundwater extraction and recovery system. To complete this evaluation, monitoring locations were selected and categorized per their relative location to the groundwater recovery wells (Figure 5-1). This list was first presented in the Second Quarter 2013 Groundwater Monitoring Report (ARCADIS 2013h) and was expanded to include additional locations per the Revised IRAP Addendum (ARCADIS 2013g):

- Upgradient wells: O-5, O-5-65, O-6, O-19, MW-130-25, MW-175-90, MW-199-150, and S-43.
- Wells within the treatment zone: O-2, MW-113-15, MW-125-25, MW-186 A-15/B-60/E-75, and MW-334-15/65.
- Downgradient wells: MW-127-25, MW-129-40, MW-139-25, MW-142-20, MW-145-20, MW-154A-75/B-95, MW-309-15/66, O-3, O-4, O-12, O-1265, O-24, O-24-65, and O-26.

Based on visual evaluation of the concentration graphs included in Appendix L, sulfolane concentrations detected in samples collected from wells upgradient from the groundwater extraction and recovery system treatment zone (O-5, O-5-65, O-6, O-19, MW-130-25, MW-175-90, MW-199-150, S-43) are decreasing or stable. These results are likely minimally influenced by operation of the groundwater extraction and recovery system, but are the result of a decreasing upgradient source mass. BTEX trends in this area are still being established because many of these wells were recently added to the monitoring program.

Sulfolane results for upgradient wells are discussed below:

- Since being added to the monitoring program, the results for well S-43 (screened across the water table) have been below the LOQ during each monitoring event.
- Wells MW-175-90 (screened 85.8 to 90.3 feet bgs) and MW-199-150 (screened 144.7 to 149.4 feet bgs) are deeper wells and the results have been below the LOQ.
- Well O-19 (screened across the water table) was recently added to the monitoring program and only four sampling events have been completed. The fourth quarter monitoring result was lower than the previous event with potential seasonal variation;

thus, future monitoring will allow better evaluation of a trend at this location. Installation of additional nested wells at O-19 was completed during the reporting period and these wells will be monitored in 2014 to evaluate sulfolane concentration trends at greater depths immediately upgradient from the treatment zone.

- The results for well O-6 (screened across the water table) have indicated relatively constant concentrations following the initial monitoring event in the fourth quarter 2011, which had a higher concentration.

- The results for well MW-130-25 (screened 19 to 23 feet bgs) have fluctuated since the initial monitoring event in 2011, although a decreasing trend has been observed since second quarter 2011. The monitoring results for the second, third, and fourth quarter 2013 were consistent with each.

- Wells O-5 and O-15-65 were recently added to the monitoring program and trends will be evaluated in future reports.

BTEX results for upgradient wells are discussed below:

- Wells O-5, O-5-65, O-19, MW-175-90, MW-199-150, and S-43 were recently added to the monitoring program and trends will be evaluated in future reports. The results at O-5-65, MW-175-90, and MW-199-150 were below the LOQs.

- Well O-6 is outside the BTEX plume and results have been below the LOQs.

- Well MW-130 has historically exhibited elevated BTEX concentrations; however, the results indicate a steady decrease since installation. Well MW-130 was recently added to the semiannual monitoring program and trends will be evaluated in future reports.

Based on visual evaluation of the concentration graphs in Appendix J, sulfolane concentrations detected in samples collected from monitoring wells within the treatment zone (O-2, MW-113-15, MW-125-25, MW-186 A-15/B-60/E-75, MW-334-15/65) exhibit a general decreasing trend. BTEX trends in this area are still being established because many of these wells were recently added to the monitoring program.

Sulfolane results for wells located within the treatment zone are summarized below:

- Well O-2 (screened across the water table) was recently added to the monitoring program; however, a downward trend is observable through four monitoring events.

- At well MW-113-15 (screened 11.5 to 15 feet bgs), a decreasing trend has been observed over the past five monitoring events.

- The concentrations at well MW-125-25 (screened 19.5 to 24 feet bgs) have been below detection limits since the first quarter 2012.

- A decreasing trend has been observed at well MW-186A-15 (screened across the water table) since installation. The results for well MW-186B-60 (screened 50 to 60 feet bgs) and well MW-186E-75 (screened 70 to 75 feet bgs) have been lower than well MW-186A-15 and stable since installation. The concentrations at well MW-186B-60 varied from 17.3 to 26.9 µg/L in 2013. At well MW-186E-75, the concentrations varied from 8.3 J to 15.4 µg/L in 2013.

- A decreasing trend has been observed at well MW-334-15 (screened across the water table) since the initial monitoring event in the third quarter 2012. The concentrations at well MW-334-65 (screened 60 to 65 feet bgs) have been estimated (J-flagged) detections below the LOQ since the initial monitoring event in the third quarter 2012.

BTEX results for wells located within the treatment zone are discussed below:

- Wells MW-113-15, MW-186B-60, MW-186E-75, and MW-334-65 currently exhibit BTEX concentrations near or below the LOQ, which indicate that the wells are located near the edge or outside of the BTEX plume.

- Historically, well MW-125-25 has exhibited elevated BTEX concentrations, but these concentrations have decreased steadily through time.

- Well MW-334-15 is located within the BTEX plume. This well has been sampled four times and concentrations have fluctuated.

- Wells O-2 and MW-186A were recently added to the semiannual BTEX monitoring program and only two sampling events have been completed; thus, trends at these locations will be discussed in future reports. BTEX concentrations were detected at both locations.

Based on visual evaluation of the concentration graphs provided in Appendix J, sulfolane concentrations detected in samples collected from monitoring wells downgradient from the treatment zone (MW-127-25, MW-129-40, MW-139-25, MW-142-20, MW-145-20, MW-154A-75/B-95, MW-309-15/66, O-3, O-4, O-12, O-12-65, O-24, O-24-65, O-26) exhibit decreasing trends, with some exceptions as noted below:

- Consistent decreasing trends have been observed at well MW-127-25 (screened 20 to 25 feet bgs), well MW-142-20 (screened across the water table), well O-12 (screened across the water table), and well O-26 (screened across the water table). Although seasonal fluctuations have been observed at some locations (including the fourth quarter 2013 results for well MW-142-20), annual maximum concentrations have decreased each year. A deeper well nest was installed at well O-26 during the reporting period and monitoring will be completed in 2014 to allow for further evaluation of sulfolane concentration trends at greater depths immediately downgradient from the treatment zone.

- Sulfolane has not been detected in samples collected from wells MW-129-40 (screened 37 to 41.5 feet bgs) and MW-145-20 (screened across the water table) since monitoring was initiated, indicating that these wells are located outside the sulfolane plume area. Well O-12-65 (screened 60 to 65 feet bgs) was recently added to the monitoring program and all results have been below the LOQ, indicating that this well is located outside the sulfolane plume area.

- A decreasing trend has been observed at wells MW-154A-75 (screened 71 to 75 feet bgs) and MW-309-66 (screened 59 to 64 feet bgs). The fourth quarter results were near the LOQ at well MW-309-66 and below the LOQ at well MW-154A-75.

- The sulfolane concentrations at well MW-309-15 (screened across the water table) have been relatively stable, with a sharp decline measured during the reporting period. Installation of an additional groundwater recovery well in this area is planned as part of the Revised IRAP Addendum (ARCADIS 2013g).

- Sulfolane concentrations measured at wells O-3 and O-24 (both screened across the water table) have remained near or below the LOQ since installation. A deeper well was installed at well O-24 (O-24-65) during the reporting period and the initial monitoring result was below the detection limit.

- Sulfolane concentrations have decreased at well MW-154B-95 (screened 90 to 95 feet bgs) during the last four monitoring events, following increasing concentrations noted during two monitoring events in 2012. Monitoring well MW-139-25 is located downgradient from the MW-154 area, and a similar increase in concentration was observed during the last two monitoring events.

- Concentrations initially increased in samples collected from well O-4 (screened across the water table) upon installation; however, during the three most recent sampling events the concentration has decreased. This monitoring well is near the location of new recovery well R-43 and future monitoring results will be used to further evaluate trends and the performance of well R-43.

BTEX trends in this area are still being established because many of these wells were recently added to the monitoring program.

BTEX results for wells located downgradient from the treatment zone are discussed below:

- BTEX concentrations were below the LOQ in samples collected from wells MW-129-40, MW-142-20, MW-145-20, MW-154A-75, MW-154B-95, MW-309-15, MW-309-66, O-12-65, and O-24-65. Data from these locations are used to define the BTEX plume boundaries.

- BTEX concentrations since installation have been near or below the LOQ at wells O-4, O-12, and O-24.

- Historically, BTEX concentrations have been detected in samples collected from well MW-139-25. BTEX concentrations decreased during the past four monitoring events. Well MW-127-25 had detectable BTEX concentrations during the reporting period. These wells are the furthest downgradient monitoring locations with detectable BTEX concentrations. Well MW-142-20, located an additional 175 feet downgradient from well MW-139-25, does not have detectable BTEX concentrations.

- Wells O-3 and O-26 have been sampled only three times and trends at these locations will be discussed in future reports. BTEX concentrations have been detected at both locations, although the concentrations during the reporting period were low level (O-3) or below the LOQ (O-26).

The performance network has been revised to include newly installed monitoring wells and to differentiate BTEX versus sulfolane monitoring locations; changes are presented in the RSAP.

5.8.2 Transects

To further evaluate the effectiveness of the groundwater recovery system, sulfolane concentration trends were evaluated along three longitudinal transects parallel to the groundwater flow path (Figure 5-3). Transects A and B (Figures 5-4 and 5-5) comprise shallow wells (water table and 10 to 55 feet below water table) while Transect C (Figure 5-6) comprises deeper wells (55 to 90 feet below water table). Monitoring wells are noted on the figures based on their location relative to the groundwater recovery system (upgradient, within the treatment zone, or downgradient). Also shown are the pumping rates of the groundwater extraction and recovery system to demonstrate the effects of increased groundwater recovery on sulfolane concentrations in these wells since 2010.

The data presented on Figures 5-4 and 5-5 demonstrate that concentrations downgradient from the treatment zone are lower than concentrations upgradient from the treatment zone and that decreasing downgradient concentrations correlate with increased pumping from the treatment system. This indicates that the ongoing groundwater extraction is successfully recovering sulfolane-impacted groundwater and reducing the migration of sulfolane-impacted groundwater downgradient from the remediation system. After brief increases in sulfolane concentrations in 2012, recent sulfolane concentrations measured at deeper wells MW-154B-95 and MW-186E-75 (Figure 5-6) have shown decreasing or stable concentrations, respectively. Additionally, deeper wells have been installed at well O-19 and will be monitored in 2014, which will allow comparison to an upgradient concentration (Figure 5-6).

Sulfolane concentrations in the deeper portions of the aquifer near the recovery system are substantially lower than the concentrations reported in the shallow groundwater. The recently installed deeper recovery wells will result in increased capture from these deeper zones with lower sulfolane concentrations. While this may decrease the average sulfolane concentration in the recovered groundwater, the hydraulic recovery of groundwater impacted with sulfolane has improved.

5.9 Summary of Nonroutine Repairs, Changes, and Maintenance

Overall, the groundwater recovery system maintained a runtime 99.9 percent during the reporting period. However, downtime occurred at five recovery wells from November 21 to December 10, 2013 in response to LNAPL reaching the Gallery Pond and elevated BTEX and PAH concentrations in the treatment system effluent, as described in Section 5.3.3. Downtime and changes in the reporting period are summarized below:

- *October 7, 2013*. Recovery well R-44 was temporarily shut down for 1.75 hours for safety reasons unrelated to the system operation.

- *October 29, 2013*. Recovery well R-45 was temporarily shut down for 20 minutes for maintenance.

- *November 14, 2013*. Recovery wells R-44, R-45, and R-46 were down due to a power outage associated with strong winds. The downtime for the wells was 2.33 hours, 0.5 hour, and 0.42 hour, respectively.

- *November 21, 2013*. Recovery wells R-21, R-35R, R-43, R-44, and R-45 were shut down to address issues associated with LNAPL in the Gallery Pond and loading to the GAC vessels (as described in Section 5.3.3). The flowrates at wells R-42 and R-46 were reduced to 40 gpm at each well to maintain minimal flow to prevent freezing of water in the piping. The wells were returned to service on December 10,

2013. During the period of reduced operation, the GAC was changed out in Vessels A and B.

- *December 10, 2013*. Prior to returning all wells to service, wells R-42 and R-46 were shut down for 1 hour for changeout of the coalescer cartridges.

- *December 31, 2013*. Recovery wells R-35R, R-44, and R-45 were shut down for short periods for cleaning of the flowmeter at each location. The downtime for the wells was 1.25 hours, 1.28 hours, and 0.66 hour, respectively.

5.10 **Summary**

During the reporting period and throughout 2013, the remediation system continued to operate reliably and effectively, except during one event in November in which LNAPL reached the Gallery Pond and the treatment system effluent concentration increased. FHRA took immediate action to correct the problem and the system returned to reliable performance. FHRA is evaluating additional steps to prevent similar issues in the future.

Concentrations of sulfolane and BTEX in the downgradient portion of the onsite plume continue to show an overall decline, thus indicating the effectiveness of the groundwater extraction and recovery system.

6. Analytical Quality Assurance and Quality Control

Quality assurance (QA)/quality control (QC) procedures assist in producing data of acceptable quality and reliability. Analytical results for laboratory QC samples were reviewed and a QA assessment of the data was conducted as the data were generated. The QA review procedures documented the accuracy and precision of the analytical data and confirmed that the analyses were sufficiently sensitive to detect analytes at levels below suggested action levels or regulatory standards, where such standards exist. The laboratory reports for each of the samples for this report, including case narratives describing laboratory QA results and completed ADEC data review checklists, are included in Appendices D and E. SWI conducted QA/QC reviews of the data for this reporting period. Data quality flags applied to the analytical results are summarized in Table 6-1.

In email correspondence dated March 20, 2012, the ADEC reduced the requirement for continued submittal of Level IV data packages for residential results. Level IV data packages are required for 10 percent of the residential well samples. Level IV data packages and third-party review will continue to be required for monitoring well data if an interference is noted in a groundwater sample from a new well or is identified in an existing well where no interference was previously identified. Level IV data packages were not requested for monitoring well sulfolane data during the reporting period.

Level IV laboratory reports are required for 10 percent of residential well data and were not available at the time of submittal of this report. Level IV laboratory reports and level IV validation reports prepared by Environmental Standards Inc. for the reporting period will be included in the First Quarter 2014 Groundwater Monitoring Report.

6.1 Water Sample Data Quality

This section summarizes the results of the QA/QC review of data for the reporting period. Samples were submitted to SGS for analysis of sulfolane and/or BTEX for select monitoring wells. Samples were also collected from some wells for stable isotope and/or microbial analysis by UAF; these data were not reviewed and are not included in this QA summary. Residential water well sulfolane samples collected during the reporting period were reviewed. ADEC data review checklists are included in Appendix E.

The SGS work orders (WOs) reviewed for the reporting period are listed in the table below.

Groundwater Monitoring WOs							
1138561	1138567	1138572	1138580	1138591	1138594	1138604	1138616
1138628	1138634	1138636	1138643	1138648	1138668	1138670	1138674

1138695	1138716	1138724	1138731	1135693	1138760	1138757	

The SGS WOs reviewed for the Phase 8 initial groundwater samples collected during the reporting period are listed in the table below.

New Phase 8 Initial Groundwater Sample WOs							
1138559	1138593	1138595	1138545	1138524	1138635	1138557	1138592
1138603	1138669	1138671	1138672	1138675	1138681	1138707	1138714
1138718	1138721	1138735	1138727	1138744	1138769	1138773	1138788
1138793							

The SGS WOs reviewed for the initial and resampled private well groundwater samples are listed in the table below.

Initial and Resampled Private Well Sample WOs							
1138506	1138560	1138576	1138583	1138684	1138698	1138702	1138706
1138705	1138712	1138730	1138784	1138785	1138507	1138508	1138699
1138697	1138701	1138713					

The Pace WOs reviewed for the water well POE samples are listed in the table below.

POE Sample Pace WOs							
10239311	10239311	10239311	10239311	10239311	10239311	10239311	10239311
10243142	10243145	10243739	10243741	10243742	10243743	10243744	10244165
10244167	10244170	10244172	10245392	10245394	10245397	10245400	10246174
10246176	10246178	10246180	10246182	10246183	10246845	10246846	10246849
10247161	10247165	10247573	10248290	10248292	10248294	10248676	10248677
10248678	10249036	10249040	10249041	10249044	10249046	10249613	10249617
10249620	10249903	10249907	10249908	10249910	10249913	10249901	10251334
10251333	10250245	10250804	10250807	10250801	10250904	10250903	10250249
10250248	10250806	10250799	10250808				

The SGS and ALS Environmental Laboratory of Simi Valley, California (ALS) WOs reviewed for the deep private well monitoring samples collected during the reporting period are listed in the table below.

Deep Private Well Water WO List							
1138739	1138742	1138743	1138748	1138749	1138752	1138753	1138764
1138763	1138771	1138772	1138774	1138789	1138799	1138800	

Methane samples were submitted to ALS.

Results of the QA/QC review are discussed below. Only those issues that affected data quality (i.e., resulted in applying data qualifiers) are summarized; for additional details regarding QA/QC for each WO, refer to the data review checklists provided in Appendix E.

6.2 Sample Handling

Monitoring and residential well samples were hand delivered to the SGS (Fairbanks, Alaska) receiving office and then shipped overnight via Lynden Transport or Alaska Airlines Goldstreak to SGS in Anchorage, Alaska to perform the requested analyses, using the methods specified in the chain of custody records. POE samples were shipped to the Pace in Minneapolis, Minnesota via FedEx overnight service to perform the requested analyses, using the methods specified in the chain of custody records.

Sample receipt forms for each WO for both SGS Alaska locations or for Pace were reviewed and checked to verify that samples were received in good condition and within the acceptable temperature range. ADEC data review checklists (Appendix E) contain details regarding this review. ADEC considers temperatures received between 0 and 6 degrees Celsius (°C) acceptable in the absence of ice, as specified by USEPA Method SW-846. Therefore, for this report, temperatures between 0 and 6°C are considered acceptable.

Samples were received within the acceptable temperature range upon arrival at each location during the reporting period, and were received properly preserved and in good condition.

Chain of custody records for each WO were also reviewed to confirm that information was complete, custody was not breached, and samples were analyzed within the acceptable holding time. Chain of custody records were complete and correct, except for several minor naming or sample time discrepancies that did not affect data quality or usability (see checklists in Appendix E for details). Samples were analyzed within holding times, with the following exceptions:

- *SGS Work Order 1138592*. Samples O-37 and O-36 were re-extracted for sulfolane analysis outside of the 7-day holding time using the water cleanup method, due to hydrocarbon interference in the original extraction. Sulfolane results for these samples are considered estimated and biased low, detected results are flagged 'JL,' and results where sulfolane was not detected are flagged 'UJ' at the limit of detection (LOD).

- *SGS WO 1138595.* Sample O-34 was re-extracted for sulfolane analysis outside of the 7-day holding time using a smaller sample volume, due to a high concentration of sulfolane in the original extraction (above calibration limits). Sulfolane results for this sample are considered estimated and biased low, and are flagged 'JL'.

- *SGS WO 1138716.* Samples MW-176A-15 and O-1 were re-extracted for sulfolane analysis outside of the 7-day holding time using a smaller sample volume, due to high concentrations of sulfolane in the original extraction (above calibration limits). Sulfolane results for these two samples are considered estimated and biased low, and are flagged 'JL.'

- *Pace WO 10239311.* Samples 'A' and 'C1' were extracted for sulfolane analysis outside of the 7-day holding time. Both sample results are considered estimated and biased low. Sample 'A' is flagged 'JL' and sample 'C1' is flagged 'UJ' (sulfolane was not detected). Full private well sample names are provided in the QC checklists (Appendix E).

- SGS Work Orders 1138742, 1138743 and 1138763: Samples in these work orders arrived in the Anchorage laboratory outside of acceptable temperature. Affected data are considered estimated, biased low, and flagged 'JL'. Please see the data review checklists for more information on affected samples.

- ALS Work Orders 1138742 and 1138743: Samples in these work orders arrived in the Anchorage laboratory outside of acceptable temperature prior to shipment to the ALS laboratory. Affected data are considered estimated, biased low, and flagged 'JL'. Please see the data review checklists for more information on affected samples.

No other sample handling anomalies were identified during the reporting period that would adversely affect data quality.

6.3 Analytical Sensitivity and Blanks

Reported LODs for regulated analytes were below ADEC cleanup levels or interim action levels during the reporting period.

Laboratory method blanks were analyzed in association with samples collected for this project to check for contributions to the analytical results possibly attributable to laboratory-based contamination. Trip blanks were submitted with groundwater samples for BTEX analysis to verify that cross-contamination did not occur during sample handling and transport. Equipment blanks were collected to assess the possibility of cross-contamination from sampling equipment. There were no blank detections affecting data quality for the reporting period, with the following exceptions:

- *SGS WO 1138731.* Ethylbenzene, o-xylene, p & m-xylenes, and total xylenes were detected below the LOQ in the equipment blank collected on November 16, 2013. Samples collected on the same day, using the same pump, with detected concentrations of these analytes within five times the concentration in the equipment blank are considered affected. Results were affected for sample MW-134-20; o-xylene, p & m-xylenes, and total xylenes are considered not detected in the sample and are flagged ‘UB’ at the LOQ.

- *SGS WO 1138670.* p & m-xylenes were detected in the trip blank. Samples where this analyte was detected within five times the concentration in the trip blank are considered affected. Results were affected for samples MW-109-15 and MW-124-25; p & m-xylenes are considered not detected in these samples and are flagged ‘UB’ at the LOQ.

- SGS Work Orders 1138749, 1138771 and 1138799: Total organic carbon was detected in the method blanks. Sample results for TOC were above the LOQ but within five times the respective concentrations in the respective method blanks. Data are considered non-detect and flagged ‘UB’ at the detected concentration. Please see the data review checklists for more information on affected samples.

6.4 Accuracy

Laboratory analytical accuracy may be assessed by evaluating the analyte recoveries from continuing calibration verification (CCV), laboratory control sample (LCS), and LCS duplicate (LCSD) analyses. LCS/LCSD samples assess the accuracy of analytical procedures by checking the laboratory’s ability to recover analytes added to clean aqueous matrices. In some cases, the laboratory spiked project samples as matrix spike (MS) and MS duplicate (MSD) samples to assess their ability to recover analytes from a matrix similar to that of project samples. Accuracy was also assessed for organic analyses by evaluating the recovery of analyte surrogates added to project samples. For sulfolane results, the recovery of the internal standard (sulfolane-d8) was evaluated.

There were no CCV or initial calibration verification failures affecting data quality for samples obtained during the reporting period. Recovery information was reviewed for all LCS/LCSDs and MS/MSDs associated with project samples. There were no MS/MSD recovery failures affecting data quality for the reporting period. LCS, LCSD, MS, and MSD recoveries were within laboratory control limits for each preparatory batch, with the following exception:

- *Pace WO 10243140*. Sulfolane was recovered below laboratory control limits in the MS associated with sample 'D'. Sulfolane results for this sample are considered estimated and biased low, and are flagged 'UJ' (sulfolane was not detected). Full residential sample names can be found in the QC checklists.

Recovery of analyte surrogates and the sulfolane internal standard were within laboratory control limits, with the following exceptions:

- *Pace WOs 10249901 and 10243142*. Internal standard sulfolane-d8 was recovered outside laboratory control limits for one or more samples in these WOs. Sulfolane results for affected samples are considered estimated and flagged 'J'. Additional details regarding affected samples and full private well sample names are provided in the QC checklists (Appendix E).

Laboratory CCV, LCS/LCSD, MS/MSD, and surrogate recovery information indicate that the analytical results were accurate, with the exceptions noted above.

6.5 Precision

Field duplicate samples were collected at a frequency of approximately 10 percent of the overall number of samples collected, to evaluate the precision of analytical measurements as well as the reproducibility of the sampling technique. The relative percent difference (RPD; difference between the sample and its field duplicate divided by the mean of the two) was calculated to evaluate the precision of the data. An RPD was evaluated only if the results of the analyses for both duplicates are detected quantitatively (above the LOQ).

During the reporting period, the following duplicate samples were collected:

- Thirty-four duplicates for monitoring well samples analyzed for sulfolane (359 samples total)
- Nine duplicates for monitoring well samples analyzed for BTEX (83 samples total)
- Two duplicates for initial and resample private well water well samples analyzed for sulfolane (19 samples total)
- Forty-two duplicates for POE samples analyzed for sulfolane (70 total raw-water samples, additional POE port samples)

- Two duplicates for deep private well samples were analyzed for sulfolane, ammonia, TOC, sulfate, alkalinity, nitrate, nitrite, chloride, total metals, dissolved methane and dissolved metals. Seventeen samples total were submitted during the reporting period for the deep private well monitoring program.

Results of RPD calculations for each of these duplicate samples were within the data quality objective (DQO) of 30 percent, where calculable, with the following exceptions:

- *SGS WO 1138731.* Field duplicate RPDs for benzene and toluene were above the DQO for duplicate sample set O-2/O-200. Benzene and toluene results for the sample and duplicate are considered estimated and flagged 'J'.

- *SGS WO 1138716.* Field duplicate RPDs for ethylbenzene, p & m-xylenes, o-xylene, and total xylenes were above in the DQO for duplicate sample set MW-180A-15/ MW-280A-15. Results for the analytes listed above for the sample and duplicate are considered estimated and flagged 'J'.

- *SGS WO 1138695*. Field duplicate RPDs for ethylbenzene, o-xylene, p & m-xylenes, and total xylenes were above in the DQO for duplicate sample set MW-132-20/ MW-232-20. Results for the analytes listed above for the sample and duplicate are considered estimated and flagged 'J'.

- SGS Work Order 1138753: Field duplicate RPD for ammonia was above in the DQO. Results for ammonia for the sample and duplicate are considered estimated and flagged 'J'. Please see the data review checklists for more information.

Laboratory analytical precision can also be evaluated by laboratory RPD calculations using the LCS/LCSD and MS/MSD, or laboratory duplicate sample results. There were no RPDs above laboratory control limits that affected data quality for the reporting period, with the following exception:

- SGS Work Order 1138789: Laboratory duplicate RPD for ammonia was above in the DQO. Results for ammonia for the original sample are considered estimated and flagged 'J'.

Based on a review of the data, water results associated with the reporting period are considered precise.

6.6 Hydrocarbon Interference and Level IV Review

In addition to the standard QA review described in the sections above, additional review of select private well WOs will be conducted by Environmental Standards Inc. and included in the First Quarter 2014 Groundwater Monitoring Report.

In addition to the QA and QC issues noted above, a hydrocarbon-interference issue prevented the laboratory from identifying sulfolane in one sample. For SGS WO 1138557, sulfolane could not be quantified for sample O-31 due to hydrocarbon interference. According to the laboratory case narrative, the “sample could not be re-extracted due to limited volume and lab error.” Sulfolane results for this sample are not reported, and are flagged ‘R’ as rejected.

6.7 Data Quality Summary

Based on the methods outlined in the RSAP, the samples collected are considered to be representative of site conditions at the locations and times they were obtained. Based on the QA review, no samples were rejected as unusable due to QC failures. In general, the quality of the analytical data for this reporting period does not appear to have been compromised by analytical irregularities and results affected by QC anomalies are qualified with the appropriate data flags.

7. Conclusions and Recommendations

Groundwater monitoring data collected during the reporting period are consistent with data collected during recent quarters. Sulfolane concentrations and trends continue to decrease in the onsite area and offsite area near the NPR north property boundary while concentrations and trends continue to increase in the moving core and distal portions of the plume. Benzene and total xylenes concentrations are consistent with historical detections and are limited to the developed area onsite. As is characteristic for the fourth quarter, severe cold weather limited access to some wells in the monitoring well network; however, the prioritized data collected during the reporting period are representative of the onsite and offsite monitoring plans outlined in the RSAP (Appendix A).

During the reporting period, the magnitude of onsite horizontal hydraulic gradient at the water table was calculated at approximately 0.0015 foot per foot (ft/ft). The magnitude of offsite horizontal hydraulic gradients at the water table and onsite and offsite hydraulic gradients at 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table were calculated at 0.0009 ft/ft. These results are consistent with historical data. FHRA collected groundwater and surface water elevation data from the area of the NGP. A preliminary evaluation of the data collected indicates that the horizontal hydraulic gradients were to the north-northwest direction consistent with historical data.

AS post-pilot testing monitoring was ongoing during the reporting period subsequent to pilot system shut down on July 10, 2013. FHRA will continue post-shutdown monitoring during the first quarter 2014. The 2013 onsite and offsite characterization activities are complete. Additional tracer test data will be collected to support model calibration and to further support the conclusions presented in the SCR Addendum.

Deep private well monitoring will continue through 2014 and POE treatment system results will continue to be added to the private well dataset. The maximum offsite sulfolane concentration (657 µg/L) was detected during the reporting period in the sample collected from deep private well PW-1230. This is a slight increase of the sulfolane concentration of 652 µg/L collected during third quarter 2013.

The statistical analysis of benzene, total xylenes, and sulfolane shows that concentrations at various locations across the plume are stable or decreasing. Several locations at the leading edge of the sulfolane plume exhibit increasing trends which are consistent with past predictive efforts. Statistical trends will continue to be calculated and reported quarterly, and will be used to inform the CSM.

During the reporting period and throughout 2013, the remediation system continued to operate reliably and effectively to remediate sulfolane-, benzene- and total xylenes-impacted groundwater, provide hydraulic control of the dissolved-phase sulfolane, benzene and total xylenes plumes, and enhance LNAPL recovery. As noted, in November LNAPL reached the Gallery Pond and the treatment system effluent concentration increased. FHRA took immediate action to correct the problem and the system returned to reliable performance. FHRA is evaluating additional steps to prevent similar issues in the future.

The groundwater monitoring programs described in the RSAP (Appendix A) and the POE SAP (Barr 2013b) are underway for the next reporting period (first quarter 2014). Approved changes to the monitoring networks and frequencies are documented in Version 6 of the RSAP (Appendix A and will be implemented during the second quarter 2014 sampling event.

8. References

ARCADIS U.S., Inc. 2012a. Revised Draft Final Human Health Risk Assessment. May 24, 2012.

ARCADIS U.S., Inc. 2012b. North Pole Refinery – Deep Private Well Monitoring Plan. June 20, 2012.

ARCADIS U.S., Inc. 2013a. Revised 2013 Onsite Site Characterization Work Plan. July 19, 2013.

ARCADIS U.S., Inc. 2013b. Revised 2013 Offsite Site Characterization Work Plan. July 19, 2013.

ARCADIS U.S., Inc. 2013c. Onsite Site Characterization Report – 2013 Addendum. December 20, 2013.

ARCADIS U.S., Inc. 2013d. Offsite Site Characterization Report – 2013 Addendum. December 20, 2013

ARCADIS U.S., Inc. 2013e. Interim Remedial Action Plan Addendum. January 18, 2013.

ARCADIS U.S., Inc. 2013f. Fourth Quarter 2012 Groundwater Monitoring Report. March 1, 2013.

ARCADIS U.S., Inc. 2013g. Revised Interim Remedial Action Plan Addendum. July 31, 2013.

ARCADIS U.S., Inc. 2013h. Second Quarter 2013 Groundwater Monitoring Report. July 31, 2013.

ARCADIS US., Inc.2013i. Work Plan for Additional Site Monitoring Activities During Construction Dewatering. August 26, 2013.

ARCADIS U.S., Inc. 2013j. Tracer Test Field Implementation Work Plan. August 27, 2013.

ARCADIS U.S., Inc. 2013k. Third Quarter 2013 Groundwater Monitoring Report. October 31, 2013.

ASTM International. 2012. Standard Guide for Estimation of LNAPL Transmissivity, E 2856-12, ASTM International, West Conshohocken, PA.

Barr Engineering Company. 2010a. Site Characterization Work Plan. Revised September 2010.

Barr Engineering Company. 2010b. Interim Removal Action Plan. Revised September 2010.

Barr Engineering Company. 2011. Site Characterization and First Quarter 2011 Groundwater Monitoring Report. May 2011.

Barr Engineering Company. 2012. Site Characterization Report – Through 2011. December 2012.

Barr Engineering Company. 2013a. Technical Memorandum: Recovery Well Replacement, Start-Up Aquifer testing for Recovery System Hydraulic Capture Performance Monitoring. April 19, 2013.

Barr Engineering Company. 2013b. Final Alternative Water Solutions Program – Management Plan. July 31, 2013.

Cardona, T. 2013. Email to Loren Garner of FHRA transmitting ADEC's comments on the Evaluation of Recovery Well Replacement, Start-up Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring. Sent October 9, 2013.

Cederstrom, D.J. 1963. Ground-Water Resources of the Fairbanks Area Alaska: U.S. Govt. Print. Off., U.S. Geological Survey Water-Supply Paper 1590. 84 p.

Farhat, S., C. Newell, and E. Nichols. 2006. Mass Flux Toolkit to Evaluate Groundwater Impacts, Attenuation, and Remediation Alternatives. User's Manual. Version 1.0. March, 2006.

Ferrians, O.J. 1965. Permafrost Map of Alaska. U.S. Geological Survey Miscellaneous Investigations Series Map I-445. 1 plate.

Geomega Inc. 2013. Groundwater Model Report. February 4, 2013.

Glass, R.L., M.R. Lilly, and D.F. Meyer. 1996. Ground-water levels in an alluvial plain between the Tanana and Chena Rivers near Fairbanks, Alaska, 1986-93: U.S. Geological Survey Water-Resources Investigations Report 96-4060, 39 p. + 2 appendices.

Lilly, M.R., K.A. McCarthy, A.T. Kriegler, J. Vohden, and G.E. Burno. 1996. Compilation and Preliminary Interpretations of Hydrologic and Water-Quality Data from the Railroad

Industrial Area, Fairbanks, Alaska, 1993-94. U.S. Geological Survey Water-Resources Investigations Report 96-4049. 75 p.

Miller, J.A., R.L. Whitehead, D.S. Oki, S.B. Gingerich, and P.G. Olcott. 1999. Ground Water Atlas of the United States: Segment 13, Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. U.S. Geological Survey Hydrologic Atlas Number 730-N. 36 p.

Nakanishi, A.S., and M.R. Lilly. 1998. Estimate of aquifer properties by numerically simulating ground-water/surface-water interactions, Fort Wainwright, Alaska: U.S. Geological Survey Water-Resources Investigations Report 98-4088, 35 p.

Shannon and Wilson, Inc. 2013. Standard Operating Procedure (SOP) for Groundwater-Elevation Monitoring. 2013

Williams, J.R. 1970. Ground Water in the Permafrost Regions of Alaska. U.S. Geological Survey Professional Paper 696. U.S. Government Printing Office, Washington, D.C. 83 p.

Tables

Figures

Appendices
(on enclosed CD)

ARCADIS

Appendix **A**

Revised Sampling Analysis Plan

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Appendix **B**

Private Well Location Map

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Appendix **C**

Historical Data Tables for Groundwater Elevation and LNAPL Thickness, BTEX, Sulfolane, Geochemical Parameters, Private Wells, COPCs, and Culvert Water Elevations

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Appendix **D**

Analytical Laboratory Reports

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Appendix **E**

ADEC QA/QC Checklists

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Appendix **F**

Field Data Sheets

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Appendix **G**

Hydrographs

Appendix **H**

LNAPL Transmissivity Calculations

Appendix I

Mass Flux Methods

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Appendix **J**

Mann-Kendall Trend Analysis Summary

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Appendix **K**

Amended temporary water use permit

Appendix **L**

Contaminant Capture Analysis