Flint Hills Resources Alaska, LLC

SECOND SEMIANNUAL 2015 ONSITE GROUNDWATER MONITORING REPORT

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

January 29, 2016

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ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
amsl	above mean sea level
Arcadis	Arcadis U.S., Inc.
Barr	Barr Engineering Company
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
bwt	below the water table
city	North Pole, Alaska
COC	constituent of concern
CSM	conceptual site model
DNR	Department of Natural Resources
DPE	dual-phase extraction
DRO	total petroleum hydrocarbons as diesel-range organics
FHRA	Flint Hills Resources Alaska, LLC
ft/ft	foot per foot
ft^2/day	square foot per day
g/day	grams per day
GAC	granular activated carbon
GAC East	original treatment system
GAC West	expanded groundwater recovery and treatment system
gpm	gallons per minute
GRO	total petroleum hydrocarbons as gasoline range organics
GRTS	groundwater remediation and treatment system
ITRC	Interstate Technology & Regulatory Council
lb/day	pound per day
LNAPL	light nonaqueous phase liquid

LTM Plan	Long-Term Monitoring Plan
MAROS	Monitoring and Remediation Optimization System
mg/L	milligrams per liter
NGP	North Gravel Pit
NSZD	natural source zone depletion
OCP	Final Onsite Cleanup Plan
OMM Plan	Operations, Maintenance, and Monitoring Plan
Onsite RSAP	Revised Onsite Sampling and Analysis Plan
Onsite SCR – 2013	Onsite Site Characterization Report –2013 Addendum
PID	photo ionization detector
QA	quality assurance
QC	quality control
report	Second Semiannual 2015 Onsite Groundwater Monitoring Report
reporting period	third and fourth quarters of 2015
SGP	South Gravel Pit
site	Flint Hills Resources Alaska, LLC North Pole Terminal, a petroleum terminal located on H and H Lane in North Pole, Alaska
SOP	standard operating procedure
SWI	Shannon & Wilson, Inc.
toolkit	Mass Flux Toolkit
VPT	vertical profiling transect
µg/L	micrograms per liter

1 INTRODUCTION

On behalf of Flint Hills Resources Alaska, LLC (FHRA), Arcadis U.S., Inc. (Arcadis) prepared this Second Semiannual 2015 Onsite Groundwater Monitoring Report (report) for the FHRA North Pole Terminal, located on H and H Lane in North Pole, Alaska (site). This report summarizes onsite field activities completed during the third and fourth quarters of 2015 (reporting period) as described in Section 3 and Table 1-1. A separate Second Semiannual 2015 Offsite Groundwater Monitoring Report is being submitted concurrently with this report.

The data, analyses, and conclusions presented in this report are the product of a collaborative effort among FHRA's consulting team members. The team includes qualified professionals in a variety of technical disciplines from three environmental consulting firms: Arcadis, Shannon & Wilson, Inc. (SWI), and Barr Engineering Company (Barr). FHRA engaged these consulting firms to perform various tasks for the project. Pursuant to 18 Alaska Administrative Code (AAC) 75.335(c)(1), this report was prepared and submitted by a Qualified Environmental Professional. Samples were collected and analyzed in accordance with 18 AAC 75.355(a). The sampling and analyses for this reporting period were completed in accordance with the following documents, which were prepared by a Qualified Environmental Professional and approved by the Alaska Department of Environmental Conservation (ADEC):

- Final Onsite Cleanup Plan (OCP; Arcadis 2014a)
- Long-Term Monitoring Plan (LTM Plan; Arcadis 2014b)
- Operations, Maintenance, and Monitoring Plan (OMM Plan; Barr 2014)
- Revised Onsite Sampling and Analysis Plan (Onsite RSAP; Arcadis 2015a)

Updates to the LTM Plan (Arcadis 2014b) and OMM Plan (Barr 2014) were prepared in December 2015 (LTM Plan – 2015 Update; Arcadis 2015c and OMM Plan – 2015 Update; Barr 2015) and will be implemented beginning first quarter 2016. Additionally, an update to the Onsite RSAP is included as Appendix A of this report.

2 SITE SETTING

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 the Fairbanks North Star Borough (Figure 2-1). Future land use of the site will remain consistent with an industrial manufacturing setting given its significant infrastructure and capabilities. Current site features are shown on Figure 2-2. An onsite site plan is presented on Figure 2-3.

Permafrost is largely absent under the developed portions of the site. Discontinuous permafrost is present in the northern portions of the site. Small discontinuous masses of permafrost are believed to be located at monitoring wells MW-154A-75/B-95 and MW-179A-15/B-50/C-90/D-135 and along the vertical profiling transect (VPT), as suggested by installed monitoring wells and geophysical data (Arcadis 2013a). The southern edge of a large, relatively continuous permafrost mass is present near the North Property Boundary.

The site, offsite area, and the site's physical setting are described in the conceptual site model (CSM), which was presented as Appendix A of the Onsite Site Characterization Report – 2013 Addendum (Onsite SCR – 2013; Arcadis 2013a).

3 CURRENT GROUNDWATER MONITORING PROGRAM AND METHODS

Table 1-1 summarizes the field activities completed during the reporting period. Tables 3-1a and 3-1b summarize monitoring well and piezometer construction details. Well locations are shown on Figure 2-3. Monitoring networks were modified throughout the reporting period in accordance with parameters defined in the LTM Plan (Arcadis 2014b). Updated monitoring networks were included in the LTM Plan – 2015 Update (Arcadis 2015c) and OMM Plan – 2015 Update (Barr 2015).

3.1 Groundwater Elevation and Light Nonaqueous Phase Liquid Monitoring

The third and fourth quarter 2015 groundwater elevation monitoring events were conducted on August 12, and 13, 2015 and November 19 and 20, 2015, respectively. Two additional groundwater elevation monitoring events (August 19 and October 6, 2015) were completed during the reporting period to monitor the hydraulic capture of the GRTS. Groundwater elevation measurements collected as part of the hydraulic capture performance monitoring are presented in Section 6.1.

LNAPL measurements were collected to determine the LNAPL thicknesses and to confirm the stability of the LNAPL plume. LNAPL thicknesses in monitoring, observation, and recovery wells were measured throughout the reporting period.

In addition to manual water-level measurements, automated measurements were collected from a network of wells using pressure transducers to observe hydrogeological conditions in wells screened at various locations and depths within the suprapermafrost aquifer. Groundwater elevation measurements were downloaded from the deployed transducers during both the third and fourth quarters.

The standard operating procedure (SOP) for groundwater elevation monitoring (SWI 2013) was used to evaluate vertical hydraulic gradients within well nests and horizontal hydraulic gradients and groundwater flow directions between groups of wells.

3.2 Light Nonaqueous Phase Liquid Transmissivity Testing

LNAPL baildown tests are conducted during periods when groundwater levels are at or near seasonal lows (water table minima), which have been historically observed in March and late October (Arcadis 2014b). LNAPL thickness was measured at greater than 0.5 foot in fifteen wells (MW-176A-15, MW-334-15, O-11, O-31, O-33, O-38, R-20R, R-21, R-32R, R-35R, R-40, S-22, S-39, S-44 and S-51) during the reporting period. Baildown testing was previously performed at each of these wells except recovery wells R-20R, R-21, R-32R, and R-35R. Recovery wells R-21 and R-35R are active groundwater recovery wells. Baildown testing for R-20R and R-32R will be conducted during first quarter 2016 during the groundwater minima.

Groundwater extraction-enhanced LNAPL recovery results from the third and fourth quarters of 2015 are included in Section 4.3.4 for R-21 and R-40. R-35R had 0.55 foot of LNAPL present on November 21, 2015, and manual recovery was conducted, but measurable LNAPL has not returned.

3.3 Natural Source Zone Depletion Assessment

An annual evaluation of the potential efficacy of natural source zone depletion (NSZD) in the saturated zone was completed following protocols outlined in the Technology Overview for Evaluating Natural Source Zone Depletion at Sites with LNAPL (Interstate Technology & Regulatory Council [ITRC] 2009) as noted in the Onsite RSAP (Arcadis 2015a). The NSZD assessment is discussed in Section 4.3.3.

3.4 Groundwater Sampling Deviations and Additions

The following deviations from the LTM Plan (Arcadis 2014b) were noted during the reporting period:

- LNAPL was encountered in wells MW-115-15, MW-136-20, MW-138-20, MW-176A-15, MW-334-15, MW-336-15, O-2, S-44, and S-50 during planned monitoring events within the reporting period; therefore, samples were not collected from these wells for BTEX, GRO, and DRO analysis.
- Well MW-305-8 was dry during the reporting period and was not sampled.
- Well S-39 was purged dry during sampling attempts for both the third and fourth quarters of 2015; therefore samples were not collected from this well.
- A sample from well MW-304-10 was not collected during fourth quarter 2015 because the well was frozen.
- Well MW-105A-25 was sampled during third quarter 2015; however, the results were rejected due to significant quality control (QC) failures or interference.

Additionally, newly installed wells MW-372-15 and MW-373-15 were sampled for sulfolane during fourth quarter 2015 and added to the groundwater elevation and sulfolane monitoring networks.

4 GROUNDWATER MONITORING RESULTS

Groundwater impacts have been characterized and continue to be monitored through the analysis of water-level gauging data and groundwater samples collected from onsite monitoring wells. This section presents the results of water-level gauging and groundwater analyses of onsite well samples. Groundwater field parameters, groundwater elevations, vertical gradient network groundwater elevations, hydraulic capture performance monitoring, LNAPL thickness measurements, LNAPL migration measurements, NSZD, and groundwater extraction-enhanced LNAPL recovery results are presented in Tables 4-1 through 4-6c. Tables 4-7 through 4-10 present results of BTEX, GRO, and DRO analysis; sulfolane analysis (including at the VPT); and sulfolane mass flux. Historical groundwater elevation and LNAPL thickness measurements, and BTEX, GRO, DRO, sulfolane, and geochemical analytical results are included as Appendix B. Analytical laboratory reports are included as Appendix C. A data quality evaluation including ADEC quality assurance (QA)/QC checklists is included as Appendix D. Field data sheets are included as Appendix E.

4.1 Groundwater Elevation

Depth to water measurements were collected from monitoring wells on August 12 and 13, 2015 during third quarter 2015; and November 19 and 20, 2015 during fourth quarter 2015. Potentiometric maps are included for each monitoring zone: water table, 10 to 55 feet below the water table (bwt), 55 to 90 feet bwt, and 90 to 160 feet bwt (Figures 4-1 through 4-8). 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. Groundwater elevations and horizontal hydraulic gradients were within the range of historical groundwater data.

Groundwater elevations are summarized in Table 4-2. Groundwater elevation measurements collected as part of the hydraulic capture performance monitoring are presented in Section 6. Groundwater elevations near the GRTS are discussed in Section 6.

Groundwater elevations for wells completed at or near the water table listed in Table 3-1 of the LTM Plan (Arcadis 2014b) are contoured on Figures 4-1 and 4-5, with the following exceptions. Actively pumped recovery wells (R-21, R-35R, R-40, and R-42) are listed in Table 3-1 of the LTM Plan (Arcadis 2015b) and were not used for contouring on these figures. Data from adjacent monitoring wells were used to contour Figures 4-1 and 4-5.

In addition to manual water-level measurements, automated measurements were collected with transducers from 62 individual wells and 17 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), are shown on the well nest hydrographs presented in Appendix F. Data from five monitoring wells were not retrieved for the reasons identified in the table below.

Monitoring Well	Reason for Omitted Data	Comments
MW-179A-15	Monitoring well was frozen during first and second quarters of 2015. Data are not considered representative of actual conditions due to low battery voltage. Battery expired on June 20, 2015.	Data omitted from April 30 to September 24, 2015.
MW-179C-90	Monitoring well was frozen during first and second quarters of 2015. Data did not save correctly during download (third quarter 2015) and were lost. Data were invalid and not imported due to inaccurate measurement ranges.	Data omitted from December 9, 2014 to November 25, 2015.
MW-179D-135	Monitoring well was frozen during first and second quarters of 2015. Data are not considered representative of actual conditions due to low battery voltage. Battery expired on June 2, 2015.	Data omitted from March 24 to September 24, 2015.
MW-186A-15	A procedure for adjusting data to account for LNAPL in the well has not been established.	No data have been imported into the database.
MW-351-150	Data logger malfunction observed during second quarter 2015. New data logger was installed August 3, 2015.	Data omitted from December 15, 2014 to August 3, 2015.

A detailed evaluation of transducer data and hydraulic gradients through 2013 is provided in Appendix 6B of the Onsite SCR – 2013 (Arcadis 2013) and has been updated periodically, including an update through the reporting period in Appendix N of this report. The hydraulic gradient evaluations indicate that although the hydrologic system at the site is dynamic, the system variability has been reasonably captured by the monitoring program. For example, as the estimated average direction of horizontal hydraulic gradient is updated based on new information, the average value does not change markedly for a given group of wells. The third and fourth quarters of 2015 groundwater elevation monitoring results for this reporting period are consistent with historical gradients.

4.2 Surface Water Elevation

Measurements were recorded from gauging points located at the North Gravel Pit (NGP) and South Gravel Pit (SGP) on August 13, 2015 and on November 19, 2015. At the NGP, the surface water elevation was measured at a surveyed mark on an I-beam above a grate in the fire pumphouse, which is situated over the water on the southeast end of the pit. At the SGP, the surface water elevation was measured at a 12-foot staff gauge in the pit. During third quarter 2015, surface water elevations at the NGP and the SGP were 485.60 and 489.99 feet above mean sea level (amsl), respectively. During fourth quarter 2015, surface water elevations at the NGP and the SGP were 484.30 and 489.81 feet amsl, respectively. Data are summarized in Table 4-2 and on Figures 4-1 and 4-5. Historical gauging data are summarized in Appendix B.

4.3 Light Nonaqueous Phase Liquid Monitoring Results

LNAPL migration observations and thickness measurements were collected from a network of monitoring, observation, and recovery wells screened across the water table according to the LTM Plan (Arcadis 2014b). Additionally, LNAPL was gauged throughout the reporting period during monitoring events outside of the LNAPL migration and thickness networks. A comprehensive LNAPL gauging table is presented in Appendix L.

4.3.1 Light Nonaqueous Phase Liquid Extent

Per the LTM Plan (Arcadis 2014b), LNAPL migration observations were made from wells along the perimeter of the LNAPL plume. LNAPL was not observed in any of the LNAPL migration monitoring wells during the reporting period. The wells noted with LNAPL during this monitoring period were consistent with past observations at these locations.

4.3.2 Light Nonaqueous Phase Liquid Thickness

Per the LTM Plan (Arcadis 2014b), LNAPL thickness and migration measurements were made from wells within the LNAPL thickness monitoring well network and the LNAPL migration monitoring well network. These results are included in Tables 4-3 and 4-4, respectively. Additionally, LNAPL was gauged during the following monitoring events throughout the quarter: groundwater elevation monitoring, groundwater sampling and field parameter collection, vertical gradient monitoring, hydraulic capture monitoring, and FHRA operator gauging. A comprehensive table including gauging data from each monitoring event conducted at the site during the reporting period is included in Appendix L.

During third quarter, a total of 56 wells were gauged for LNAPL. A measurable LNAPL thickness was recorded in 27 of 56 wells gauged ranging from 0.02 foot to 1.68 feet. A visible sheen was recorded in 11 wells. The maximum LNAPL thickness measured or observed LNAPL sheen for each well during the third quarter is shown on Figure 4-9.

During fourth quarter, a total of 89 wells were gauged for LNAPL. A measurable LNAPL thickness was recorded in 38 of 89 wells gauged ranging from 0.01 foot to 2.64 feet. A visible sheen was recorded in seven wells. The maximum LNAPL thickness measured or observed LNAPL sheen for each well during the third quarter is shown on Figure 4-10.

LNAPL thickness measurements are similar to historical results with no new wells containing LNAPL thickness measurements or visible LNAPL sheen observations. LNAPL recovery results are discussed in Section 5.3.

4.3.3 Natural Source Zone Depletion Assessment Results

Twelve monitoring wells were sampled for the NSZD parameters to evaluate the potential for NSZD to occur at the site. Sample locations included two upgradient (MW-105A-25 and MW-196-15), four downgradient (MW-101A-25, MW-142-20, MW-145-20, and MW-369-16), and six LNAPL source zone wells (MW-116-15, MW-125-25, MW-130-25, MW-180A-15, MW-321-15, and MW-336-20). LNAPL was not present in any of the NSZD monitoring wells. Field parameters were collected from all 12 monitoring wells and are presented in Table 4-1 and Figure 4-11.

Biodegradation and dissolution of the submerged portion of the LNAPL are assessed by comparing the chemical composition of groundwater upgradient from the source zone with groundwater in the source zone and immediately downgradient from the source zone. Moving from upgradient through the source zone, if biodegradation is occurring, a decrease in the concentrations of electron acceptors and a corresponding increase in the concentrations of biodegradation transformation products will be observed. The natural attenuation parameters (iron, manganese, sulfate, and methane) are presented in Table 4-5. A comparison of the upgradient and source zone/downgradient data indicates the following:

- Sulfate was 34.2 and 47.5 milligrams per liter (mg/L) at upgradient wells MW-105A-25 and MW-196-15, respectively, while sulfate in source zone wells decreased to an average of 9.6 mg/L.
- Dissolved iron increased from non-detect and 2.74 mg/L at upgradient wells MW-196-15 and MW-105A-25, respectively, to an average of 31.1 mg/L in the source zone monitoring locations.
- Dissolved manganese increases from 2.06 and 0.0132 mg/L at the upgradient wells MW-105A-25 and MW-196-15, respectively, to an average of 5.4 mg/L in the source zone monitoring locations.
- The methane concentration increased from 0.051 and 0.0028 mg/L at upgradient wells MW-105A-25 and MW-196-15, respectively, to an average of 3.1 mg/L in the source zone monitoring locations.

This spatial comparison of upgradient and source zone natural attenuation parameters shows a clear decreasing trend in electron acceptor and an increasing trend in biodegradation transformation products, which indicates that biodegradation of LNAPL is occurring in the submerged portion of the LNAPL body. Downgradient parameters do not continue to show this trend, because concentrations appear to have reached background conditions in downgradient wells owing to distance from the source zone. Dissolved oxygen was measured at nominal levels from 0.05 to 1.53 mg/L in the NSZD network monitoring wells, indicating that oxygen was not readily available as an electron acceptor. Additional dissolved phase hydrocarbon data and natural attenuation parameters data are included as Appendix G.

4.3.4 Groundwater Extraction-Enhanced Light Nonaqueous Phase Liquid Recovery

FHRA calculated the LNAPL transmissivity for recovery wells R-21 and R-40 using remediation system data collected during the reporting period. LNAPL and groundwater drawdowns are required input values for the LNAPL transmissivity calculation. Two simplifying assumptions were made to facilitate the LNAPL transmissivity calculations:

- LNAPL drawdown used in the calculations was based on the observed thickness of LNAPL in the well during gauging and system data collection.
- Groundwater drawdown can be reasonably calculated for R-21 and R-40 by pairing the recovery well with a monitoring well outside the zone of capture.

Recovery wells R-21 and R-40 were paired with O-5 and MW-125-25, respectively, to complete the calculation. Groundwater drawdown was calculated for this location based on historical fluid gauging data. LNAPL transmissivity results from the groundwater extraction-enhanced LNAPL recovery at R-21 and R-40 are included in Tables 4-6a and 4-6b, respectively. Semiannual and overall results are summarized in Table 4-6c. Time series plots for groundwater extraction-enhanced LNAPL recovery at R-21 and R-40 are included on Figures 4-11a and 4-11b, respectively. Appendices H-1 and H-2 include data analysis output for groundwater extraction-enhanced LNAPL recovery at R-21 and R-40, respectively.

LNAPL transmissivities at R-21 for the reporting period ranged from 0.01 to 0.04 ft^2/day with a cumulative overall transmissivity of 0.3 ft^2/day since 2010. The current reporting period LNAPL transmissivities at R-21 are below upper limit of 0.8 ft^2/day, though historically have been above the limit (except in 2013, when data were likely skewed low due to large drawdown observed in the well during the testing period). Only one recovery event was analyzed for LNAPL transmissivity at R-40 during the reporting period. LNAPL transmissivity during the reporting period was 0.1 ft^2/day with a cumulative overall transmissivity of 0.1 ft^2/day since 2010. These transmissivities are below the upper limit of 0.8 ft^2/day, and have historically been below the limit. It should be noted that datasheets for both wells R-21 and R-40 indicated LNAPL recovery of 24 and 34 gallons per well, respectively, on August 1, 2015. These data were not included in this analysis, as this material was recovered over an extended period and an exact recovery period was not determined; thus, accurate LNAPL transmissivities could not be concluded. Groundwater extraction-enhanced recovery data is included as Appendix H.

4.4 Onsite Monitoring Well Sampling

90 onsite wells included in the Other COCs Monitoring Network in the LTM Plan (Arcadis 2014b) were sampled for BTEX, GRO, and DRO during the reporting period. Results are summarized in Table 4-7. Figure 4-13 presents analytical results for benzene, including the inferred extent of the dissolved-phase benzene distribution within the suprapermafrost aquifer at the site. Results for BTEX, GRO, and DRO are discussed in Section 4.4.1. Historical BTEX, GRO, and DRO analytical results are included in Appendix B.

Sulfolane data were collected from the wells identified in the LTM Plan (Arcadis 2014b) and from wells that are on a monthly performance monitoring schedule for the GRTS, as described in the OCP (Arcadis 2014a). Groundwater samples collected from 261 onsite wells during third quarter 2015 and 110 onsite wells during fourth quarter 2015 were analyzed for sulfolane during the reporting period.

Sulfolane analytical results are summarized in Table 4-8 and on Figures 4-14 through 4-21, which show the inferred extent (based on current and past data) of the dissolved-phase sulfolane distribution at the water table, 10 to 55 feet bwt, 55 to 90 feet bwt, and 90 to 160 feet bwt within the suprapermafrost aquifer at the site. Onsite sulfolane analytical results are discussed in Section 4.4.2.

Fifty-eight samples were collected during third quarter 2015 and three samples were collected during fourth quarter 2015 from the VPT, which includes well clusters MW-301 through MW-306. Groundwater samples were analyzed for sulfolane and results are presented in Section 4.4.3, in Table 4-8, and on Figures 4-14 through 4-21. Sulfolane concentrations for MW-141-20 and the VPT wells are also summarized in Table 4-9 and on Figures 4-22 and 4-23. Historical sulfolane analytical results are included as Appendix B.

4.4.1 Petroleum Hydrocarbons

During the reporting period, samples were collected from 69 wells screened across the water table and 21 wells screened from 10 to 55 feet bwt for petroleum hydrocarbon analytical parameters. Benzene was detected in 27 of the 69 wells screened across the water table, at concentrations ranging from an estimated 0.18 µg/L (MW-134-20) to 16,900 µg/L (MW-337-20). Among the wells screened from 10 to 55 feet bwt, benzene was detected in five of the 21 wells sampled, ranging from an estimated 0.42 µg/L (MW-105A-25) to 386 µg/L (MW-130-25).

In general, toluene, ethylbenzene, total xylenes, GRO, and DRO were not detected in samples where benzene was below the detection limit, so benzene is used as an indicator of petroleum impacts (Arcadis 2014a). Other detected petroleum hydrocarbons within water table wells are summarized below:

- Toluene was detected in 12 water table wells, at concentrations ranging from an estimated 0.660J µg/L (S-43) to 7,470 µg/L (MW-135-20).
- Ethylbenzene was detected in 21 water table wells, at concentrations ranging from an estimated 0.620J µg/L (MW-186A-15) to 1,950 µg/L (MW-135-20).
- Total xylenes were detected in 24 water table wells, at concentrations ranging from an estimated 1.11J µg/L (O-4) to 13,800 µg/L (MW-135-20).
- GRO was detected in 26 water table wells, at concentrations ranging from an estimated 0.0313J µg/L (MW-336-55) to 64.9 µg/L (MW-337-20).
- DRO was detected in 18 water table wells, at concentrations ranging from an estimated 0.183J µg/L (O-24) to an estimated 13.3J* µg/L (MW-336-20).

The estimated horizontal extent of the benzene plume at the water table is identified on Figure 4-13 as an isopleth based on benzene concentrations from current and prior quarters.

4.4.2 Sulfolane

Sulfolane was not detected in samples collected during third quarter 2015 from 34 onsite wells screened across the water table, 47 wells screened from 10 to 55 feet bwt, 37 wells screened from 55 to 90 feet bwt, and 29 wells screened from 90 to 160 feet bwt. Sulfolane was not detected in samples collected during fourth quarter 2015 from seven onsite wells screened across the water table, eight wells screened from 10 to 55 feet bwt, five wells screened from 55 to 90 feet bwt, and three wells screened from 90 to 150 feet bwt.

Sulfolane was detected in groundwater samples from the remaining onsite wells as follows:

- In wells screened across the water table (70 wells during third quarter 2015 and 58 wells during fourth quarter 2015), at concentrations ranging from an estimated 3.14J µg/L (MW-135-20) to an estimated 22,500JL* µg/L (MW-336-20) and from an estimated 3.47J µg/L (MW-358-20) to 14,300JL* µg/L (MW-336-20), respectively.
- In wells screened from 10 to 55 feet bwt (38 wells during third quarter 2015 and 23 wells during fourth quarter 2015), at concentrations ranging from an estimated 3.34J µg/L (MW-303-49) to 940 µg/L

(MW-354-35) and from an estimated 3.47J µg/L (MW-351-55) to 813J* µg/L (MW-354-35), respectively.

- In wells screened from 55 to 90 feet bwt (five wells during third quarter 2015 and six wells during fourth quarter 2015), at concentrations ranging from an estimated 4.46J µg/L (MW-362-80) to 18.9 µg/L (MW-345-75) and an estimated 4.67J µg/L (O-19-90) to 17.1 µg/L (MW-154B-95), respectively.

Sulfolane concentrations were flagged as estimated for groundwater samples collected from 49 wells during third quarter 2015 and 24 during fourth quarter 2015 (Table 4-8). Estimated sulfolane concentrations are discussed in Appendix D. Sulfolane concentration isopleths at the water table, 10 to 55 feet bwt, 55 to 90 feet bwt, and 90 to 160 feet bwt are presented on Figures 4-14 through 4-21.

4.4.3 Vertical Profiling Transect

Groundwater samples were collected from the VPT wells to evaluate the vertical distribution of sulfolane concentrations and for mass flux estimation (Section 4.4.4). Sampling frequency of VPT wells was reduced during fourth quarter 2015 in accordance with parameters defined in the LTM Plan (Arcadis 2014b). Sulfolane results for MW-141-20 and the VPT wells are summarized in Table 4-9 and on Figures 4-22 and 4-23. Additionally, Figures 4-14 through 4-21 show sulfolane concentrations for the VPT cluster locations at depths appropriate for each figure; Appendix J, Figures 2A through 2D show the temporal sulfolane trends in the VPT wells. Sulfolane concentrations continue to decline along the VPT, with the shallow data at the MW-304 nest showing the highest lingering concentrations. This location is near the historical axis of the plume, and in geology that tracer studies showed is likely influenced by dual-porosity characteristics.

4.4.4 Sulfolane Mass Flux

The sampling frequency of VPT wells was reduced during fourth quarter 2015 in accordance with parameters defined in the LTM Plan (Arcadis 2014b). Mass flux was evaluated utilizing third quarter 2015 results. 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 estimated at approximately 86 grams per day (g/day; or 0.19 pound per day [lb/day]). A sulfolane mass flux of approximately 7.3 g/day (0.02 lb/day) was calculated for third quarter 2015, less than one-tenth of the initial flux calculated in samples collected in November 2011. Mass flux rates across the VPT continue to decrease and are presented on Figure 4-25. The zones exhibiting the majority of mass flux are summarized in Table 4-10.

During third quarter 2015, 79 percent of the total sulfolane mass flux was discharged across the VPT near MW-302 (water table to 32 feet bgs), MW-303 (approximately 13 to 42 feet bgs), and MW-304 (water table to 27 feet bgs zone; Figure 4-22). In addition, during third quarter 2015, sample concentrations within the 10-, 20-, and 30-foot bgs depth intervals at MW-302; 29-, 39-, and 49-foot bgs depth intervals at MW-303; and 30-foot bgs depth interval at MW-304 were flagged as estimated by the laboratory (J-flags).

The estimated values during the reporting period 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, a low rate of mass flux is indicated across the alternative point of compliance. 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 the deep intervals from well clusters MW-301, MW-302, MW-303, MW-304, and MW-305, these sampling points act as a boundary and were assigned values equal to zero rather than one-half of the detection limit.

4.5 Statistical Analysis of Benzene 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) is used to complete the Mann-Kendall trend analysis for benzene and sulfolane in select groundwater monitoring wells using data collected through third quarter 2015. Mann-Kendall trend analysis will be completed for the next reporting period using data collected through the first quarter 2016 sampling event.

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 trend analysis was applied to groundwater monitoring data collected since 2006 from monitoring and observation wells. Wells having a historical presence of LNAPL were excluded from the evaluation of the benzene statistical trend.

A statistical and graphical evaluation of benzene and sulfolane concentration trends is conducted semiannually during the first and third quarters at monitoring and observation wells. The data are used to evaluate plume migration and stability and remedial action effectiveness, and to identify relationships between dissolved-phase concentrations, groundwater elevations, and flow directions. Section 6.2 describes an additional evaluation of the sulfolane and benzene concentration trends for data collected from the performance monitoring network associated with the GRTS since 2011. The analysis trends are expressed as probably increasing, increasing, probably decreasing, decreasing, stable, or no trend. Results of the Mann-Kendall trend analysis for the reporting period are presented in Tables 1 and 2 and Figures 1A through 2D of Appendix J, and are summarized in the table below.

Parameter Trend	Third Quarter	
	Benzene	Sulfolane
No. of wells	140	293
All results non-detect[1]	86	113
Insufficient data points[1]	6	10
Probably decreasing	3	10
Decreasing	8	92
Probably increasing	0	4
Increasing	2	4
Stable	10	35
No trend	25	25

Note:

[1]Wells with insufficient data points for the statistical analysis (less than four points), but with all results below detection limits, are listed under "all results non-detect."

Using data from 2006 through the third quarter 2015, benzene concentrations in groundwater from 11 monitoring wells and sulfolane concentrations in groundwater from 102 monitoring wells were found to have decreasing or probably decreasing trends.

Using data from 2006 through third quarter 2015, benzene concentrations in groundwater from two monitoring wells (out of 140 sampled) and sulfolane concentrations in groundwater from eight monitoring wells (out of 293 sampled) were found to have increasing or probably increasing trends. These results are discussed below.

4.5.1 Benzene Statistical Evaluation

The Mann-Kendall trend analysis resulted in an increasing benzene concentration trend at R-46 and O-24. Benzene concentrations at O-24 ranged from 1.42 µg/L (May 2013) to 56.4 µg/L (August 2015). Based on the benzene time series plots included as Attachment 1 in Appendix J, concentrations at well O-24 appear to be increasing. Well O-24 is within the detectable benzene plume at the site, near the downgradient extent.

Benzene concentrations in R-46 ranged from 28.8 µg/L (April 2014) to 140 µg/L (October 2014). Based on the benzene time series plots included as Attachment 1 in Appendix J, concentrations at well R-46 appear to be decreasing since October 2014. During third quarter 2015, the benzene concentration at R-46 was 75.6 µg/L. Well R-46 is within the detectable benzene plume at the site and is currently being actively pumped by the recovery system which is likely influencing dissolved benzene concentrations at this location.

4.5.2 Sulfolane Statistical Evaluation

Using statistical approaches to evaluate groundwater monitoring data collected since 2006, increasing or probably increasing trends were observed at only eight onsite monitoring wells: MW-179B-50, MW-304-96, MW-321-65, MW-355-15, O-27-65, O-5-65, MW-345-75, and MW-348-65.

Wells MW-321-65 and MW-304-96 are outside the detectable sulfolane plume and have not exhibited detections since third quarter 2012 and third quarter 2013, respectively. Sulfolane was detected in 16.7 and 46.2 percent of the monitoring events, at concentrations ranging from an estimated 3.5 µg/L (June 2012) to an estimated 3.54 µg/L (July 2012) and from an estimated 3.21 µg/L (July 2013) to an estimated 5.05 µg/L (January 2013) at MW-321-65 and MW-304-96, respectively. The trend in these wells is likely a false increasing trend as it is related to the reporting limit that is used for the “non-detect” value being greater than the “low-level” estimated detections exhibited prior to 2012 for MW-321-65 and 2013 for MW-304-96.

Sulfolane was detected in 100 percent of the monitoring events for wells MW-345-75 and MW-348-65, at concentrations ranging from an estimated 7.03 µg/L (November 2013) to 18.9 µg/L (July 2015) and from an estimated 4.95 µg/L (April 2014) to 14.4 µg/L (February 2015) at MW-345-75 and MW-348-65, respectively.

Sulfolane was detected in more than 70 percent of the monitoring events for wells MW-179B-50, MW-355-15, O-27-65, at concentrations ranging from an estimated 3.4 µg/L (August 2011) to an estimated 7.68 µg/L (August 2014), from an estimated 3.49 µg/L (March 2014) to 77 µg/L (October 2014) and from an estimated 5.94 µg/L (December 2013) to 14.4 µg/L (February 2015), respectively.

Sulfolane was detected in only 44 percent of the monitoring events for well O-5-65, at concentrations ranging from an estimated 6.18 µg/L (August 2014) to 11.9 µg/L (October 2014).

Wells MW-179B-50, MW-355-15, O-27-65, O-5-65, MW-345-75, and MW-348-65 are located within the detectable sulfolane plume. Of these, wells MW-179B-50, MW-355-15, and O-5-65 are located upgradient or adjacent to the GTRS and are therefore influenced by the groundwater remediation effort. A visual observation of the concentration trend plots (Attachment 1 of Appendix J) show that concentrations at most locations with increasing Mann-Kendall trends are either stable or decreasing since October 2014. The exceptions include O-27-65, MW-345-75, and MW-348-65. Concentrations have remained below 15 µg/L at O-27-65 and MW-348-65, and below 20 µg/L at MW-345-75 since sampling began at these locations.

4.6 Non-routine Activities

In October 2015, Homestead Drilling Company of Fairbanks, Alaska installed two shallow groundwater monitoring wells at the site with oversight provided by SWI. Monitoring wells MW-372-15 and MW-373-15 were installed in accordance with Section 8 of the LTM Plan (Arcadis 2014b).

Monitoring wells MW-372-15 and MW-373-15 were installed to monitor shallow groundwater quality in the areas downgradient of piezometer PZ-2-15 and the MW-355 well nest, between the wash skid and south gravel pit. MW-372-15 was installed on the north side of the drum storage shed; MW-373-15 was installed to the north-northwest of PZ-2-15 and the south gravel pit. The new monitoring well locations are shown on Figure 2-3.

4.6.1 Well Construction Methodology

On October 15, 2015, monitoring wells MW-372-15 and MW-373-15 were installed according to the procedures described in the Onsite RSAP (Arcadis 2015a). The screened interval was selected according to the observed depth to water (DTW) during drilling and known seasonal variation in groundwater levels. Soil saturation within the boring for monitoring well MW-372-15 was observed at approximately 12.5 feet bgs. Based on the observed soil saturation depth, the well screen for monitoring well MW-372-15 was set at 6.01 to 15.77 feet bgs. Soil saturation within the boring for monitoring well MW-373-15 was observed at approximately 10 feet bgs. Based on the observed soil saturation depth, the well screen for monitoring well MW-373-15 was set at 4.26 to 14.02 feet bgs. Boring logs and monitoring well construction details are included in Appendix K.

4.6.2 Soil Classification

Soil was described according to the Unified Soil Classification System, as summarized in the Onsite RSAP (Arcadis 2015a). The soil conditions encountered during drilling were generally consistent with those observed throughout the site. Soil encountered from the ground surface to approximately 5 to 8 feet bgs was a mixture of sand, gravel, and silt, with no apparent bedding. Fine-grained silt and sand mixtures followed to the target depth below saturation. Saturated soil was encountered at approximately 12.5 feet bgs (MW-372-15) and 10 feet bgs (MW-373-15). Boring logs are included as Appendix K.

4.6.3 Soil Screening and Sampling

Split-spoon soil samples were field screened according to the Onsite RSAP (Arcadis 2015a) using a hand-held photo ionization detector (PID). Field PID screening results did not exceed 1 part per million organic vapor concentrations. Therefore, analytical soil samples were not submitted for laboratory analysis. Soil cuttings were stored onsite in steel drums, pending disposal; the steel drums were labelled with pertinent information including boring name, investigation date, and maximum PID reading.

4.6.4 Well Development and Water Sampling

On October 22 and 23, 2015, SWI developed monitoring wells MW-372-15 and MW-373-15 according to procedures described in the Onsite RSAP (Arcadis 2015a). The total volumes of development water removed from monitoring wells MW-372-15 and MW-373-15 was approximately 120 and 70 gallons, respectively. Following development, an initial groundwater sample was collected from each well for sulfolane analysis. Development water was temporarily stored onsite, in labelled steel drums. Development water was then transferred to the site wastewater treatment system by FHRA personnel via vacuum truck after development was completed. Sulfolane results are discussed in Section 4.4.2 and presented in Table 4-8. Field forms containing monitoring well development details are included in Appendix E.

5 GROUNDWATER REMEDIATION AND TREATMENT SYSTEM RESULTS AND EVALUATION

This section discusses operating results for the existing GRTS for the reporting period. Ongoing remediation efforts at the site include groundwater recovery and treatment and LNAPL recovery and recycling, as described in Sections 5.2 and 5.3, respectively. The GRTS layout is shown on Figure 5-1 and process flow diagrams for the systems are shown on Figures 5-2a and 5-2b.

5.1 Associated Permits

Treated groundwater from GAC East is discharged at the SGP in accordance with wastewater disposal permit 2005-DB0012 issued by ADEC, temporary water use permit A2011-48 issued by the Department of Natural Resources (DNR), and temporary water use permit LAS24907 issued by the DNR.

Treated groundwater from GAC West, including recovery well R-42, is discharged at the NGP in accordance with an Interim Approval to Operate issued by ADEC, temporary water use permit A2011-48 for R-42 issued by the DNR, and temporary water use authorization A2014-13 issued by DNR.

5.2 Groundwater Recovery and Treatment

The stated objective set out in the OCP (Arcadis 2014a) for groundwater is to meet the Table C cleanup levels and the sulfolane performance standard at the alternative point of compliance. The GTRS, along with monitoring and Institutional Controls were proposed to meet these objectives.

5.2.1 During the Reporting Period

The average groundwater recovery rate for the GRTS was 544 gallons per minute (gpm) during the reporting period. This rate was calculated from the combined GAC East and GAC West flowrates. For comparison, during 2014, the groundwater recovery rate for the GRTS averaged 454 gpm.

Pumping rates for the individual recovery wells are measured continuously by the facility process control system, with the exception of recovery well R-40, which is not connected to the process control system; therefore, flow readings are recorded manually. FHRA plans to connect R-40 to the process control system in 2016.

The average flow rates (when pumping) and total and percent runtimes for the reporting period are shown in the table below, along with the target flow rate for each well.

Location	Third and Fourth Quarter 2015 Average Flow Rate	Target Flow Range*	Third and Fourth Quarter 2015 Runtime	Percent Runtime
R-21	46.4 gpm	40 to 50 gpm	4,253 hours	96.3
R-35R	48.8 gpm	50 to 65 gpm	4,054hours	91.8

Location	Third and Fourth Quarter 2015 Average Flow Rate	Target Flow Range*	Third and Fourth Quarter 2015 Runtime	Percent Runtime
R-40	10.9 gpm	See R-45 below	4,241 hours	96.0
R-42	84.8 gpm	60 to 85 gpm	4,400 hours	99.6
R-43	65.1 gpm	60 to 85 gpm	4,219 hours	95.5
R-44	66.5 gpm	60 to 70 gpm	4,219 hours	95.5
R-45	39.7 gpm (with R-40, 50.6 gpm)	50 to 65 gpm (combined with R-40)	4,060 hours	91.9
R-46	31.0 gpm	30 to 40 gpm	3,866 hours	87.6
R-47	73.1 gpm	55 to 80 gpm	4,299 hours	97.3
R-48	107.4 gpm	80 to 120 gpm	4,375 hours	99.1

* Target flow ranges as presented in the OMM Plan – 2015 Update (Barr 2015).

Each of the recovery wells maintained a high runtime during the reporting period. Downtime for each recovery well is further discussed in Section 5.6; the most significant event was planned downtime at recovery wells R-35R, R-45, R-46, and R-47 for completion of chemical well rehabilitation to restore the specific capacity of each well. Results of the chemical well rehabilitation are discussed in Section 5.6. Additional downtime for the GAC East wells (R-21, R-35R, R-40, R-43, R-44, R-45, and R-46) occurred during installation of a baffle system within the gallery pond, as further discussed in Section 5.6. During portions of the operating and reporting period, recovery rates at several individual wells periodically exhibited some typical variability compared to target flow rates; however, as described in Section 6.1, hydraulic capture was maintained in aggregate.

The majority of reporting period downtime for recovery wells connected to GAC West (R-42, R-47, and R-48) was planned to accommodate recharge of the green sand filter through the addition of potassium permanganate, and for well rehabilitation at R-47.

5.2.2 Cumulative Groundwater Recovery

Table 5-1 summarizes the volume and rate of groundwater recovered monthly from 2009 through the end of the reporting period. Annual groundwater recovery totals, as measured at the final effluent of the treatment systems, 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
- 2014: 237,348,487 gallons
- 2015: 291,422,897 gallons

5.2.3 Groundwater Treatment Performance Evaluation

5.2.3.1 GAC East

In accordance with the OCP (Arcadis 2014a) and the wastewater disposal permit for GAC East, FHRA conducted monthly monitoring of the GAC East effluent during the reporting period. FHRA also conducted multiple additional monitoring events to evaluate performance of the treatment system. Results for the monthly and additional monitoring events are summarized in Tables 5-2a through 5-2d.

The sulfolane concentration measured in the GAC East final effluent was both below 15 µg/L and the detection limits during each monitoring event for the reporting period (Table 5-2a).

BTEX and semi-volatile organic compound concentrations measured at the GAC East final effluent were below the discharge limits for the system during each monitoring event (Table 5-2b and 5-2c). Additionally, the results of the GAC East effluent were below detection limits, with the exception of low-level detections of phenanthrene (0.0220 J µg/L) on August 5, 2015 and naphthalene (0.0523 J µg/L) on December 2, 2015. These detections were flagged and are considered estimated because they are below the limit of quantitation. The concentrations reported are well below the discharge permit limits for total aromatic and aqueous hydrocarbons. Total organic carbon, total suspended solids, iron, and manganese monitoring were performed to evaluate system operation; results are included in Table 5-2d. Analytical laboratory reports are provided in Appendix B.

No GAC media changeouts were completed during the reporting period.

5.2.3.2 GAC West

During the reporting period, GAC West was sampled at an increased frequency (in addition to the required monthly sampling) to evaluate system performance. Results for monitoring completed at GAC West are included in Tables 5-3a, 5-3b, and 5-3c.

As shown in Table 5-3a, GAC West removed sulfolane and the final effluent was below 15 µg/L during each monitoring event in the reporting period. Quarterly BTEX monitoring was also conducted and the results are shown in Table 5-3b. Results for the GAC West recovery wells (R-42, R-47, and R-48) were below detection limits for BTEX. Iron and manganese monitoring were performed to evaluate system operation and the results are included in Table 5-3c.

The GAC media were changed out for the A and B vessels during the reporting period in November 2015.

5.3 Light Nonaqueous Phase Liquid Recovery and Recycling

5.3.1 Volumetric Recovery Rates

During the reporting period, FHRA performed LNAPL recovery via a skimmer system when adequate LNAPL was consistently present in wells MW-334-15, R-21, and R-40 (Figure 5-1). Manual LNAPL recovery was conducted using a vacuum truck or portable LNAPL pump at wells MW-138-20, MW-176A-15, MW-334-15, O-11, O-31, O-33, R-20R, R-32, R-32R, R-35R, R-40, S-22, S-39, and S-51. Additionally, sufficient LNAPL for recovery was measured at O-38 and S-44 late during the fourth quarter and recovery was initiated in January 2016, and thus not reflected in Table 5-4 or Figure 5-1. LNAPL recovered from the skimmer systems and from manual recovery activities is stored onsite until it is recycled.

LNAPL recovery for the reporting period is summarized in Table 5-4; historical LNAPL recovery at the site since 1986 is summarized in Table 5-5. During the reporting period, 192 gallons of LNAPL were recovered, the majority of which was removed from wells MW-334-15, R-21, R-32, and R-40. From 1986 to present, approximately 397,020 gallons of LNAPL have been recovered. LNAPL gauging data collected as part of the operations and maintenance of the LNAPL recovery efforts are included in Appendix L.

5.4 Benzene, Toluene, Ethylbenzene, and Xylenes Mass Capture

FHRA monitored the BTEX concentrations in recovered groundwater on a quarterly basis to calculate mass removal rates (Table 5-6).

Based on the monitoring results, BTEX mass removal averaged 0.66 lb/day and totalled approximately 113 pounds during the reporting period, for a total of approximately 249 pounds during 2015. For comparison, GAC East removed approximately 293 pounds of BTEX in 2014 and 403 pounds during 2013 (Arcadis 2013a).

The BTEX concentrations were below detection limits in GAC West recovery well samples (Table 5-3b); therefore, GAC West is not included in the mass removal calculations shown in Table 5-6.

5.5 Sulfolane Mass Capture

5.5.1 Per Well Capture

FHRA monitored the sulfolane concentration in recovered groundwater at each active recovery well; mass recovery rates for each well are summarized in Tables 5-7a and 5-7b for GAC East and GAC West, respectively. During the reporting period, the highest average mass recovery rate was measured at well R-21 (0.15 lb/day; Table 5-7a). Well R-46 had no measurable recovery of sulfolane and is considered to be outside the sulfolane plume (Table 5-7a); however, groundwater recovery currently continues at well R-46 resulting in capture of the BTEX plume in this area.

5.5.2 Cumulative Capture

Table 5-8 summarizes the combined sulfolane mass removal rates for GAC East and GAC West. The rates were calculated from sulfolane concentrations measured monthly in the GRTS influent or individual recovery wells. Approximately 144,300,000 gallons of recovered groundwater were remediated during the reporting period. Sulfolane mass removal averaged 0.34 lb/day and, based on the system runtime, totalled approximately 63 pounds during the reporting period and 122 pounds for 2015.

5.6 Summary of Routine and Non-routine Repairs, Changes, and Maintenance

The GRTS maintained a high runtime percentage as demonstrated at the individual recovery wells (Section 5.2.1). Four recovery wells (R-35R, R-45, R-46, and R-47) had downtime for well rehabilitation but maintained a high overall runtime percentage for the reporting period. Rehabilitation was conducted to improve the specific capacity of the recovery wells. The work was completed using methods similar to previous well rehabilitation efforts and in accordance with information provided to ADEC and a Letter of Non-Objection (ADEC Division of Water 2015).

Step drawdown testing was performed pre- and post-rehabilitation at recovery wells R-35R, R-45, R-46, and R-47. Results of the step-drawdown testing are provided in Appendix M. In each case, the well rehabilitation was successful at improving the specific capacity of the well. Significant increases were observed at R-35R and R-47, while less substantial increases were observed at R-45 and R-46. As a result of the well rehabilitation, all of the recovery wells are currently capable of operating within target flow ranges noted in the OCP (Arcadis 2014a) with the exception of R-45. As a result, FHRA will continue to operate nearby recovery well R-40 to further ensure capture near R-45.

As noted during previous groundwater monitoring reports (Arcadis 2015a; Arcadis 2015b), a packer was installed within R-45 in an attempt to reduce the rate of decline in well capacity. The packer was removed prior to the well rehabilitation and not reinstalled. Placement of a similar packer in R-45 will be decided based on post-rehabilitation performance of the well without the packer.

The majority of downtime events were associated with changeout of the coalescer filters (GAC East) while they were online, with a typical duration of 1 to 2 hours. Additional downtime for maintenance events and changes at the individual recovery wells or treatment systems during the reporting period are summarized in Table 5-9.

During the reporting period, FHRA installed a baffle system in the GAC East gallery pond to lengthen the hydraulic retention time and create a zone for suspended solids to settle out. The ADEC Division of Water was notified of the changes to the treatment system in accordance with wastewater disposal permit 2005-DB0012 and had no objections. The changes were completed in September 2015. During the downtime to install the baffle system, solids were removed from the gallery pond, characterized and transported offsite for treatment and disposal as non-hazardous waste.

With the successful increase in gallery pond retention time with the baffle system, FHRA was able to bypass the prefilters and coalescer during operation of the treatment system. ADEC was notified of these changes and did not have objections. The purpose of the coalescer was to remove any LNAPL that may accidently be captured by the groundwater recovery pumps within the recovery wells. To prevent unintended LNAPL capture, operation of the treatment system will continue in accordance with procedures to remove LNAPL via the skimmer pumps at each recovery well and prevent entrainment in the groundwater pumps. FHRA installed floating skimming booms within the gallery pond. If LNAPL reaches the gallery pond, the skimming booms will prevent migration to the discharge pump intake area.

As further described in Section 6, results of the hydraulic capture events and continued overall declines in concentration in the sulfolane and BTEX plumes north of the GRTS capture zone indicate the effectiveness of the GRTS during the third and fourth quarters of 2015 and preceding quarters. Thus, operation of the GRTS is meeting its performance goals, and limited downtime events in the reporting period fell within design expectations.

5.7 Summary

During the reporting period, FHRA maintained a high runtime for the recovery wells and treatment systems. FHRA continued to meet goals associated with maintaining hydraulic capture, which is further discussed in Section 6, and treatment of recovered groundwater. FHRA completed several tasks to maintain the recovery wells and treatment systems, including well rehabilitation at four recovery wells.

6 GROUNDWATER REMEDIATION AND TREATMENT SYSTEM PERFORMANCE MONITORING

This section discusses performance monitoring results for the GRTS, as defined in the OCP (Arcadis 2014a), including two quarterly hydraulic capture events conducted during the third and fourth quarters of 2015.

6.1 Groundwater Capture Evaluation

Performance monitoring for the GRTS includes hydraulic capture monitoring (quarterly) and water quality assessment (quarterly to semiannually). Performance monitoring is conducted to confirm the continued effectiveness of the GRTS. Hydraulic capture of the sulfolane and BTEX plumes was evaluated during the reporting period using groundwater elevation and groundwater quality data as described below. Beginning in third quarter 2015, the hydraulic capture monitoring frequency was reduced from monthly to quarterly per the schedule presented in the OCP (Arcadis 2014a).

During the reporting period, the GRTS demonstrated hydraulic control at the water table from east of well MW-137-20 westward to the NGP in each of two quarterly events described in Section 6.1.1. This hydraulic capture zone encompassed the entire width and depth of the BTEX plume and the width of the sulfolane plume east of the NGP. The estimated capture zone extends vertically to depths up to 80 feet bgs, below the known extent of sulfolane concentrations greater than 15 µg/L with one exception. The sulfolane concentration in the sample collected from MW-345-75 during the third quarter 2015 was detected at a concentration of 18.9 µg/L. Therefore, the capture zone during third quarter 2015 was estimated to extend to a depth just above the bottom of the screen of MW-345-75 (Figure 3, Appendix N.)

The concentration in the fourth quarter 2015 sample from MW-345-75 trended downward to 16.6 µg/L and the capture zone in the fourth quarter 2015 was estimated to extend below the bottom of the screen of MW-345-75 (Figure 8, Appendix N). Section 1 of Appendix N provides additional detail regarding the capture zone evaluation.

The capture evaluation results indicate that operation of the GRTS at rates achieved throughout the third and fourth quarters of 2015 supports meeting the combined groundwater extraction and treatment system performance standard of 15 µg/L at the alternative point of compliance (ARCADIS 2014a).

6.1.1 Manual 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 defined in the OCP (Table 5-1 of Arcadis 2014a) and augmented as indicated in Attachment 1 of the OMM Plan – 2015 Update (Barr 2015).

The hydraulic capture measurements (water-level measurements with concurrent top of casing surveys) were taken to provide the most accurate groundwater elevation data for delineation of the capture zone of the GRTS. These measurements were recorded on the dates noted below, including combined pumping rates, as read from the individual recovery well flow meters at the time of the hydraulic capture field measurements:

- August 19, 2015: combined pumping rate of 611 gpm.
- October 6, 2015: combined pumping rate of 563 gpm. Note that the nominal pumping rates for wells R-47 and R-48 were reduced from 80 to 65 gpm and 120 to 95 gpm, respectively, several days prior to this event.

Measured DTW, calculated hydraulic heads, and capture zone estimates based on these measurements are presented in Appendix N. Capture zone estimates are made for each event at the water table and in four cross sections.

The third and fourth quarter 2015 capture zone evaluations included measurement of the NGP surface water elevation. A series of control points along the shoreline of the NGP were used with the estimated elevations shown on Figures 1 and 6 in Appendix N. This approach is based on the observation that surface water in the NGP is hydraulically connected to the suprapermafrost aquifer, which is consistent with the CSM (Arcadis 2013a). Field measurements made in each of the hydraulic capture measurement events during the reporting period were determined to be acceptable for use.

6.1.2 Capture Zone Summary

With implementation (in January 2010) of the improvements identified in the Interim Removal Action Plan (Barr 2010), FHRA began to increase the overall groundwater recovery rate of the GRTS. Groundwater recovery rates further increased in July 2011 following the installation of R-42 and again in June 2013 following implementation of the Revised Interim Removal Action Plan Addendum (Arcadis 2013c) and installation of wells R-43, R-44, R-45, and R-46. The effects of these improvements and additions were demonstrated in the hydraulic capture zone analysis (Barr 2013) and, along with the monthly measurement events conducted between August 2013 and May 2014, indicate that the GRTS maintained hydraulic control at the water table from east of well MW 137-20 westward to at least the MW-309 nest. With the addition of recovery wells R-47 and R-48 in June 2014, the capture zone of the GRTS consistently extends to the NGP and vertically to depths up to 80 feet bgs.

6.2 Concentration Trend Evaluation

FHRA monitors sulfolane concentrations (quarterly) and benzene (semiannually) to determine trends and evaluate the performance of the GRTS. As discussed in Section 4.5, Mann-Kendall concentration trends are calculated using the protocol described in Appendix J and are based on analysis of the dataset since 2006 or since well installation, whichever is more recent, through third quarter 2015. While an excellent tool for evaluating concentration trends, Mann-Kendall trend analysis has limitations. For example, within a long-term dataset, it may not recognize more recent trends that are influenced by recently implemented remediation measures. Therefore, FHRA also performs a visual inspection of the concentration graphs.

6.2.1 Sulfolane

Table 6-1 summarizes FHRA's interpretation of the current sulfolane concentration trends at individual GRTS performance monitoring wells; wells are generally presented in the table from west to east. The analyses summarized in Table 6-1 focus on the trends in more recent monitoring data and identify the effects of enhanced groundwater remediation implemented since 2010. The performance monitoring wells identified in Table 6-1 are categorized based on location relative to the treatment zone; each area is summarized below:

- *Upgradient*. Sulfolane concentration trends in wells upgradient from the GRTS treatment zone are decreasing or stable. It is likely that the upgradient locations are minimally influenced by operation of the GRTS; these trends are believed to primarily be the result of a decreasing stored sulfolane mass in upgradient source areas.
- *Within the treatment zone*. Sulfolane concentration trends from monitoring wells within the treatment zone are decreasing or stable with the following exceptions:
  - *Well O-5*. Sulfolane concentrations in O-5 have been fluctuating between 100 and 260 µg/L, although they decreased during 2015. This variation may be the result of increased capture with operation of the GAC West recovery wells, which is altering the flow paths in this area prior to capture.
  - *Well O-5-65*. Sulfolane concentrations in O-5-65 fluctuated between non-detect and 12 µg/L in 2014 and 2015. This variation may be the result of increased capture with operation of the GAC West recovery wells, which is altering the flow paths in this area prior to capture.
  - *Well O-2*. Sulfolane concentrations increased between second quarter 2014 and second quarter 2015, although the increase did not continue during the reporting period, which may be the result of changes in the groundwater recovery rate at nearby R-44.
  - *Wells MW-345-55 and MW-345-75*. Sulfolane concentrations in MW-345-55 and MW-345-75 have slowly increased with some fluctuation since 2013, which may be the result of increased pumping at R-43.
- *Downgradient*. Sulfolane concentration trends for monitoring wells downgradient from the treatment zone are decreasing or stable.

In addition to the trends presented in Table 6-1, a low concentration zone has developed immediately north (downgradient) of the recovery wells. For example, sulfolane was reported as non-detect or at low concentrations (less than 15 µg/L) in water table wells MW-351-15, MW-371-15, O-4, O-12, and O-31 (Figures 4-15 and 4-19), and deeper wells MW-351-55, MW-371-55, O-12-65, O-26-65, MW-127-25, (Figures 4-16 and 4-20) and MW-351-75 and MW-371-75 (Figures 4-17 and 4-21). Overall downward trends in concentration and mass flux at the VPT are consistent with the source controls and operation of the GRTS (Sections 4.4.3 and 4.4.4).

6.2.2 Benzene

Performance monitoring for benzene occurred during third quarter 2015, with the exceptions noted in Section 3.4. Table 6-2 summarizes FHRA's interpretation of the current benzene concentration trends at individual performance monitoring wells, generally presented from west to east. A few of the wells were recently added to the performance monitoring network; therefore, insufficient data have been generated to evaluate trends at these wells. The concentration trend analyses for benzene summarized in Table 6-2 focus on trends in more recent monitoring data and identify the effects of the GRTS implementation since 2010. The performance monitoring wells identified in Table 6-2 are categorized based on location relative to the treatment zone; each area is summarized below:

- *Upgradient*. Of the seven monitoring locations upgradient of the GRTS, two wells (MW-369-16 and O-6) are located west of the benzene plume and one well is screened below the benzene plume (O-19-55); therefore, samples from these wells are consistently non-detect. The three shallow wells located within the benzene plume (O-19, MW-130-25, and S-43) exhibit fluctuating or increasing trends. One well (S-51) lacks sufficient data to analyze the trend.
- *Within the treatment zone*. Ten of the 13 treatment zone monitoring wells have decreasing or stable concentrations. Two of the 13 monitoring wells were not sampled due to the presence of LNAPL, and concentrations are fluctuating at low concentrations at one well (O-5).
- *Downgradient*. Ten of the 12 downgradient wells have stable or decreasing concentrations. Fluctuating concentrations of benzene were noted at well O-12 and concentrations at well O-24 are increasing.

6.3 Transect Trend Evaluation

To further evaluate the effectiveness of the GRTS, sulfolane concentration trends were evaluated along three longitudinal transects parallel to the groundwater flow path (Figure 6-1). Transects A and B (Figures 6-2 and 6-3) comprise shallow wells (water table and 10 to 55 feet bwt); Transect C (Figure 6-4) comprises deeper wells (55 to 90 feet bwt). Monitoring wells are noted on the figures based on their location relative to the GRTS (upgradient, within the treatment zone, or downgradient). Also shown are the pumping rates of the GRTS to demonstrate the effects of increased groundwater recovery on sulfolane concentrations in these wells since 2010.

The data presented on Figures 6-2 and 6-3 demonstrate that shallow sulfolane concentrations downgradient from the treatment zone are lower than concentrations upgradient from the treatment zone. In addition, these figures show that decreasing downgradient sulfolane concentrations correlate with increased pumping from the GRTS starting in 2010. This indicates that ongoing groundwater remediation is successfully recovering sulfolane-impacted groundwater and is eliminating the migration of sulfolane-impacted groundwater past the GRTS. Additionally, concentrations measured in deeper wells MW-154B-95 and MW-186E-75 are decreasing or stable (Figure 6-4). Deeper well O-19-90 is upgradient of the treatment zone along the Figure 6-4 transect, and sulfolane has not been detected at this location and depth.

Sulfolane concentrations in deeper portions of the aquifer near the GRTS are lower than concentrations reported in the shallow groundwater, as demonstrated at the MW-186, MW-334, MW-344, and MW-345 well nests (Figures 4-16 and 4-20).

7 CONCLUSIONS

Groundwater monitoring and sampling events were conducted during third quarter and fourth quarter 2015 in accordance with the LTM Plan (Arcadis 2014b) and the Onsite RSAP (Arcadis 2015a). During this reporting period the GRTS system was operated and monitored in accordance with the OCP (Arcadis 2014a) and the OMM Plan (Barr 2014). This section summarizes conclusions based on results of the onsite field activities conducted during the reporting period:

- Groundwater monitoring data collected during the reporting period are consistent with data collected during recent quarters.
- The statistical analyses included in Appendix J show that sulfolane concentrations at 102 wells and benzene concentrations at 11 wells across the plume are decreasing or probably decreasing while sulfolane concentrations at eight wells and benzene concentrations at two wells across the plume are increasing or probably increasing.
- Sulfolane concentrations and trends continue to decrease in the onsite areas near the site boundary.
- Sulfolane concentrations and the estimated sulfolane mass flux rate across the OCP alternative point of compliance continue to decrease.
- BTEX concentrations are consistent with historical detections and the BTEX plume appears to be stable. BTEX concentrations continue to be limited to the developed area onsite.
- During the reporting period, the GRTS continued to capture and remediate sulfolane- and BTEX-impacted groundwater.
- Concentrations of sulfolane and BTEX in the downgradient portion of the plume adjacent to the capture zone continue to show an overall decline, thus indicating the effectiveness of the GRTS.

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