University of Alaska Gold Creek Spill Site Panel Review Report

Prepared for the

Alaska Railroad Corporation

Prepared By

Craig Woolard, University of Alaska Anchorage, School of Engineering

David Barnes, University of Alaska Fairbanks, Department of Civil and Environmental Engineering

Daniel White, University of Alaska Fairbanks, Department of Civil and Environmental Engineering

Larry Acomb, Geosphere, Inc.

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Introduction

On December 22, 1999 a southbound Alaska Railroad Corporation (ARRC) fuel train derailed approximately 40 miles north of Talkeetna, Alaska spilling approximately 120,000 gallons of jet-A fuel. Since that time, a variety of spill response, fuel recovery and remediation activities have taken place at the site.

The ARRC contracted with the University of Alaska to form a 4-person expert panel to peer review the existing data and provide an opinion on the condition of the site. Specifically, the ARRC requested that the panel:

- Identify the resource at risk and comment on the extent of risk posed by the spill
- Assess the short-term stability of the free product plume
- Review the existing data and identify significant questions raised by those data including water sampling, groundwater mapping and plume mapping and other factors as appropriate.

To prepare this report, we conducted a site visit and had numerous consultations with the ARRC, their consultants, and the Alaska Department of Environmental Conservation (ADEC). However, the majority of our effort was spent reviewing and reducing the existing data and assembling the information into a conceptual model that describes the site. We attempted to verify site data when possible, however, in most cases we relied on the accuracy of the information we were provided. Conservative estimates were used whenever questions about the existing data were identified.

Our conceptual model provided the basis for our evaluation of the risks posed by the site and clarified the technical issues that must be resolved to accurately evaluate those risks. A discussion of the major technical issues, including the results of the preliminary calculations prepared during the course of our review are included in the report. Our conclusions as well as a list of additional data collection and analyses efforts, which we believe will help eliminate existing data gaps, conclude the report.

Risks Posed by the Gold Creek Spill Site

The Gold Creek spill potentially poses risks to both human health and the environment. Although a quantitative risk assessment was not within the scope of this study, we have qualitatively considered the potential human health and ecological risks posed by the site in an effort to define the major contaminant transport pathways.

Human health risks posed by the site include consumption of contaminated groundwater, ingestion of contaminated soil and inhalation of fuel vapors. At the present time, there are no known drinking water wells within or down gradient of the site, and provided that no new drinking water wells are constructed within or to the west of the spill site, we believe the site poses no appreciable human health risk through the consumption of contaminated groundwater. We also believe that because the site is remote that the human health risk posed by ingestion of contaminated soils and inhalation of fuel vapors will be minor provided that future land uses do not result in increased visitation at the site.

We believe the primary ecological risk posed by the site is contamination of the Susitna River with light non-aqueous phase liquid (LNAPL) free product and dissolved phase fuel compounds. Our review of the project documents indicates that a general consensus on this issue exits.

A quantitative assessment of the risks posed by the site will require an accurate estimate of the amount and type of the dissolved and free-phase contaminants that could reach the river. Our review indicates that these core technical issues require additional investigation.

Major Technical Issues at the Gold Creek Site

Conceptual Site Model

The stratigraphy, properties of the soils and hydrogeology in the area between the spill site and the Susitna River control the movement of free and dissolved phase fuel. An understanding of these factors is essential to explain the existing observations and make predictions about future hydrocarbon fate and transport. In the remainder of this section, the existing data, information from aerial photographs and soil property estimates have been assembled into a conceptual site model of the Gold Creek site. In subsequent sections, this conceptual model will be used in discussions of dissolved and free-phase contaminant transport.

Site Geology

The existing soils data consists primarily of boring logs from most of the recovery wells and monitoring wells installed at the site. Appendix A is a reproduction of Gold Creek site map from September 19, 2000 that shows the locations of the monitoring and recovery wells. The wells installed at the site include:

- 56 recovery wells with 6-inch casings installed by air rotary drilling
- 50 Elvis (ELV) series monitoring wells with 2-inch casings installed by hollow stem auger drilling
- 20 Hendrix (HDX) series monitoring wells with 2-inch casings installed by hollow stem auger drilling
- 5 LKZ series monitoring wells with 2-inch casings installed by hollow stem auger drilling
- 6 PW series monitoring wells with 2-inch casings installed by hollow stem auger drilling
- 9 West series monitoring wells with 2-inch casings installed by hollow stem auger drilling.

Soils logs were also available for a large diameter caisson, several soil borings, a few test pits and some of the trenches excavated for remedial system piping. Despite the relatively large number of soil logs from the site the data in the logs is limited due to the following:

- The air rotary drilling method which was used to expeditiously install the 6-inch diameter recovery wells yields only highly disturbed soil returns at the ground surface
- The Hendrix wells and most of the Elvis wells were not sampled with split spoon or continuous core soil sampling devices
- The Elvis, PW and West series wells which were sampled using split spoon samplers can only yield information on the minus 2-inch soil fraction
- None of the soil samples were analyzed in a geotechnical laboratory so no sieve, hydrometer, bulk density, Atterburg limit, permeameter or moisture retention etc. data is available.
- Pump tests and/or slug tests have not been performed so field scale soil permeability data is not available
- The borings were logged by a relatively large number of different individuals which leads to adjacent borings having different soil texture descriptions and differing levels of detail. In general the logs with more soil strata and more complete descriptions were thought to be more accurate.

Geomorphology and Topography

Topographic maps and aerial photographs of the site suggests that in the vicinity of the spill the Susitna River flows through a relatively narrow fluvial valley (about 0.5 miles wide) incised into a broader glacial valley (about 4 to 5 miles wide) bounded by the Talkeetna Mountains to the east and Kesugi Ridge to the west. The fluvial valley contains several glacial outwash terraces, and the current active river channel and its adjacent floodplain.

At the spill site the railroad tracks appear to lie on a glacial outwash terrace with a surface elevation about 700 feet above sea level. To the east of the spill site the ground surface slopes gently upward for a few hundred feet (likely due to colluvium deposited over the terrace surface), and then rises more steeply up the side slopes of the Talkeetna Mountains. To the west of the spill site there is a very shallow depression on the outwash terrace (possibly be a relict stream channel), a small mound (which may be remnant of a higher level terrace), and a steep slope down to active channel of the Susitna River or its floodplain. The active channel lies immediately at the base of the outwash terrace due west of the spill site. To the southwest of the spill site, a portion of the active floodplain lies at the base of the outwash terrace at an elevation of about 672 feet.

Stratigraphy

Soil borings used for the installation of monitoring and recovery wells provide some information on the stratigraphy between the spill site and the Susitna River. On the outwash terrace, the boring logs are interpreted to generally show the presence of three distinctly different soil strata. The geologic strata shown in Figure 1 are from a cross section extending from the spill site to the Susitna River along a northeast-southwest line.

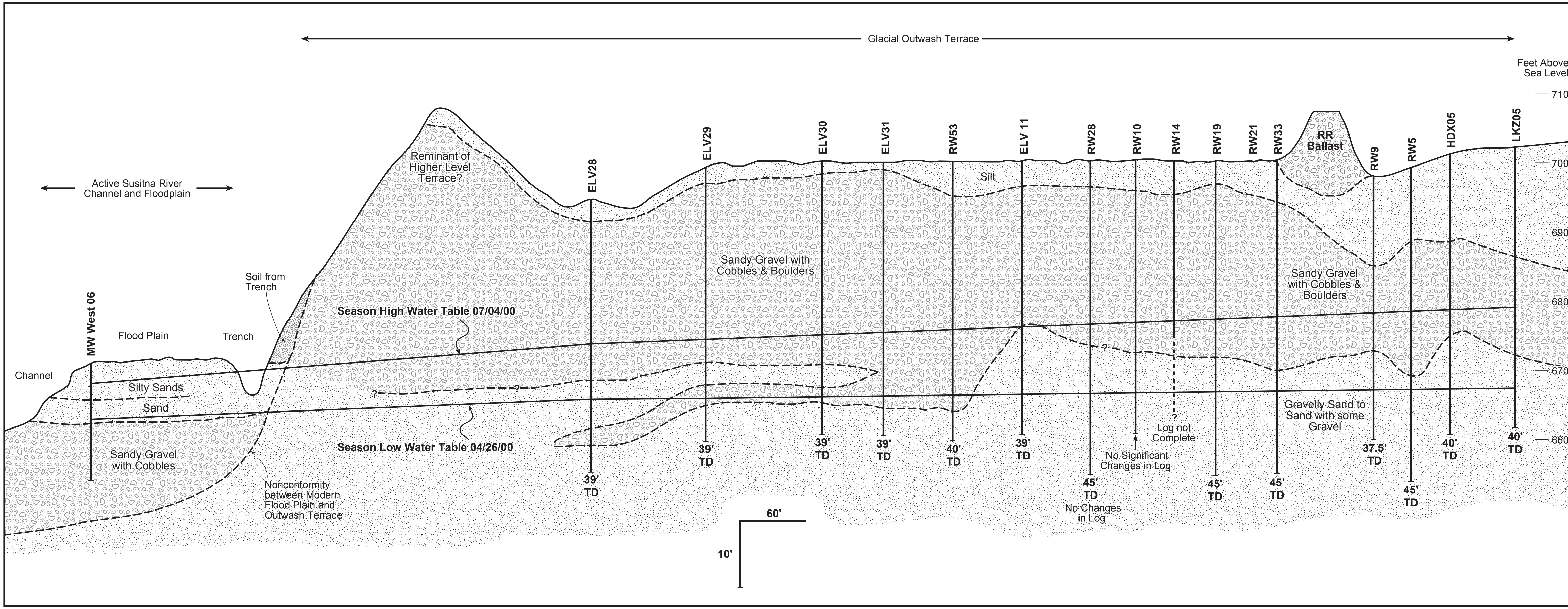


Figure 1

Geologic Cross Section Between the ARRC Gold Creek Spill Site and Susitna River

At the ground surface on the outwash terrace, most boring logs show a fine-grained soil described variously as a silt, fine sandy silt, or clayey silt. For simplicity, this surficial fine-grained soil is referred to as silt in this document. The silt reportedly is stratified, contains organics, is moist but not saturated, and is often oxidized to a red, brown, yellow or tan color. The silt varies in thickness from up to 16 feet on the east edge of the site (LKZ05) to 13 feet on the east side of the railroad tracks (RW9), to 6 feet on the west side of the tracks (RW33), and is only about 2 feet near the western edge of the outwash terrace (ELV 29). The silt is thought to be overbank floodplain sediments of the same age as the outwash terrace and/or alluvial fan sediments and colluvium from the Talkeetna Mountain slopes to the east. The silt likely increases in thickness to the east of the tracks

Most boring logs show a very coarse-grained soil underlying the silt. This material has been described variously as a gravel with cobbles and boulders, sandy gravel with cobbles and boulders, or just cobbles and boulders. In this report, for simplicity, this soil layer is described as a gravel. The most distinctive characteristic of this soil layer is the abundance of cobbles and boulders, which are described as comprising up to 40 or 50 percent of the soil volume. The presence of the cobbles and boulders indicates a very high-energy depositional environment, suggesting that the sands present in the soil are likely to be coarse sands and that silt and fine sand contents of the gravel layer are relatively low. The very coarse-grained texture of the soil indicates that the gravel layer likely has a very high hydraulic conductivity and retains relatively little fuel as pendular (i.e., fuel retained by capillary forces in the vadose zone) or insular (i.e., fuel retained by capillary forces in the saturated zone) residual saturation. The gravelly layer appears to extend to a depth of about 25 to 32 feet below grade. On the outwash terrace, this corresponds to an elevation of about 670 feet above sea level.

Most boring logs show the presence of a sand or gravelly sand layer underlying the gravel soil. For simplicity, this soil layer is described as a sand in this report. The sand grain size reportedly varies from a fine to coarse-textured sand. The layer contains some gravel and scattered cobbles, and limited blow count data indicate that the sand is moderately dense. Because most borings in the outwash terrace terminate at a depth of about 40 feet below ground surface (or at about the 660-foot elevation) in the sand layer, the thickness of the sand layer and the elevation of the bottom of the sand layer are not known.

The mound at the western edge of the outwash terrace (which may be a remnant of a higher level terrace) was penetrated by a single boring for monitoring well ELV 50. The boring log is thought to show soil stratigraphy similar to that reported on the terrace to the west (a thin layer of surficial silt, underlain by a coarse sandy gravel with cobbles and boulders, which is in turn underlain by a sand).

To the southwest of the spill site, at the base of the outwash terrace, lies a portion of the active Susitna River floodplain. The floodplain soils are documented in one soil boring (from monitoring well MW West 06) and are visible in the trench excavated at the base of the outwash terrace. The boring and the trench both show surficial silty, fine sands with some organic material extending to a depth of about 5 feet. These surficial soil layers are interpreted to be floodplain overbank sediments. Underlying overbank sediments are gravelly sands and sandy gravels with cobbles and boulders. These soils are river channel sediments and are derived primarily from reworking of the outwash terrace sediments.

Soil Properties

Some critical soil properties have been estimated based on the soil boring logs, observations made during our site visit and text book/literature reference values. In all cases, the values listed should be considered as representative, but approximate, estimates of the soil properties present at the site.

Table 1 – Literature Estimates of Soil Parameters at the Gold Creek Site

Property	Silt	Gravel	Sand
Hydraulic Conductivity (cm/s)	10^{-7}-10^{-3}	0.1-10	0.001-0.1
Porosity	0.34-0.52	0.21-0.40	0.24-0.48
Bulk Density (lb/ft^3)	80-110	100-130	85-125

Hydrogeology

Understanding the stratigraphy and the properties of the soils between the spill site and the Susitna River helps to provide understanding of the site hydrogeology and the range of possibilities for LNAPL flow and dissolved-phase hydrocarbon transport. The available soil stratigraphy data from the site are interpreted to indicate that for at least 10 feet above and below the water table, coarse-grained sand and gravel soils exist continuously between the spill site and the Susitna River. Hence, the stratigraphy is interpreted to indicate that there is a direct hydraulic connection between the groundwater at the spill site and the Susitna River.

The vast majority of the time, groundwater is interpreted to flow from the spill site area toward the Susitna River. When groundwater flow is toward the Susitna River, the groundwater is interpreted to flow into the river across the entire bottom of the channel and possibly across the river bank surface slightly above the river level. Infiltrating water which reaches the water table close to the river is thought to enter the river channel close to the river bank, while infiltrating water which reaches the water table far up gradient of the river is thought to enter the channel more towards the center of the channel. This suggests that if either dissolved or free product reaches the river then it will likely enter the channel at or close to the east bank of the river. During short-duration peak water level and/or peak flow events in the Susitna River (for example, those associated with ice jams and heavy precipitation in the basin upstream of Gold Creek) water levels in the river are expected to rise above groundwater levels in the banks of the river, allowing short-term flow reversals to occur.

Groundwater Flow Direction and Gradient
Numerous groundwater surface maps were present in the documents we reviewed. Much of the information was confusing containing, for example, discrepancies in water table elevations and contour maps that were produced using drafting software not designed for groundwater contouring. Because an accurate understanding of the groundwater surface is essential to understanding hydrocarbon fate and transport, we developed a number of contour maps using the site data provided and the kriging subroutine in Surfer 6.0 (Golden Software).

Figure 2a is a typical groundwater surface contour map for August 16, 2000. This map was created using groundwater elevations from 104 different monitoring wells located at the site. The contour map suggests that groundwater surface has a number of depressions and mounds near the tracks. Because maximum free product recovery rates using the skimming pumps are low (on the order of a few gallons per day), and the soils are highly transmissive, the operation of the recovery wells could not realistically produce the large drawdowns observed in this figure. Likewise, the operation of the soil vapor extraction system at the site could not account for the large mounds shown in Figure 2a (at most, the SVE system would create only a few inches of water table mounding which would be difficult to measure in an open well). Data entry errors, well casing survey errors and data transcription errors are the most likely explanation for the atypical groundwater surface contours shown in Figure 2a.

A somewhat different picture of the groundwater surface on August 16 is shown in Figure 2b. This figure was generated using 17 data points provided in the data table on the site map dated September 19, 2000 attached as Appendix A. None of the mounds and depressions shown in Figure 2a are present in Figure 2b. If only three data points are used, as was done in Appendix A, a somewhat different picture of the groundwater gradient and direction would again be anticipated. Eliminating data from some of the monitoring wells definitely “cleans up” the contour map and eliminates certain odd features, but it also reduces resolution and the ability to detect details in the groundwater gradients that could exist at the site.

Despite the limitations of the existing data, it was necessary to make some estimates of the groundwater flow direction and gradient. The approach used was to take data from the map attached as Appendix A and prepare a series of contour maps for March 27, May 3, July 27 and August 16, 2000. These maps are attached as Appendix B. The groundwater surface contours indicate that on March 27 and May 3, groundwater flow at the site was primarily to the west and southwest. On July 27 and August 16 the flow direction was essentially due west.

Traveling southwest, the distance from the tracks in the center of the spill to the bank of the Susitna River is approximately 1,050 ft. However, the nearest riverbank is approximately 750 ft. due west of the tracks at the center of the spill site suggesting that the highest risk of dissolved or free phase contaminant transport to the river occurs when the groundwater flows west. The available data indicates that the groundwater flow direction due west during a portion of the year and that a significant westward flow component exists throughout the year. Therefore, we assumed as a worst case that groundwater flow at the site was due west in our analysis of groundwater flow gradients and velocities.

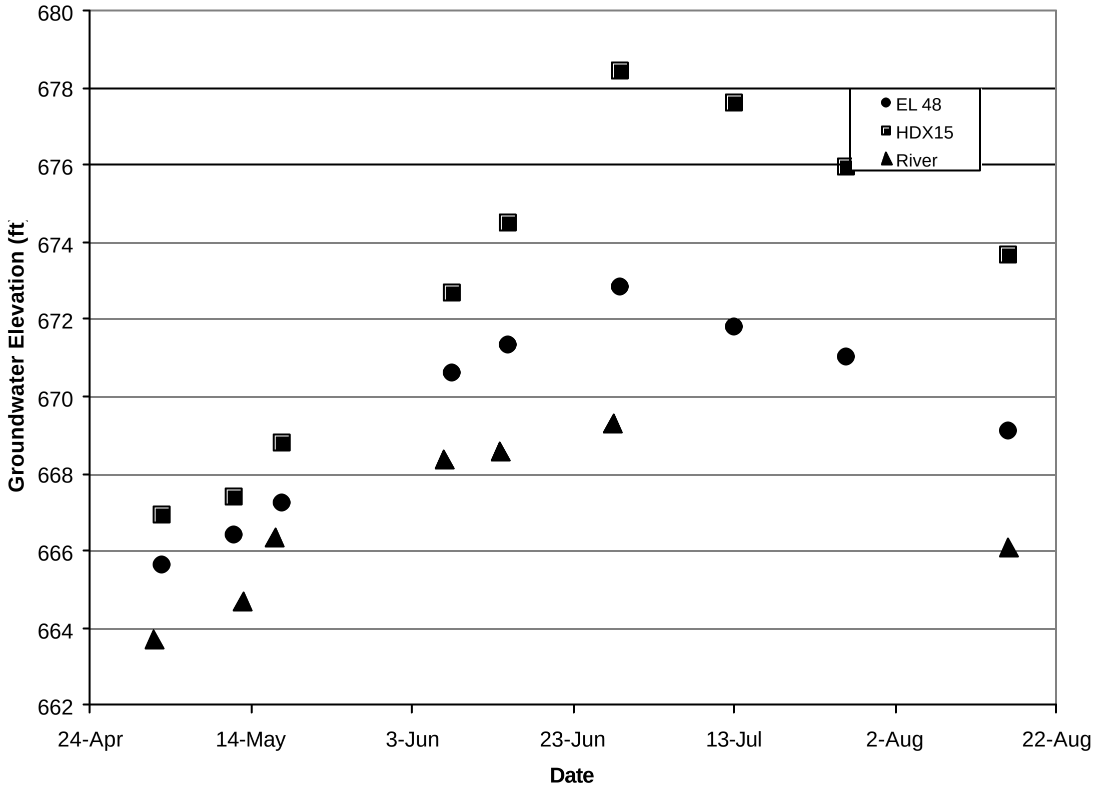
To estimate the groundwater gradient present at the site, well data from three monitoring wells were used to calculate the groundwater gradient. Monitoring well HDX 15 (or HDX16) was used to establish the groundwater table at the eastern boundary of the site. Monitoring well ELV48, which is one of the sentinel wells, was used to establish the water table elevation at the edge of the bluff. Data from monitoring well West 06 and the estimated gradient of the Susitna River (0.0025 ft/ft) were used to approximate the river elevation due west of the spill site (i.e., 1 ft. was added to each West 06 water table elevation). Figure 3 plots the water table elevations at each location. Large changes in the groundwater table elevation in all three monitoring wells are apparent. The largest change (over 10 ft from May to July) was measured in monitoring well HDX15. It is also apparent from diverging slopes of the monitoring well data that the groundwater gradient changes over time.

Table 2 summarizes the groundwater gradients (in feet per foot) calculated using the water table elevation from EL48, HDX15 and the Susitna River. Two separate gradients were calculated. The HDX15-ELV48 data describes the gradient between the railroad tracks and the bluff. The ELV48-River data describes the gradient between the bluff and the river. Both sets of data show that the groundwater gradient increases with increasing water table elevation from May to end of July.

Table 2 – Estimated Groundwater Gradients for the Gold Creek Spill Site

Date	HDX15-EL48	EL48-River
3-May	2.28E-03	8.53E-03
15-Jun	5.58E-03	1.23E-02
29-Jun	9.84E-03	1.50E-02
13-Jul	1.02E-02	NA
16-Aug	8.02E-03	1.33E-02

NA indicates data from WEST06 was not available to estimate Susitna River elevation.


680
678
676
674
672
670
668
666
664
662
Groundwater Elevation (ft)
24-Apr
14-May
3-Jun
23-Jun
13-Jul
2-Aug
22-Aug
Date
EL 48
HDX15
River

Groundwater Velocities
Using the gradients from Table 2 and the estimated hydraulic conductivity of the gravels and sands in Table 1, a range of potential groundwater velocities were calculated. The results are summarized in Table 3. Note that the estimates typically span several orders of magnitude. Increased accuracy will be possible only if additional soil testing and field measurements of hydraulic conductivity are conducted.

Table 3 – Groundwater Velocity Estimates for the Gold Creek Site. (Velocities reported are low - high estimates based on the range of hydraulic conductivities).

Date	HDX15-EL48 Velocity (ft/day) Gravel Layer	HDX15-EL48 Velocity (ft/day) Sand Layer	EL48-River Velocity (ft/day) Gravel Layer	EL48-River Velocity (ft/day) Sand Layer
3-May	0.65-65	0.0065-0.65	2.4-242	0.024-2.4
15-Jun	1.58-158	0.0050-0.50	3.5-348	0.035-3.5
29-Jun	2.8-279	0.016-1.6	4.4-443	0.044-4.4
13-Jul	2.9- 289	0.028-2.8	NA	NA
16-Aug	2.3-227	0.023-2.3	3.8-377	0.038-3.8

NA indicates data from WEST06 was not available to estimate Susitna River elevation.

Transport of LNAPL Phase Contaminants

General Phenomena

Evaluating the impact of a release of light nonaqueous phase liquid (LNAPL) to the subsurface requires an estimate of the volume of mobile and immobile LNAPL thought to be contained in the unsaturated and saturated soil. In this section, a conceptual description of LNAPL movement through porous media is presented as background to a discussion of the observations at made the site.

Usual practice divides the subsurface into three distinct zones, the unsaturated or vadose zone, the capillary fringe and the saturated zone. Once a LNAPL is released to unsaturated soil, there are two forces that act on the fluid – gravity and capillary pressure. Gravity will be the predominate force as free-phase LNAPL progresses downward towards the water table. As the free phase LNAPL moves towards the capillary fringe, capillary pressure forces control the lateral spreading of the LNAPL. The extent of free-phase LNAPL flow is dependent on such factors as the volume released, the magnitude of the gradient, the characteristics of the porous medium, the rise and fall of the ground water table, as well as other factors.

The LNAPL contained in the unsaturated zone will drain until, for all practical purposes, a "minimum" volume of LNAPL remains in the unsaturated soil. This "minimum" vadose zone volume is often referred to as pendular residual saturation and is dependent on the soil type and the heterogeneous nature of the porous medium. At residual saturation the LNAPL exists in the pores of the medium as discrete volumes disconnected from LNAPL contained in neighboring pores. Under these conditions, the LNAPL has become a discontinuous phase that is not conducive to flow. Any fuel present in excess of the pendular residual saturation capacity of the soils at the site will pool on the groundwater table forming a near continuous zone, or pancake, of free product. As the groundwater table rises and falls, the free product pancake will be buoyed with the water table creating a smear zone. In this zone, some of the free product will be trapped below the groundwater table as insular saturation. As the free product moves downgradient and the water table fluctuates, more insular and pendular residual saturation will be deposited until the mobile free phase product is exhausted.

Explanation for LNAPL Movement Observed at Gold Creek Site

The flow of mobile free product may be monitored by the appearance of free phase product in the monitoring and recovery wells at the Gold Creek site. Numerous measurements of the free product thickness were made at the site using a free product interface probe. These measurements have been summarized on the site map included in Appendix C to show the extent of mobile free product at four different dates. In mid February, the area containing free product appears to extend only slightly beyond the area of initial contamination. Over the next 6 weeks (until April 5), the free product area almost doubled in size. From April 5 to May 31, the free product continued to spread but the rate of expansion appeared to be relatively low. This decrease in spreading rate is consistent with the decreasing free product gradient that would be anticipated as the free product footprint area expanded. As the groundwater reached its summer high level, the free product footprint appeared to expand dramatically reportedly reaching the sentinel wells ELV1, 25, 26, 28, 29, 43, 44, 45 and 46 in the period between June 28 and July 4.

The stratigraphy and hydrogeology at the site coupled with a basic understanding of multiphase flow suggests a possible explanation for the rapid, westward expansion of the free product plume observed at the end of June. From the time of the spill until May of 2000, the groundwater table elevation appears to be below the top of the sand layer (below the 670-foot elevation) at the spill site and the groundwater gradient was at the lower end of its site specific range. In June, the water table elevation increased to approximately 672 to 674 feet which allowed the bottom portion of the gravel layer to become saturated (see Figure 1). In addition, the groundwater gradient between the spill site and the river appeared to increase. The gravel layer has a lower pore entry pressure, an estimated hydraulic conductivity that is an order of magnitude or more greater than the underlying sand layer, and it retains significantly less fuel as insular residual saturation than the sand layer. Hence, a given quantity of the free phase product would be expected to have a higher mobility (expressed in a more rapid advance of the free product front and a greater total transport distance) in the gravel layer than in the sand layer.

Estimate of the Residual LNAPL Potentially Immobilized at the Site

As the water table fluctuates and the free product foot print area expands, an increasing volume of free product becomes immobilized in the soil as insular and pendular residual saturation. A simple calculation of the volume of free product potentially immobilized in the soil may be useful in assessing the future mobility of the free product. While the actual calculation of this residual volume of LNAPL is not complicated, the parameters required for the calculation can have a high level of uncertainty associated with them. The equation used for the calculation is as follows:

$$V_r = S_r \phi V$$

where V_r equals volume of residual LNAPL, S_r equals residual saturation, ϕ equals porosity, and V equals the volume of the porous medium. Uncertainty in the calculation is mostly in the estimate of S_r, which is dependent on soil type. Several researchers have published measured values for residual saturation. Mercer and Cohen (1990) have tabulated to date the most comprehensive list of estimated values for S_r.

The calculation of residual LNAPL volume for the Gold Creek site utilizes the simplified cross section presented in Figure 4. The conceptual cross sections show the changing water table elevations and the associated changing areas of pendular and insular residual saturation. The volume of product potentially immobilized at the site was estimated using the following assumptions:

1. Following release, the LNAPL spread over a 20,000 square foot area and infiltrated to the water table over the same footprint area.
2. The porous medium consists of three distinct zones: a silty layer below the ground surface, a gravel layer below the silty layer, and a sand layer below the gravel layer.
3. The porosity of each layer is as follows: ϕ_{silt} = 0.39, ϕ_{gravel} = 0.33, and $\phi_{gravel/sand}$ = 0.33
4. The pendular and insular residual saturation for each layer is as follows: $S_{r(silt)}$ = 0.037 and 0.093, $S_{r(gravel)}$ = 0.015 and 0.032, $S_{r(gravel/sand)}$ = 0.032 and 0.063.
5. The footprint areas of mobile free product were as mapped in Appendix C.

Results of the immobile residual calculation are shown in Table 4. The calculations indicate that as the water table fluctuates the volume of free product potentially immobilized increases. For example, in the February to late May time frame the potential residual product volumes increase from about 40,000 gallons to over 90,000 gallons. As the foot print area expanded in late June and early July the potential residual product volume could increase to over 180,000 gallons, a volume greater than the spill volume. The calculations suggest that given the reported water table fluctuation and free product foot print area the entire spill volume could be immobilized even when using very conservative (i.e. low) residual saturation values.

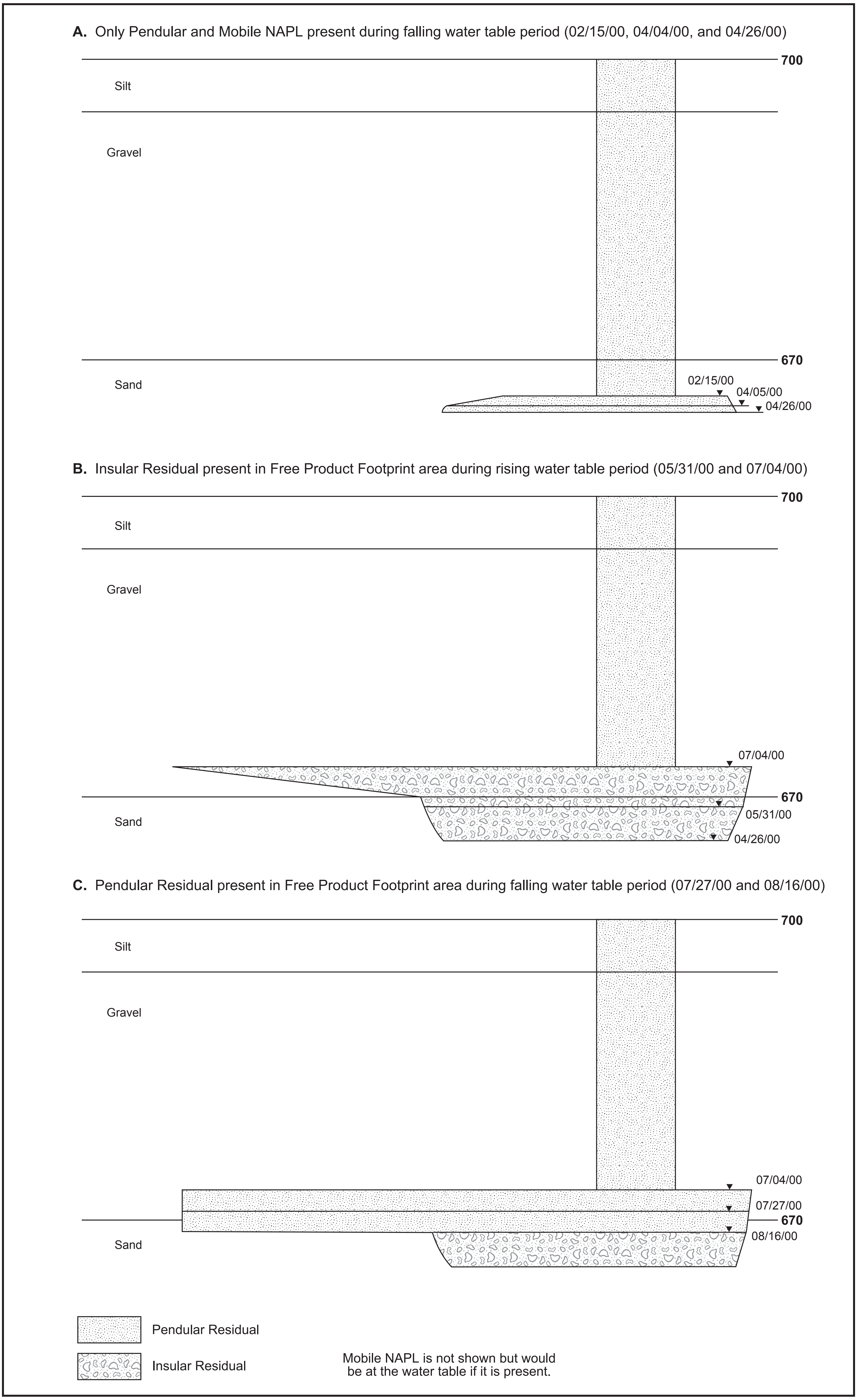


Figure 4

Conceptual Cross Section Showing the Potential Distribution of Pendular and Insular Residual Saturation at Selected Dates

Table 4 – Potential Residual Saturation Volumes at Selected Dates

Soil Type Residual Type Date	Silt pendular gallons	Silt insular gallons	Gravel pendular gallons	Gravel insular gallons	Sand pendular gallons	Sand insular gallons	Total Residual Volume gallons
2/15	11024	0	20564	0	5536	0	37125
4/5	11024	0	20564	0	10543	0	42131
4/26	11024	0	20564	0	12351	0	43939
5/31	11024	0	20564	0	1803	64164	97555
7/4	11024	0	18333	62748	0	88027	180133
7/27	11024	0	49476	22029	0	88027	170556
8/16	11024	0	66324	0	30972	68978	177299

Given the uncertainty in the parameters used to calculate this volume, this value should be only considered a crude estimate of the residual volume of LNAPL that could be contained at the Gold Creek site. Multiphase flow modeling is likely necessary to assess the soil properties and hydrogeologic conditions that could produce the reported free product movement and to assess the potential for further product flow.

Dissolved Phase Contaminant Discussion

Groundwater Flow Rate Estimates

The conceptual site model described in the previous paragraphs suggests that significant amounts of pendular and insular residual fuel saturation exist at the Gold Creek site. Individual hydrocarbon species will dissolve in the groundwater flowing through the site as well as the in the precipitation infiltrating through the site. The concentration of the individual dissolved species will be a function of each compounds solubility and mole fraction in the original jet fuel mixture.

Most of the individual compounds in jet fuel are relatively high molecular weight ($>C_{10}$) aliphatic and aromatic hydrocarbons that are sparingly soluble in water. The low molecular weight aromatic hydrocarbons benzene, ethylbenzene, toluene and xylene (BTEX) are more soluble and typically pose the greatest ecological risk. These compounds are typically present in small amounts in jet fuel. We anticipate that the saturation concentration of BTEX from jet fuel will be only a few milligrams per liter. However, actual fuel samples should be analyzed to determine actual fuel BTEX content.

To make a conservative estimate of the amount of dissolved phase contaminants entering the Susitna River, we made the following assumptions.

- The width of the contaminant plume extends upstream 1,000 ft. from monitoring well West 06.
- The depth of the contaminated groundwater plume is 10 ft., or approximately the depth of the observed smear zone caused by fluctuations in the groundwater table.

- The groundwater flows through the sand layer in the winter and through the gravel layer (see cross section shown in Figure 1) in the spring and summer when the water table rises.
- The groundwater velocity ranges from 0.005 to 4.4 ft/day in the sand layer and from 0.65-443 ft/day in the gravel layer.

With these assumptions, the during the winter and early spring when groundwater is expected to be in the sand layer, approximately 0.0006 to 0.51 cubic feet per second (cfs) of contaminated groundwater would enter the river. During the late spring and summer, the groundwater flow rate through the gravel layer to the river is estimated to range from 0.07-50 cfs.

According to the USGS gauging station data from Gold Creek, the long term average flow rate in the Susitna River ranges from a low of 1,300 cfs (in March) to a high of 26,000 cfs (in June). Thus, groundwater flow from the contaminated site represents an insignificant portion of the total flow and a high degree of dilution would be expected. Considering the relative magnitudes of the groundwater and river flows and the dilution that would occur and the mass fraction of BTEX likely present in the spilled fuel, we estimate that BTEX would most likely be detected only at the point of groundwater entry (i.e., immediately adjacent to the stream bed).

Presence of Contamination in Monitoring Well West 06.

Three sets of samples were collected from the well West 06 and the Susitna River. West 06 is adjacent to the Susitna River (25 ft) and is the well nearest to the River. West 06 was sampled and analyzed for BTEX, gasoline range organics (GRO) and diesel range organics (DRO) on June 30, 2000, and again July 5 and July 9, 2000. On June 30, 2000 xylene was detected in the BTEX analysis at a concentration of 5 μg/L. Xylene was again detected at a concentration of 2 μg/L on July 5 but was not detected above the detectable limit of 1 μg/L on July 9. We are not aware of any documented naturally occurring xylene observed in other wells around the state. GRO was also analyzed but was not present above the reportable detection limit in any samples. Despite this fact, GC chromatograms indicated the probable presence of GRO.

All West 06 samples were also tested for DRO. DRO was detected in at concentrations of 16,400 μg/L, 19,400 μg/L and 2,280 μg/L on June 30, July 5 and July 9 respectively. The first two of these samples were above the solubility of typical diesel fuels (5,000 μg/L) but below some jet fuels such as Jet-4 (300,000 μg/L). The predominant pattern observed in West 06 DRO chromatograms is distinctly petroleum in origin.

Five river samples were collected on June 30 and tested for BTEX, GRO and DRO. BTEX in all samples was below reportable detection limits as was GRO. DRO was detected (330 μg/L) in the River 1 sample, however, a laboratory note states that the chromatogram did not match the typical DRO fingerprint. It is our also opinion that the chromatogram did not match a typical DRO fingerprint, however, the origin of the material cannot be determined. A similar pattern is present in the West 06 samples as well as the River 2-5 samples and even a trace of the signal is evident in the water blank.

The signal cannot be ruled out as biogenics, nor can it be ruled out as a petroleum derived signal.

Two river samples were collected on July 5 and again on July 9, 2000 at SRB and SRC. Neither BTEX, GRO nor DRO were detected in any of the river samples on July 5 or 9.

A significant amount of xylene was detected in WEST 06 on two of the three sampling events. In both cases the xylenes were accompanied by a significant DRO signal, indicating the presence of petroleum derived fuels. The DRO signal was greatest on July 5 and diminished on July 9. Although records indicate that samples were subsequently collected from WEST 06, no data was available at the time of this report. It is unkown if the fuel is still present. It is unlikely that a DRO signal detected on three separate and subsequent sampling events would be derived from anything other than fuel. The signals coincide in time with the first observation of fuel product in the "sentinel wells".

Although there was a DRO signal observed in the River 1 sample on June 30, it could not be confirmed that the signal was derived from fuel, accidental contamination in handling or biogenic interference. No subsequent DRO signals were observed. No signals from BTEX or GRO were observed in the river.

Aside from the single DRO observation in the river samples, the river does not appear contaminated. It is our opinion, however, that the inability to analytically detect or visually observe fuel in the river samples does not mean dissolved phase fuel is not reaching the river. We believe it should be assumed that dissolved phase fuel has reached or will imminently reach the river. As previously discussed, a high degree of dilution would be expected in the river.

Conclusions

From our review and analysis of the site data collected to date, it is our opinion that:

1. No appreciable human health risk through the consumption of contaminated groundwater currently exists at the site. The human health risk posed by ingestion of contaminated soils and inhalation of fuel vapors will be minor provided that future land uses do not result in increased visitation at the site.
2. The primary ecological risk posed by the site is the potential contamination of the Susitna River with light non-aqueous phase liquid free product and dissolved phase fuel compounds.
3. It is likely that dissolved phase contaminants have reached or will soon reach the Susitna River. However, the relative flow volumes suggest that a high degree of dilution will occur in the river.
4. The absence of free product at the sentinel wells indicates that no mobile free product is currently present at the sentinel well locations. The preliminary calculations conducted for this report suggest that the remaining fuel is primarily present as non-mobile residual saturation.
5. The observations to date indicate that the potential for free product migration towards the Susitna River is greatest when the groundwater table is in the gravel

layer. Our conceptual model and long term stream hydrographs suggests that the groundwater elevation will remain below the gravel layer throughout the winter and early spring and that rapid free product migration toward the river is not likely during this period.

6. Significant data gaps and data quality issues exist for the Gold Creek site.

Our conclusions have several implications for future spill response and remedial activities at the Gold Creek site. First, the presence of substantial amounts of non-mobile residual saturation in the vadose and saturated zone suggest that the site will serve as a source of groundwater contamination well into the future. Additional free product recovery has the potential to reduce the longevity of the source of contamination, but it will not likely change the dissolved phase contaminant concentrations in the short term. In addition, our understanding of soil conditions and spill history suggests that only limited additional free product recovery should be anticipated at the site.

Removal of the BTEX compounds from the source area LNAPL will reduce the concentration and duration these compounds reach the river. The SVE system currently in place, when operated at low water elevations observed at the site in the winter and spring, should be able to reduce the amount of BTEX in the source area by stripping these compounds from the LNAPL present in the vadose zone. Removal of contaminated surficial silts and gravels above the smear zone will likely not reduce the concentration of the dissolved phase contaminants that reaches the river, but may reduce the length of time contaminated groundwater enters the river.

Recommendations for Future Work

We recommend that additional data reduction, data collection and numerical modeling activities be conducted to better characterize and understand the Gold Creek site.

The reduction of existing data should involve the following tasks:

- Organize the existing groundwater and free product depth data into a spreadsheet database.
- Organize the existing water chemistry and soil chemistry data into a spreadsheet database.
- Produce new groundwater maps using corrected groundwater elevations data that can be used to accurately estimate groundwater gradients.

New data collection efforts should focus on filling in the data gaps which most effect our understanding of risk and impact future remedial actions at the site. These data collection efforts should include:

- Measurement of groundwater and product depth in selected monitoring wells.
- Collection and analysis of groundwater samples from selected monitoring wells.
- Analyze samples of the spilled product bailed from the site wells to determine concentrations of aliphatic and aromatic constituents.
- Resurvey existing well casings to help improve the accuracy of the water table maps.

- Conduct pump tests and/or slug tests to characterize the hydraulic conductivity of the site soils. Tests in both the sand and gravel layers should be conducted.

Modeling efforts should be focused on assessing the migration of LNAPL and the fate and transport of dissolved phase contaminants at the site. LNAPL migration should be characterized with a multiphase flow model, calibrated to match the observed conditions at the site, to better predict the potential for free product migration in subsequent summer seasons. A dissolved phase model should be used to assess the BTEX concentrations in the groundwater reaching the river and estimate the longevity of the source. In-stream mixing models could be used to assess the dilution of the dissolved contaminants that reach the river. The combination of these models would allow a quantitative estimate of the contaminant mass reaching the Susitna River. This data could then be used to set remedial goals and evaluate the benefit of alternate remedial actions.

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