FOCUSED FEASIBILITY STUDY – GROUNDWATER

ANIAK MIDDLE SCHOOL
ANIAK, ALASKA

NTP 18400211028

FINAL
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ACRONYMS AND ABBREVIATIONS

ADEC .... Alaska Department of Environmental Conservation
bgs .... Below ground surface
CERCLA........ Comprehensive Environmental Response, Compensation and Liability Act
CHP............... Catalyzed hydrogen peroxide
CSM .... Conceptual site model
cm/sec........... centimeters per second
cy................... Cubic yards
DCE............... Dichloroethene
DO................. Dissolved oxygen
EPA .... Environmental Protection Agency
ERD............... Enhanced reductive dechlorination
FS.................. Feasibility study
ft/ft .... Feet per foot
g/kg .... Gram per kilogram
gpm .... gallons per minute
HRC™ .... Hydrogen Release Compound
IDC .... inhalation/direct contact pathway (cleanup levels)
ISCO .... In situ chemical oxidation
µg/L .... Micrograms per liter
µg/m^3 .... Micrograms per cubic meter
mg/kg .... Milligrams per kilogram
m/s .... meters per second
MNA .... Monitored natural attenuation
MTG .... Migration to groundwater (cleanup levels)
N.................... nitrogen
NCP............... National Contingency Plan
OASIS .... OASIS Environmental, Inc.
ORP .... oxidation-reduction potential
PCBs............. polychlorinated biphenyls
PCE............... Tetrachloroethene
ppbv .... parts per billion by volume
RAO .... Remedial action objective
RCRA............ Resource Conservation and Recovery Act
SSD............... Sub-slab depressurization
SI................... site investigation
SVE .... Soil vapor extraction
TOC............... total organic carbon
TCE .... Trichloroethene
USCS .... United States Classification System

VI.................. vapor intrusion
VMP .... Vapor monitoring point
VOC .... Volatile organic compound
WACS .... White Alice Communications System

1. PURPOSE AND EXECUTIVE SUMMARY

The purpose of this focused feasibility study (FS) is to evaluate remedial alternatives for addressing contaminated groundwater at the former Aniak White Alice Communications System (WACS) site located in Aniak, Alaska. The Aniak WACS site is currently used by the Kuspuk school district. The former WACS building is currently known as the Aniak Middle School (and alternatively as the Joe Parent School) and is used as a secondary school, temporary lodging, and administration and staff offices.

Soil, soil gas, and groundwater at the Aniak WACS site are contaminated by the chlorinated solvent, trichloroethene (TCE) and its degradation product, cis-1,2-dichloroethene (cDCE). This contamination has resulted in VOC concentrations exceeding the Alaska Department of Environmental Conservation (ADEC) vapor intrusion target levels for residential groundwater and subslab soil gas and drinking water risk-based thresholds. This contamination contributes to exceedances of ADEC Target Levels for indoor air. In addition, shallow soil at the site is also contaminated by polychlorinated biphenyls (PCBs) above ADEC soil cleanup levels.

This Focused FS is a followup analysis to a detailed site characterization report (Shannon & Wilson, 2010a). The Shannon & Wilson report identified the nature and extent of soil gas, soil, and groundwater contamination at the Aniak WACS site and presented remedial alternatives for addressing vapor intrusion and vadose zone soil contamination. Only one remedial alternative for groundwater contamination, air sparging, was presented. The purpose of this Focused FS is to prepare a comprehensive analysis of groundwater remedial alternatives, including remediation of a silt layer that is present across most of the site and is saturated during times of moderate to high groundwater elevations.

Vapor intrusion mitigation has been implemented at the Aniak Middle School, and remedial activities are planned to address vadose zone soil contamination. Vapor intrusion is being mitigated by air purification filters inside the school and a sub-slab depressurization system (SSD). Excavation is planned to address soil contaminated by PCBs above the Alaska cleanup level of 1 milligram per kilogram (mg/Kg). Some of the planned PCB excavation area also has commingled TCE contamination that will be removed along with the PCB contamination. Soil vapor extraction (SVE) is planned to address the vadose-zone TCE contamination remaining after the PCB excavation. The groundwater alternatives evaluated in this Focused FS consider these planned and ongoing soil and soil gas remedies.

A pre-draft Focused FS was prepared in April 2011 (OASIS, 2011a; also included as Appendix D to this report). It presented a summary of the nature and extent of the groundwater contamination, a conceptual site model (CSM) of exposure pathways to the contamination, established preliminary remedial action objectives, identified technologies to be considered in this Focused FS, and made recommendations for addressing data gaps. Based on recommendations in the pre-draft FS, groundwater monitoring events were performed in May and October 2011, pressure transducers with dataloggers were placed into eight monitoring wells, and the silt layer was analyzed to the maximum degree possible with existing site characterization information.

This Focused FS presents results of the 2011 monitoring events, an updated discussion of the nature and extent of groundwater contamination, an interpretation of the silt layer, five remedial alternatives for addressing groundwater contamination (including the silt layer), and an comparative analysis of the alternatives. Responses to comments received on the draft Focused FS are provided in Appendix E. The five alternatives include one alternative analyzed by Shannon & Wilson (Shannon & Wilson, 2010a), i.e., air sparging, and four additional alternatives. The alternatives are listed below with their estimated remedial timeframes.

- Alternative GW-1: No Action (infinite remedial timeframe)
- Alternative GW-2: Monitored Natural Attenuation (MNA)/Long-Term Monitoring (LTM) (35-year remedial timeframe)
- Alternative GW-3: In Situ Chemical Oxidation (ISCO) (10-year remedial timeframe)
- Alternative GW-4: Enhanced Reductive Dechlorination (ERD) (20-year remedial timeframe)
- Alternative GW-5: Air Sparging (20-year remedial timeframe)

The five alternatives were evaluated against the nine criteria described in Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) §300.430(f)(5)(i). Results of the comparative analysis are summarized below in Table 1-1. The two “threshold criteria” must be met in order for an alternative to be considered for selection; therefore, “yes” and “no” were used as the scores for these criteria. A numerical scoring scheme was used for evaluating the five balancing criteria. Each alternative was assigned a numerical score between 0 (worst) and 5 (best) for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives.

TABLE 1-1: COMPARISON OF REMEDIAL ALTERNATIVES

Remedial Alternative		Threshold Criteria		Effectiveness Scores				Cost				
Identifier	Description	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness	Implementability	Cost Score	Estimated Present Worth Range (-50% to + 100%) (in thousands of dollars)	**Effectiveness Total**	**Total Score**	**Effectiveness to Cost Quotients**
Groundwater Alternatives												
GW-1	No Action	No	No	0.0	0.0	0.0	5.0	5.0	$0 $0	0.0	10.0	 NA
GW-2	LTM/MNA	Yes	Yes	2.0	2.0	3.3	4.0	2.2	$1,217 $4,870	7.3	13.5	0.60 0.15
GW-3	ISCO (Chemical Oxidation)	Yes	Yes	4.0	4.0	2.5	3.0	0.0	$2,152 $8,608	10.5	13.5	0.49 0.12
GW-4	ERD (Substrate Addition)	Yes	Yes	3.5	3.0	3.3	3.0	1.0	$1,715 $6,858	9.8	13.8	0.57 0.14
GW-5	Air Sparging	Yes	Yes	2.5	2.0	2.5	2.0	0.8	$1,813 $7,252	7.0	9.8	0.39 0.10

Explanation of Scores:

0 Worst (Criterion not satisfied)
1 Poor
2 Below Average
3 Average
4 Above Average
5 Best (Criterion completely satisfied)

Preferred Alternative

Selection of a preferred alternative depends on the relative importance of the variables. GW-2 (MNA) and GW-4 (ERD) are the most cost-effective alternatives; ERD has a higher effectiveness than MNA, but the increased effectiveness is countered by its higher cost. If achieving cleanup in the shortest time is the most important factor, then Alternative GW-3 (ISCO) is preferred, although it is also the most expensive alternative. Air sparging has the lowest total score and effectiveness to cost quotient and is least likely to be considered the preferred alternative.

Overall, it appears that additional plume characterization and implementation of the soil remedies would be beneficial before selecting a groundwater remedy. Additional plume characterization activities should include installing soil borings and monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. During the PCB soil excavation in the vicinity of the former septic tank and truck fill, soil samples should also be analyzed for TCE. If high TCE concentrations are detected in the silt at the base of the PCB excavation, overexcavation of TCE-contaminated soil or direct treatment using a reductant (or possibly an oxidant) during the PCB soil excavation may be a very beneficial and cost-effective remediation strategy. Alternatively, depending on the location, magnitude, and extent of the TCE contamination and silt characteristics, installation of an engineered solution, such as placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically, may be warranted. Sampling details and a decision protocol should be incorporated into the excavation work plan.

Based on existing data and weighing the effectiveness and cost considerations, Alternative 2 (MNA) or Alternative 4 (ERD) may be considered preferred. MNA would be expected to perform satisfactorily at this site if the following conditions are met. The conditions are based on a decision flowchart for MNA and enhanced attenuation presented in (ITRC, 2007).

1. Additional site characterization confirms that there is no distinct source/primary plume in the saturated zone. There is no evidence of free-phase or residual-phase TCE, and maximum groundwater concentrations remain three-to-four orders of magnitude below the solubility limit. The groundwater plume configuration is generally as outlined in this FS.
2. Additional groundwater monitoring supports the conclusion that the plume is stable.
    a. The groundwater plume is stable or shrinking, and there is no risk to the nearby drinking water wells. An alternative point of compliance can be established downgradient of the source area.
    b. The PCB soil excavation and SVE adequately address vapor intrusion risk (i.e., most of the contaminant mass is in the vadose zone). Although volatilization from the silt layer/saturated interval below the silt layer may provide a continuing source for soil gas contamination, the level of continued volatilization is currently unknown and may be minor, especially if the upper portion of the silt layer is directly treated during the PCB soil excavation.
    c. Future VOC and geochemical parameter sampling indicates that there are zones or areas of highly-reducing groundwater in which reductive dechlorination of TCE is occurring at sustainable rates to adequately remediate the contamination over time.
    d. This alternative is deemed acceptable to ADEC and all of the interested parties.
3. If the above criteria are not completely satisfied, then it may be advantageous to implement ERD in a phased approach.

2. SITE BACKGROUND

Aniak is located approximately 300 miles west of Anchorage and is bordered on the north by the Kuskokwim River and on the south by the Aniak Slough. The Middle School site is approximately 600 feet southeast of the northwest end of the runway and approximately 900 feet south of the Kuskokwim River, as shown on Figure 1. The property and immediate vicinity is generally flat, although the surrounding area has a general slope to the east towards the Aniak Slough. The site is situated on a gravel pad overlying the native alluvial deposits. A site plan showing the location of the former Aniak Middle School on an aerial photograph is provided as Figure 2.

2.1. Investigation Summary

Extensive site investigation and remediation work has been performed at the site, beginning with a 1997 Site Inspection (SI) conducted by the Environmental Protection Agency (EPA). Widespread PCB contamination was documented both inside and outside the Middle School building, and the site has been assigned Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Site Number AK8570028615. A brief summary of the investigation and remediation work performed at the site is provided below; a detailed discussion of the pre-2010 work can be found in Shannon & Wilson (2010a).

- In 1997-1998, PCBs were removed from the inside of the building, and exterior contaminated areas were capped.
- Additional soil sampling was performed in 1999.
- In 2001, limited PCB cleanup activites were performed from a portion of the area that had been capped and from other areas identified by the 1999 sampling. Approximately 872 tons of PCB-impacted material was removed from the site.
- Feasibility studies were performed in 2004 and 2005.
- Site characterization activities in the vicinity of the WACS former septic system were performed in 2006 (Shannon & Wilson, 2007). Activities included soil and groundwater sampling; TCE contamination was discovered, along with additional areas of PCB contamination.
- In 2008, soil and groundwater sampling were performed to delineate the TCE contamination (Shannon & Wilson, 2009). Two distinct source areas and associated groundwater plumes were identified (Figures 2 and 3). The primary source appears to be the Former Septic System and floor drains formerly located within the Middle School Metal Shop. A second source area appears to be the Maintenance Building floor drain or leakage/spillage from a former drum storage area on the south side of the Maintenance Building. Although a third apparent source area was identified off-site in the vicinity of the Runway Apron/Disposal Pit area, it is considered unlikely that this contamination is related to the TCE-

impacted soil and groundwater encountered at the Middle School and is not discussed in this FS.

- Also in 2008, approximately 2,300 cubic yards (cy) of PCB-contaminated soil, construction debris, and tank content wastes were removed from the site. It was concluded that additional PCB contamination likely extends beneath the building foundations. It was not possible to remove all of the PCB contamination with available funding.
- The 2008 Former Septic System excavation reached a maximum depth of approximately 26 feet below ground surface (bgs) in the vicinity of the former seepage pit. The base of the deepest excavation measured approximately 20 feet (east-west) by 25 feet (north-south). The septic tank excavation reached a maximum depth of approximately 18 feet bgs. The excavation depth of the east and west septic line reached a maximum of approximately 11 feet bgs. Groundwater was not encountered during the excavation. The west septic line and seepage pit excavations were not backfilled to their original elevation. The ground surface over these areas is approximately 8 feet lower than the pre-excavation ground surface.
- In 2009, a vapor intrusion (VI) assessment performed at the site determined that TCE exceeded the risk-based screening levels (0.21 parts per billion by volume (ppbv) for commercial indoor air and 0.041 ppbv for residential indoor air[1]) for all three indoor air sample locations at the school.
- Also in 2009, Site Characterization activities were performed to further delineate the PCB and TCE contamination, and a Site Cleanup Plan was prepared (Shannon & Wilson, 2010b). Site characterization activities included a soil gas survey, PCB soil borings, installation and sampling of groundwater monitoring wells, feasibility testing for remedial alternatives, and soil and groundwater sampling. Results are shown on Figure 3. The site investigation report also evaluated remedial alternatives for addressing remaining site contamination. The remedial alternative discussion focused on soil remedies, although air sparging was evaluated for groundwater.
- In 2010, a hydrogeologic evaluation was completed to increase the understanding of groundwater behavior at the site, specifically the potential for groundwater contamination to impact the nearby drinking water wells for the Middle School and High School (Figure 2) (Shannon & Wilson, 2010a).
- Also in 2010, air purification filters and a subslab depressurization system (SSD) were installed to mitigate vapor intrusion risk in the Middle School building (OASIS, 2010).

[1] Screening levels from ADEC 2009 *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009). This guidance is undergoing review and update due to revisions in EPA Regional Screening Levels and TCE toxicity values that were recently finalized in IRIS.

- In May 2011, dataloggers were installed into seven monitoring wells, and groundwater samples were collected from all available monitoring wells (i.e., MW-5 through MW-12), as well as two soil gas points (SGP-2 and SGP-9) that were available for groundwater monitoring due to the high water level. The datalogger study is documented in Appendix A to this FS, and the groundwater sampling event is summarized in Appendix B.
- In October 2011, the dataloggers were downloaded and replaced into the monitoring wells. Groundwater samples were collected from all available monitoring wells (i.e., MW-6 through MW-12). MW-5 and the soil gas points were dry due to the low water level.

2.2. Groundwater Contamination Summary

Groundwater impact by TCE above the Alaska Department of Environmental Conservation (ADEC) Table C cleanup level has been documented in two locations: south of the Maintenance Building and beneath the Former Septic System (Figure 3). The Maintenance Building[2] plume (referred to as the MW-4 plume in this FS) is estimated to cover approximately 2,500 square feet. The Former Septic System[3] plume (referred to as the MW-5/7 plume in this FS) was estimated at 12,500 square feet in the April 2011 Pre-Draft FS (OASIS, 2011a); however, based on a groundwater TCE detection in SGP-9 (May 2011) and soil gas detections (2009), the groundwater plume is now interpreted to extend under the Aniak Middle School with an estimated area of 22,000 square feet. Note that groundwater monitoring wells have not been installed at the location of the highest TCE concentration measured in soil gas at SGP-17, within the footprint of the Maintenance or Middle School Buildings, east of the Middle School Building, or between the two plumes, so there is a fair degree of uncertainty in the plume sizes. As shown on Figures 2 and 3, the MW-5/7 groundwater plume has been extended to encompass the locations of Soil Gas Points SGP-8 and SGP-17 and the former floor drains located within the Middle School Metal Shop.

Groundwater contamination plume details are provided in Section 2.5 of this FS.

2.3. Geologic Setting

2.3.1. Regional Surface Geology

Aniak is situated on the floodplain of the Kuskokwim River. The Aniak River flows northward into the Kuskokwim River just east of the village of Aniak, while the Aniak Slough flows southward from the general area where the Aniak River meets the Kuskokwim River. The Kuskokwim River cuts through the Kuskokwim Mountains

[2] The text in Shannon & Wilson (2010) reports the extent of contamination at 15,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-2) is approximately 2,500 square feet.
[3] The text in Shannon & Wilson (2010) reports the extent of contamination at 25,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-2) is approximately 12,500 square feet.

approximately 60 miles upstream of Aniak; downstream of the Kuskokwim Mountains, the river flows through a broad floodplain with no significant topography. The central Kuskokwim River floods annually or biennially, usually as a result of ice breakup, which typically occurs in May.

The surficial geology in the vicinity of Aniak consists of Kuskokwim flood plain deposits of unconsolidated silt, sand, and gravel. The river deposits include: sediment deposits of bed-load sand, gravel, and silt from river-channel activity, fine-grained (silt and fine sand) sediments deposited on river banks during flood periods, and sediments deposited during heavy floods (Krause, 1984). Silt thicknesses in Aniak have been reported to range from 1 to 6 meters (Krause, 1984).

The site is located approximately ½-mile south of the Kuskokwim River and 3/4-mile west of the Aniak Slough.

2.3.2. Local Surface Geology

The school is built on a gravel pad overlying alluvial sediments of the Kuskokwim River floodplain. The pad material consists of soil classified as sandy gravel in accordance with the United Soil Classification System (USCS). The thickness of the pad near the school varies significantly from 12 to 27 feet bgs based on soil borings advanced to install soil gas points around the school by Shannon & Wilson during August 2009 (Shannon & Wilson, 2010a). The native soil type underneath the pad is comprised of a horizon classified as predominantly silt from approximately 10 to 25 feet thick. The silt horizon overlies native material classified as gravelly sand. The silt horizon appears to have been partially removed beneath the Aniak Middle School, presumably prior to building construction. Also, the silt horizon was partially removed during PCB excavation activities at the former septic system (Figure 4A). Specifically it was removed to a depth of approximately 18 feet bgs at the former septic tank location and completely removed (to a depth of 26 feet bgs) around the former seepage pit.

Figure 5 displays elevations of the silt layer base along with plan view locations of cross-sections A-A’ and B-B’. The cross-sections, presented in Figures 6 and 7, illustrate the subsurface geology and contamination across the site.

Shannon & Wilson (2010a) conducted grain size classification tests on five soil samples from the site to characterize the subsurface materials. Samples, descriptions, and results are summarized below in Table 2-1.

TABLE 2-1: GRAIN SIZE CLASSIFICATION RESULTS

Sample	Boring	Depth	Description	Classification
VES2-9	VES2	25.5-27.5	Gravel fill above silt	Sandy gravel
SB25-0	B25/MW-12	0-2	Native silt	Slightly sandy silt
B20-32	B20/MW-7	32-33	Native sand in water-bearing zone	Gravelly sand
B21-32	B21/MW-8	32-33		
SB14-32	SB14	32-33		

2.4. Hydrogeology

2.4.1. Groundwater Elevation and Horizontal Groundwater Flow

The groundwater elevations at the Aniak WACS site have been investigated by two datalogger studies. Shannon & Wilson recorded groundwater elevations using pressure transducers/dataloggers in five site monitoring wells (MW-8 through MW-12 -- see Figure 2) between September 2009 and May 2010 (Shannon & Wilson, 2010a). OASIS began recording groundwater elevations using pressure transducers/dataloggers in seven monitoring wells (MW-5 and MW-7 through MW-12) in May 2011 and continuing through the date of this report. The dataloggers were downloaded in October 2011. Groundwater elevation plots and groundwater contour maps created from the datalogger data are presented in Appendix A and discussed below.

Chart A1-1 displays all groundwater elevations from the period between May and October 2011, along with the elevation data for the Kuskokwim River at Crooked Creek (USGS Gaging Station 15304000)[4]. The Kuskokwim River at Crooked Creek gaging station, located approximately 50 miles upriver of Aniak, is the nearest USGS gaging station to Aniak. In Aniak, the Kuskokwim River is located approximately ¼-mile from the site. Chart A1-1 shows a strong correlation between the groundwater and Kuskokwim River elevation patterns.

Charts A1-2 and A1-3 display the groundwater elevations in more detail over the spring and summer months, respectively. Groundwater elevations are labeled on these charts for four days: May 14 (spring very high water level); June 12 (early summer high water); August 20 (mid-summer high water); and October 16 (fall low water). The following conclusions were reached from these charts:

- When the groundwater level was at its highest (i.e., early- to mid-May and mid-August 2011), MW-11 had the highest groundwater elevation, while MW-12 experienced the lowest groundwater elevation. This situation occurred only for short periods of time during the highest water levels and is interpreted to represent a "losing stream" situation, i.e., groundwater flowing away from the Kuskokwim River towards the site.
- During the rest of the period between May and October 2011, MW-12 had the highest groundwater elevation, and MW-11 experienced the lowest groundwater elevation. This situation represents groundwater flow from the site toward the Kuskokwim River.
- There is little difference between the groundwater elevations of all site monitoring wells, indicating a relatively low horizontal groundwater gradient.

Figures 7 through 10 are water table elevation contour maps prepared for the four selected dates shown on Charts A1-2 and A1-3 (May 14, June 12, August 20, and

[4] The gaging station was destroyed by flooding in May 2011 so the record is incomplete until the gaging station was replaced in late June 2011.

October 16) to illustrate the different groundwater flow scenarios. Groundwater flow directions and gradients for these dates are summarized below.

- May 14, 2011 (very high groundwater elevation [72.5 feet amsl in MW-7]): Groundwater flow direction to the south-southwest at a gradient of approximately 0.002 feet/foot
- June 12, 2011 (high groundwater elevation [62.4 feet amsl in MW-7]): Groundwater flow direction to the north-northeast at a gradient of approximately 0.001 feet/foot
- August 20, 2011 (high groundwater elevation [63.5 ft amsl in MW-7]: Groundwater flow direction to the south-southwest at a gradient of approximately 0.0004 feet/foot
- October 16, 2011 (low groundwater elevation [59.7 ft amsl in MW-7]: Groundwater flow direction to the north-northeast at a gradient of approximately 0.0005 feet/foot

The water table elevation graph (Graph 1) and groundwater contour maps (Figures H-1 through H-5) prepared by Shannon & Wilson (2010a) are also included in Appendix A. Groundwater flow directions and gradients measured by Shannon & Wilson (2010a) are summarized below.

- October 3, 2009 (low groundwater elevation [58.1 feet amsl in MW-8]): Groundwater flow direction to the north at a gradient of approximately 0.0004 feet/foot (Shannon & Wilson Figure H-1).
- High groundwater elevation (Fall 2009 and Winter 2009 [60.0 and 60.2 feet amsl in MW-8]): Groundwater flow direction to the south at gradients of 0.0005 and 0.0002 feet/foot (Shannon & Wilson Figures H-2 and H-3).
- January through April 2010 (sustained low groundwater elevation [58.2 feet amsl in MW-8 in February 2010; Shannon & Wilson Figure H-4]): Groundwater flow generally to the west at a gradient of 0.0003 feet/foot.
- May 2010 (maximum groundwater elevation [63.4 feet amsl in MW-8]): Groundwater flow to the south at a gradient of approximately 0.002 feet/foot (Shannon & Wilson Figure H-5).

Overall, the datalogger evaluations concluded that the groundwater elevation is closely tied to the Kuskokwim River. There are significant seasonal fluctuations in the groundwater table elevation and groundwater flow direction, although the groundwater gradient was consistently fairly flat (low). Based on the available data (September 2009 through May 2010 and May 2011 through October 2011), three groundwater flow regimes have been identified:

- Very high water level (i.e., 2 weeks in May 2011)
- High water level (i.e., May through September)
- Low water level (i.e., October through April).

These groundwater flow regimes are summarized below in Table 2-2.

TABLE 2-2: ANIAK GROUNDWATER FLOW REGIMES

Scen-ario	Description	Approx. GW Elev. (ft amsl)	Timeframe	Primary GW Flow Dir./ Grad	Secondary GW Flow Dir./ Grad.	Basis
Very High	Spring, short duration	72 max	May 2011 (2 weeks +/-)	S-SW 0.002	NA	OASIS dataloggers
High	Consistent drop in water level from end of very high regime (i.e., late May) through mid-June. Fluctuations (<1 to 2.5 ft) due to Kuskukwim River stage changes. Smaller fluctuations possibly due to precipitation events.	61-64	May-Sept. (4.5 months +/-)	N-NE 0.001	S-SW 0.0004 (< 1 month duration)	OASIS dataloggers
Low	Low groundwater corresponding to low river stage. Fluctuations (58-60 ft amsl) in Sept through Dec due to precipitation event (10/10) and temperature variations (above-freezing temps in early 12/10). Late January through April sustained water elevations between 58-58.5 ft amsl.	58-61	Oct.-April (7 months +/-)	W 0.0003 (Jan-Apr 2010: S&W)	N-NE 0.0005 (10/16/11) 0.0002 to 0.0005 (Fall/Winter 2009 S&W)	OASIS dataloggers (9-10/11); Shannon & Wilson dataloggers

Definitions:
ft amsl: feet above mean sea level
GW – groundwater
S – south N – north E – east W - west

2.4.2. Vertical Groundwater Flow

The vertical groundwater flow gradient between monitoring wells MW-7 and MW-8 is being investigated by the OASIS datalogger study. These two monitoring wells are located within approximately 5-feet of each other. Both wells are sxcreened across the sand-gravel interval below the silt; MW-7 is screened from 23-38 feet bgs, while MW-8 is screened from 47-52 ft bgs.

A review of Charts A1-1 through A1-3 illustrates that there is no visible difference between the groundwater elevations in MW-7 and MW-8 over most of the time period between May and October 2011. The groundwater elevations posted on Charts A1-2 and A1-3 indicate a maximum elevation difference of 0.02 feet between MW-7 and MW-8. This elevation difference is within the range of possible measurement error, especially considering that the well elevations have not been surveyed since 2009, and therefore not considered definitive. Chart A1-4 presents a detailed view of the groundwater elevations in only MW-7 and MW-8 over the period between June 16 and August 10, 2011. Chart A1-4 illustrates that there is no measurable difference between the groundwater elevations in MW-7 and MW-8 over this time period. Based on the datalogger data from May 2011 through October 2011, there is no definitive vertical gradient between the screened intervals of MW-7 and MW-8.

2.4.3. Hydraulic Conductivity and Seepage Velocity

Based on the grain size classification tests shown in Table 2-1, physical aquifer parameters were obtained from literature and are summarized below in Table 2-3.

TABLE 2-3: GROUNDWATER FLOW PARAMETER SUMMARY

		Hyd Cond (K) [cm/s] [a,b]			Total Porosity (n) [a]	Eff. Porosity (n) [a]	Dry Bulk Density (lbs/ft^3) [b]
Description	Soil Type [c]	High	Low	Geo. Mean	Average	Average	Average
Fill (vadose)	Sandy Gravel (GW)	1	0.03	0.17	0.32	0.28	130
Silt (saturated & vadose)	Slightly Sandy Silt (ML)	1.0E-03	1.0E-07	1.0E-05	0.48	0.16	108
Native Sand Below Silt (saturated)	Gravelly Sand (SP)	1	0.003	0.055	0.39	0.28	110

a *Natural Attenuation of Fuels and Chlorinated solvents in the Subsurface*, Wiedemeier, 1999.
b Freeze & Cherry 1979
c *Civil Engineering Reference Manual, Sixth Edition*, Lindeburg, 1992.
d *S&W 2010 Grain Size Classification Tests*

Seepage velocities were calculated for the gravelly sand layer based on the average hydraulic conductivity, porosity, and the range of measured hydraulic gradients. Theoretical annual travel distances were calculated from the seepage velocities reflecting the seasonally-variable groundwater flow directions (northerly, southerly, and westerly directions) and are presented below in Table 2-4. Note that Table 2-4 presents only travel distances based on average hydraulic conductivity and porosity values for sand and does not consider travel through the silt or any heterogeneitites.

The travel speed of dissolved-phase contamination is slower than the travel speed of the water, due to sorption processes slowing the contaminant front. This phenomenon is generally referred to as "retardation" and may be quantified by a retardation coefficient that expresses how much slower a contaminant moves compared to the water. The retardation coefficient for TCE at the Aniak site was calculated by the following equation.

$$R = 1 + \frac{Kd * \rho b}{\varphi}$$

Where: R is the retardation coefficient = 1.25, based on parameter values below;

ρb is the bulk density (2.65*[1- φ]=1.9 g/cm^3);

K_d is the sorption coefficient = K_{oc} [organic carbon coefficient of contaminant]*foc [fraction of organic carbon in the soil]) (100 L/kg*0.00045=0.045; and

φ is the porosity (0.3).

A retardation factor of 1.25 indicates that TCE travel will be retarded by a factor of 1.25 compared to the groundwater velocity. This is a low retardation factor, reflecting TCE's high mobility and low affinity for sorption onto soil. The calculated TCE travel distance is presented in Table 2-4, along with the groundwater travel distance.

TABLE 2-4: TRAVEL DISTANCE CALCULATIONS (GRAVELLY SAND)

Flow Regime	Duration	Grad	Dir	K (avg) cm/sec	Vd (cm/sec)	Vs (avg) (cm/sec)	Vs (avg) (m/d)	Ground water Distance traveled (m)	TCE Retarda-tion factor	TCE Vs (m/day)	TCE Distance traveled (m)
Spring High Water	14 days	0.002	S-SW	0.055	1.E-04	4.E-04	3.E-01	5	1.25	0.272	4
Summer Normal	115 days	0.0009	N-NE	0.055	5.E-05	2.E-04	2.E-01	18	1.25	0.122	14
Summer Reversal	21 days	0.0004	S-SW	0.055	2.E-05	8.E-05	7.E-02	1	1.25	0.054	1
Sep-Dec	107 days	0.0005	N-NE	0.055	3.E-05	1.E-04	8.E-02	9	1.25	0.068	7
Jan-Apr	108 days	0.0003	W	0.055	2.E-05	6.E-05	5.E-02	5	1.25	0.041	4
Total	365 days							**Water**	**Total distance**		**TCE**
						Total to S-SW:		6			5
						Total to N-NE:		27			21
Definitions:						Total to W:		5			4
K- Hydraulic conductivity											
Vd- Darcy velocity						Net m/yr to N-NE		20			16
Vs- Seepage velocity						Net m/yr to W		5			4
m- meter	d- day										
cm- centimeter	yr- year					Net ft/yr to N-NE		67			54
ft- feet						Net ft/yr to W		18			14

2.4.4. Pump Test

As part of the hydrogeologic evaluation, Shannon & Wilson performed pumping tests of the Middle School and High School drinking water wells to determine whether pumping affects water levels in nearby monitoring wells and, by extension, whether it can affect migration of the groundwater TCE plumes (Shannon & Wilson, 2010a and 2010b).

Shannon & Wilson installed monitoring Wells MW-11 and MW-12 for use in the pumping tests and as sentry wells for the Middle School and the High School drinking water wells. respectively. MW-11 is located about 55 feet from the Middle School drinking water well, and MW-12 was positioned about 75 feet north of the High School drinking water well (Figure 2). The Middle School drinking water well is about 60 feet deep, whereas the High School drinking water well is about 45 feet deep. During the pumping test, groundwater contact was measured at about 32 feet in MW-11 and 29 feet in MW-12.

Three pumping tests were performed:

- Middle School pumping test in which the drinking water well was pumped at a total net flow rate of about 20 gallons per minute (gpm) for 3.5 hours.
- High School pumping test in which the drinking water well was pumped at a total net flow rate of about 11 gpm for 6 hours.
- Combined pumping test in which both drinking water wells were pumped at a total net flow rate of about 31 gpm for 4 hours.

In all three tests, groundwater level measurements were collected using pressure transducers/dataloggers in five monitoring wells (MW-8, MW-9, MW-10, MW-11, and MW-12), and atmospheric pressure measurements were also collected to correct for barometric pressure variations. All three pumping tests showed very little change in water level during or after pumping. Shannon & Wilson concluded that pumping from the drinking water wells had no measureable influence on water levels in the five nearby monitoring wells.

2.4.5. Silt

As discussed previously, there is a silt layer underlying the sandy gravel pad at the Aniak WACS site. Away from the pad, the silt extends to the ground surface; underneath the pad, the depth to silt varies from approximately 12 to 27 feet bgs[5]. The thickness of the silt layer is variable; in addition to natural variabilities, the silt horizon appears to have partially removed beneath the Aniak Middle School (presumably prior to building construction) and modified further during PCB excavation activities at the former septic system. Specifically, the silt layer was removed to a depth of approximately 18 feet bgs at the former septic tank location and completely removed (to a depth of 26 feet bgs) around the former seepage pit. Figures 4A and 4B show the approximate location of the excavations.

Three figures were prepared to assist in interpreting the silt layer. Figure 5 presents base of silt elevations and the locations of two cross-sections, A-A' and B-B' (Figures 6 and 7, respectively). Each of these figures is discussed below.

Plan View Silt Map: The base of silt elevation was selected as the best way to depict the characteristics of the silt layer in plan view relative to groundwater remediation. The base of the silt elevation better represented the variability of the silt with respect to the water table than a top of silt elevation map or a silt thickness (isopach map). The soil boring logs showed the top of the silt to be relatively constant at an elevation of approximately 80 feet across most of the site, except where it has been modified. The silt appears to have been removed to an elevation of approximately 65 feet under the Aniak Middle School Building and approximately 75 feet under the Maintenance Building and Former Truck Fill stand. In addition as discussed above, the silt was removed to varying elevations (approximately 65 to 75 feet) during the septic system PCB excavation activities. A draft silt isopach map was prepared but did not prove useful for evaluating the relationship between the silt and the variable groundwater elevations.

As shown on Figure 5, the base of silt elevation ranged from a minimum of 59 feet amsl to a maximum between 70 and 75 feet amsl[6]. In comparison, the groundwater table elevation has ranged between approximately 59 and 72 feet amsl. Therefore, during

[5] based on soil borings advanced to install soil gas points around the school by Shannon & Wilson during August 2009 (Shannon & Wilson, 2010)
[6] Note, however, that only a fraction of the soil borings advanced at the site penetrated completely through the silt layer. In particular, the base of the silt layer was not reached in MW-5 and was not logged in B-13, so the minimum silt elevation is not actually known.

times of low groundwater elevation (i.e., October through April, see Table 2-2), most or all of the silt is above the water table. During times of extreme high groundwater elevation (i.e., approximately two weeks in May, see Table 2-2) the base of the silt is well below the water table, saturating a significant portion of the silt layer (see also Figure 6). During the summer months (May through September, see Table 2-2), the base of the silt will be up to approximately 5 feet below the water table.

Cross-Section A-A’: Cross-Section A-A’ extends in a southwest to northeast direction located to the west of and roughly parallel to the middle school. Cross-Section A-A’ intersects B-B’ at MW-5. The thickness of the silt layer across Cross-Section A-A’ varies from 1 foot (B-8) to at least 16 feet thick in B-13. Note that B-13 was not logged below the bottom of the silt, so the bottom depth is unknown. Three water levels are shown on the cross-section: very high water level (May 2011; approximately 72 feet amsl), high water level (June 2008; approximately 64 feet amsl), and low water level (August 2009 and October 2010; approximately 60 feet amsl).

The groundwater table was located within or above the silt layer at the May 2011 very high water level, resulting in saturated conditions for much of the silt. However, at the June 2008 high water level, only the lower portions of the silt layer are saturated in certain portions of the site, specifically in the vicinity of MW-5, B-11, and B-13. At the August 2009/October 2010 low water level, most of the silt layer was above the water table in the vadose zone[7].

The area of highest groundwater contamination concentrations extends between temporary well B-12 and MW-5. MW-5 is believed to be screened primarily within the silt (although neither the top nor the bottom of the silt was logged in this location), suggesting that the groundwater contamination may be mainly within the silt. However, temporary well B-12, located approximately 25 feet to the south of MW-5, was screened across 1-foot of silt (64 to 65 feet amsl) and 4-feet of sand (60 to 64 feet amsl), suggesting groundwater contamination may be mainly within the sand at this location. Deeper field-screening in temporary well B-12 indicated TCE contamination in the gravelly layer below the silt. Although at lower concentrations, contamination was also detected by field-screening between 46 and 51 feet amsl. These results suggest that contamination is present in both the silt and underlying sand and gravel horizons in this area. Furthermore, there is at least a 6-foot variation in the elevation of the top of the silt in this area.

Cross-Section B-B’: Cross-Section B-B’ extends in a northwest to southeast direction across most of the Aniak WACS site. It runs parallel to the former septic system and under the middle school. The thickness of the silt layer across Cross-Section B-B’ varies from zero (in the former septic system excavation area) to a maximum of 17 feet thick in MW-8. East of SB-14, there are no penetrations completely through the silt layer, so its thickness is unknown. In particular, the top and base of the silt layer are completely unknown between SGP-17, on the west side of Aniak Middle School, and SGP-13,

[7] Note, however, that there is no data regarding the bottom of the silt layer in MW-5 and B-13.

located on the east side of the school building. Based on boring logs from other boreholes located near the school building, it is inferred that the silt was removed to an elevation of approximately 66 feet amsl under the school building, as shown in Figure 7. Three water levels are shown on the cross-section: very high water level (May 2011; approximately 72 feet amsl), high water level (June 2008; approximately 64 feet amsl), and low water level (August 2009 and October 2010; approximately 60 feet amsl).

Relative to the groundwater table, most of the silt layer was saturated at the May 2011 very high water level. However, at the lower water levels (June 2008, August 2009, and October 2011), most of the silt layer was above the water table in the vadose zone. The deepest silt was encountered in MW-8 (approximately 59 feet amsl) and MW-5 (silt to bottom of well at approximately 59 feet amsl).

The monitoring well with the highest levels of contamination is MW-5, which is interpreted to be screened across 10-feet of silt between an elevation of approximately 59 and 69 feet amsl (although the boring was not logged above 65 feet amsl so the top of silt elevation is inferred from nearby borings). At this location, the silt is saturated during all moderate-to-high water levels and may also be saturated during lowest water levels. The contamination appears to be located largely within the silt layer.

2.5. Detailed Summary of Site Groundwater Conditions

The groundwater TCE plumes are shown in Figure 3. Maintenance Building (MW-4) plume data are summarized in Table 2-5, and Septic System (MW-5/ 7) plume data are summarized in Table 2-6. The plumes are discussed in detail in the following subsections.

TABLE 2-5: MAINTENANCE BUILDING (MW-4) PLUME DATA SUMMARY

	Elevation (TOC)	Screened Interval	2008 Color-Tec Screening (ppb)	2008 TCE (ug/L)	Depth to GW (ft bgs)	Silt Interval (ft bgs)	Sand/ Gravel Interval (ft bgs)	Screened in (Saturated)	Comment
MW-4 (B-17)	90.68	22-32	--	**19.3**	27.05*	?-<25	25-31	SAND	Not logged 0-25'
B4	--	--	--	--	--	14-27+	0-14	--	No GW sample; Bottom of boring at 27'
TWB6S	91.03	26.5-31.5 (T)	15 to 30	**24.5**	27.5*	17-27	27-40	SAND	
TWB6M	91.03	33-38 (T)	1.25 to 5	--	26.5*			SAND	
TWB6D	91.03	40-45 (T)	0 to 5	--	26.5*			SAND	
TWB7	91.16	26.5-31.5 (T)	12.5-15	**10.1**	26.3*	18-20	20-40	SAND	
TWB8	90.82	25.5-30.5 (T)	0 to 5	3.21	26.2*	19.3-19.8	19.8-30	SAND	Defines south plume boundary; located between MW-4 and B11
TWB9	91.41	26-31 (T)	0 to 5	ND (<1)	26.5*	13.5-30	0-13.5	SILT	Defines north plume boundary; located north of Maintenance Bldg
TWB9	91.41	26-31 (T)	0 to 5	ND (<1)	26.5*	13.5-30	0-13.5	SILT	Defines north plume boundary; located north of Maintenance Bldg
TWB10	90.77	25.9-30.9 (T)	0 to 5	ND (<1)	25.8*	14-30	0-14	SILT	Between Maint. Bldg and School

Notes:

TOC = top of casing
ppb = parts per billion
ug/L = micrograms per liter
TW = temporary well
ft bgs = feet below ground surface
GW = groundwater
-- = not available
(T)=temporary well
TCE groundwater results
TCE=trichloroethene
ND = not detected

Results above 5 ug/L Table C cleanup level shown in bold

* DTW measured 5/21-5/23/08 (Table 2-2 of Shannon & Wilson, 2009 report)

Table 2-6: FORMER SEPTIC SYSTEM (MW-5/7) PLUME DATA SUMMARY

				Groundwater Sample TCE Results (ug/L)											
	Elevation (TOC)	Screened Interval (ft bgs)	2008 Color-Tec Screening (ppb)	10/21/ 2006	5/19/ 2008	6/4/ 2008	8/22/ 2009	5/11/ 2011	10/19/ 2011	Depth to GW* (Range in ft bgs)	Silt Interval (ft bgs)	Bottom of Silt Elev (ft)	Sand/ Gravel Interval (ft bgs)	Screened In (Saturated)	Comment
MW-1 (B1)	86.76	19-29	--	ND (<1)	3.63	**8.24**	--	--	--	21.7-24	17-24.5	62	24.5-30	Silt: 19-25'; SAND: 25-29'	High gw - contam in silt; Low gw-contam in sand
MW-2 (B2)	89.76	22-32	--	**5.44**	**11.4**	**8.48**	--	--	--	24.7-27	14.5-24.5	65	24.5-32	SAND	Bottom of boring at 32
MW-5 (B18)	90.24	22-32	--	--	--	**157**	--	**77**	--	18.6 (5/11); 27.2 (6/08)	25-31	<59	unk	SILT	Not logged 0-25; assume silt begins betw. 17 and 23 ft bgs (B11 and B12). Base of silt unknown.
MW-7 (B20)	90.04	23-38	--	--	--	--	**47.5** (cDCE 2.73)	ND (<0.2)	**42** (cDCE 3.1)	18 (5/11); 30.3 (8/09 and 10/11)	13-26	64	26-38	(Silt: 23-26'); SAND	Based on MW-8 datalogger, GW depth range 27-32 ft bgs. Saturated interval is below silt.
MW-8 (B21)	90.03	47-52	--	--	--	--	ND (<1)	ND (<0.2)	ND (<0.2)	see MW-7	14-31	59	31-52	SAND	
MW-3 (B5)	80.75	12-22	--	ND (<1)	--	ND (<1)	--	--	--	17-18	19.5-23	58	15-19.5 (Silt above & below)	Sand: 17-19.5'; Silt: 19.5-23'	Silt to bottom of boring at 23
TWB-19	88.36	24-29	0-5	--	--	--	--	--	--	24.6**	13-22	66	22-29	SAND	Temp well and perm well MW-6 at B-19
MW-6 (B19)	88.36	18-28	--	--	--	ND(<1)	ND (<1)	ND (<0.2)	ND(<0.2)	16.7-28.6	13-22	66	22-29	SAND	
MW-9 (B22)	83.24	13-28	--	--	--	--	ND (<1)	ND (<0.2)	ND (<0.2) (cDCE 0.26)	11.6 (5/11); 23.5 (8/09 and 10/11)	3-10.5	73	10.5-29	SAND	Bottom of boring at 29
MW-10 (B23)	91.18	25-40	--	--	--	--	ND (<1)	ND (<0.2)	ND (<0.2)	19.2 (5/11); 31.4 (8/09 and 10/11)	16-21	70	21-40	SAND	Bottom of boring at 40
B3	--	--	--	--	--	--	--	--	--	*17****	12-19.5	unk	9.5-12	--	Silt to bottom of boring at 19.5
TWB11S	90.87	26-31 (T)	27.5-52.5	--	**32.4**	--	--	--	--	26.7**	23.5-30	60.87	0-23.5	SILT	
TWB11M	90.87	33-38 (T0	0-5	--	--	--	--	--	--	26.7**				unk	
TWB11D	90.87	40-45 (T)	0-5	--	--	--	--	--	--	26.7**				unk	Bottom of boring at 30
TWB12S	91.03	26-31 (T)	115-265	--	**187 (D)** (cDCE 5.72)	--	--	--	--	26.2**	16.7-27	64	27-45	Silt: 26-27'; Sand: 27-30'; Gravel 30-45'	
TWB12M	91.03	32.8-37.8 (T)	***60-124***	--	--	--	--	--	--	26.2**				Gravel	
TWB12D	91.03	40-45 (T)	***15-30***	--	--	--	--	--	--	26.2**				Gravel	Saturated interval is below silt.
TWB13S	89.31	26-31 (T)	7.5-15	--	1.58 (cDCE 18.8)	--	--	--	--	25.8**	14-30	<59	unk	SILT	
TWB13M	89.31	33-38 (T)	5-10	--	--	--	--	--	--	29.8**				unk	
TWB13D	89.31	40-45 (T)	0-5	--	--	--	--	--	--	26.1**				unk	Apparently not logged below 30' bgs
B14	81.23	16-21 (T)	--	--	3.79	--	--	--	--	16.7**	0-17	64	17-22	SAND	
B15	80.4	16.6-21.6 (T)	--	--	0.43J	--	--	--	--	17.3**	0-15	65	15-22	SAND	
B16	79.79	17-22 (T)	--	--	ND (<1)	--	--	--	--	17.1**	0-15	65	15-22	SAND	
SGP-9	91.8	25.6-26.6	--	--	--	--	--	0.29	--	19	25-27	<27	unk	SILT	Soil gas point sampled at high water

Notes:

TOC = top of casing
ppb = parts per billion
ug/L = micrograms per liter

ft bgs = feet below ground surface
GW = groundwater
(T)=temporary well

TCE groundwater results
TCE=trichloroethene
cDCE=cis-1,2-dichloroethene

unk=unknown
-- = not available
ND = not detected

Results above 5 ug/L Table C cleanup level shown in bold

*At time of sampling
** DTW measured 5/23-5/24/08 (Table 2-2 of Shannon & Wilson, 2009 report)
*** GW depth per boring log at time of drilling

2.5.1. Maintenance Building (MW-4) Plume

Shannon & Wilson (2010) estimated the surface area of the MW-4 plume to be approximately 2,500 square feet[8]. However, this area should be considered a fairly rough estimate, as the plume delineation is based on one groundwater sample each from MW-4 and temporary wells B-6 and B-7. During the two 2011 monitoring events, OASIS was unable to collect a sample from MW-4, because it was covered by a connex. The plume is bounded to the north by a non-detect in B-9, although TCE and cDCE detections in soil gas at SGP-5, also located on the north side of the maintenance building, indicate contamination in the silt at that location. The plume is bounded to the south by a detection of 3.21 micrograms per liter (µg/L) in B-8 (below the ADEC Table C Cleanup level of 5 µg/L). The plume has not been delineated to the east or the west, except by MW-3 (located 90 feet west of the interpreted plume boundary). The presence of underground utilities and fuel tanks limited the ability to install monitoring wells to the east and west of this plume.

The MW-4 plume is characterized by TCE concentrations between 10.1 µg/L and 24.5 µg/L (one single sample event for three temporary wells and one permanent well in 2008). The monitoring wells were generally screened across the sand interval below the silt, except for temporary well B-9, which was screened within the silt.

The MW-4 plume is illustrated in Cross Section A-A' (Figure 6). As shown in Figure 6 and discussed in the previous section, the thickness and composition of the saturated interval varies vertically with water table elevation and laterally with variations in the silt layer. To assist in evaluating remedial alternatives for this FS, the following simplified interpretation was made for the saturated interval in the MW-4 groundwater plume: 10-foot saturated interval in sand (54 to 64 feet amsl). The simplified interpretation refers to the use of an annualized saturated thickness instead of performing multiple calculations based on the expected saturated interval thickness during each water level scenario (see Table 2-2). The top of the saturated interval corresponds to the summer high water level shown in Table 2-2, which is expected to approximate or overestimate the saturated interval for most of the year, with the exception of the very short-duration breakup period in the spring (approximately 2 weeks). The remedial alternatives evaluated under this assumption would therefore be expected to treat the entire impacted saturated zone during approximately 50 weeks of the year and additionally treat the lower vadose zone during winter low water levels. The saturated thickness interpretations are discussed further with respect to the remedial alternatives in Sections 4.2.3 and 4.2.4.

[8] The text in Shannon & Wilson (2010) reports the extent of contamination at 15,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 2,500 square feet.

2.5.2. Former Septic System (MW-5/7) Plume

The Former Septic System[9] plume was estimated at 12,500 square feet in the April 2011 Pre-Draft FS (OASIS, 2011a); however, based on a groundwater TCE detection in SGP-9 (May 2011) and soil gas detections (2009), the groundwater plume is interpreted to extend under the Aniak Middle School with an estimated area of 22,000 square feet (Figure 3). The plume boundaries have been well-delineated to the south by temporary wells B-13 through B-16 and monitoring wells MW-6 and MW-9. The plume is not well-delineated to the north (temporary well B-8 only), northeast (MW-3 is approximately 80 feet to the north-northeast), east, or west. It is not delineated at all under or to the east of the Aniak Middle School building (except the single groundwater sample from SGP-9). An elevated TCE concentration was detected in the soil gas sample from SGP-8, located on the east side of the middle school building. There are no groundwater monitoring wells in the vicinity of SGP-8, so it is unknown whether the groundwater plume extends to that area. It should also be noted that the soil gas concentrations detected in SGP-17 and SGP-18 were more than an order of magnitude higher than the soil gas concentrations detected anywhere else in the soil gas survey. There are no groundwater monitoring wells at these locations; the closest groundwater samples were collected from temporary wells B-12 and B-13.

The MW-5/7 plume can be divided into three areas: western lobe, central portion, and eastern lobe. Groundwater in the western lobe is characterized by TCE concentrations between 5 µg/L and 47.5 µg/L. The monitoring wells were generally screened across the sand interval below the silt. Based on MW-8, which was screened in the sand from 47 to 52 feet bgs and exhibited no contaminant detections, the contamination appears to decrease with depth below the silt. Groundwater in the central portion of the plume is characterized by TCE concentrations between 32.4 µg/L and 187 µg/L. These temporary and permanent monitoring wells were generally screened across the silt. Groundwater in the eastern lobe has not been characterized, because there are no monitoring wells under the Aniak Middle School building or to the east of it. For purposes of this FS, it is assumed that this portion of the plume has TCE concentrations less than approximately 10 µg/L.

The MW-7 plume is illustrated in Cross Sections A-A' and B-B' (Figure 6 and 7). As shown in these figures and discussed in the previous section, the thickness and composition of the saturated interval varies vertically with water table elevation and laterally with variations in the silt layer. To assist in evaluating remedial alternatives for this FS, the following simplified interpretation was made for the saturated interval in the MW-7 groundwater plume: 5-foot saturated interval in silt (59 to 64 feet amsl) and 10-foot saturated interval in sand (49 to 59 feet amsl). The simplified interpretation refers to the use of an annualized saturated thickness instead of performing multiple calculations based on the expected saturated interval thickness during each water level scenario

[9] The text in Shannon & Wilson (2010) reports the extent of contamination at 25,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 12,500 square feet.

(see Table 2-2). The top of the saturated interval corresponds to the summer high water level shown in Table 2-2, which is expected to approximate or overestimate the saturated interval for most of the year, with the exception of the very short-duration breakup period in the spring (approximately 2 weeks). The remedial alternatives evaluated under this assumption would therefore be expected to treat the entire impacted saturated zone during approximately 50 weeks of the year and additionally treat the lower vadose zone during winter low water levels. The saturated thickness interpretations are discussed further with respect to the remedial alternatives in Sections 4.2.3 and 4.2.4.

2.6. Conceptual Site Model

Shannon & Wilson prepared a pictoral conceptual site model and a graphical human health conceptual site model (CSM) using the ADEC CSM template (ADEC 2005), in their 2010 report. Because this focused FS is limited to groundwater remediation and remediation of the silt layer, only groundwater and subsurface soil pathways are discussed in this report. The following groundwater and subsurface soil exposure pathways are potentially complete:

- **Ingestion of groundwater**: All groundwater in Alaska is considered a potential drinking water source unless determined otherwise using the criteria presented in 18 AAC 75.350. No groundwater determination has been completed for this site under 18 AAC 75.350. There are two drinking water wells near the site (high school drinking water well and middle school drinking water well). Contamination has not been detected in either drinking water well, and sentry monitoring wells installed between the groundwater contamination and the drinking water wells have also not detected any contamination.

  Ingestion of groundwater is a potentially complete pathway for the following receptors:

  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.
- **Inhalation of volatile compounds in tap water (showering):** TCE is a volatile compound. If a contaminated water supply were used for tap water, the inhalation of volatile compounds would be a complete exposure pathway for the following receptors:
  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.
- **Inhalation of volatile compounds in indoor air:** Indoor air inhalation is considered a potentially complete pathway for TCE in groundwater and for TCE in the vadose zone. As discussed previously, air purifying filters and an SSD are in place to mitigate the vapor intrusion pathway for TCE in the Middle School building. The contribution of volatilizing TCE from groundwater to the vapor intrusion pathway is unknown, but ADEC CSM guidance (ADEC, 2005) states that the vapor intrusion

pathway should be considered complete if nonpetroleum contamination in soil or groundwater is found within 100 vertical or horizontal feet of a building.

Several of the pathways shown to be potentially complete in the CSM for the entire site are not considered complete when considering only the groundwater TCE plumes, as explained below.

- Outdoor air inhalation is not considered a potentially complete pathway for TCE in groundwater due to the groundwater depth. ADEC (2005) states that the outdoor inhalation pathway must be considered for contamination detected between ground surface and 15 feet bgs.
- Dermal adsorption is not considered a potentially complete pathway for TCE and DCE (ADEC, 2005).
- Surface water exposure is not considered a potentially complete pathway. The hydrogeological evaluation showed a very low groundwater gradient at the site with variable flow direction. There is no evidence that the groundwater contamination has migrated off-site towards Aniak Slough or the Kuskokwim River, nor do the data suggest that future off-site migration is a concern.

3. REMEDIAL ACTION OBJECTIVES

The overall objectives of environmental site restoration are to ensure that conditions at the site are protective of human health and the environment and to comply with relevant state and federal regulations. The primary goal of remedial action at the Aniak WACS site is to reduce current human health exposure risk below the ADEC threshold cancer risk level of 1:100,000 and threshold non-cancer hazard index of 1.

This Focused FS addresses only groundwater contamination. As such, remedial action objectives (RAOs) are presented only for addressing contamination dissolved in groundwater and in the silt layer that is acting as a source for dissolved-phase groundwater contamination. Full protectiveness of human health at the Aniak WACS site also requires remedial action to address vadose zone soil contamination as evaluated previously (Shannon & Wilson, 2010a) and mitigation of the vapor intrusion pathway, which is being addressed through SSD and air purifying filters. The relative contribution of groundwater versus vadose zone contamination to the vapor intrusion pathway has not been determined.

The specific RAOs proposed to reduce human health exposure risk due to groundwater contamination are listed below.

1. Reduce concentrations of TCE in groundwater to meet the ADEC Table C cleanup levels protective of drinking water (ADEC, 2008) (Table 3-1).
2. Reduce concentrations of TCE in groundwater within 100 feet of the Aniak Middle School building to meet the ADEC Residential Target Levels for Groundwater protective of vapor intrusion (ADEC, 2009) (Table 3-1).
3. If the remedial action results in generation of TCE degradation products (i.e., cDCE and vinyl chloride), ensure that they do not exceed ADEC Table C cleanup levels (ADEC, 2008) or Residential Target Levels for vapor intrusion (Table 3-1) when remedial action is complete.

TABLE 3-1: MAXIMUM GROUNDWATER CONCENTRATIONS AND ADEC CLEANUP LEVELS

Contaminant	Maximum Concentration (µg/L)	Location of Maximum Concentration (Sample Month)	ADEC Residential Target Levels for Groundwater (µg/L)*	ADEC Table C Cleanup Level (µg/L)**
2011 Sampling				
TCE	77	MW-5 (May)	0.55	5
cDCE	3.1	MW-7 (October)	220	70
Vinyl chloride	ND	--	0.71	2
2009 Sampling				
TCE	47.5	MW-7 (August)	0.55	5
cDCE	2.81	MW-7 (August)-dup	220	70
Vinyl chloride	ND	--	0.71	2
2008 Sampling				
TCE	187	TWB-12S (June)-dup	0.55	5
cDCE	18.8	TWB-13S (June)	220	70
Vinyl chloride	ND	--	0.71	2

Notes:
µg/L = Micrograms per liter
ND = Not detected
TCE = trichloroethene
cDCE = cis-1,2-dichloroethene
Vinyl chloride not detected above laboratory reporting limits in groundwater samples.
*Residential target levels are provided in *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009). This guidance is undergoing review and update due to revisions in EPA Regional Screening Levels and TCE toxicity values that were recently finalized in IRIS.
**Cleanup levels are provided in Table C of the Alaska Contaminated Site Regulations (18 AAC 75.345).

4. DESCRIPTION OF ALTERNATIVES

The pre-draft FS (OASIS, 2011a; also included as Appendix D to this Focused FS) identified remedial technologies that are potentially appropriate for treating dissolved TCE contamination at the Former Aniak WACS site. The following technologies were considered in the pre-draft: monitored natural attenuation (MNA), enhanced bioremediation, air sparging, chemical oxidation, in-well air stripping, and ex situ (i.e., pump and treat) remediation with several different treatment technologies (oxidation and air stripping). In addition, institutional controls (ICs) were discussed as either a standalone remedy or a remedy component. The no action alternative is always included as a baseline for comparison with all of the active alternatives. Containment technologies, along with passive/reactive treatment walls, were not considered appropriate for the Aniak WACS site, because of the groundwater plume's proximity to the Aniak Middle School building. Plume containment could not accomplish the RAO of reducing groundwater TCE concentrations to vapor intrusion target levels at the school. Furthermore, available data suggests minimal groundwater plume migration is occurring so containment may not be necessary for protection of downgradient receptors.

In accordance with comments received to the pre-draft FS, this FS includes remediation of the silt layer in the evaluation of alternatives.

4.1. Remedial Alternatives

Five remedial alternatives were developed and evaluated to address contamination of the groundwater and silt layer at the Former Aniak WACS site. The alternatives are listed below and discussed in the following sections. The cost estimates for each alternative are provided in Appendix C.

GW-1. No Action;
GW-2. MNA/Long-Term Monitoring (LTM);
GW-3. In-Situ Chemical Oxidation (ISCO);
GW-4. Enhanced Reductive Dechlorination (ERD); and
GW-5 Air Sparging (evaluated in [Shannon & Wilson, 2010a]).

Although not evaluated as a standalone remedy, treatment of contaminated silt in conjunction with the planned excavation of PCB-contaminated soil in the vicinity of MW-5 is recommended. The excavation in the vicinity of MW-5 will offer unique access to the contaminated silt. Either an oxidant or reductant (depending on the technology selected for groundwater remediation) could be placed into the excavation before backfilling it. Depending on the location, volume, depth, thickness, and magnitude of the silt contamination, it may also be advantageous to overexcavate TCE-contaminated silt, perform some mechanical mixing of the oxidant or reductant to increase its distribution in the silt, or alternatively to install an engineered solution, such placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically. Costs were not evaluated for this potential remedy component, because the costs are highly dependent on more complete characterization of the TCE contamination in the silt, in particular relative to the horizontal and vertical location of the PCB-contaminated soil. The detailed silt characterization has not yet been performed.

The pre-draft FS (OASIS, 2011a) presented detailed discussions about all of the remedial technologies evaluated and is included as Appendix D. The following sections discuss the application of each alternative's technology to the Aniak WACS site but do not repeat the general technology descriptions provided in the pre-draft FS.

4.2. General Assumptions for all Alternatives (except No Action)

4.2.1. Vapor Intrusion Mitigation

Although the scope of this Focused FS is limited to remedial alternatives for groundwater (and the silt layer), in order to provide a consistent basis for comparing alternatives, the operation, monitoring and maintenance (OM&M) costs of mitigating the vapor intrusion pathway (via SSD) were included in the analysis. The primary current human health risk at this site is indoor air inhalation due to vapor intrusion into the Aniak Middle School Building and possibly also due to an indoor air source(s). Therefore, continued operation of the SSD system is assumed for protection of human health until groundwater RAOs are met[10]. SSD system operation costs include OM&M activities on a quarterly basis for five years and semi-annually thereafter, annual electricity costs, and blower replacement every five years for the duration of the remedy. Ultimate decommissioning costs of the SSD system were not included in this groundwater FS, because the decommissioning costs are considered fixed costs independent of the groundwater remedy timeframe.

4.2.2. Vadose Zone Remediation

All of the groundwater alternatives assume that vadose zone soil remediation will be performed at the site. The vadose zone soil remediation is outside the scope of this Focused FS, and no soil remediation costs are included in any of the groundwater alternatives. Soil contaminated by PCBs above 1 mg/Kg (which is understood to include some soil also contaminated by TCE) will be excavated and shipped off-site for treatment and disposal. Vadose zone soil contaminated by TCE above soil RAOs will be remediated *in situ* by SVE.

[10] The relative contribution to the vapor intrusion pathway of dissolved-phase TCE from the saturated zone versus TCE from soil gas in the vadose zone has not been established. If vadose zone soil remediation decreases soil gas and indoor air TCE concentrations below ADEC target levels, then it is possible that SSD could be discontinued before groundwater RAOs are met. However, this possibility is not considered in the Focused FS cost analysis.

4.2.3. Saturated Zone Assumptions

The approximate areas for active groundwater remediation are shown on Figure 4B, and the planned soil remediation areas are shown on Figure 4A. Area, thickness, and concentration assumptions are listed below for both plumes:

- **MW-4 Plume**:
  - Approximate 2,500-square foot area south of the Maintenance Building in the vicinity of MW-4;
  - Saturated zone contamination thickness of 10 feet in sand (54 to 64 feet elevation). The silt is generally above the water table, except during spring high water events.
  - Groundwater contamination concentration of 19 ug/L; soil contamination concentration of 200 ug/Kg.
- **MW-5/7 Plume**:
  - Approximate 9,000-square foot area in the vicinity of MW-5 and MW-7.
  - Saturated contamination thickness of 5 feet in silt (59 to 64 feet elevation) and 10 feet in sand (49 to 59 feet elevation).
  - Groundwater contamination concentration of 175 ug/L; soil contamination concentration of 600 ug/Kg.

For the MW-5/7 Plume, the area of active remediation is limited to the central plume area. Although the MW-5/7 Plume extends to the east and the west of the 9,000-square foot area shown on Figure 4B, the groundwater concentrations in the east and west lobes are assumed to be near although slightly above the 5 μg/L Table C cleanup level. Most of the contamination is believed to be present in the central portion of the plume.

In both plumes, approximately the top five feet of the groundwater treatment zone is expected to be saturated only seasonally (i.e., approximately from May through September; see Table 2-2). In addition, for a short period of time during spring breakup (i.e., approximately two weeks), the saturated interval is expected to extend up to another eight feet above the top of the groundwater treatment zone. The seasonal saturation is expected to potentially result in TCE rebound in the groundwater (see discussion in Section **Error! Reference source not found.**). The silt layer, whether saturated or not, is expected to have a relatively high moisture content and provide a fairly competent barrier to air flow, so significant aeration of the seasonally-saturated zone is not expected.

4.2.4. Silt Remediation

The groundwater alternatives evaluated in this Focused FS include remediation of the portion of the silt layer that is saturated during a significant fraction of the year (approximately May through September), which is interpreted to be the interval between approximately 59 and 64 feet amsl in the MW-5/7 plume[11]. Based on the limited groundwater datalogger data available, the interval above approximately 64 feet amsl is understood to only be saturated for a short time during spring breakup (Table 2-2 and Figures 5 through 7).

Although the seasonally-saturated silt layer is included in the groundwater remedial alternatives, remediation of the silt is expected to be difficult. Its hydraulic conductivity is estimated to be approximately three orders of magnitude lower than the hydraulic conductivity of the underlying sand layer. Its seasonal saturation is expected to result in a relatively high moisture content and a correspondingly low permeability to air. The remedial alternatives were designed to address the silt characteristics as discussed in Section **Error! Reference source not found.**. Specifics of each groundwater alternative regarding silt remediation are discussed in Sections 4.4 through 4.7.

The portion of the silt layer that is located primarily in the vadose zone (i.e., the interval above 64 feet amsl) will not be addressed by the groundwater remedial alternatives, because it is considered to be part of the vadose zone and was therefore included in Shannon & Wilson's remedial alternative analysis for soil (Shannon & Wilson, 2010a).

4.2.5. Design Assumptions for the Injection Alternatives

Allowances were made in the two injection alternatives, Alternative GW-3 (ISCO) and Alternative GW-4 (ERD), to address the challenges posed by the seasonal TCE recharge and the low-permeability silt layer discussed in the previous sections. Both of the injection alternatives were designed to include four annual injection events. Each subsequent injection event will address seasonal TCE recharge that occurred since the previous injection event. The four separate injection events will allow better oxidant or reductant distribution in the low-permeability silt than a single injection event. The injection locations can be shifted for each subsequent injection event to account for the small radius of influence anticipated for each injection. Monitoring results from the first event will be used to optimize subsequent events to address the seasonal TCE recharge and low-permeability silt layer.

4.2.6. Groundwater Monitoring

Groundwater monitoring is an important component of all of the alternatives. The following groundwater monitoring scope was used for each alternative for cost-estimating purposes, although the actual monitoring scope may deviate somewhat from the details provided below.

- Installation of 12 new monitoring wells;
- Quarterly groundwater monitoring of 15 wells for one year;
- Semi-annual groundwater monitoring of 15 wells for three years;

[11] As shown on Figure 6, this interval is actually comprised of a combination of silt and sand but is assumed to have silt characteristics in the FS analysis.

- Annual groundwater monitoring of 15 wells for 15 years (or until remedy completion); and
- Groundwater monitoring of 15 wells every 5 years until remedy completion.
- Confirmation sampling to verify that RAOs have been reached will be provided by the annual groundwater monitoring.

4.2.7. Institutional Controls

All of the groundwater alternatives will have an IC component to protect human health until RAOs are met. In general, ICs include engineering controls, such as fences, and document controls, such as deed restrictions, to restrict site activities that could pose a potential threat to human health. The ICs anticipated for the Aniak WACS site include restricting the installation of drinking water wells in the vicinity of the groundwater plume.

The formality and duration of ICs will vary by alternative, depending on its remedial timeframe. The costs for establishing ICs are not specifically included in the cost analysis but would be included in the contingencies.

4.2.8. Cost Estimating

Costs for each alternative were prepared consistent with the *FS Cost Estimating Guidance* (EPA, 2000). The detailed cost estimates include capital costs, OM&M costs, contingencies, and present value analysis to allow direct comparison of alternatives with different remedial timeframes. Present value costs were calculated using a 7 percent discount rate, as recommended for non-federal-government-funded projects in the EPA guidance. Although detailed cost estimates were prepared for each alternative, the cost estimate accuracy is considered to be more similar to a screening-level analysis than a detailed analysis, due to the significant data gaps remaining with respect to the nature and extent of contamination at the site and the delineation of the silt layer. Therefore, the costs are presented in a range of -50% to +100%, which is the high end of the uncertainty range shown in Exhibit 2-3 of the FS guidance.

4.2.9. Data Gaps

As discussed in the pre-draft FS, there are still some significant data gaps to be addressed before implementing groundwater remediation at this site. The top of the silt layer has been reasonably well-characterized; however, its depth is unknown across much of the site (Figure 5). Geotechnical data are very limited. The nature and extent of contamination in site soil and groundwater has been incompletely characterized. A very small number of soil samples have been analyzed for TCE, and there is no delineation of soil contamination across the silt or underlying sand/gravel units. The relative mass of contamination held in the gravel fill of the vadose zone relative to the mass of contamination in the silt layer is unknown. The extent of groundwater contamination under and to the east of the Aniak WACS Middle School building is unknown. There have been no soil or groundwater samples collected in the vicinity of SGP-17 and SGP-18, the locations with the highest soil gas detections.

Additional plume characterization activities should include installing soil borings and monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. Additional characterization and a pilot test (or tests) of the most promising alternative(s) should be performed before implementing a full-scale cleanup and are recommended before final remedy selection.

4.3. Alternative GW-1: No Action

The No Action Alternative is used as a baseline reflecting current conditions without remediation. This alternative is used for comparison with each of the other alternatives.

4.4. Alternative GW-2: MNA/LTM

Alternative GW-2 uses natural processes occurring in groundwater to reduce contaminant concentrations over time (MNA) and LTM to track progress of the MNA and evaluate the remedy's effectiveness. As with the other alternatives, ICs will be used to protect human health until RAOs are reached.

Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater. Of these processes, reductive dechlorination (using biological and/or abiotic degradation processes) is usually the most significant degradation process for chlorinated solvents such as TCE. MNA would allow these processes to continue to occur as they have in the past, without disturbances potentially caused by implementation of active remedial technologies.

Specific considerations and assumptions for implementing Alternative GW-2 at the Aniak WACS site are presented below in Sections 4.4.1 and 4.4.2.

4.4.1. MNA Considerations at Aniak WACS

Two rounds of geochemical parameter samples have been collected from the Aniak groundwater monitoring wells. Samples from MW-1 through MW-6 were analyzed for geochemical parameters in June 2008 (Shannon & Wilson, 2009), and samples from MW-5 through MW-12 were analyzed for geochemical parameters in May 2011. Results are presented in Table 4-1, along with field parameter results from October 2011 and discussed below. It is worth noting that both rounds of geochemical parameter sampling were performed at relatively high groundwater levels.

- The DO and oxidation-reduction potential (ORP) measurements are variable, with indications of somewhat reducing groundwater conditions (DO less than 1 mg/L and negative ORP values) and oxidizing conditions (DO greater than 1 mg/L and positive ORP values) at different times in most of the monitoring wells. The correlation between DO and ORP readings is not great. For example, in September 2009, the

DO concentration in MW-9 was 0.3 mg/L with a negative ORP of -129 mV, indicating anaerobic groundwater conditions. However, in October 2011, the DO concentration in MW-9 was 0.5 mg/L but with a positive ORP of 164 mV.

- Both the 2008 and 2011 laboratory results show low levels of total organic carbon (TOC) in the groundwater, with a maximum TOC concentration of 3.9 mg/L in MW-3, and most concentrations below 1 mg/L. These TOC concentrations are generally not considered adequate for complete TCE reduction.
- The 2008 laboratory results indicated elevated nitrate and sulfate concentrations, with very low concentrations of dissolved iron and manganese and no methane. These results suggest aerobic groundwater conditions (i.e., there is no indication of significant nitrate, manganese, iron, or sulfate reduction). Also, the elevated nitrate and sulfate concentrations suggest significant competing electron acceptors that will need to be reduced before significant complete TCE reduction would be expected.
- The 2011 laboratory results indicated lower but still elevated nitrate-nitrite and sulfate concentrations. Different monitoring locations are interpreted to be the primary reason for the difference between the 2011 and 2008 nitrate-nitrite and sulfate results. The monitoring wells sampled in 2008 were closer to the former sewer line. Dissolved iron was not detected in any of the 2011 samples, and dissolved manganese results were less than 1 mg/L, suggesting that the groundwater is not significantly iron- or manganese-reducing. Methane was also not detected in 2011. Overall, the 2011 results indicate aerobic or possibly nitrate-reducing groundwater conditions. Significant complete reduction of TCE is not expected in these geochemical conditions.

The presence of TCE degradation products in site groundwater samples is another line of evidence for MNA (reductive dechlorination). Historical groundwater monitoring results (Table 2-5 and Table 2-6) indicate that low concentrations of cDCE have been detected in samples from three site monitoring wells: MW-1, MW-7, and MW-9. In addition, high concentrations of cDCE were detected in the soil gas sample from SGP-18, and the cDCE concentration in temporary monitoring well B-13 (18.8 µg/L) exceeded its TCE concentration (1.57 µg/L). The cDCE detections indicate that reductive dechlorination is occurring in some sections of the plume, most significantly in the silt near SGP-18. Elevated total petroleum hydrocarbons (TPH) detected in SGP-18 suggest that petroleum contamination may be providing a carbon source for reductive dechlorination in this area. The difference in MW-7 VOC results between the May 2011 high water level event and the October 2011 low water event (i.e., ND in May 2011; 44 µg/L TCE and 3 µg/L cDCE in October 2011) also shows that water level affects contaminant concentrations and may also be expected to affect MNA.

.

Table 4-1: Geochemical Parameter Results
2008 - 2011
Aniak WACS, Alaska

Monitoring Well	Sample ID	Sample Date	Screened Interval (ft bgs)	pH	Conduc-tivity	DO (mg/L)	ORP (mV)	Ethane/ Ethene (mg/L)	Methane (mg/L)	Alkalinity(mg/L)	Nitrate-Nitrite (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Iron, dissolved(mg/L)	Manganese, dissolved (mg/L)	Iron, total (mg/L)	Manganese, total (mg/L)
MW-1		5/19/2008	19-29	6.0	0.19	1.4	78	--	--	--	--	--	--	--	--	--	--	--
		6/3/2008		6.1	0.59	5.3	173	--	ND (0.0072)	78.8	35.1	1.74	2.09	60.5	<0.02	5.03	0.11	--
MW-2		5/19/2008	22-32	5.93	0.16	1.7	142	--	--	--	--	--	--	--	--	--	--	--
		6/3/2008		5.85	0.28	2.5	163	--	ND (0.0072)	111	4.12	1.92	1.06	11	<0.02	0.00223	0.111	--
MW-3		6/3/2008	12-22	6.32	0.7	3.9	137	--	ND (0.0072)	331	3.29	3.89	2.16	45.9	0.216	0.0107	5.75	--
MW-4		6/3/2008	22-32	6.1	0.32	1.5	201	--	ND (0.0072)	146	2.67	0.0953	3.45	10.1	0.229	0.0713	0.0234	--
	8/22/09: Dry; 5/11/11 and 10/19/11: Covered by Conex																	
MW-5		6/3/2008	22-32	6.1	0.34	3.2	122	--	ND (0.0072)	151	2.77	1.98	1.83	14	0.0212	0.0322	0.0645	
	11-AWA-010-GW	5/11/2011		7.6	0.29	4.6	66	ND (<0.010)	ND (<0.007)	123	2	0.72	4.5	11.9	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	11-AWA-011-GW	5/11/2011		--	--	--	--	ND (<0.010)	ND (<0.007)	121	1.83	0.68	4.4	12.2	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	8/22/09: Dry; 10/19/11: Dry																	
MW-6		6/3/2008	18-28	6	0.43	1.4	182	--	ND (0.0072)	204	2.2	1.3	1.08	18.2	0.248	0.425	1.41	--
		8/27/2009		6.1	0.28	7.3	203	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-004-GW	5/10/2011		6.3	0.28	**0.9**	78	ND (<0.010)	ND (<0.007)	123	1.72	0.67	3	11	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	11-AWA-016-GW	10/19/2011		5	0.26	10.2	232	--	--	--	--	--	--	--	--	--	--	--
MW-7		8/30/2009	23-38	7.3	0.24	**0.6**	-65	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-003-GW	5/10/2011		6.4	0.34	**0.8**	147	ND (<0.010)	ND (<0.007)	154	1.29	0.66	2.7	13.7	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	11-AWA-015-GW	10/19/2011		5.5	0.4	2.0	143	--	--	--	--	--	--	--	--	--	--	--
MW-8		8/30/2009	47-52	7.4	0.28	**0.3**	-85	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-002-GW	5/10/2011		6.4	0.27	1.1	129	ND (<0.016)	ND (<0.011)	127	0.53	0.46	2.4	13.3	ND (<0.100)	0.252	ND (<0.100)	0.269
	11-AWA-014-GW	10/18/2011		5.5	0.24	**0.6**	149	--	--	--	--	--	--	--	--	--	--	--
MW-9		9/1/2009	13-28	7.3	0.23	**0.3**	-129	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-001-GW	5/10/2011		6.4	0.31	7.4	141	ND (<0.010)	ND (<0.007)	137	0.7	0.59	2.6	16.1	ND (<0.100) UJ	0.278 J	ND (<0.100)	0.253
	11-AWA-013-GW	10/18/2011		5.5	0.35	**0.5**	164	--	--	--	--	--	--	--	--	--	--	--
MW-10		9/1/2009	25-40	8.9	0.25	**0.4**	-242	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-006-GW	5/10/2011		6.3	0.27	**0.8**	169	ND (<0.008)	ND (<0.006)	123	1.21	0.63	2.1	10.9	ND (<0.100)	0.51	ND (<0.100)	0.245
	11-AWA-020-GW	10/19/2011		5.8	0.46	1.1	222	--	--	--	--	--	--	--	--	--	--	--
MW-11		9/1/2009	25-40	10.5	0.2	2.2	-267	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-008-GW	5/11/2011		6.4	0.29	1.3	20.3	ND (<0.010)	ND (<0.007)	129	0.88	0.79	2.3	11.4	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	11-AWA-018-GW	10/19/2011		5.5	0.31	1.8	218	--	--	--	--	--	--	--	--	--	--	--
MW-12		9/1/2009	22-37	9.6	0.23	**0.8**	-265	--	--	--	--	--	--	--	--	--	--	--
	11-AWA-005-GW	5/10/2011		6.2	0.25	**1.0**	116	ND (<0.010)	ND (<0.007)	119	1.65	0.71	2.1	9.1	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
	11-AWA-017-GW	10/19/2011		5.7	0.42	4.0	232	--	--	--	--	--	--	--	--	--	--	--
SGP-2	11-AWA-009-GW	5/11/2011	28.5-29.5	8.4	0.24	3.2	31	ND (<0.010)	ND (<0.007)	92	1.05	3.23	23.1	5.4	5.14	0.312	129	3.44
SGP-9	11-AWA-007-GW	5/11/2011	25.6-26.6	5.9	0.22	7.1	201	ND (<0.010)	ND (<0.007)	94	0.57	2.21	15.2	4.6	6.57	0.781	128	5.23

Notes:

AWA = Aniak White Alice
GW = groundwater

ft = feet
in = inches
bgs=below ground surface

ND = not detected
na = not applicable

DO=dissolved oxygen
ORP=oxidation-reduction potential

2008 data
2009 data
Bold, red: DO<1

Overall, data suggest that TCE is being reduced to cDCE in some portions of the site (i.e., the southern portion of the former truck fill area). There is no evidence of further reduction of cDCE to vinyl chloride or ethene to-date. Geochemical parameter data indicate generally aerobic groundwater conditions at high water level, while geochemical conditions at low water level have not been evaluated. Site data do not suggest that MNA (by reductive dechlorination) will be an effective remedy in the short-term, and it is unknown whether MNA can adequately treat groundwater contamination at the Aniak WACS site in the long-term.

4.4.2. Assumptions for Alternative GW-2 at Aniak WACS

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.5 would be followed. The remediation timeframe was selected to be 35 years, because it is significantly longer than the longest remediation timeframe estimated for an active remedy (20 years), and because the present worth of costs beyond 35 years becomes insignificant (< $10,000 for SSD OM&M and groundwater monitoring). However, the 35-year timeframe is also somewhat arbitrary, because there has not yet been sufficient monitoring to establish a downward trend in groundwater contamination levels. If future monitoring shows that there are significant areas where reductive dechlorination is occurring at the site and soil remediation addresses most of the risk due to vapor intrusion, the remedial timeframe would be expected to be less than 35 years.

The primary risk associated with this alternative is the uncertainty about whether groundwater geochemistry is sufficiently reducing across enough of the groundwater plume to effectively dechlorinate the TCE and DCE to meet RAOs. If reducing geochemical conditions are established in the aquifer, reaeration due to the fluctuating groundwater level is possible but not expected to be significant. The silt layer present across much of the MW-5/7 plume is expected to have a high moisture content that is expected to minimize air flow from the vadose zone. Reoxygenation of the aquifer from the Kuskokwim River is similarly not expected to be significant, due to the approximate ½-mile distance to the river.

4.5. Alternative GW-3: In Situ Chemical Oxidation (ISCO)

In Alternative GW-3, a chemical oxidant would be injected into site groundwater to oxidize the contamination. Several different forms of oxidants have been used for ISCO, including permanganate (MnO_4^-), Fenton's hydrogen peroxide (H_2O_2) and ferrous iron (Fe^{+2}) or catalyzed hydrogen peroxide (CHP), ozone (O_3), and persulfate ($S_2O_8^{2-}$). In addition, there are proprietary oxidants, such as RegenOx® by Regenesis Bioremediation Products. All of these oxidants are considered effective for oxidizing TCE and its degradation products, DCE and vinyl chloride (ITRC, 2005).

4.5.1. ISCO Considerations at Aniak WACS

Shannon & Wilson (2010) performed an analysis of chemical oxidation for soil at the Aniak WACS site. Groundwater treatment using chemical oxidation was not considered based on the potential risk to the drinking water wells. However, ISCO for groundwater is considered in this Focused FS, because existing data suggests that the actual risk to the drinking water wells may not be significant, based on pumping test results and pressure transducer/datalogger data suggesting limited migration of groundwater contamination (discussed in Section 2.4).

Shannon & Wilson assumed treatment of the TCE-impacted soil using a potassium permanganate ($KMnO_4$) solution. Potassium permanganate has a relatively longer half-life than other oxidants, which will allow better distribution in the low-permeability silt. Natural oxidant demand tests performed on three saturated soil samples (SB-14, B-20/MW-7, and B-21/MW-8 from 31-33 feet bgs) showed the oxidant demand of subsurface organic and inorganic components in the soil and groundwater ranged from 3 to 14.6 grams of oxidant ($KMnO_4$) per kilogram of soil plus groundwater.

Shannon & Wilson assumed that the potassium permanganate liquid mixture would be gravity-fed into the subsurface at points spaced through the zone of contamination. They assumed it would take approximately 1 year for liquid to permeate 5 feet of silt. The initial application would include sufficient liquid to saturate the area so that the chemical could react with available TCE and then still have enough remaining to slowly saturate the silt over an estimated 1 year infiltration period. Bench scale and field pilot tests would be performed to evaluate the radius of influence for the application wells, to determine oxidant dosing requirements, and to refine assumptions regarding the number of applications required.

Extending Shannon & Wilson's soil treatment analysis to groundwater treatment by ISCO, the most significant considerations are the silt layer overlying the saturated layer and the groundwater flow characteristics (low gradient and variable flow direction). To treat the groundwater, the oxidant would be applied through injection points drilled most of the way through the silt layer. In areas where contamination is present in sandy soils below the silt layer (i.e., near temporary well B-13), some injection points may be drilled deeper into the sand layer to distribute oxidant below the silt. This distribution system would allow some oxidation of contaminants in the silt layer, although the distribution of oxidant within the silt layer would be expected to be poor. Similarly, it would be difficult or impossible to achieve a consistent oxidant "front" in or below the silt layer. Instead, the oxidant would migrate into and through the saturated zone in channels/preferential pathways, resulting in incomplete oxidant distribution. Injection of the permanganate oxidant mixture will also be inhibited by precipitation of dissolved metals, and permanganate particles will result in temporary permeability loss in the already low permeability silt. However, the presence of some permanganate particles may be beneficial in that they can provide a source that will dissolve once in the aquifer, thereby extending the half-life of the oxidant in the aquifer. The distribution issues will likely result in the need to inject the oxidant several times to complete remediation.

An additional consideration of ISCO at this site is the potential risk of introducing heavy metals such as arsenic and chromium, found as impurities in the $KMnO_4$, into the groundwater or mobilizing metals from the soil or aquifer matrix due to changes in pH.

Literature research (i.e., Huling and Pivetz, 2006) indicates that arsenic and chromium introduction could result in MCL exceedences, although natural attenuation has generally achieved adequate reductions in acceptable distances. Remediation-grade $KMnO_4$ has been developed that contains only minute concentrations of heavy metals. In addition, changes in pH that could occur in conjunction with ISCO and also ERD can also mobilize metals from the soil or aquifer matrix. Bench-scale testing is recommended to evaluate the risk of heavy metal introduction or mobilization, especially at this site with nearby drinking water wells.

4.5.2. Assumptions for Alternative GW-3 at Aniak WACS

Prior to completing the remedial design at the Aniak WACS site, bench-scale testing and a pilot test would be performed for ISCO. The primary goals of the bench-scale testing would be to evaluate the risk of heavy metal mobilization (such as arsenic and chromium) from the $KMnO_4$ into groundwater, to more directly assess natural oxidant demand, and to evaluate different oxidants. The primary goals of the pilot test would be to assess realistic injection rates and oxidant distribution in the silt in the most highly-contaminated portion of the site (currently thought to be between the former truck fill area and SGP-17).

Potassium permanganate was the oxidant assumed for Alternative GW-3. Permanganate was selected based on its relatively greater persistence in the environment (greater than 3 months [Huling and Pivetz, 2006]) and therefore greater ability to diffuse through the low-permeability silt before degrading. In addition, it is consistent with Shannon & Wilson's remedial alternative analysis for soil. If ISCO is selected as the groundwater remedy, the actual oxidant selection will be based on bench-scale and pilot-scale testing results. Any cost differences are expected to be within the -50% to +100% cost range of this FS.

In Alternative GW-3, the oxidant was assumed to be injected as an aqueous solution into a total of 54 injection points (42 injection points in the MW-5/7 plume and 12 injection points in the MW-4 plume, based on a 15-foot radius of influence) (Figure 4B). The aqueous solution was assumed to have a concentration of approximately 3% oxidant. The injection rate was assumed to be up to approximately 20 liters per minute to help distribute the oxidant within the silt. The chemical oxidation injections would occur over a 4-year period, with 25% of the total calculated oxidant demand injected each year. The purpose of the 4-year injection period is to optimize injection locations by allowing an assessment of the oxidant distribution between injections and thereby revising the injection geometry for subsequent injection events. In particular, oxidant distribution in the low-permeability silt is expected to be problematic, and the four separate injection events are planned to aid the oxidant distribution.

To calculate the amount of oxidant required, average soil TCE concentrations of 200 µg/Kg (for sand in both plumes) and 600 µg/Kg (for silt) and average groundwater TCE concentrations of 19 µg/L (MW-4 plume) and 175 µg/L (MW-5/7 plume) were assumed. The average value from Shannon & Wilson's oxidant demand analysis (7.4 g $KMnO_4$/kg soil plus groundwater) was used to calculate the natural oxidant demand (approximately 73,000 kg oxidant for 8E+06 kg soil and 1.9E+06 kg groundwater). The total amount of oxidant required for the contamination was calculated at approximately 8 kg.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.5 would be followed. The remedial timeframe for Alternative GW-3 was estimated at ten years.

4.6. Alternative GW-4: Enhanced Reductive Dechlorination (ERD)

In Alternative GW-4, a substrate would be injected into site groundwater to enhance the biological degradation processes already occurring to a limited degree at the site. The purpose of the substrate addition is to promote environmental conditions necessary for biodegradation of the chlorinated solvents (i.e., reducing conditions). The substrate provides a carbon source for naturally occurring microorganisms to consume oxygen and other electron acceptors such as nitrate and sulfate and a source of hydrogen necessary for the anaerobic biodegradation process.

There are a variety of substrates available for promoting reductive dechlorination at contaminated sites (e.g., sodium lactate, vegetable oil, and Hydrogen Release Compound [HRC™], among others). HRC™ is a viscous (honey-like), proprietary substance manufactured by Regenesis Corporation that, when hydrated, slowly releases lactic acid over a period of months. HRC™ is composed of glycerol tripolylactate, which is a nontoxic, food-grade substance. Because of its time-release feature, HRC™ requires less frequent injections than sodium lactate.

4.6.1. Enhanced Bioremediation Considerations at Aniak WACS

A significant consideration for enhanced bioremediation at the Aniak WACS site is the substrate distribution in the lower permeability silt layer. There are no specific concerns about substrate distribution in the saturated gravelly sand.

Another consideration for enhanced bioremediation at this site is concern over the ability to drive the groundwater plume to anaerobic conditions and maintain these conditions over time. The 2008 and 2011 MNA parameter sample results indicate that the site groundwater is generally aerobic (at high water levels), and there are significant competing electron acceptors that will need to be reduced before much TCE reduction will occur. Geochemical conditions at low water level have not been assessed. Groundwater sampling for dehalococcoides ethenogenes (DHC), which are the only known organisms capable of the complete dechlorination of PCE and TCE to ethene, has not been performed at the site.

A third consideration for enhanced bioremediation at the site is the low groundwater temperatures. The dataloggers recorded a temperature range between approximately 2ºC and 4ºC over the period between May and October 2011. Although enhanced bioremediation of chlorinated solvents has been shown to be effective at cold water sites in Alaska, the Aniak groundwater temperatures are approximately 2ºC to 5ºC colder. As discussed in Section 4.2.9, use of Bio-Trap® in-situ microcosms would help evaluate the potential effectiveness of enhanced bioremediation at this site.

Changes in pH that could occur in conjunction with ERD (and also ISCO) can also mobilize metals from the soil or aquifer matrix.

Although the planned SVE system could adversely affect enhanced bioremediation by inducing the flow of oxygenated air into the subsurface, the effects would be expected to be minimized by the low-permeability silt layer.

4.6.2. Assumptions for Alternative GW-4 at Aniak WACS

Prior to completing the remedial design at the Aniak WACS site, bench-scale testing and a pilot test would be performed for ERD. The primary goals of the bench-scale testing would be to evaluate the performance of different electron donors (substrates) and bioaugmentation on reductive dechlorination using site soils and groundwater. The primary goals of the pilot test would be to assess realistic injection rates and substrate distribution in the silt in the most highly-contaminated portion of the site (currently thought to be between the former truck fill area and SGP-17). The effects of cold site groundwater temperatures on the reductive dechlorination process will also be evaluated.

For costing purposes, it was assumed that HRC™ would be the substrate injected at the Aniak site. However, other substances would likely work as well, or better. For example, Regenesis has also developed a substance called HRC Primer™, which is less viscous and more readily bioavailable than HRC™. Regenesis recommends use of HRC Primer™ to initiate the remedial process at some sites. Because it is less viscous than HRC™, HRC Primer™ is expected to have better distribution in tighter, less-permeable soil layers than HRC™. However, HRC Primer™ will require more frequent reinjection than HRC™. There are also nonproprietary substances such as sodium lactate or emulsified vegetable oil or combinations of substances that could be used. If Alternative GW-4 is selected for groundwater remediation at this site, microcosm and/or pilot testing would be used to select the actual substrate to inject.

An online calculator provided by Regenesis (www.regonlinesoft.com) was used to estimate the volume of HRC™ required for this alternative. To calculate the amount of substrate required, an average soil TCE concentration of 200 μg/Kg was assumed for sand in both plumes, a groundwater TCE concentration of 19 μg/L was assumed for the MW-4 plume, a TCE concentration of 600 μg/Kg was assumed for the silt in the MW-5/7 plume, and a groundwater TCE concentration of 175 μg/L was assumed for the MW-5/7 plume. The average geochemical parameter values from the May 2011 monitoring event were used to calculate the competing electron acceptor concentrations: 2.4 mg/L oxygen, 1.0 mg/L nitrate, 5 mg/L manganese, 128.5 mg/L iron, and 10.9 mg/L sulfate.

The remedial design for enhanced bioremediation was consistent with the design of ISCO; i.e., a 15-foot radius of influence resulting in a total of 42 injection wells in the MW-5/7 plume and 12 injections in the MW-4 plume (Figure 4B). Based on these assumptions, the Regenesis calculator determined a total requirement of 3,800 pounds of HRC™. A closer injection spacing is expected to be necessary to increase substrate distribution within the silt, and some reoxidation of the groundwater may occur with Kuskokwim River fluctuations; therefore, the remedial design includes an initial injection of 3,800 pounds of HRC™ followed by three additional annual injections of 2,850 pounds of HRC™ each (i.e., 75% of the initial injection mass), for a total of 12,350 pounds of HRC™.

This alternative also includes bioaugmentation (i.e., injection of appropriate microbial community [DHC organisms]) for complete reductive dechlorination of TCE to ethene. The presence or absence of DHC organisms is unknown at this site, but bioaugmentation was included in the cost estimate. Bioaugmentation is relatively inexpensive relative to the entire project cost, and it may assist and will not hurt reductive dechlorination at the site. For costing purposes, three bioaugmentation events each of 100 liters of KB-1® dechlorinator were assumed. The KB-1® would be injected into one of the substrate injection rows; i.e., 3 injections in the MW-4 plume and 7 injections in the MW-5 plume. KB-1® injection should not occur until the aquifer has been driven anaerobic; therefore the bioaugmentation was considered to occur in years 1 through 3. KB-1® is a naturally occurring, non-pathogenic microbial culture that contains DHC, the only group of microorganisms documented to promote the complete dechlorination of chlorinated ethenes to non-toxic ethene. KB-1® is used to establish complete dechlorination at sites that do not contain DHC (or the right DHC) and to accelerate dechlorination rates to achieve treatment goals. As with the other assumptions in this FS, selection of the actual microbial consortium for injection would occur after additional characterization and in conjunction with a pilot test.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.5 would be followed. The remedial timeframe for Alternative GW-4 was estimated at twenty years.

4.7. Alternative GW-5: Air Sparging

Alternative GW-5 involves air sparging in conjunction with SVE, as evaluated by Shannon & Wilson (2010a). Air sparging is an in-situ technology in which air is injected into a contaminated aquifer using air sparge wells to induce volatilization of contaminants. As air moves through the saturated soil within the zone of influence of the air sparge wells, volatile organic contaminants are stripped from the water. Using an SVE system in conjunction with air sparge will enhance the process by increasing flow through the groundwater, controlling gas/vapor movement through the subsurface, and capturing volatiles before they escape at the surface.

4.7.1. Air Sparging Considerations at Aniak WACS

Shannon & Wilson performed an air sparge pilot test that showed that air could be injected into the water-bearing zone beneath the silt with a radius of influence of about 20 feet. However, they also identified that air sparge may not be an effective remedial alternative as the contaminated groundwater is located in a semiconfined aquifer system. The silt layer overlying the saturated sandy gravel to gravelly sand soil may act as an aquitard, creating semi-confined conditions. Air injected into the semi-confined aquifer could become trapped by the overlying, semi-confining layer and may not be able to escape to the unsaturated zone for capture using SVE wells. However, the competence of the silt layer has not been determined, so the degree to which it may act as an aquitard is not known.

Air sparge is not expected to be an effective remedy for contamination in the silt layer. Due to the fluctuating water table, the silt layer is expected to have a relatively high water saturation. The high water saturation is expected to inhibit air flow through the silt layer.

4.7.2. Assumptions for Alternative GW-5 at Aniak WACS

To ensure that the assumptions used in the air sparge alternative were consistent with the assumptions in Alternatives GW-2 through GW-4, OASIS revised the cost estimate prepared by Shannon & Wilson (2010). In particular, revisions were made to the monitoring schedule and system installation costs. The assumptions for Alternative GW-5 are discussed below.

Consistent with Alternatives GW-3 and GW-4, GW-5 assumes that an air sparge pilot test would be performed prior to remedial system design. Although an air sparge pilot test has been performed at the Aniak WACS site, a second pilot test would be necessary to specifically assess the radius of influence in the silt layer in the most highly-contaminated portion of the site (i.e., between the former truck fill area and SGP-17).

The physical assumptions of Alternative GW-5 are consistent with Shannon & Wilson's physical assumptions, i.e., 15 sparge wells to a total depth of 45 feet bgs (Figure 4B). Costs for the SVE component are already included in the SVE soil remediation and are therefore not repeated in groundwater alternative GW-5. After the first year of operation, the sparge system power requirement was assumed to drop to 50% of the initial power requirement due to system cycling. Blower replacement was assumed every 5 years, with complete sparge system well replacement after ten years.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.5 would be followed. The remedial timeframe for Alternative GW-5 was estimated at twenty years.

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5. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

5.1. Evaluation Criteria

The five groundwater remedial alternatives identified in the previous section of this Focused FS were evaluated against the nine criteria described in Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) §300.430(f)(5)(i). The CERCLA criteria are classified as threshold criteria, balancing criteria, and modifying criteria.

Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria—the alternative must meet them or it is unacceptable. The following are classified as threshold criteria:

- Overall protection of human health and the environment
- Compliance with regulations

Balancing criteria weigh the tradeoffs between alternatives. These criteria represent the standards upon which the detailed evaluation and comparative analysis of alternatives are based. In general, a high rating on one criterion can offset a low rating on another balancing criterion. Five of the nine criteria are considered balancing criteria:

- **Long-term effectiveness and permanence**: This criterion refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, after the remedy has been completed.
- **Reduction of toxicity, mobility, and volume through treatment**: This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.
- **Short-term effectiveness**: This criterion addresses the effectiveness of the remedy during its implementation. It includes the period of time needed to implement the remedy along with any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.
- **Implementability**: This criterion addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.
- **Cost:** This criterion addresses the cost-effectiveness of a remedy based upon design, construction, start-up, monitoring, and maintenance costs.

Modifying criteria evaluate public acceptance and can therefore not be considered in the FS. The final two criteria are considered modifying criteria**:**

- Community acceptance
- State/regulatory agency acceptance

5.2. Comparative Analysis of Alternatives

A comparative analysis was performed to identify the advantages and disadvantages of each alternative relative to the other alternatives. The relative performance of each alternative was evaluated with respect to each of the NCP criteria. The scoring procedure is discussed in this section.

Threshold criteria are either met or not met; therefore, “yes” and “no” were used as the scores for threshold criteria.

A numerical scoring scheme was used for evaluating the balancing criteria. Each alternative was assigned a numerical score between 0 and 5 for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives. The numerical scores are presented and defined below:

0: Worst (Criterion not satisfied)

1: Poor

2: Below Average

3: Average (Criterion partially satisfied)

4: Above Average

5: Best (Criterion completely satisfied)

All of the criteria except cost were evaluated on a qualitative basis. Cost was evaluated quantitatively by calculating the expected range of costs (within a range of -50% to +100%) and then normalizing the costs to the 0 to 5 scale, with the least expensive alternative receiving a score of 5, and the most expensive alternative receiving a score of 0. The quantitative cost evaluation was performed based on the EPA document entitled *A Guide to Developing and Documenting Cost Estimates During the Feasibility Studies* (EPA, 2000).

5.3. Comparison of Groundwater Alternatives

The numerical scores of the five groundwater alternatives for the nine NCP criteria are presented in Table 5-1 and discussed in this section. All of the groundwater alternatives assume implementation of the planned vadose zone remedies and continued operation of the SSD system for the duration of the groundwater remedy, i.e., until groundwater RAOs have been met. As discussed in Section 4.2.1, OM&M costs for continued operation of the SSD system for the duration of each groundwater remedy are included in the cost evaluation. Impacts to vadose zone soil and vapor intrusion risk by the groundwater remedies is not considered in the following analysis, except to the extent that the groundwater remedy may directly impact the vadose zone or vapor intrusion.

Table 5-1: Comparative Analysis of Alternatives

Remedial Alternative		Threshold Criteria		Effectiveness Scores			Implementability	Cost		**Effectiveness Total**	**Total Score**	**Effectiveness to Cost Quotients**
Identifier	Description	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness		Cost Score	Estimated Present Worth Range (-50% to + 100%) (in thousands of dollars)			
Groundwater Alternatives												
GW-1	No Action	No	No	0.0	0.0	0.0	5.0	5.0	$0 $0	0.0	10.0	 NA
GW-2	LTM/MNA	Yes	Yes	2.0	2.0	3.3	4.0	2.2	$1,217 $4,870	7.3	13.5	0.60 0.15
GW-3	ISCO (Chemical Oxidation)	Yes	Yes	4.0	4.0	2.5	3.0	0.0	$2,152 $8,608	10.5	13.5	0.49 0.12
GW-4	ERD (Substrate Addition)	Yes	Yes	3.5	3.0	3.3	3.0	1.0	$1,715 $6,858	9.8	13.8	0.57 0.14
GW-5	Air Sparging	Yes	Yes	2.5	2.0	2.5	2.0	0.8	$1,813 $7,252	7.0	9.8	0.39 0.10

Explanation of Scores:

0	Worst (Criterion not satisfied)	3	Average
1	Poor	4	Above Average
2	Below Average	5	Best (Criterion completely satisfied)

5.3.1. Threshold Criteria

5.3.1.1. Protection of Human Health and the Environment

Alternative GW-1 (No Action) is not expected to protect human health or the environment and received a score of "**no**" for this criterion.

The other four alternatives (GW-2 through GW-5) are expected to provide protection of human health and the environment. For all alternatives GW-2 through GW-5, continued operation of the SSD system will mitigate vapor intrusion risk, and ICs will be used as necessary to protect human health until groundwater RAOs are met. Although there are drinking water wells near the site, pumping tests and datalogger studies suggest minimal groundwater migration is occuring. There is no evidence that groundwater contamination will migrate to the drinking water wells under current conditions, and none of the alternatives are expected to increase plume migration. The monitoring component of all four alternatives GW-2 through GW-5 would be used to monitor any plume migration and thereby ensure protectiveness. Alternatives GW-2 through GW-5 received a score of "**yes**" for this criterion.

5.3.1.2. Compliance with Regulations

Alternative GW-1 (No Action) is not expected to meet ADEC Table C cleanup levels and received a score of "**no**" for this criterion.

Evaluating compliance with regulations for the other four alternatives required an assumption that an alternative point of compliance could be established downgradient of the source area. It is possible that none of the alternatives will be able to meet ADEC Table C cleanup levels throughout the site, depending on the amount of contamination held in the silt layer and the permeability of the silt layer, both of which have not yet been assessed.

All four alternatives GW-2 through GW-5 are expected to eventually meet ADEC Table C cleanup levels if a point of compliance were established downgradient of the source area and therefore received scores of "**yes**" for this criterion. Alternatives GW-3 (ISCO) and GW-4 (ERD) are considered to meet cleanup levels to the maximum extent practicable for the site and therefore are considered to be compliant with regulations. There is greater uncertainty to meet compliance with Alternatives GW-2 (MNA) and GW-5 (SVE); this uncertainty is reflected in lower balancing criteria scores discussed below.

5.3.2. Balancing Criteria

5.3.2.1. Long-Term Effectiveness

Alternative GW-1 (No Action) does not provide any groundwater treatment and is not expected to protect human health or the environment in the long-term and received a score of "0" for long-term effectiveness.

Alternatives GW-3 (ISCO) and GW-4 (ERD) are expected to treat most of the groundwater contaminated by TCE to below the ADEC Table C cleanup levels to the maximum extent practicable. For these alternatives, distribution of the oxidant (GW-3) and substrate (GW-4) in the low-permeability silt layer is considered the most difficult part of the remedy. To the degree that the oxidant and/or substrate can be distributed within the silt layer, both ISCO and ERD are considered effective remedies. For comparison purposes, the silt layer is expected to similarly affect alternatives GW-3 and GW-4. Alternative GW-3 is ranked the highest ("4") for long-term effectiveness, because there are no expected impediments to effective groundwater treatment using ISCO other than distribution concerns. The ERD alternative (GW-4) is ranked "3.5," because ERD requires activity from microbial communities whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. Both ISCO and ERD are considered permanent remedies that are effective in the long-term and not reversible.

The air sparge alternative (GW-5) received a score of "2.5" for long-term effectiveness. The effectiveness of air sparging is expected to be limited by the silt layer. In areas of the site where the silt layer is not present or not highly-competent, air sparging would be expected to be effective. However, even in highly-permeable soils, the sparged air tends to travel in preferential pathways, creating a challenge to complete groundwater treatment. Air sparging is not expected to be effective for addressing contamination within the silt layer, because the relatively high expected water saturation levels will create a barrier to air flow. Air sparging is considered a permanent remedy that is effective in the long-term and not reversible.

The MNA alternative (GW-2) received a score of "2" for long-term effectiveness. MNA is considered a permanent and effective remedy; however, the effectiveness of reductive dechlorination (the primary biological component of MNA for TCE) is dependent upon anaerobic groundwater conditions and the presence of a carbon source. The analytical evidence suggests that organic carbon content in the aquifer may be a limiting factor for effective and complete degradation of TCE to its non-toxic endpoint, ethene. Also, the analytical evidence suggests that aerobic groundwater conditions are present across most of the site, at least at high water levels. The uncertainty of this alternative is reflected in the long remedial timeframe (35 years) as well as the long-term effectiveness score of "2."

5.3.2.2. Reduction in Toxicity, Mobility, and Volume through Treatment

Alternative GW-1 (No Action) does not provide any treatment, so it received a score of "0" for reduction in toxicity, mobility, and volume through treatment.

The remaining alternatives are expected to treat most of the groundwater contaminated by TCE to below the ADEC Table C cleanup levels as described below.

- The ISCO alternative (GW-3) is ranked highest ("4") for reduction in toxicity, mobility, and volume through treatment, because it results in the immediate destruction of the contaminant where contacted.

- The ERD alternative (GW-4) is received a score of “3” for reduction in toxicity, mobility, and volume through treatment. It relies on activity from a microbial community whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. In addition, ERD creates toxic intermediate daughter products (i.e., vinyl chloride) whose presence is expected to be of limited duration but must be managed properly. ERD provides the carbon source that is necessary for the reductive dechlorination and therefore has a higher likelihood of effectively treating groundwater than MNA alone.
- The air sparge alternative (GW-5) received a score of “2,” because air sparging does not actually treat the TCE contamination but instead volatilizes it to air. In addition, there is uncertainty about whether the TCE volatilized below the silt layer can be effectively captured and removed from the site through SVE rather than simply readsorbing to the silt. Air sparging is not expected to be effective within the silt layer due to its high water saturation and resulting low permeability to air.
- The MNA alternative (GW-2) received a score of “2” for this criterion. MNA reduces toxicity, mobility, and volume of contamination; however, its effectiveness is dependent upon anaerobic groundwater conditions and the presence of a carbon source. The analytical evidence suggests that elevated oxygen and low organic carbon content in the aquifer may be limiting factors for effective and complete degradation of TCE to its non-toxic endpoint, ethene.

5.3.2.3. Short-Term Effectiveness

Alternative GW-1 (No Action) does not provide any treatment. Although the community, workers, and environment do not incur any added risks due to this remedy, there is an infinite time frame until remedy completion. Alternative GW-1 received a score of “0” for short-term effectiveness.

As discussed previously, the short-term effectiveness criterion contains two main components: protection of the community, workers, and environment during remedy implementation, and time until remedy completion. The ranking of alternatives for these two components is nearly opposite each other, resulting in similar overall short-term effectiveness scores. These components are discussed separately below with respect to Alternatives GW-2 through GW-5.

Regarding the first component (protection during remedy implementation), Alternative GW-2 (MNA/LTM) is the most protective, because it involves very little risk due to remedy construction. The only exposure to groundwater contamination would be from groundwater monitoring; this exposure can be readily mitigated by appropriate worker health and safety procedures. Added risks from implementation of Alternative GW-4 (ERD) result from handling of the substrate, although the substrate handling risks are considered minor, because it is not reactive. Alternative GW-5 (Air Sparging) volatilizes

TCE and daughter products that were previously dissolved in water, resulting in added vapor inhalation risks. This risk can be mitigated by capturing the volatilized chemicals through the SVE system; however, the silt layer increases the uncertainty of complete capture. Added risks to the community from Alternative GW-3 (ISCO) result from handling of the oxidant. The reactivity of the oxidant will pose increased risk to workers relative to the other alternatives, although the risk can be mitigated with appropriate health and safety procedures.

Regarding the second component (remedy time frame), Alternative GW-3 (ISCO) is superior to the other alternatives, because it offers the shortest time to remedy completion (ten years). Alternatives GW-4 (ERD) and GW-5 (air sparging) have equal times to remedy completion (20 years). The time frame for air sparging is expected to be lengthy, because treatment of contamination located in the silt and sand layers away from the preferential pathways for air flow is diffusion-limited. The lengthy time frame assumed for the ERD alternative is based on the need to establish and maintain reducing geochemical conditions and an active microbial community of reductive dechlorinators. Also, the cold groundwater temperatures are expected to lengthen treatment time relative to treatment in warmer temperatures. The time frame until remedy completion using MNA (GW-2) is uncertain and likely to take many years; a remediation timeframe of 35 years was assumed.

Based on the two components of short-term effectiveness, the overall short-term effectiveness scores for Alternatives GW-2 and GW-4 are “3.3,” whereas the overall short-term effectiveness for the other alternatives is “2.5.”

5.3.2.4. Implementability

There are no technical or administrative barriers to implementation of Alternative GW-1 (No Action). Alternative GW-1 received the maximum score of “5” for this criterion.

Alternative GW-2 (MNA) received an implementability score of “4.” There are no significant barriers to implementing MNA at this site, but groundwater sampling and analysis is required. Alternatives GW-3 and GW-4 both received scores of “3” for this criterion, because they involve similar implementation tasks such as drilling, plumbing, monitoring, and logistics. Alternative GW-5 received an implementatbility score of “2,” because of expected implementability difficulties associated with the silt layer. If the silt layer is higly competent and continuous across the site, then air sparging would be considered to be poorly implementable and earn a score of “1;” however, the competency and extent of the silt layer is unknown. Alternatives GW-3, GW-4, and GW-5 all involve obtaining property owner consent and drilling multiple injection or extraction wells at this site.

5.3.2.5. Cost

The relative cost scores of the three groundwater alternatives are presented in Table 5-1, and detailed cost spreadsheets are presented in Appendix C.

There are no costs associated with Alternative GW-1; therefore, it received the maximum normalized score of "5" for the cost criterion. Alternative GW-3 (ISCO) was the most expensive alternative ($2,200,000 to $8,600,000); therefore, it received the minimum normalized score of "0" for this criterion. Excluding the No Action Alternative, Alternative GW-2 (MNA/LTM) was the least expensive ($1,200,000 to $4,900,000) and received a cost score of "2.2." Alternatives GW-4 (ERD) ($1,700,000 to $6,900,000) and GW-5 (Air Sparge) ($1,800,000 to $7,300,000) received cost scores of "1.0" and "0.8," respectively.

5.4. Preferred Alternative

In addition to the individual criteria scores discussed above, there are three comparison tools presented in Table 5-1 that may be used to help select the preferred alternative: the total effectiveness score, the total score, and the effectiveness to cost ratio. The total effectiveness score reflects the expected overall effectiveness of the alternative; the alternative with the highest score is expected to be the most effective, without regard for implementability and cost. The total score includes cost and implementability considerations along with effectiveness. Therefore, an alternative that is very expensive and/or difficult to implement will have a lower total score compared to an alternative that is less expensive and/or easier to implement. The effectiveness to cost ratio is a measure of the cost-effectiveness of the remedy; a high effectiveness to cost ratio implies a cost-effective remedy.

Results for the Aniak WACS groundwater alternatives are summarized below.

- Alternative GW-3 (ISCO) received the highest effectiveness score, "10.5." The second-highest effectiveness score was ERD with "9.8," followed by MNA at 7.3 and Air Sparging at 7.0.
- Alternative GW-4 (ERD) received the highest total score, "13.8." The second-highest total scores were Alternatives GW-2 (MNA) and GW-3 (ISCO) with "13.5." Air Sparging has the lowest total score of 9.8, which interestingly was even lower than Alternative GW-1 (No Action).
- For each alternative, effectiveness to cost quotients were calculated for both the low-end and high-end of the cost range. The low-end quotients are used in the comparison discussion in this paragraph. Alternative GW-2 (MNA) and Alternative GW-4 (ERD) received the highest effectiveness to cost ratios, "0.60" and "0.57," respectively. ISCO has an effectiveness to cost ratio of "0.49," and Air Sparging has the lowest effectiveness to cost ratio of "0.39."

Selection of a preferred alternative depends on the relative importance of the variables. GW-2 (MNA) and GW-4 (ERD) are the most cost-effective alternatives; ERD has a higher effectiveness than MNA, but the increased effectiveness is offset by its higher cost. If achieving cleanup in the shortest time is the most important factor, then Alternative GW-3 (ISCO) is preferred, although it is also the most expensive alternative. ISCO is expensive primarily because most of the oxidant will be used to treat the natural oxidant demand in the soil and groundwater (i.e., 72,840 kg $KMnO_4$ versus 8 kg $KMnO_4$

to treat the contamination). Air sparging has the lowest total score and effectiveness to cost quotient and is least likely to be considered the preferred alternative.

To evaluate the relative merits of MNA versus ERD (the two most cost-effective alternatives) at this site, a decision flowchart from the Interstate Technology Regulatory Council (ITRC) (ITRC, 2007) was used. The decision flowchart presents three criteria for consideration. These three criteria are listed below, with an interpretation of how the Aniak WACS site meets them.

1. Source and/or Primary Plume Treatment;

   The current understanding of the groundwater contamination at the Aniak WACS site suggests a plume of low-to-moderate concentrations that has not migrated significantly. Based on the plume geometry, there has been no distinct source and/or primary plume area identified in the saturated zone. The highest TCE concentration detected is 0.19 mg/L (almost four orders of magnitude below the solubility limit of 1,100 mg/L). It is possible that the mass of TCE released at the site is relatively small and mostly in the vadose zone; however, the site has not been adequately characterized to definitively state this.

2. Evaluate Plume Stability;

   a. Are the risks acceptable?
   b. Is the plume stable or shrinking?
   c. Are conditions sustainable?
   d. Is the remediation timeframe acceptable?
   e. Are the cost-benefits acceptable?

   The groundwater monitoring performed to-date is insufficient to definitively answer the five questions on plume stability. However, a preliminary analysis based on existing monitoring data suggests that the plume is stable or shrinking (i.e., no evidence of plume expansion). The risks due to drinking water appear to be acceptable, because there is no evidence of plume migration toward the existing drinking water wells. Risks due to vapor intrusion into the Aniak Middle School Building are not acceptable without vapor mitigation (i.e., SSD system), although the relative contribution of groundwater versus vadose zone contamination to the vapor intrusion pathway has not been determined. The sustainability of biodegradation over the expected life of the plume is something that cannot yet be determined. Current data suggest that there is an insufficient carbon source for significant reductive dechlorination plume-wide; however, the apparent plume stability suggests that attenuation mechanisms are acting to limit plume size. The acceptability of the remediation timeframe and cost-benefit analysis must be determined by the responsible parties and regulators.

3. Evaluate Enhancement Options.

Enhancement options (i.e., ERD) may be considered if the plume stability criteria are not met or as a contingency if future monitoring suggests that MNA is not progressing adequately.

Overall, it appears that additional plume characterization and implementation of the soil remedies would be beneficial before selecting a groundwater remedy. Additional plume characterization activities should include installing soil borings and monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. During the PCB soil excavation in the vicinity of the former septic tank and truck fill, soil samples should also be analyzed for TCE. If high TCE concentrations are detected in the silt at the base of the PCB excavation, direct treatment using a reductant (or possibly an oxidant) during the PCB soil excavation may be a very beneficial and cost-effective remediation strategy. Alternatively, depending on the location, magnitude, and extent of the TCE contamination and silt characteristics, installation of an engineered solution, such as placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically, may be warranted. Sampling details and a decision protocol should be incorporated into the excavation work plan.

Based on existing data, Alternative 2 (MNA) with Alternative 4 (ERD) as a contingency may be considered preferred. MNA would be expected to perform satisfactorily at this site if the following conditions (based on future characterization and planned soil remediation efforts to address the three ITRC criteria) are met.

1. Additional site characterization confirms that there is no distinct source/primary plume in the saturated zone. There is no evidence of free-phase or residual-phase TCE, and maximum groundwater concentrations remain three-to-four orders of magnitude below the solubility limit. The groundwater plume configuration is generally as outlined in this FS.
2. Additional groundwater monitoring supports the conclusion that the plume is stable.
    a. The groundwater plume is stable or shrinking, and there is no risk to the nearby drinking water wells. An alternative point of compliance can be established downgradient of the source area.
    b. The PCB soil excavation and SVE adequately address vapor intrusion risk (i.e., most of the contaminant mass is found in the vadose zone). Although volatilization from the silt layer/saturated interval below the silt layer may provide a continuing source for soil gas contamination, the level of continued volatilization is currently unknown and may be minor,

especially if the upper portion of the silt layer is directly treated during the PCB soil excavation.

c. Future VOC and geochemical parameter sampling indicates that there are zones or areas of highly-reducing groundwater in which reductive dechlorination of TCE is occurring at sustainable rates to adequately remediate the contamination over time

d. This alternative is deemed acceptable to ADEC and all of the interested parties.

3. If the above criteria are not completely satisfied, then it may be advantageous to implement ERD in a phased approach.

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FIGURES

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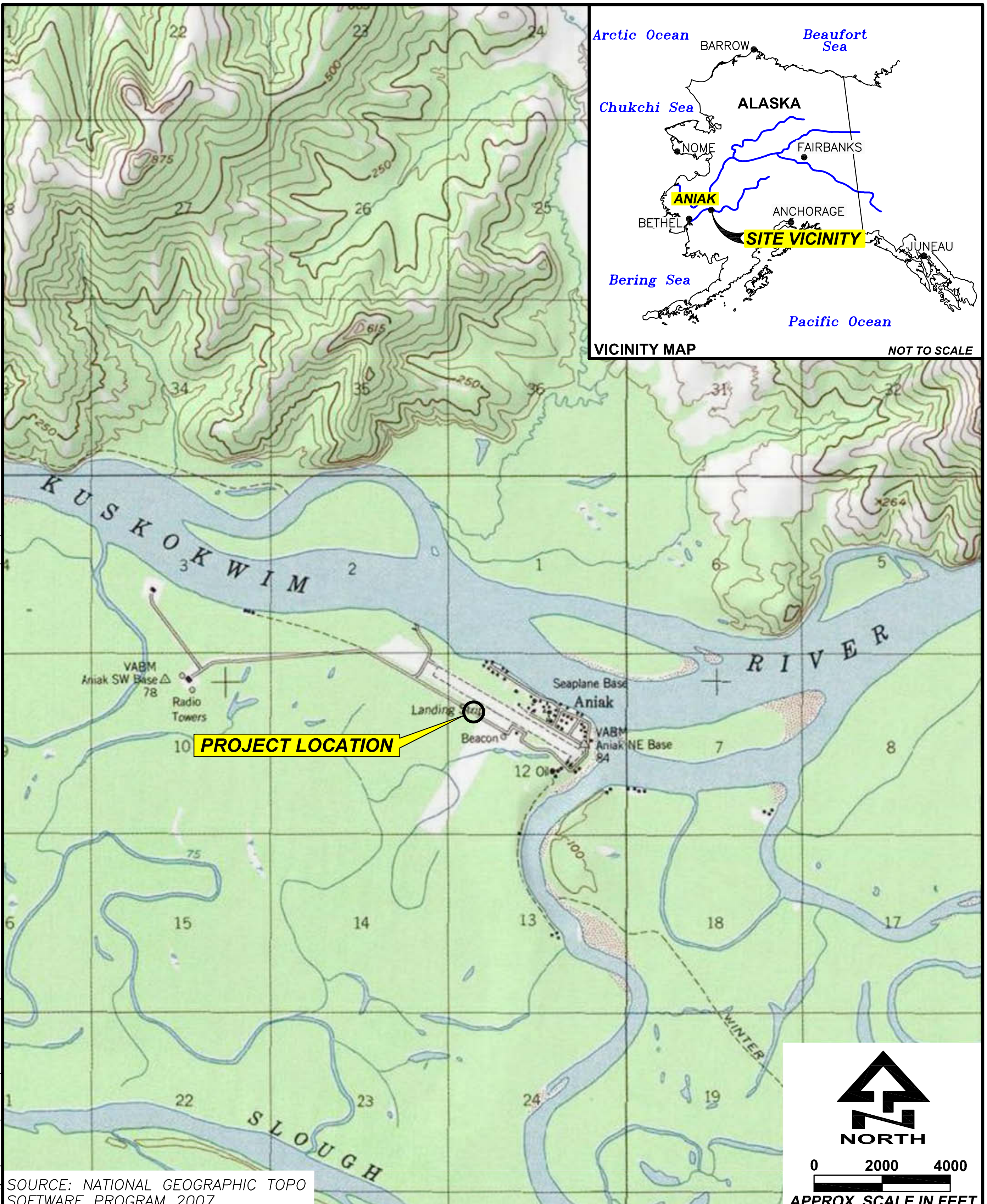

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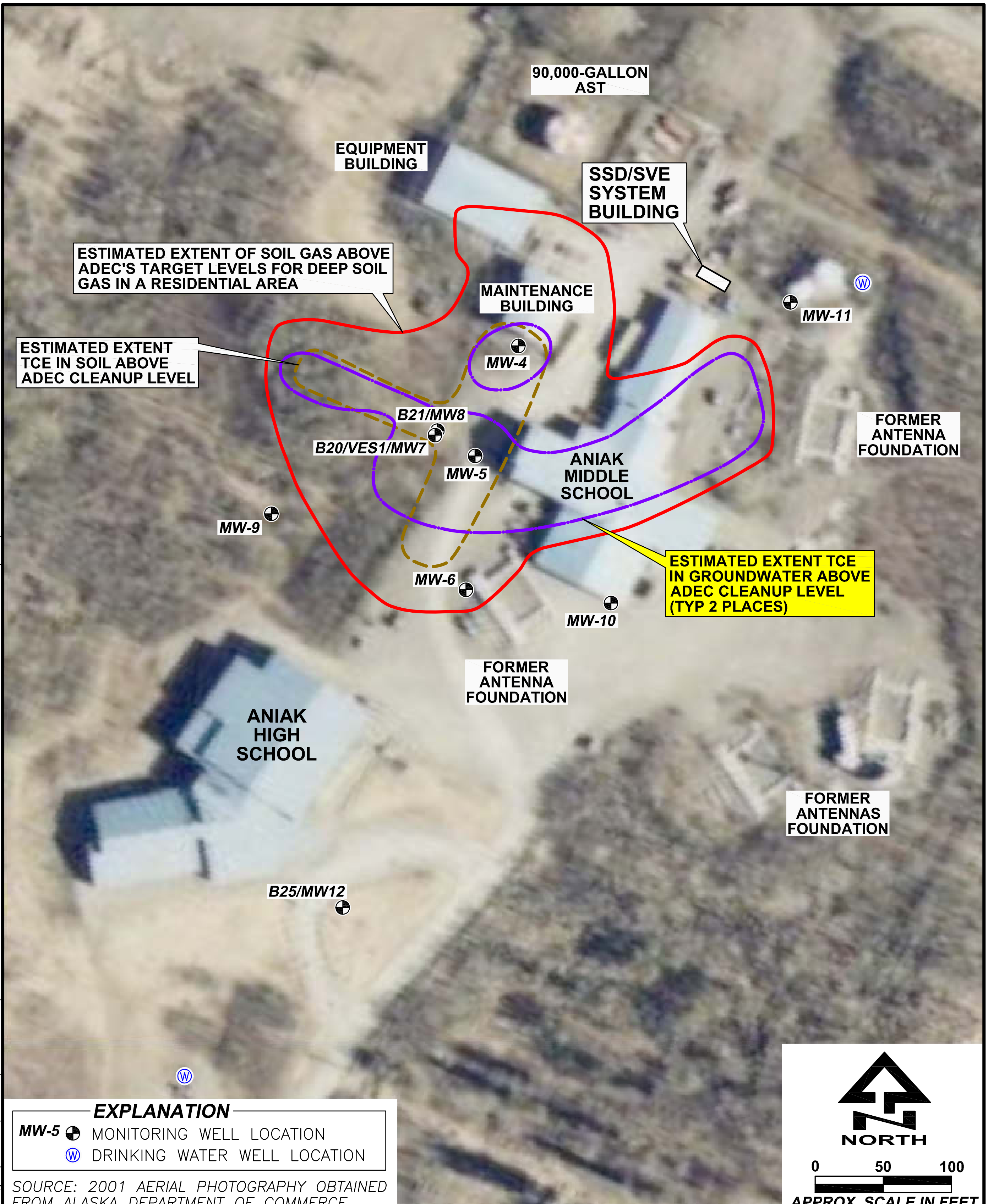
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

SITE LOCATION MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE 1



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SITE PLAN

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE 2

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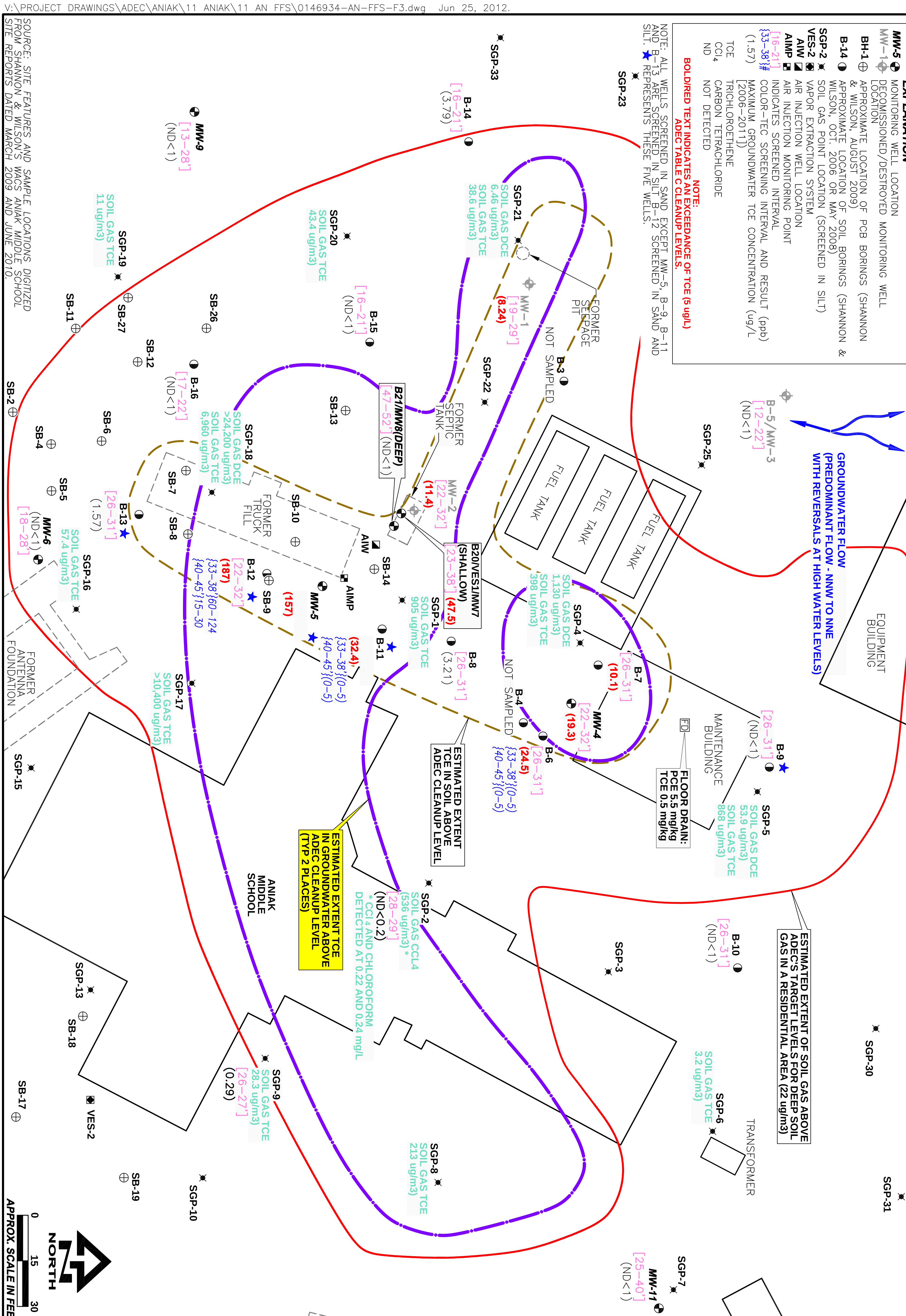

oasis ENVIRONMENTAL	DATE: FEB. 2012 CHKD: J.H.P. DRAWN: D.R.F. PROJ. No.: 0146934 825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880	**GROUNDWATER TCE PLUME** ANIAK MIDDLE SCHOOL/WHITE ALICE SITE FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION Aniak, Alaska	FIGURE 3

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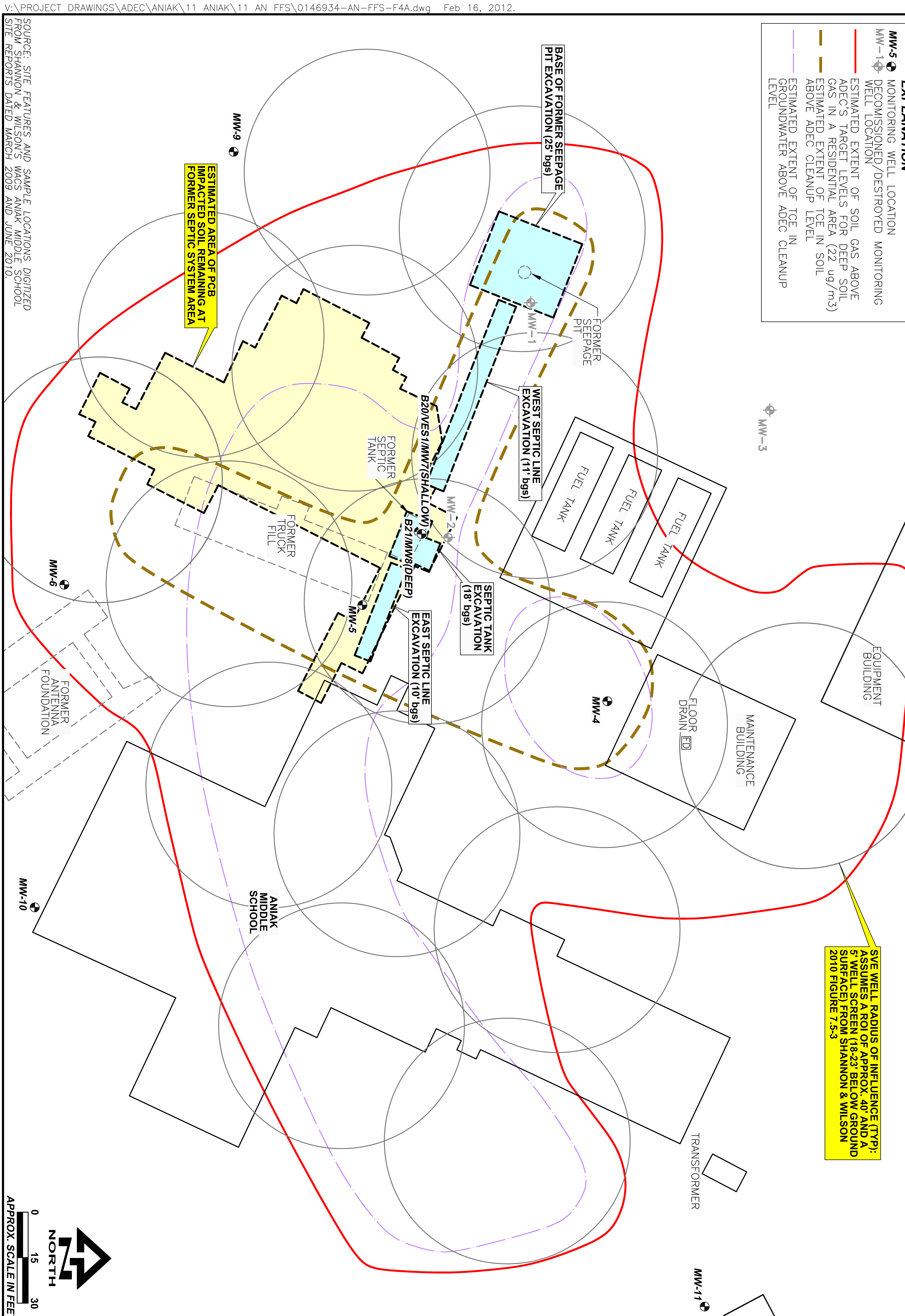

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PLANNED SOIL REMEDIATION ACTIVITY AREAS

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
4A

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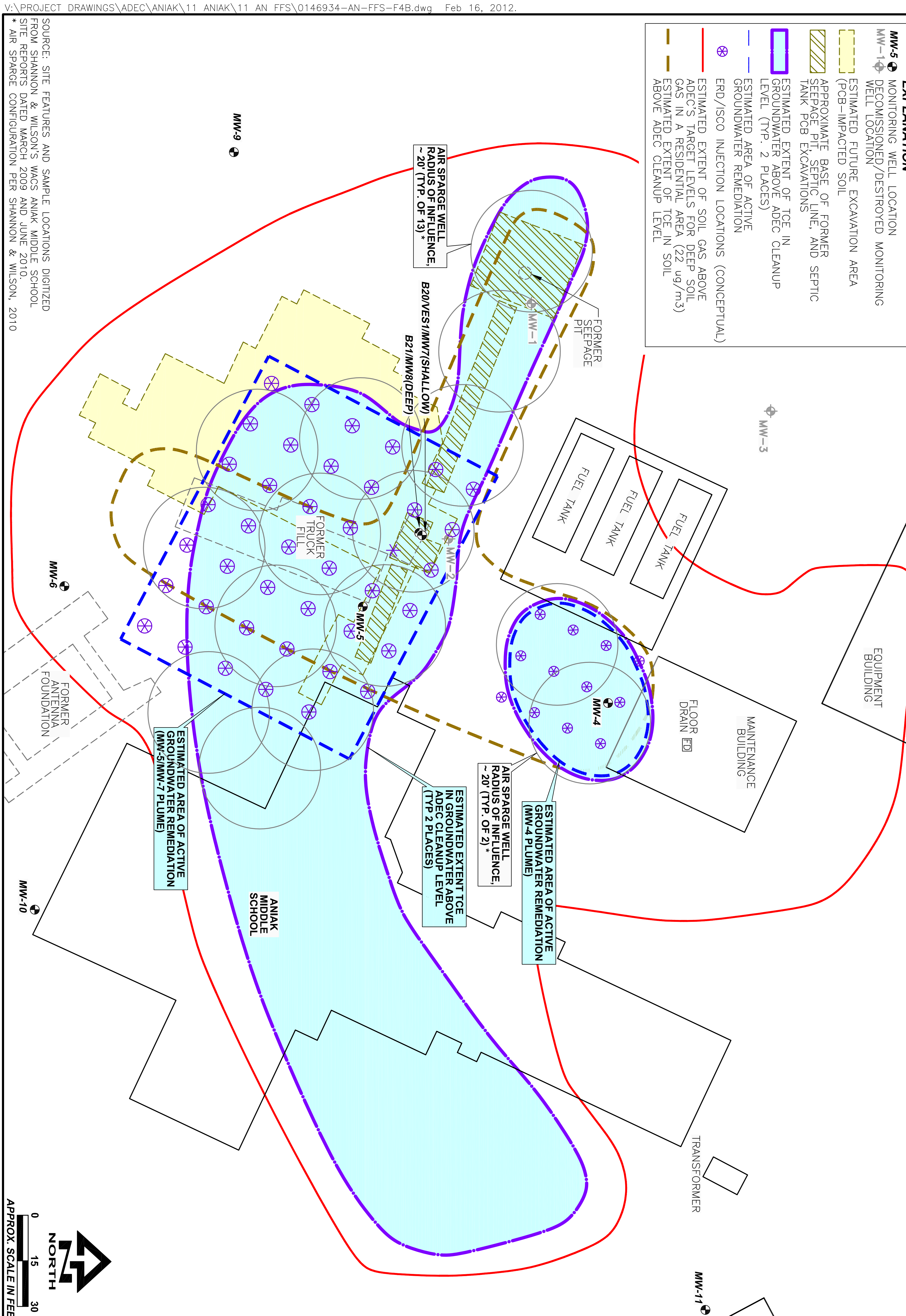

oasis ENVIRONMENTAL DATE: FEB. 2012 CHKD: J.H.P. DRAWN: D.R.F. PROJ. No.: 0146934 825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880	**GROUNDWATER REMEDIAL ALTERNATIVES** ANIAK MIDDLE SCHOOL/WHITE ALICE SITE FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION Aniak, Alaska	FIGURE **4B**

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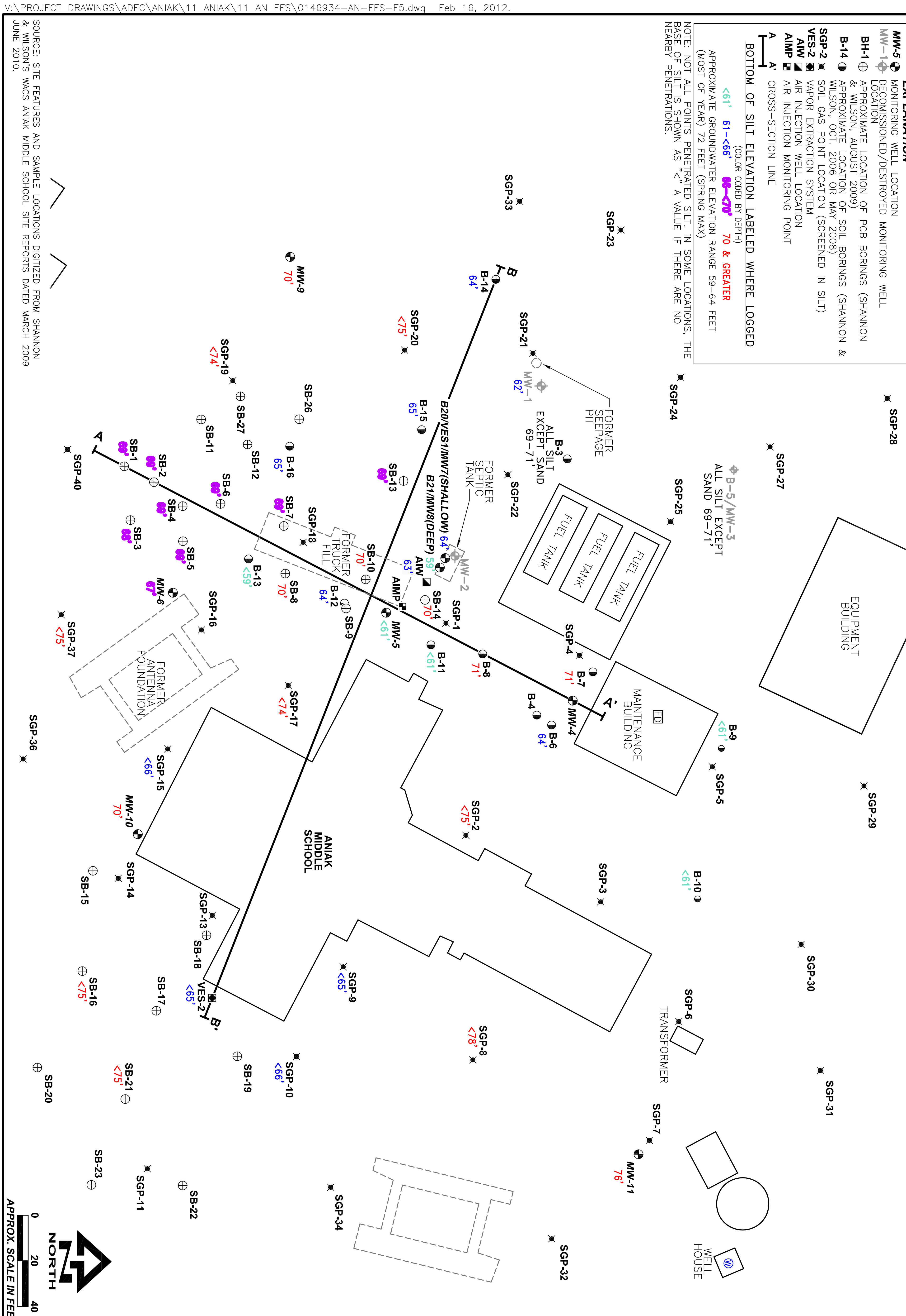

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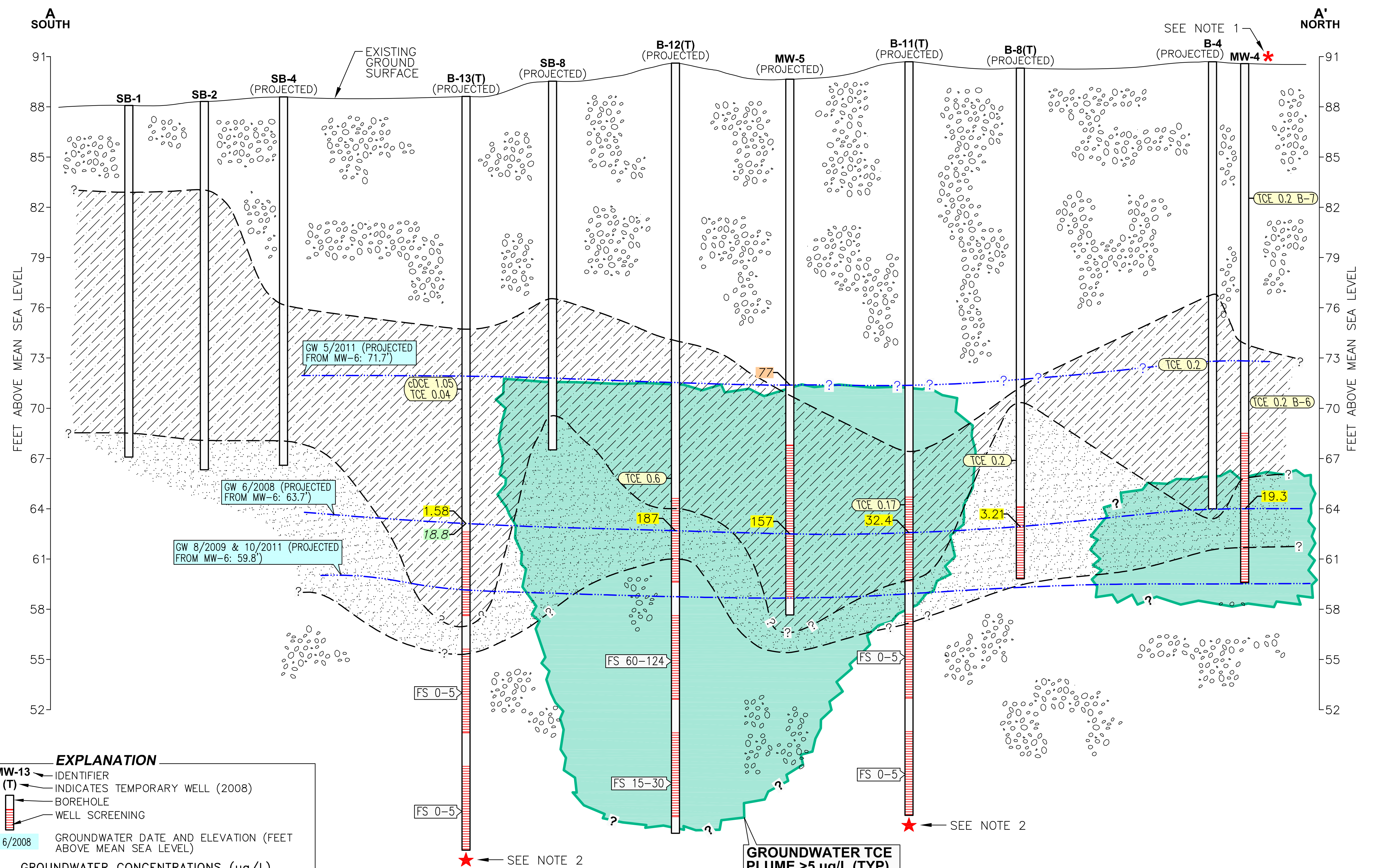
BASE OF SILT ELEVATION

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
5



EXPLANATION

- MW-13 — IDENTIFIER
- (T) — INDICATES TEMPORARY WELL (2008)
- BOREHOLE
- WELL SCREENING
- GW 6/2008 — GROUNDWATER DATE AND ELEVATION (FEET ABOVE MEAN SEA LEVEL)

GROUNDWATER CONCENTRATIONS (ug/L)
(SHOWN AT WATER LEVEL AT TIME OF SAMPLING (APPROX.)

- 1.58 — 2008 TRICHLOROETHENE (TCE)
- 77 — 2011 TRICHLOROETHENE (TCE)
- 18.8 — 2008 cis-1,2-DICHLOROETHENE (cDCE)

SOIL CONCENTRATIONS

- FS 0-5 — FIELD SCREENING RESULTS (ppm)
- TCE 0.17 — SOIL SAMPLE RESULTS (mg/kg)

NOTE: MUST BE PRINTED IN COLOR.

SOIL TYPES

- GRAVEL
- SILT
- SAND

NOTES:

1. MW-04 AND MW-5 LOGGED 25-31' BELOW GROUND SURFACE. TOP OF SILT INTERPRETED FROM NEARBY BORINGS.
2. B-11 AND B-13 WERE LOGGED TO 30-FOOT BELOW GROUND SURFACE. LITHOLOGY BELOW LOGGED INTERVAL IS NOT KNOWN. BOTTOM OF SAND EXTRAPOLATED FROM B-12.

HORIZONTAL SCALE: 1"-20'
VERTICAL SCALE: 1" -6'
EXAGGERATION 3.33X
1 INCH

FIGURE 6

CROSS SECTION A-A'

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

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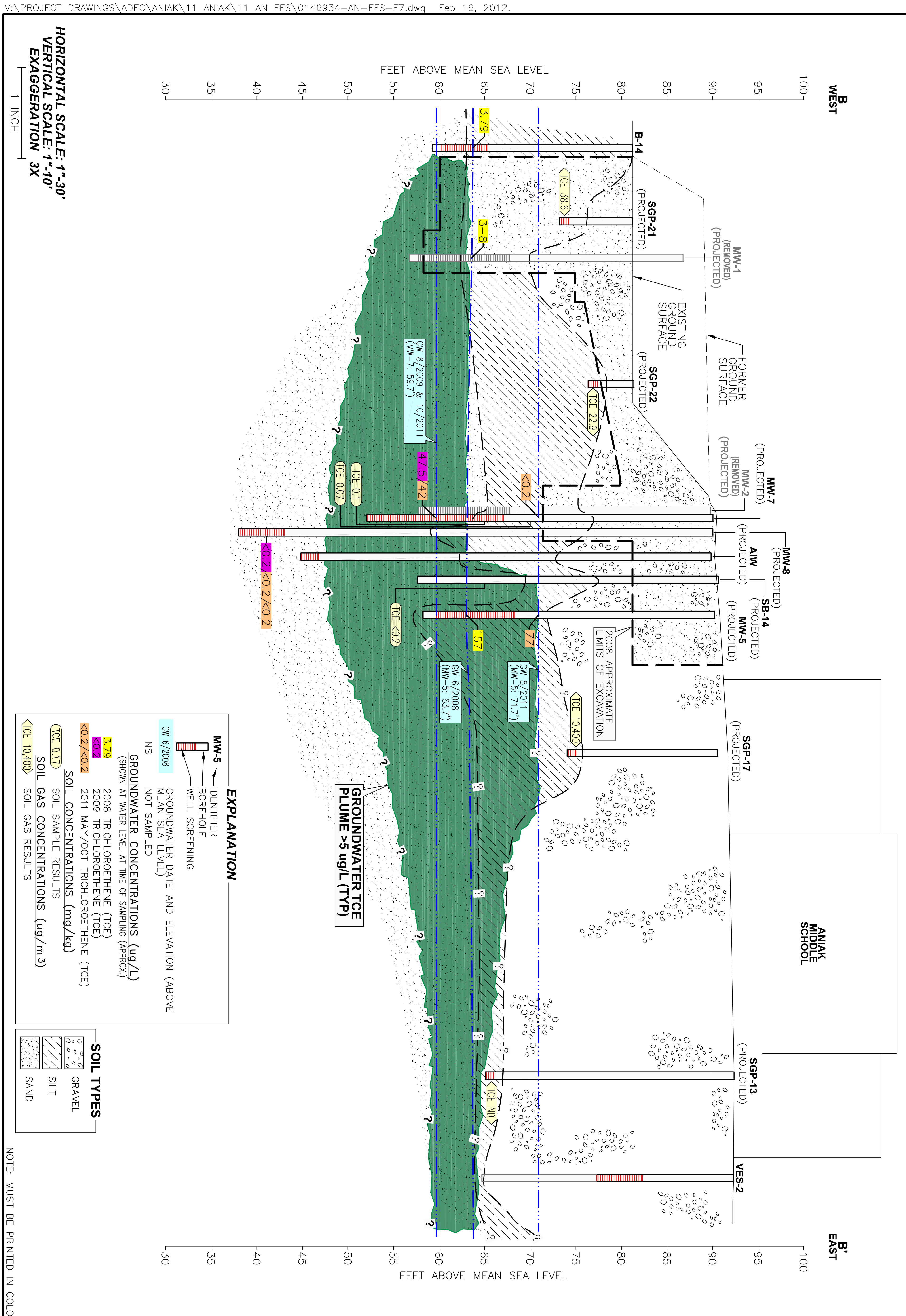

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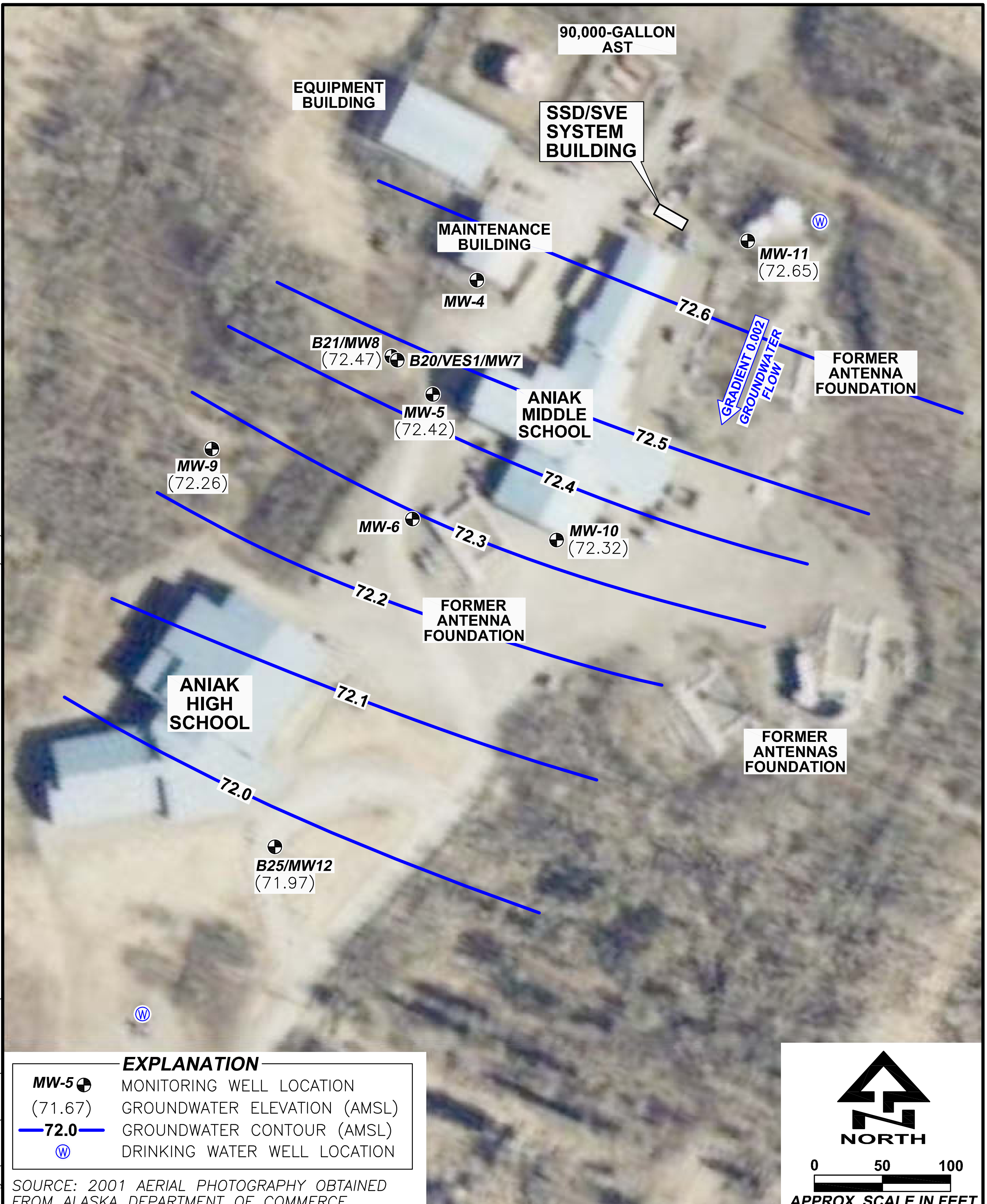
CROSS SECTION B-B'

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
7



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MAY 14, 2011
POTENTIOMETRIC SURFACE MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
8

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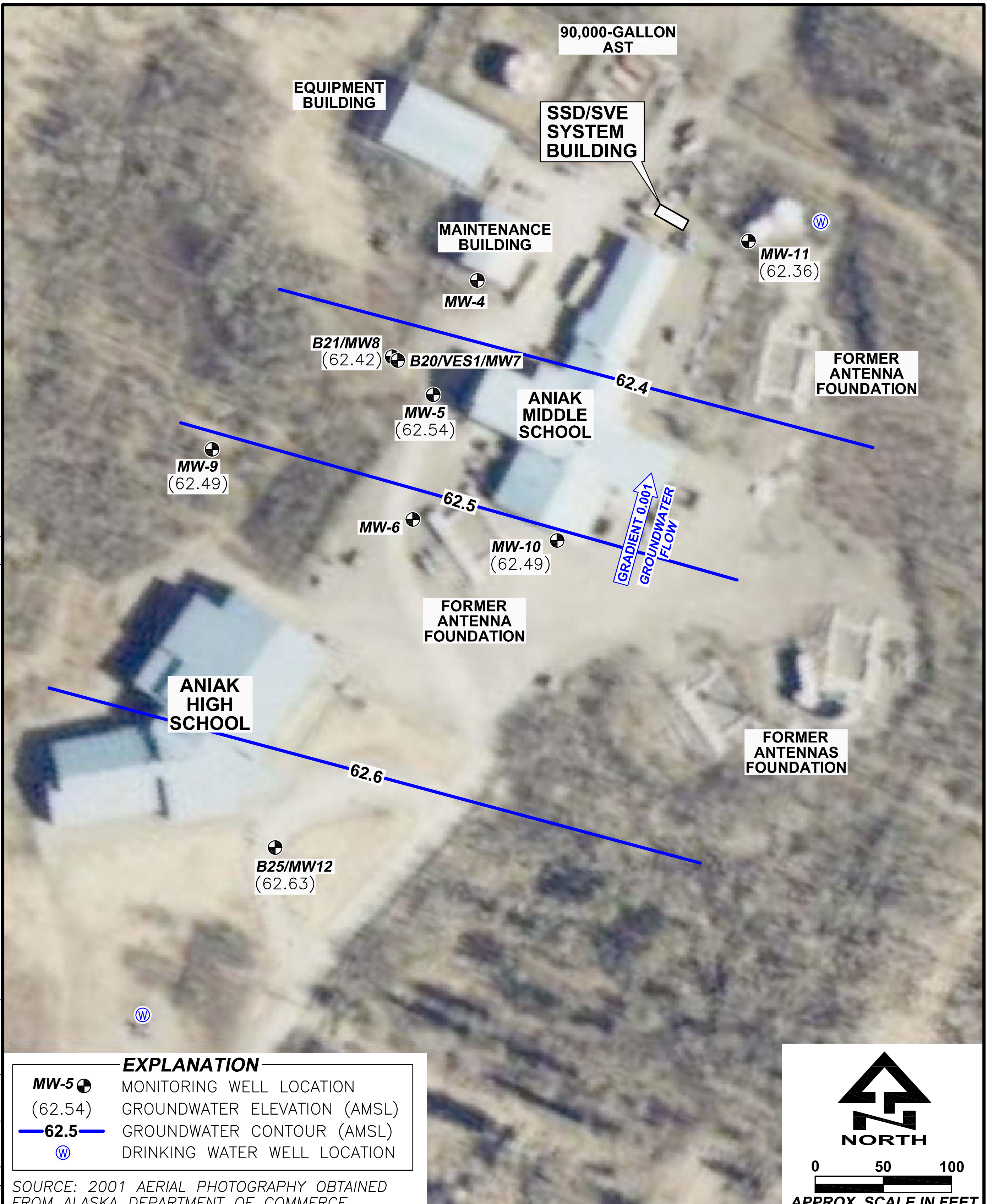

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JUNE 12, 2011
POTENTIOMETRIC SURFACE MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
9

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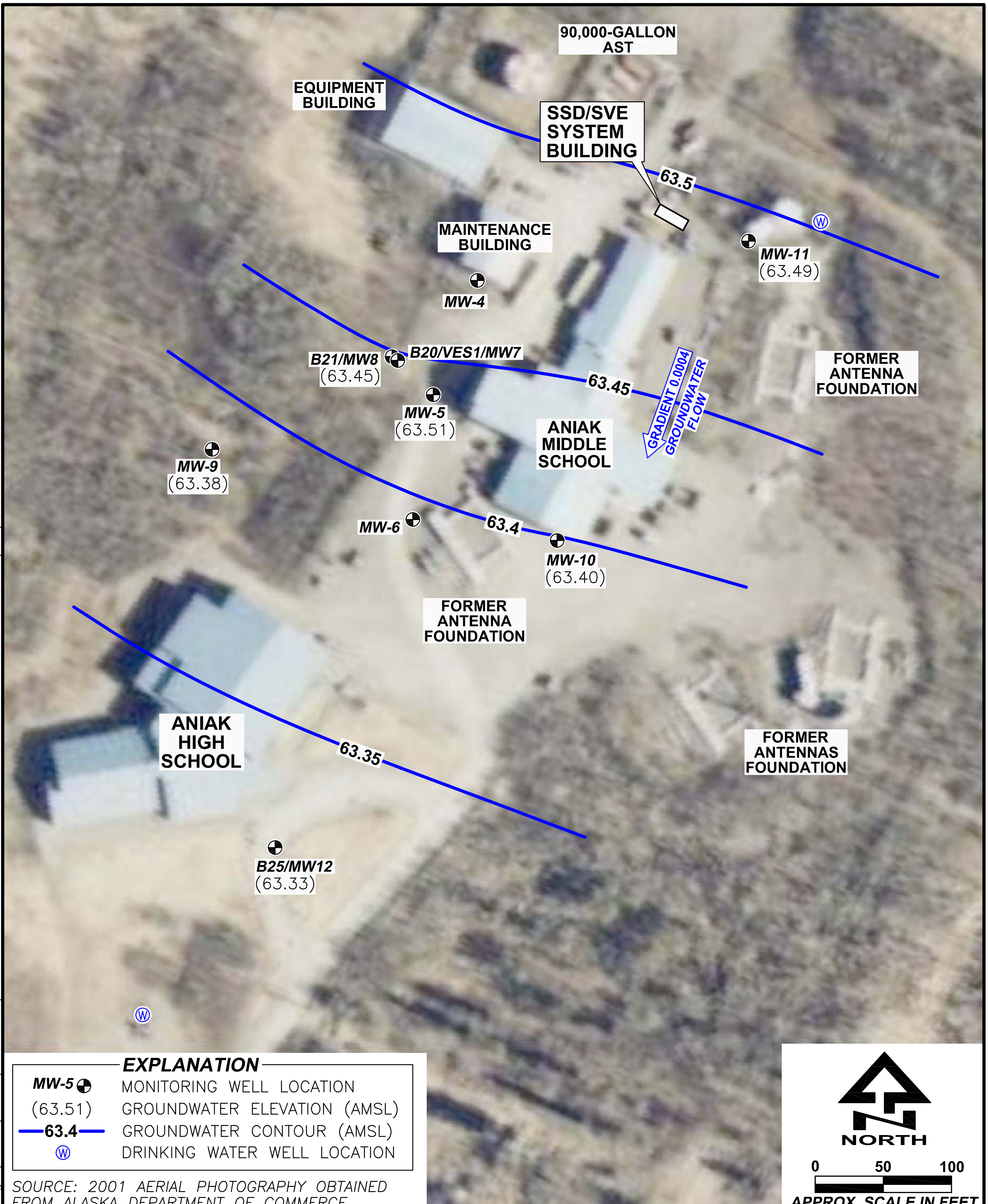

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DRAWN: C.E.H.
PROJ. No.: 14-201

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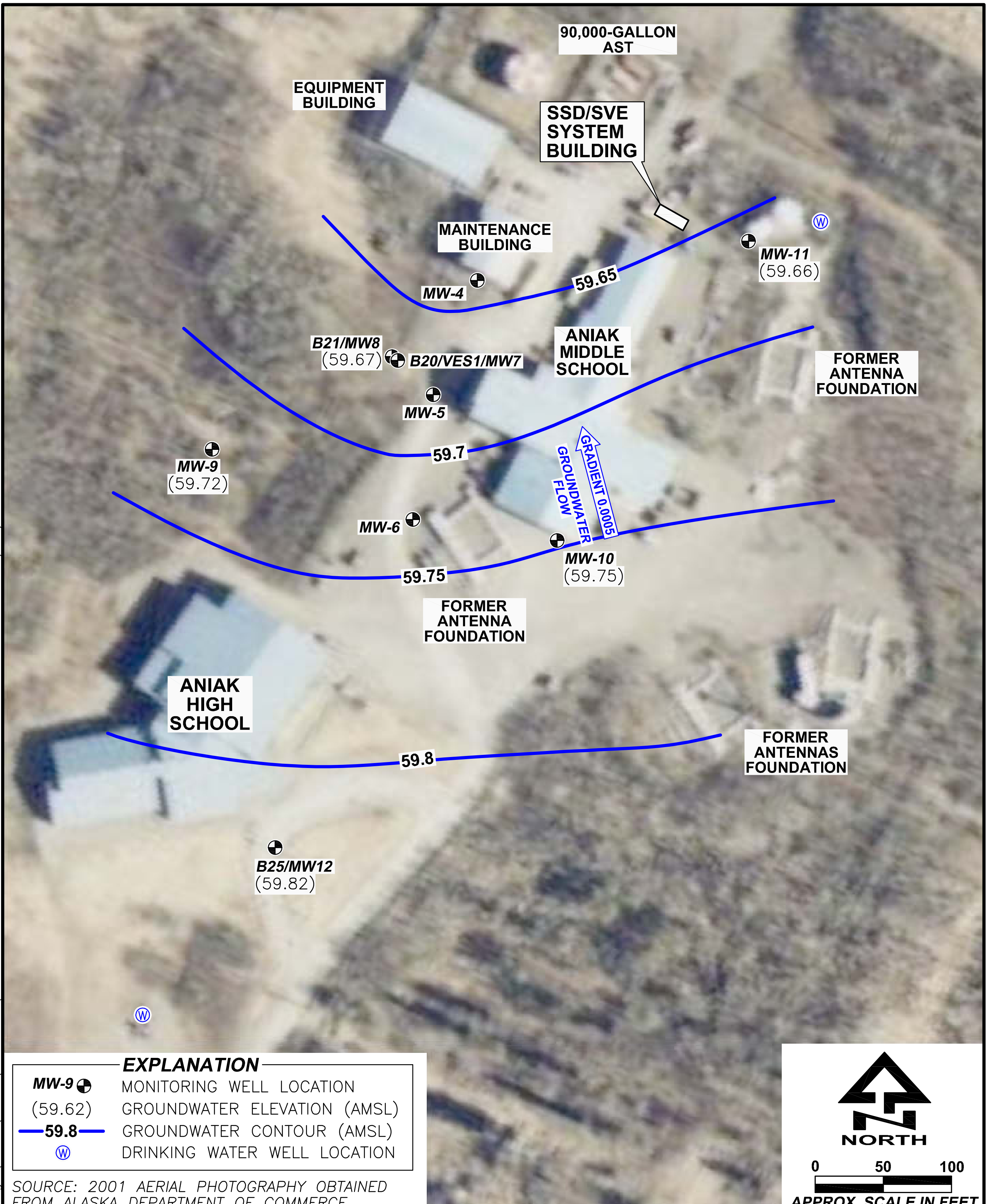
AUGUST 20, 2011 POTENTIOMETRIC SURFACE MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE 10



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PROJ. No.: 14-201

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OCTOBER 16, 2011 POTENTIOMETRIC SURFACE MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE 11

APPENDIX A

Hydrologic (Datalogger) Analysis

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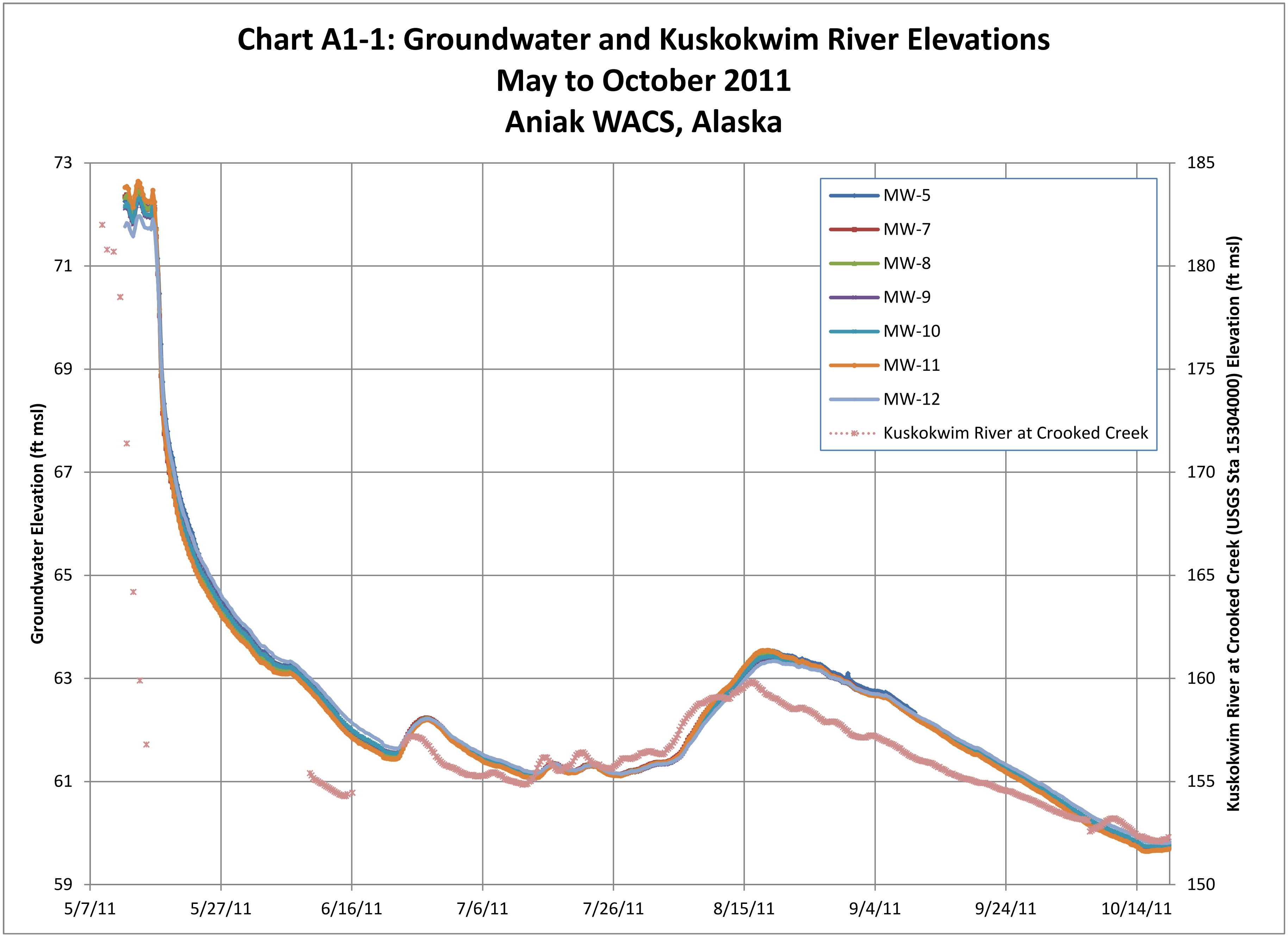


Chart A1-1: Groundwater and Kuskokwim River Elevations
May to October 2011
Aniak WACS, Alaska
73
71
69
67
65
63
61
59
185
180
175
170
165
160
155
150
5/7/11
5/27/11
6/16/11
7/6/11
7/26/11
8/15/11
9/4/11
9/24/11
10/14/11
Groundwater Elevation (ft msl)
Kuskokwim River at Crooked Creek (USGS Sta 15304000) Elevation (ft msl)
MW-5
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
Kuskokwim River at Crooked Creek

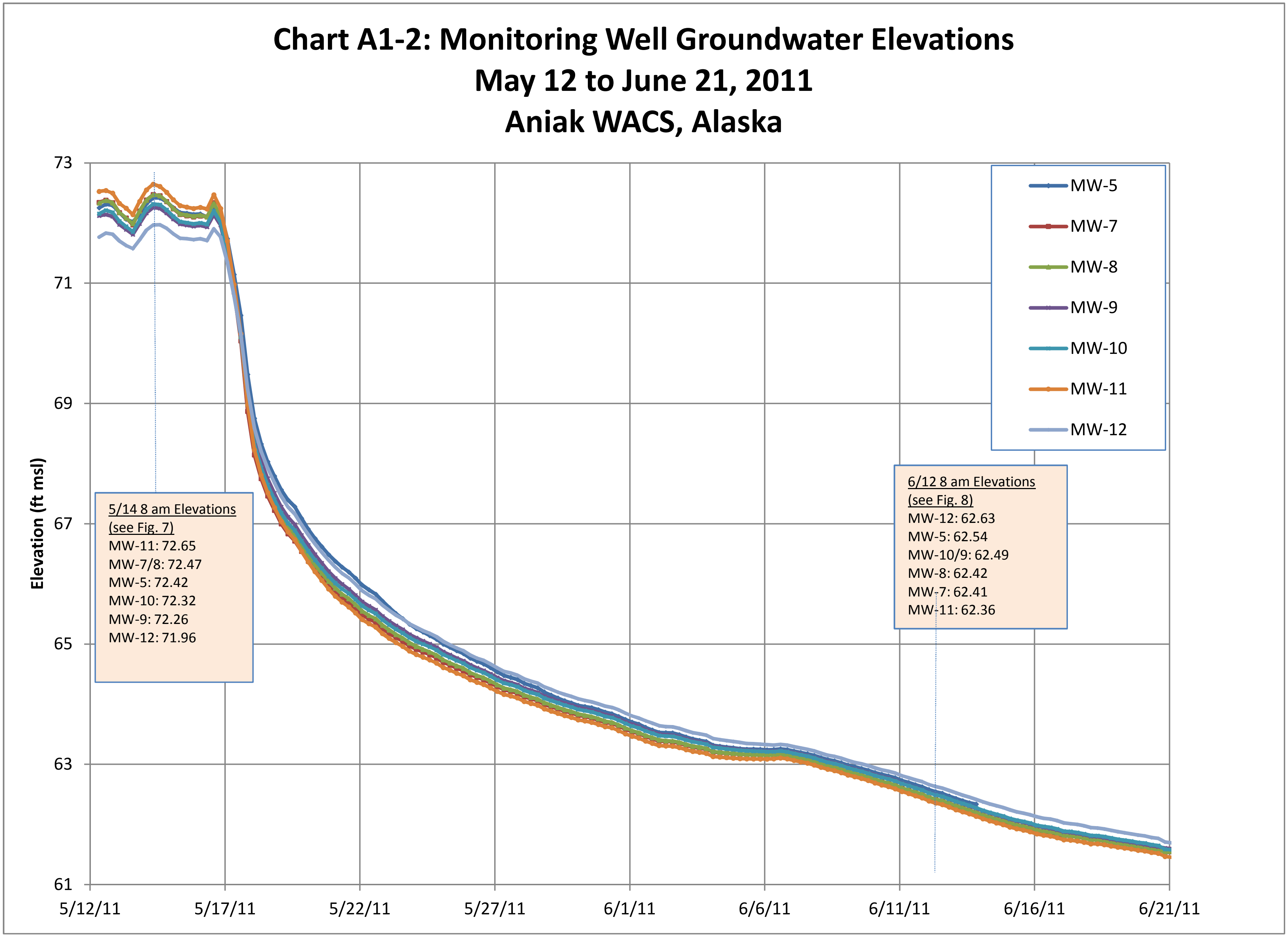


Chart A1-2: Monitoring Well Groundwater Elevations
May 12 to June 21, 2011
Aniak WACS, Alaska
Elevation (ft msl)
73
71
69
67
65
63
61
5/12/11
5/17/11
5/22/11
5/27/11
6/1/11
6/6/11
6/11/11
6/16/11
6/21/11
MW-5
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
5/14 8 am Elevations
(see Fig. 7)
MW-11: 72.65
MW-7/8: 72.47
MW-5: 72.42
MW-10: 72.32
MW-9: 72.26
MW-12: 71.96
6/12 8 am Elevations
(see Fig. 8)
MW-12: 62.63
MW-5: 62.54
MW-10/9: 62.49
MW-8: 62.42
MW-7: 62.41
MW-11: 62.36

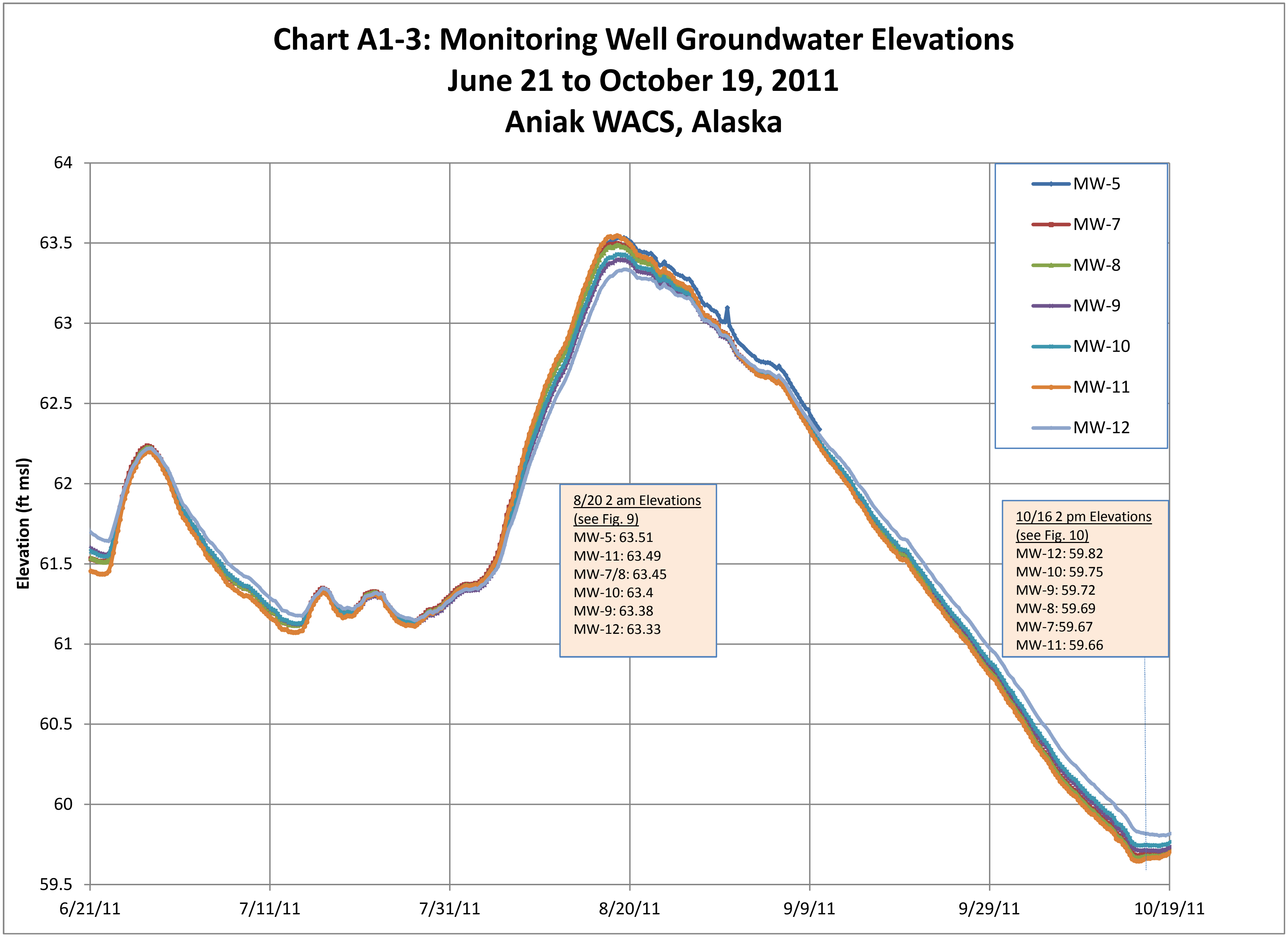


Chart A1-3: Monitoring Well Groundwater Elevations
June 21 to October 19, 2011
Aniak WACS, Alaska
Elevation (ft msl)
64
63.5
63
62.5
62
61.5
61
60.5
60
59.5
6/21/11
7/11/11
7/31/11
8/20/11
9/9/11
9/29/11
10/19/11
MW-5
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
8/20 2 am Elevations
(see Fig. 9)
MW-5: 63.51
MW-11: 63.49
MW-7/8: 63.45
MW-10: 63.4
MW-9: 63.38
MW-12: 63.33
10/16 2 pm Elevations
(see Fig. 10)
MW-12: 59.82
MW-10: 59.75
MW-9: 59.72
MW-8: 59.69
MW-7:59.67
MW-11: 59.66

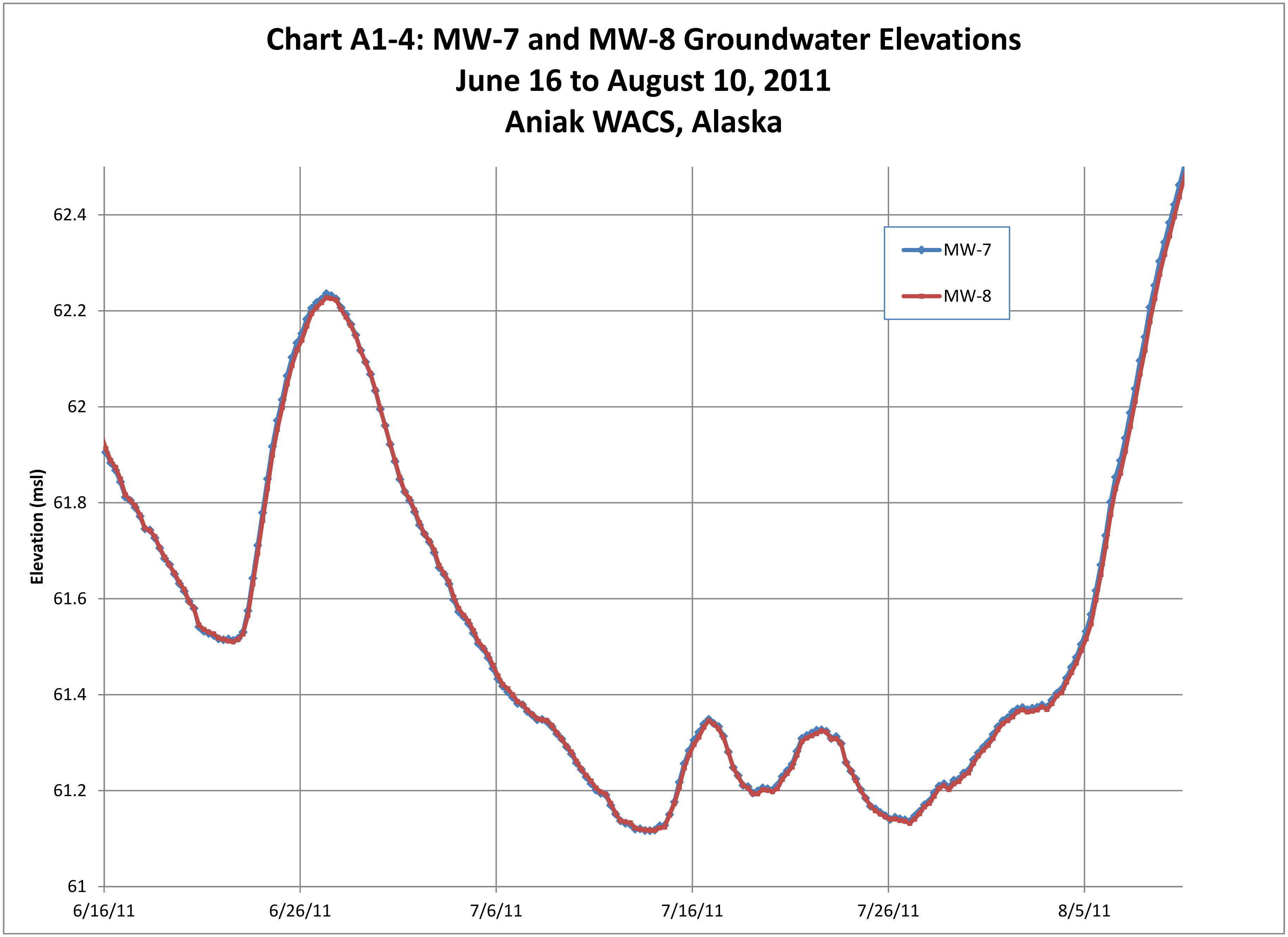
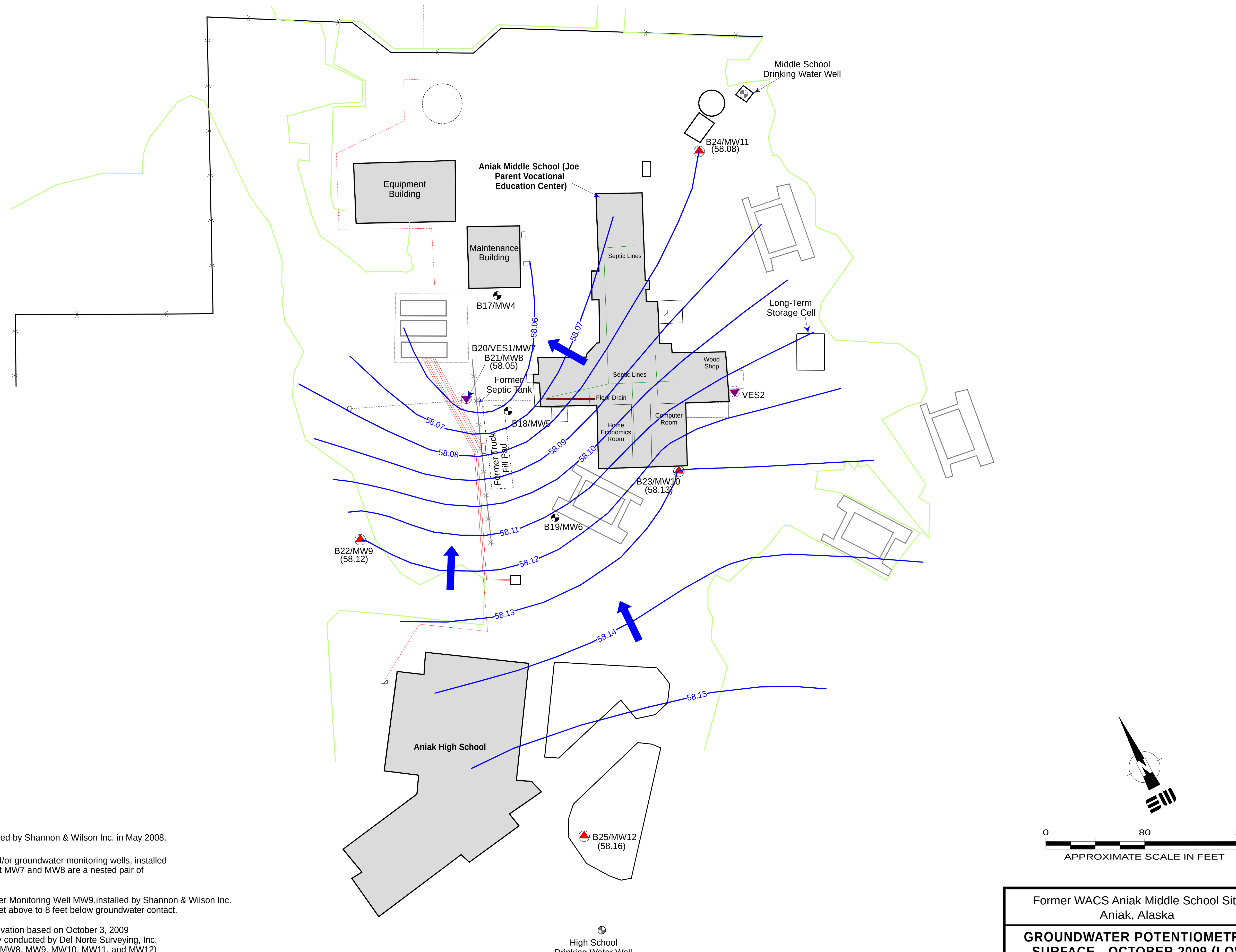


Chart A1-4: MW-7 and MW-8 Groundwater Elevations
June 16 to August 10, 2011
Aniak WACS, Alaska
Elevation (msl)
62.4
62.2
62
61.8
61.6
61.4
61.2
61
6/16/11
6/26/11
7/6/11
7/16/11
7/26/11
8/5/11
MW-7
MW-8



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7 B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

58.15 — Groundwater potentiometric surface contour and elevation based on October 3, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

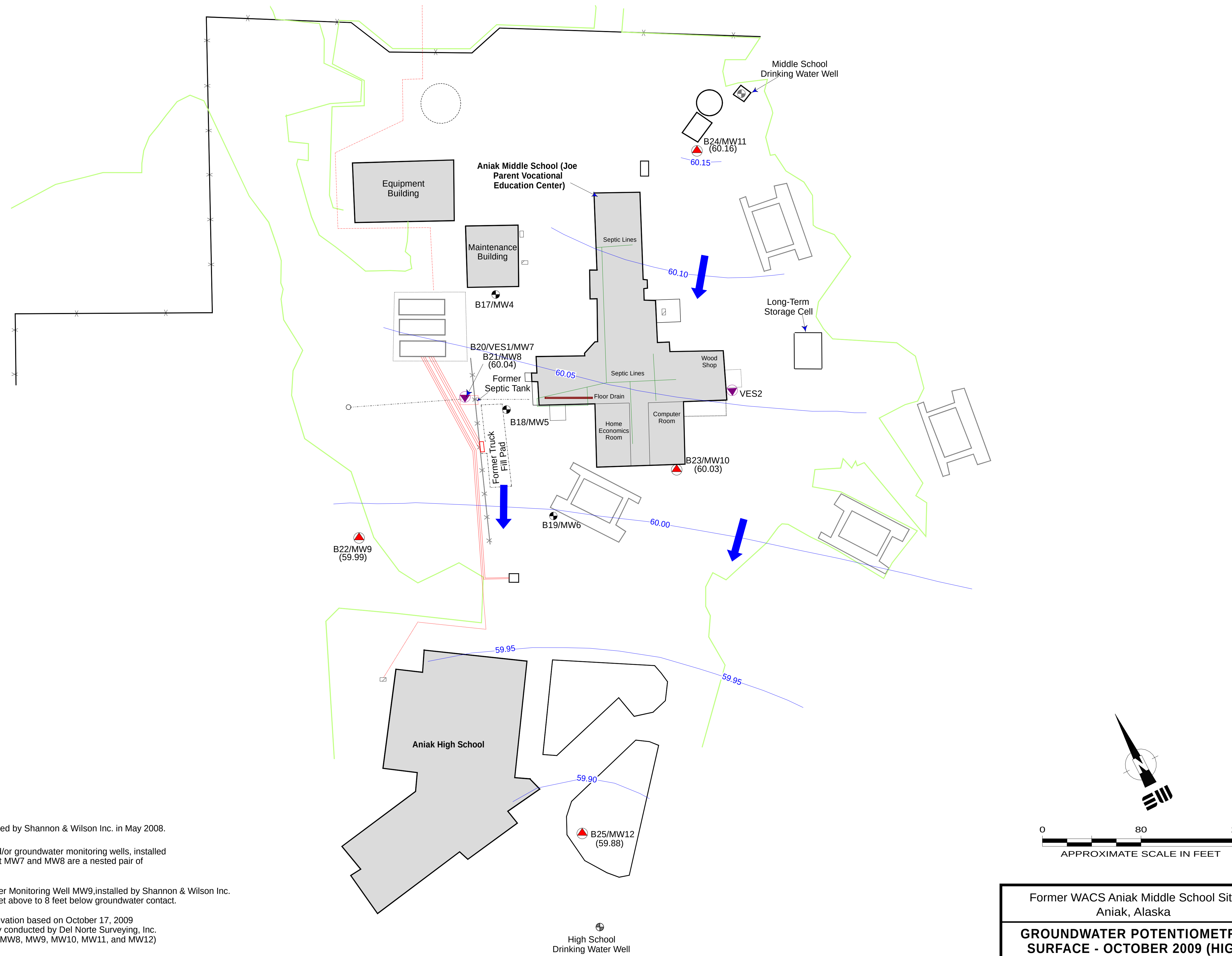
Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - OCTOBER 2009 (LOW)

June 2010 — 32-1-17308-002

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-1



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7 B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

60.05 — Groundwater potentiometric surface contour and elevation based on October 17, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

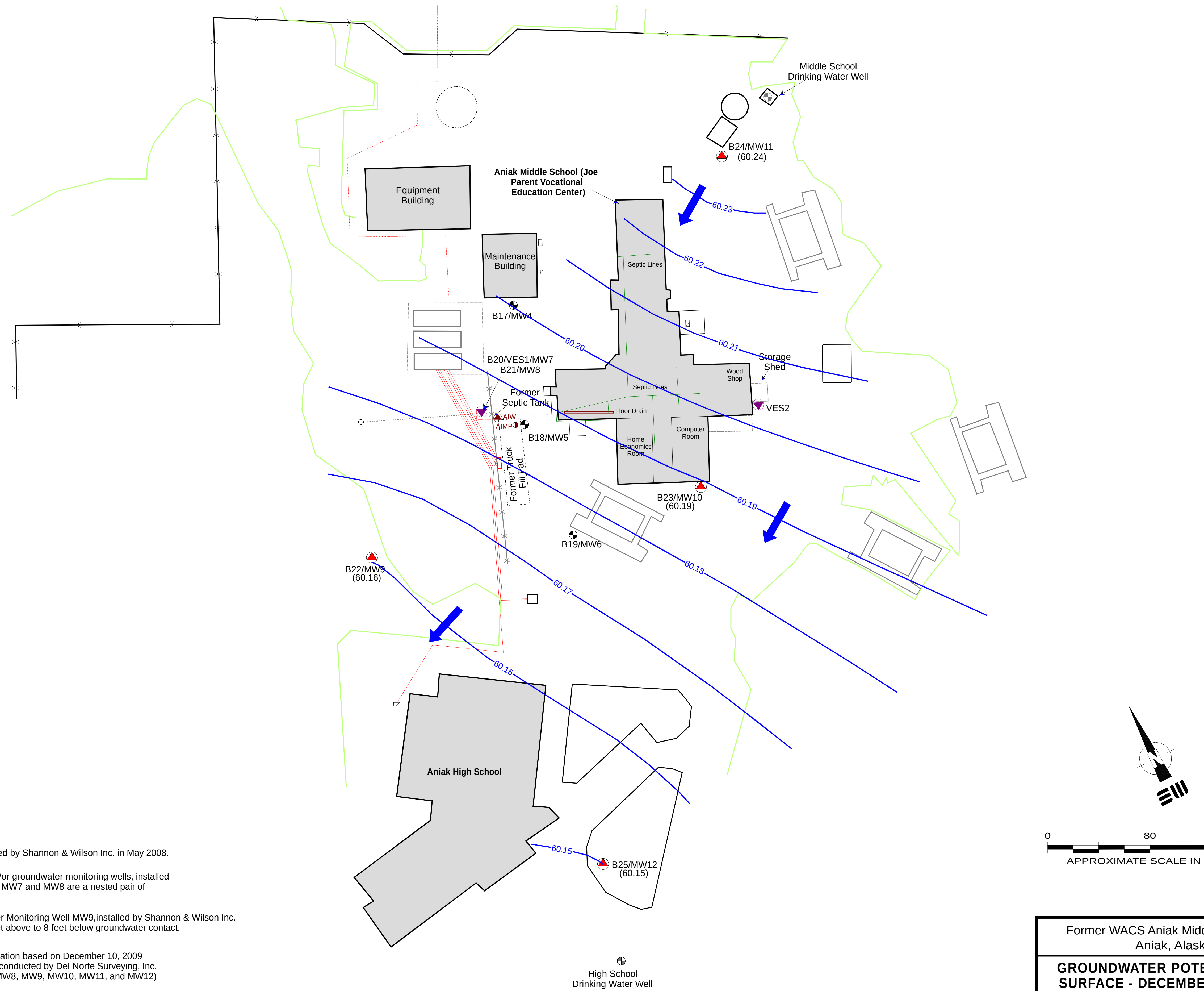
Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - OCTOBER 2009 (HIGH)

June 2010 — 32-1-17308-002

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-2



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7
B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

60.20 — Groundwater potentiometric surface contour and elevation based on December 10, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

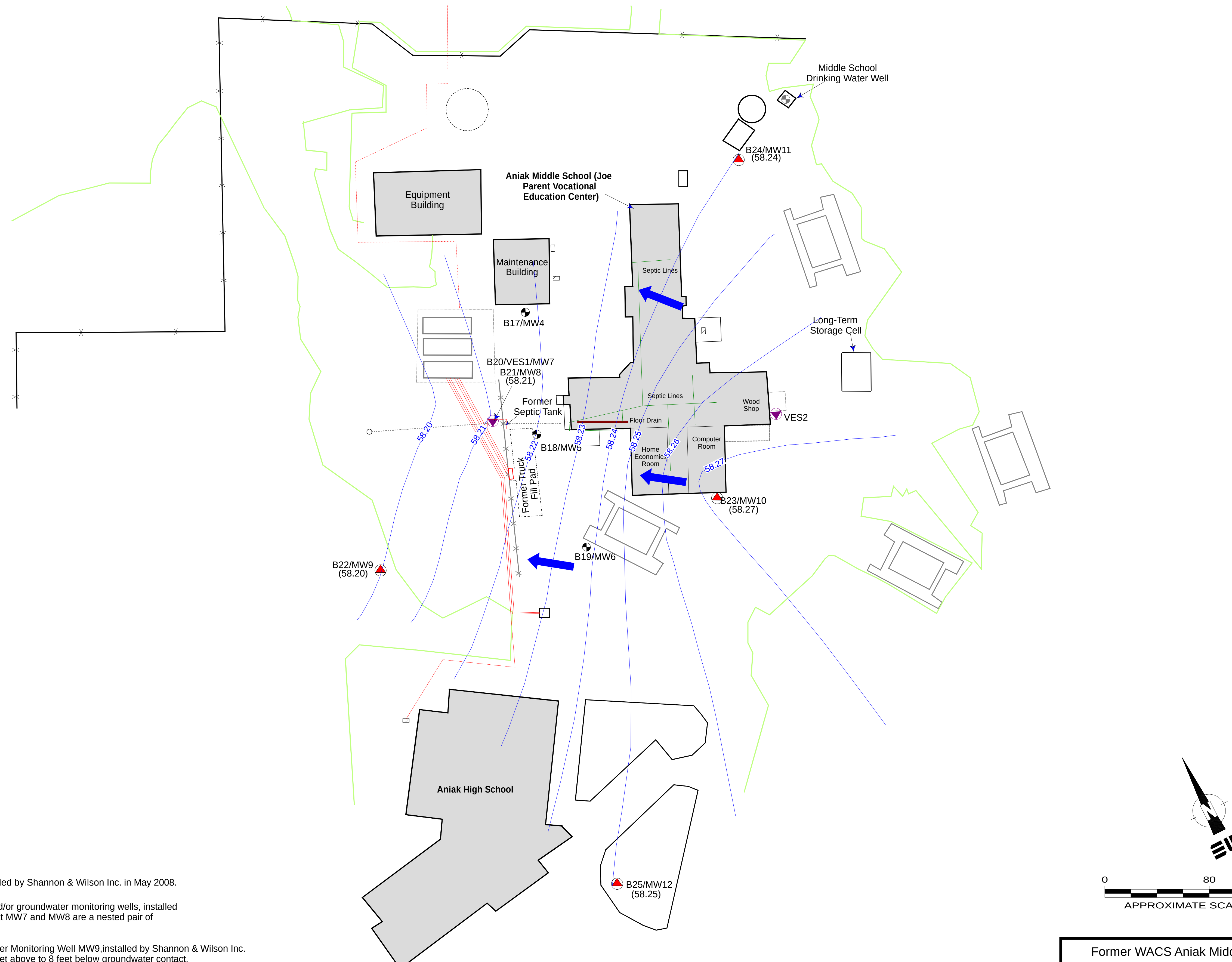
Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - DECEMBER 2009 (HIGH)

June 2010 | 32-1-17308-002

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-3



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7
B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

58.25 — Groundwater potentiometric surface contour and elevation based on February 19, 2010 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

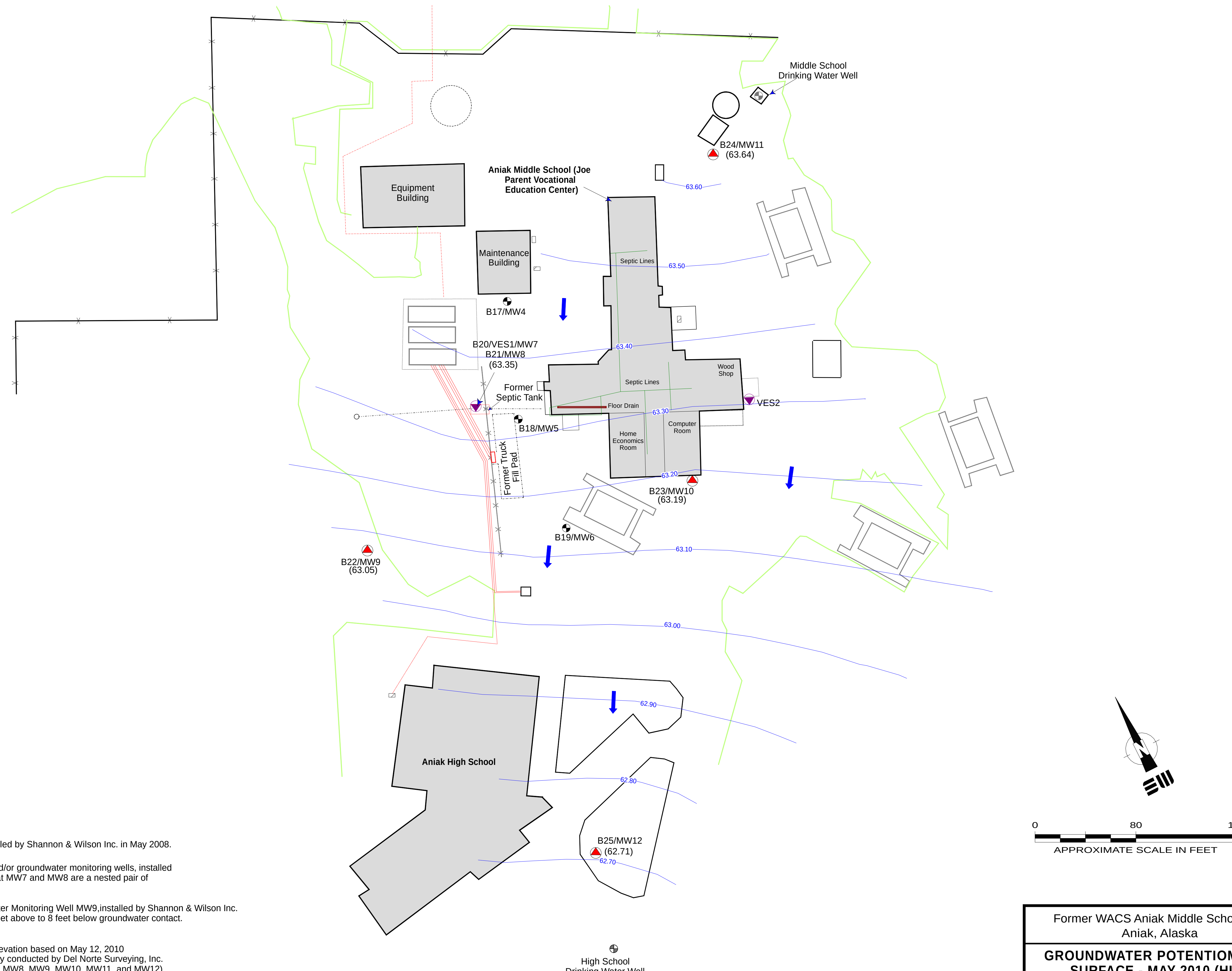
Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - FEBRUARY 2010 (LOW)

June 2010 32-1-17308-002

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-4



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7
B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

58.15 — Groundwater potentiometric surface contour and elevation based on May 12, 2010 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

Former WACS Aniak Middle School Site
Aniak, Alaska

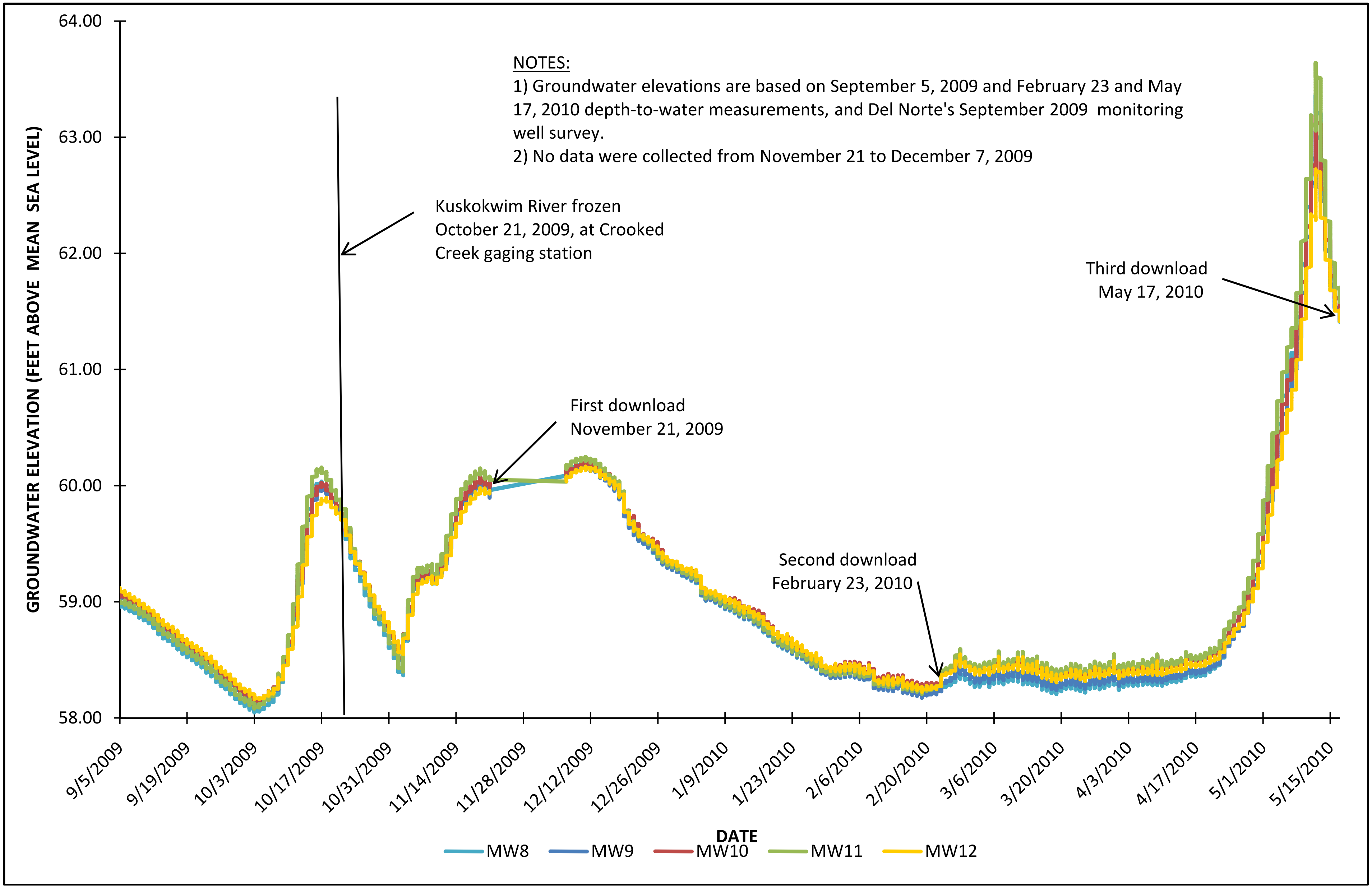
GROUNDWATER POTENTIOMETRIC SURFACE - MAY 2010 (HIGH)

June 2010 32-1-17308-002

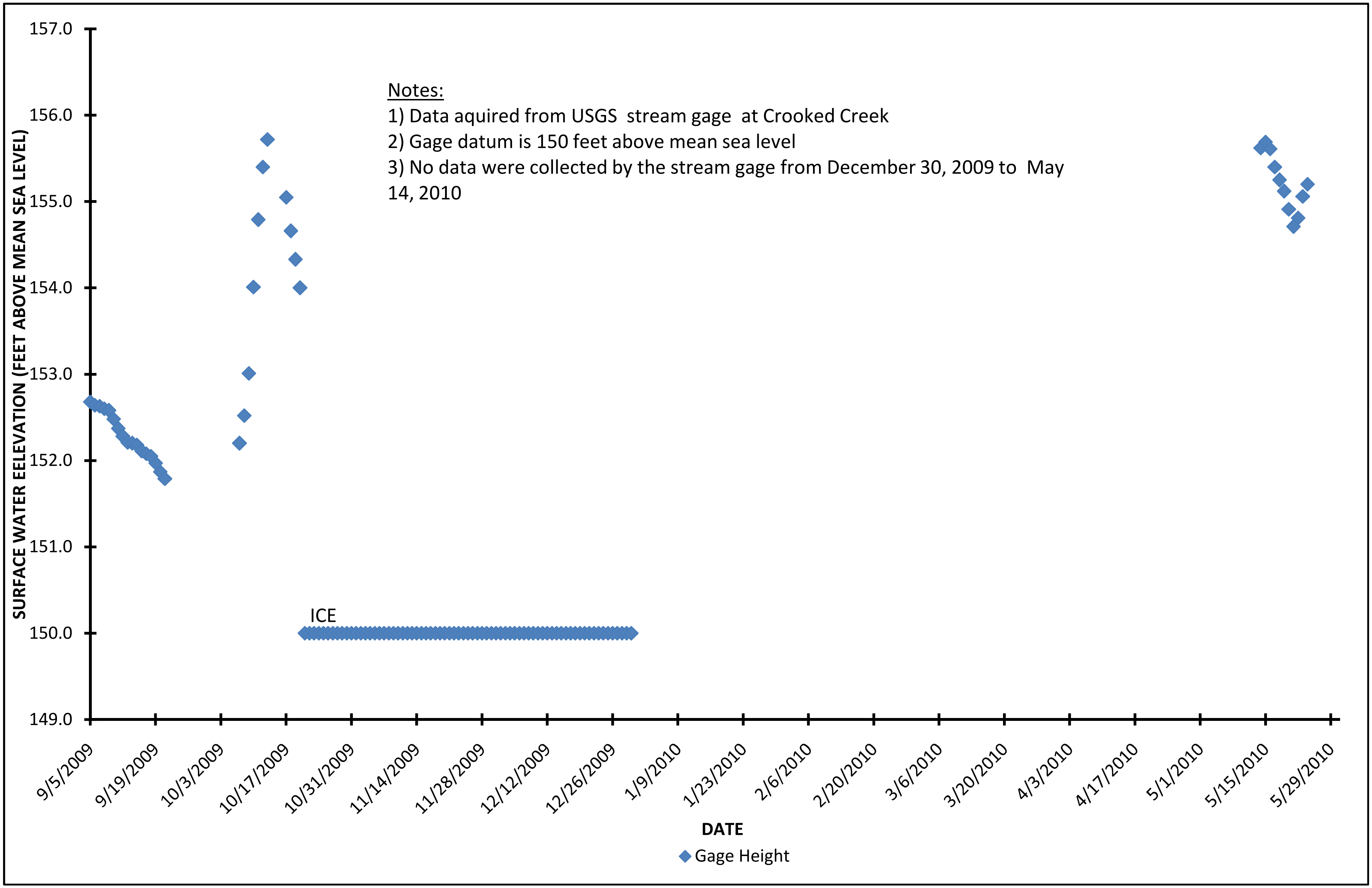
SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-5

GRAPH 1 - ANIAK MIDDLE SCHOOL GROUNDWATER ELEVATIONS



GRAPH 2 - KUSKOKWIM RIVER ELEVATION



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APPENDIX B

Summary of 2011 Groundwater Monitoring Events

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TABLE OF CONTENTS

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ACRONYMS AND ABBREVIATIONS

ADEC .... Alaska Department of Environmental Conservation
bgs .... Below ground surface
DCE............... Dichloroethene
DO................. Dissolved oxygen
EPA............... Environmental Protection Agency
FS.................. Feasibility study
µg/L............... Micrograms per liter
mg/L.............. Milligrams per liter
MNA.............. Monitored natural attenuation
O&M.............. operation and maintenance
OASIS........... OASIS Environmental, Inc.
ORP .... oxidation-reduction potential
QAR .... quality assurance review
QA/QC........... quality assurance/quality control
PCBs............. polychlorinated biphenyls
SSD............... Sub-slab depressurization
TOC............... total organic carbon
TCE............... Trichloroethene
VOC .... Volatile organic compound
WACS .... White Alice Communications System

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1. 2011 GROUNDWATER MONITORING EVENTS

In accordance with Modification 1 and 2 to NTP 18400211028, OASIS performed groundwater monitoring events at the Aniak White Alice Communications Site (WACS) on May 9-12, 2011 and October 18-20, 2011. In addition, OASIS placed groundwater pressure transducers with dataloggers into selected monitoring wells on May 12, 2011 and downloaded the data in June, September, and October 2011. The 2011 monitoring activities provided additional data to support a focused feasibility study (FS) for evaluating groundwater remedies for the site.

The purpose of the groundwater sample events was to augment existing groundwater monitoring data for the site. Prior to May 2011, there was only one round of analytical data available for most site monitoring wells (MW-1 through MW-3 were sampled in October 2008 for volatile organic compounds [VOCs], polychlorinated biphenyls (PCBs), and metals; MW-1 through MW-6 were sampled in June 2008 for VOCs and geochemical parameters; and MW-6 through MW-12 were sampled in August-September 2009 for VOCs only). Prior sampling has showed the presence of two groundwater plumes with trichloroethene (TCE) present above its ADEC Table C cleanup level of 5 micrograms per liter (µg/L).

The Datalogger Study is an expansion of a datalogger study performed by Shannon & Wilson in 2010. Shannon & Wilson placed groundwater pressure transducers with dataloggers into site monitoring wells MW-8, 9, 10, 11, and 12 from September 2009 until May 2010. The dataloggers recorded significant groundwater elevation fluctuations (approximately 5 feet) over this time period. However, the period of maximum groundwater fluctuations would be expected to occur during spring breakup of the Kuskokwim River and summer precipitation, which were not completely recorded in the 2009-2010 study. The purposes of the new Datalogger Study are to fill the data gap from the previous datalogger study and to provide ongoing groundwater elevation information.

1.1. Scope

The work scope is summarized below:

- Install Solinst Gold Leveloggers into the following monitoring wells: MW-5, MW-7, MW-8, MW-9, MW-10, MW-11, and MW-12. Program the Leveloggers to record the groundwater level four times per day.
- Collect groundwater samples from all existing groundwater monitoring wells (MW-4 through MW-12).
- Analyze samples for VOCs and, for the May event only, also for the following geochemical parameters: permanent gases (methane, ethane, ethene), total organic carbon (TOC), dissolved and total iron and manganese, alkalinity, chloride, sulfate, and nitrate-nitrite.

1.2. Summary of Field Procedures

The May and October 2011 monitoring events were performed in accordance with the Work Plan and its addendum (OASIS, 2011a and b). The field procedures are summarized below in this section, and a copy of the field notebook and water sample data sheets is included as Attachment 1 to this Appendix. A photograph log is included as Attachment 2 to this Appendix. Note that all of the field documentation consistently switches MW-7 and MW-8; i.e., all of the information recorded for MW-7 actually pertains to MW-8 and vice versa. The monitoring wells are not labeled in the field so the field crew inadvertently referenced MW-7 and MW-8 incorrectly. The error was discovered due to the depth difference of the monitoring wells. MW-7 is approximately 38 feet deep, and MW-8 is approximately 51 feet deep. Although the field documentation incorrectly references MW-7 and MW-8, all text, tables, and figures present the information correctly. To avoid this problem in the future, labeling the site monitoring wells during the next monitoring event is recommended.

1.2.1. Datalogger Installation and Download

OASIS installed the Leveloggers into monitoring wells MW-5, MW-7, MW-8, MW-9, MW-10, MW-11, and MW-12 between 0645 and 0800 on May 12, 2011. In addition, a Barologger (used to measure barometric pressure) was deployed well above the water table in MW-8. In MW-5 and MW-7, the dataloggers were deployed using steel cables. The other dataloggers were deployed using strings that were still attached to the well caps from Shannon & Wilson's datalogger study. The dataloggers are programmed to record water level four times per day; i.e., at 0200, 0800, 1400, and 2000.

The dataloggers were downloaded in conjunction with subslab depressurization system (SSD) operation & maintenance (O&M) activities after the 1400 reading on June 20, 2011, September 20, 2011, and October 19, 2011. On June 20, 2011, all dataloggers were downloaded, and the dataloggers in monitoring wells MW-8, MW-9, and MW-10 were re-deployed on steel cables. On September 20, 2011, only dataloggers MW-7, MW-8, MW-9, and the Barologger were downloaded. On October 19, 2011, all dataloggers were downloaded, and the dataloggers in monitoring wells MW-11 and MW-12 were re-deployed on steel cables.

1.2.2. May Groundwater Monitoring

OASIS mobilized to the site on May 9, 2011. OASIS found all of the monitoring wells to be in good condition and able to be sampled, except MW-4, which was located under a Connex and therefore could not be accessed. The water level was measured and found to be high enough to submerge the screens in some of the deeper soil gas points installed by Shannon & Wilson in 2009. Therefore, groundwater samples were collected from SGP-2 and SGP-9, in addition to monitoring wells MW-5 through MW-12.

The monitoring wells were purged and samples collected using low-flow methodology. A stainless steel submersible Fultz sample pump (i.e., the same sample technique used by Shannon & Wilson in 2009) was used for purging and sampling, until the pump quit working due to the silt load from SGP-9 . Locations MW-5, MW-11, and SGP-2 were purged and sampled using a peristaltic pump. At all locations, a YSI 556 MPS multiparameter instrument was used to measure field parameters, including pH, temperature, conductivity, dissolved oxygen (DO), and oxidation-reduction potential (ORP). When all readings stabilized to within the acceptable range as stated in the work plan, samples were collected for VOC analysis and the following geochemical parameters: alkalinity, total & dissolved manganese, total & dissolved iron, TOC, sulfate, nitrate-nitrite, chloride, and methane.

Investigation-Derived Waste (IDW) included disposable sample equipment (i.e., sample gloves and tubing) and purge water/decontamination water. The disposable sample equipment was shipped to Anchorage and disposed of in a permitted landfill. The purge/decontamination water was collected in 5-gallon buckets and transferred to a 50-gallon drum that was available onsite after each well was sampled. From May 10, 2011 until the morning of May 12, 2011, an air-sparging treatment system constructed from a section of PVC screen operated inside the drum to treat the purgewater to below the 5 µg/L cleanup level for TCE. A drum sample was collected on May 12, 2011. Pending analytical results, the drum was labeled “Satellite Accumulation Area – Potentially TCE contaminated waste,” and stored in the locked SSD system enclosure. Upon confirmation that the drum sample was below cleanup levels for all contaminants, the drum contents were discharged to the gravel pad on June 20, 2011.

VOC samples were analyzed by OnSite Environmental of Redmond, Washington. OnSite is an ADEC-approved laboratory for these analyses. MNA parameter samples were analyzed by Keystone Laboratories of Newton, Iowa. Although Keystone is not an ADEC-approved laboratory, they are approved by other states (Iowa and Kansas) and have been used for MNA parameter analysis for other projects in Alaska.

1.2.3. October Groundwater Monitoring

October Field Procedures: OASIS mobilized to the site on October 18, 2011. OASIS found all of the monitoring wells to be in good condition and able to be sampled, except MW-4, which was located under a Connex and therefore could not be accessed. MW-5 was found to be dry and therefore could not be sampled. Groundwater samples were collected from monitoring wells MW-4 and MW-6 through MW-12.

The monitoring wells were purged and samples collected using low-flow methodology. A stainless steel submersible SS Monsoon sample pump was used for purging and sampling, except for MW-6. MW-6 was purged and sampled using a bailer, because its recharge rate was too slow for the submersible pump. At all locations, a YSI 556 MPS multiparameter instrument was used to measure field parameters, including pH, temperature, conductivity, DO, and ORP. When all readings stabilized to within the acceptable range as stated in the work plan, samples were collected for VOC analysis

IDW included disposable sample equipment (i.e., sample gloves and tubing) and purge water/decontamination water. The disposable sample equipment was shipped to Anchorage and disposed of in a permitted landfill. The purge/decontamination water was collected in 5-gallon buckets and transferred to a 50-gallon drum that was available onsite after each well was sampled. From October 18, 2011 until the morning of October 20, 2011, an air-sparging treatment system constructed from a section of PVC screen operated inside the drum to treat the purgewater to below the 5 µg/L cleanup level for TCE. A drum sample was collected on October 20, 2011. Pending analytical results, the drum was labeled “Satellite Accumulation Area – Potentially TCE contaminated waste,” and stored in the locked SSD system enclosure. As discussed in the Results section of this Appendix, the drum sample was below cleanup levels for all contaminants, so the drum contents will be discharged to the gravel pad during the next SSD system O&M event.

VOC samples were analyzed by OnSite Environmental of Redmond, Washington. OnSite is an ADEC-approved laboratory for these analyses.

1.3. Water Levels

The May 2011 monitoring event occurred during a period of very high water level associated with spring breakup. The October 2011 monitoring event occurred during a period of low water level. A comparison of Photographs 19 and 20 (Attachment 2) illustrates the difference between the level of the Aniak Slough/Kuskokwim River during the May and October 2011 monitoring events.

Table B-1 summarizes the groundwater depths measured during the 2011 and previous groundwater monitoring events.

The datalogger results are discussed in Section 2.4 of the main body of the FS report, and graphs of the datalogger data are presented in Appendix A of the FS report.

1.4. Groundwater Monitoring Results

1.4.1. Data Validation

The laboratory data were reviewed by an OASIS chemist for quality assurance/quality control (QA/QC) purposes to evaluate the integrity of the analytical data generated during the May and October sample events. The Quality Assurance Review (QAR) discussion and ADEC QA/QC checklists are included as Attachment 3 to this Appendix.

The overall quality of the data was acceptable for the objectives established for this project. Two sample results (dissolved iron and dissolved manganese in sample 11-AWA-001-GW) required J- or UJ-flagging as “estimated” due to matrix spike duplicate percent recoveries outside quality control limits. All sample results are considered usable for project objectives. No results were rejected. The overall project completeness is 100%.

1.4.2. VOC Results

VOC Results: The 2011 groundwater VOC results are presented in Table B-2 and shown in Figure B-1. Contaminants of concern in the site groundwater include TCE and its degradation products cis-1,2-dichloroethene (cDCE), trans-1,2-dichloroethene (tDCE), and vinyl chloride. Detections of TCE and its degradation products above Table C cleanup levels are summarized below:

- 77 µg/L TCE in MW-5 (May)
- 42 µg/L TCE in MW-7 (October)

Detections of TCE and its degradation products below Table C cleanup levels are summarized below:

- 0.29 µg/L TCE in SGP-9 (May)
- 3.1 µg/L cDCE in MW-7 (October)
- 0.3 µg/L cDCE in MW-7 (October)
- 0.26 µg/L cDCE in MW-9 (October)

Several other VOCs were detected at concentrations below their Table C cleanup levels, as summarized below.

- Carbon tetrachloride was detected at a concentration of 0.22 µg/L in SGP-2
- Chloroform was detected at a concentration of 0.24 µg/L in SGP-2
- Carbon disulfide was detected at concentration of 0.39 µg/L in MW-6 (October)
- Dichlorodifluoromethane was detected at concentrations between 0.54 µg/L and 2.1 µg/L in MW-5, MW-6, MW-7, MW-9,and MW-11

Groundwater plume analysis is provided in Section 2.5 of the FS report.

1.4.3. Geochemistry Results

The 2011 groundwater geochemical parameter results are presented in Table B-3 and summarized below.

- pH ranged between 5.9 and 8.4 pH units. Excluding the two soil gas points, the pH range was between 6.2 and 7.6 pH units.
- Alkalinity ranged between 92 milligrams per liter (mg/L) (SGP-2) and 154 mg/L (MW-8). Most alkalinities were between approximately 120 mg/L and 140 mg/L, except SGP-2 and SGP-9, which were below 100 mg/L, and MW-8, which was above 140 mg/L.
- Chloride ranged between 2.1 mg/L (MW-12) and 23.1 mg/L (SGP-2). Excluding the two soil gas points, the maximum chloride detection was 4.5 mg/L (MW-5).
- TOC ranged between 0.46 mg/L (MW-7) and 3.23 mg/L (SGP-2). Excluding the two soil gas points, TOC values were all below 1 mg/L.
- DO ranged between 7.4 mg/L (MW-9) and 0.79 mg/L (MW-10). DO was below 1 mg/L in MW-6, MW-7, MW-10, and MW-12, suggesting somewhat depleted oxygen levels compared to the rest of the site.
- ORP ranged between 201 millivolts (mV) (SGP-9) and 31 mV (SGP-2). All of the ORP values were positive, suggesting generally oxidizing conditions.
- Nitrogen (nitrate plus nitrite) ranged between 2 mg/L (MW-5) and 0.53 mg/L (MW-7).

- Dissolved and total manganese were detected in MW-7, MW-9, and MW-10 and in SGP-2 and SGP-9. Dissolved manganese concentrations ranged from 0.781 mg/L (SGP-9) to 0.252 mg/L (MW-7). Total manganese concentrations ranged from 5.23 mg/L (SGP-9) to 0.245 mg/L (MW-10).
- Dissolved and total iron were not detected in any of the monitoring well samples. Dissolved iron was detected at 5.14 mg/L and 6.57 mg/L in SGP-2 and SGP-9, respectively. Total iron was detected at 129 mg/L and 128 mg/L in SGP-2 and SGP-9, respectively.
- Sulfate ranged between 16.1 mg/L (MW-9) and 4.6 mg/L (SGP-9).
- Ethene, ethane, and methane were not detected in any monitoring wells.

The geochemical parameter results are used in the monitored natural attenuation (MNA) analysis presented in Section 4.4.1 of the FS report.

2. REFERENCES

OASIS, 2011a. Letter Work Plan to Mr. John Halverson, re: Final Work Plan for Additional Characterization and Groundwater Monitoring at Former Aniak WACS Site, Aniak, Alaska. May 2.

OASIS, 2011b. Letter Work Plan to Mr. John Halverson, re: Addendum to May 2, 2011 Final Work Plan for Additional Characterization and Groundwater Monitoring at Former Aniak WACS Site, Aniak, Alaska. October 6.

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TABLES

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Table B-1: Groundwater Elevation Summary
2006 through 2011 Monitoring Events
Aniak WACS, Alaska

					Depth to Groundwater (ft bgs)									
	Elevation (TOC)[1]	Screened Interval (ft bgs)	Well Depth (ft bgs)*	Well Diameter (in)	10/21/06	5/19/08	6/3/2008	8/22/09	5/10/11-5/11-11	10/19/11	GW Elevation (5/10/11-5/11-11)	GW Elevation (10/19/11)	Min. GW Elevation (ft)	Max. GW Elevation (ft)
MW-1	86.76	19-29	--	--	24.07	21.72	23.09	--	--	--	--	--	62.69	65.04
MW-2	89.76	22-32	--	--	27.05	24.72	26.07	--	--	--	--	--	62.71	65.04
MW-3	80.75	12-22	--	--	18	--	17.01	--	--	--	--	--	62.75	63.74
MW-4	90.68	22-32	31.78	2	--	--	27.05	>31.78	nm	nm	nm	nm	<59.22	63.63
MW-5	90.24	22-32	29.75	2	--	--	27.22	>29.94	18.57	>29.75	71.67	<60.95	<59.24	71.67
MW-6	88.36	18-28	29.91	2	--	--	24.7	28.55	16.66	28.61	71.7	59.75	59.75	71.7
MW-7	90.04	23-38	37.5	4	--	--	--	30.3	17.99	30.31	72.05	59.73	59.73	72.05
MW-8	90.03	47-52	50.65	2	--	--	--	30.3	18.01	30.31	72.02	59.72	59.72	72.02
MW-9	83.24	13-28	30.95	2	--	--	--	23.45	11.59	23.5	71.65	59.74	59.74	71.65
MW-10	91.18	25-40	36.86	2	--	--	--	31.37	19.23	31.41	71.95	59.77	59.77	71.95
MW-11	92.12	25-40	37.25	2	--	--	--	32.37	19.58	32.41	72.54	59.71	59.71	72.54
MW-12	87.63	22-37	34.31	2	--	--	--	28.78	16.16	27.81	71.47	59.82	59.82	71.47
SGP-2	91.86	28.5-29.5	28.71**	2				nm	19.08	nm	72.78	nm	nm	72.78
SGP-9	91.8	25.6-26.6	25.67**	2				nm	18.96	nm	72.84	nm	nm	72.84

Notes:

[1]: MW-1, MW-2, and MW-3 elev surveyed 10/26/06. MW-4 through MW-12 and SGPs surveyed 9/2/09 (data from Shannon & Wilson Table 6.4-1 and Appendix N).

wells are decommissioned ft = feet TOC = top of casing
-- = well does not exist in = inches GW = groundwater
nm=not measured bgs = below ground surface

Table B-2: 2011 Groundwater Monitoring Results
Volatile Organic Compounds (VOCs)
Aniak WACS, Aniak Alaska

Monitoring Well	Sample ID	Sample Date	Screened Interval (ft bgs)	Well Depth (ft bgs)	Well Diameter (in)	PCE (ug/L)	TCE (ug/L)	tDCE (ug/L)	cDCE (ug/L)	Vinyl chloride (ug/L)	Dichloro-difluoro-methane (ug/L)	Carbon disulfide (ug/L)	Carbon tetra-chloride (ug/L)	Chloro-form (ug/L)
Table C Cleanup Level (ug/L)						*5*	*5*	*100*	*70*	*2*	*7300*	*3700*	*5*	*140*
MW-4	*not sampled; covered by Conex*		22-32	31.78	2	--	--	--	--		--		--	--
MW-5	11-AWA-010-GW	5/11/2011	22-32	29.94	2	ND(<0.4)	**77**	ND(<0.4)	ND(<0.4)	ND(<0.4)	0.55	ND(<0.2)	ND(<0.4)	ND(<0.4)
MW-5 (Dup)	11-AWA-011-GW	5/11/2011	23-38	29.94	2	ND(<0.4)	**77**	ND(<0.4)	ND(<0.4)	ND(<0.4)	0.56	ND(<0.2)	ND(<0.4)	ND(<0.4)
	well was dry	10/18/2011				*well dry-no sample collected*								
MW-6	11-AWA-004-GW	5/10/2011	18-28	30.1	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	0.79	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-016-GW	10/19/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	0.54	0.39	ND(<0.2)	ND(<0.2)
MW-7	11-AWA-002-GW	5/10/2011	23-38	38.11	4	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-015-GW	10/19/2011				ND(<0.2)	**42**	0.3	3.1	ND(<0.2)	2.1	ND(<0.2)	ND(<0.2)	ND(<0.2)
MW-8	11-AWA-003-GW	5/10/2011	47-52	52	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-014-GW	10/18/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
MW-9	11-AWA-001-GW	5/10/2011	13-28	31.13	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-013-GW	10/18/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	0.26	ND(<0.2)	0.85	ND(<0.2)	ND(<0.2)	ND(<0.2)
MW-10	11-AWA-006-GW	5/10/2011	25-40	38.86	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWEA-020-GW	10/19/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
MW-11	11-AWA-008-GW	5/11/2011	25-40	38.25	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-018-GW	10/19/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	0.54	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-019-GW	10/19/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	0.53	ND(<0.2)	ND(<0.2)	ND(<0.2)
MW-12	11-AWA-005-GW	5/10/2011	22-37	34.46	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
	11-AWA-017-GW	10/19/2011				ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
SGP-2	11-AWA-009-GW	5/11/2011	28.5-29.5	29.5	2	ND(<0.2)	ND (<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	0.22	0.24
SGP-9	11-AWA-007-GW	5/11/2011	25.6-26.6	26.6	2	ND(<0.2)	0.29	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)	ND(<0.2)
DRUM	11-AWA-012-GW	5/12/2011	na	na	na	ND(<0.2)	ND (<0.2)	0.22	ND(<0.2)	ND(<0.2)	ND (<0.2)	ND (<0.2)	ND (<0.2)	ND (<0.2)
DRUM	11-AWA-021-GW**	10/20/2011	na	na	na	ND(<0.2)	ND (<0.2)	0.33	ND(<0.2)	ND(<0.2)	ND (<0.2)	ND (<0.2)	ND (<0.2)	ND (<0.2)

Notes:

ft = feet
in = inches
bgs = below ground surface
ug/L = micrograms per liter
AWA = Aniak White Alice
GW = groundwater

ND = not detected
na = not applicable
PCE = tetrachloroethene
TCE = trichloroethene
cDCE = cis-1,2-dichloroethene
t-DCE = trans-1,2-dichloroethene

* 18 AAC 75.345(b)(1) Table C Groundwater Cleanup Levels
Results exceeding Table C Cleanup Levels shown in bold

** Other detections: acetone 9.6 ug/L and
2-Butanone 13 ug/L

Table B-3: 2011 Groundwater Monitoring Results
Geochemical Data
Aniak WACS, Alaska

Monitoring Well	Sample ID	Sample Date	Screened Interval (ft bgs)	Well Depth (ft bgs)	Well Diameter (in)	pH	DO (mg/L)	ORP (mV)	Ethane (mg/L)	Ethene (mg/L)	Methane (mg/L)	Alkalinity(mg/L)	Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Iron, dissolved(mg/L)	Manganese, dissolved (mg/L)	Iron, total (mg/L)	Manganese, total (mg/L)
MW-4	*not sampled; covered by Conex*		22-32	31.78	2	--	--	--	--	--	--	--		--	--					--
MW-5	11-AWA-010-GW	5/11/2011	22-32	29.94	2	7.6	4.6	66	ND (<0.010)	ND (<0.010)	ND (<0.007)	123	2	0.72	4.5	11.9	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
MW-5 (Dup)	11-AWA-011-GW	5/11/2011	23-38	29.94	2				ND (<0.010)	ND (<0.010)	ND (<0.007)	121	1.83	0.68	4.4	12.2	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
MW-6	11-AWA-004-GW	5/10/2011	18-28	30.1	2	6.3	0.87	78	ND (<0.010)	ND (<0.010)	ND (<0.007)	123	1.72	0.67	3	11	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
MW-7	11-AWA-002-GW	5/10/2011	23-38	38.11	4	6.4	0.82	147	ND (<0.016)	ND (<0.016)	ND (<0.011)	127	0.53	0.46	2.4	13.3	ND (<0.100)	0.252	ND (<0.100)	0.269
MW-8	11-AWA-003-GW	5/10/2011	47-52	52	2	6.4	1.1	129	ND (<0.010)	ND (<0.010)	ND (<0.007)	154	1.29	0.66	2.7	13.7	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
MW-9	11-AWA-001-GW	5/10/2011	13-28	31.13	2	6.4	7.4	141	ND (<0.010)	ND (<0.010)	ND (<0.007)	137	0.7	0.59	2.6	16.1	ND (<0.100) UJ	0.278J	ND (<0.100)	0.253
MW-10	11-AWA-006-GW	5/10/2011	25-40	38.86	2	6.3	0.79	169	ND (<0.008)	ND (<0.008)	ND (<0.006)	123	1.21	0.63	2.1	10.9	ND (<0.100)	0.51	ND (<0.100)	0.245
MW-11	11-AWA-008-GW	5/11/2011	25-40	38.25	2	6.4	1.3	20.3	ND (<0.010)	ND (<0.010)	ND (<0.007)	129	0.88	0.79	2.3	11.4	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
MW-12	11-AWA-005-GW	5/10/2011	22-37	34.46	2	6.2	0.95	116	ND (<0.010)	ND (<0.010)	ND (<0.007)	119	1.65	0.71	2.1	9.1	ND (<0.100)	ND (<0.005)	ND (<0.100)	ND (<0.005)
SGP-2	11-AWA-009-GW	5/11/2011	28.5-29.5	29.5	2	8.4	3.2	31	ND (<0.010)	ND (<0.010)	ND (<0.007)	92	1.05	3.23	23.1	5.4	5.14	0.312	129	3.44
SGP-9	11-AWA-007-GW	5/11/2011	25.6-26.6	26.6	2	5.9	7.1	201	ND (<0.010)	ND (<0.010)	ND (<0.007)	94	0.57	2.21	15.2	4.6	6.57	0.781	128	5.23

Notes:
ft = feet
in = inches
bgs = below ground surface
mg/L = milligrams per liter
AWA = Aniak White Alice
GW = groundwater

ND = not detected
na = not applicable
J = estimated value

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FIGURES

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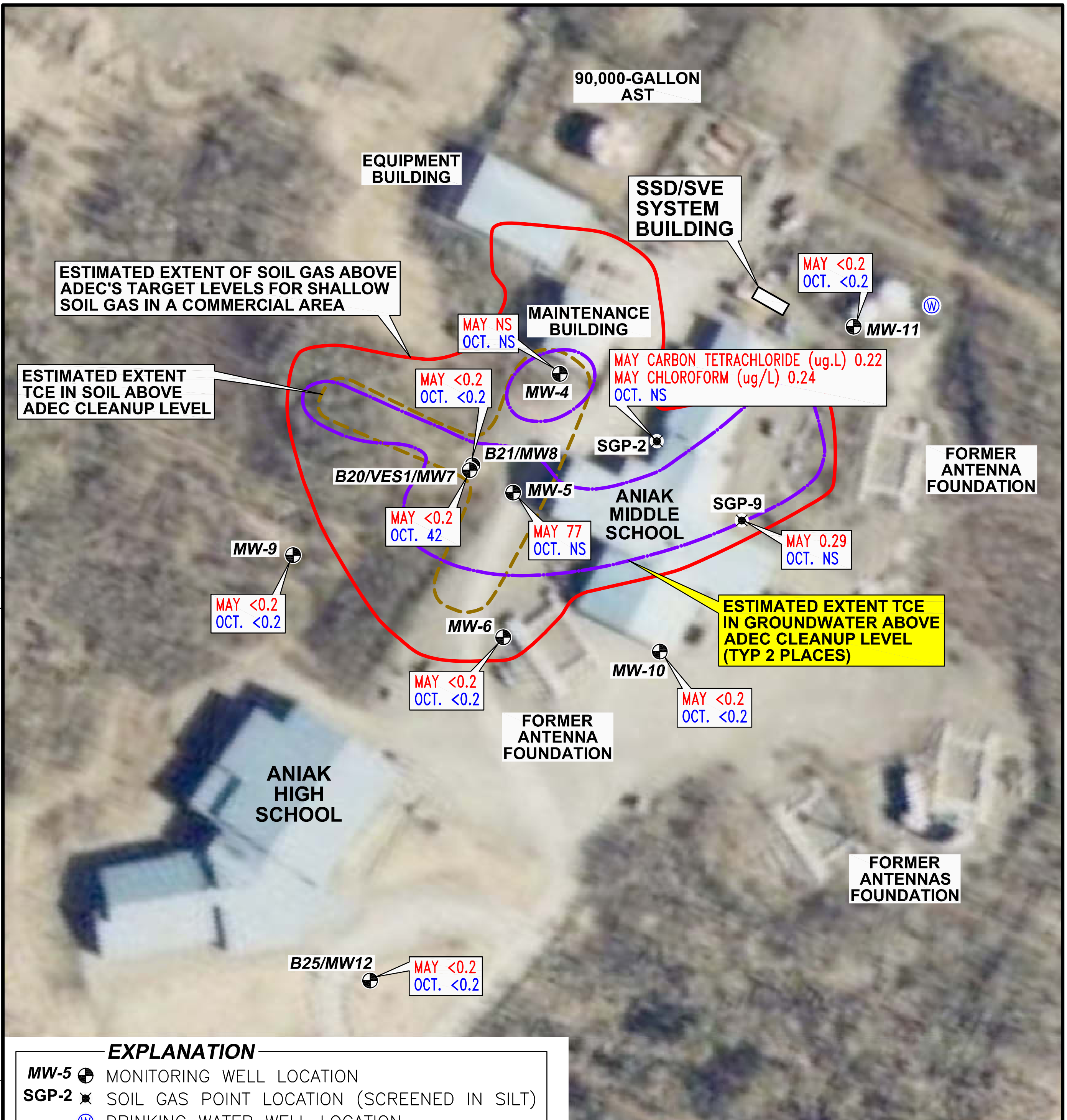

EXPLANATION

MW-5	MONITORING WELL LOCATION
SGP-2	SOIL GAS POINT LOCATION (SCREENED IN SILT)
Ⓦ	DRINKING WATER WELL LOCATION
MAY <0.2	MONTH/TCE RESULT (RED=MAY/BLUE=OCT)
TCE	TRICHLOROETHENE (ug/L)
NS	NOT SAMPLED

NOTE: cis-1,2-DICHLOROETHENE ALSO DETECTED AT 3.1 ug/L (MW-7 OCTOBER), AND 0.29 ug/L (MW-9 OCTOBER). DICHLORODIFLOUROMETHANE ALSO DETECTED BETWEEN 0.5 TO 2.1 ug/L IN MW-6, 6, 7, 9, AND 11. CARBON DISULFIDE DETECTED AT 0.39 ug/L IN MW-6 (OCTOBER).

SOURCE: 2001 AERIAL PHOTOGRAPHY OBTAINED FROM ALASKA DEPARTMENT OF COMMERCE.

NORTH

0 50 100

APPROX. SCALE IN FEET

oasis ENVIRONMENTAL

DATE: DEC. 2011
CHKD: J.H.P.
DRAWN: C.E.H.
PROJ. No.: 14-201

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

MAY AND OCTOBER 2011 MONITORING RESULTS

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE B-1

PATH: V:\Project Drawings\ADEC\Aniak\11 Aniak\11 AN FFS FILE: 14-201-AN-FSS-B1.DWG PLOTTED: 12/21/11.

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ATTACHMENT 1

Field Notes and Water Sample Data Sheets

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16.66

Item No. 303
ISBN: 978-1-932149-83-8

"Rite in the Rain"®
ALL-WEATHER
TRANSIT
No. 303

Aniak White Alice Communications Site

Groundwater Study – May 11

3

"Rite in the Rain"®
ALL-WEATHER WRITING PAPER

Name

Address

Phone

Project Aniak White Alice
Communications Site
14-201-2-1 dataloggers
-2 GW sample

CONTENTS

PAGE	REFERENCE	DATE
	Internet	
	knspuk	
	17f25Ø331e	

R. Bryan
W. Rhodes

Amak WACS
14-201-2

50F, sun
Mon, 5-9-11

1240 Charlie Thacker pickup OASIS at Aniak Airport & transport to Aniak Middle School dormitories

1300 Erin McDonald, OASIS conducts tailgate safety meeting

1400 p/u Era cargo

1500 Rena Bryan & Will Rhodes to locate, swingtie, gage, & record observations on well conditions

See table

1830 OASIS offsite, will call Jane tomorrow am. to ask about replacement for MW-4M

R. Bryan
W. Rhodes

Aniak WACS
14-201-2

50E, sun
Mon, 5-9-11

Time	Well	DTW (ft BTOC)	TD (ft BTOC)	Well Frost Jacked
~~15:44~~ RB	~~MW-11~~ RB			
1544	MW-11	20.23'	37.25'	No
1606	MW-10	19.69'	36.86'	No
1617	MW-6	17.05'	29.91'	No
1633	MW-12	16.56'	34.31'	No
1648	MW-9	11.50'	30.95'	No
	~~MW-7~~ RB			
	~~MW-8~~ RB			
1703	MW-7	18.31'	50.65'	No
1717	MW-8	18.34'	37.5'	No
1732	MW-5	18.82	29.75'	No
1740	MW-4			
1758	~~MW-X~~ sgp?	N/A	15.52'	No
1817	~~MW-X~~ sgp 3	19.72'	28.41'	No
5-11-11 1549	sgp 2	18.96'	28.71'	
5-11-11 0920	sgp 9	19.98'	23.67'	

R. Bryan
W. Rhodes

Aniak WACS
14-201-2

50E, sun
Mon, 5-9-11

Casing Movement Observations

Other Movement	Description	Photo
No, intact	flush, 37.5' string	368, 369
Minor?: gravel subsided slightly	flush, 36.8' string, could consider replacement monument lid.	370, 371, 372
No, intact	flush	373, 374, 375
No, intact	flush, 33.5' string	376, 377
No, intact	stickup, 30.5' string yellow stickup in swamp	378, 379, 380, 381
No, intact	flush, 46.2' string closest to fuel line*	382, 383, 834,
	flush, closest to fence* 4" ID	385, 386
	* as-built labeling conflicts w/ table labeling for MW-7 & 8	
No, intact	flush, 2" ID	387, 388, 389, 390
	underneath conex	392
No, intact	flush, ~~replacement for MW-4?~~ RB no water	393
No, intact	flush, ~~replacement for MW-4?~~ sgp 2 is preferred	394, 395
		441, 442, 443, ~~444~~
		438, 439, 440

R. Bryan
W. Rhodes

Aniak WACS
14-201-2

30F sun
Tues, 5-10-11

0715 conduct tailgate safety meeting
0730 call/email Jane update/ replacement well question
0830 calibrate YSI
1030 confirm w/ Jane to not use sgp3 as a replacement for MW-4, but to use sgp2
1031 mobilize to MW-9, see datasheet
1125 collect VOC & MNA primary on MW-9, Sample ID: 11-AWA-001-GW
1200 move to MW-7*, closest to fuel line, See datasheet
*note as-built labeling conflicts w/ table labeling for MW-7 & 8
1230 break for lunch, check email: also sample Sgp-9 in addition
1350 collect VOC & MNA primary on MW-7, Sample ID: 11-AWA-002-GW
1415 move to MW-8*, closest to fence, see datasheet.
1455 collect VOC & MNA primary on MW-8, sample ID: 11-AWA-003-GW
1525 move to MW-6, see datasheet
1615 collect VOC & MNA primary on MW-6, sample ID: 11-AWA-004-GW

R. Bryan
W. Rhodes

Aniak WACS
14-201-2

30F, overcast
Tues, 5-10-11

1720 move to MW-12, see datasheet
1800 collect MW-12 primary VOC & MNA sample, Sample ID: 11-AWA-005-GW
1830 move to MW-10, see datasheet
1910 collect VOC & MNA primary Sample on MW-10, sample ID: 11-AWA-006-GW
2000 Check email on sgp-9, Send email on deploying dataloggers.
2010 OASIS offsite, samples on ice in cool metal shop room.

0715 W. Rhodes conduct tailgate safety meeting

0800 replace ice in sample cooler and move to shade outside main entrance.

0830 Check email from Jane, confirm to do MNAs on sgp-9, dup VOC on MW-5, ms/msd on MW-11, calibrate YSI

0920 mobilize to sgp-9, see datasheet
This well had not been previously sampled as it is a soil gas point. A portion of the purge time and high turbidity of the water is attributed to no prior well development.

1034 water quality parameters stabilize

1040 collect VOC & MNA primary sample on sgp-9, Sample ID: 11-AWA-007-GW

1115 move to MW-11, see datasheet

1120 troubleshoot fultz pump

1200 break for lunch, more trouble-

shoot fultz pump

1330 return to MW-11, peristaltic pump set up w/ 1/2" poly & silicone tubing - ok from Jane

<u>fultz pump issue summary</u>: sgp-9 may have been too turbid for fultz pump. Upon set up at MW-11, fultz amps increased to 4 then decreased to zero, control box stopped working, started working again w/ AC power, stopped again when forward switch flipped, ok from Jane. switch to peristaltic pump

1505 collect <u>primary & ms/msd</u> <u>VOC</u> & primary MNA samples on MW-11, Sample ID: 11-AWA-008-GW

1522	438	sgp-9	photo
1523	439	sgp-9	photo
1523	440	sgp-9	photo
1526	441	sgp-2	photo
1526	442	sgp-2	photo
1526	443	sgp-2	photo
1526	444	sgp-2	photo

1549 move to sgp-2, see datasheet

1659 Hole in silicone tubing caused pumping delay. Begin pumping.

1725 Sand began depositing inside the flow through cell during purging. Water quality parameters not yet stable, decide to sample to avoid clogging the YSI & flow through cell.

1730 collect VOC & MNA primary on sgp-2, sample ID: 11-AWA-009-GW, samples contain water and sand.

1808 move to MW-5, see datasheet

1810 discover we have enough MNA bottles to do a duplicate MNA as well as duplicate VOC sample on MW-5

1849 water quality parameters did not stabilize

1850 collect primary VOC & MNA sample on MW-5, sample ID: 11-AWA 010-GW

1910 collect duplicate VOC & MNA sample on MW-5, Sample ID:

11-AWA-011-GW

2045 Sample Summary.

Date	Time	Well	Sample ID	VOC	MNA	Notes
5-10-11	1125	MW-9	11-AWA-001-GW	X	X	
5-10-11	1350	MW-7	11-AWA-002-GW	X	X	
5-10-11	1455	MW-8	11-AWA-003-GW	X	X	
5-10-11	1615	MW-6	11-AWA-004GW	X	X	
5-10-11	1800	MW-12	11-AWA-005GW	X	X	
5-10-11	1910	MW-10	11-AWA-006-GW	X	X	
5-11-11	1040	sgp-9	11-AWA-007-GW	X	X	
5-11-11	1505	MW-11	11-AWA-008-GW	X	X	ms/msd VOC only
5-11-11	1730	sgp-2	11-AWA-009GW	X	X	
5-11-11	1850	MW-5	11-AWA-010-GW	X	X	
5-11-11	1910	MW-5	11-AWA-011-GW	X	X	VOC & MNA duplicate
5-12-11	0845	DRUM	11-AWA-012-GW	X		waste characterization

2100 Checked leveloggers are all correctly logging - started 5/8 1400, 6 hr interval, reasonable room temp & pressure

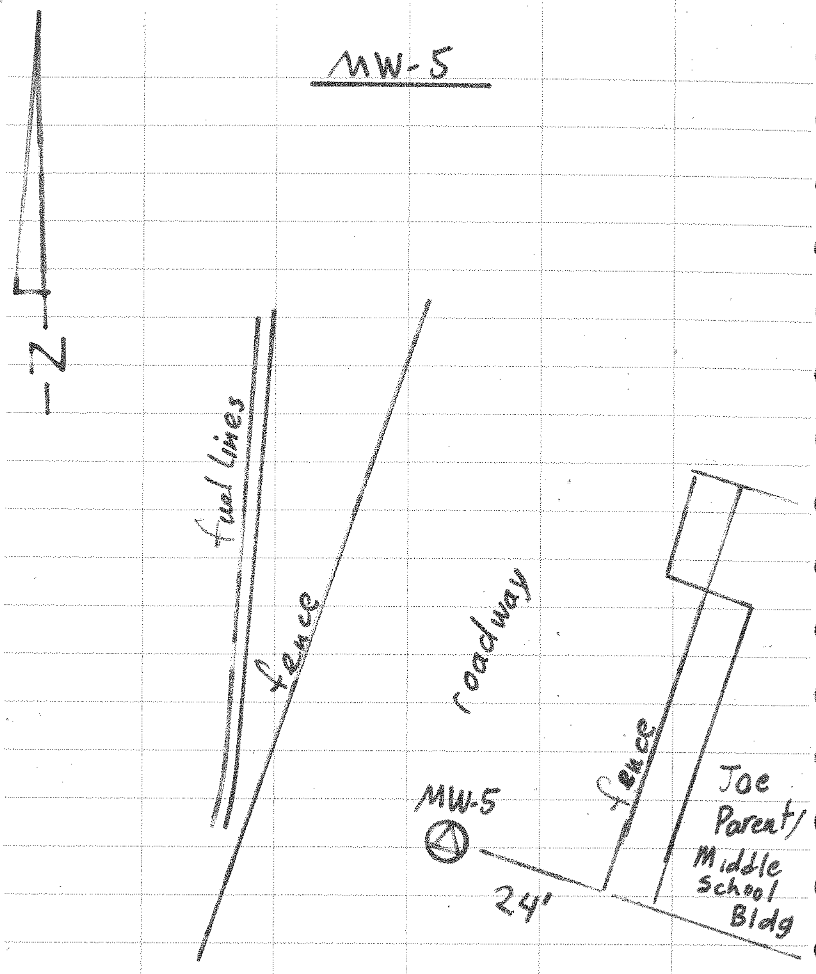
2120 draw swingties for wells sampled

2300 prep levelogger cables.

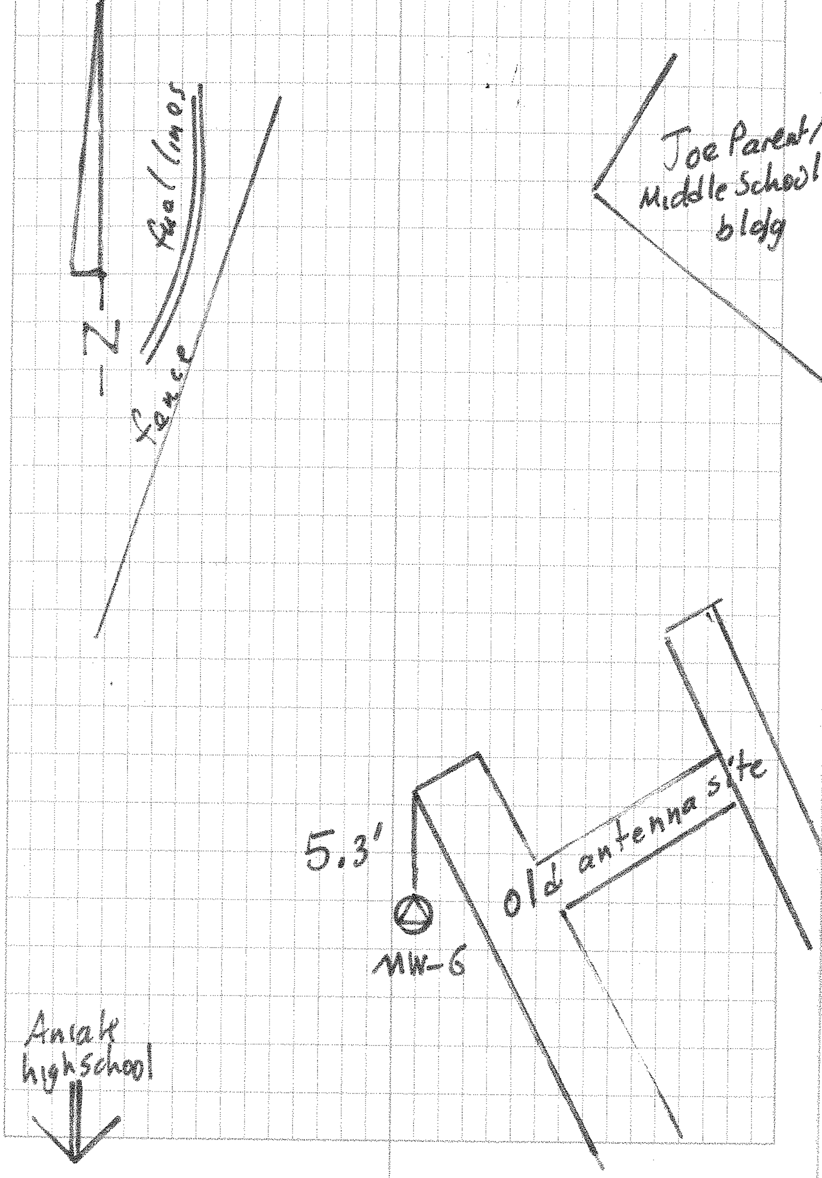
2330 OASIS offsite

Rueullun

MW-5

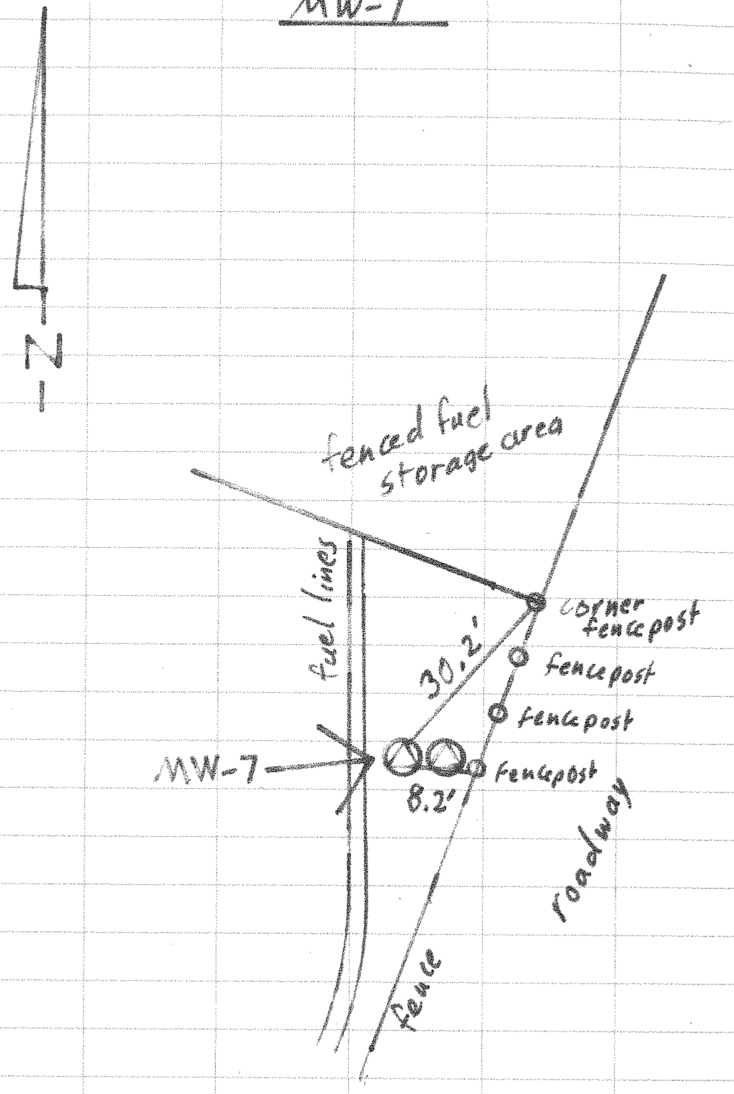


MW-6



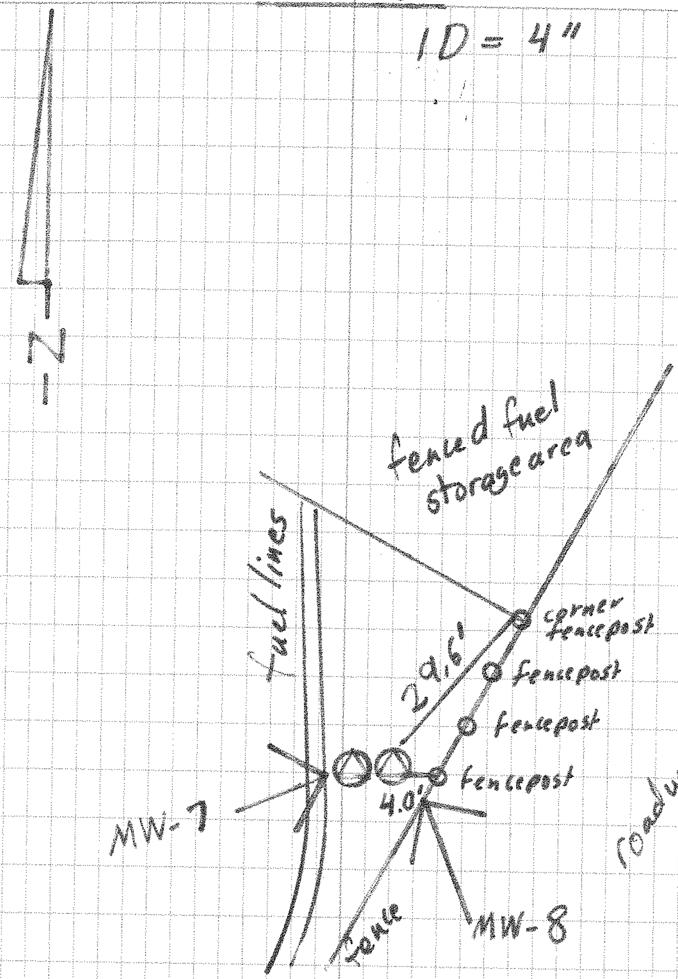
"Rite in the Rain"

MW-7 closest to fuel lines



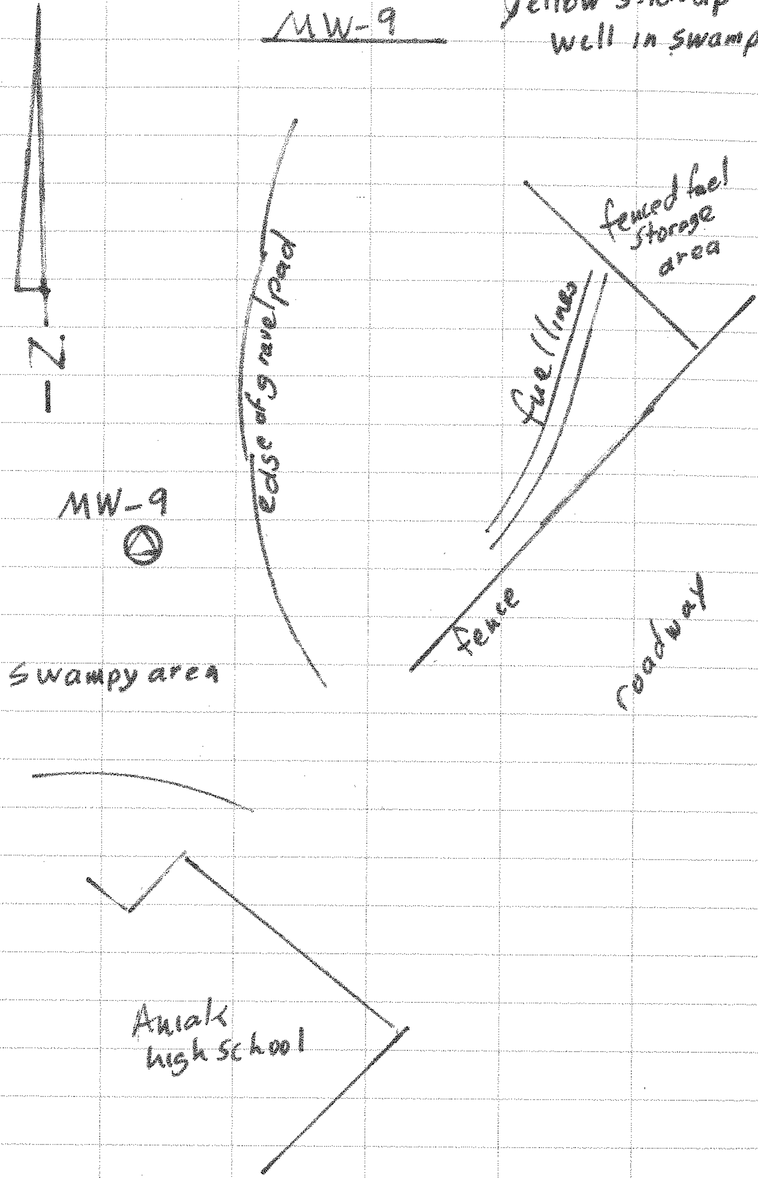
MW-8 closest to fence

ID = 4"

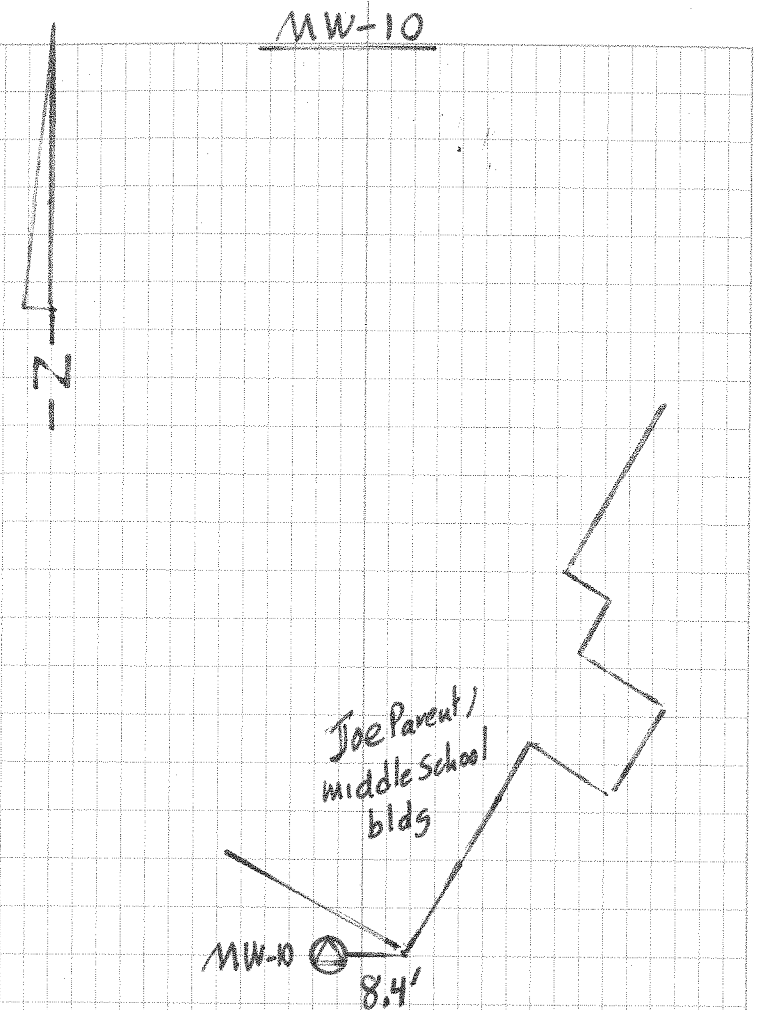


MW-9

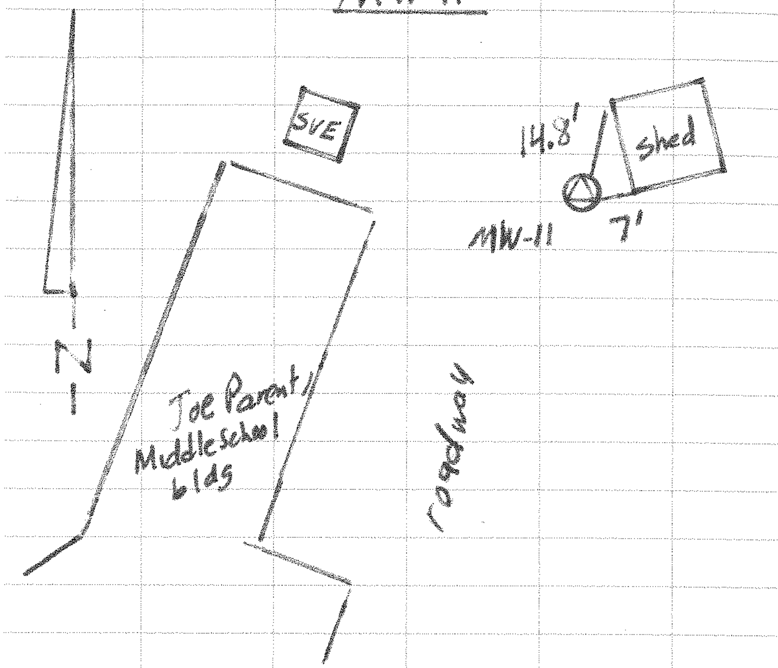
yellow stickup
well in swamp



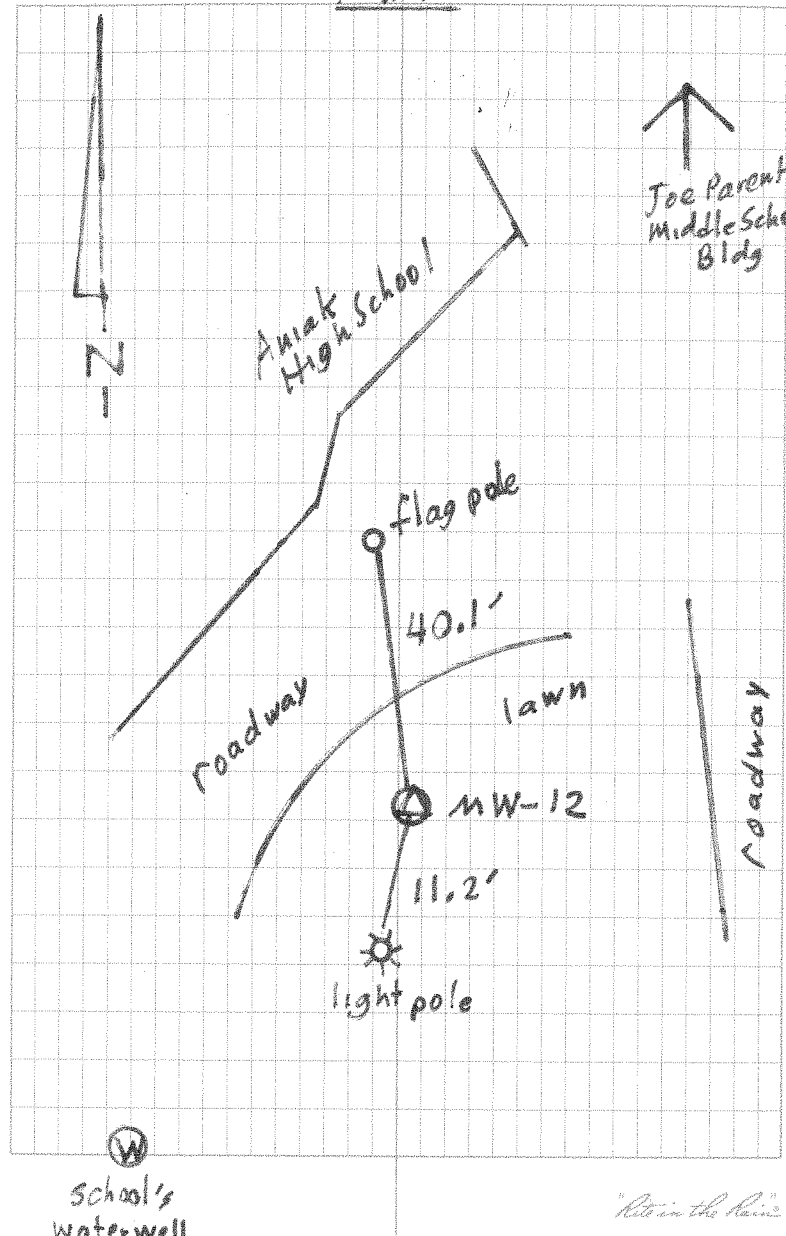
MW-10



MW-11

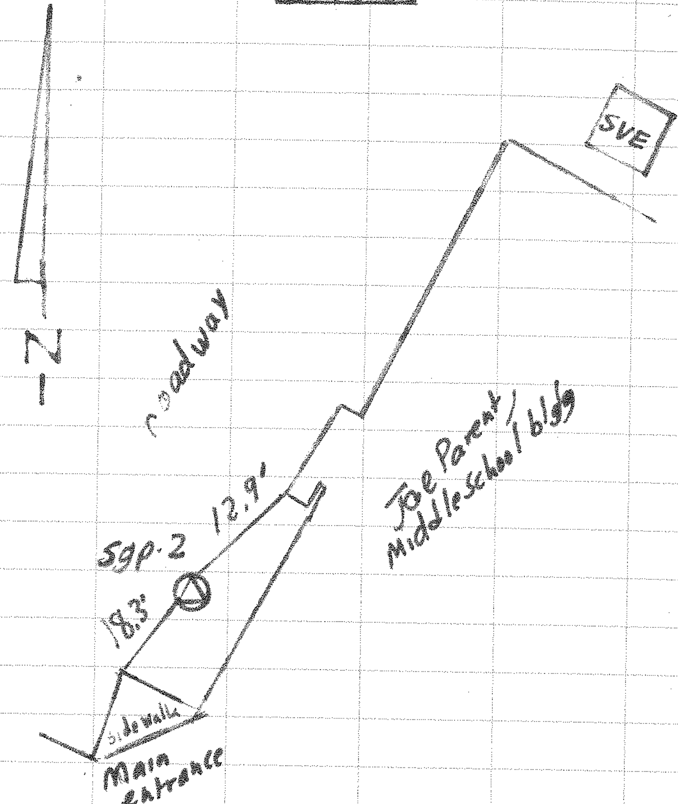


MW-12



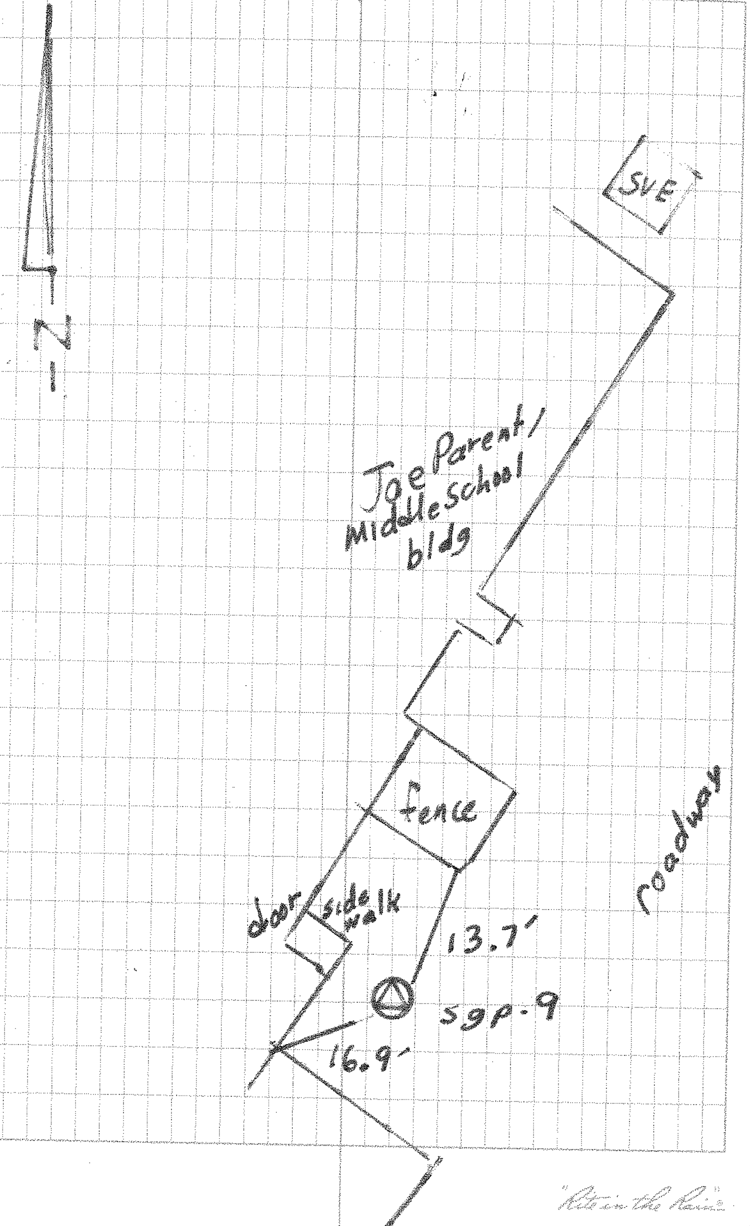
"Rite in the Rain"

SGP-2



N
roadway
SVE
Joe Parent, Middleschool bldg
12.9'
SGP-2
18.3'
sidewalk
Main entrance

SGP-9



N
SVE
Joe Parent, Middleschool bldg
fence
door
sidewalk
13.7'
SGP-9
16.9'
roadway

R. Bryan
W. Rhodes
E. McDonald

Aniak WACS
14-201-21

40 F, sun
Thurs, 5-12-11

Time	Well	DTW w/o	DTW w/	TD	datalogger
0655	MW-5	18.06'	18.05'	29.75'	1062390
~~0701~~ 0801	MW-6	16.31' ~~N/A~~ ~~17.68~~	N/A ~~17.68'~~	29.91'	N/A
0710	MW-7	17.67'	17.66'	50.65'	1062873
0701	MW-8	17.68'	17.68'	37.5'	1062265
0725	MW-9	11.14'	11.14'	30.95'	1062388
0739	MW-10	18.97'	18.97'	36.86'	1062867
0747	MW-11	19.54'	19.54'	37.25'	1062866
0730	MW-12	15.81'	15.81'	34.31'	1061507
0810	sgp-2	18.95'	N/A	28.71'	N/A
0755	sgp-9	18.96' ~~N/A~~	N/A ~~18.96'~~	25.67'	N/A
0710	MW-7	17.67'	17.66'	50.65'	1062728

0630 conduct tailgate safety meeting
0645 Onsite to gage wells & deploy dataloggers
0845 collect waste characterization Sample (VOC only) from sparging purge water / decon water drum, Sample ID: 11-AWA-012-GW
Purge / decon water summary: After sampling each well (5-10-11 – 5-11-11) purge & decon water was containerized in 5-gal bucket & transfered to 55-gal

1 of 2

R. Bryan

Aniak WACS
14-201-2

40F, Sun
Thurs, 5-12-11

~~datalogger~~ Notes	length to measurement line
OASIS location	27.92 ' BTOC
DTW: 16.31'	~~35.75 ' BTOC~~ N/A
S&W location	34.80 ' BTOC
OASIS location	35.75' BTOC
S&W location	29.65' BTOC
S&W location	32.64' BTOC
S&W location	33.60' BTOC
S&W location	32.02' BTOC
Soil gas point	N/A
Soilgas point	N/A
Barologger	1.28' BTOC

drum where sparging was occuring. Sparging continued overnight for 2 nights, until 0840 on 5-12-11.
0905 QA/QC Samples & complete COC., pack coolers, & supplies.
1100 ship gear.
1135 OASIS offsite

2 of 2

BOOK #2

Rite in the Rain®
ALL-WEATHER
FIELD
№ 353N

ANIAK - WHITE ALICE
COMMUNICATIONS SITE
GROUNDWATER STUDY

PROJECT # M-201

~~6/20/11~~ 6/21/11 E. McDONALD RAIN/CLOUDS 1

ANIAK ≈55°F

11:50 ARRIVED IN ANIAK

12:15 UNPACKE GEAR, ATE LUNCH.

13:00 PREPPED TO DOWNLOAD LEVELLOGGERS

TIME	WELL	DTW	LOGGER	NOTES
15:35	MW-5	28.65	1062390	N/A
13:35	MW-6	26.72	N/A	N/A
14:05	MW-7	28.46	1062873	DEPLOYED ON ROPE SO RE-DEPLOYED W/STEEL CABLE 34.80' BTOC
14:35	MW-8	28.45	1062265	N/A
15:55	MW-9	21.61	1062388	RE-DEPLOYED ON STEEL CABLE @ 29.65' BTOC
16:40	MW-10	29.53	1062867	RE-DEPLOYED ON STEEL CABLE @ 32.64' BTOC
18:00	MW-11	30.60	1062866	STILL ON STRING NEED TO RE-DEPLOY
17:30	MW-12	25.86	1061507	STILL ON STRING NEED TO REDEPLOY
--	SG-2	--	--	TRUCK PARKED ON TOP
18:20	SG-9	DRY	N/A	N/A
--	MW-7	--	1062728	BAROLOGGER (B-1)

13:15 FOUND WELLS - WAIT TILL AFTER ~~2~~ 14:00 READING BEFORE PULLING.

~~15:25~~

17:30 RAN OUT OF SWIVELS FOR RE-DEPLOYING LEVELOGGERS WHICH ARE ON S&W STRING. MW-11 & MW-12 WERE REPLACED IN WELL W/STRING.

18:40 COMPLETED GAGING, LEVELOGGER DWNLD & RE-DEPLOYING W/STEEL WHERE POSSIBLE.

2 6/20/11 ~~6/21/11~~ EMcDONALD

ANIAK

NOTE: STRING WAS PRETTY STRETCHY, SOMEWHAT DIFFICULT TO TELL WHERE THEY WERE MEASURING TO. I MEASURED STEEL LENGTH BASED ON MEASUREMENT RECORDED BY R.BRYAN ON 5/12/11. & CLIPPED LOGGERS TO SIDE OF CASING W/SWIVEL CLIP.

19:45 SET UP SYPHON TO DISPOSE OF PURGE H_2O FROM MAY EVENT PER ANALYTICAL RESULTS. WORKING ON 14-184.

21:45 EMAIL CODY & JANE. END OF DAY.

2 6/20/11 ~~6/21/11~~ EMcDONALD

ANIAK

NOTE: STRING WAS PRETTY STRETCHY, SOMEWHAT DIFFICULT TO TELL WHERE THEY WERE MEASURING TO. I MEASURED STEEL LENGTH BASED ON MEASUREMENT RECORDED BY R.BRYAN ON 5/12/11. & CLIPPED LOGGERS TO SIDE OF CASING W/SWIVEL CLIP.

19:45 SET UP SYPHON TO DISPOSE OF PURGE H_2O FROM MAY EVENT PER ANALYTICAL RESULTS. WORKING ON 14-184.

21:45 EMAIL CODY & JANE. END OF DAY.

M. Ahlrichs ANIAK 60 sunny no wind 9/22/13

~~1400~~ MA 9/22 1345 Arrive on site + uncover lids

1405 MW-9, depth to water = 21.88ft

1415 MW-7, DTW = 28.71ft

1425 MW-8, DTW = 28.70 ft

1600 MW-6, DTW = 26.99ft

* Note: unable to locate MW-5. Road has been graded + was unable to find w/ swing ties + metal detector

M. Ahlrichs

10/18/11 N. Ballou Rain/Snow
Aniak +35°F

1400 Unpack gear at school
1430 Calibrate YSI
1640 Set up on MW-09
1725 Sample ID: 11-AWA-013-GW
1800 Set up on MW-07
Sample ID: 11-AWA-014-GW
time: 1835
1845 Pack up gear and return to School.

10/18/11

Overcast N. Ballou &
+30°F R. Burich
Aniak 10/19/11

Calibrate YSI
1030 Load up gear on 4-wheeler.
1040 Set up on MW-8
Sample ID: 11-AWA-015-GW
time: 1115
Also collect MS/MSD
1140 Set up on MW-6
Sample ID: 11-AWA-016-GW
time: 1330
Submersible pump was not able to have low enough flow for this well so used bailer.
1400 Remove, download, re-deploy data loggers (see next page)
1550 Set up on MW-12
Sample ID: 11-AWA-017-GW Time: 1650
Pump stopped working while taking parameters. Changed pumphead and it worked fine
1720 Set up on MW-11
Sample ID: 11-AWA-018-GW Time: 1745
dup Sample ID: 11-AWA-019-GW Time: 1755

10/19/11

1/4

10/18/11 — N. Bullock, R. Burich — Aniak — + 30's Overcast

Photos

- looking towards MW-9 from -MW-8.
- looking towards Main entrance from MW-8
- looking towards former antenna foundation from MW-5
- looking at wood shop door
- looking at high school from wood shop
- antenna Foundation from MW-11
- Backside of SSD trailer from MW-11
- from backside of SSD trailer looking towards runway
- from antenna found. to MW-11
- Antenna found to highschool
- MW-10
- Burnt out pump (2 photos)
- Bubbler system of purge water
- Main entrance JPVC
- MW-4 not accessable
- Tank farm from MW-5
- Near MW-9 towards Runway

N. Bullock, R. BURICH, E. McDONALD

10/19/11 ANIAK

TIME	WELL	1° DTW	2° DTW	LOGGER	NOTES
14 09	MW-5	N/A	N/A	1062390	DRY
N/A	MW-6	—	—	N/A	—
14 20	MW-7	30.31	30.31	1062873	—
14 27	MW-8	30.31	30.31	1062265	—
14 51	MW-9	23.50	23.50	1062388	—
15 05	MW-10	31.41	31.41	1062867	—
GM 15 35 ~~15 19~~	MW-11	32.41 ~~27.81~~	N/A	1062866	STRING 33.38 CABLE 33.60
1519 ~~15 35~~	MW-12	27.81 ~~31.41~~	N/A	1061507	STRING 32.10 CABLE 32.02
N/A	MW-7	— —	— —	1062728	BAROLOGGER (B-1)

NOTE: AS DESCRIBED ON 6/20/11 THE STRINGS WERE VERY STRETCHY & IT WAS DIFFICULT TO DETERMINE WHERE TO MEASURE FROM. AN ATTEMPT WAS MADE BY PULLING, NOT TO THE MAX, BUT FIRMLY & THEN MEASURING TO THE INTERIOR CAP RING. THE CABLE WAS THEN CUT TO MATCH THE LENGTH MEASUREMENT RECORDED ON 5/12/11. THE DIFFERENCE SHOWS ERROR INTRODUCED. IT IS NOT CLEAR WHY THE MEASURED STRING LENGTH IN MW-11 WAS SHORTER THAN MEASURED ON 5/12/11.

[signature] 10/19/11

N. Ballou
R. Burich

10/19/11 Aniak Overcast + 30's

1800 Set up on MW-10
Sample ID: 11-AWA-020-GW
Time: 1830

1840 Pack up gear and return to school
NOTE: MW-5 was dry so no sample was taken.

1900 Take purge water to bubbler

1915 off site

4/4

N. Ballou
R. Burich

Aniak

Overcast 30's 10/20/11

0900 Sample Summary

Date	Time	Well	Sample ID	VOC	Notes
10-18-11	1725	MW-09	11-AWA-013-GW	X	
10-18-11	1835	MW-07	11-AWA-014-GW	X	
10-19-11	1115	MW-08	11-AWA-015-GW	X	MS/MSD
10-19-11	1330	MW-06	11-AWA-016GW	X	
10-19-11	1650	MW-12	11-AWA-017GW	X	
10-19-11	1745	MW-11	11-AWA-018-GW	X	
10-19-11	1755	MW-11	11-AWA-019GW	X	Dup
10-19-11	1830	MW-10	11-AWA-020-GW	X	
10-20-11	1015	DRUM	11-AWA-021-GW	X	Waste Charact.

0930 Pack up gear for shipping. including GW IDW from ~~15~~ May 2011 and Oct 2011 events.

1010 Take waste characterization sample from purge/decon water drum. Sample ID: 11-AWA-021-GW
time: 1015

N. Ballou 10/20/11

1/2

10/20/11 HMI AK N. Bullau R. Burich overcast 30's

1040 Ice and pack sample cooler up.

1140 Take gear to everett's air cargo for shipping

1200 Clean/Sweep wood shop

1300 leave for airport

N. Bullau 10/20/11

2/2

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-9
Date: 5-10-11
Start Time: 1040
End Time:

Project # : 14-201, Phase 2
Project Name: Aniak WACS FS
Site: Aniak WACS
Field Team: R. Bryan / W. Rhodes
Sample ID: 11-AWA-001-GW Time: 1125 primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): fultz
Total Volume Purged:

Weather Conditions: 30F, sun

Depth to Top of Product (ft BTOC):
Depth to Oil/Water Interface* (ft BTOC):
* Note: Same as depth to water

Depth to Water (ft BTOC): 11.59'
Total Depth (ft BTOC): 30.95'

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge / sample rate ≈ 160 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1105	4.89	6.46	0.309	None	17.7	195.0	Clear	None	11.58'	-0.01'
2	1108	5.26	6.38	0.307		9.5	176.1			11.58'	0.00'
3	1111	5.01	6.37	0.308		9.1	169.2			11.58'	0.00'
4	1114	4.66	6.37	0.308		8.0	159.0			11.58'	0.00'
5	1117	4.43	6.37	0.309		7.6	148.3			11.58'	0.00'
6	1120	4.26	6.42	0.309		7.4	141.1			11.58'	0.00'
Final 7 post sample	1200									11.56'	-0.02'
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/ite	1	
Fe/Mn	1	
(F) Fe/Mn	1	

Signed: [signature] Date: 5-10-11

Ethane/Ethene/Methane 2

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

		Well ID:	MW-7* closest to fuel line
Project # :	14-201, Phase 2	Date:	5-10-11
Project Name:	Aniak WACS FS	Start Time:	1320
Site:	Aniak WACS	End Time:	1415
Field Team:	R. Bryan/W. Rhodes		

Sample ID:	11-AWA-002-GW	Time: 1350	primary	dup	split	ms/msd
Sample ID:		Time:	primary	dup	split	ms/msd
Sample ID:		Time:	primary	dup	split	ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): fultz

Total Volume Purged:

Weather Conditions: 30F, partly cloudy

Depth to Top of Product (ft BTOC):	/	Depth to Water (ft BTOC):	17.99'
Depth to Oil/Water Interface* (ft BTOC):	/	Total Depth (ft BTOC):	30.65'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge/sample rate ≅ 200 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1330	5.04	6.56	0.256	LOW	6.09	162.5	Clear	None	17.99'	0.00'
2	1333	4.87	6.48	0.260	|	2.67	155.4	|	|	18.00	0.01'
3	1336	4.77	6.42	0.267	None	1.51	147.7	|	|	18.00	0.00'
4	1339	4.75	6.43	0.269	|	1.44	142.5	|	|	18.00	0.00'
5	1342	4.57	6.43	0.270	|	1.30	136.7	|	|	17.99	-0.01'
6	1345	4.76	6.44	0.270	|	1.19	131.5	|	|	18.00	0.01'
7	1348	4.70	6.44	0.271	|	1.11	128.7				
Final 8 post sample	1413									17.97	-0.03'
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/-ite	1	
Fe/Mn	1	
(F) Fe/Mn	1	

Signed: R. Bryan Date: 5-10-11

Ethane/Ethene/Methane 2

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-8*, closest to fence

Project # : 14-201, Phase 2 — Date: 5-10-11

Project Name: Aniak WACS FS — Start Time: 1415

Site: Aniak WACS — End Time: 1525

Field Team: R. Bryan / W. Rhodes

Sample ID: 11-AWA-003-GW — Time: 1455 — primary dup split ms/msd

Sample ID: — Time: — primary dup split ms/msd

Sample ID: — Time: — primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): fultz

Total Volume Purged:

Weather Conditions: 35F, sun

Depth to Top of Product (ft BTOC): — Depth to Water (ft BTOC): 18.01'

Depth to Oil/Water Interface* (ft BTOC): — Total Depth (ft BTOC): 37.5'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Sample/purge rate ≈ 200 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1435	5.02	6.45	0.345	None	3.58	184.0	Clear	None	18.01'	0.00'
2	1438	4.21	6.48	0.341	|	1.18	171.2	|	|	18.00'	-0.01'
3	1441	4.08	6.44	0.340	|	1.02	161.5	|	|	18.00'	0.00'
4	1444	3.93	6.43	0.338	|	0.92	152.5	|	|	18.00'	0.00'
5	1447	3.95	6.43	0.337	|	0.88	149.5	|	|	18.00'	0.00'
6	1450	3.80	6.42	0.338	|	0.82	146.8	|	|	18.00'	0.00'
Final 7 post sample										18.00'	0.00'
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/ite	1	
Fe/Mn	1	
(E) Fe/Mn	1	
Ethane-Ethene-Methane	2	

Signed: R. Bryan — Date: 5-10-11

Signed/reviewer: — Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-6

Project # : 14-201, Phase 2 | Date: 5-10-11

Project Name: Aniak WACS FS | Start Time: 1525

Site: Aniak WACS | End Time: 1700

Field Team: R. Bryan, W. Rhodes

Sample ID: 11-AWA-004-GW Time: ~~1415~~ 1615 RB primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Fultz

Total Volume Purged:

Weather Conditions: 40F, partly cloudy, wind

Depth to Top of Product (ft BTOC): / | Depth to Water (ft BTOC): ~~29.~~ ~~16.73~~ ~~16.66~~ 16.66' RB

Depth to Oil/Water Interface* (ft BTOC): / | Total Depth (ft BTOC): 29.91' RB

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge/sample rate ≈ mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1554	6.16	6.20	0.287	None	5.85	152.7	Clear	None	16.73'	~~0.00~~ RB
2	1557	4.70	6.15	0.290	Low	2.02	134.2	|	|	16.75'	0.02'
3	~~1560~~ 1600	4.21	6.23	0.279	|	1.12	118.5	|	|	16.74'	-0.01'
4	1603	4.25	6.25	0.276	|	1.01	111.1	|	|	16.74'	0.00'
5	1606	4.61	6.31	0.274	None	0.92	92.4	|	|	16.74'	0.00'
6	1609	4.76	6.32	0.275	|	0.88	80.9	|	|	16.73'	-0.01'
7	1612	4.33	6.32	0.277	|	0.87	78.1	|	|	16.73'	0.00
Final 8 Post sample	1700									16.66'	
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/-ite	1	
Fe/Mn	1	
(F) Fe/Mn	1	
Ethane/Ethene/Methane	2	

Signed: [signature] Date: 5-10-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-12

Project # : 14-201, Phase 2 Date: 5-10-11

Project Name: Aniak WACS FS Start Time: 1720

Site: Aniak WACS End Time: ~~1720~~ RB

Field Team: R. Bryan / W. Rhodes

Sample ID: 11.AWA-005-GW Time: 1800 primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): fultz

Total Volume Purged:

Weather Conditions: 30 F, overcast, wind

Depth to Top of Product (ft BTOC): Depth to Water (ft BTOC): 16.16'

Depth to Oil/Water Interface* (ft BTOC): Total Depth (ft BTOC): 34.31'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge / sample rate ≈ 200 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1741	2.05	6.28	0.257	Very Turbid	2.99	134.0	Brown	None		
2	1744	2.28	6.22	0.251	High	1.50	129.9	Grey	|	16.16'	0.00'
3	1748	2.02	6.21	0.253	Low	1.16	128.3	|	|		
4	1751	2.53	6.18	0.253	|	1.01	125.8	|	|	16.16'	0.00'
5 1754	~~1753~~	2.75	6.27	0.254	Clear	0.99	118.9	Clear	|	16.16'	0.00'
6	1757	2.96	6.19	0.254	|	0.95	115.5	|	|		
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/ite	1	
Fe/Mn	1	
F) Fe/Mn	1	
Ethane/ethene/methane	2	

Signed: [signature] Date: 5-10-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-10
Project # : 14-201, Phase 2 | Date: 5-10-11
Project Name: Aniak WACS FS | Start Time: 1830
Site: Aniak WACS | End Time:
Field Team: R. Bryan / W. Rhodes
Sample ID: 11-AWA-006-GW Time: 1910 primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Fultz
Total Volume Purged:

Weather Conditions: 30F, overcast, wind

Depth to Top of Product (ft BTOC): — | Depth to Water (ft BTOC): 19.23'
Depth to Oil/Water Interface* (ft BTOC): — | Total Depth (ft BTOC): 36.86'
* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	RB Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1849	5.20	6.44	0.275	~~Low~~ None	8.63	200.4	Clear	None	19.24	0.01
2	1852	4.96	6.30	0.272	|	1.70	193.2	|	|	19.23	-0.01
3	1855	4.13	6.27	0.270	|	0.78	180.7	|	|	19.23	0.00
4	1858	3.85	6.27	0.270	|	0.75	174.7	|	|	19.23	0.00
5	1901	3.72	6.29	0.270		0.79	168.9			19.22	-0.01
Final 6 Post sample	1920									19.20	-0.02
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	
Alk/Sulf/Chloride	1	
TOC	4	
Nitrate/Nitrite	1	
Fe/Mn	1	
(F) Fe/Mn	1	
Ethane/ethene/methane	2	

Signed: [signature] Date: 5-10-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: SGP-9

Project # : 14-201, Phase 2 | Date: 5-11-11

Project Name: Aniak WACS FS | Start Time: 0920

Site: Aniak WACS | End Time: 1100

Field Team: Rhodes, Bryan

Sample ID: 11-AWA-007-GW Time: 1040 primary dup split ms/msd

Sample ID: ____ Time: ____ primary dup split ms/msd

Sample ID: ____ Time: ____ primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Fultz

Total Volume Purged:

Weather Conditions: 30°F, Overcast

Depth to Top of Product (ft BTOC): / | Depth to Water (ft BTOC): 19.08

Depth to Oil/Water Interface* (ft BTOC): / | Total Depth (ft BTOC): 25.67

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge / sample rate ≅ 200 mL / min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1007	4.96	6.47	0.164	None	15.10	220.6	Clear	None	20.09'	1.01'
2	1011	4.57	6.00	0.163	|	12.21	221.0	|	|	20.30'	0.21'
3	1014	4.16	5.87	0.172	Low	10.35	217.4	Grey	|	20.08'	-0.22'
4	1017	3.94	5.95	0.180	|	10.11	212.2	|	|	20.05'	-0.03'
5	1020	3.71	5.90	0.185	|	9.53	204.7	|	|	20.05'	0.00'
6	1023	3.94	5.94	0.192	High	8.56	209.6	Brown	|	20.38'	0.33'
7	1027	4.04	5.93	0.216	|	7.88	205.1	|	|	20.28'	-0.10'
8	1030	3.86	5.93	0.222	|	7.58	204.1	|	|	20.26'	-0.02'
9	1034	4.05	5.91	0.222	|	7.09	201.2	|	|	20.31'	0.05'
Final 10 post sample	1059									19.55'	
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected
VOC	3
Alk/Sulf/Chloride	1
TOC	4
Fe / Mn	1
(F) Fe / Mn	1
Nitrate/-ite	1
Ethane / Ethene / Methane	2

Comments: This well had not been previously sampled as it is a soilgas point. A portion of the purge time and high turbidity of the water is attributed to no prior well development.

Signed: [signature] Date: 5-11-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-11

Project # : 14-201, Phase 2 — Date: 5-11-11

Project Name: Aniak WACS FS — Start Time: 1115

Site: Aniak WACS — End Time: 1545

Field Team: R. Bryan, W. Rhodes

Sample ID: 11-AWA-008-GW Time: 1505 primary dup split ms/msd

Sample ID: ______ Time: ______ primary dup split ms/msd

Sample ID: ______ Time: ______ primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): ~~fultz~~ peristaltic

Total Volume Purged:

Weather Conditions: 40F, sun

Depth to Top of Product (ft BTOC): /

Depth to Oil/Water Interface* (ft BTOC): /

* Note: Same as depth to water

Depth to Water (ft BTOC): 19.58'

Total Depth (ft BTOC): 37.25'

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge/sample rate ≅ 160 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1428	4.37	7.54	0.290	Low	5.55	42.9	Grey	None	19.55	-0.03'
2	1432	4.17	8.47	0.290	|	2.47	-30.9	|	|	19.55	0.00'
3	1436	4.11	8.08	0.289	None	1.93	-51.7	Clear	|	19.55	0.00'
4	1439	4.22	7.19	0.288	|	1.71	-35.9	|	|	19.55	0.00'
5	1442	4.16	6.74	0.287	|	1.59	-21.2	|	|	19.55	0.00'
6	1446	4.14	6.62	0.286	|	1.52	-12.1	|	|	19.55	0.00'
7	1449	4.04	6.56	0.286	|	1.47	-10.0	|	|	19.55	0.00'
8	1452	3.96	6.46	0.287	|	1.40	0.4	|	|	19.55	0.00'
9	1455	4.06	6.49	0.285	|	1.31	12.8	|	|	19.55	0.00'
10	1459	4.09	6.37	0.284	|	1.27	16.8	|	|	19.55	0.00'
11	1502	4.01	6.35	0.285	|	1.27	20.3	|	|	19.55	0.00'
Final 12 post sample										19.52	-0.03'

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected
VOC	3 x3 = 9
Alk(sulf)Chloride	1
TOC	4
Nitrate/-ite	1
Fe/Mn	1
(F) Fe/Mn	1
Ethane/Ethene/Methane	2

Comments: Sgp-9 may have been too turbid for fultz pump. Upon set up at MW-11, fultz pump amps increased to 4, then decreased to 0, then control box stopped working. OKed w/ Jane, switch to peristaltic pump.

Signed: [signature] Date: 5-11-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: SgP-2
Date: 5-11-11
Start Time: 1549
End Time: 1800

Project # : 14-201, Phase 2
Project Name: Aniak WACS FS
Site: Aniak WACS
Field Team: R. Bryan / W. Rhodes
Sample ID: 11-AWA-009-GW Time: 1730 primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): peristaltic
Total Volume Purged:

Weather Conditions: 40 F, sun

Depth to Top of Product (ft BTOC): /
Depth to Oil/Water Interface* (ft BTOC): /
* Note: Same as depth to water

Depth to Water (ft BTOC): 18.96'
Total Depth (ft BTOC): 28.71'

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge / sample rate ≅ 160 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1659	4.94	6.66	0.302	Medium	10.38	132.1	brown	none	20.11	1.15'
2	1704	4.37	7.20	0.297		5.00	73.8			20.10	-0.01'
3	1707	4.24	7.34	0.291		4.48	45.1			19.85	-0.25'
4	1710	4.17	7.49	0.291	High	4.20	21.0			19.97	0.12'
5	1713	4.18	7.92	0.287	Very Turbid	3.92	4.5			19.98	0.01'
6	1716	4.33	7.99	0.286		3.44	13.5			19.99	0.01'
7	1719	4.37	8.04	0.284		3.54	33.6			20.07	0.08'
8	1722	4.26	8.08	0.276		3.11	79.6			20.30	0.23'
9	1725	4.34	8.37	0.235		3.24	30.5				
Final 10 post sample	1750									19.71	-0.59'
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected
VOC	3
Alk/Sulf/Chloride	1
TOC	4
Nitrate/-ite	1
Fe/Mn	1
(F) Fe/Mn	1
Ethane/Ethene/Methane	2

Comments: Hole in silicone tubing caused pumping delay (1549-1659). Sand deposited inside flow through cell during purging.

Signed: R. Bryan Date: 5-11-11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-5

Project # : 14-201, Phase 2 — Date: 5-11-11

Project Name: Aniak WACS FS — Start Time: 1808

Site: Aniak WACS — End Time: 1930

Field Team: R. Bryan / W. Rhodes

Sample ID: 11-AWA-010-GW — Time: 1850 — primary dup split ms/msd (VOC & MNA)

Sample ID: 11-AWA-011-GW — Time: 1910 — primary dup split ms/msd (VOC & MNA)

Sample ID: — Time: — primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): peristaltic

Total Volume Purged:

Weather Conditions:

Depth to Top of Product (ft BTOC): / — Depth to Water (ft BTOC): 18.57'

Depth to Oil/Water Interface* (ft BTOC): / — Total Depth (ft BTOC): 29.75'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

purge/sample rate = 200 mL/min

Round	Time	Temp °C	pH	Conduct'ity (mS/cm)	OB Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1816	7.11	6.45	0.291	~~Clear~~ None	7.95	153.4	Clear	None	18.21	-0.36'
2	1822	5.30	6.12	0.295		6.48	149.6			18.21	0.00'
3	1825	6.21	6.14	0.294		5.50	137.0			18.21	0.00'
4	1828	6.24	6.26	0.293		5.15	128.0			18.21	0.00'
5	1831	4.65	6.49	0.297		5.07	123.6			18.21	0.00'
6	1834	4.73	6.58	0.292		4.69	114.6			18.21	0.00'
7	1837	4.98	6.79	0.291		4.62	102.9			18.21	0.00'
8	1840	4.88	6.84	0.291		4.65	96.0			18.21	0.00'
9	1843	5.18	7.07	0.287		4.46	86.1			18.21	0.00'
10	1846	5.37	7.31	0.285		4.46	76.5			18.21	0.00'
11	1849	5.12	7.57	0.286		4.61	66.0				
Final 12 post sample	1929									18.20	-0.01'

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3 x 2 = 6	We have enough MNA bottles to do a duplicate
Alk/Sulf/Chloride	1 x 2 = 2	on MNAs also.
TOC	4 x 2 = 8	Parameters did not stabilize.
Nitrate/ite	1 x 2 = 2	
Fe / Mn	1 x 2 = 2	

Ethane/Ethene/Methane 2 x 2 = 4

Signed: [signature] — Date: 5-11-11

(F) Fe / Mn 1 x 2 = 2

Signed/reviewer: — Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-9

Project # : 14-201, Phase 2

Date: 10/18/11

Project Name: Aniak WACS FS

Start Time: 1640

Site: Aniak WACS

End Time: 1730

Field Team: N Bulle R Burich

Sample ID: 11-AWA-013-GW Time: 1725 primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Submersible

Total Volume Purged: 2.5 gal

Weather Conditions: Snow/Rain 30's

Depth to Top of Product (ft BTOC): N/A

Depth to Oil/Water Interface* (ft BTOC): N/A

Depth to Water (ft BTOC): 23.51'

Total Depth (ft BTOC): 29.98'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Round	Time	Temp °C	pH	Conduct'ity (mS/cm³)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1650	5.13	5.57	.351	Med	4.657	161.4	Green	None	23.52	-.01
2	1655	4.52	5.51	.352	Low	.52	163.5	Clear	|	23.52	0.0
3	1658	4.38	5.49	.354	|	.48	163.6	|	|		
4									Final	23.58	
5											
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	

Signed: Nelle Bahr

Date: 10/19/11

Signed/reviewer:

Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-8

Project # : 14-201, Phase 2 | Date: 10/19/11

Project Name: Aniak WACS FS | Start Time: 1040

Site: Aniak WACS | End Time: 1130

Field Team: N. Ballou / R. Burich

Sample ID: ~~MW~~ 11-ANA-015-GW Time: 1115 primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): submersible

Total Volume Purged: 1.5 gal

Weather Conditions: +30°s. overcast

Depth to Top of Product (ft BTOC): N/A | Depth to Water (ft BTOC): 30.31'

Depth to Oil/Water Interface* (ft BTOC): N/A | Total Depth (ft BTOC): 37.92'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Flow = 300 mL/min

Round	Time	Temp °C	pH	Conduct'ity ( )	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1106	3.12	5.81	.413	None	2.72	112.0	Clear	None	30.32	~.01
2	1109	3.39	5.47	.403	|	2.20	132.6	|	|	30.32	0.0
3	1111	3.48	5.47	.405	|	2.07	138.9	|	|	|	|
4	1114	3.69	5.47	.405	|	1.98	142.6	|	|		|
5									Final	30.32	
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected
VOC	9

Comments:

1.98
.198
1.178

Signed: N. Ballou | Date: 10/19/11

Signed/reviewer: | Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Project # : 14-201, Phase 2	Well ID: MW-06
Project Name: Aniak WACS FS	Date: 10-19-11
Site: Aniak WACS	Start Time: 1140
Field Team: N. Ballew/ R. Burich	End Time: 1330

Sample ID: ~~MW~~ 11-AWA-06-GW Time: 1315 primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): ~~Sub.~~ Bailer*
Total Volume Purged: 2400 mL

Weather Conditions: Sunny ≈35°F

Depth to Top of Product (ft BTOC): N/A
Depth to Oil/Water Interface* (ft BTOC): N/A
Depth to Water (ft BTOC): 28.61'
Total Depth (ft BTOC): 29.91
* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Round	Time	Temp °C	pH	Conduct'ity ( )	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1255	3.85	5.28	.275	HIGH	9.89	187.8	Brown	None	28.91	-.3
2	1300	3.65	3.24	.275	Medium	8.09	211.4	|	|	28.60	+.3
3	1313	2.98	4.96	.255	|	10.18	232	|	|	28.91	-.3
4									Final	28.61	+.3
5											
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected
VOC	3

Comments:

Purge Volume: 800, 150, 500, 450, 500 = 2400

2" dia. casing
*Had to use bailer because water column was small and recharging very slowly.
Removed 3 well casings volumes before sample

Signed: Nalin Ballew Date: 10/19/11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MM-12
Date: 10-19-11
Start Time: ~~1550~~ 1550
End Time: ~~16~~ 1700

Project # : 14-201, Phase 2
Project Name: Aniak WACS FS
Site: Aniak WACS
Field Team: N. Ballon / R. Burich

Sample ID:	Time:				
~~AAA~~ 11-AWA-017-GW	1650	primary	dup	split	ms/msd
		primary	dup	split	ms/msd
		primary	dup	split	ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Submersible
Total Volume Purged: 3 gal

Weather Conditions: Overcast + 30's ≈

Depth to Top of Product (ft BTOC):
Depth to Oil/Water Interface* (ft BTOC):
* Note: Same as depth to water

Depth to Water (ft BTOC): 27.80'
Total Depth (ft BTOC): 34.34

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Flow rate 360 ml/min / 250 ml/min after pump motor changeout

Round	Time	Temp °C	pH	Conduct'ity ( )	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1557	2.44	5.57	0.553	High	2.47	256.7	Grey	none	27.81	0
2	1600	2.46	5.57	0.503	Medium	2.36	254.9	Grey	none	27.81	0
3	1603	2.52	5.58	0.482	Clear/None	2.26	249.1	Clear	none	27.81	0
4	1636	2.95	5.68	0.434	High	5.83	240.4	Grey	none	27.81	0
5	1640	3.11	5.68	0.427	Medium	5.02	235.5	Grey	none	27.81	0
6	1643	3.10	5.70	0.427	Medium	4.51	233.7	Grey	none	27.81	0
7	1646	3.23	5.70	0.424	Low	3.96	231.7	Clear	none	27.81	0
8										final 22.81	
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	changed pump head out 1603

Signed: Nelly Ballon Date: 10/19/11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-11
Date: 10-19-11
Start Time: 1720
End Time: 1800

Project # : 14-201, Phase 2
Project Name: Aniak WACS FS
Site: Aniak WACS
Field Team: M. Ballou / R. Burich
Sample ID: 11-AWA-018-GW Time: 1745 primary dup split ms/msd
Sample ID: 11-AWA-019-GW Time: 1755 primary dup split ms/msd
Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Sub.
Total Volume Purged: 1.5 gal

Weather Conditions: Overcast low+ 30's

Depth to Top of Product (ft BTOC): N/A
Depth to Oil/Water Interface* (ft BTOC): N/A
* Note: Same as depth to water

Depth to Water (ft BTOC): 32.41'
Total Depth (ft BTOC): 37.32'

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:
Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown
Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations Flow = 320 ml/L

Round	Time	Temp °C	pH	Conduct'ity ( )	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1734	2.89	5.50	.318	Medium	2.48	237.4	Grey	None	32.45	-.04
2	1737	3.10	5.48	.315		1.94	234.2			32.47	-.02
3	1740	3.55	5.51	.311		1.96	223.5			32.50	-.03
4	1743	3.45	5.54	.313		1.82	218.4			32.46	+.04
5									Final	32.41	
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	6	1.96 .196 2.16 1.82 .182 2.00

Signed: [signature] Date: 10/19/11

Signed/reviewer: Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-10

Date: 10-19-11

Project # : 14-201, Phase 2

Project Name: Aniak WACS FS

Start Time: 1800

Site: Aniak WACS

End Time: 1840

Field Team: W. Ballan / R. Burch

Sample ID	Time				
11-AWA-020-GW	1830	primary	dup	split	ms/msd
		primary	dup	split	ms/msd
		primary	dup	split	ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Submersible

Total Volume Purged: ~~1 gal~~

Weather Conditions: overcast high 20's

Depth to Top of Product (ft BTOC): N/A

Depth to Oil/Water Interface* (ft BTOC): NA

Depth to Water (ft BTOC): 31.41'

Total Depth (ft BTOC): 36.90'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations

Flow = 250 ml/min

Round	Time	Temp °C	pH	Conduct'ity ( )	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1813	3.28	5.72	.450	Med.	3.34	229.9	Grey	/	31.44	-.03
2	1816	3.78	5.72	.454	|	2.52	227.7	|	|	31.44	.0
3	1819	3.72	5.79	.460	|	1.41	222.8	|	|	|	|
4	1822	3.64	5.81	.460	|	1.09	221.9	|	|		
5									Final	31.41'	
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	.460 × .03 = .0138 ; .460 + .0138 = .470

Signed: WmBallan

Date: 10/19/11

Signed/reviewer:

Date:

Low-Flow Groundwater Sampling with Minimal Drawdown Worksheet

Well ID: MW-7

Project # : 14-201, Phase 2

Date: 10/18/11

Project Name: Aniak WACS FS

Start Time: 1800

Site: Aniak WACS

End Time: 1845

Field Team: N Ballar R. Burch

Sample ID: 11-AWA-014-GW Time: 1835 primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Sample ID: Time: primary dup split ms/msd

Purging and Sampling Method (e.g. peristaltic, bladder, submersible): Submersible

Total Volume Purged: 2 gal

Weather Conditions: Overcast +30s light snow

Depth to Top of Product (ft BTOC): N/A

Depth to Water (ft BTOC): 30.34'

Depth to Oil/Water Interface* (ft BTOC): N/A

Total Depth (ft BTOC): 51.2'

* Note: Same as depth to water

Criteria for Stable Parameters

Parameter	Working Range	Stability Criteria	Notes
Temperature	>0.00 °C	± 3%	
pH	0-14	± 0.1	
Conductivity	0-999 mS/m	± 3%	
ORP	± 1999 mV	± 10 mv	
Dissolved Oxygen	0-19.99 mg/L	± 10%	
Turbidity	0-800 NTU		

Sensory Observations

Color: Clear, Amber, Tan, Brown, Grey, Milky White, Other:

Odor: None, Low, Medium, High, Very Strong, H2S, Fuel Like, Chemical ?, Unknown

Turbidity: None, Low, Medium, High, Very Turbid, Heavy Silts

Instrument Observations .45 L/m

Round	Time	Temp °C	pH	Conduct'ity (ms/cm)	Turbidity (NTUs)	DO (mg/L)	ORP (mV)	Color	Odor	Water Level (ft BTOC)	Draw-down
1	1818	3.59	5.35	.141	Clear	.77	158.2	clear	None	30.35	-.01
2	1821	4.90	5.53	.229	None	.66	147.0	clear	|	30.36	-.01
3	1824	3.69	5.52	.230	|	.59	148.5	|	|	|	-|
4	1827	3.73	5.50	.243	|	.60	149.0	|	|	|	|
5										Final	30.35
6											
7											
8											
9											
10											
11											
12											

Notes: Drawdown should be less than 0.3 feet while sampling. Minimal drawdown shall be achieved and measured by pumping at a low rate (approximately 0.1 to 0.5 liter/minute) and continually measuring water levels in the well. Note that site's hydrogeology may make it difficult to achieve this specification.

Analyses	# of Bottles Collected	Comments:
VOC	3	

Signed: Nelie Baller

Date: 10/19/11

Signed/reviewer:

Date:

ATTACHMENT 2

Photograph Log

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Appendix B, Attachment 2:

Photo Log for 2011 Groundwater Monitoring Events

Photographs 1 through 15: General Site Photographs (October 2011)
Photographs 16 through 18: Detailed Monitoring Well Photographs (May 2011)
Photographs 19 and 20: Aniak Slough/Kuskokwim River (May 2011 and October 2011)

PHOTOGRAPH 1: LOOKING TOWARDS WOOD SHOP ENTRANCE FROM HIGH SCHOOL

PHOTOGRAPH 2: STANDING ADJACENT TO WOODSHOP LOOKING TOWARDS MW-11

PHOTOGRAPH 3: TAKEN FROM MW-11 LOOKING TOWARDS E. ANTENNA FOUNDATION

PHOTOGRAPH 4: TAKEN FROM MW-11 LOOKING N. TOWARDS RUNWAY

PHOTOGRAPH 5: TAKEN FROM MW-11 LOOKING WEST

PHOTOGRAPH 6: TAKEN FROM BEHIND SYSTEM TRAILERLOOKING SOUTHWEST

PHOTOGRAPH 7: MAIN ENTRANANCE

PHOTOGRAPH 8: TAKEN FROM MAIN ENTRANCE, MW-4 UNDER CONNEX

PHOTOGRAPH 9: TAKEN FROM MW-5 LOOKING TOWARDS BUILDING

PHOTOGRAPH 10: TAKEN FROM MW-5 LOOKING TOWARDS S ANTENNA FOUNDATION

PHOTOGRAPH 11: NEAR MAIN ENTRANCE LOOKING TOWARDS HIGH SCHOOL

PHOTOGRAPH 12: TAKEN NEAR HIGH SCHOOL LOOKING TOWARDS MW-5

PHOTOGRAPH 13: LOOKING TOWARDS MW-9 FROM MW-8

PHOTOGRAPH 14: TAKEN NEAR FENCE TO MW-9 LOOKING N. TOWARDS RUNWAY

PHOTOGRAPH 15: TAKEN AT MW-6 LOOKING TOWARDS HIGH SHOOL

PHOTOGRAPH 16: MW-7 (CLOSEST TO FENCE) AND MW-8

PHOTOGRAPH 17: SGP-9

PHOTOGRAPH 18: LEVELOGGER SETUP

PHOTOGRAPH 19: ANIAK SLOUGH/KUSKOKWIM RIVER AT ANIAK, LOOKING ROUGHLY NE (PHOTO TAKEN FROM RETAINING WALL; WATER LEVEL ¾ UP THE WALL)

PHOTOGRAPH 20: SAME GENERAL VIEW AS PHOTOGRAPH 19, (TAKEN 10/20/11)

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ATTACHMENT 3

QAR and ADEC Checklists

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Appendix B, Attachment 3:

Quality Assurance/Quality Control (QA/QC) Text and ADEC Checklists

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Laboratory QA/QC data associated with the analysis of project samples has been reviewed to evaluate the integrity of the analytical data generated during the May and October 2011 groundwater sampling events at the Joe Parent Voc-Technical Educational building in Aniak, AK to support the Focused Feasibility Study (FS) for groundwater remediation at the Former Aniak White Alice Site, Aniak, Alaska. Sampling was performed in accordance with a May 2011 work plan and its October 2011 addendum (OASIS, 2011a and b).

Water samples were shipped to OnSite Environmental Inc in Redmond, WA and Keystone Laboratories Inc in Newton, IA for analysis. May 2011 results were reported in work orders (WO): 1105-150 (OnSite) and 11E0946 (Keystone). October 2011 results were reported in OnSite WO 1110-167. Samples were collected, reported, and shipped in general accordance with the ADEC-approved work plan and addendum (OASIS, 2011a and b).

All data were reviewed in accordance with United States Environmental Protection Agency (USEPA) National Functional Guidelines for Organic Methods (EPA 2008), USEPA National Functional Guidelines for Inorganic Methods (EPA 2010) and ADEC regulatory guidance documents (ADEC 2005; 2008; 2009a; 2009b; 2010a; 2010b). This data review focused on the following QC parameters and their effect on the quality of data and usability: sample handling and chain-of-custody documentation; holding time compliance; field QC (trip blanks, field duplicates); laboratory QC (method blanks, surrogates, matrix spikes (MS) and MS duplicates (MSD); method reporting limits; and completeness).

All samples were extracted, digested and analyzed within the holding time criteria for the applicable analytical methods and in accordance with work plan (OASIS, 2010) specifications. All trip blank results were not detected (ND) at concentrations above the analytical reporting limit (RL) or practical quantitation limit (PQL).

During the May 2011 sampling event, 11 primary samples and 1 duplicate were collected and submitted – primary 10-AWA-010-GW with duplicate 10-AWA-011-GW. During the October 2011 sampling event, 8 primary samples and 1 duplicate were collected and submitted – primary 10-AWA-018-GW with duplicate 10-AWA-019-GW. All RPDs between primary and duplicate samples were within the ADEC recommended <30% between field duplicates.

The LCS percent recoveries (%R) and relative percent differences (RPDs) were within limits. MS/MSD %R and RPDs were within limits, with one exception. In WO 11E0946, the MSD %R and RPD was outside the quality control limits for dissolved iron and dissolved manganese. The associated sample is 11-AWA-001-GW. Associated positive and ND results were flagged J and UJ, and considered estimated. Method Reporting Limits (MRLs) and PQLs met or were below established criteria specified for all analyses in the project work plan. The reporting limits were also below the ADEC established cleanup levels and target levels.

The overall quality of the data was acceptable for the objectives established for this project. All sample results are considered usable for project objectives. No results were rejected. The overall project completeness is 100%.

REFERENCES

ADEC. 2005. *Draft Guidance on Developing Conceptual Site Models*, March 24.

ADEC. 2008. *18 AAC 75, Oil and Other Hazardous Substances Pollution Control*, October 9.

ADEC. 2009a. Technical Memorandum: Environmental Laboratory Data and Quality Assurance Requirements. March.

ADEC. 2009b. Draft Vapor Intrusion Guidance for Contaminated Sites. July.

ADEC. 2010a. Laboratory Data Review Checklist. Version 2.7. January.

ADEC. 2010b. Laboratory Data Review Checklist for Air Samples. Version 1.0. January.

EPA. 2008. *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA 540/R-94/012).

EPA. 2010. *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.* January (EPA 540-R-10-011).

OASIS, 2011a. Letter Work Plan to Mr. John Halverson, re: Final Work Plan for Additional Characterization and Groundwater Monitoring at Former Aniak WACS Site, Aniak, Alaska. May 2.

OASIS, 2011b. Letter Work Plan to Mr. John Halverson, re: Addendum to May 2, 2011 Final Work Plan for Additional Characterization and Groundwater Monitoring at Former Aniak WACS Site, Aniak, Alaska. October 6.

Laboratory Data Review Checklist

Completed by:	Melissa Pike		
Title:	Environmental Scientist	Date:	May 27, 2011
CS Report Name:	FORMER ANIAK WHITE ALICE SITE, ANIAK, AK	Report Date:	Jun 17, 2011
Consultant Firm:	OASIS Environmental, Inc		
Laboratory Name:	OnSite Environmental	Laboratory Report Number:	1105-150
ADEC File Number:		ADEC RecKey Number:	

1. Laboratory

a. Did an ADEC CS approved laboratory receive and perform all of the submitted sample analyses?

◉ Yes ○ No ○ NA (Please explain.) Comments:

b. If the samples were transferred to another "network" laboratory or sub-contracted to an alternate laboratory, was the laboratory performing the analyses ADEC CS approved?

◉ Yes ○ No ○ NA (Please explain) Comments:

Samples were not subcontracted or transferred to another network laboratory.

2. Chain of Custody (COC)

a. COC information completed, signed, and dated (including released/received by)?

◉ Yes ○ No ○ NA (Please explain) Comments:

b. Correct analyses requested?

◉ Yes ○ No ○ NA (Please explain) Comments:

3. Laboratory Sample Receipt Documentation

a. Sample/cooler temperature documented and within range at receipt (4° ± 2° C)?

◉ Yes ○ No ○ NA (Please explain) Comments:

Case narrative states samples were received within range. It is not documented on the COC.

b. Sample preservation acceptable - acidified waters, Methanol preserved VOC soil (GRO, BTEX, Volatile Chlorinated Solvents, etc.)?

◉ Yes ○ No ○ NA (Please explain) Comments:

c. Sample condition documented - broken, leaking (Methanol), zero headspace (VOC vials)?

◉ Yes ○ No ○ NA (Please explain) Comments:

Samples were reported in good condition.

d. If there were any discrepancies, were they documented? - For example, incorrect sample containers/ preservation, sample temperature outside of acceptance range, insufficient or missing samples, etc.?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no discrepancies.

e. Data quality or usability affected? (Please explain)

Comments:

Data quality and usability is not affect with respect to the laboratory receipt documentation.

4. Case Narrative

a. Present and understandable?

◉ Yes ○ No ○ NA (Please explain) Comments:

b. Discrepancies, errors or QC failures identified by the lab?

◉ Yes ○ No ○ NA (Please explain) Comments:

There are no discrepancies.

c. Were all corrective actions documented?

◉ Yes ○ No ○ NA (Please explain) Comments:

There are no corrective actions.

d. What is the effect on data quality/usability according to the case narrative?

Comments:

Data quality and usability is not affected.

5. Samples Results

a. Correct analyses performed/reported as requested on COC?

◉ Yes ○ No ○ NA (Please explain) Comments:

b. All applicable holding times met?

◉ Yes ○ No ○ NA (Please explain) Comments:

c. All soils reported on a dry weight basis?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no soil samples in this sample delivery group.

d. Are the reported PQLs less than the Cleanup Level or the minimum required detection level for the project?

◉ Yes ○ No ○ NA (Please explain) Comments:

e. Data quality or usability affected? (Please explain)

Comments:

Data quality and usability is not affected with respect to the reported sample results.

6. QC Samples

a. Method Blank

i. One method blank reported per matrix, analysis and 20 samples?

◉ Yes ○ No ○ NA (Please explain) Comments:

ii. All method blank results less than PQL?

◉ Yes ○ No ○ NA (Please explain) Comments:

iii. If above PQL, what samples are affected? Comments:

NA. All results are ND.

iv. Do the affected sample(s) have data flags? If so, are the data flags clearly defined?

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All results are ND.

v. Data quality or usability affected? (Please explain) Comments:

Data quality and usability is not affected with respect to the reported method blank results.

b. Laboratory Control Sample/Duplicate (LCS/LCSD)

i. Organics - One LCS/LCSD reported per matrix, analysis and 20 samples? (LCS/LCSD required per AK methods, LCS required per SW846)

○ Yes ◉ No ○ NA (Please explain) Comments:

There is no LCS/LCSD. There is an MS/MSD.

ii. Metals/Inorganics - One LCS and one sample duplicate reported per matrix, analysis and 20 samples?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no metals or inorganic analyses.

iii. Accuracy - All percent recoveries (%R) reported and within method or laboratory limits? And project specified DQOs, if applicable. (AK Petroleum methods: AK101 60%-120%, AK102 75%-125%, AK103 60%-120%; all other analyses see the laboratory QC pages)

◉ Yes ○ No ○ NA (Please explain) Comments:

iv. Precision - All relative percent differences (RPD) reported and less than method or laboratory limits? And project specified DQOs, if applicable. RPD reported from LCS/LCSD, MS/DMSD, and or sample/sample duplicate. (AK Petroleum methods 20%; all other analyses see the laboratory QC pages)

◉ Yes ○ No ○ NA (Please explain) Comments:

v. If %R or RPD is outside of acceptable limits, what samples are affected?
Comments:

NA. All results are within acceptable limits.

vi. Do the affected samples(s) have data flags? If so, are the data flags clearly defined?

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All results are within acceptable limits.

vii. Data quality or usability affected? (Please explain) Comments:

Data quality and usability is not affected with respect to the reported LCS/LCSD results.

c. Surrogates - Organics Only

i. Are surrogate recoveries reported for organic analyses - field, QC and laboratory samples?

◉ Yes ○ No ○ NA (Please explain) Comments:

ii. Accuracy - All percent recoveries (%R) reported and within method or laboratory limits? And project specified DQOs, if applicable. (AK Petroleum methods 50-150 %R; all other analyses see the laboratory report pages)

◉ Yes ○ No ○ NA (Please explain) Comments:

iii. Do the sample results with failed surrogate recoveries have data flags? If so, are the data flags clearly defined?

◉ Yes ○ No ○ NA (Please explain) Comments:

iv. Data quality or usability affected? (Use the comment box to explain.).

Comments:

Data quality and usability is not affected with respect to the reported surrogate results.

d. Trip Blank - Volatile analyses only (GRO, BTEX, Volatile Chlorinated Solvents, etc.): <u>Water and Soil</u>

i. One trip blank reported per matrix, analysis and for each cooler containing volatile samples? (If not, enter explanation below.)

◉ Yes ○ No ○ NA (Please explain.) Comments:

ii. Is the cooler used to transport the trip blank and VOA samples clearly indicated on the COC? (If not, a comment explaining why must be entered below)

◉ Yes ○ No ○ NA (Please explain.) Comments:

iii. All results less than PQL?

◉ Yes ○ No ○ NA (Please explain.) Comments:

All results are ND.

iv. If above PQL, what samples are affected?

Comments:

NA. All results are ND.

v. Data quality or usability affected? (Please explain.)

Comments:

Data quality and usability are not affected with respect to the reported trip blank results.

e. Field Duplicate

i. One field duplicate submitted per matrix, analysis and 10 project samples?

◉ Yes ○ No ○ NA (Please explain) Comments:

There was one field duplicate -- primary 11-AWA-010-GW with duplicate 11-AWA-011-GW.

ii. Submitted blind to lab?

◉ Yes ○ No ○ NA (Please explain.) Comments:

iii. Precision - All relative percent differences (RPD) less than specified DQOs?
(Recommended: 30% water, 50% soil)

$$\text{RPD (\%)} = \text{Absolute Value of: } \frac{(R_1 - R_2)}{((R_1 + R_2)/2)} \times 100$$

Where R_1 = Sample Concentration
R_2 = Field Duplicate Concentration

◉ Yes ○ No ○ NA (Please explain) Comments:

iv. Data quality or usability affected? (Use the comment box to explain why or why not.)

○ Yes ◉ No ○ NA (Please explain) Comments:

Data quality and usability is not affected with respect to the reported field duplicate results.

f. Decontamination or Equipment Blank (if applicable)

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All sampling equipment was disposable.

i. All results less than PQL?

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All sampling equipment was disposable. No decontamination or equipment blanks were collected.

ii. If above PQL, what samples are affected?

Comments:

NA. No decontamination or equipment blanks were collected.

iii. Data quality or usability affected? (Please explain.)

Comments:

NA. No decontamination or equipment blanks were collected.

7. Other Data Flags/Qualifiers (ACOE, AFCEE, Lab Specific, etc.)

a. Defined and appropriate?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no other data flags or qualifiers.

Reset Form

Laboratory Data Review Checklist

Completed by:	Melissa Pike		
Title:	Environmental Scientist	Date:	Dec 6, 2011
CS Report Name:	FORMER ANIAK WHITE ALICE SITE, ANIAK, AK	Report Date:	December 2011
Consultant Firm:	OASIS Environmental, Inc		
Laboratory Name:	OnSite Environmental	Laboratory Report Number:	1110-167
ADEC File Number:		ADEC RecKey Number:	

1. Laboratory

a. Did an ADEC CS approved laboratory receive and perform all of the submitted sample analyses?

(●) Yes ( ) No ( ) NA (Please explain.) Comments:

b. If the samples were transferred to another "network" laboratory or sub-contracted to an alternate laboratory, was the laboratory performing the analyses ADEC CS approved?

(●) Yes ( ) No ( ) NA (Please explain) Comments:

Samples were not subcontracted or transferred to another network laboratory.

2. Chain of Custody (COC)

a. COC information completed, signed, and dated (including released/received by)?

(●) Yes ( ) No ( ) NA (Please explain) Comments:

b. Correct analyses requested?

(●) Yes ( ) No ( ) NA (Please explain) Comments:

3. Laboratory Sample Receipt Documentation

a. Sample/cooler temperature documented and within range at receipt (4° ± 2° C)?

(●) Yes ( ) No ( ) NA (Please explain) Comments:

Case narrative states samples were received within range. It is not documented on the COC.

b. Sample preservation acceptable - acidified waters, Methanol preserved VOC soil (GRO, BTEX, Volatile Chlorinated Solvents, etc.)?

◉ Yes ○ No ○ NA (Please explain) Comments:

c. Sample condition documented - broken, leaking (Methanol), zero headspace (VOC vials)?

◉ Yes ○ No ○ NA (Please explain) Comments:

Samples were reported in good condition.

d. If there were any discrepancies, were they documented? - For example, incorrect sample containers/ preservation, sample temperature outside of acceptance range, insufficient or missing samples, etc.?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no discrepancies.

e. Data quality or usability affected? (Please explain)

Comments:

Data quality and usability is not affect with respect to the laboratory receipt documentation.

4. Case Narrative

a. Present and understandable?

◉ Yes ○ No ○ NA (Please explain) Comments:

b. Discrepancies, errors or QC failures identified by the lab?

◉ Yes ○ No ○ NA (Please explain) Comments:

There are no discrepancies.

c. Were all corrective actions documented?

◉ Yes ○ No ○ NA (Please explain) Comments:

There are no corrective actions.

d. What is the effect on data quality/usability according to the case narrative?

Comments:

Data quality and usability is not affected.

5. Samples Results

a. Correct analyses performed/reported as requested on COC?

(•) Yes ( ) No ( ) NA (Please explain) Comments:

b. All applicable holding times met?

(•) Yes ( ) No ( ) NA (Please explain) Comments:

c. All soils reported on a dry weight basis?

( ) Yes ( ) No (•) NA (Please explain) Comments:

There are no soil samples in this sample delivery group.

d. Are the reported PQLs less than the Cleanup Level or the minimum required detection level for the project?

(•) Yes ( ) No ( ) NA (Please explain) Comments:

e. Data quality or usability affected? (Please explain)

Comments:

Data quality and usability is not affected with respect to the reported sample results.

6. QC Samples

a. Method Blank

i. One method blank reported per matrix, analysis and 20 samples?

(•) Yes ( ) No ( ) NA (Please explain) Comments:

ii. All method blank results less than PQL?

(•) Yes ( ) No ( ) NA (Please explain) Comments:

iii. If above PQL, what samples are affected? Comments:

NA. All results are ND.

iv. Do the affected sample(s) have data flags? If so, are the data flags clearly defined?

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All results are ND.

v. Data quality or usability affected? (Please explain) Comments:

Data quality and usability is not affected with respect to the reported method blank results.

b. Laboratory Control Sample/Duplicate (LCS/LCSD)

i. Organics - One LCS/LCSD reported per matrix, analysis and 20 samples? (LCS/LCSD required per AK methods, LCS required per SW846)

○ Yes ◉ No ○ NA (Please explain) Comments:

There is no LCS/LCSD. There is an MS/MSD.

ii. Metals/Inorganics - One LCS and one sample duplicate reported per matrix, analysis and 20 samples?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no metals or inorganic analyses.

iii. Accuracy - All percent recoveries (%R) reported and within method or laboratory limits? And project specified DQOs, if applicable. (AK Petroleum methods: AK101 60%-120%, AK102 75%-125%, AK103 60%-120%; all other analyses see the laboratory QC pages)

◉ Yes ○ No ○ NA (Please explain) Comments:

iv. Precision - All relative percent differences (RPD) reported and less than method or laboratory limits? And project specified DQOs, if applicable. RPD reported from LCS/LCSD, MS/DMSD, and or sample/sample duplicate. (AK Petroleum methods 20%; all other analyses see the laboratory QC pages)

◉ Yes ○ No ○ NA (Please explain) Comments:

v. If %R or RPD is outside of acceptable limits, what samples are affected?

Comments:

NA. All results are within acceptable limits.

vi. Do the affected samples(s) have data flags? If so, are the data flags clearly defined?

○ Yes ○ No ● NA (Please explain) Comments:

NA. All results are within acceptable limits.

vii. Data quality or usability affected? (Please explain) Comments:

Data quality and usability is not affected with respect to the reported LCS/LCSD results.

c. Surrogates - Organics Only

i. Are surrogate recoveries reported for organic analyses - field, QC and laboratory samples?

● Yes ○ No ○ NA (Please explain) Comments:

ii. Accuracy - All percent recoveries (%R) reported and within method or laboratory limits? And project specified DQOs, if applicable. (AK Petroleum methods 50-150 %R; all other analyses see the laboratory report pages)

● Yes ○ No ○ NA (Please explain) Comments:

iii. Do the sample results with failed surrogate recoveries have data flags? If so, are the data flags clearly defined?

● Yes ○ No ○ NA (Please explain) Comments:

iv. Data quality or usability affected? (Use the comment box to explain.).

Comments:

Data quality and usability is not affected with respect to the reported surrogate results.

d. Trip Blank - Volatile analyses only (GRO, BTEX, Volatile Chlorinated Solvents, etc.): <u>Water and Soil</u>

i. One trip blank reported per matrix, analysis and for each cooler containing volatile samples? (If not, enter explanation below.)

● Yes ○ No ○ NA (Please explain.) Comments:

ii. Is the cooler used to transport the trip blank and VOA samples clearly indicated on the COC? (If not, a comment explaining why must be entered below)

● Yes ○ No ○ NA (Please explain.) Comments:

iii. All results less than PQL?

◉ Yes ○ No ○ NA (Please explain.) Comments:

All results are ND.

iv. If above PQL, what samples are affected?

Comments:

NA. All results are ND.

v. Data quality or usability affected? (Please explain.)

Comments:

Data quality and usability are not affected with respect to the reported trip blank results.

e. Field Duplicate

i. One field duplicate submitted per matrix, analysis and 10 project samples?

◉ Yes ○ No ○ NA (Please explain) Comments:

There was one field duplicate -- primary 11-AWA-018-GW with duplicate 11-AWA-019-GW.

ii. Submitted blind to lab?

◉ Yes ○ No ○ NA (Please explain.) Comments:

iii. Precision - All relative percent differences (RPD) less than specified DQOs?
(Recommended: 30% water, 50% soil)

$$\text{RPD (\%)} = \text{Absolute Value of: } \frac{(R_1 - R_2)}{((R_1 + R_2)/2)} \times 100$$

Where R_1 = Sample Concentration
R_2 = Field Duplicate Concentration

◉ Yes ○ No ○ NA (Please explain) Comments:

iv. Data quality or usability affected? (Use the comment box to explain why or why not.)

○ Yes ◉ No ○ NA (Please explain) Comments:

Data quality and usability is not affected with respect to the reported field duplicate results.

f. Decontamination or Equipment Blank (if applicable)

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All sampling equipment was disposable.

i. All results less than PQL?

○ Yes ○ No ◉ NA (Please explain) Comments:

NA. All sampling equipment was disposable. No decontamination or equipment blanks were collected.

ii. If above PQL, what samples are affected?

Comments:

NA. No decontamination or equipment blanks were collected.

iii. Data quality or usability affected? (Please explain.)

Comments:

NA. No decontamination or equipment blanks were collected.

7. Other Data Flags/Qualifiers (ACOE, AFCEE, Lab Specific, etc.)

a. Defined and appropriate?

○ Yes ○ No ◉ NA (Please explain) Comments:

There are no other data flags or qualifiers.

Reset Form

APPENDIX C

FS Cost Estimate Spreadsheets

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Aniak WACS Site Feasibility Study Alternative Cost Summary							
Remedial Alternatives at Aniak WACS Site		**Cost**	**Potential Range**		**Normalized Score**		
			(-50%)	**(+100%)**			
Alternative GW-1	No Action	$ -	$ -	$ -	0.00	1.00	**5.0**
Alternative GW-2	LTM/MNA	$ 2,434,927	$ 1,217,463	$ 4,869,853	0.57	0.43	**2.2**
Alternative GW-3	Chemical Oxidation	$ 4,304,138	$ 2,152,069	$ 8,608,276	1.00	0.00	**0.0**
Alternative GW-4	ERD	$ 3,429,247	$ 1,714,624	$ 6,858,495	0.80	0.20	**1.0**
Alternative GW-5	Air Sparging	$ 3,626,153	$ 1,813,077	$ 7,252,306	0.84	0.16	**0.8**

Alternative GW-2 LTM/MNA (35 years)						
Function	**Units**	**Quantity**	**Cost Per Unit**	**Total Cost**	**Total Cost (- 50%)**	**Total Cost (+ 100%)**
Capital Costs (Year 0 for PW analysis)						
Establish ICs and LTM Network and conduct intial year of LTM and SSD						
Well Installation	event	1	$60,000	$60,000		
Well Installation Oversight	hr	120	$85	$10,200		
Surveying	estimate	1	$15,000	$15,000		
Soil Sampling	estimate	1	$4,000	$4,000		
Well Installation Oversight Transportation and per diem	event	1	$4,000	$4,000		
GW Monitoring Equipment, Materials, Shipping	event	4	$2,500	$10,000		
GW Monitoring Labor Transportation and per diem	event	4	$2,600	$10,400		
GW Monitoring Labor	hr	336	$85	$28,560		
Laboratory Analysis (VOC)	well	40	$200	$8,000		
Laboratory Analysis (MNA param)	well	40	$350	$14,000		
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000		
Capital Costs Total				**$264,160**		
OM&M Costs (Years 1-3)						
Monitoring Labor (semiannual)	hr	168	$85	$14,280		
GW Monitoring Equipment, Materials, Shipping	event	2	$2,500	$5,000		
GW Monitoring Labor Transportation and per diem	event	2	$2,600	$5,200		
Laboratory Analysis (VOC)	well	40	$200	$8,000	$136,897	$384,410
Laboratory Analysis (MNA param)	well	40	$350	$14,000	$127,941	
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000	$119,571	
Annual Costs Total (Years 1-3)				**$146,480**		
Present Worth of OM&M Costs (Years 1-3)				**$384,410**		
OM&M Costs (Years 4-14)						
Monitoring Labor (annual)	hr	84	$85	$7,140		
GW Monitoring Equipment, Materials, Shipping	event	1	$2,500	$2,500		
GW Monitoring Labor Transportation and per diem	event	1	$2,600	$2,600		
Laboratory Analysis (VOC)	well	20	$200	$4,000		
Laboratory Analysis (MNA param)	well	20	$350	$7,000		
VI Mitigation: SSD O&M (1/2ly) and Power	estimate	1	$60,000	$60,000		
Annual Costs Total (Years 4-14)				**$83,240**		
SSD System replace parts/repair (Years 4, 9, 14)	estimate	1	$10,000	$10,000		
Present Worth of SSD System Maintenance (Years 4,9,14)				**$16,946**		
Present Worth of OM&M Costs Total (Years 4-14)				**$526,471**		
OM&M Costs (Years 15-34)						
VI Mitigation: SSD O&M (1/2ly) and Power (Years 15-34)	estimate	1	$60,000	$60,000		
Present Worth of 1/2ly SSD O&M (Years 15-34)				**$246,512**		
SSD System replace parts/repair (Years 19, 24, 29)	estimate	1	$10,000	$10,000		
Monitoring labor, equipment, analysis (Years 19, 24, 29, 34)	estimate	1	$23,240	$23,240		
Present Worth of Every 5 Year Costs (Years 19-34)				**$22,746**		
Present Worth of OM&M Costs Total (Years 15-34)				**$269,258**		
Well Decommissioning (Year 34)						
Well decommissioning	estimate	1	$50,000	$50,000		
Well decommissioning oversight	hours	78	$85	$6,630		
Well decommissioning oversight transportation and per diem	event	1	$3,200	$3,200		
Decommissioning Costs Total (Year 34)				**$59,830**		
Present Worth of Decommissioning Cost Total (Year 34)				**$5,996**		
Total Present Worth of OM&M (Years 1-34)				**$1,186,135**		
Cost (Capital + OM&M) Subtotal				**$1,450,295**	**$725,148**	**$2,900,591**
Bid Contigency	%	1	15%	$217,544		
Scope Contigency	%	1	20%	$290,059		
Capital + OM&M Cost Plus Contingency Subtotal				**$1,957,899**	**$978,949**	**$3,915,797**
Project Management	%	1	6%	$117,474		
Remedial Design	%	1	12%	$42,794		
Construction Management	%	1	8%	$28,529		
Technical Support (Annual OM&M)	%	1	18%	$288,231		
Professional/Technical Cost Subtotal				**$477,028**	**$238,514**	**$954,056**
Total Present Worth Cost				**$2,434,927**	**$1,217,463**	**$4,869,853**

Alternative GW-3 Chemical Oxidation (10 years)						
Function	**Units**	**Quantity**	**Cost Per Unit**	**Total Cost**	**Total Cost (- 50%)**	**Total Cost (+ 100%)**
Capital Costs (Year 0 for PW analysis)						
Chemical Oxidation Application						
Pilot Test	event	1	$70,000	$70,000		
Permanganate	kg	18,212	$11	$200,335		
Permanganate Shipping	kg	18,212	$1	$18,212		
Water for Chemical Oxidation	liters	610,000	$0.05	$30,500		
Permanganate Injection Drilling Subcontractor	est	1	$115,000	$115,000		
Subsurface Injection Equipment	estimate	1	$30,000	$30,000		
Permanganate Injection Oversight	hr	540	$75	$40,500		
Permanganate Injection Oversight Transportation and per diem	event	1	$10,500	$10,500		
Install 12 new monitoring wells	lump	1	$58,200	$58,200		
Surveying	estimate	1	$15,000	$15,000		
GW Post Injection Monitoring Labor	hr	336	$85	$28,560		
GW Monitoring Equipment, Materials, Shipping	event	4	$2,500	$10,000		
GW Monitoring Labor Transportation and per diem	event	4	$2,600	$10,400		
GW Laboratory Analysis - Groundwater Monitoring	well	80	$550	$44,000		
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000		
Capital Costs Total				**$781,208**		
Annual Chemical Oxidation (Years 1 - 3)						
Permanganate	kg	18,212	$11	$200,335		
Permanganate Shipping	kg	18,212	$1	$18,212		
Water for Chemical Oxidation	liters	610,000	$0.05	$30,500		
Permanganate Injection Equipment & Subcontractor	est	1	$115,000	$115,000		
Permanganate Injection Oversight	hr	540	$75	$40,500		
Permanganate Injection Oversight Transportation and per diem	event	1	$10,500	$10,500		
GW Semi-Annual Monitoring Labor	hr	168	$85	$14,280		
GW Monitoring Equipment, Materials, Shipping	event	2	$2,500	$5,000		
GW Monitoring Labor Transportation and per diem	event	2	$2,600	$5,200		
GW Laboratory Analysis - Groundwater Monitoring	well	40	$550	$22,000		
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000		
Total for Annual Source Area Chemical Oxidation				**$561,528**		
Present Worth of Annual Chemical Oxidation Injection (Years 1-3)				**$1,473,626**		
Annual OM&M Costs (Years 4 -9)						
GW Long-Term Monitoring Labor	hr	84	$85	$7,140		
GW Monitoring Equipment, Materials, Shipping	event	1	$2,500	$2,500		
GW Monitoring Labor Transportation and per diem	event	1	$2,600	$2,600		
GW Laboratory Analysis - Groundwater Monitoring	well	20	$550	$11,000		
VI Mitigation: SSD O&M (1/2ly) and Power	estimate	1	$60,000	$60,000		
Annual Costs Total (Years 4-9)				**$83,240**		
SSD System replace parts/repair (Year 4)	estimate	1	$10,000	$10,000		
Present Worth of SSD System Maintenance (Year 4)				**$7,629**		
Total Present Worth of OM&M (Years 4-9)				**$331,509**		
Well Decommissioning (Year 9)						
Well decommissioning, oversight, transportation & per diem	estimate	1	$69,830	$69,830		
Present Worth of Decommissioning Cost Total (Year 9)				**$37,983**		
Total Present Worth of OM&M (Years 1-9)				**$1,843,117**		
Cost (Capital + OM&M) Subtotal				**$2,624,325**	**$1,312,162**	**$5,248,650**
Bid Contigency	%	1	15%	$393,649		
Scope Contigency	%	1	20%	$524,865		
Capital + OM&M Cost Plus Contingency Subtotal				**$3,542,839**	**$1,771,419**	**$7,085,677**
Project Management	%	1	5%	$177,142		
Remedial Design	%	1	12%	$126,556		
Construction Management	%	1	8%	$84,370		
Technical Support (Annual OM&M)	%	1	15%	$373,231		
Professional/Technical Cost Subtotal				**$761,299**	**$380,650**	**$1,522,599**
Total Present Worth Cost				**$4,304,138**	**$2,152,069**	**$8,608,276**

Alternative GW-4 ERD (20 years)						
Function	**Units**	**Quantity**	**Cost Per Unit**	**Total Cost**	**Total Cost (- 50%)**	**Total Cost (+ 100%)**
Capital Costs (Year 0 for PW analysis)						
Enhanced Reductive Dechlorination - Substrate Application						
Pilot Test	event	1	$70,000	$70,000		
ERD Substrate	lbs	3,800	$10	$38,000		
ERD Substrate Shipping	lbs	3,800	$1	$3,800		
ERD Substrate Injection Drilling Subcontractor	est	1	$115,000	$115,000		
ERD Substrate Injection Oversight	hr	540	$75	$40,500		
ERD Substrate Injection Oversight Transportation and per diem	event	1	$10,500	$10,500		
Install 12 new monitoring wells	lump	1	$58,200	$58,200		
Surveying	estimate	1	$15,000	$15,000		
GW Post Injection Monitoring Labor	hr	336	$85	$28,560		
GW Monitoring Equipment, Materials, Shipping	event	4	$2,500	$10,000		
GW Monitoring Labor Transportation and per diem	event	4	$2,600	$10,400		
GW Laboratory Analysis - Groundwater Monitoring	well	80	$550	$44,000		
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000		
Capital Costs Total				**$543,960**		
Annual ERD Costs (Years 1-3)						
ERD Substrate	lbs	2,850	$10	$28,500		
ERD Substrate Shipping	lbs	2,850	$1	$2,850		
ERD Substrate Injection Equipment & Subcontractor	est	1	$100,000	$100,000		
ERD Substrate Injection Oversight	hr	432	$75	$32,400		
ERD Substrate Injection Oversight Transportation and per diem	event	1	$8,700	$8,700		
Bioaugmentation	event	1	$25,000	$25,000		
GW Semi-Annual Monitoring Labor	hr	168	$85	$14,280		
GW Monitoring Equipment, Materials, Shipping	event	2	$2,500	$5,000		
GW Monitoring Labor Transportation and per diem	event	2	$2,600	$5,200		
GW Laboratory Analysis - Groundwater Monitoring	well	40	$550	$22,000		
VI Mitigation: SSD O&M (1/4ly) and Power	estimate	1	$100,000	$100,000		
Total for Annual ERD Costs				**$343,930**		
Present Worth of Annual ERD Costs (Years 1-3)				**$902,581**		
Annual OM&M Costs (Years 4-14)						
MNA Monitoring Labor	hr	84	$85	$7,140		
MNA Monitoring Equipment, Materials, Shipping	event	1	$2,500	$2,500		
MNA Monitoring Labor Transportation and per diem	event	1	$2,600	$2,600		
MNA Laboratory Analysis - Groundwater Monitoring	well	20	$550	$11,000		
VI Mitigation: SSD O&M (1/2ly) and Power	estimate	1	$60,000	$60,000		
Total for Annual OM&M Costs				**$83,240**		
SSD System replace parts/repair (Years 4, 9, 14)	estimate	1	$10,000	$10,000		
Present Worth of SSD System Maintenance (Years 4 -14)				**$16,946**		
Total Present Worth of OM&M (Years 4-14)				**$526,471**		
OM&M Costs (Years 15-19)						
VI Mitigation: SSD O&M (1/2ly) and Power (Years 15-19)	estimate	1	$60,000	$60,000		
Present Worth of 1/2ly SSD O&M (Years 15-19)				**$95,408**		
GW Monitoring labor, equipment, analysis (Year 19)	estimate	1	$23,240	$23,240		
Present Worth of Every 5 Year Costs (Year 19)				**$6,426**		
Present Worth of OM&M Costs Total (Years 15-19)				**$101,834**		
Well Decommissioning (Year 19)						
Well decommissioning, oversight, transportation & per diem	estimate	1	$69,830	$69,830		
Present Worth of Decommissioning Cost Total (Year 19)				**$19,309**		
Total Present Worth of OM&M (Years 1-19)				**$1,550,194**		
Cost (Capital + OM&M) Subtotal				**$2,094,154**	**$1,047,077**	**$4,188,309**
Bid Contigency	%	1	15%	$314,123		
Scope Contigency	%	1	20%	$418,831		
Capital + OM&M Cost Plus Contingency Subtotal				**$2,827,108**	**$1,413,554**	**$5,654,217**
Project Management	%	1	5%	$141,355		
Remedial Design	%	1	12%	$88,122		
Construction Management	%	1	8%	$58,748		
Technical Support (Annual OM&M)	%	1	15%	$313,914		
Professional/Technical Cost Subtotal				**$602,139**	**$301,069**	**$1,204,278**
Total Present Worth Cost				**$3,429,247**	**$1,714,624**	**$6,858,495**

REGENESIS
Technical Support (949) 366-8000

HRC Grid Design

Version 1

Site Name: Aniak GW [MW-4]
Location: FS Scoping
Consultant: Oasis

Basic Site Characteristics

Width of plume (intersecting flow)	50	ft
Length of plume	50	ft
Depth to contaminated zone	25	ft
Thickness of contaminated saturated zone	10	ft
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	sand	
Porosity	0.39	
Hydraulic conductivity, Kh	100	ft/day
Hydraulic gradient	0.0007	ft/ft
Seepage velocity 0.179 ft/day =	65.5	ft/yr
Treatment Zone Pore Volume (cu. ft.)	9,750	ft^3

Dissolved Phase Groundwater VOC Concentrations: Cgw in mg/L

PCE	0.00
TCE	0.02
DCE	0.01
VC	0.00
Carbon tetrachloride	0.00
Chloroform	0.00
TCA	0.00
DCA	0.00

Sorbed Phase VOC Mass:

Soil bulk density	1.9	kg/L
Fraction of organic carbon: foc	0.002	

(Values are estimated using Soil Conc=foc*Koc*Cgw) (Adjust Koc as nec. to provide realistic estimates)	Koc (L/kg)	Soil Conc. (mg/kg)
PCE	450	0.00
TCE	107	0.00
DCE	80	0.00
VC	2.5	0.00
Carbon tetrachloride	110	0.00
Chloroform	34	0.00
TCA	183	0.00
DCA	40	0.00

Competing Electron Acceptor (CEA) Concentrations:

	(mg/L)
Oxygen	2.40
Nitrate	1.00
Manganese reduction potential	5.00
Iron reduction (potential amount of Fe2+ that can be formed)	128.50
Sulfate reduction	10.90

Microbial Demand Factor	3	Recommend 3-4x
Additional Demand Factor	3	Recommend 2-3x

Injection Point Spacing	**Rec.**	Min.	Max.
Nominal injection spacing (ft)	10.0	5	15
# points in row(w/desired spacing)	5	10	3
Actual spacing between columns (ft)	10.0	5.0	16.7
# rows (w/desired spacing)	5	10	3
Actual spacing between rows (ft)	10.0	5.0	16.7
Advective travel time bet. rows (days)	56	28	93
Number of points in grid	25	100	9

HRC Injection Amount			
Minimum req. HRC per foot (lbs/ft)	2.5	2.0	6.9
Feasibility of above HRC per foot:	(ok)	(ok)	(ok)

Proposed HRC Grid Specifications		
Proposed number of HRC delivery points (adjust as nec. for site)		25
Proposed HRC applic. rate lbs/foot (adjust as nec. for site)		2.5
Corresponding amount of HRC per point (lbs)		25
Buckets per injection point		0.8
Total Buckets		21
Total Amt of HRC (lbs)		625
Unit cost of HRC	$	9.00
Total Material Cost	**$**	**5,625**
Shipping and/or Tax Estimate		
HRC ($0.1 to $0.4/lb, call for exact rate) cost per lb: 1	$	625
Sales tax (call for exact rate) rate: 0%	$	-
Total Regenesis Material Cost	**$**	**6,250**

HRC Installation Cost Estimate (responsibility of customer to contract work)		
Footage for each inj. point = uncontaminated + HRC inj. interval (feet)		35
Total vertical feet for project (feet)		875
Estimated production rate (feet per hour: 50 for push, 25 for drilling)		25
Estimated hole completion rate (holes per hour)		0.7
Time per day spent pushing/drilling (hrs)		8
Required number of days		5
Mob/demob cost for injection subcontrator	$	15,000
Daily rate for inj. Sub. ($1-2K for geoprobe or $3-4K for drill rig)	$	5,000
Total injection subcontrator cost for application	$	40,000
Total Project Cost(not including consultant oversight, GWM, etc.)	**$**	**46,250**

REGENESIS
Technical Support (949) 366-8000

HRC Grid Design
Version 1

Site Name: Aniak GW [MW-5]
Location: FS Scoping
Consultant: Oasis

Basic Site Characteristics

Width of plume (intersecting flow)	90	ft
Length of plume	100	ft
Depth to contaminated zone	25	ft
Thickness of contaminated saturated zone	15	ft
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	silty sand	
Porosity	0.44	
Hydraulic conductivity, Kh	40	ft/day
Hydraulic gradient	0.0007	ft/ft
Seepage velocity 0.064 ft/day =	23.2	ft/yr
Treatment Zone Pore Volume (cu. ft.)	59,400	ft^3

Dissolved Phase Groundwater VOC Concentrations: Cgw in mg/L

PCE	0.00
TCE	0.18
DCE	0.01
VC	0.00
Carbon tetrachloride	0.00
Chloroform	0.00
TCA	0.00
DCA	0.00

Sorbed Phase VOC Mass:

Soil bulk density	1.9	kg/L
Fraction of organic carbon: foc	0.002	

(Values are estimated using Soil Conc=foc*Koc*Cgw) (Adjust Koc as nec. to provide realistic estimates)	Koc (L/kg)	Soil Conc. (mg/kg)
PCE	450	0.00
TCE	107	0.04
DCE	80	0.00
VC	2.5	0.00
Carbon tetrachloride	110	0.00
Chloroform	34	0.00
TCA	183	0.00
DCA	40	0.00

Competing Electron Acceptor (CEA) Concentrations:

	(mg/L)
Oxygen	2.40
Nitrate	1.00
Manganese reduction potential	5.00
Iron reduction (potential amount of Fe2+ that can be formed)	128.50
Sulfate reduction	10.90

Microbial Demand Factor	3	Recommend 3-4x
Additional Demand Factor	3	Recommend 2-3x

Injection Point Spacing	**Rec.**	Min.	Max.
Nominal injection spacing (ft)	15.0	5	15
# points in row(w/desired spacing)	6	18	6
Actual spacing between columns (ft)	15.0	5.0	15.0
# rows (w/desired spacing)	7	20	7
Actual spacing between rows (ft)	14.3	5.0	14.3
Advective travel time bet. rows (days)	224	79	224
Number of points in grid	42	360	42

HRC Injection Amount			
Minimum req. HRC per foot (lbs/ft)	6.1	2.0	6.1
Feasibility of above HRC per foot:	(ok)	(ok)	(ok)

Proposed HRC Grid Specifications		
Proposed number of HRC delivery points (adjust as nec. for site)		42
Proposed HRC applic. rate lbs/foot (adjust as nec. for site)		4.9
Corresponding amount of HRC per point (lbs)		74
Buckets per injection point		2.4
Total Buckets		103
Total Amt of HRC (lbs)		3,087
Unit cost of HRC	$	9.00
Total Material Cost	**$**	**27,783**
Shipping and/or Tax Estimate		
HRC ($0.1 to $0.4/lb, call for exact rate) cost per lb: 1	$	3,087
Sales tax (call for exact rate) rate: 0%	$	-
Total Regenesis Material Cost	**$**	**30,870**

HRC Installation Cost Estimate (responsibility of customer to contract work)		
Footage for each inj. point = uncontaminated + HRC inj. interval (feet)		40
Total vertical feet for project (feet)		1,680
Estimated production rate (feet per hour: 50 for push, 25 for drilling)		25
Estimated hole completion rate (holes per hour)		0.6
Time per day spent pushing/drilling (hrs)		8
Required number of days		9
Mob/demob cost for injection subcontrator	$	15,000
Daily rate for inj. Sub. ($1-2K for geoprobe or $3-4K for drill rig)	$	5,000
Total injection subcontrator cost for application	$	60,000
Total Project Cost(not including consultant oversight, GWM, etc.)	**$**	**90,870**

Aniak Site Characteristics

Dissolved Phase Plume [c]

Area	23,550	sq ft	MW-4 and MW-7 Plumes
Average HVO Concentration	175	µg/L	Average concentration in Septic Central

Soil Type	Hyd Cond (K) [cm/s] [a] High	Low	Geo. Mean	Hyd Cond (K) [ft/day] [a] High	Low	Geo. Mean	Total Porosity (n) [a] High	Low	Average	Eff. Porosity (n) [a] High	Low	Average	Dry Bulk Density (lbs/ft^3) [b] High	Low	Average
Sandy Gravel	1	0.03	0.17	2835	85	491	0.38	0.25	0.32	0.35	0.2	0.28	135	125	130
Slightly Sandy Silt	0.00100	0.0000001	0.000010	3	0.0003	0.03	0.61	0.34	0.48	0.30	0.01	0.16	120	95	108
Coarse Sand (GW)	1.00000	0.003	0.055	2835	8.5039	155	0.46	0.31	0.39	0.35	0.2	0.28	120	100	110
Average	**0.66700**	**0.01100**	**0.07600**	**1,891**	**31**	**215**	**0.48**	**0.30**	**0.39**	**0.33**	**0.14**	**0.24**	**125**	**107**	**116**

Groundwater [d]	Gradient	K	Eff. Porosity	Seepage Velocity						Direction
Spring High Water	0.002	0.05	0.28	4.0E-04	cm/sec	412	ft/yr	1.13	ft/day	S-SW
Summer Normal	0.0009	0.05	0.28	1.8E-04	cm/sec	185	ft/yr	0.51	ft/day	N-NE
Summer Reversal	0.0004	0.05	0.28	8.0E-05	cm/sec	82	ft/yr	0.23	ft/day	S-SW
Sep-Dec	0.0005	0.05	0.28	1.0E-04	cm/sec	103	ft/yr	0.28	ft/day	N-NE
Jan-Apr	0.0003	0.05	0.28	6.0E-05	cm/sec	62	ft/yr	0.17	ft/day	W

Chemical Oxidation Calculations (Ozone/Water Recirculation) [NOT EVALUATED AS AN ALTERNATIVE]	Area [c]	Thickness	Soil Volume (ft^3)	Soil Mass (lbs)	Soil Mass (kg)	C_{HVO} Soil (µg/kg)	$Mass_{HVO}$ Soil (kg)	C_{HVO} GW (µg/L)	$Mass_{HVO}$ GW (kg)	$Mass_{HVO}$ Total (kg)
Septic - Central (silt) [60-65 msl]	9,000	5	45,000	4,838,000	2,199,091	200	0.44	175	0.11	0.55
Septic - Central (sand) [50-60 msl]	9,000	10	90,000	9,900,000	4,500,000	200	0.90	175	0.17	1.07
					6,699,091		1.34			

Chemical Oxidation Calculations (Ozone/Water Recirculation) [NOT EVALUATED AS AN ALTERNATIVE]	Void Volume (ft^3)	Void Volume (L)	Oxygen: Contaminant Mass Ratio 3:1	Measured Oxidant Demand (g/kg-MnO_4)	Contaminant Oxidant Demand (kg)	Total Oxygen Demand in Soil (kg)	Mass per volume of injection (Aq. Sol. at 5 °C) mg/L	Volume of O_3 Laden Water to meet Oxygen Demand (L)	Recirculation Rate (lpm)	Years of Recirculation
Septic - Central (silt) [60-65 msl]	21,375	605,340	3	5.60	1.63726	12317	30	410,551,545		
Septic - Central (sand) [50-60 msl]	34,650	981,288	3	5.60	3.21518	25203	30	840,107,173		
						37520		1,250,658,718	200	11.9

Chemical Oxidation Calculations (Permanganate Injection)	Area [c]	Thickness	Soil Volume (ft^3)	Soil Mass (lbs)	Soil Mass (kg)	C_{HVO} Soil (µg/kg)[d]	$Mass_{HVO}$ Soil (kg)	C_{HVO} GW (µg/L)[e]	$Mass_{HVO}$ GW (kg)	$Mass_{HVO}$ Total (kg)	Void Volume (ft^3)	Void Volume (L)
Septic - Central (silt) [59-64 msl]	9,000	5	45,000	4,838,000	2,199,091	600	1.32	175	0.11	1.43	21,375	605,340
Septic - Central (sand) [49-59 msl]	9,000	10	90,000	9,900,000	4,500,000	200	0.90	175	0.17	1.07	34,650	981,288
MW-4 plume (sand) [54-64]	2,500	10	25,000	2,750,000	1,250,000	200	0.25	19	0.01	0.26	9,625	272,580
					7,949,091		2.47					

Chemical Oxidation Calculations (Permanganate Injection)	kg KMnO4/kg Contaminant[f]	% oxygen in Potassium Permanganate[g]	Measured Natural Oxidant Demand (g KMnO4/kg soil+gw)[h]	Contaminant Oxidant Demand (kg KMnO4)	Total KMnO4 Demand in Soil and Groundwater (kg)i	Potassium Permanganate (kg)	Volume of Water for 3% Solution (L) [j]	Injection Flow Rate (L per minute per well)	Number of Wells	Injection Time (Hours)
Septic - Central (silt) [59-64 msl]	3.00	40%	7.43	4.28	20829	20829	693,592	20	42	41
Septic - Central (sand) [49-59 msl]	3.00	40%	7.43	3.22	40712	40712	1,355,705			
MW-4 plume (sand) [54-64]	3.00	40%	7.43	0.77	11309	11309	376,581	20	12	26
				8.26	72849	72849	2,425,878		54	

Enhanced Reductive Dechlorination (Substrate Addition)	Area [c]	Thickness	Soil Volume (ft^3)	Soil Mass (lbs)	Soil Mass (kg)	Void Volume (ft^3)	Void Volume (L)	Mass of Water in Void Volume (kg)
Septic - Central (silt) [59-64 msl]	9,000	5	45,000	4,838,000	2,199,091	21,375	605,340	602386
Septic - Central (sand) [49-59 msl]	9,000	10	90,000	9,900,000	4,500,000	34,650	981,288	976500
MW-4 plume (sand) [54-64]	2,500	10	25,000	2,750,000	1,250,000	9,625	272,580	271250
					7,949,091	65,650	1,859,208	1850136

Total # of Injection Minutes at 20 Lpm	Total # of Injection Minutes per well (54 wells)	Total # of Injection hours per well (54 wells)
121293.9	2246.2	37.4

Assume inject 25% of total volume each year for 4 years	606469.4	Liters
	11230.9	Total annual L/well (54 wells)
	1123.1	If inject in one 10-hr day; L/hour/well
	18.7	Liters per minute per well
Assume inject 4 wells/10-hour day		Less than 20 L/minute so should be feasible to do a well in a day
Approx gallons (3.79L/gal)	160018.3	Total annual injection volume
	2963.3	Total injection volume per well (annual)
	296.3	Gallons per hour (10-hr day)
	4.9	gpm

Enhanced Reductive Dechlorination - Substrate Addition	Substrate (lbs)	% Carbon in Substrate*	Substrate (mg)	Increase in TOC (mg/L)
HRC (scoping worksheet) [Septic - Central]	3,087	40%	1,400,000,000	354
HRC (scoping worksheet) [MW-4 Plume]	625	40%	300,000,000	417

* Primary component of HRC has chemical formula - CH3CHOHCOOH (90 g/mol of which 36 g/mol is carbon - or 40%)

Sources:

a *Natural Attenuation of Fuels and Chlorinated solvents in the Subsurface*, Wiedemeier, 1999.
b *Civil Engineering Reference Manual, Sixth Edition*, Lindeburg, 1992.
c *S&W March 2009 as modified in FS Figures*
d Maximum soil concentration 600 ug/Kg in B-12 (silt); most other soil detections ~ 200 ug/Kg
e 175 ug/L=approx. avg. two highest groundwater detections (187 ug/L and 157 ug/L) for MW-5/7 plume; 19 ug/L=MW-4 detection for MW-4 plume
f from *EPA Engineering Issue In Situ Chemical Oxidation* (EPA/600/R-06/072) (Huling & Pivetz)
The stoichiometric requirement for PCE, TCE, DCE, and VC are 1.33, 2.0, 2.67, and 3.33 mol KMnO4/mol contaminant, respectively.
Converting molar ratio to mass ratio: (2 mol KMnO4/mol TCE)*(mol TCE/131.4 g TCE)*(158 g KMnO4/mol KMnO4)=2.4 g KMnO4/g TCE
For DCE: (2.67 mol KMnO4/mol DCE)*(mol DCE/97 g DCE)*(158 g KMnO4/mol KMnO4)=4.35 g KMnO4/g DCE
Contamination is mostly TCE but there is some DCE; use a factor of 3 g KMnO4/g contaminant for calculations
g **Not used in this analysis**: KMnO4: (39+55+16*4)=158 g/mol (atomic weight); 48/158=40.5% oxygen
h Average of Calculated Natural Oxidant Demand (g/kg) KMnO4 from Shannon & Wilson, 2010 (3, 14.6, and 4.7 g/kg KMnO4)
i Total oxidant demand=(Natural oxidant demand)*(Mass of soil + groundwater) + (Contaminant oxidant demand)
j Solubility of KMnO4 = 60 g/L (6%); 3% is typical injection concentration (EPA/600/R-06/072)
Volume of H2O for 3% solution=(kg KMnO4)*(1000 g/Kg)*(L H20/30g KMnO4); density of H2O is 1 kg/L

Molecular Weight			Molar Ratio	Mass Ratio
158	g/mol	Permanganate		
131.4	g/mol	TCE	2	2.40
97	g/mol	DCE	2.67	4.35

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APPENDIX D

Pre-Draft FS

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FEASIBILITY STUDY

ANIAK MIDDLE SCHOOL
ANIAK, ALASKA

Pre-DRAFT
April 2011

Prepared for:

ALASKA Department of Environmental Conservation

555 Cordova Street
Anchorage, AK 99501

Prepared by:

oasis ENVIRONMENTAL

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Anchorage, AK 99501

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ACRONYMS AND ABBREVIATIONS

ADEC .... Alaska Department of Environmental Conservation
bgs .... Below ground surface
CERCLA........ Comprehensive Environmental Response, Compensation and Liability Act
CHP............... Catalyzed hydrogen peroxide
CSM .... Conceptual site model
cm/sec........... centimeters per second
cy................... Cubic yards
DCE............... Dichloroethene
DO................. Dissolved oxygen
EPA............... Environmental Protection Agency
ERD............... Enhanced reductive dechlorination
FS.................. Feasibility study
ft/ft .... Feet per foot
g/kg .... Gram per kilogram
gpm .... gallons per minute
HRC™........... Hydrogen Release Compound
IDC................ inhalation/direct contact pathway (cleanup levels)
ISCO .... In situ chemical oxidation
µg/L .... Micrograms per liter
µg/m^3............. Micrograms per cubic meter
mg/kg .... Milligrams per kilogram
m/s .... meters per second
MNA .... Monitored natural attenuation
MTG .... Migration to groundwater (cleanup levels)
N.................... nitrogen
NCP............... National Contingency Plan
OASIS .... OASIS Environmental, Inc.
ORP .... oxidation-reduction potential
PCBs............. polychlorinated biphenyls
PCE............... Tetrachloroethene
ppbv .... parts per billion by volume
RAO .... Remedial action objective
RCRA............ Resource Conservation and Recovery Act
SSD............... Sub-slab depressurization
SI................... site investigation
SVE............... Soil vapor extraction
TOC............... total organic carbon
TCE............... Trichloroethene
USCS .... United States Classification System

VI.................. vapor intrusion
VMP .... Vapor monitoring point
VOC .... Volatile organic compound
WACS .... White Alice Communications System

1. PURPOSE AND EXECUTIVE SUMMARY

The purpose of this focused feasibility study (FS) is to evaluate remedial alternatives for addressing contaminated groundwater at the former Aniak White Alice Communications System (WACS) site located in Aniak, Alaska (Figure 1). The Aniak WACS site is currently used by the Kuspuk school district. The former WACS building is currently known as the Joe Parent school (and alternatively as the Aniak Middle School) and is used as a secondary school, temporary lodging, and administration and staff offices (Figure 2).

Soil, soil gas, and groundwater at the Aniak WACS site are contaminated by the chlorinated solvent, trichloroethene (TCE) and its degradation product, cis-1,2-dichloroethene (DCE) (Figure 3). This contamination has resulted in levels exceeding both indoor air quality and drinking water risk based thresholds. In addition, shallow soil at the site is also contaminated by polychlorinated biphenyls (PCBs).

The goal of this FS is to identify remedial alternatives for the two groundwater plumes. Remedies for soil and soil gas contamination have already been proposed. Vapor intrusion into the Joe Parent School is being mitigated by air purification filters inside the school and a sub-slab depressurization system (SSD). Soil excavation is planned to address soil contaminated by PCBs above the Alaska cleanup level of 1 milligram per kilogram (mg/Kg) (Figure 4). Some of the planned PCB excavation area also has commingled TCE contamination that will be removed along with the PCB-contamination. Soil vapor extraction (SVE) is planned to address the remaining vadose-zone TCE contamination (Figure 4). The groundwater alternatives evaluated in the focused FS will consider these planned and ongoing soil and soil gas remedies.

This pre-draft focused FS presents a summary of the nature and extent of the groundwater contamination, a conceptual site model (CSM) of exposure pathways to the contamination, identifies site features that should be considered when evaluating groundwater remedial alternatives, establishes preliminary remedial action objectives, and identifies technologies that may be considered in the detailed focused FS. The Treatment Technologies Screening Matrix (Table 3-2 in www.frtr.org) was used as the first step in identifying technologies for the pre-draft FS.

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2. SITE BACKGROUND

Aniak is located approximately 300 miles west of Anchorage and is bordered on the north by the Kuskokwim River and on the south by the Aniak Slough. The Middle School site is approximately 600 feet southeast of the northwest end of the runway and approximately 900 feet south of the Kuskokwim River, as shown on Figure 1. The property and immediate vicinity is generally flat, although the surrounding area has a general slope to the east towards the Aniak Slough. The site is situated on a gravel pad overlaying the native alluvial deposits. A site plan showing the location of the former Aniak Middle School on an aerial photograph is provided as Figure 2.

2.1. Contamination Summary

Extensive site investigation and remediation work has been performed at the site, beginning with 1997 Site Inspection (SI) conducted by the Environmental Protection Agency (EPA). Widespread PCB contamination was documented both inside and outside the Middle School building, and the site has been assigned Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Site Number AK8570028615. A brief summary of the investigation and remediation work performed at the site is provided below; a detailed discussion can be found in Shannon & Wilson (2010a).

- In 1997-1998, PCBs were removed from the inside of the building, and exterior contaminated areas were capped.
- Additional soil sampling was performed in 1999.
- In 2001, limited PCB cleanup activites were performed from a portion of the area that had been capped and from other areas identified by the 1999 sampling. Approximately 872 tons of PCB-impacted material was removed from the site.
- Feasibility studies were performed in 2004 and 2005.
- Site characterization activities in the vicinity of the WACS former septic system were performed in 2006 (Shannon & Wilson, 2007). Activities included soil and groundwater sampling; TCE contamination was discovered, along with additional areas of PCB contamination.
- In 2008, soil and groundwater sampling were performed to delineate TCE contamination at the site (Shannon & Wilson, 2009). Two distinct source areas and associated groundwater plumes were identified (Figure 3). The primary source appears to be the Former Septic System and floor drains formerly located within the Middle School Metal Shop. A second source area appears to be the Maintenance Building floor drain or leakage/spillage from a former drum storage area on the south side of the Maintenance Building. Although a third apparent source area was identified off-site in the vicinity of the Runway Apron/Disposal Pit area, it is considered unlikely that this contamination is related to the TCE-

impacted soil and groundwater encountered at the Middle School and is not discussed in this FS.

- Also in 2008, approximately 2,300 cubic yards (cy) of PCB-contaminated soil, construction debris, and tank content wastes were removed from the site. It was concluded that additional PCB contamination likely extends beneath the building foundations. It was not possible to remove all of the PCB contamination with available funding.
- The 2008 Former Septic System excavation (Figure 4) reached a maximum depth of approximately 26 feet below ground surface (bgs) in the vicinity of the former seepage pit. The base of the deepest excavation measured approximately 20 feet (east-west) by 25 feet (north-south). The septic tank excavation reached a maximum depth of approximately 18 feet bgs. The excavation depth of the east and west septic line reached a maximum of approximately 11 feet bgs. Groundwater was not encountered during the excavation. The west septic line and seepage pit excavations were not backfilled to their original elevation. The ground surface over these areas is approximately 8 feet lower than the pre-excavation ground surface.
- In 2009, a vapor intrusion (VI) assessment performed at the site determined that TCE exceeded the risk-based screening level (0.21 parts per billion by volume (ppbv) for commercial indoor air and 0.041 ppbv for residential indoor air) for all three indoor air sample locations at the school.
- Also in 2009, Site Characterization activities were performed to further delineate the PCB and TCE contamination, and a Site Cleanup Plan was prepared (Shannon & Wilson, 2010a). Site characterization activities included a soil gas survey, PCB soil borings, installing and sampling groundwater monitoring wells, conducting feasibility testing for remedial alternatives, and collecting soil and groundwater samples. The site investigation report also evaluated remedial alternatives for addressing remaining site contamination. The remedial alternative discussion focused on soil remedies; only three groundwater alternatives were considered for the TCE contamination: no action, enhanced bioremediation, and air sparging.
- Also in 2010, a hydrogeologic evaluation was completed to increase the understanding of groundwater behavior at the site, specifically the potential for groundwater contamination to impact the nearby drinking water wells for the Middle School and High School (Figure 2) (Shannon & Wilson, 2010b).
- In 2010, air purification filters and an SSD were installed to mitigate vapor intrusion risk in the Middle School building.

2.2. Groundwater Contamination Summary

Groundwater impact by TCE above Alaska Department of Environmental Conservation (ADEC) cleanup levels has been documented in two locations: an estimated 2,500 square foot plume south of the Maintenance Building[1] and an estimated 12,500 square foot plume beneath the Former Septic System[2] from the Former Seepage Pit location to the western portion of the Middle School. Note that groundwater monitoring wells have not been installed at the location of the highest TCE concentration measured in soil gas at SGP17, or within the footprint of the Maintenance or Middle School Buildings, or between the two plumes. As shown on Figure 3, the groundwater plume at the Former Septic System has been extended to encompass the locations of Soil Gas Point SGP17 and the former floor drains located within the Middle School Metal Shop.

More details about the groundwater contamination are provided in Section 2.5 of this FS.

2.3. Geologic Setting

2.3.1. Regional Surface Geology

The site is situated on the floodplain of the Kuskokwim River. The Aniak River flows northward into the Kuskokwim River just east of the village of Aniak, while the Aniak Slough flows southward from the general area where the Aniak River meets the Kuskokwim River. The Kuskokwim River cuts through the Kuskokwim Mountains approximately 60 miles upstream of Aniak; downstream of the Kuskokwim Mountains, the river flows through a broad floodplain with no significant topography. The central Kuskokwim River floods annually or biennially, usually as a result of ice breakup, which typically occurs in May.

The surficial geology in the vicinity of Aniak consists of Kuskokwim flood plain deposits of unconsolidated silt, sand, and gravel. The river deposits include: sediment deposits of bed-load sand, gravel, and silt from river-channel activity, fine-grained (silt and fine sand) sediments deposited on river banks during flood periods, and sediments deposited during heavy floods (Krause, 1984). Silt thicknesses in Aniak have been reported to range from 1 to 6 meters (Krause, 1984).

2.3.2. Site-Specific Geology

The school is built on a gravel pad overlying alluvial sediments of the Kuskokwim River floodplain. The pad material consists of soil classified as sandy gravel in accordance with the United Soil Classification System (USCS). The thickness of the pad near the school varies significantly from 12 to 27 feet bgs based on soil borings advanced to install soil gas points around the school by Shannon & Wilson during August 2009 (Shannon & Wilson, 2010). The native soil type underneath the pad is comprised of a horizon classified as predominantly silt from 10 to 25 feet thick. The silt horizon overlies native material classified as gravelly sand. The silt horizon appears to have been

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[1] The text in Shannon & Wilson (2010) reports the extent of contamination at 15,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 2,500 square feet.

[2] The text in Shannon & Wilson (2010) reports the extent of contamination at 25,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 12,500 square feet.

partially removed beneath the Aniak Middle School, presumably prior to building construction. Also, the silt horizon was partially removed during PCB excavation activities at former septic system (Figure 4) specifically it was removed to a depth of approximately 18 feet bgs at the former septic tank location and completely removed (to a depth of 26 feet bgs) around the former seepage pit.

Shannon & Wilson (2010a) prepared cross-sections E-E’ and F-F’ to display the subsurface geology across the site. The locations of these cross-sections are shown on Figure 3, and the cross-sections are provided in Appendix A.

Shannon & Wilson (2010a) conducted grain size classification tests on five soil samples from the site to characterize the subsurface materials. Samples, descriptions, and results are summarized below in Table 2-1.

TABLE 2-1: GRAIN SIZE CLASSIFICATION RESULTS

Sample	Boring	Depth	Description	Classification
VES2-9	VES2	25.5-27.5	Gravel fill above silt	sandy gravel
SB25-0	B25/MW-12	0-2	Native silt	Slightly sandy silt
B20-32	B20/MW-7	32-33	Native sand in water-bearing zone	Gravelly sand
B21-32	B21/MW-8	32-33		
SB14-32	SB14	32-33		

2.4. Hydrogeology

2.4.1. Groundwater Elevation

Shannon & Wilson placed dataloggers in five site monitoring wells (MW-8 thorugh MW-12-see Figure 2) between September 2009 and May 2010 to measure groundwater table fluctuations (Shannon & Wilson, 2010b). Overall, the datalogger evaluation concluded that there are significant seasonal fluctuations in the groundwater table and groundwater flow direction, although the groundwater gradient was consistently fairly flat (low). There were four separate events that caused observable increases in the groundwater elevation:

- A precipitation event in October raised the groundwater elevation an average of 1.9 feet;
- A period of above-freezing temperatures in early December resulted in a second groundwater elevation peak; and
- The low groundwater level was measured on February 23, 2010, and groundwater levels began slowly rising on April 20, concurrent with the first notable increasing air temperatures for the season.
- Between April 20 and May 12 and 13, groundwater elevations increased approximately 5 feet to the maximum groundwater elevation measured during the study.

Over this time period, the depth to groundwater is summarized below for each location:

- MW-8: 27 ft bgs to 32 ft bgs;
- MW-9: 20 ft bgs to 25 feet bgs;
- MW-10: 28 ft bgs to 33 ft bgs;
- MW-11: 29 ft bgs to 34 ft bgs; and
- MW-12: 25 ft bgs to 30 ft bgs.

2.4.2. Horizontal Groundwater Flow

Water table elevation graphs and groundwater contour maps prepared by Shannon & Wilson are included in Appendix B to this report. Groundwater flow directions and gradients measured by Shannon & Wilson (2010b) are summarized below.

- October 3, 2009 (low groundwater elevation): Groundwater flow direction to the north at a gradient of approximately 0.0004 feet/foot.
- High groundwater elevation (Fall 2009 and Winter 2009): Groundwater flow direction to the south at gradients of 0.0005 and 0.0002 feet/foot.
- January through April 2010 (sustained low groundwater elevation): Groundwater flow generally to the west at a gradient of 0.0003 feet/foot.
- May 2010 (maximum groundwater elevation): Groundwater flow to the south at a gradient of approximately 0.002 feet/foot.

Hydraulic conductivities and seepage velocities were calculated for the silt and native sand layers at the Aniak WACS site, as shown in Table 2-2 and described below.

Based on the grain size classification tests (Table 2-1), a hydraulic conductivity of approximately 4E-02 centimeters per second (cm/sec) was calculated for the gravelly sand layer (using the Hazen Method). Literature hydraulic conductivity values for the sand range from approximately 1 to 1E-03 cm/sec and for the slightly sandy silt range from approximately 1E-03 to 1E-07 cm/sec (Freeze & Cherry, 1979).

Seepage velocities were calculated for the silt and gravelly sand layers based on the minimum and maximum hydraulic gradients (0.0002 ft/ft to 0.002 ft/ft), the minimum and maximum hydraulic conductivities and estimated porosities.

- Gravelly sand: 0.2 meters per year (m/yr) to 2000 m/yr
- Slightly sandy silt: 3E-05 m/yr to 3 m/yr

However, the variable groundwater flow directions (northerly, southerly, and westerly directions measured) suggest that the groundwater is not expected to migrate significantly in any one direction.

TABLE 2-2: GROUNDWATER FLOW PARAMETER SUMMARY

Soil Description	Soil Classification (1)	Porosity (2)	Hydraulic Conductivity (cm/sec) (3)	Hydraulic Conductivity (cm/sec) (4)	Hydraulic Conductivity (cm/sec) (5)	Hydraulic Gradient Range (ft/ft) (6)	Darcy velocity (min, max) cm/sec (7)	Seepage velocity (min, max) cm/sec (8)	Seepage velocity (min, max) m/yr	Seepage velocity (average) m/yr (9)
Gravel Fill Above Silt	Sandy gravel (GW)	0.28	n/c	n/c	n/c					
Native Silt	Slightly sandy silt (ML)	0.2		1E-07 to 1E-03	1E-06 to 1E-04	0.0002 to 0.002	2E-06 to 2E-11	1E-10 to 1E-05	3E-05 to 3	0.008
Native Sand (Water-Bearing)	Gravelly sand (SP)	0.3	0.04	5E-03 to 1	1E-03 to 1E-01	0.0002 to 0.002	2E-07 to 2E-03	7E-07 to 8E-03	0.2 to 2000	21

Notes

(1) Grain size analysis (Shannon & Wilson, 2010a); reported in Table 1
(2) Literature values reported in (Shannon & Wilson, 2010)
(3) Hazen method: $K=c(d_{10})^2$; d_{10}=0.02 cm and C ~ 100; Hazen method only applicable for d_{10} from 0.1 to 3 mm
(4) Table 2.2 in (Freeze & Cherry, 1979) range for silt, loess (native silt) and clean sand (gravelly sand)
(5) Table 4.5 in (Fetter, 1988) range for silt and sandy silts (native silt) and well-sorted sands (gravelly sand)
(6) Shannon & Wilson (2010a): min gradient 0.0002 ft/ft to W-SW in Dec. 2009 (medium water level) and 0.0003 ft/ft to W (winter low water) and max gradient 0.002 ft/ft to the S May 2010 (high water)
(7) V_d=Q/A=Hyd. Cond. * Gradient
(8) $V_s=V_d$/porosity
(9) Based on available data: Grad (avg) = 0.0005 ft/ft; Hyd. Cond. (avg) for sand=0.04 cm/sec and for silt=1E-05 cm/sec
n/c Not calculated; gravel fill is unsaturated or method is inappropriate for soil type

2.4.3. Vertical Groundwater Flow

Vertical groundwater gradient has not been evaluated at this site.

2.4.4. Pump Test

As part of the hydrogeologic evaluation, Shannon & Wilson performed pumping tests of the Middle School and High School drinking water wells to determine whether pumping affects water levels in nearby monitoring wells and, by extension, whether it can affect migration of the groundwater TCE plumes (Shannon & Wilson, 2010a and 2010b).

Shannon & Wilson installed monitoring Wells MW-11 and MW-12 for use in the pumping tests and as sentry wells for the Middle School and the High School drinking water wells. MW-11 is located about 55 feet from the Middle School drinking water well, and MW-12 was positioned about 75 feet north of the High School drinking water well (Figure 2). The Middle School drinking water well is about 60 feet deep, whereas the High School drinking water well is about 45 feet deep. During the pumping test, groundwater contact was at about 32 feet in MW-11 and 29 feet in MW-12.

Three pumping tests were performed:

- Middle School pumping test in which the drinking water well was pumped at a total net flow rate of about 20 gallons per minute (gpm) for 3.5 hours.
- High School pumping test in which the drinking water well was pumped at a total net flow rate of about 11 gpm for 6 hours.
- Combined pumping test in which both drinking water wells were pumped at a total net flow rate of about 31 gpm for 4 hours.

In all three tests, groundwater level measurements were collected using pressure transducer/dataloggers in five monitoring wells (MW-8, MW-9, MW-10, MW-11, and MW-12), and atmospheric pressure measurements were also collected to correct for barometric pressure variations. All three pumping tests showed very little change in water level during or after pumping. Shannon & Wilson concluded that pumping from the drinking water wells had no measureable influence on water levels in the five nearby monitoring wells.

2.5. Detailed Summary of Site Groundwater Conditions

The groundwater TCE plumes are shown in Figure 3. MW-4 plume data are summarized in Table 2-3, and Septic System plume data are summarized in Table 2-4.

TABLE 2-3: MAINTENANCE BUILDING (MW-4) PLUME DATA SUMMARY

	Elevation (TOC)	Screened Interval	2008 TCE (ug/L)	Depth to GW (ft bgs)	Silt Interval (ft bgs)	Gravel Interval (ft bgs)	Screened in (Saturated)	Comment
MW-4 (B-17)	90.68	22-32	**19.3**	27->32	?-<25	25-31	SAND	Not logged 0-25'
B4	--	--	--	--	14-27+	0-14	--	No GW sample; Bottom of boring at 27'
B6	91.03	26.5-31.5 (T)	**24.5**	27.5	17-27	27-40	SAND	
B7	91.16	26.5-31.5 (T)	**10.1**	26.3	18-20	20-40	SAND	
B8	90.82	25.5-30.5 (T)	3.21	26.2	19.3-19.8	19.8-30	SAND	Defines south plume boundary; located between MW-4 and B11
B9	91.41	26-31	ND (<1)	26.5	13.5-30	0-13.5	SILT	Defines north plume boundary; located north of Maintenance Bldg

Notes:
TOC = top of casing
ug/L = micrograms per liter
TCE=trichloroethene
GW = groundwater
bgs = below ground surface
(T)=temporary well

2.5.1. Maintenance Building (MW-4) Plume

Shannon & Wilson (2010) estimated the surface area of the MW-4 plume to be approximately 2,500 square feet[3]. However, this area should be considered a fairly rough estimate, as the plume delineation is based on one groundwater sample each from MW-4 and temporary wells B-6 and B-7. The plume is bounded to the north and south by a non-detect in B9 and a dectection of 3.21 micrograms per liter (µg/L) in B-8.

[3] The text in Shannon & Wilson (2010) reports the extent of contamination at 15,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 2,500 square feet.

TABLE 2-4: SEPTIC SYSTEM (MW-7) PLUME DATA SUMMARY

			Groundwater Sample TCE Results (ug/L)									
	Elevation (TOC)	**Screened Interval (ft bgs)**	**10/21/2006**	**5/19/2008**	**6/4/2008**	**8/22/2009**	**Depth to GW (Range in ft bgs)**	**Silt Interval (ft bgs)**	**Bottom of Silt Elev (ft)**	**Sand/ Gravel Interval (ft bgs)**	**Screened In (Saturated)**	**Comment**
MW-1 (B1)	86.76	19-29	<1	3.63	**8.24**	--	21.7-24	17-24.5	62	24.5-30	Silt: 19-25; SAND: 25-29	High gw - contam in silt; Low gw-contam in sand
MW-2 (B2)	89.76	22-32	**5.44**	**11.4**	**8.48**	--	24.7-27	14.5-24.5	65	24.5-32	SAND	Bottom of boring at 32
MW-5 (B18)	90.24	22-32	--	--	**157**	--	27.2->31	25-31	<59		SILT	Not logged 0-25; assume silt begins betw. 17 and 23 ft bgs (B11 and B12). Base of silt unknown.
MW-7 (B20)	90.04	23-38	--	--	--	**47.5**	30.3	13-26	64	26-38	(Silt: 23-26); SAND	Based on MW-8 datalogger, GW depth range 27-32 ft bgs. Saturated interval is below silt.
MW-8 (B21)	90.03	47-52	--	--	--	ND (<1)	27-32*	14-31	59	31-52	SAND	
MW-3 (B5)	80.75	12-22	<1	--	ND (<1)	--	17-18	19.5-23	58	15-19.5 (Silt above & below)	Sand: 17-19.5; Silt: 19.5-23	Silt to bottom of boring at 23
MW-6 (B19)	88.36	18-28	--	--	--	ND (<1)	24.7-28.6	13-22	66	22-29	SAND	
MW-9 (B22)	83.24	13-28	--	--	--	ND (<1)	20-25*	3-10.5	73	10.5-29	SAND	Bottom of boring at 29
MW-10 (B23)	91.18	25-40	--	--	--	--	28-33*	16-21	70	21-40	SAND	Bottom of boring at 40
B3	--	--	--	--	--	--	*17***	12-19.5		9.5-12	--	Silt to bottom of boring at 19.5
B11	90.87	26-31 (T)	--	**32.4**	--	--	*27***	23.5-30	61	0-23.5	SILT	Bottom of boring at 30
B12	91.03	26-31 (T)	--	**187 (dup)**	--	--	*27***	16.7-27	64	27-45	Silt: 26-27; Sand: 27-31	Saturated interval is below silt.
B13	89.31	26-31 (T)	--	1.58	--	--	*26***	14-30	<59		SILT	Bottom of boring at 30
B14	81.23	16-21 (T)	--	3.79	--	--	*17***	0-17	64	17-22	SAND	
B15	80.4	16.6-21.6 (T)	--	0.43J	--	--	*17***	0-15	65	15-22	SAND	
B16	79.79	17-22 (T)	--	ND (<1)	--	--	*17***	0-15	65	15-22	SAND	

Notes:

TOC = top of casing   bgs = below ground surface   (T)=temporary well
ug/L = micrograms per liter   GW = groundwater
*Datalogger 9/09-5/10   ** GW depth per boring log at time of drilling

The plume has not been delineated to the east or the west, except by MW-3 (located 90 feet west of the interpreted plume boundary). The presence of underground utilities limited the ability to install monitoring wells to the east of this plume.

Within the plume, the subsurface is generally characterized by:

- Gravel from ground surface to approximately 15 feet bgs;
- Silt from approximately 15 feet bgs to 27 feet bgs*; and
- Sand from approximately 30 feet bgs to 40 feet bgs.

*However, the silt layer was substantially thinner in boring B7 (18-20 feet bgs) and B8 (19.3-19.8 feet bgs).

Based on limited data (two events), the depth to groundwater varied from approximately 27 feet bgs to greater than 32 feet bgs.

The plume is characterized by TCE concentrations between 10.1 µg/L and 24.5 µg/L (one single sample event for 3 temporary wells and 1 permanent well in 2008). The monitoring wells were generally screened across the sand interval below the silt, except for temporary well B9, which was screened within the silt.

There is the potential for groundwater to perch in the coarse-grained sediments on top of the silt particularly beneath the Aniak Middle School where the top of the silt is at a lower elevation relative to the surrounding area. Perched groundwater was only observed in one of the soil borings at this site (MW-2), suggesting that groundwater ponding would most likely only be temporary. The potential for perched groundwater has not been characterized.

2.5.2. Former Septic System (MW-7) Plume

Shannon & Wilson (2010) estimated the surface area of the Former Septic System plume to be approximately 12,500 square feet[4]. The plume boundaries have been well-delineated to the south by temporary wells B-13 through B-16 and monitoring wells MW-6 and MW-9. The plume is not well-delineated to the north (temporary well B8 only), northeast (MW-3 is approximately 80 feet to the north-northeast), east, or west.

Within the plume, the subsurface is generally characterized by variable layers of silt, sand, and gravel. In the western lobe of the plume (between MW-1 and AIW), the subsurface is generally characterized as follows:

- Silt (MW-1) or Sandy/gravelly fill from ground surface to approximately 15 feet bgs;
- Silt from approximately 15 feet bgs to 25 feet bgs*; and
- Sand from approximately 25 feet bgs to 30 feet bgs.

*Note, however, that the soil in the vicinity of the former seepage pit was excavated to a maximum depth of 26 feet bgs in 2008, thereby removing most or all of the silt in that

[4] The text in Shannon & Wilson (2010) reports the extent of contamination at 25,000 square feet; however, the area shown in their figures and their air sparging calculation (Table L-4) is approximately 12,500 square feet.

area. The soil in the vicinity of the former septic tank was excavated to a maximum depth of 18 feet bgs in 2008, thereby removing some of the silt in that area. Note further that the excavation was not completely backfilled to the former ground surface over the west septic line and former seepage pit area, resulting in a ground surface approximately 8 feet lower than the pre-excavation surface. This elevation change is not reflected in the depths cited above.

Groundwater in the western lobe of the Septic System plume is characterized by TCE concentrations between 5 µg/L and 47.5 µg/L. The monitoring wells were generally screened across the sand interval below the silt. Based on MW-8, which was screened in the sand from 47 to 52 feet bgs and exhibited no contaminant detections, the contamination appears to decrease with depth below the silt.

The subsurface in the central portion of the Septic system plume (between AIMP, MW-5, B-12, and B-13) is generally characterized by:

- Gravel fill from ground surface to approximately 17-23 feet bgs;
- Silt from approximately 17-23 feet bgs to 27-30 feet bgs; and
- Sand from approximately 27 feet bgs to 45 feet bgs*.

*Based on the B-12 boring log; most of the boring logs did not extend below approximately 30 feet bgs.

Groundwater in the central portion of the plume is characterized by TCE concentrations between 32.4 µg/L and 187 µg/L. These temporary and permanent monitoring wells were generally screened across the silt.

The northwest, northeast, and southeast portions of the plume have not been fully delineated. An elevated TCE concentration was detected in the soil gas sample from SGP-8, located on the east side of the middle school building. There are no groundwater monitoring wells in the vicinity of SGP-8, so it is unknown whether the groundwater plume extends to that area. It should also be noted that the soil gas concentrations detected in SGP-17 and SGP-18 were more than an order of magnitude higher than the soil gas concentrations detected anywhere else in the soil gas survey.. There are no groundwater monitoring wells at these locations; the closest ones groundwater samples were collected from temporary wells B-12 and B-13.

Based on the MW-8 datalogger data, the depth to groundwater varied from approximately 27 feet bgs to 32 feet bgs. Manual measurements from MW-1 and MW-2 (May and June 2008) suggest a higher groundwater table (24 to 27 feet bgs).

As discussed in the previous section, there is the potential for groundwater to perch in the coarse-grained sediments on top of the silt. Perched groundwater was only observed in one of the soil borings at this site (MW-2), suggesting that groundwater ponding would most likely only be temporary. The potential for perched groundwater has not been characterized.

2.5.3. General Conclusions/Considerations for Groundwater Remedial Alternatives Analysis

- Groundwater remediation alternatives should consider the planned soil remediation activities for the site. The timeframe for these activities has not been established yet. The planned soil remediation activities are summarized below. They would not be expected to have much of an effect on contamination in the silt layer.
  - Figure 4 shows the locations of the planned excavation of soil contaminated by PCBs commingled with TCE. Planned excavation depths are variable, primarily dependent upon the depths of PCB contamination.
  - Figure 4 also shows the locations of the planned SVE system for vadose zone treatment. The SVE system has not yet been designed; however, the preliminary design described in Shannon & Wilson (2010) calls for SVE wells with a 5-foot well screen installed at approximately 2/3 the depth to silt (roughly 18 feet to 23 feet bgs).
- Available data suggests a very slow groundwater seepage velocity at the site, with significant seasonal variability in the flow direction. Monitoring data and a pumping test performed by Shannon & Wilson (2010) do not indicate that the groundwater contamination plume is migrating. However, the groundwater elevation dataset is incomplete; there are no datalogger data available from May and September, which is when the highest water table and maximum water table fluctuations would be expected. Collection of additional datalogger data is strongly recommended before deciding on a groundwater remedy at this site.
- Available data indicates dramatic seasonal fluctuations in the groundwater table elevation (from approximately 24 to 32 feet bgs). As discussed in the previous bullet, the groundwater elevation dataset is incomplete, and collection of additional datalogger data is strongly recommended before deciding on a groundwater remedy at this site.
- The silt layer appears to hold much, if not most, of the TCE contamination; as such, remediation of the silt layer is necessary to affect overall site cleanup goals. The highest TCE concentrations were detected in monitoring wells screened across the silt (MW-5) or across both the silt and the underlying sand (B-12). The planned soil remediation activities (excavation and SVE) are unlikely to adequately address vadose zone contamination in the silt layer. To be effective, site remediation will need to address both sorbed and dissolved-phase contamination in the silt layer. Remediation in the silt layer will be complicated by the approximately 8-foot zone of groundwater fluctuation. Contamination allowed to remain in the vadose zone silt will continue to provide a source of both soil vapor and dissolved-phase groundwater contamination.
- The potential for perched groundwater contamination on top of the silt layer has not been evaluated.

2.6. Conceptual Site Model

Shannon & Wilson prepared a pictoral conceptual site model and a graphical human health conceptual site model (CSM) using the ADEC CSM template (ADEC 2005), in their 2010 report. Because this focused FS is limited to groundwater remediation, only groundwater pathways are discussed in this report. The following groundwater exposure pathways are potentially complete:

- **Ingestion of groundwater**: All groundwater in Alaska is considered a potential drinking water source unless determined otherwise using the criteria presented in 18 AAC 75.350. No groundwater determination has been completed for this site under 18 AAC 75.350. There are two drinking water wells near the site (high school drinking water well and middle school drinking water well).
  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.
- **Inhalation of volatile compounds in tap water (showering):** TCE is a volatile compound.
  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.
  - Indoor air inhalation is considered a potentially complete pathway for TCE in groundwater, as well as for TCE in the vadose zone. As discussed previously, air purifying filters and a sub-slab depressurization system (SSD) are in place to mitigate the vapor intrusion pathway for TCE in the Middle School building. The contribution of volatilizing TCE from groundwater to the vapor intrusion pathway is unknown, but ADEC CSM guidance (ADEC, 2005) states that the vapor intrusion pathway should be considered complete if nonpetroleum contamination in soil or groundwater is found within 100 vertical or horizontal feet of a building.

Several of the pathways shown to be potentially complete in the CSM for the entire site are not considered complete when considering only the groundwater TCE plumes.

- Outdoor air inhalation is not considered a potentially complete pathway for TCE in groundwater due to the groundwater depth. ADEC (2005) states that the outdoor inhalation pathway must be considered for contamination detected between ground surface and 15 feet bgs.
- Dermal adsorption is not considered a potentially complete pathway for TCE and DCE (ADEC, 2005).
- Surface water exposure is not considered a potentially complete pathway. The hydrogeological evaluation showed a very low groundwater gradient at the site with variable flow direction. There is no evidence that the groundwater contamination has migrated off-site towards Aniak Slough or the Kuskokwim River, nor do the data suggest that future off-site migration is a concern. However, a longer-duration (i.e., including all seasons) datalogger study would be very useful before completely ruling this out.

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3. REMEDIAL ACTION OBJECTIVES

The overall objectives of environmental site restoration are to ensure that conditions at each site are protective of human health and the environment and to comply with relevant state and federal regulations. The primary goals of remedial action at the Aniak WACS site are the following:

- Reduce current human health exposure risk below the ADEC threshold cancer risk level of 1:100,000 and threshold non-cancer hazard index of 1.

The specific remedial action objective (RAO) proposed to reduce human health exposure risk is listed below.

1. Reduce concentrations of TCE and DCE in groundwater to meet the ADEC Table C cleanup levels (ADEC 2008) (Table 3-1).

TABLE 3-1: 2008-2009 MAXIMUM GROUNDWATER CONCENTRATIONS AND ADEC CLEANUP LEVELS

Contaminant	Maximum Concentration (µg/L)	Location of Maximum Concentration (Sample Depth in ft)	ADEC Table C Cleanup Level (µg/L)*
2009 Sampling			
TCE	47.5	MW-7 (34)	5
cis-1,2-DCE	2.81	MW-7 (34)-dup	70
Vinyl chloride	*		2
2008 Sampling			
TCE	187	TWB-12S (26-31)-dup	5
Cis-DCE	18.8	TWB-13S (26-31)	70
Vinyl chloride	*		2

Notes:
µg/L = Micrograms per liter
Vinyl chloride not detected above laboratory reporting limits in groundwater samples.
*Cleanup levels are provided in Table C of the Alaska Contaminated Site Regulations (18 AAC 75.345).

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4. REMEDIAL TECHNOLOGIES

The EPA's 13th Annual Superfund Remedy Report (EPA, 2010) was reviewed to investigate recent trends in groundwater remedial actions. Although the report is limited to remedial actions at Superfund sites, it is reflective of current trends in technology. The report presented the following conclusions:

- The selection of in situ treatment, monitored natural attenuation (MNA), and institutional controls (ICs) has increase over time, whereas the selection of pump and treat has decreased.
- Bioremediation and chemical treatment are the most frequently selected in situ groundwater treatment technologies.

The Federal Remediation Technologies Roundtable Table 3-2: Treatment Technologies Screening Matrix (http://www.frtr.gov/matrix2/section3/table3_2.pdf) was used to identify remedial technologies that are potentially appropriate for consideration at the Aniak WACS site. Table 4-1 presents all of the treatment technologies shown in the FRTR matrix for groundwater, along with a brief description of the technology, FRTR's rating of the technology for cleanup of halogenated VOCs, and a brief discussion of site-specific considerations for use of the technology at the Aniak WACS site. The technologies presented in Table 4-1 are color-coded to reflect whether they are discussed in this pre-draft FS (green), not considered applicable and therefore not discussed in this pre-draft FS (red), or not a standalone remedy (yellow).

As shown in Table 4-1, containment technologies, along with passive/reactive treatment walls, were not considered appropriate for consideration at the Aniak WACS site. The groundwater plume is located right beside and possibly underneath the Aniak Middle School building, so plume containment would not accomplish the RAO of reducing risk to people inside the school. Furthermore, available data suggests minimal groundwater plume migration is occurring so containment is likely not necessary for protection of downgradient receptors.

Based on Table 4-1, the following technologies warrant consideration for use at the Aniak WACS site: monitored natural attenuation (MNA), enhanced bioremediation, air sparging, chemical oxidation, in-well air stripping, and ex situ (i.e., pump and treat) with several different treatment technologies (oxidation and air stripping). Although not shown in Table 4-1, institutional controls (ICs) may be considered as either a standalone remedy or a remedy component. The no action alternative is always included as a baseline for comparison with all of the active alternatives. Detailed discussions of these technologies are presented in the following sections of this report.

Table 4-1: Treatment Technologies Screening for Halogenated VOCs in Groundwater (from www.frtr.gov, Table 3-2)

Technology	Effectiveness Rating	Brief Description	Aniak WACS Site-Specific Considerations
In-Situ Biological Treatment			
Enhanced Bioremediation	Effectiveness highly dependent on site-specific conditions	Enhance natural biodegradation processes by increasing the concentration of electron acceptors and/or nutrients.	Evaluated by Shannon & Wilson (2010) Low groundwater flow gradients will aid residence time; substrate distribution may be problematic.
Monitored Natural Attenuation	Average	Use natural biodegradation processes to degrade contaminants. Chlorinated ethenes degrade under anaerobic conditions.	Evaluated by Shannon & Wilson (2010)
Phytoremediation	Average	Use plants to remove, transfer, stabilize, or destroy contamination.	Groundwater too deep for in-situ phytoremediation (> 25 ft bgs). Not applicable.
In Situ Physical/Chemical Treatment			
Air Sparging	Average	Air is injected into saturated matrices to remove contaminants through volatilization.	Evaluated by Shannon & Wilson (2010). Silt layer will likely impede volatilization.
Bioslurping	Average	Bioslurping combines the two remedial approaches of bioventing and vacuum-enhanced free-product recovery.	No evidence of free-phase solvent at the site. Not applicable
Chemical Oxidation	Average	Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide	Evaluated by Shannon & Wilson (2010) for soil; potentially applicable for groundwater also. Oxidant distribution may be problematic.
Directional wells (enhancement)	Average	Drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling	Not a standalone technology. Possibly appropriate as a remedy component in near buildings.
Dual Phase Extraction	Above Average	A high vacuum system is applied to simultaneously remove contaminated groundwater, separate-phase product, and vapor from the subsurface.	No evidence of free-phase solvent at the site. Not applicable
Thermal Treatment	Above Average	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated	Silt layer will likely impede vaporized/volatilized contaminants.
Hydrofracturing Enhancements	Average	Injection of pressurized water through wells cracks in low permeability sediments. Cracks are filled with porous media that serve as substrates for bioremediation or to improve pumping efficiency	Not a standalone technology. Possibly appropriate as a remedy component in silt layer.
In-Well Air Stripping	Average	Air is injected into a double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Once in the well, some of the VOCs in the contaminated ground water are transferred from the dissolved phase to the vapor phase by air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a soil vapor extraction system.	Silt layer will likely impede use of in-well air stripper. Circulating wells may have an application.

Technology	Effectiveness Rating	Brief Description	Aniak WACS Site-Specific Considerations
Passive/Reactive Treatment Walls	Above Average	These barriers allow the passage of water while causing the degradation or removal of contaminants.	Variable groundwater flow direction would make this technology difficult to implement. Furthermore, the source area of the plume underlies the Aniak Middle School and is therefore the primary target treatment area.
		Ex Situ Biological Treatment	
Bioreactors	Above Average	Contaminants in extracted groundwater are put into contact with microorganisms in attached or suspended growth biological reactors.	Not appropriate for this site.
Constructed Wetlands	Average	The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove contaminants from influent waters.	Not appropriate for this site.
		Ex Situ Physical/Chemical Treatment	
Adsorption/ Absorption	Average	In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase.	Not appropriate for this application.
Advanced Oxidation Processes	Above Average	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect, or escape.	Possibly appropriate.
Air Stripping	Above Average	Volatile organics are partitioned from extracted groundwater by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration	Possibly appropriate.
Granulated Activated Carbon/Liquid Phase Cation Adsorption	Above Average	Groundwater is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.	Inferior to air stripping or oxidation as an ex-situ technology, due to the need for periodic replacement of carbon.
Pump and Treat	Average	Groundwater pumping is a component of many pump-and-treat processes, which are some of the most commonly used ground water remediation technologies at contaminated sites.	Would be a component of any ex situ technology.
Ion Exchange	Below Average	Ion exchange removes ions from the aqueous phase by exchange with counter ions on the exchange medium.	Not applicable.
Precipitation/ Coagulation/ Floccuation	Below Average	This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation.	Not applicable.
Separation	Above Average	Separation techniques concentrate contaminated waste water through physical and chemical means (i.e., distillation or filtration).	Not applicable.
Sprinkler Irrigation	Above Average	The process involves the pressurized distribution of VOC-laden water through a standard sprinkler irrigation system.	Not applicable.

Technology	Effectiveness Rating	Brief Description	Aniak WACS Site-Specific Considerations
Containment			
Physical Barriers	Above Average	These subsurface barriers consist of vertically excavated trenches filled with slurry. The slurry, usually a mixture of bentonite and water, hydraulically shores the trench to prevent collapse and retards ground water flow.	Available hydrogeology data suggests that groundwater is not migrating off-site. Probably not appropriate.
Deep Well Injection	Average	Deep well injection is a liquid waste disposal technology. This alternative uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers.	Not applicable.
*Air Emissions/Off-Gas Treatment**			
A number of technologies have been widely applied for removal of VOCs from off-gas streams. These technologies are not specifically considered in this FS, which is primarily concerned with groundwater remediation technologies. Shannon & Wilson (2010) concluded that off-gas treatment would most likely not be necessary.			

Color Key	
	Technology evaluated in pre-draft FS
	Technology not evaluated in pre-draft FS
	Not a standalone remedy

4.1. No Action

The No Action Alternative is used as a baseline reflecting current conditions without remediation. This alternative is used for comparison with each of the other alternatives.

4.2. MNA

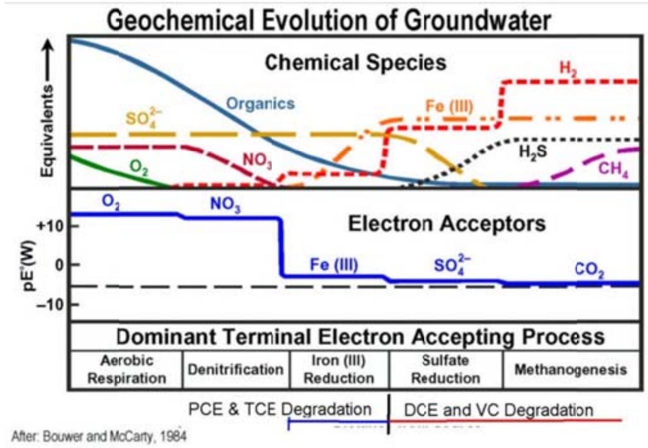
MNA uses periodic sampling to monitor the reduction of contaminant concentrations by natural processes occurring in groundwater. Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater. Of these processes, biological degradation is usually the most significant. MNA would allow these processes to continue to occur as they have in the past, without disturbances potentially caused by implementation of active remedial technologies.

4.2.1. Biological Degradation of TCE

The most important process for the natural biodegradation of the most highly chlorinated solvents (PCE and TCE) is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, and a chlorine atom is removed and replaced with a hydrogen atom. In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride to ethene. Reductive dechlorination occurs in anaerobic groundwater conditions; the most rapid rates occur under highly reducing (sulfate-reducing and methanogenic) conditions (Wiedemeier, et. al. 1998), although reductive dechlorination has also been documented to occur under nitrate- and iron-reducing conditions. Because chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination, there must be an appropriate source of carbon for microbial growth in order for this process to occur. Potential carbon sources include natural organic matter, fuel hydrocarbons, or other anthropogenic organic compounds.

The geochemical evolution of groundwater is shown in the diagram below. Dissolved oxygen (DO) is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon. During aerobic respiration, DO concentrations decrease. After depletion of DO, anaerobic microbes will use nitrate as an electron acceptor, followed by iron (and manganese, not shown on the diagram), sulfate, and finally carbon dioxide (methanogenesis). Each sequential reaction drives the oxidation-reduction potential of the groundwater downward into the range within which reductive dechlorination can occur. PCE and TCE degradation can occur in less reducing (i.e., iron-reducing) groundwater than DCE and vinyl chloride degradation (i.e., sulfate-reducing and methanogenic).

Although reductive dechlorination is the most prominent method for biological degradation of PCE and TCE, the daughter products DCE and vinyl chloride can be oxidized either anaerobically or aerobically. In fact, the aerobic oxidation rate of vinyl chloride is actually much faster than the anaerobic reductive dechlorination rate.



Therefore, at some sites the optimal remedial technique is reductive dechlorination of PCE and TCE and possibly DCE, followed by downgradient oxidation of vinyl chloride, and possibly also DCE. Due to the dramatically different geochemical conditions required for reductive dechlorination and aerobic oxidation, combining these two degradation mechanisms can be difficult.

4.2.2. MNA Considerations for Aniak WACS

Natural attenuation potential was evaluated during the 2008 TCE Characterization efforts (Shannon & Wilson, 2009). Natural attenuation parameters were measured in samples from monitoring wells MW1 through MW6; results are presented in Table 4-2.

The data in Table 4-2 do not suggest that any significant reductive dechlorination is occurring at the site. The elevated DO and oxidation-reduction potential (ORP) concentrations suggest oxygenated groundwater. The elevated nitrate and sulfate concentrations suggest that no significant nitrate or sulfate reduction has occurred at the site, and, furthermore, that there are significant competing electron acceptors that will need to be reduced before TCE reduction will occur. Methane was not detected in any of the samples. The low total organic carbon (TOC) concentrations indicate the need for an outside carbon source for the reductive dechlorination process.

The presence of TCE degradation products in site groundwater samples is another line of evidence for MNA. A review of groundwater monitoring results shows that only low concentrations of cis-DCE have been detected in samples from two site monitoring wells: MW-1 and MW-7. However, high concentrations of cis-DCE were detected in the soil gas sample from SGP-18, and the cis-DCE concentration in B-13 (18.8 µg/L) exceeded its TCE concentration (1.57 µg/L), suggesting that MNA is occurring in this section of the plume. Elevated total petroleum hydrocarbons (TPH) detected in SGP-18 suggest that petroleum contamination may be providing a carbon source for reductive dechlorination in this area.

TABLE 4 2: ANIAK WACS GROUNDWATER MNA PARAMETER DATA (2008)

	Units	**MW-1**	**MW-2**	**MW-3**	**MW-4**	**MW-5**	**MW-6**
Alkalinity	mg/L	78.8	111	331	146	151	204
Chloride	mg/L	2.09	1.06	2.16	3.45	1.83	1.08
Iron	mg/L	0.11	0.111	5.75	0.0234	0.0645	1.41
Dissolved Iron	mg/L	<0.02	<0.02	0.216	0.229	0.0212	0.248
Dissolved Manganese	mg/L	5.03	0.00223	0.0107	0.0713	0.0322	0.425
Nitrate-N	mg/L	35.1	4.12	3.29	2.67	2.77	2.2
Nitrite-N	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/L	60.5	11	45.9	10.1	14	18.2
Methane	mg/L	<0.0072	<0.0072	<0.0072	<0.0072	<0.0072	<0.0072
Total Organic Carbon	mg/L	1.74	1.92	3.89	0.0953	1.98	1.3
pH	pH units	6.11	5.85	6.32	6.1	6.06	6.04
Dissolved Oxygen	mg/L	5.25	2.48	3.89	1.51	3.17	1.35
ORP	mV	173.2	162.7	137.3	200.6	122	182.1

mg/L milligrams per liter
ORP oxidation-reduction potential
N nitrogen

Overall, site data do not suggest MNA is a viable alternative for treating groundwater contamination at the Aniak WACS site. However, another round of MNA parameter sampling is suggested to evaluate whether the groundwater geochemistry has changed since 2008. The current monitoring well network is more extensive than the 2008 monitoring well network.

4.3. Enhanced Bioremediation

4.3.1. Enhanced Bioremediation Description

Enhanced bioremediation would involve injection of a substrate into site groundwater to enhance (or initiate) the reductive dechlorination process at the site. The purpose of the substrate addition is to promote environmental conditions necessary for biodegradation of the chlorinated solvents (i.e., reducing conditions). The substrate provides a carbon source for naturally occurring microorganisms to consume oxygen and other electron acceptors such as nitrate and sulfate and a source of hydrogen necessary for the anaerobic biodegradation process.

There are a variety of substrates available for promoting reductive dechlorination at contaminated sites (e.g., sodium lactate, vegetable oil, and Hydrogen Release Compound [HRC™], among others).

4.3.2. Enhanced Bioremediation Considerations for Aniak WACS

Although Shannon & Wilson's 2010 report evaluated enhanced bioremediation for soil at the Aniak WACS site, they did not consider enhanced bioremediation for groundwater, due to concerns about impacting the drinking water wells. The final chlorinated end product of reductive dechlorination (vinyl chloride) is considered a human carcinogen so incomplete reductive dechlorination could potentially pose a risk to the drinking water wells. However, the hydrogeologic evaluation performed by Shannon & Wilson suggests that migration of the contaminated groundwater is limited and there is no evidence that it has migrated to the drinking water wells.

In order to more fully evaluate the potential risks of enhanced bioremediation at the site, a more complete hydrogeologic evaluation is needed. The hydrogeologic evaluation performed by Shannon & Wilson (2010a, 2010b) and discussed in Section 2.4 of this FS did not suggest significant migration of the groundwater plume or plume impacts by pumping of the drinking water wells. The more complete hydrogeologic evaluation should include pressure transducer/datalogger recordings of groundwater levels in site monitoring wells for the summer months (i.e., period of maximum expected groundwater level fluctuation and flow direction variability), at a minimum, and preferably for a whole year. A second pumping test at a different groundwater elevation may also be warranted.

A significant consideration for enhanced bioremediation is the substrate distribution. There are no specific concerns about substrate distribution in the saturated gravelly sand; however, effective substrate distribution in the lower permeability silt layer would be expected to be difficult. If the enhanced bioremediation only targeted the gravelly sand layer, then contamination sorbed onto the silt would continue to desorb into groundwater and provide a continuing source of dissolved-phase contamination.

Another specific consideration for enhanced bioremediation is concern over the ability to drive the groundwater plume to anaerobic conditions and maintain these conditions over time. The 2008 MNA parameter sample results indicate that the site groundwater is generally aerobic and there are significant competing electron acceptors that will need to be reduced before TCE reduction will occur. In addition, the significant recharge events shown by Shannon & Wilson's datalogger study likely result in significant influxes of aerobic water to the subsurface that would have to be driven anaerobic. Groundwater sampling for dehalococcoides ethenogenes (DHC), which are the only known organisms capable of the complete dechlorination of PCE and TCE to ethene, has not been performed at the site. However, DHC sampling is not currently recommended for this site, because low TCE daughter product concentrations suggest that the native DHC population would be low. In summary, it appears likely that the natural aerobic conditions at the site and periodic influxes of aerobic recharge water will exert a significant substrate demand, in addition to the substrate necessary to initiate and sustain the degradation of TCE. Because limited reductive dechlorination appears to be occurring at the site naturally, its effectiveness at this site is unknown.

Although the planned SVE system could also adversely affect enhanced bioremediation by inducing the flow of oxygenated air, the effects would be expected to be minor due to the silt layer.

4.4. Air Sparging

4.4.1. Air Sparging Technology Description

Air sparging is an in-situ technology in which air is injected into a contaminated aquifer to induce volatilization of contaminants. Air is forced into the saturated soil using air sparge wells. As air moves through the saturated soil within the zone of influence of the air sparge wells, volatile organic contaminants are stripped from the water. An SVE system is usually used in conjunction with air sparge to enhance the process by increasing flow through the groundwater, controlling gas/vapor movement through the subsurface, and capturing volatiles before they escape at the surface or expand the zone of contamination.

Air sparging is a proven and effective technology for addressing volatile contaminants in groundwater. Air sparging depends upon efficient mass transfer processes from the dissolved contaminanation into the air. The major limitation of the mass transfer process is the soil matrix itself. Injected air will flow in channels rather than in a uniform front across the soil. Small changes in soil texture (heterogeneities) can cause significant channeling of the air flow.

4.4.2. Air Sparging Considerations for Aniak WACS

Shannon & Wilson performed two air sparging pilot tests for the Aniak WACS site in September and November 2009. The second test was performed due to problems with the first test. For the pilot test, they installed an air injection well (designated AIW) and an air injection monitoring point (designated AIMP) in the vicinity of the Former Septic Tank and vapor extraction pilot test well VES1 (Figure 3). The AIW consists of 2-inch pipe with a 2.5-foot section of well screen set at about 15 feet below the water table (42.1 to 44.6 feet bgs) in granular soil. The AIMP consists of 2-inch pipe with a 2.5-foot section of well screen set at about 5 feet below the water table (33.1 to 35.6 feet bgs) in granular soil. Positive pressure was applied to the AIW to induce sparging. In the September test, a vacuum was also applied to VES-1, although no vacuum was applied in the November test. The radius of influence (ROI) of the air injected at the AIW was evaluated by measuring changes in water depth, dissolved oxygen levels, and pressure at nearby monitoring points. A change in water depth was not notable in AIMP, MW8, or VES1 during the air sparge test. The water level in AIW was depressed during the blower test from about 31.17 feet below the monitoring point before applying pressure to about 32.60 feet below the monitoring point and rising rapidly after applying pressure at AIW. Pressure increases were recorded in monitoring points AIMP (0 to 0.13 psi), VES1 (0 to 0.18 psi), MW5 (0 to 0.12 psi) and SGP1 (0 to 0.11 psi) located 15, 13, 21, and 12 feet from AIW, respectively. Likewise, increases in DO content were measured in monitoring points AIMP (0.68 ppm to 0.75 ppm), VES1 (0.78 ppm to 1.02 ppm), and MW8 (0.73 ppm to 0.77 ppm).

Results of the pilot testing conducted at the site indicate that air can be injected into the water bearing zone beneath the silt with a radius of influence of about 20 feet. One possible advantage of air sparging over other in situ technologies is that the radius of influence could allow some remediation under the Middle School building. However, air sparging may not be an effective remedial alternative as the silt layer overlying the saturated sandy gravel/gravelly sand may act as an aquitard, creating semi-confined conditions. Air injected into the semi-confined aquifer could become trapped by the overlying, semi-confining layer and may not be able to escape to the unsaturated zone for capture using SVE wells.

4.5. Chemical Oxidation

Chemical oxidation is potentially both an in-situ and ex-situ groundwater cleanup technology. In situ oxidation is described in the following subsection, whereas ex situ oxidation is discussed in Section 4.7.3.

4.5.1. Chemical Oxidation Technology Description

In situ chemical oxidation (ISCO) is a rapidly growing remedial technology that involves the introduction of a chemical oxidant into the subsurface to transform groundwater or soil contamination into innocuous substances such as carbon dioxide and water. The ISCO technology is briefly summarized in this pre-draft FS; much more detail on the technology and its application is available in the following publications by the EPA and the Interstate Technology and Regulatory Council (ITRC): *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater* (ITRC, 2005) and EPA Engineering Issue: In-Situ Chemical Oxidation (Huling and Pivetz, 2006). In addition, the Department of Defense's Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) are developing a Technology Practices Manual for ISCO that is due out later in 2011 (ER-200623).

In general, the oxidant is reduced by accepting electrons released from the transformation (oxidation) of target and non-target reactive species. Oxidation can result in the rapid and complete chemical destruction of many toxic organic chemicals, although some oxidants do not result in complete contaminant destruction. ISCO is applicable to treatment of chlorinated solvents, as well as a variety of other contaminants including petroleum hydrocarbons, PCBs, organochloride pesticides, and munitions.

Several different forms of oxidants have been used for ISCO, including permanganate (MnO_4^-), Fenton's hydrogen peroxide (H_2O_2) and ferrous iron (Fe^{+2})) or catalyzed hydrogen peroxide (CHP), ozone (O_3), and persulfate ($S_2O_8^{2-}$). In addition, there are proprietary compounds, such as RegenOx® by Regenesis Bioremediation Products. All of these oxidants are considered effective for oxidizing TCE and its degradation products DCE and vinyl chloride (ITRC, 2005). For other contaminants detected at the site (carbon tetrachloride detected in soil gas and PCBs detected in soil), permanganate, ozone, and persulfate are not considered effective. Peroxone (ozone/hydrogen peroxide) and Fenton's (H_2O_2/Fe) show some positive results for oxidation of carbon tetrachloride and PCBs.

The type of oxidant selected for an ISCO application depends on both the target contaminant and subsurface conditions. Stronger oxidants have less persistence in the subsurface than weaker oxidants and are therefore more suitable for high permeability layers and hot spots. On the other hand, weaker oxidants with more persistence are better suited for diffusion-controlled distribution in low permeability layers. For example, permanganate persists for long periods of time (greater than 3 months [Huling and Pivetz, 2006]), and diffusion into low-permeability materials and greater transport distances through porous media are possible. Ozone and H_2O_2 has been reported to persist in soil and aquifer material for minutes to hours, and the diffusive and advective transport distances will be relatively limited (Huling and Pivetz, 2006). Permanganate and non-activated persulfate are more suitable for low permeability layers and diffuse contamination, while CHP and activated persulfate are more suitable in high permeability layers and hotspots. Although low soil permeability is a barrier to all forms of remediation, ozone can be used to take advantage of the much higher gas-phase permeability (ITRC, 2005).

Two advantages of ISCO over other conventional treatment technologies are that large volumes of waste material are not usually generated, and the treatment time is frequently much shorter.

As with most in situ technologies, a primary consideration for effective in situ oxidation is the ability to effectively distribute the oxidant throughout the area of contamination. Other key considerations for effective ISCO include proper oxidant selection and dosage. Proper oxidant selection is based on the type of contaminant and subsurface conditions (i.e., heterogeneities). Correct oxidant dosage must consider the contaminant mass (both dissolved and sorbed), along with the inherent natural oxygen demand of the soil. Therefore, the ability to overcome site-specific heterogeneitites and geochemistry are key requirements for effective ISCO implementation.

4.5.2. Chemical Oxidation Considerations for Aniak WACS

Shannon & Wilson (2010) performed an analysis of chemical oxidation for soil at the Aniak WACS site. Groundwater treatment using chemical oxidation was not considered based on the risk to the on-site drinking water well. As discussed in Section 4.3.2, existing data suggests that the actual risk to the on-site drinking water well may not be significant, although further evaluation is needed.

Shannon & Wilson assumed treatment of the TCE-impacted soil using a potassium permanganate solution, although other equally viable oxidants are available. They performed oxidant demand tests which showed the oxidant demand of subsurface organic and inorganic components in the soil and groundwater was relatively low, ranging from about 0.3 to 1.5 percent by weight of soil.

Shannon & Wilson assumed that the potassium permanganate liquid mixture would be gravity-fed into the subsurface at points spaced through the zone of contamination. They assumed it would take approximately 1 year for liquid to permeate 5 feet of silt. The initial application will include sufficient liquid to saturate the area so that the chemical can react with available TCE and then still have enough remaining to slowly saturate the silt over an estimated 1 year infiltration period. Bench scale and field pilot tests would be performed to evaluate the radius of influence for the application wells, to determine oxidant dosing requirements, and to refine assumptions regarding the number of applications required.

Extending Shannon & Wilson's analysis to groundwater treatment by ISCO, the most significant considerations for in situ chemical oxidation at Aniak WACS are the silt layer overlying the saturated layer and the low and variable groundwater flow direction. To treat the groundwater, the oxidant would be applied through injection points drilled most of the way through the silt layer. This distribution system would allow some oxidation of contaminants in the base of the silt layer, although the distribution of oxidant within the silt layer would be expected to be poor. Similarly, it would be difficult or impossible to achieve a consistent oxidant "front" below the silt layer. Instead, the oxidant would migrate into and through the saturated zone in channels/preferential pathways, resulting in incomplete oxidant distribution. Injection of the permanganate oxidant mixture will also be inhibited by precipitation of dissolved metals, and permanganate particles will result in temporary permeability loss in the already low permeability silt. The issues will likely result in the necessity to inject the oxidant several times to complete remediation.

There are several potentially competing considerations for oxidant selection at Aniak WACS. Based on its greater persistence in the environment and therefore greater ability to diffuse through the low-permeability silt before degrading, permanganate would be expected to be the best oxidant for consideration of groundwater remediation in the dissolved-phase plume within the silt.However, shipping of permanganate to Aniak will be expensive, versus an on-site ozone generation system would likely be more cost-effective over the long term. A combination of in situ and ex situ ozone treatment may be worth considering; ozone is discussed further as an ex situ technology.

4.6. In-Well Air Stripping

In-well air stripping technology involves the injection of air into a vertical well that has been screened at two depths. The lower screen is set in the groundwater saturated zone, and the upper screen is in the unsaturated zone. Pressurized air is injected into the well below the water table, aerating the water. The aerated water rises in the well and flows out of the system at the upper screen. Contaminated groundwater is drawn into the system at the lower screen. The VOCs vaporize within the well at the top of the water table, as the air bubbles out of the water. The vapors are drawn off by an SVE system. The partially treated groundwater is never brought to the surface; it is forced into the unsaturated zone, and the process is repeated as water follows a hydraulic circulation pattern or cell that allows continuous cycling of groundwater. As groundwater circulates through the treatment system in situ, contaminant concentrations are gradually reduced. In-well air stripping is a pilot-scale technology.

Modifications to the basic in-well stripping process may involve additives injected into the stripping well to enhance biodegradation (e.g., nutrients, electron acceptors, etc.).

Alternatively, the area around the well affected by the circulation cell (radius of influence) can be modified through the addition of oxidants to affect chemical oxidation.

The duration of in-well air stripping is short- to long-term, depending contaminant concentrations, Henry's law constants of the contaminants, the radius of influence, and site hydrogeology. In general, in-well air strippers are more effective at sites containing high concentrations of dissolved contaminants with high Henry's law constants. In well air stripping may not be efficient in sites with strong natural flow patterns.

4.6.1. In-Well Air Stripping Considerations for Aniak WACS

The most significant consideration for application of in-well air stripping for Aniak WACS is the presence of the silt layer. The silt layer will limit the ability to draw off vapors by an SVE system and circulate groundwater at the water table.

4.6.2. Circulating Wells

Circulating wells provide a technique for subsurface remediation by creating a three-dimensional circulation pattern of the groundwater. Groundwater is drawn into a well through one screened section and is pumped through the well to a second screened section where it is reintroduced to the aquifer. The flow direction through the well can be specified as either upward or downward to accommodate site-specific conditions. Because groundwater is not pumped above ground, pumping costs and permitting issues are reduced and eliminated, respectively. Also, the problems associated with storage and discharge are removed. In addition to ground water treatment, circulating well systems can provide simultaneous vadose zone treatment in the form of bioventing or soil vapor extraction.

Circulating well systems can provide treatment inside the well, in the aquifer, or a combination of both. For effective in-well treatment, the contaminants must be adequately soluble and mobile so they can be transported by the circulating ground water. Because circulating well systems provide a wide range of treatment options, they provide some degree of flexibility to a remediation effort.

Circulating well systems are most effective at treating sites with volatile contaminants with relatively high aqueous solubility and strong biodegradation potential, e.g., halogenated and non-halogenated VOCs. Circulating wells operate more efficiently with horizontal conductivities greater that 10-3 cm/sec and a ratio of horizontal to vertical conductivities between 3 and 10. A ratio of less than 3 indicates short circulation times and a small radius of influence. If the ratio is greater that 10, the circulation time may be unacceptably long.

Effective circulating well installations require a well-defined contaminant plume to prevent the spreading or smearing of the contamination. They should not be applied to sites containing NAPLs to prevent the possibility of smearing the contaminants. Circulating wells are limited to sites with horizontal hydraulic conductivities greater than 10-5 cm/sec and should not be utilized at sites that have lenses of low-conductivity deposits.

4.6.3. Circulating Well Considerations for Aniak WACS

Circulating wells may be an effective groundwater remedy component at Aniak WACS. The use of circulating wells may assist in distributing oxidant (for ISCO) or substrate (for enhanced bioremediation) in the gravelly sand layer under the silt. However, circulating wells cannot be effectively used for remediation of contamination within the silt layer.

4.7. Ex-Situ Treatment

4.7.1. Groundwater Pumping

Possible objectives of groundwater pumping include removal of dissolved contaminants from the subsurface, or containment of contaminated groundwater to prevent migration. Groundwater containment is not desired at the Aniak WACS site; therefore, the groundwater pumping discussion is limited to consideration of removal of dissolved contaminants.

The criteria for well design, pumping system, and treatment are dependent on the physical site characteristics and contaminant type. Actual treatment may include the design of a train of processes to remove specific contaminants. Possible treatment processes are discussed in subsequent subsections of this FS.

Another component of any groundwater extraction system is a groundwater monitoring program to verify its effectiveness. One documented drawback of most pump and treat systems is the long time necessary to achieve site cleanup. Groundwater pumping does not effectively treat residual saturation of the contaminant in the soil pores or sorbed to the soil matrix. Pumping is not applicable to contaminants with high residual saturation, high sorption capabilities, and homogeneous aquifers with hydraulic conductivity less than 10-5 cm/sec.

Biofouling of the extraction wells and associated treatment stream is a common problem which can severely affect system performance. The potential for this problem should be evaluated prior to the installation.

4.7.2. Air Stripping:

Volatile organics are partitioned from groundwater by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

4.7.3. Oxidation

Similarly to ISCO, oxidation can be used in ex situ applications. Oxidation of target contaminants is caused by direct reaction with an oxidizing agent. Unlike in situ applications, where a slow reaction time is desirable, fast reaction times are desired for ex situ applications. Combinations of oxidizers are also beneficial for some treatment systems. If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase.

Possible oxidizing agents include Fenton's (H_2O_2 + Fe), ultraviolet (UV) light, ozone (O_3), ozone plus UV, and ozone plus peroxide (O_3 + H_2O_2), which react to create a hydroxyl radical, similar to the Fenton's. However, oxidation by UV light is highly dependent on water clarity and will not be effective in turbid water without pretreatment. Permanganate and persulfate reactions are too slow for effective ex situ applications.

A combination of ozone and peroxide or ozone and UV may be applicable for ex situ oxidation at Aniak WACS. Ozone is a gas and a strong oxidant that upon reaction does not leave a residual other than O_2. Environmental contaminants can be oxidized either by direct reaction with O_3, or indirectly via O_3 decomposition and formation of the hydroxyl radical (·OH), a stronger oxidant. Direct oxidation of PCE and TCE is impractical due to slow reaction time, although direct oxidation of DCE and vinyl chloride is very rapid. However, TCE and PCE are readily oxidized by the hydroxyl radical. The addition of H_2O_2 or UV to O_3 in water generates·OH, thereby increasing the oxidative capabilities of the treatment system and increasing oxidation rates for PCE and TCE.

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5. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

Promising groundwater technologies will be developed into three to five detailed alternatives and evaluated against the nine criteria described in Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) §300.430(f)(5)(i).

The costing of remedial alternatives will be conducted in accordance with the *USEPA Remedy Cost Estimating Procedures Manual: A Guide to Developing and Documenting Remedial Alternative Cost Estimates During the Feasibility Study* (USEPA 2000).

5.1. Evaluation Criteria

The CERCLA criteria are classified as threshold criteria, balancing criteria, and modifying criteria.

Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria—the alternative must meet them or it is unacceptable. The following are classified as threshold criteria:

- Overall protection of human health and the environment
- Compliance with regulations

Balancing criteria weigh the tradeoffs between alternatives. These criteria represent the standards upon which the detailed evaluation and comparative analysis of alternatives are based. In general, a high rating on one criterion can offset a low rating on another balancing criterion. Five of the nine criteria are considered balancing criteria:

- **Long-term effectiveness and permanence**: This criterion refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, after the remedy has been completed.
- **Reduction of toxicity, mobility, and volume through treatment**: This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.
- **Short-term effectiveness**: This criterion addresses the effectiveness of the remedy during its implementation. It includes the period of time needed to implement the remedy along with any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.
- **Implementability**: This criterion addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.
- **Cost**: This criterion addresses the cost-effectiveness of a remedy based upon design, construction, start-up, monitoring, and maintenance costs.

Modifying criteria evaluate public acceptance and can therefore not be considered in the FS. The final two criteria are considered modifying criteria:

- Community acceptance
- State/regulatory agency acceptance

5.2. Comparative Analysis of Alternatives

A comparative analysis will be performed to identify the advantages and disadvantages of each alternative relative to the other alternatives. The relative performance of each alternative will be evaluated with respect to each of the NCP criteria. The scoring procedure is discussed in this section.

Threshold criteria are either met or not met; therefore, “yes” and “no” will be used as the scores for threshold criteria.

A numerical scoring scheme will be used for evaluating the balancing criteria for the various alternatives. Each alternative will be assigned a numerical score between 0 and 5 for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives. The numerical scores are presented and defined below:

0: Worst (Criterion not satisfied)

1: Poor

2: Below Average

3: Average (Criterion partially satisfied)

4: Above Average

5: Best (Criterion completely satisfied)

All of the criteria except cost will be evaluated on a qualitative basis. Cost will be evaluated quantitatively by calculating the expected range of costs (within a range of -50% to +100%) and then normalizing the costs to the 0 to 5 scale, with the least expensive alternative receiving a score of 5, and the most expensive alternative receiving a score of 0. The quantitative cost evaluation will be performed based on the EPA document entitled *A Guide to Developing and Documenting Cost Estimates During the Feasibility Studies* (EPA, 2000).

5.3. Site-Specific Considerations Affecting Remedy Selection

5.3.1. Data Gaps

As discussed in Section 2.5.3, further evaluation is warranted at this site to address the following data gaps.

- Incomplete record of seasonal groundwater elevations. Dataloggers recorded groundwater elevations between September 2009 and May 2010 (Shannon & Wilson, 2010b); however, there is no record of groundwater elevations over the summer months when fluctuations would be expected to be the greatest.

- Scarcity of groundwater sample results. The plume delineation is primarily based on one round of groundwater monitoring results, collected during different times of the year (and associated groundwater elevations). The temporary well data were collected in May/June 2008 at a relatively high groundwater level, whereas the samples from monitoring wells MW-7 through MW-12 were collected in August 2009 at a relatively low groundwater level. There is also only one round of MNA parameter results available. Another round of groundwater samples would help verify the plume characterization.
- No characterization of groundwater under the Aniak Middle School or to the east of the school. Soil gas results from SGP-8 indicate elevated TCE soil gas results. There has been no soil or groundwater characterization in this area.
- Incomplete characterization of the Septic Tank Plume. The southern plume boundary is well delineated; however, the plume boundaries have not been well-defined to the northwest (in the vicinity of the ASTs), northeast (under Aniak Middle School building), or to the southeast. Soil gas readings from SGP-17 and SGP-18 suggest that the maximum contaminant concentrations are in this area. There are no monitoring wells to characterize groundwater in this area.
- Incomplete characterization of the Maintenance Building TCE plume has not been completely characterized. The east, west, and northern boundaries of the plume are not defined..
- Incomplete characterization of the silt layer. Additional characterization of the top and base of the silt layer, especially in the area of highest contamination levels, would be very helpful in determining the amount of contamination at the site.

Incomplete characterization of groundwater flow patterns could result in a misunderstanding of groundwater flow at the site. An understanding of groundwater flow is critical for designing an effective groundwater remedy.

Incomplete characterization of the groundwater plumes could result in a significantly larger (or smaller) area of groundwater contamination, which could have a significant impact on remedy costs and evaluation.

5.3.2. Silt Layer

The presence of low-permeability silt overlying slightly gravelly sand and the seasonal groundwater elevation fluctuation of at least 5 feet significantly complicates groundwater remediation at the site. The scope of this focused FS is limited to evaluating groundwater remedies, and the planned soil remedial activities (excavation and SVE) will only address contamination in the fill above the silt layer. However, the available data suggests that the highest contaminant concentrations were detected in the silt. The contamination sorbed to silt (in the vadose zone and in the groundwater fluctuation interval) will act as a continuing source of both dissolved-phase contamination and soil gas. In order to effectively address contamination at the site, contamination in the silt must also be remediated.

5.4. Recommended Technologies for Consideration in the Detailed FS

OASIS recommends a detailed evaluation of the following groundwater remedial technologies in the detailed FS:

- No Action
- MNA and ICs: The feasibility of this potential remedy is contingent on additional monitoring results showing the occurrence of significant MNA at the site and a decision by ADEC and the stakeholders that this remedy is appropriate. Available (although incomplete) groundwater data suggests minimal migration of the groundwater plume, so it is possible that groundwater plume migration to existing drinking water wells or further offsite is not a complete pathway. However, the vapor intrusion pathway into the Middle School building from groundwater is a potentially complete pathway that needs to be considered.
- Chemical oxidation: Chemical oxidation appears to be a more promising technology than enhanced bioremediation at this site, primarily due to the site's (apparent) aerobic groundwater geochemistry. A key challenge for chemical oxidation at this site is delivery of the oxidant. Several delivery methods may be considered, including direct application of a solid oxidant (such as permanganate) on the base of the planned PCB/TCE soil excavation (Figure 4), direct injection of oxidant into the silt and underlying sand, or use of circulating wells for oxidant distribution.

Air sparging may also warrant further evaluation but also faces considerable challenges due to the presence of the silt layer. The feasibility of sparging in the silt layer has not been evaluated, and sparging beneath the silt layer could cause entrapment of air bubbles under the silt. Further delineation of the silt and contamination in the southwest portion of the septic tank plume (near SGP-17) would be helpful in evaluating the potential applicability of air sparging at this site. Excavation data suggests that the silt layer may be mostly or entirely removed in the seepage pit area; however, a thick silt layer was detected in all of the borings/monitoring wells near MW-5 and B-12 (where the highest groundwater contamination was detected).

Enhanced bioremediation may also warrant further evaluation, although the naturally aerobic groundwater conditions will need to be driven anaerobic, and there are concerns about groundwater reoxygenation during river- and snowmelt-driven recharge events. One possible application of enhanced bioremediation may be injection in recirculating wells.

OASIS recommends considering expanding the scope of this FS to include remediation of contamination in the silt in the vadose zone and zone of groundwater fluctuation.

Pilot testing will be critical to choosing an effective remedy at this site, especially considering remediation of contamination in the silt layer.

6. REFERENCES

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FIGURES

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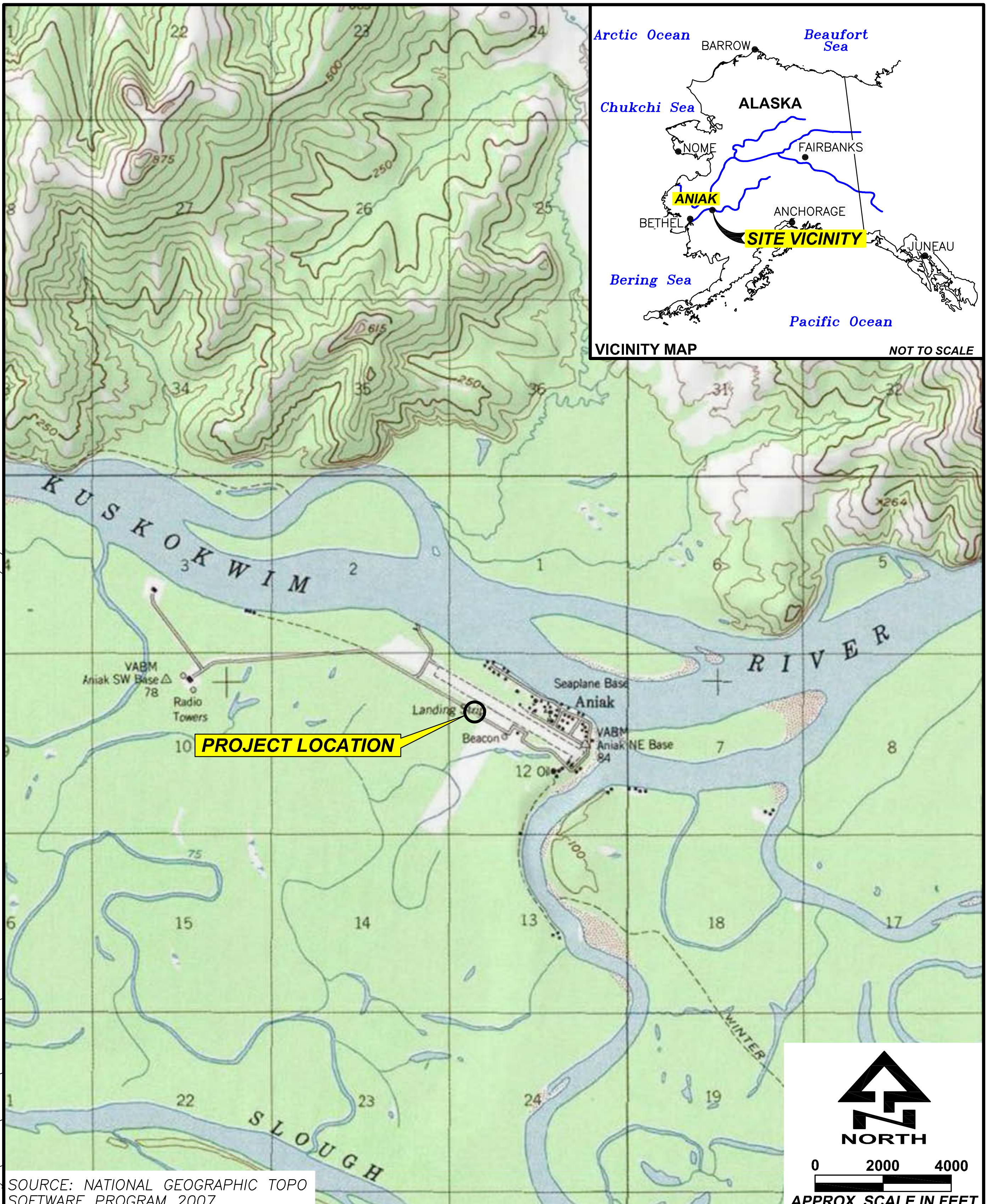

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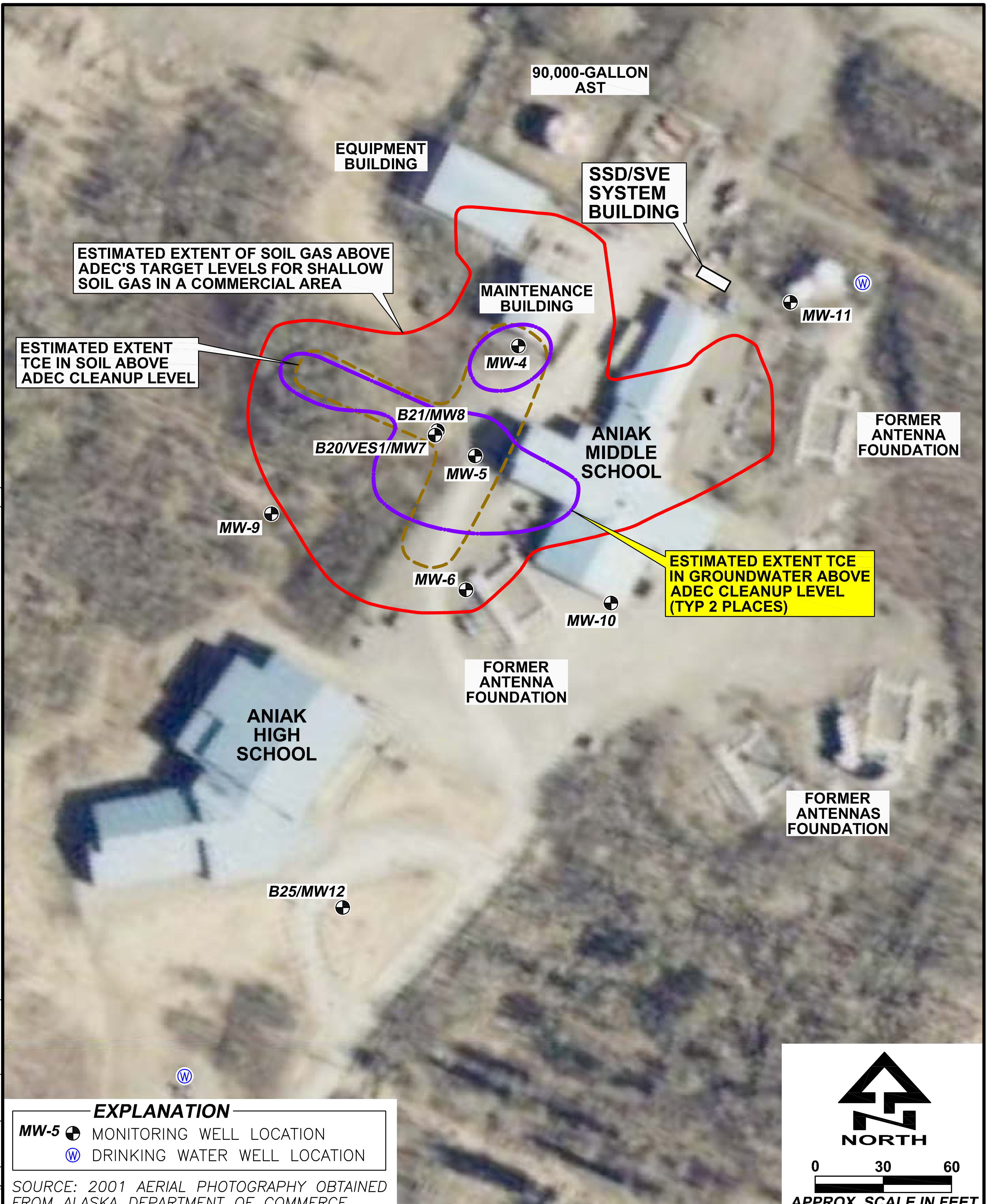
oasis ENVIRONMENTAL

DATE: APRIL 2011
CHKD: J.H.P.
DRAWN: C.E.H.
PROJ. No.: 14-201
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

SITE LOCATION MAP

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE 1



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DATE: APRIL 2011
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DRAWN: C.E.H.
PROJ. No.: 14-201
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SITE PLAN

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY
GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

FIGURE
2

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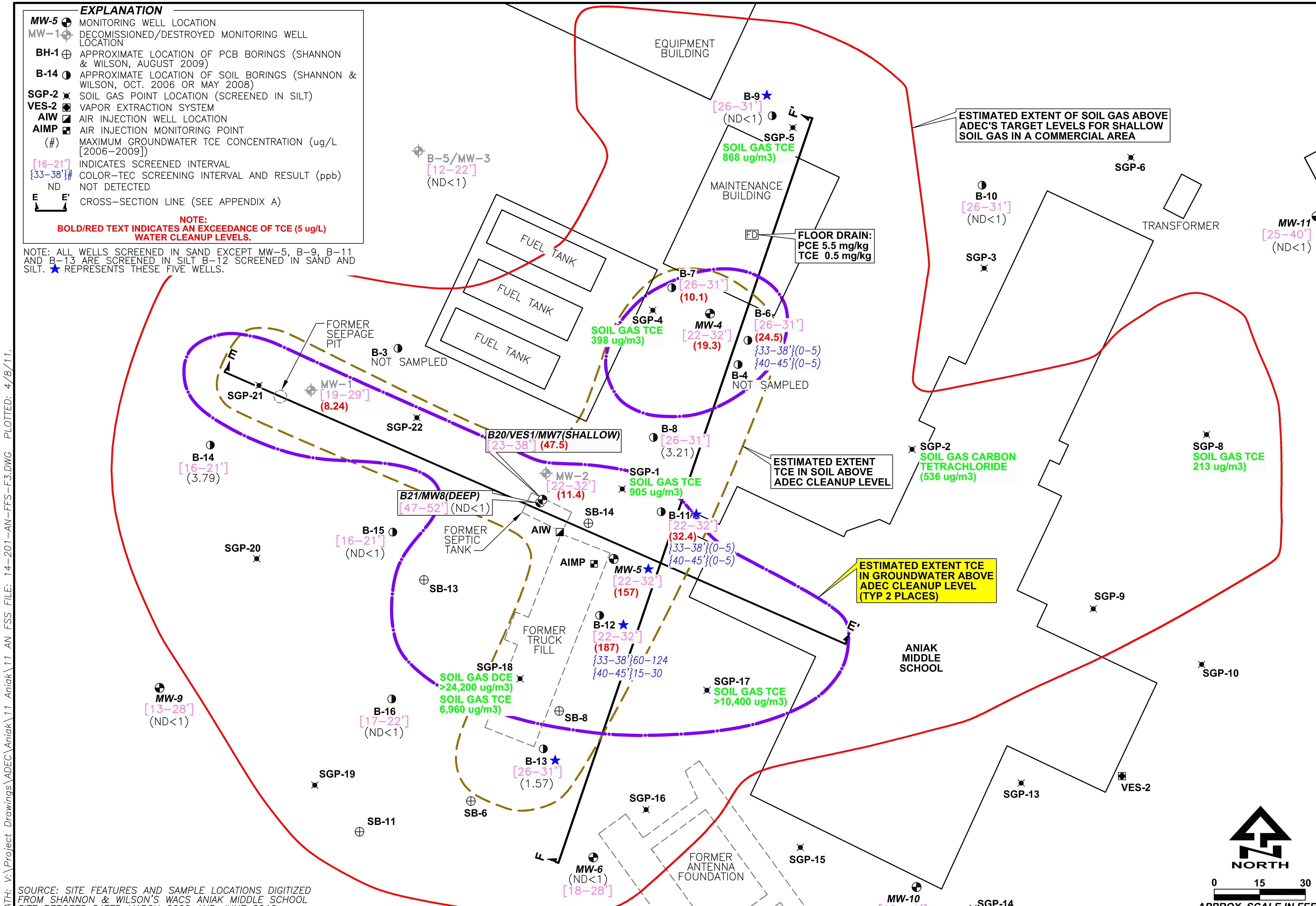

FIGURE 3

GROUNDWATER TCE PLUME

ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska

DATE: APRIL 2011
CHKD: J.H.P.
DRAWN: C.E.H
PROJ. No.: 14–201

825 W. 8th Ave., Anchorage, AK 99501, (907) 258–4880

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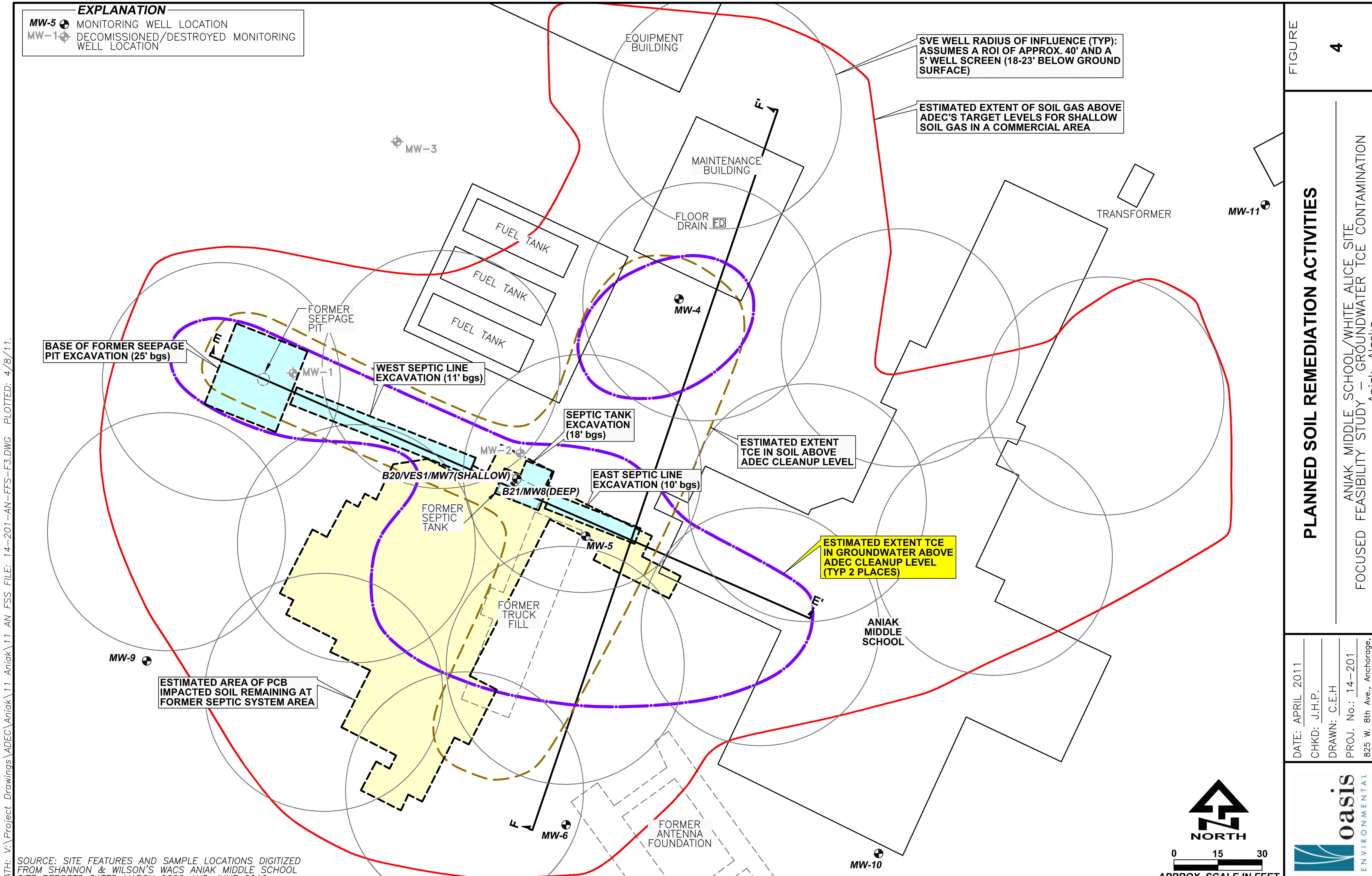

EXPLANATION
MW-5 MONITORING WELL LOCATION
MW-1 DECOMISSIONED/DESTROYED MONITORING WELL LOCATION
EQUIPMENT BUILDING
MAINTENANCE BUILDING
FLOOR DRAIN FD
MW-3
FUEL TANK
FUEL TANK
FUEL TANK
TRANSFORMER
MW-11
SVE WELL RADIUS OF INFLUENCE (TYP): ASSUMES A ROI OF APPROX. 40' AND A 5' WELL SCREEN (18-23' BELOW GROUND SURFACE)
ESTIMATED EXTENT OF SOIL GAS ABOVE ADEC'S TARGET LEVELS FOR SHALLOW SOIL GAS IN A COMMERCIAL AREA
F'
F
FORMER SEEPAGE PIT
BASE OF FORMER SEEPAGE PIT EXCAVATION (25' bgs)
E
E'
MW-1
WEST SEPTIC LINE EXCAVATION (11' bgs)
MW-4
SEPTIC TANK EXCAVATION (18' bgs)
MW-2
B20/VES1/MW7(SHALLOW)
B21/MW8(DEEP)
EAST SEPTIC LINE EXCAVATION (10' bgs)
ESTIMATED EXTENT TCE IN SOIL ABOVE ADEC CLEANUP LEVEL
FORMER SEPTIC TANK
MW-5
ESTIMATED EXTENT TCE IN GROUNDWATER ABOVE ADEC CLEANUP LEVEL (TYP 2 PLACES)
FORMER TRUCK FILL
ANIAK MIDDLE SCHOOL
MW-9
ESTIMATED AREA OF PCB IMPACTED SOIL REMAINING AT FORMER SEPTIC SYSTEM AREA
MW-6
FORMER ANTENNA FOUNDATION
MW-10
NORTH
0 15 30
APPROX. SCALE IN FEET
SOURCE: SITE FEATURES AND SAMPLE LOCATIONS DIGITIZED FROM SHANNON & WILSON'S WACS ANIAK MIDDLE SCHOOL SITE REPORTS DATED MARCH 2009 AND JUNE 2010.
PATH: V:\Project Drawings\ADEC\Aniak\11 Aniak\11 AN FSS FILE: 14-201-AN-FFS-F3.DWG PLOTTED: 4/8/11.
FIGURE 4
PLANNED SOIL REMEDIATION ACTIVITIES
ANIAK MIDDLE SCHOOL/WHITE ALICE SITE
FOCUSED FEASIBILITY STUDY – GROUNDWATER TCE CONTAMINATION
Aniak, Alaska
DATE: APRIL 2011
CHKD: J.H.P.
DRAWN: C.E.H
PROJ. No.: 14-201
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880
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APPENDIX A

Cross-Sections E-E’ and F-F’

(Shannon & Wilson, 2010a)

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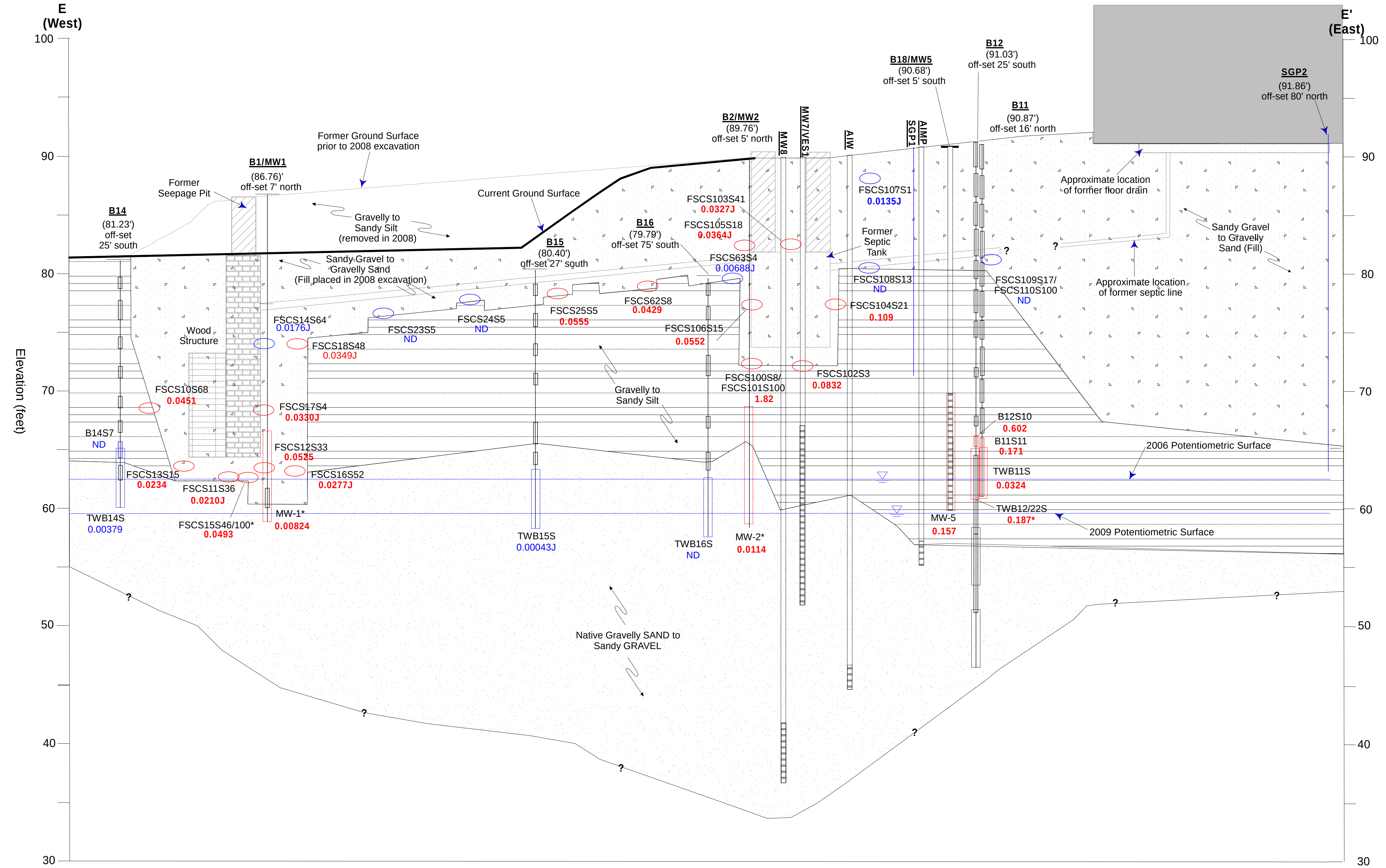

LEGEND

TWB14S 0.00379 — Concentration of TCE detected (mg/L for water or mg/kg for soil). Blue color indicates concentrations less than the applicable cleanup level. Bold red color indicates concentrations exceeding the applicable cleanup level.

Confirmation soil sample collected from the 2008 excavation. Blue color indicates concentrations less than the applicable cleanup level. Bold red color indicates concentrations exceeding the applicable cleanup level.

Soil boring sample

Water sample from temporary or permanent monitoring well

B14 (81.23') — Top of casing or ground surface elevation based on 2006 or 2008 survey data.

Approximate potentiometric surface elevation based on 2006 and 2009 water level measurements in on-site monitoring wells.

ND — Non-detect

J — Concentration is an estimation detected below the laboratory detection limit but above the method detection limit.

* — Duplicate or replicate samples collected from this location. The highest TCE concentration is shown.

Note that the contact between soil types is gradual and the contact of silt/gravel depicts estimated conditions along the cross-section line.

See Figure 6.0-1 for Cross Section E-E' location. See Figure 4.0-1 for Soil Gas Point locations. See March 2009 TCE Characterization Report for confirmation sample descriptions and analytical results.

0 20 40
APPROXIMATE HORIZONTAL SCALE IN FEET

Former WACS Aniak Middle School Site
Aniak, Alaska

FORMER SEPTIC SYSTEM
CROSS SECTION E-E'

June 2010 32-1-17308-003

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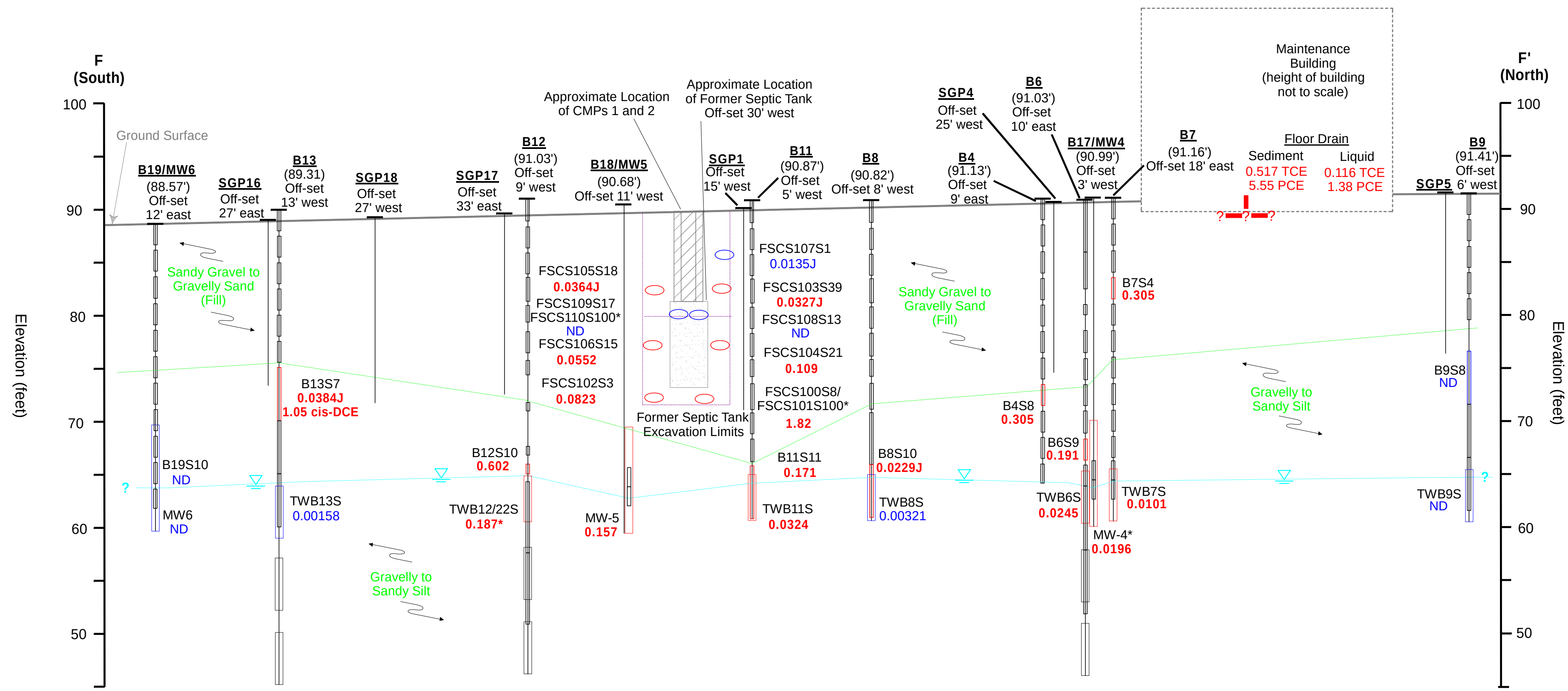
Fig. 6.2-1



LEGEND

TWB13S 0.00158	Concentration of TCE detected (mg/L for water or mg/kg for soil). Blue color indicates concentrations less than the applicable cleanup level. Bold red color indicates concentrations exceeding the applicable cleanup level.
	Excavation confirmation soil sample
	Soil boring sample
	Water sample from temporary or permanent monitoring well
B6 (91.03')	Top of casing or ground surface elevation based on 2006 or 2008 survey data.
	Inferred groundwater elevation based on depth to water measurements from individual borings.
ND	Non-detect
J	Concentration is an estimation detected below the laboratory detection limit but above the method detection limit.
*	Duplicate or replicate samples collected from this location. The highest TCE concentration is shown.

Note that the contact between soil types is gradual and the contact of soil/gravel depicts estimated conditions along the cross-section line.

0 15 30
APPROXIMATE VERTICAL SCALE IN FEET

0 30 60
APPROXIMATE HORIZONTAL SCALE IN FEET

Former WACS Aniak Middle School Site
Aniak, Alaska

CROSS SECTION F - F'

June 2010 32-1-17308-003

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Fig. 6.2-2

APPENDIX B

Potentiometric Surface Maps

October 2006
August 2009
October 2009 (High)
October 2009 (Low)
December 2009 (High)
February 2010 (Low)
May 2010 (High)
and
Groundwater Elevation Graph (September 2009 through May 2010)
(Shannon & Wilson, 2007, 2010a, and 2010b)

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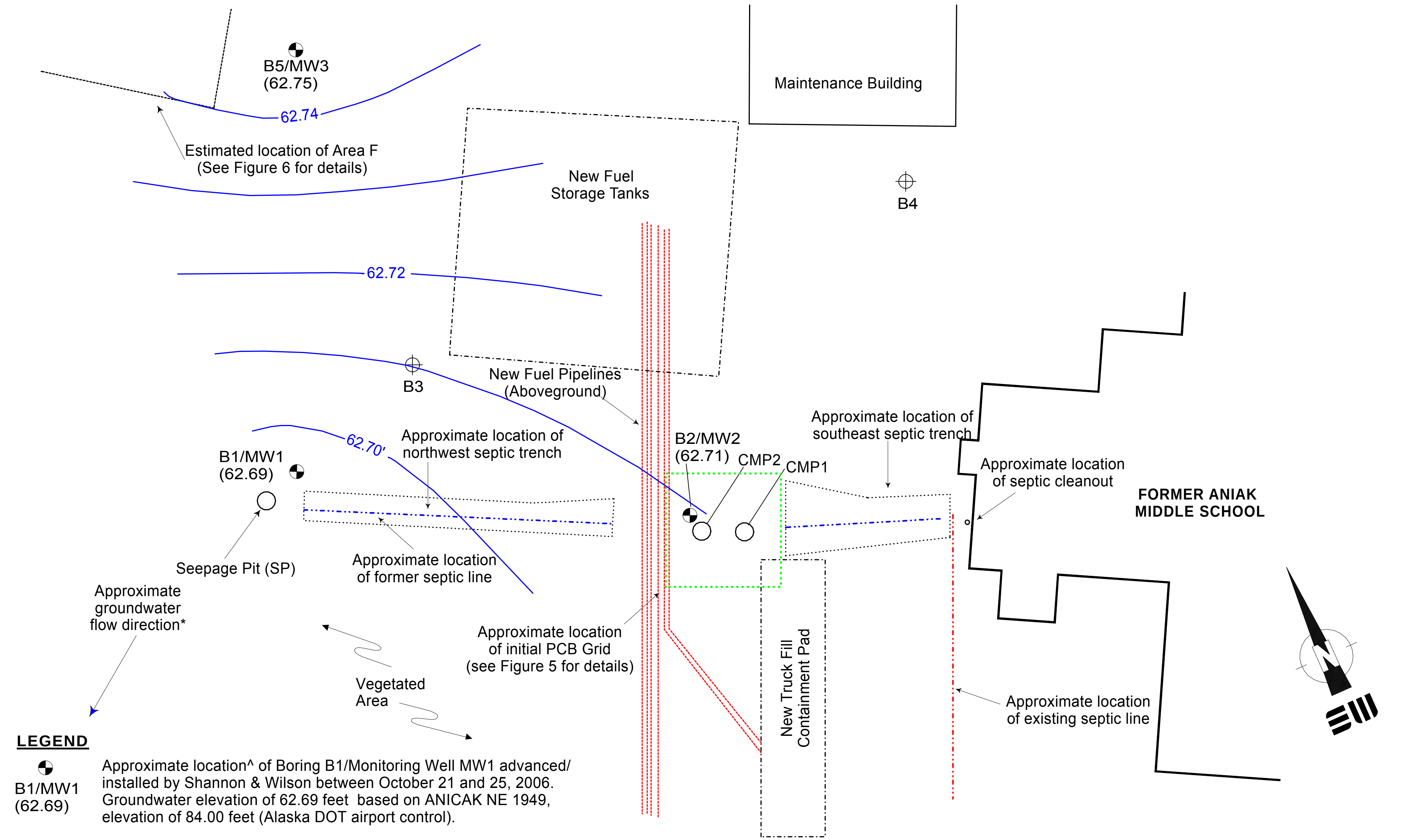

LEGEND

B1/MW1 (62.69) — Approximate location^ of Boring B1/Monitoring Well MW1 advanced/installed by Shannon & Wilson between October 21 and 25, 2006. Groundwater elevation of 62.69 feet based on ANICAK NE 1949, elevation of 84.00 feet (Alaska DOT airport control).

B3 — Approximate location^ of Boring B3 advanced by Shannon & Wilson October 21 through 25, 2006

62.70' — Groundwater elevation isopleth based on October 25, 2006 water level measurements. Becuase the groundwater flow gradient is flat, the flow direction may exhibit seasonal fluctuations.

^ See Appendix F for Del Norte suvey coordinates.

Former WACS Aniak Middle School Site
Aniak, Alaska

SITE PLAN

May 2007 32-1-17070

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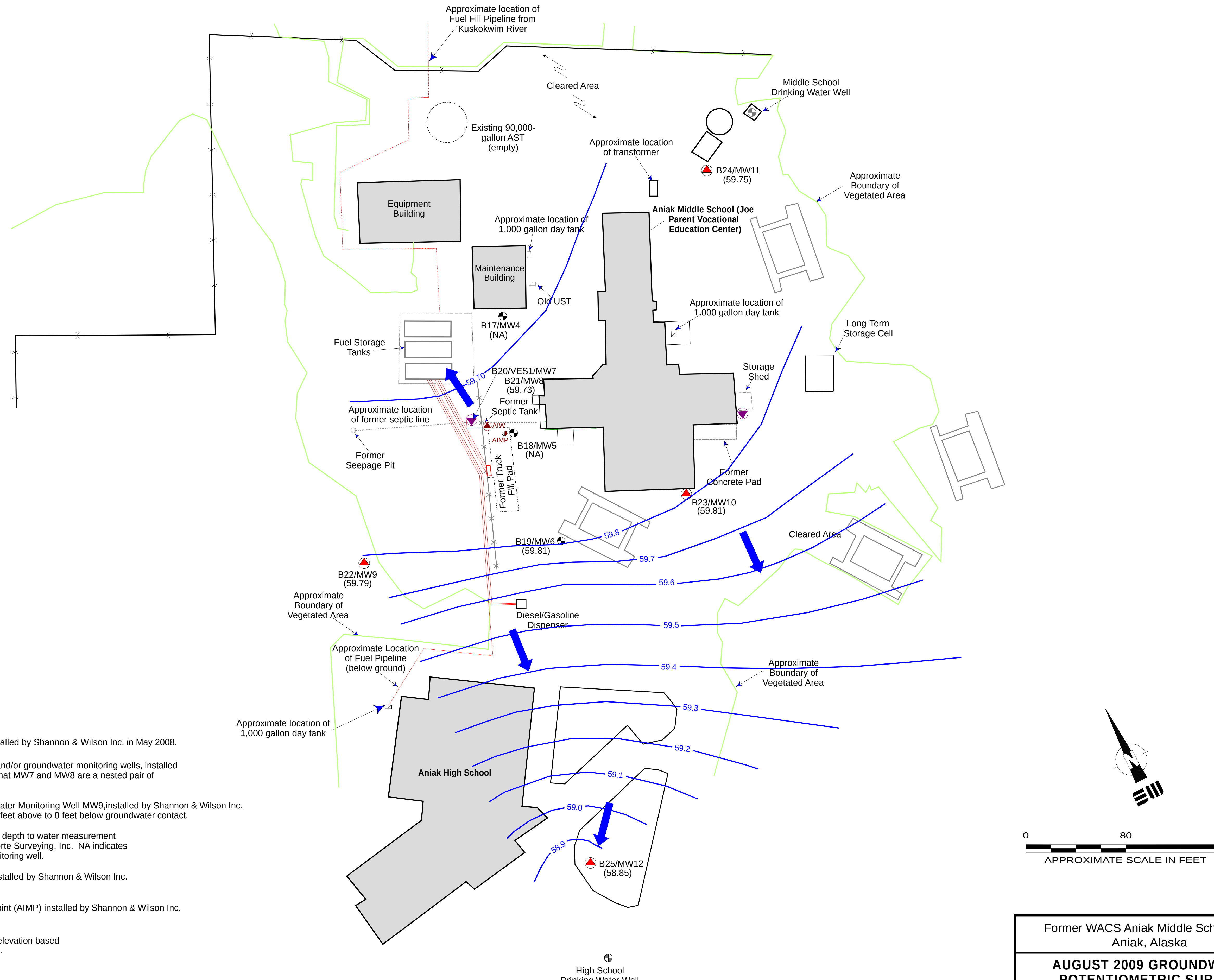
Fig. 4



LEGEND

B19/MW6	Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.
B20/VES1/MW7 B21/MW8	Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.
B22/MW9	Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.
(59.73)	Groundwater elevation based on August 22, 2009 depth to water measurement and September 2009 survey conducted by Del Norte Surveying, Inc. NA indicates that groundwater was not encountered in the monitoring well.
AIW	Approximate location of air injection well (AIW) installed by Shannon & Wilson Inc. in August 2009 for air injection pilot testing.
AIMP	Approximate location of air injection monitoring point (AIMP) installed by Shannon & Wilson Inc. in August 2009 for air injection pilot testing.
59.7	Groundwater potentiometric surface contour and elevation based on August 22, 2009 depth to water measurements.
	Approximate groundwater flow direction.

Former WACS Aniak Middle School Site
Aniak, Alaska

AUGUST 2009 GROUNDWATER POTENTIOMETRIC SURFACE

June 2010 32-1-17308-003

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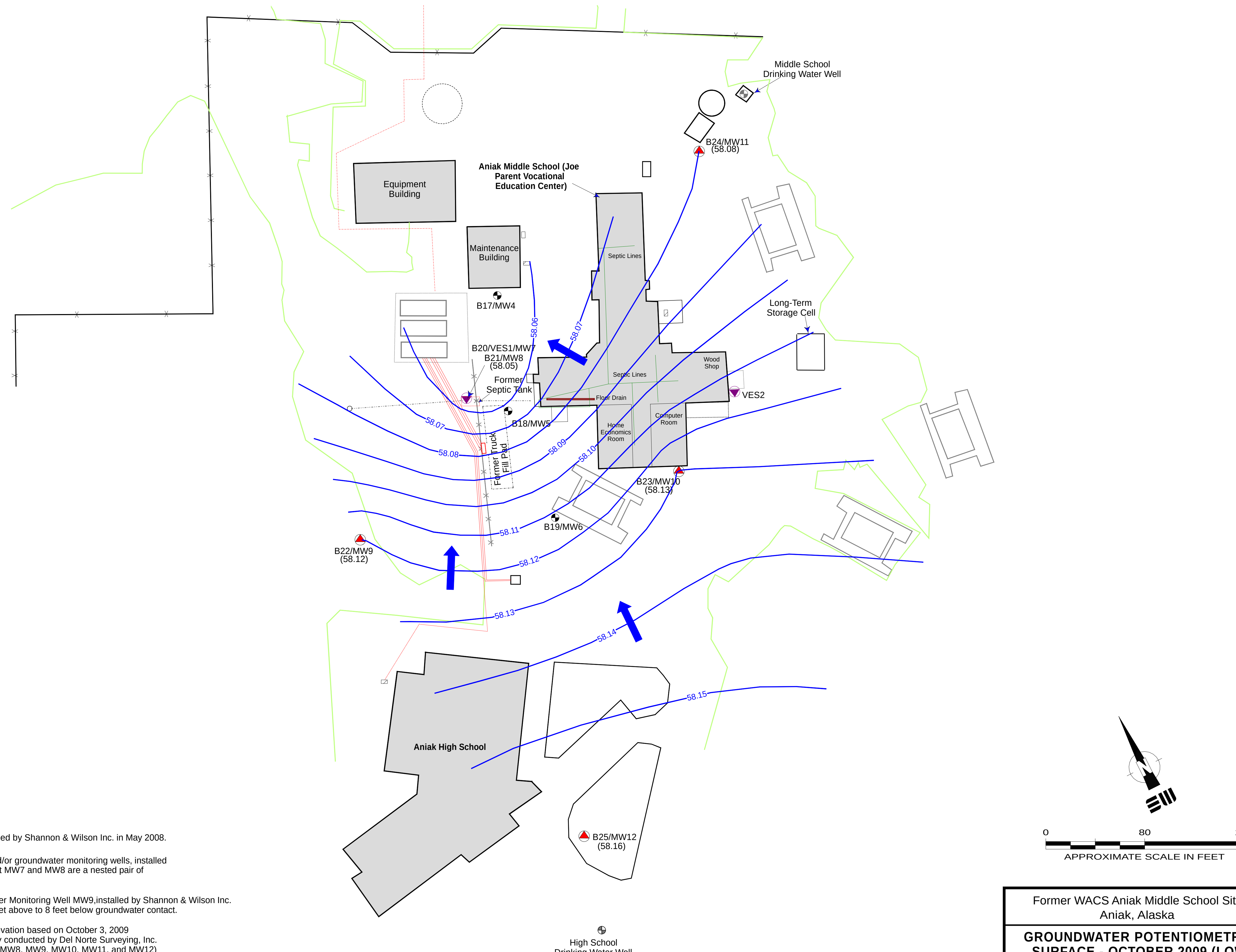
Fig. 6.6-1



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7
B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

58.15 — Groundwater potentiometric surface contour and elevation based on October 3, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - OCTOBER 2009 (LOW)

June 2010 | 32-1-17308-002

SHANNON & WILSON, INC.
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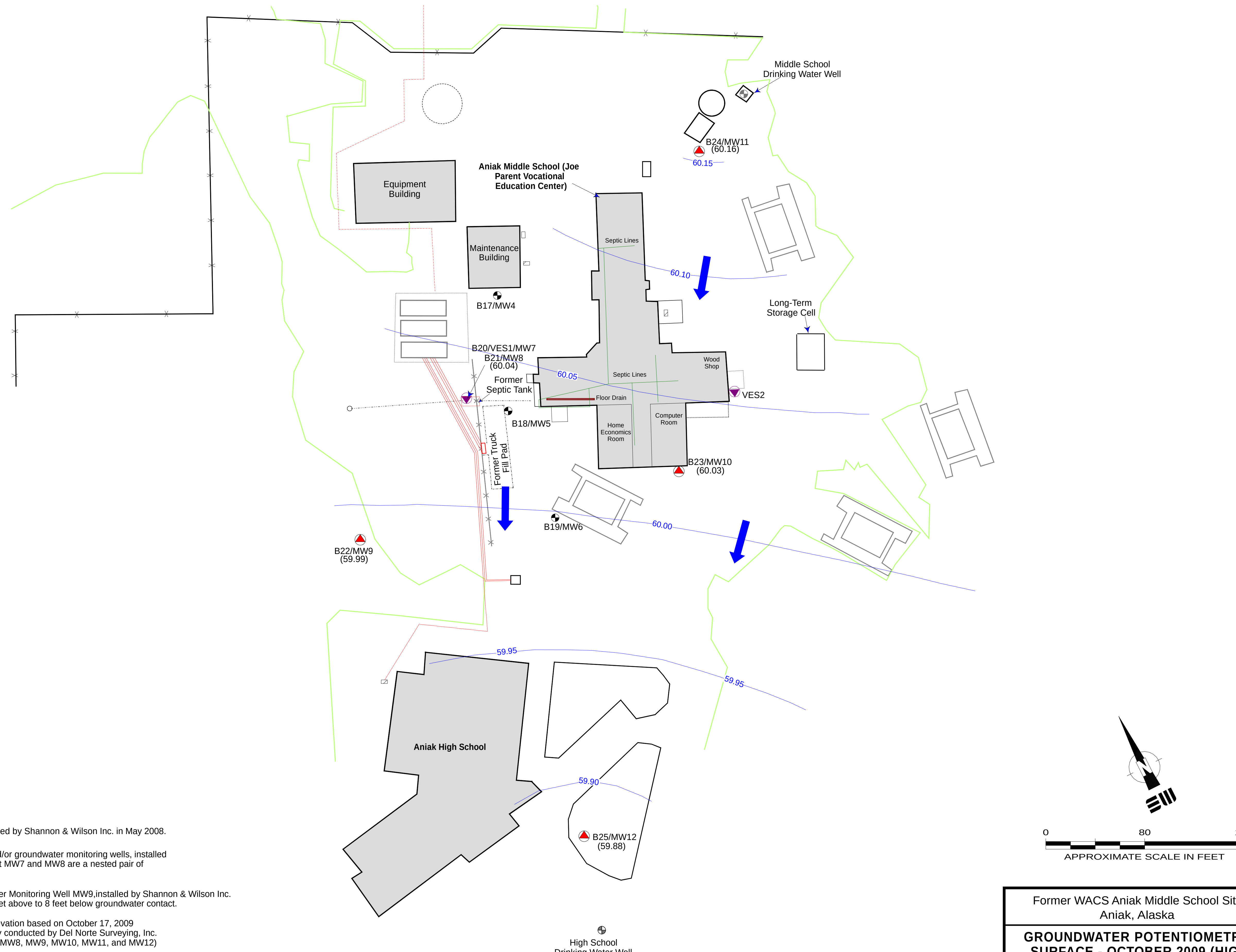
Fig. H-1



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7 B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

60.05 — Groundwater potentiometric surface contour and elevation based on October 17, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - OCTOBER 2009 (HIGH)

June 2010 32-1-17308-002

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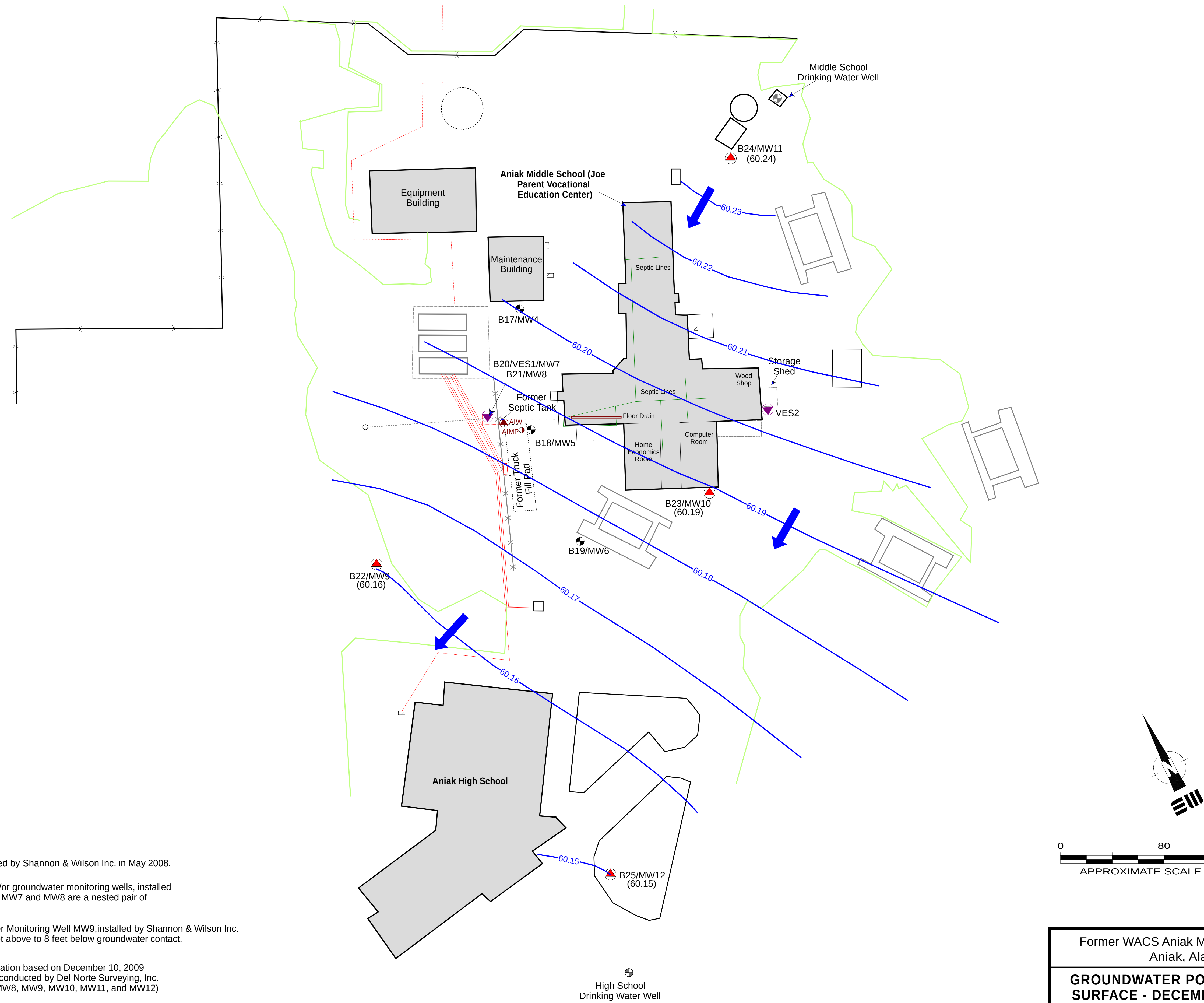
Geotechnical & Environmental Consultants

Fig. H-2



LEGEND

B19/MW6 — Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.

B20/VES1/MW7 B21/MW8 — Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.

B22/MW9 — Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.

60.20 — Groundwater potentiometric surface contour and elevation based on December 10, 2009 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)

Approximate groundwater flow direction

Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - DECEMBER 2009 (HIGH)

June 2010 | 32-1-17308-002

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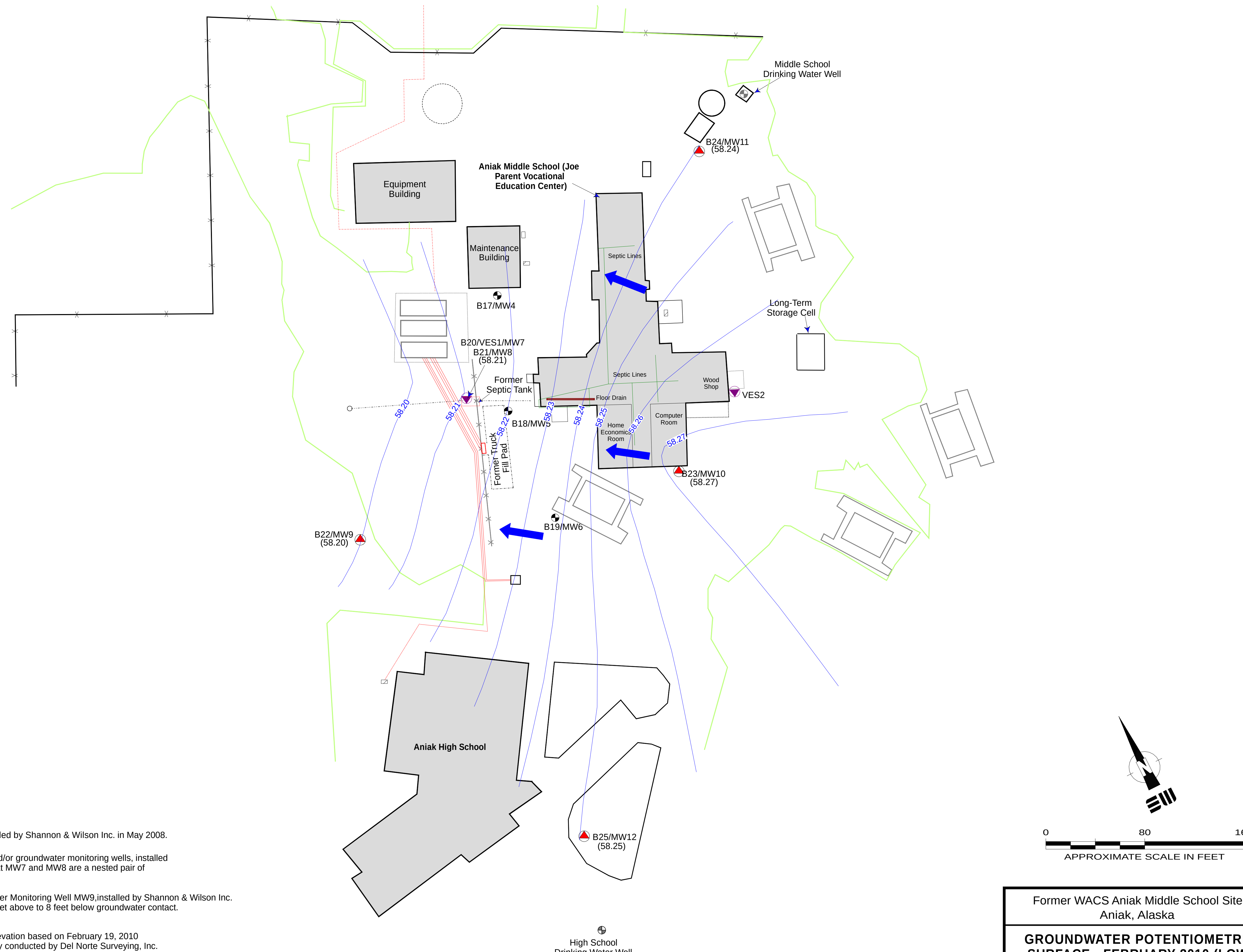
Fig. H-3



LEGEND

B19/MW6	Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.
B20/VES1/MW7 B21/MW8	Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.
B22/MW9	Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.
58.25	Groundwater potentiometric surface contour and elevation based on February 19, 2010 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)
	Approximate groundwater flow direction

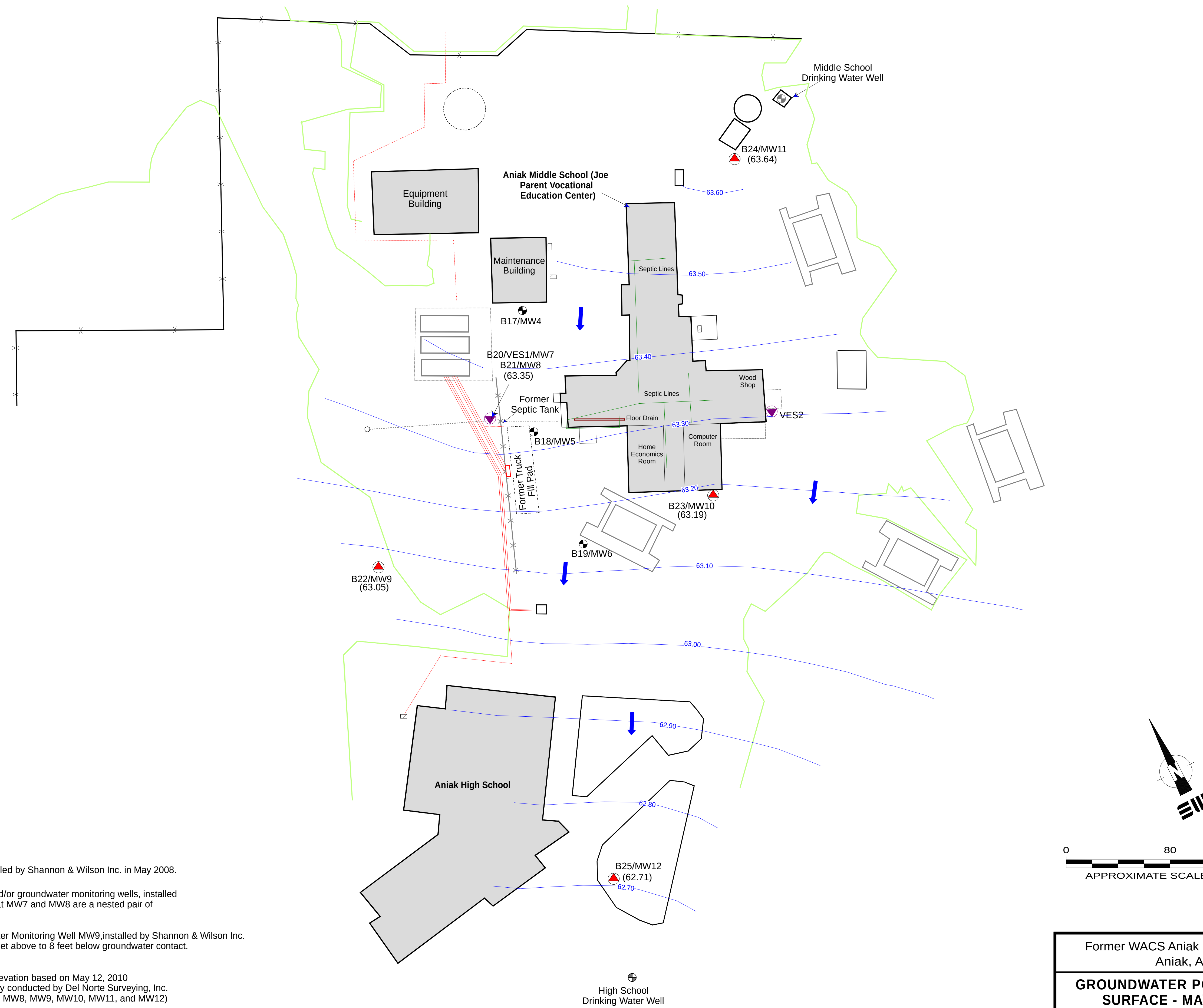
Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - FEBRUARY 2010 (LOW)

June 2010 32-1-17308-002

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

Fig. H-4



LEGEND

B19/MW6	Approximate location of Monitoring Well MW6 installed by Shannon & Wilson Inc. in May 2008.
B20/VES1/MW7 B21/MW8	Approximate location of vapor extraction system and/or groundwater monitoring wells, installed by Shannon & Wilson, Inc. in August 2009. Note that MW7 and MW8 are a nested pair of groundwater monitoring wells.
B22/MW9	Approximate location of Soil Boring B22/Groundwater Monitoring Well MW9,installed by Shannon & Wilson Inc. in August 2009. Well was screened from about 7 feet above to 8 feet below groundwater contact.
58.15	Groundwater potentiometric surface contour and elevation based on May 12, 2010 groundwater elevations and September 2009 survey conducted by Del Norte Surveying, Inc. (based on elevations measured at Monitoring Wells MW8, MW9, MW10, MW11, and MW12)
	Approximate groundwater flow direction

Former WACS Aniak Middle School Site
Aniak, Alaska

GROUNDWATER POTENTIOMETRIC SURFACE - MAY 2010 (HIGH)

June 2010 32-1-17308-002

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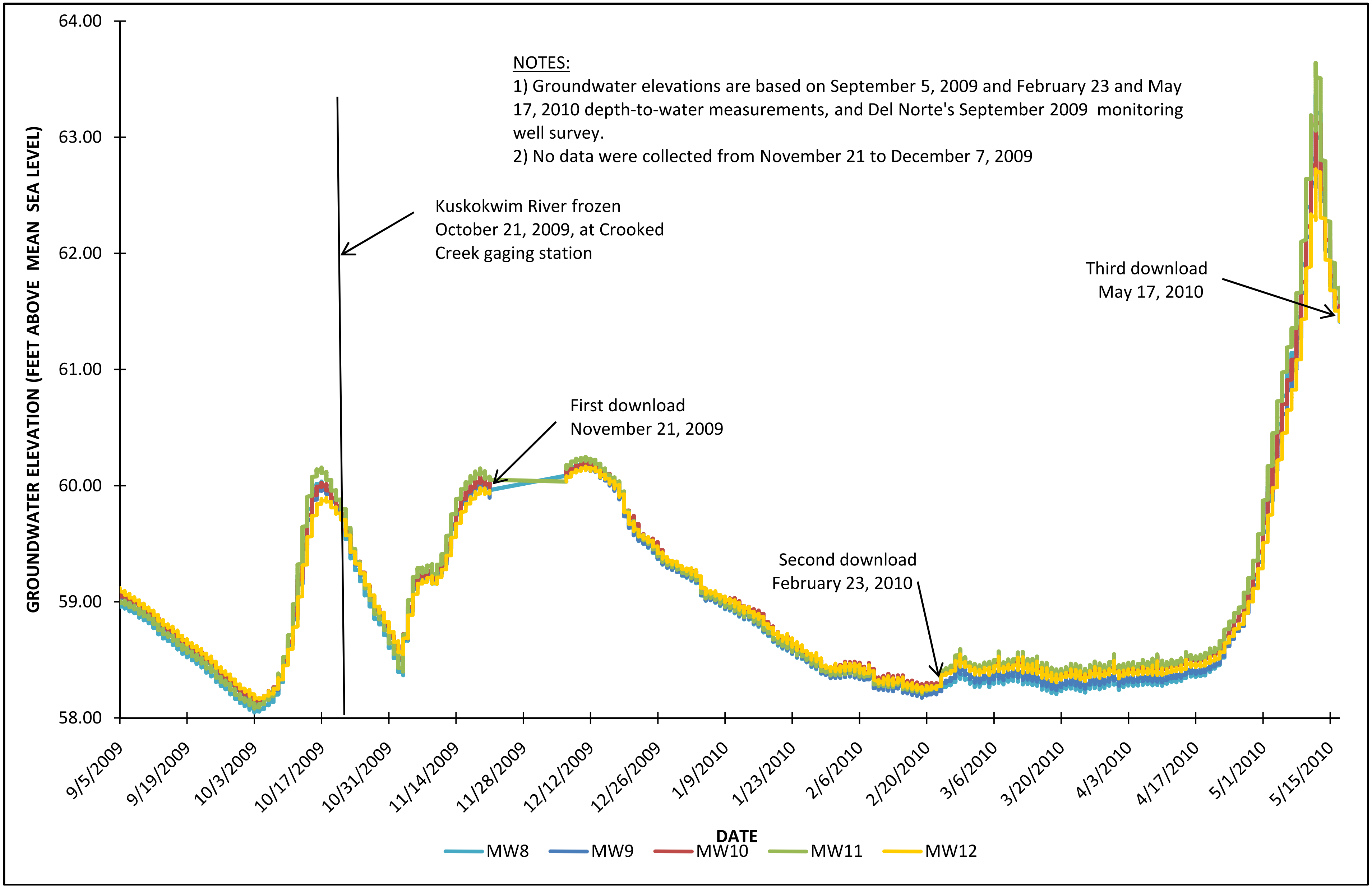
Fig. H-5

GRAPH 1 - ANIAK MIDDLE SCHOOL GROUNDWATER ELEVATIONS



APPENDIX E

Comment Response Summary

REVIEW COMMENTS **PROJECT: Aniak WACS PRP/HTRW**
DOCUMENT: Draft Focused Feasibility Study - Groundwater– February 2012 Location: Aniak, AK

U.S. ARMY CORPS OF ENGINEERS	DATE: 13 April 2012 REVIEWER: Aaron Shewman PHONE: 753-5558	Action taken on comment by:

Item No.	Drawing Sheet No., Spec. Para.	COMMENTS	CONTRACTOR RESPONSE	COMMENTOR REPLY (A-AGREE) (D-DISAGREE)
1.	Page 2, Section 1, Tables 1-1 and 5-1	Please add a note with a definition of how a score of 0 relates to a score of 1, etc. up to a score of 5.	The scoring explanation in Section 5-2 was copied into Section 1, above Table 1-1. This explanation is provided below. The two "threshold criteria" are either met or not met; therefore, "yes" and "no" were used as the scores for these criteria. A numerical scoring scheme was used for evaluating the five balancing criteria. Each alternative was assigned a numerical score between 0 (worst) and 5 (best) for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives. Also, footnotes were provided on Tables 1-1 and 5-1 explaining the relative meaning of scores 0 to 5.	
2.	Figure 3	B20/VES1/MW7 (shallow) is shown as shaded, which indicates it has been decommissioned/destroyed. Please clarify.	The monitoring wells in this area are mislabeled and will be labeled correctly for the final report. The shaded well is MW-2; the one labeled B21/MW8 should actually be B20/VES1/MW7 (shallow), and the well to the right of that should be B21/MW8.	
3.	Page 20 Section 2.5.2	First paragraph, last sentence – Delete "ones".	OK	
4.	Page 27 Section 4.2.4	Second paragraph, last sentence – Change "expect" to "expected".	OK	

REVIEW COMMENTS

PROJECT: Aniak WACS PRP/HTRW
DOCUMENT: Draft Focused Feasibility Study - Groundwater– February 2012 Location: Aniak, AK

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Item No.	**Drawing Sheet No., Spec. Para.**	**COMMENTS**	**CONTRACTOR RESPONSE**	**COMMENTOR REPLY (A-AGREE) (D-DISAGREE)**
5.		End of Comments		
6.				
7.				
8.				
9.				
10.				
11.				

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1. 1	1.	Second paragraph: Oasis writes, "This contamination has resulted in levels exceeding both indoor air quality and drinking water risk-based thresholds." The fact that sub-slab depressurization has decreased sub-slab vapor concentrations but not had an appreciable impact on indoor air strongly suggests that an indoor source is, at a minimum, contributing to indoor air quality exceedances. Suggest revising: "This contamination has resulted in VOC levels exceeding drinking water risk-based thresholds, and is potentially contributing to levels exceeding indoor air quality."	The data do suggest a possible indoor air source; however, the subslab samples also indicate that vapor intrusion is occurring (without the SSD system). We suggest the following wording This contamination has resulted in VOC levels exceeding the ADEC vapor intrusion target levels for residential groundwater and subslab soil gas and drinking water risk-based thresholds. This contamination contributes to exceedances of ADEC Target Levels for indoor air.
2. 12	2.4.3	A note should be added to this section to make it clear that TCE will not migrate at the same rate as groundwater, i.e., that TCE will be subject to some retardation factor. Some estimate of the rate of TCE migration should be added to Section 2.5 or 2.6.	The following text will be added: The travel speed of dissolved-phase contamination is slower than the travel speed of the water, due to sorption processes slowing the contaminant front. This phenomenon is generally referred to as "retardation" and may be quantified by a retardation coefficient that expresses how much slower a contaminant moves than does the water itself. The retardation coefficient for TCE at the Aniak site was calculated by the following

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			equation. $$R = 1 + \frac{Kd * \rho b}{\varphi}$$ Where: R is the retardation coefficient = 1.25, based on parameter values below; ρb is the bulk density (2.65*[1- φ]=1.9 g/cm^3); K_d is the sorption coefficient = K_{oc} [organic carbon coefficient of contaminant]*foc [fraction of organic carbon in the soil]) (100 L/kg*0.00045=0.045; and φ is the porosity (0.3). A retardation factor of 1.25 indicates that TCE travel will be retarded by a factor of 1.25 compared to the groundwater velocity. This is a low retardation factor, reflecting TCE's high mobility and low affinity for sorption onto soil. The TCE travel distance is presented in Table 2-4, along with the groundwater travel distance.
3. 13	2.4.4	This section re-states conclusions made by Shannon and Wilson in their 2010 *Final Site*	The purpose of Section 2.4.4 is specifically to present the information from Shannon &

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		Characterization Report and *Hydrogeologic Evaluation*. Oasis' interpretation of the geometry of the TCE plume, as depicted on Figure 3, raises the question of whether operation of the Middle School well is affecting plume migration. This could impact the effectiveness of the long-term MNA remedy. Refer also to Page 2-Section1; Page 20-Section 2.5.2; Page 30-Section 4.4.1; Page 32-Section 4.4.2.	Wilson's pump test. OASIS has not performed any additional pump tests. Regarding the plume geometry shown in Figure 3, the plume lobe east of the school building is based on the soil gas detection in SGP-8 (corroborated by the fact that there was a groundwater detection associated with the soil gas detection in SGP-9). There have been no groundwater samples collected in this area, so the potential plume has not been confirmed but is suspected based on the soil gas detection. There may be an additional source area in this location that has not been delineated. Also, because there has been no sampling under the building, the groundwater plume was extended from the known plume on the west side of the building to incorporate SGP-8. The plume geometry is discussed in Section 2.5.2. Additional characterization is required to further refine the plume shape and to determine whether it suggests possible influence from the middle school well as

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			suggested by the reviewer. No changes to the text are recommended in this section that specifically is reporting the results of Shannon & Wilson's pump test.
4. 19	2.5.1 and 2.5.2	Both sections state that a simplified interpretation is made with respect to the saturated interval to assist in evaluating remedial alternatives. Would changes in the assumptions, e.g., assuming a thicker saturated interval, change the evaluation of remedial alternatives?	The simplified interpretation in these sections refers to the use of an annualized saturated thickness instead of performing multiple calculations based on the expected saturated interval thickness during each water level scenario (see Table 2-2). The assumed saturated thicknesses cited in the report (54-64′ in sand at MW-4 and 59-64′in silt and 54-59′ in sand) are based on the maximum "summer" water level of ~64′, which is expected to overestimate the saturated interval for most of the year, with the exception of the very short-duration breakup period in the spring. The following explanatory text will be added to both Sections 2.5.1 and 2.5.2, right after the simplified interpretation is presented. The simplified interpretation refers to the use of an annualized saturated thickness instead of

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			performing multiple calculations based on the expected saturated interval thickness during each water level scenario (see Table 2-2). The top of the saturated interval corresponds to the summer high water level shown in **Error! Reference source not found.**, which is expected to approximate or overestimate the saturated interval for most of the year, with the exception of the very short-duration breakup period in the spring (approximately 2 weeks). The remedial alternatives evaluated under this assumption would therefore be expected to treat the entire impacted saturated zone during approximately 50 weeks of the year and additionally treat the lower vadose zone during winter low water levels. The saturated thickness interpretations are discussed further with respect to the remedial alternatives in Sections 4.2.3 and 4.2.4.
5. 23	3.	Numbered bullet 1 should specify the area over which the cleanup level is to be met, presumably the entire plume extent.	The area over which the cleanup level is to be met has not been determined. If an alternative point of compliance is established at this site (see discussion in Section 5.3.1.2), then the cleanup level would need to be met at the alternative point of compliance. Otherwise, the cleanup level will need to be met throughout the entire plume extent, as

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			suggested in the comment. Suggest no changes to the RAO, because the area has not yet been determined.
6. 25	4.1	It would be helpful to combine the relevant portions of the pre-draft FS with this document.	Concur; the pre-draft will be added as an appendix.
7. 25	4.1	Last paragraph. Does Oasis think an engineered remedy implemented in conjunction with excavation of PCB contaminated soil in the vicinity of MW-5 deserve consideration? For example, placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface could be used to deliver reagents periodically. Refer also to Page 3, Item 2b.	Concur this is a good suggestion. The following text (in red) was added to Section 4.1. Depending on the location, volume, depth, thickness, and magnitude of the silt contamination, it may also be advantageous to overexcavate TCE-contaminated silt, perform some mechanical mixing of the oxidant or reductant to increase its distribution in the silt, or alternatively to install an engineered solution, such placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically. Costs were not evaluated for this potential remedy component, because the costs are highly dependent on more complete characterization of the TCE contamination in the silt, in particular relative to

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			the horizontal and vertical location of PCB-contaminated soil. The detailed silt characterization has not yet been performed. Also, the recommended additional characterization paragraph in the executive summary and recommended alternative sections was revised as follows: Overall, it appears that additional plume characterization and implementation of the soil remedies would be beneficial before selecting a groundwater remedy. Additional plume characterization activities should include installing monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of

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			substrate amendment. During the PCB soil excavation in the vicinity of the former septic tank and truck fill, soil samples should also be analyzed for TCE. If high TCE concentrations are detected in the silt at the base of the PCB excavation, overexcavation of TCE-contaminated soil or direct treatment using a reductant (or possibly an oxidant) during the PCB soil excavation may be a very beneficial and cost-effective remediation strategy. Alternatively, depending on the location, magnitude, and extent of the TCE contamination and silt characteristics, installation of an engineered solution, such as placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically, may be warranted. Sampling details and a decision protocol should be incorporated into the excavation work plan.
8. 26	4.2.1	Oasis states: "The primary current human health risk associated at this site is indoor air inhalation due to vapor intrusion into the Aniak Middle School Building." For the reasons discussed in comments to Section 1 (Comment #1), recommend revising to: "The primary current human health risk associated	Suggest the following revised wording to account for possible indoor air sources in addition to vapor intrusion: The primary current human health risk at this site is indoor air inhalation, due to vapor intrusion into the Aniak Middle School Building and

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		at this site is indoor air inhalation, possibly due in part to vapor intrusion into the Aniak Middle School Building and possibly due to an indoor air source(s).”	possibly also due to an indoor air source(s).
9. 27	4.2.3	Last paragraph. Does Oasis think the seasonal saturation of the silt might result in rebound of TCE in groundwater if ISCO or ERD were employed as a remedy?	Rebound is anticipated, which is one of the reasons that four separate injection events are included in both the ISCO and ERD alternatives. The following changes were made to the text to better explain this. The following text (in red) was added in Section 4.2.3. In both plumes, approximately the top five feet of the groundwater treatment zone is expected to be saturated only seasonally (i.e., approximately from May through September; see Table 2-2). In addition, for a short period of time during spring breakup (i.e., approximately two weeks), the saturated interval is expected to extend up to another eight feet above the top of the groundwater treatment zone. The seasonal saturation is expected to potentially result in TCE rebound in the groundwater (see discussion in Section 4.2.5). The silt layer (discussed further below), whether saturated or not, is expected to

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			have a relatively high moisture content and provide a fairly competent barrier to air flow, so significant aeration of the seasonally-saturated zone is not expected. The second-to-last paragraph in Section 4.2.4 was rewritten as follows: Although the seasonally-saturated silt layer is included in the groundwater remedial alternatives, remediation of the silt is expected to be difficult. Its hydraulic conductivity is estimated to be approximately three orders of magnitude lower than the hydraulic conductivity of the underlying sand layer. Its seasonal saturation is expected to result in a relatively high moisture content and a correspondingly low permeability to air. The remedial alternatives were designed to address the silt characteristics as discussed in Section **Error! Reference source not found.**. Specifics of each groundwater alternative regarding silt remediation are discussed in Sections 4.4 through 4.7. New Section 4.2.5 was inserted:

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			4.2.5 Design Assumptions for the Injection Alternatives Allowances were made in the two injection alternatives, Alternative GW-3 (ISCO) and Alternative GW-4 (ERD), to address the seasonal TCE recharge and the low-permeability silt layer discussed in the previous sections. Both of the injection alternatives were designed to include four annual injection events. Each subsequent injection event will address seasonal TCE recharge that occurred since the previous injection event. The four separate injection events will allow better oxidant or reductant distribution in the low-permeability silt than a single injection event. The injection locations can be shifted for each subsequent injection event to account for the small radius of influence anticipated for each injection. Monitoring results from the first event will be used to optimize subsequent events to address the seasonal TCE recharge and low-permeability silt layer.
10. 28	4.2.5	Without seeing a groundwater monitoring plan, the installation of 12 new wells for this site seems excessive given the low TCE concentrations, small size of the site, and	There are some significant data gaps remaining with respect to groundwater plume delineation at the site. The 12 new monitoring wells are based on the need to

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		limited extent of migration observed to date.	address data gaps identified in Sections 2.5.1 and 2.5.2. The actual number of new monitoring wells required at this site may differ from 12, but OASIS contends that 12 is a reasonable approximation, and the actual number is expected to fall within the -50%/+100% cost range for this FS.
11. 28	4.2.5	Quarterly monitoring is likely impractical at Aniak.	Quarterly monitoring would be expensive at Aniak but may be needed to provide adequate detail about initial remedial system performance. Quarterly monitoring in the first year would also provide the data necessary to begin robust trend analysis using Mann-Kendall. In recognition of the difficulty and expense associated with quarterly monitoring at Aniak, the cost estimates assumed only one year of quarterly monitoring. Changing the monitoring frequency for one year would not be expected to affect overall remedy costs beyond the -50%/+100% range.

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12. 28	4.2.6	Should the type of institutional controls considered be expanded and/or other options considered in conjunction with MNA? e,g, shutdown of the Middle School well with substitution of alternative water supply from a new well or connection to the High School supply well?	If additional data collection suggests the plume may be migrating toward the Middle School well then well shutdown may indeed be worth considering. IC costs were not specifically included in the FS but would be included in the contingencies. The contingencies would be expected to cover an additional IC such as the one suggested by the reviewer.
13. 30	4.4.1	First bullet point, change DO and ORP concentrations to DO and ORP measurements or readings	OK
14. 30	4.4.1	Second bullet point, last sentence. Omit "significant".	OK
15. 32	4.4.1	1st full paragraph. Should be 'ethene' rather than 'ethane'.	Yes
16. 33	4.5.1	Fourth Paragraph: Did Oasis consider that ISCO using potassium permanganate may mobilize constituents such as arsenic and chromium from the aquifer materials or whether such mobilization could pose a threat to the drinking water wells?	Literature research OASIS performed on this subject indicated that ISCO using potassium permanganate may increase groundwater concentrations of arsenic and chromium due to the presence of these metals in the KMnO4 (i.e., Huling and Pivetz, 2006). Apparently technical grade KMnO4 may contain elevated concentrations of As and Cr,

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			although remediation grade KMnO4 has been developed with lower As and Cr concentrations. Bench-scale testing and/or use of remediation grade KMnO4 is recommended to address this potential issue. In addition, changes in pH that could occur in conjunction with ISCO and also ERD can also mobilize metals from the soil or aquifer matrix. The following text was added at the end of Section 4.5.1. An additional consideration of ISCO at this site is the potential risk of introducing heavy metals such as arsenic and chromium, found as impurities in the $KMnO_4$, into the groundwater. Literature research (i.e., Huling and Pivetz, 2006) indicates that arsenic and chromium introduction could result in MCL exceedences, although natural attenuation has generally achieved adequate reductions in acceptable distances. Remediation-grade KMnO4 has been developed that contains minute concentrations of heavy metals. In addition, changes in pH that could occur in conjunction with ISCO and also ERD can also mobilize metals from the soil or aquifer matrix. Bench-scale testing is recommended to

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			evaluate the risk of heavy metal introduction or mobilization, especially at this site with nearby drinking water wells. In addition, bench testing was specifically added as a requirement in the beginning of Section 4.5.2. New text in red below. Prior to completing the remedial design, bench-scale testing and a pilot test would be performed for ISCO at the Aniak WACS site. The primary goals of the bench-scale testing would be to evaluate the risk of heavy metal mobilization (such as arsenic and chromium) ~~from the $KMnO_4$~~ into groundwater and to more directly assess natural oxidant demand. The primary goals of the pilot test would be to assess realistic injection rates and oxidant distribution in the silt in the most highly-contaminated portion of the site (currently thought to be between the former truck fill area and SGP-17). A similar paragraph was inserted into the beginning of Section 4.6.2, as shown below. Prior to completing the remedial design, bench-scale testing and a pilot test would be

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			performed for ERD at the Aniak WACS site. The primary goals of the bench-scale testing would be to evaluate the performance of different electron donors (substrates) and bioaugmentation on reductive dechlorination using site soils and groundwater. The primary goals of the pilot test would be to assess realistic injection rates and substrate distribution in the silt in the most highly-contaminated portion of the site (currently thought to be between the former truck fill area and SGP-17). The effects of cold site groundwater temperatures on the reductive dechlorination process will also be evaluated.
17. 33	4.5.1	Second paragraph discussion of ISCO with permanganate should discuss the potential of aquifer clogging due to generation of manganese oxides.	The "clogging" potential is discussed in the fourth paragraph of this section, as excerpted below. Injection of the permanganate oxidant mixture will also be inhibited by precipitation of dissolved metals, and permanganate particles will result in temporary permeability loss in the already low permeability silt. However, the presence of some permanganate particles may be beneficial in that

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			they can provide a source that will dissolve once in the aquifer, thereby extending the half-life of the oxidant in the aquifer. The distribution issues will likely result in the necessity to inject the oxidant several times to complete remediation.
18. 33	4.5.1	Given the relatively high natural potassium permanganate oxidant demand indicated by Shannon and Wilson's testing, a combination of unactivated persulfate and bicarbonate should be evaluated as an oxidant. Potassium permanganate, while certainly longer lasting, in many cases has higher oxidant demand than unactivated persulfate.	Concur that other oxidants besides potassium permanganate may be considered for use at the site. For example, the Regenesis product Regenox does not oxidize plant matter and some other carbon, so the overall consumption of oxidant on NOM is not as great as with permanganate. However, it is likely that the reduction in oxidant requirements would be offset by the increase in oxidant price. All of this would be expected to fall within the -50%/+100% cost range. If ISCO were selected as the remedy for the site, the actual oxidant selection would be based on a pilot study.
19. 34	4.5.2	Third paragraph, third sentence. Add a space between "of" and "approximately."	OK
20. 34	4.5.2	The basis for evaluation assumes a 15 ft radius of influence and injection at rates up to 20 liters per minute. Considering the assumed properties of the silt, both of these assumptions	As discussed in response to Comment #9, OASIS agrees that injection into the silt is likely to be difficult and a 15-ft radius of influence is optimistic The four planned

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		are highly optimistic. The injected fluids will likely follow preferential pathways, including induced soft sediment fractures, limiting the contact with much of the silt mass.	injection events will allow optimization of subsequent injection locations to decrease injection spacing as warranted by site conditions based on performance monitoring results.
21. 35	4.6.1	Consider the applicability of high-viscosity substrates in a low temperature aquifer.	The cost analysis was based on HRC injection, in part because Regenesis provides a good calculation tool. However, as discussed in Section 4.6.2, OASIS recognizes that HRC may not be the substrate selected for this project and concurs that a high-viscosity substrate is probably not ideal. There are several low viscosity substrates on the market. The actual substrate selection will be based on a pilot test. Substrate selection should not affect the cost estimate beyond the -50%/+100% cost range for this FS.
22.	4.6	Literature research indicates that low aquifer temperatures (5-6 ^{o}C) may adversely affect microbial activity such that EAB may be stalled at cis-1,2-DCE or vinyl chloride. Accumulation of either or both daughter products is a significant concern.	OASIS has experience with a low aquifer temperature site in which ERD has been used successfully; however, the groundwater temperatures in Aniak do appear lower than at the other site. OASIS expects that the cold temperatures will slow microbial activity

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			relative to warmer sites and may also inhibit it. The low aquifer temperatures are one of the reasons for the recommendation for a Bio-Trap study in the short-term and a pilot study before selecting the final remedy for this site. The following text was added to Section 4.6.1 to specifically address concerns with temperature. A third consideration for enhanced bioremediation at the Aniak WACS site is the low groundwater temperatures. The dataloggers recorded a temperature range between approximately 2ºC and 4ºC over the period between May and October 2011, although manual temperature readings were as high as 7ºC. As discussed in Section **Error! Reference source not found.**, use of Bio-Trap® in-situ microcosms would help evaluate the potential effectiveness of enhanced bioremediation in the cold groundwater temperatures found at this site. OASIS' experience at the other site is related below for the reviewer's information.

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			The reductive dechlorination process did indeed stall at cis-1,2-DCE for 3-5 years (different timeframes associated with different source areas and different initial geochemical conditions); however, after that, complete reduction kicked in with significant ethene generation. There was a relatively short lag period between vinyl chloride generation and ethene generation. At this other site, OASIS and the client concluded that the cold aquifer temperatures were not the primary reason for the stall, although they certainly contribute to the long treatment time. Rather, the proper geochemical conditions had not yet been established, and/or the proper microbiological community was not adequately established.
23. 36	4.6.2	Recommend assuming that bioaugmentation will be necessary, both in the approach discussion and in cost estimate.	Concur; bioaugmentation was added to the approach discussion and cost estimate. Revised text shown below. This alternative also includes bioaugmentation (i.e., injection of appropriate microbial

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			community [DHC organisms]) for complete reductive dechlorination of TCE to ethene. The presence or absence of DHC organisms is unknown at this site, but bioaugmentation was included in the cost estimate. Bioaugmentation is relatively inexpensive relative to the entire project cost, and it may assist and will not hurt reductive dechlorination at the site. For costing purposes, three bioaugmentation events each of 100 liters of KB-1® dechlorinator was assumed. The KB-1® would be injected into one of the substrate injection rows; i.e., 3 injections in the MW-4 plume and 7 injections in the MW-5 plume. KB-1® injection should not occur until the aquifer has been driven anaerobic; therefore the bioaugmentation was considered to occur in years 1 through 3. KB-1® is a naturally occurring, non-pathogenic microbial culture that contains DHC, the only group of microorganisms documented to promote the complete dechlorination of chlorinated ethenes to non-toxic ethene. KB-1® is used to establish complete dechlorination at sites that do not contain DHC (or the right DHC) and to accelerate dechlorination rates to achieve treatment goals. As with the other assumptions in this FS, selection of the actual microbial consortium for

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			injection would occur after additional characterization and in conjunction with a pilot test.
24. 39	5.	Consideration should be given to scenarios under which the school is replaced and/or demolished when the local airport runway is expanded. Should this long-term expectation be considered in scoring the remedies?	Although the airport's 20-year plan does include moving the runway closer to the site and removing the school building, there has been no funding commitment on this project to-date. Our understanding is the School District plans to continue using the building in the foreseeable future. Therefore, we do not feel like this potential future scenario can be incorporated into the FS at his point.
25. 41	Table 5.1	GW-2 – MNA is less prone to a 100% upside estimate exceedance than other remedies. MNA costs are not nearly as likely to risk a 100% overrun. If adjusted for such relative risk, MNA's total score and cost effectiveness quotient increases relative to any other alternative remedy.	The cost range is selected based on the EPA guidance document and is appropriate for the level of characterization at the site, as described in Section 4.2.8. The greater the data gaps, the greater the range. The range is not intended to be remedy specific.
26. 41	Table 5.1	GW-3 – Long-Term Effectiveness and Permanence. The relative degree of TCE contamination in the Silt, seasonal saturation of the Silt, combined with the relatively short anticipated half-life of dissolved potassium permanganate (relative to groundwater	As discussed in Section 4.2.3, the four injection events are intended to address TCE rebound and the difficulty of oxidant distribution in the silt.

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		fluctuations at the site) indicate that this remedial technology could be subject to rebound of TCE concentrations in groundwater. Recommend reducing score from '4' to '3'.	Scores are intended to be relative between different alternatives, and OASIS contends that ISCO is expected to have more of a "4" rather than "3" level LTE & permanence, relative to ERD and sparging.
27. 41	Table 5.1	GW-3 – Implementability. The discussion of ISCO presented in the FS raises serious doubts whether this technology can be successfully implemented in the silt and doesn't support a score of '3'. Recommend reducing score to '2'.	OASIS contends that ISCO can be successfully implemented at the site; however, the radius of influence is expected to be small and may require multiple injections as scoped in the FS. As discussed with comment #26, the scores are relative between different alternatives. OASIS contends that ISCO and ERD are equally implementable, because the silt is expected to have a relatively equal influence on both of these injection-type alternatives.
28. 41	Table 5.1	GW-4 – Reduction in Toxicity. EAB may not be the effective remedial option for TCE at low aquifer temperature due to potential cis-1,2-DCE or VC stall. Recommend reducing this score to '2'.	Short-term accumulation of daughter products, cis-1,2-DCE (primarily) and possibly also vinyl chloride would be anticipated with ERD. However, short-term risk will be mitigated by the SSD and air filtering systems. In the long-term, this remedy is expected to result in complete reductive dechlorination of all the TCE

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			daughter products. OASIS contends that ERD is expected to have more of a "3" rather than "2" level reduction in toxicity.
29. 41	Table 5.1	GW-5 – Implementability. The discussion of air sparging presented in the FS raises serious doubts whether this technology can be successfully implemented in the silt and doesn't support a score of '3'. Recommend reducing score to '1'.	Concur that air sparging is less implementable than ISCO and ERD and suggest reducing score to "2." OASIS contends that air sparging is expected to be implementable in areas where the silt layer is incompetent or absent but may not be implementable where it is competent. The competence of the silt is not known adequately to support a score of "1."
30. 45	5.3.2.3	Ten years versus 20 years versus 35 years tempers the significance of relative "speed."	The scores for short-term effectiveness express this tempering by providing little differentiation between alternatives.
31. 47	5.4	At the top of this page, TCE solubility is noted as 1.3 mg/L. This should be 1,100 mg/L	OK
32. appendix	HRC costing sheets	The hydraulic conductivity used in the HRC costing does not use hydraulic conductivity values consistent with estimates in the text. This is especially apparent in the case of the silt, since a hydraulic conductivity for the silt	For the sand, the text shows a geo mean K value of 155 ft/day versus 100 ft/day in the HRC costing sheet. This difference is insignificant.

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		zone costing used a value of 40 ft/day, while the text presents an estimated value of 0.03 ft/day	The value of 40 ft/day was used for the "silty sand" scenario, not silt. For the "silty sand," the assumption is 5′ of silt and 10′ of sand. In the text, the sand K is 155 ft/day and silt is 0.03 ft/day. In this scenario, most of the groundwater flow will occur in the more highly-permeable sand layer. A value of 40 was chosen to acknowledge some decrease in "average" hydraulic conductivity due to the silt layer while recognizing that the effective K value will be skewed toward the sand value, because most of the flow will occur in the sand.