ANNUAL SITE STATUS REPORT
(for the Year 2007)

FOR FORMER UST SITE 957/970
AT DEPARTMENT OF DEFENSE HOUSING FACILITY
NOVATO, CALIFORNIA

Prepared for:

Base Realignment and Closure
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ACRONYMS AND ABBREVIATIONS

ASTM	American Society of Testing and Materials
BCT	BRAC Cleanup Team
BRAC	Base Realignment and Closure (Act of 1990)
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CD	compact disc
CSM	conceptual site model
CSWRCB	California State Water Resources Control Board
DO	dissolved oxygen
DoDHF	Department of Defense Housing Facility
DQO	Data Quality Objective
LDC	Laboratory Data Consultants, Inc.
MNA	monitored natural attenuation
MTBE	methyl *tert*-butyl ether
MCL	maximum contaminant level
mg/L	milligram per liter
µg/L	microgram per liter
NEX	Naval Exchange
NFESC	Naval Facilities Engineering Service Center
ORP	oxidation reduction potential
PWC	Public Works Center
QA/QC	quality assurance/quality control
QC	quality control
SAP	Sampling and Analysis Plan
SSR	Site Status Report
SVE	soil vapor extraction
TBA	*tert*-butyl alcohol
TBF	*tert*-butyl formate
TO	Task Order
U.S. EPA	U.S. Environmental Protection Agency
UST	underground storage tank

Section 1.0: INTRODUCTION

This site status report (SSR) describes activities performed under Task Order (TO) No. 018 of the U.S. Naval Facilities Engineering Command (NAVFAC) Contract No. N68711-01-D-6009 and, in accordance with the TO, presents the results of quarterly groundwater and surface water monitoring conducted in August and November 2007. Prior to the August 2007 sampling event, the *Final Groundwater Monitoring Plan Update for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California* (Battelle, 2007) was issued for the Site. These sampling events represent the first quarters in which groundwater sampling will have been performed according to these updated reports; therefore, this Annual SSR has been updated to more specifically address the data quality objectives (DQOs) contained in the Sampling and Analysis Plan (SAP) (Battelle, 2007).

1.1 Location

The subject of this report is former Underground Storage Tank (UST) Site 957/970 at the Department of Defense Housing Facility (DoDHF) Novato, located approximately 20 miles north of San Francisco, in Marin County, CA. The Site comprises an approximate 13 acre area with dimensions of approximately 1,100 ft by 500 ft bounded on the south by Main Entrance Road and on the north by railroad tracks operated by the Golden Gate Bridge, Highway, and Transportation District. Pacheco Creek is the nearest surface water body, located approximately 800 ft northwest of former UST 957/970 (Figure 1).

1.2 Site History and Background

The Site is the location of a former Naval Exchange (NEX) gas station and a former Public Works Center (PWC) gas station (Figure 2). The NEX gas station was located at the northwest corner of Main Entrance Road and C Street, where Building 970 and associated pump islands were in use from the mid-1970s through the early 1990s. The NEX gas station was closed in the early 1990s, and subsequently the three USTs supporting the station (970-1 [10,000-gallon UST], 970-2 [10,000-gallon UST], and 970-3 [10,000-gallon UST], collectively referred to as UST 970) were removed. The PWC gas station was the location of UST 957; this 12,000-gallon UST and associated underground piping were removed in 1992.

Water and soil samples were collected from excavations during tank removal activities in the areas of former USTs 957 and 970. Analytical results from these samples indicated that gasoline was released to the environment from the USTs. Because the groundwater plumes underlying these areas have merged and are no longer distinguishable, the individual Site designations have been combined and the label “Former UST Site 957/970” has been adopted.

Though the Navy has not pursued de-designation of beneficial uses of groundwater, in accordance with provisions of California State Water Resources Control Board (CSWRCB) Resolution 88-63 (CSWRCB, 1988), impacted groundwater beneath the Site is arguably not a potential drinking water source because the water in the shallow aquifer has a high total dissolved solids concentration and low yield. No domestic, irrigation, or agricultural wells are currently impacted by the dissolved gasoline constituents released from the Site.

Starting in June 1998, an interim remedial action consisting of air sparging and soil vapor extraction (SVE) was implemented to reduce hydrocarbon mass in areas in which the highest hydrocarbon concentrations were observed in groundwater. Significant mass removal was achieved, and the air sparging and SVE systems were shut down in early October 1999 because of greatly diminished mass removal rates.

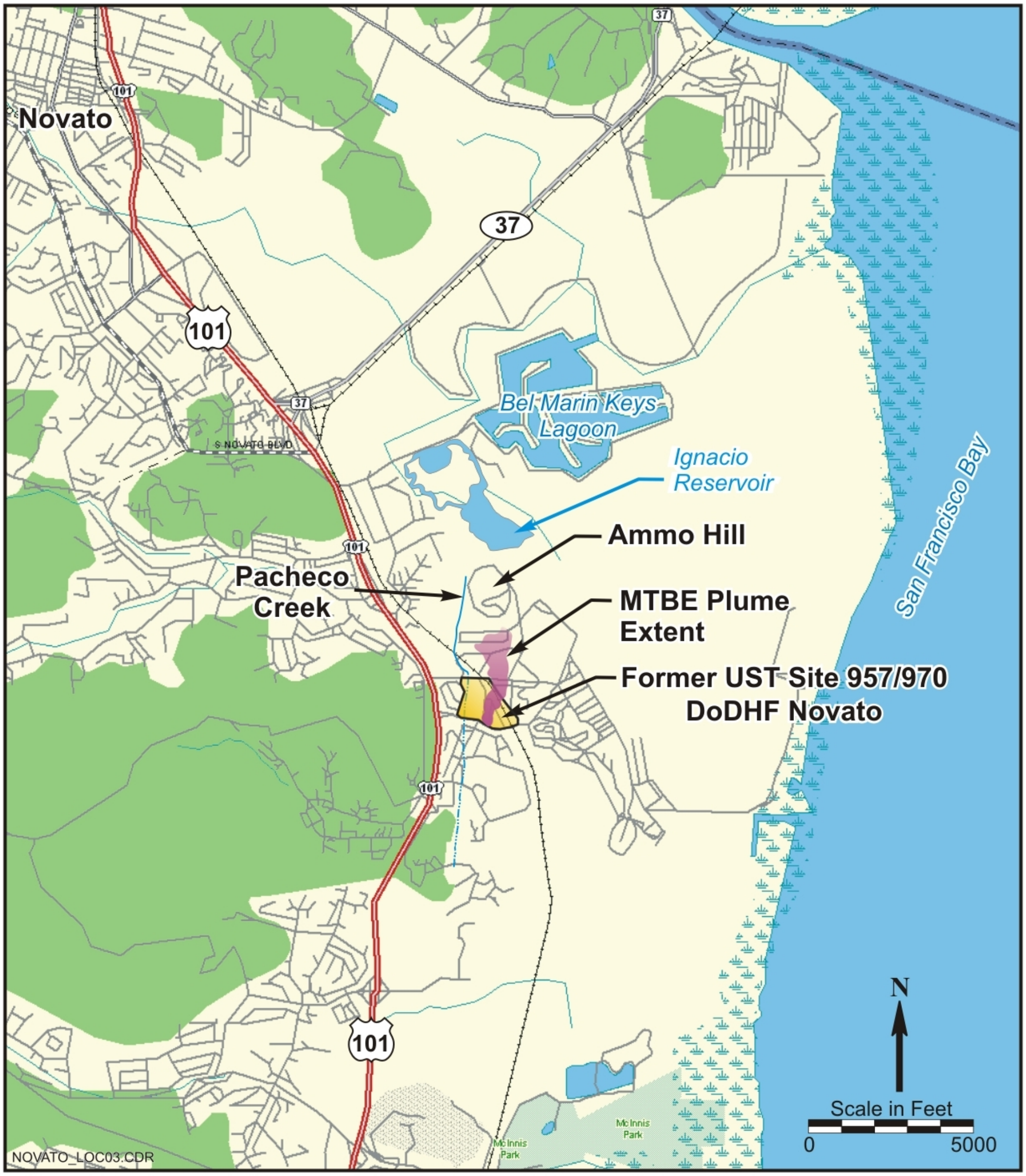

Figure 1. Site Location Map

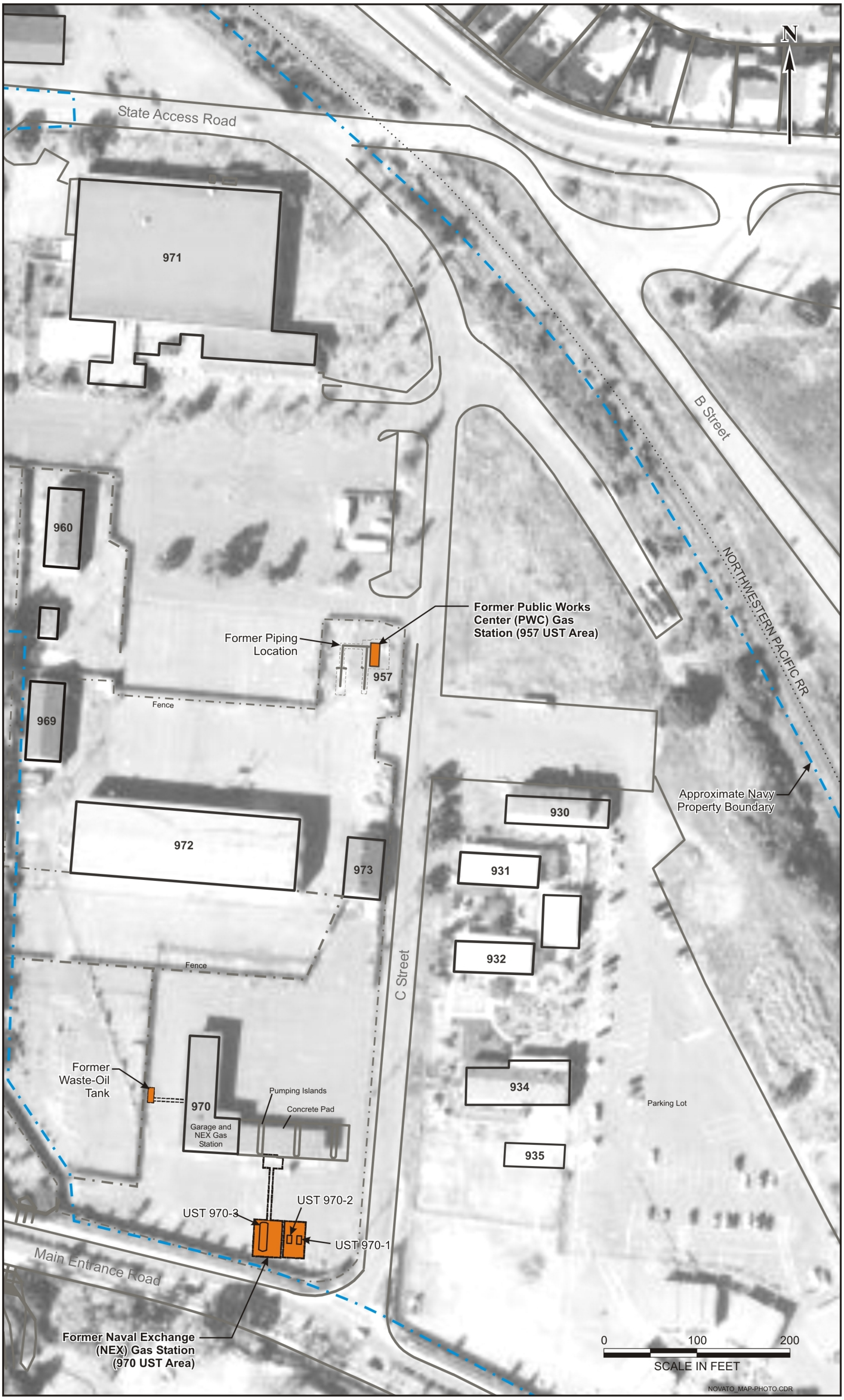

Figure 2. Location of Former NEX and PWC Gas Station

In September 2002, a biosparging system was initiated at the Site to mitigate elevated concentrations of methyl *tert*-butyl ether (MTBE) on Navy-owned property. This remediation system was temporarily shut down for one year (from March 2005 to March 2006) with approval from the San Francisco Bay Regional Water Quality Control Board (Water Board) because asymptotic removal was achieved. During this interim shutdown phase, no significant rebound of MTBE concentrations was observed. The system was restarted in March 2006 and is currently still operating, though the Navy and Water Board are close to an agreement that would allow the system to be shutdown as of the date of this report.

1.3 Summary of Current Site Activities

The biosparging system has been operating on a pulsed schedule since it was reinitated in March 2006. On July 27, 2007, a letter formally requesting permission to shut down the biosparging system and initiate a rebound monitoring program was issued by the Navy Base Realignment and Closure (BRAC) Cleanup Team (BCT) to the Water Board. On August 17, 2007, the Water Board requested a response plan in the event that MTBE concentrations at the leading edge of the plume do not begin to stabilize or decrease in the future. The Navy is currently developing a strategy for managing MTBE-impacted groundwater throughout the plume (and specifically at the leading edge) and will provide this information to the Water Board through meetings and documentation.

The *Final Groundwater Monitoring Plan Update for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California* (Battelle, 2007) for the Site was finalized and submitted to the Agencies in August of 2007. Based on the updated DQOs contained therein, this Annual SSR (and subsequent SSRs) will specifically evaluate the effects of active treatment on the MTBE plume, the conditions at the leading edge of the MTBE plume, and monitored natural attenuation (MNA) throughout the MTBE plume.

1.4 Summary of Monitoring Program

All monitoring program requirements referenced in this section correspond to the *Final Groundwater Monitoring Plan Update for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California*. In the SAP included as part of the document, a summary of the monitoring analytical program for all groundwater wells and surface water locations is provided in Table 2-1, analytical preparation and methods are summarized in Table 2-2, analytical reference limits are provided in Table 2-3, and the number of quality control (QC) samples is provided in Table 2-4.

A summary of the types of analyses and number of samples for the August and November 2007 sampling event are as follows:

- All samples collected during the August and November 2007 monitoring events were analyzed for benzene, toluene, ethylbenzene, total xylenes (BTEX), and MTBE.
- The MTBE degradation product, *tert*-butyl alcohol (TBA), and *tert*-butyl formate (TBF) were analyzed in 22 wells during August 2007 and 35 wells during November 2007.
- Nitrate, sulfate, iron and dissolved iron were analyzed in 25 wells during August 2007 and 28 wells during November 2007.
- Dissolved oxygen (DO), pH, temperature, oxidation reduction potential (ORP), conductivity, and turbidity were measured at each well during purging activities and are recorded on the well purge logs (Appendix A). All historical field parameters measured at each well are included as Appendix B.

Low flow purging and sampling was conducted for all monitoring wells based on the methodology provided in *Groundwater Sampling Guidelines for Superfund and RCRA Project Managers* (U.S. EPA, 2002) and the American Society for Testing and Materials (ASTM) Standard D 6771-02 (ASTM, 2002). Each well was inspected during groundwater monitoring activities and secured upon completion of sampling according to the protective measures described in the *Monitoring Well Protection Plan* (Battelle, 2000). Observations are included on the well purge and maintenance log sheets provided in Appendix A. All purge water and water used to decontaminate the sampling equipment were contained in drums or polyethylene tanks prior to disposal.

Quality assurance/quality control (QA/QC) samples were collected in the field to ensure that meaningful and representative data sets were generated. Table 1 summarizes the frequency of QA/QC samples collected during the August and November 2007 monitoring events.

Table 1. Summary of QA/QC Sample Collection

Sampling Event	# of Field Duplicates	# of Equipment Rinsates	# of Field Blanks	# of Trip Blanks
August 2007	5	4	5	4
November 2007	8	8	8	8

Data generated for the Site were verified by the Battelle Project QC Manager and validated by an independent contractor, Laboratory Data Consultants (LDC), Inc (included as Appendix C). Data validation involved ensuring that the holding times were met and samples were analyzed according to the frequency and methodology specified in the SAP. Results of the data validation indicated that sample analyses were conducted according to the frequency and methodology specified in the Updated Groundwater Monitoring Plan (Battelle, 2007) except for deviations described in the following section.

Based on the first two quarters in which low flow purging and sampling was implemented (February and May/June 2007), most wells were amenable for sampling using the low flow technique. However, it was found several wells were not able to be sampled using low flow purging and sampling techniques. Deviations from the low flow sampling protocol outlined in the Updated Groundwater Monitoring Plan (Battelle, 2007) included the following:

August Monitoring Event

- The following wells purged dry before water levels and water quality parameters stabilized; however, samples were collected from these wells and submitted for analyses: MW-M8-BR, MP-1D, NA-4, PZ-1, MW-3B, 970-MW3, and MW-M15.

- The following wells were purged three well volumes before sampling: 957-MW4 and MW-M28.

- The following wells were not sampled for the specified reason: MW-1E was dry, PZ-10 was setting in an area saturated with irrigation water, and PZ-11 casing is broken.

November Monitoring Event

- The following wells purged dry before water levels and water quality parameters stabilized; however, samples were collected from these wells and submitted for analyses: MW-M8, MW-3D, MW-2E-BR, MW-M2-BR, 957-MW4, NA-7, MW-1D, MP-1D, NA-4, MW-4A, NA-0, PZ-1, PZ-3, MW-3B, NA-6, MW-M15, and MW-M14S.

- The following well was purged three well volumes before sampling: MW-M8-BR.

- The following well was not sampled because it was dry: MW-1E.

All analytical results are available in Microsoft® Excel format in Appendix D and laboratory QC summary reports are provided in Appendix E both of which can be found on the compact disc (CD) enclosed with this report.

Section 2.0: SUMMARY OF FINDINGS

This section summarizes the results from the third and fourth quarterly sampling events for 2007. Groundwater and surface water monitoring for the third quarter were conducted from August 20 through August 24 and for the fourth quarter from November 5 through November 9 and November 12 through November 14. Forty-seven groundwater samples (excluding duplicates and QC samples) were collected during the August 2007 sampling event, and 92 groundwater samples and one surface water sample (excluding duplicates and QC samples) were collected during the November 2007 sampling event. All samples were collected and analyzed in accordance with the Updated Groundwater Monitoring Plan and SAP (Battelle, 2007) and the *Updated Health and Safety Plan* (Battelle, 2006).

2.1 Water-Level Measurements

A water-level measurement was taken from each monitoring well and recorded in accordance with the Updated Groundwater Monitoring Plan (Battelle, 2007) prior to any purging and sampling activities as part of each sampling event. A potentiometric map for the November 2007 sampling event is presented in Figure 3 and cumulative water-level measurements are tabulated and included as Appendix F. In general, the potentiometric surface for November 2007 illustrates that groundwater flows toward the northeast across Landfill 26 and is consistent with those reported for previous quarters. During the August and November 2007 sampling events, water levels were collected from several wells located in and around Landfill 26 (i.e., MW-78, MW-87, EW-91-07, EW-91-08, MW-82S, MW-82D, EW-91-10, MW-L26-1, EW-91-14, MW-92-43, MW-92-40, and MW-125) to determine the groundwater flow patterns in Landfill 26 and the leading edge of the MTBE plume (see Figure 3). These wells are screened within a deeper portion of the aquifer. The resulting potentiometric surface indicates that the hydraulic gradient at the leading edge of the MTBE plume is relatively flat as the groundwater flows toward the northeast, thus confirming previous interpretations made in updates to the conceptual site model for the site.

2.2 MTBE Plume Status

An MTBE plume contour map for November 2007 is presented in Figure 4 and an electronic version of all historical analytical data collected through November 2007 is included as Appendix D. A plume contour map is not presented for August 2007 because only a subset of the entire monitoring network was sampled during this event. In November 2007, MTBE was not detected in any wells within Landfill 26. The furthest extent of MTBE-impacted groundwater from the source area was measured in IT-GMP-19 at 1.7 μg/L. The maximum MTBE concentration was measured at 1,500 μg/L in PG-MW1, located on Navy property at the corner of C Street and State Access Road. This MTBE concentration is significantly less than the all time maximum in PG-MW1 of 23,000 μg/L measured in June 2002, just before the biosparge treatment system was started.

MTBE concentrations were measured at five bedrock monitoring wells (MW-9A, MW-3D, MW-M2-BR, MW-2E-BR, and MW-M8-BR) during the November 2007 sampling event. These concentrations are noted in parentheses on Figure 4, but were not used to delineate the plume contours. The maximum MTBE concentration was detected in MW-3D at 140 μg/L, which is significantly lower than its maximum concentration of 43,000 μg/L measured in February 2001. MTBE concentrations in MW-M2-BR and MW-M8-BR were below the California state maximum contaminant level (MCL) of 13 μg/L, and MTBE was not detected in MW-9A and MW-2E-BR (<0.2 μg/L) during November 2007.

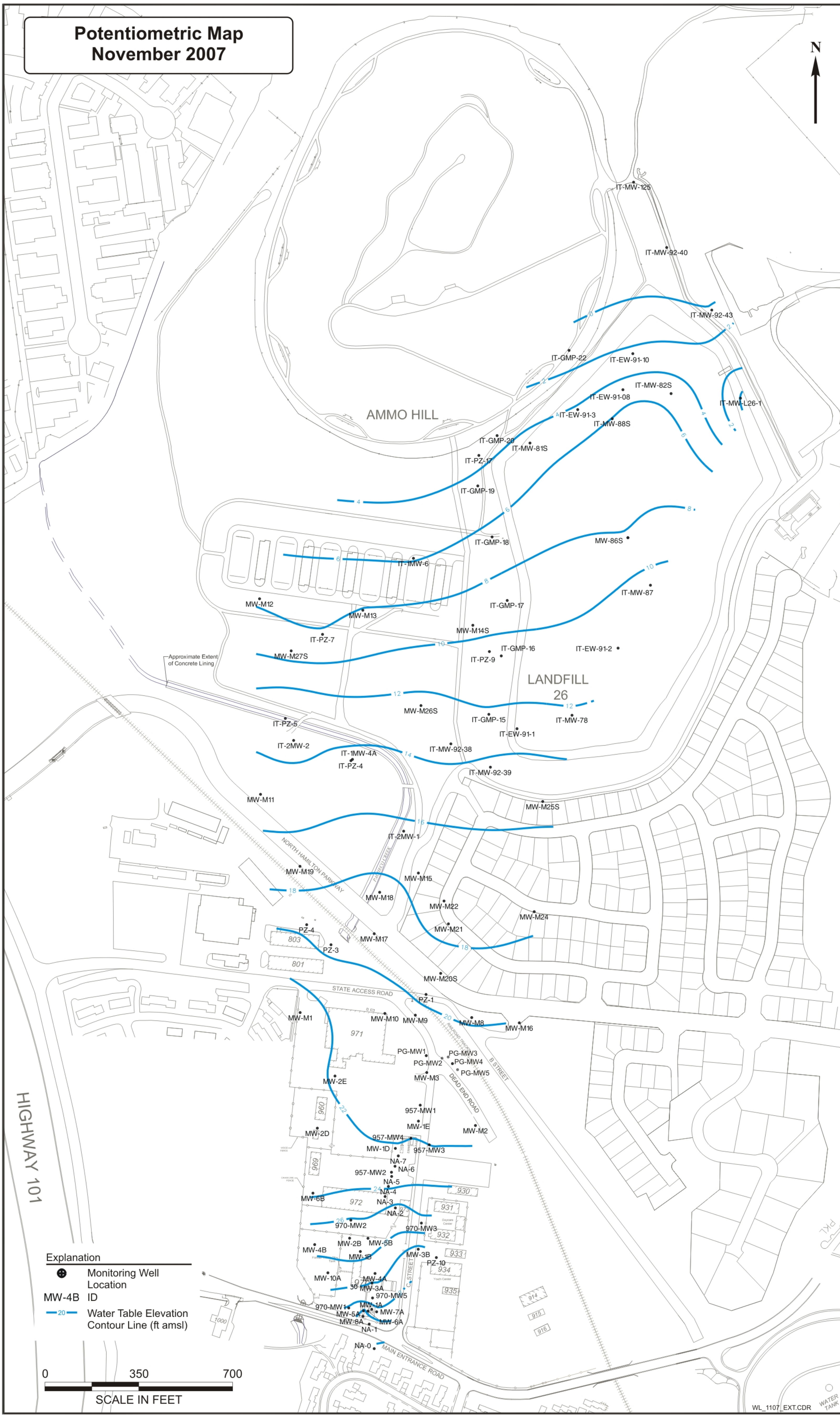

Figure 3. Potentiometric Map

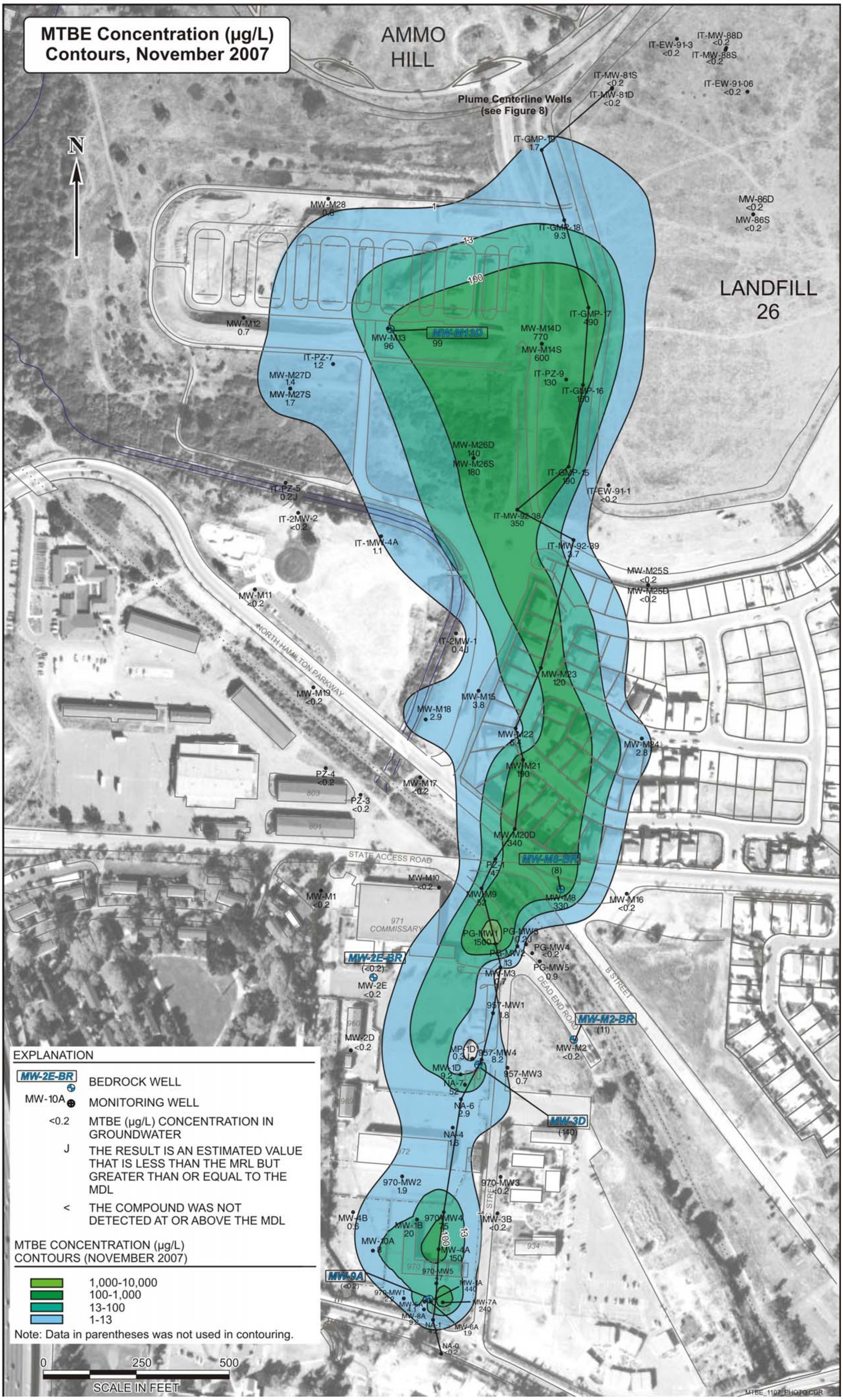

Figure 4. MTBE Groundwater Plume

2.3 Surface Water

Surface water sampling results for all locations sampled during quarterly monitoring events in 2007 are illustrated in Figure 5. Appendix D is a comprehensive electronic data set in Microsoft® Excel format and also provides surface water sampling results. The updated surface water sampling program conveyed in the Updated Groundwater Monitoring Plan and SAP (Battelle, 2007) includes MTBE and BTEX analysis once per year during November events at PC-SW-CE to confirm MTBE is not being discharged from this culvert outlet that was found to be the primary source of MTBE in Pacheco Creek.

During the November 2007 sampling event, MTBE was not detected from PC-SW-CE (<0.2 μg/L). Surface water sampling results indicate MTBE has not been detected in Pacheco Creek or the culvert outlet since November 2004. However, the Navy will continue to monitor for the presence of MTBE in Pacheco Creek by sampling PC-SW-CE annually to verify concentrations do not pose a human health or environmental concern.

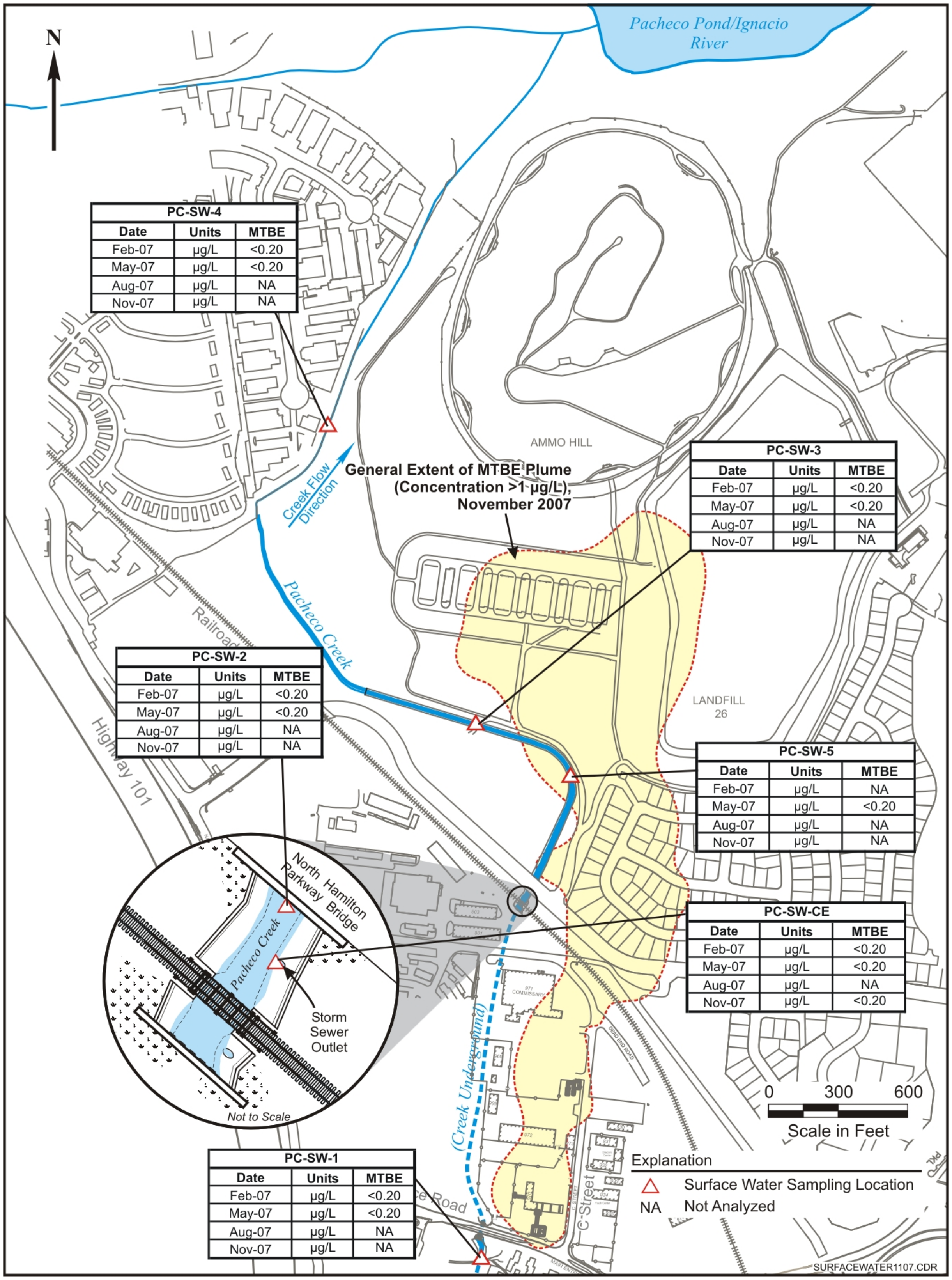

Figure 5. Surface Water Sampling Locations With Analytical Results for the Previous Year

Section 3.0: EFFECTS OF ACTIVE TREATMENT ON MTBE PLUME

3.1 Biosparging System Operations

The biosparging system was temporarily turned off in March 2005 and was reinitiated on a pulsed schedule in March 2006. In a letter to the Water Board dated July 27, 2007, the Navy BCT formally requested permission to shut down the biosparging system and initiate a rebound monitoring program. The Water Board subsequently requested a response plan in the event that MTBE concentrations at the leading edge of the plume do not begin to stabilize or decrease in the future. The biosparging system has and will continue to operate on a pulsed schedule until system shut down and the one-year rebound monitoring program begins. This period is anticipated to begin in 2008.

3.2 Verification of Effects of Active Treatment in Former Source Areas and on Downgradient Portions of MTBE Plume

Downgradient of the former source area and biosparing treatment area, eight performance goal monitoring wells (PG-MW1, PG-MW2, PG-MW3, PG-MW4, PG-MW5, MW-M3, MW-M9, and MW-M10) are sampled quarterly to assess the performance of the biosparging system. In Figure 6, MTBE concentrations and percent reductions are provided for the February, May, August, and November 2007 sampling events for all performance goal monitoring wells. The following sampling events are also included in Figure 6 because of their significance relative to the performance of the biosparging system:

- June 2002 – baseline sampling event and is used to calculate subsequent percent reductions in MTBE concentrations
- March 2005 – last sampling event before the biosparging system was temporarily turned off for one year
- February 2006 – last sampling event before the biosparging system was reinitiated on a pulsed schedule

During the time period in which the biosparging system was temporarily turned off (March 2005 to March 2006), MTBE concentrations remained relatively stable. The average MTBE concentration in the performance goal monitoring wells decreased from 2,444 μg/L in March 2005 to 2,314 μg/L in February 2006 while the system was not operational. Overall, there was no substantial rebound in any of the performance goal monitoring wells during this time period.

Since reinitiating the system on a pulsed schedule in March 2006, the average MTBE concentration in the performance goal monitoring wells decreased significantly from 2,314 μg/L in February 2006 to 196 μg/L in November 2007. During this time period, MTBE concentrations have decreased in all performance goal monitoring wells (with the exception of MW-M10 which remained below detection limits). Significant MTBE concentration reductions have been seen in the seven remaining performance goal wells, including MW-M3, MW-M9, PG-MW1, PG-MW2, PG-MW3, PG-MW4, and PG-MW5 (see Figure 6).

Overall, a ***98% reduction in average MTBE concentrations*** was observed in November 2007. These results indicate that one of the primary performance goals (95% to 99% reductions in MTBE concentrations) listed in the *Final Corrective Action Plan for Groundwater for Former UST Site 957/970* (Battelle, 2002) has been achieved at the site.

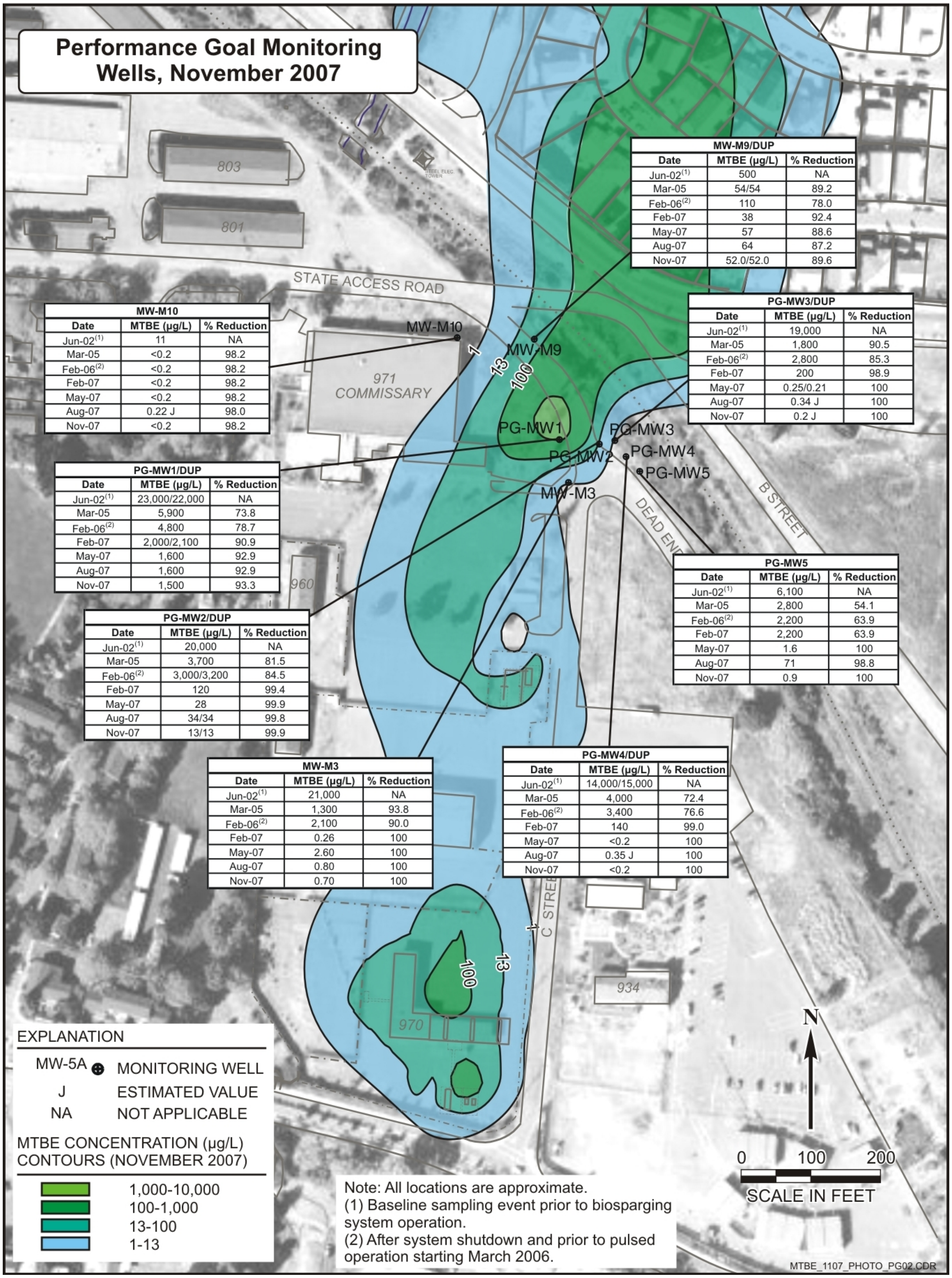

Figure 6. MTBE Concentrations and Percent Reductions in Performance Goal Monitoring Wells

The main objectives of the biosparging treatment system were to establish a stable to decreasing MTBE plume on Navy property and to cut off additional sources of MTBE to downgradient portions of the plume. Since system start up in September 2002, MTBE concentrations on Navy property have decreased significantly as demonstrated by the changes in the MTBE contours in Figure 7. In November 2001, 10 months prior to system start up, several MTBE concentrations on Navy property were greater than 10,000 μg/L. In November 2007, MTBE concentrations on Navy property were well below 1,000 μg/L, with the exception of PG-MW1 which was measured at 1,500 μg/L. Overall, effects of the biosparging system in combination with past treatment of in situ air sparging (IAS) and SVE and natural attenuation has considerably reduced the MTBE plume on Navy property.

By significantly reducing MTBE concentrations on Navy property, the previous and ongoing remediation activities have subsequently limited additional sources of MTBE to downgradient portions of the plume. From November 2001 to November 2005, overall MTBE concentrations decreased dramatically within the entire plume; however, portions of the plume that were already downgradient of the treatment area on Navy property have migrated further north, impacting monitoring wells IT-GMP-18 and IT-GMP-19. From November 2005 to November 2007, the MTBE plume did not migrate further north and concentrations continued to decrease throughout the plume as verified by the changing MTBE contours (see Figure 7).

The SAP (Battelle, 2007) presents DQOs to verify the effects of active treatment in the former source areas and on downgradient portions of the MTBE plume. To monitor the progression of active treatment, MTBE concentrations have been examined spatially and temporally along the plume centerline wells (see Figure 8). This subset of centerline monitoring wells begins upgradient from the former UST 970 source areas at NA-0 and extends through the entire plume to IT-MW-81S/D. On Navy property, MTBE concentrations decreased dramatically due to the IAS/SVE system in the Former UST 970 location and concentrations have continued to decrease once the biosparging system was implemented in the Former UST 957 location. From Figure 8, it is evident that the biosparging treatment system has continually limited additional sources of MTBE to downgradient portions of the plume over time.

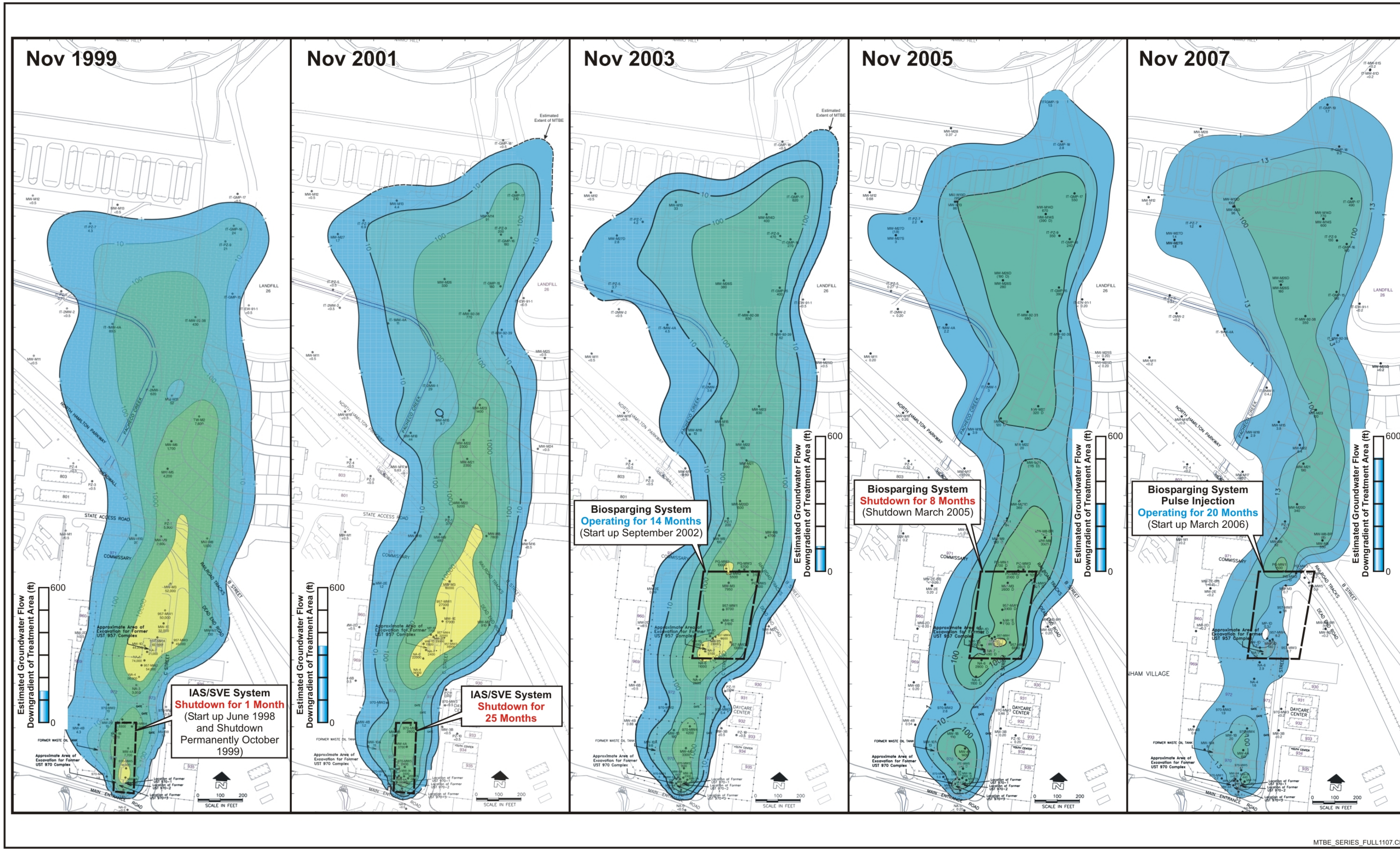

Figure 7. Effect of Active Treatment on MTBE Contours Over Time

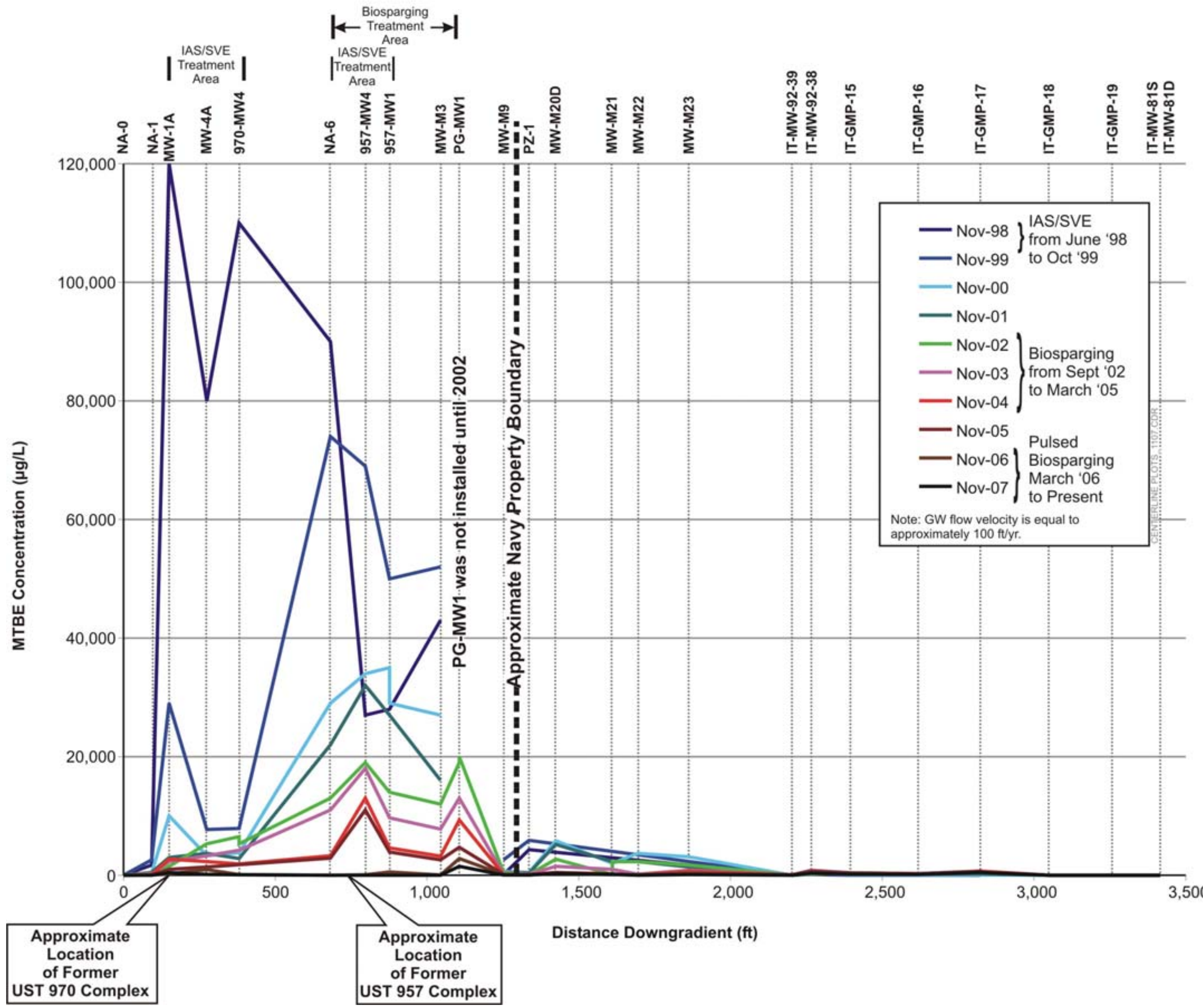

Figure 8. MTBE Concentrations in Plume Centerline Wells Over Time

Section 4.0: LEADING EDGE OF MTBE PLUME

This section evaluates the DQOs presented in the SAP (Battelle, 2007) for monitoring the leading edge of the MTBE plume. The purposes of these DQOs are to characterize the hydrogeologic conditions and MTBE concentrations at the leading edge of the plume and determine if the current monitoring well network is sufficient to delineate the downgradient extent of the MTBE plume.

4.1 Hydrogeologic Conditions at the Leading Edge

The Updated Groundwater Monitoring Plan (Battelle, 2007) presents an updated Conceptual Site Model (CSM) including a more comprehensive understanding of the hydrogeologic conditions underneath Landfill 26 in the leading edge area of the MTBE plume. The updated CSM indicates that the water-bearing capacity underneath Landfill 26 far exceeds that of the upgradient portions of the aquifer and that the hydrogeologic conditions underneath Landfill 26 may potentially control the plume and stabilize and/or reduce MTBE concentrations more effectively than conditions upgradient of Landfill 26. Characterizing the leading edge area of the MTBE plume will provide an overall understanding of the groundwater flow patterns and ensure monitoring wells within the network are in appropriate locations.

To evaluate the hydrogeologic conditions underneath Landfill 26, water levels were collected from additional wells located in the leading edge area of the MTBE plume (specifically within and downgradient of Landfill 26) during the August and November 2007 sampling events. As described in Section 2.1, a potentiometric surface was developed from the November 2007 water level measurements (see Figure 3). The potentiometric surface shown on Figure 3 demonstrates that groundwater flows to the north across Landfill 26 and that the hydraulic gradient in the leading edge area appears to be relatively flat compared to upgradient portions of the plume as demonstrated by the greater distance between the potentiometric contours.

The hydrogeological cross-section of Landfill 26 demonstrates that the portion of the aquifer underneath Landfill 26 has a greater water-bearing capacity than upgradient portions of the aquifer (see Figure 9). From well IT-MW-92-38 to MW-82 across the landfill, the aquifer thickness increases from approximately 21 to 42 feet. This larger water-bearing capacity underneath Landfill 26 may potentially control the plume and stabilize and/or reduce MTBE concentrations more effectively than conditions upgradient of Landfill 26, therefore confirming and supporting the updated CSM.

4.2 Leading Edge of MTBE Plume

Since November 1999, the leading edge of the MTBE plume has migrated approximately 500 feet to the northeast, underneath Landfill 26 (see Figure 4). Nine monitoring wells (i.e., IT-MW-81(S/D), MW-86(S/D), MW-88(S/D), IT-EW-91-1, IT-EW-91-3, and EW-91-06) located within Landfill 26 were sampled in August and November 2007 to effectively delineate the downgradient extent of the MTBE plume. These wells showed non-detectable concentrations of MTBE in August and November 2007, which is consistent with all other historical sampling events, thus bounding the leading edge of the plume. These nine wells will continue to be evaluated to determine whether there is sufficient delineation of the downgradient extent of the MTBE plume and if the plume is expanding. If groundwater samples collected from monitoring wells located within Landfill 26 continue to demonstrate non-detectable concentrations of MTBE over time, then it can be deduced that the hydrogeologic conditions underneath Landfill 26 have stabilized and/or reduced MTBE concentrations at the leading edge, thus supporting and confirming the CSM conclusions.

Figure 10 illustrates the November 2007 MTBE plume map overlaid with the potentiometric map in the leading edge area. For centerline wells in the leading edge area, MTBE concentrations from May 2002, May and November 2005, May and November 2006, and June and November 2007 also are provided in Figure 10. Analytical results from 2005, 2006, and 2007 are provided to evaluated current MTBE concentration trends in the leading edge area centerline wells and compare them to more historical results from May 2002. Overall, the landfill monitoring network is within the estimated flow path of the MTBE plume and the existing landfill monitoring well network is sufficient to ensure that the MTBE plume continues to be fully delineated at the leading edge (see Figure 10).

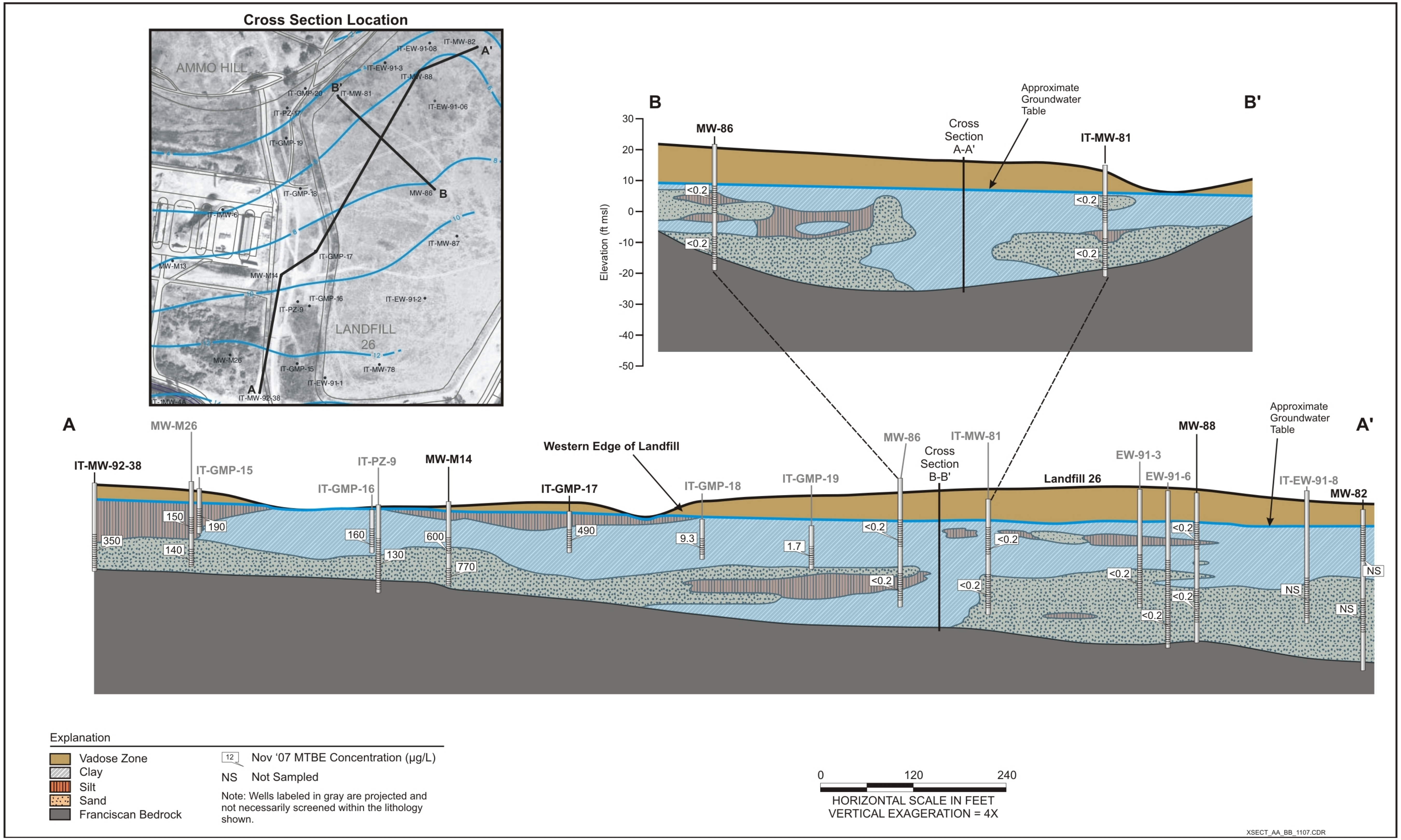

Figure 9. Hydrogeological Cross Section at the Leading Edge Area

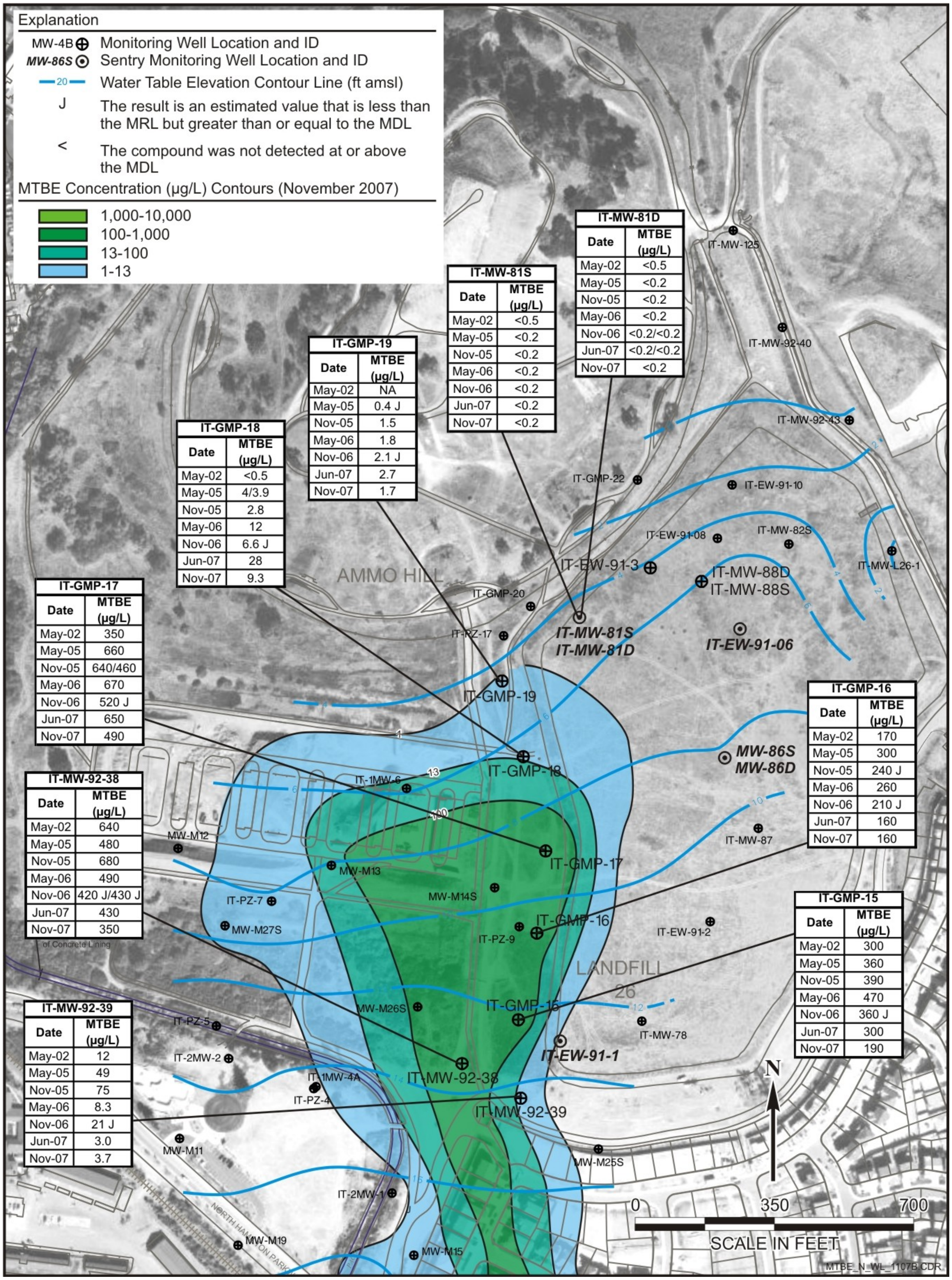

Figure 10. MTBE Plume and Potentiometric Surface at Leading Edge Area

Section 5.0: EVALUATION OF MNA THROUGHOUT MTBE PLUME

MNA is defined by the U.S. EPA as "an alternative means of achieving remediation objectives that may be appropriate for specific, well-documented site circumstances where its use meets the applicable statutory and regulatory requirements" (U.S. EPA, 2005). The Navy referred to a recent U.S. EPA (2005) publication titled *Monitored Natural Attenuation of MTBE as a Risk Management Option at Leaking Underground Storage Tank Sites* to expand upon the discussion regarding MNA at the Site. Natural attenuation relies on naturally-occurring processes, such as biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization, to reduce contaminant concentrations in groundwater; however, it is usually impossible to separate the individual contributions of each mechanism (U.S. EPA, 2005). The Former UST Site 957/970 is a large site at which multiple active treatment systems have operated in the past.

This section evaluates the DQOs presented in the SAP (Battelle, 2007) to track the occurrence of MNA throughout the MTBE plume. The purposes of these DQOs are to determine whether MNA is viable as the final remedy throughout the entire plume area. The biosparging treatment area, which extends from the former PWC 957 gas station to approximately the Navy property boundary, cannot be properly evaluated for natural attenuation because the biosparging system is actively treating this area. Therefore, evaluation of natural attenuation must focus on the areas of the MTBE plume that are not directly affected by the biosparging system, such as the leading edge area of the plume. Evidence for assessing MNA are data showing (1) plume stabilization and (2) loss of contaminant mass over time.

5.1 Plume Stabilization

This evaluation of MNA focuses on using a statistical analysis of time series MTBE data for each monitoring well to determine if the plume is stabilizing. Parametric and nonparametric regression analyses were conducted using MTBE data collected through November 2007 to quantify MTBE concentration trends at each monitoring well based on guidance provided in the current MTBE MNA guidance published by the U.S. EPA (U.S. EPA, 2005). Appendix G provides a detailed summary of the statistical analysis performed for each monitoring point.

Based on the results of the statistical analysis, each well is grouped into one of four categories, as follows:

- **Statistically Significant Increasing Trend** – This designation suggests that MTBE concentrations are increasing over time and that these trends are statistically significant based on a comparison to historical concentration trends. MTBE concentrations in these monitoring wells can be expected to increase over time.
- **Statistically Insignificant Increasing Trend** – This designation suggests that MTBE concentrations are increasing over time, however the increasing trend is not statistically significant based on a comparison to historical concentration trends.
- **Statistically Insignificant Decreasing Trend** – This designation suggests that MTBE concentrations are decreasing over time, however the decreasing trend is not statistically significant based on a comparison to historical concentration trends. If consistent decreases in MTBE concentrations continue to be observed, then it is possible for this trend to change to a statistically significant decreasing trend. At that time, MTBE concentrations in these monitoring wells can be expected to continue to decrease over time.
- **Statistically Significant Decreasing Trend** – This designation suggests that MTBE concentrations are decreasing over time and that these trends are statistically significant

based on a comparison to historical concentration trends. MTBE concentrations in these monitoring wells can be expected to decrease over time.

The Navy has been evaluating natural attenuation throughout the MTBE plume for more than seven years. The results of these evaluations have indicated that MTBE concentrations in representative monitoring wells located in the upgradient area of the plume (i.e., on Navy property and as far as 900 ft downgradient of Navy property) are statistically decreasing. However, due to the northerly direction of groundwater flow, residual MTBE mass has served to increase concentrations in some monitoring wells located in the leading edge area of the plume. Figure 11 presents the results from the statistical analysis evaluating natural attenuation for monitoring wells located within the leading edge area and upgradient area.

Leading Edge Area – Previous evaluations of natural attenuation have indicated that there is a very distinct difference in MTBE concentration trends at the leading edge of the plume. Most notably, increases in MTBE concentrations are far more prevalent at the leading edge as compared to the upgradient area of the plume. In November 2007, 28 monitoring wells were sampled within the leading edge area (see Figure 11). Of the 28 total monitoring wells in the leading edge area, 12 monitoring wells demonstrated statistically significant decreasing trends or non-detect concentrations, one monitoring well demonstrated a statistically insignificant decreasing trend, three monitoring wells demonstrated a statistically insignificant increasing trend, and 12 monitoring wells demonstrated a statistically significant increasing trend.

Upgradient Area – The upgradient area includes the monitoring wells upgradient of the leading edge and outside of the area that is directly treated by the biosparging treatment area. MTBE concentrations in these wells have been consistently decreasing over time. In November 2007, 41 monitoring wells were sampled upgradient of the leading edge and outside of the biosparging treatment area (see Figure 11). Of the 41 monitoring wells, 38 monitoring wells demonstrated statistically significant decreasing trends, two monitoring wells demonstrated a statistically insignificant decreasing trend, one monitoring well demonstrated a statistically insignificant increasing trend, and no monitoring wells demonstrated a statistically significant increasing trend.

There is a considerable difference between the MTBE concentration trends in each area. Forty-three percent of the monitoring wells located in the leading edge area have shown a statistically significant increasing trend while no wells in the upgradient area have shown this trend. In contrast, 43% of the monitoring wells in leading edge area have shown a statistically significant decreasing trend or non-detect concentrations, as compared to 93% of the upgradient monitoring wells.

The *Final Corrective Action Plan for Groundwater* (Battelle, 2002a) was approved by the Water Board in March 2002 and recommends biosparging along with MNA to be the remedial action for Former UST Site 957/970. To better evaluate the effects of natural attenuation on the leading edge area, a statistical analysis was performed using MTBE data from September 2002, when the biosparging treatment system was initiated, through November 2007. Of the 28 total monitoring wells in the leading edge area, 14 monitoring wells demonstrated statistically significant decreasing trends or non-detect concentrations, four monitoring wells demonstrated a statistically insignificant decreasing trend, three monitoring wells demonstrated a statistically insignificant increasing trend, and seven monitoring wells demonstrated a statistically significant increasing trend. The MTBE concentration trend of seven monitoring wells in the leading edge area changed once time series data coincided with initiation of the biosparging system. The changes in MTBE concentration trends are as follows:

- MW-M27S – from insignificantly increasing to insignificantly decreasing
- IT-MW-92-39 – from significantly increasing to significantly decreasing

- IT-MW-92-38 – from insignificantly increasing to insignificantly decreasing
- IT-GMP-15 – from significantly increasing to insignificantly decreasing
- IT-GMP-16 – from significantly increasing to insignificantly increasing
- IT-PZ-9 – from significantly increasing to significantly decreasing
- IT-GMP-17 – from significantly increasing to insignificantly increasing

At all seven monitoring wells, the change in MTBE concentration trend was towards a more decreasing trend. Six of these monitoring wells (IT-MW-92-39, IT-MW-92-38, IT-GMP-15, IT-GMP-16, IT-PZ-9, and IT-GMP-17) are located within close proximity to each other on the centerline of the MTBE plume indicating the effects natural attenuation may be progressively migrating through the plume. Overall, the statistical analysis of MTBE concentration trends after initiation of the biosparging system demonstrate natural attenuation is reducing MTBE concentrations in the leading edge area of the plume, an area not directly affected by the biosparging system.

5.2 Mass Estimates

The estimated total mass of MTBE in groundwater decreased by approximately 7.3 kg from November 2006 (61.9 kg) to November 2007 (54.6 kg). In general, a definitive decreasing trend in mass has been observed throughout the MTBE plume, with some variations that are likely attributable to seasonal fluctuations and modifications to the monitoring network. Only a subset of the monitoring network has been sampled during the August and February sampling events since August 2002; therefore, dissolved MTBE mass estimates are only calculated for the May and November sampling events. Figure 12 details the trends in estimated MTBE mass, as well as the percent reduction in dissolved mass of MTBE for portions of the plume on and off Navy property since May 2002 (before the active biosparging treatment system was started).

Figure 12 conceptually illustrates how the plume is changing as a result of active biosparging treatment and natural attenuation mechanisms. The bar chart tracks the trends in total mass and also details the percentage of total mass that has been present on and off Navy property over the operational history of the biosparging treatment system. The relative amount of MTBE mass on Navy property has decreased dramatically and now represents an estimated 1% of total dissolved MTBE mass in groundwater. In addition, the line plots correspond to the percent reduction in MTBE mass for the areas of the plume on and off Navy property. MTBE mass is being reduced both on and off Navy property, though a higher reduction rate is seen on Navy property as expected due to the operation of the biosparging treatment system. These reduction trends show that natural attenuation mechanisms are likely responsible for the mass decreases off Navy property. If natural attenuation were not occurring, one would expect MTBE mass downgradient of the treatment system (i.e., off Navy property) to increase as MTBE mass migrated past the property boundary. The fact that MTBE mass is decreasing throughout the entire plume suggests that MNA may be a viable long term remedy.

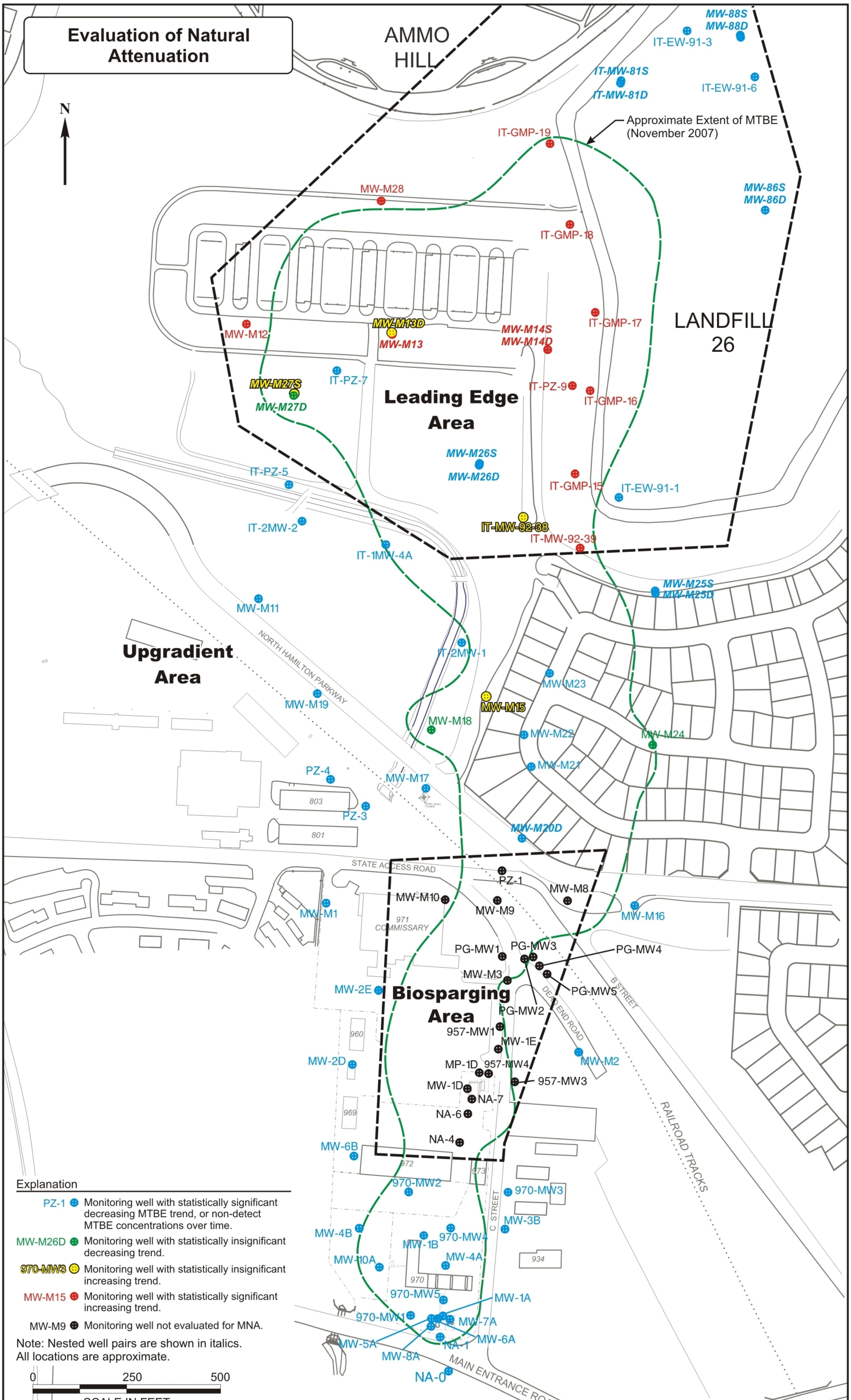

Figure 11. Subareas Evaluated for MNA

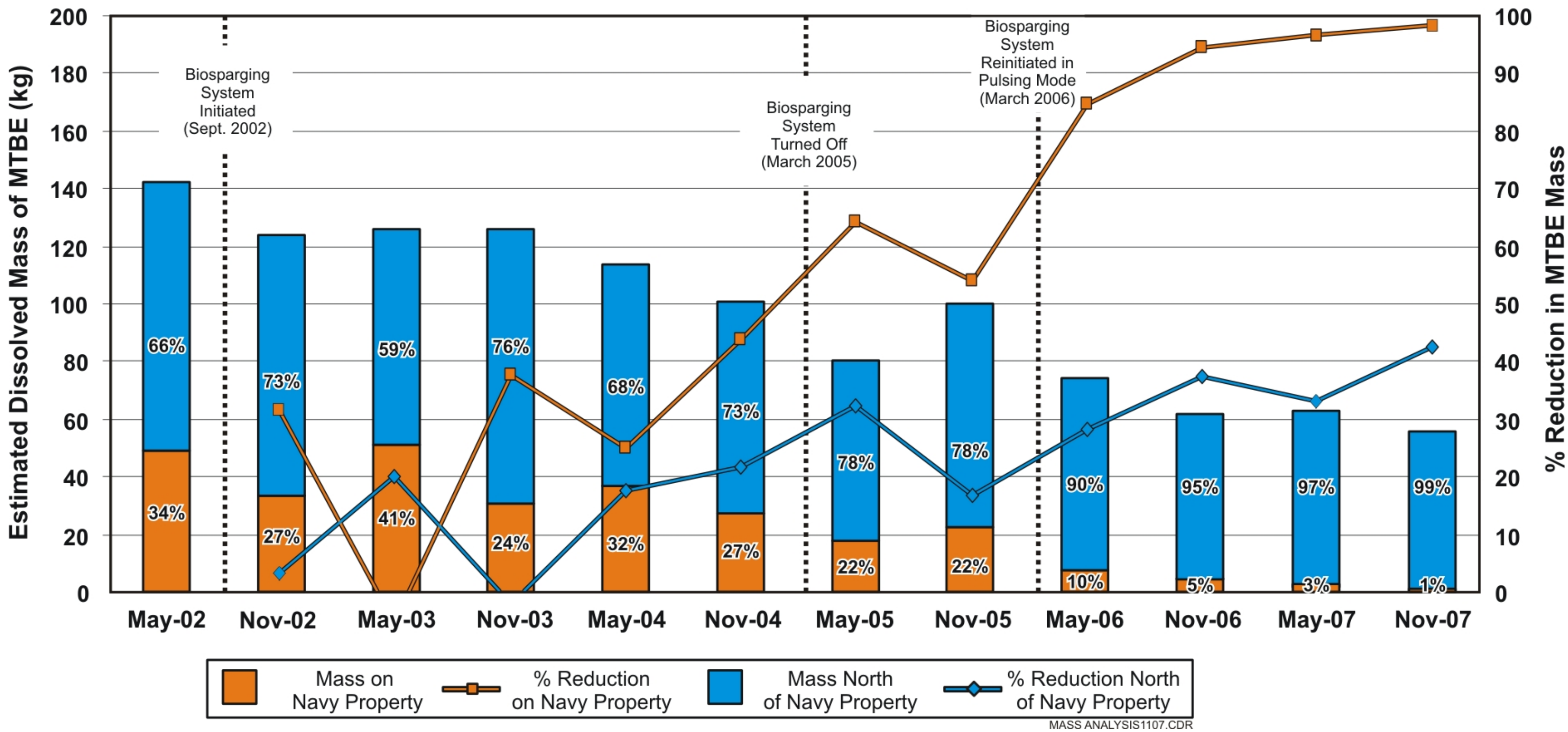

Figure 12. Change in Estimated Dissolved Mass of MTBE Over Time During the Operational Lifespan of the Biosparging Treatment System

Section 6.0: CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions based on the analytical results collected during the August and November 2007 groundwater and surface water monitoring activities, and provides recommendations based on the evaluation of the data to more effectively address the DQOs presented in the SAP (Battelle, 2007). Based on the updated DQOs contained therein, this Annual SSR specifically evaluated the effects of active treatment, the conditions at the leading edge area, and MNA throughout the MTBE plume.

6.1 Conclusions

Since initiation of the biosparging treatment system in September 2002, MTBE concentrations on Navy property decreased significantly as demonstrated by the changes in the MTBE contours (see Figure 7). The effect of biosparging in combination with past treatment of IAS/SVE and natural attenuation considerably reduced the MTBE plume on Navy property subsequently limiting additional sources of MTBE to downgradient portions of the plume over time (see Figure 8). In the performance goal monitoring wells, there was a 98% reduction in average MTBE concentrations in November 2007. Overall, these results indicate that the biosparging treatment system has achieved its primary performance goals and objectives.

In the leading edge area of the MTBE plume, the hydraulic gradient is relatively flat as groundwater migrates north across Landfill 26 (see Figure 3). The hydrogeological cross-section of Landfill 26 demonstrates that the portion of the aquifer underneath Landfill 26 has a greater water-bearing capacity than upgradient portions of the aquifer (see Figure 9). This larger water-bearing capacity underneath Landfill 26 may potentially control the plume and stabilize and/or reduce MTBE concentrations more effectively than conditions upgradient of Landfill 26, therefore confirming and supporting the updated CSM. Additionally, the landfill monitoring network is within the estimated flow path of the MTBE plume and is sufficient to ensure that the leading edge area of the plume continues to be fully delineated (see Figure 10).

To evaluate MNA throughout the MTBE plume, statistical analyses were conducted using MTBE data collected through November 2007 to quantify MTBE concentration trends at each monitoring well. Overall, there was a considerable difference between the MTBE concentration trends in the leading edge area compared to the upgradient area (see Figure 11). Forty-three percent of the monitoring wells located in the leading edge area showed a statistically significant increasing trend while no wells in the upgradient showed this trend. In contrast, 43% of the monitoring wells in leading edge area showed a statistically significant decreasing trend or non-detect concentrations, as compared to 93% of the upgradient monitoring wells.

To better evaluate natural attenuation in the leading edge area, a statistical analysis was conducted using MTBE data from September 2002, when the biosparging treatment system was initiated, through November 2007. As a result of this analysis, the MTBE concentration trend of seven monitoring wells in the leading edge area changed towards a more decreasing trend demonstrating natural attenuation is reducing MTBE concentrations in the leading edge area of the plume. A summary of the statistical analyses in the leading edge area over the two different time series are presented in Table 2.

In general, a definitive decreasing trend in mass has been observed throughout the MTBE plume. The relative amount of MTBE mass on Navy property has decreased dramatically and now represents an estimated 1% of total dissolved MTBE mass in groundwater. In addition, MTBE mass is being reduced both on and off Navy property, though a higher reduction rate is seen on Navy property as

Table 2. MTBE Concentration Trends in Leading Edge Area Monitoring Wells

Time Series MTBE Data	Significantly Decreasing	Insignificantly Decreasing	Insignificantly Increasing	Significantly Increasing
All data through November 2007	12	1	3	12
September 2002 through November 2007	14	4	3	7

expected due to the operation of the biosparging treatment system. These reduction trends indicate that natural attenuation mechanisms are likely responsible for the mass decreases off Navy property.

6.2 Recommendations

The November 2007 monitoring event constitutes the 39th groundwater sampling event performed at the Site over the past nine years. During this time, field parameters and analytical data have been collected to better understand the behavior of the MTBE plume at the Site. The following provides recommendations for optimizing the groundwater monitoring program to ensure that the updated DQOs are addressed in a cost-effective manner.

After evaluating the effects of the biosparging treatment system and MNA throughout the MTBE plume, it is no longer cost effective or technically prudent to continue to operate the biosparging treatment system to treat relatively low concentrations and such a small proportion of the dissolved MTBE mass at the Site. As stated in Section 1.3, a letter was issued by the Navy to the Water Board, formally requesting permission to shut down the biosparging system and initiate a rebound monitoring program. The Water Board subsequently requested a response plan in the event that MTBE concentrations at the leading edge of the plume do not begin to stabilize or decrease in the future. The Navy is currently developing a strategy for managing MTBE-impacted groundwater throughout the plume (and specifically at the leading edge).

Geochemical parameters (i.e., nitrate, sulfate, and iron (II)) were collected from leading edge area monitoring wells during the August and November 2007 sampling events as detailed in the SAP (Battelle, 2007). The geochemical results from these sampling events are provided in Appendix D. Geochemical parameters should continue to be collected from the leading edge area monitoring wells and additional samples should be collected from centerline wells to evaluate MNA spatially and temporally throughout the MTBE plume. The additional monitoring wells recommended for geochemical analyses are listed in Table 3. Currently, the geochemical dataset does not appear to be optimal in order to provide any substantive conclusions regarding remediation by natural attenuation processes.

All groundwater monitoring wells listed in Table 2-1 of the SAP (Battelle, 2007) were reevaluated based on the flowchart detailing the decision criteria for modifying the sampling frequency of monitoring wells in the Updated Groundwater Monitoring Plan (Battelle, 2007). The proposed modifications to the current sampling and analysis plan are detailed in Table 3.

Overall, the evidence presented in this SSR indicates MNA is a remedial option that will facilitate achievement of remedial action objectives both on and off Navy property. Although the CSM suggests that the leading edge of the MTBE plume may not migrate significantly with simply MNA, the Navy will evaluate additional remediation option for the leading edge. As stated previously, 99% of the

MTBE mass resides off Navy property therefore, accelerating natural attenuation with active remediation off Navy property, similar to that performed on Navy property, may prove to be the optimal approach to achieve remedial action objectives for the site.

Table 3. Proposed Modifications to Sampling and Analysis Plan

					Analytical Group				
Well ID	**Matrix**	**Depth[a] (ft bgs)**	**Monitoring DQO**	**Monitoring Frequency**	**BTEX, MTBE**	**DO**	**Sulfate, Iron, and Nitrate**	**TBA, TBF**	**Sampling SOP Reference or SAP Section/Comments**
970-MW4	GW	13	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
970-MW4	GW	13	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
MW-1A	GW	10.5	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
MW-1A	GW	10.5	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
MW-4A	GW	10	M, V	A	✓	✓	-	-	SAP Section 2.2.1
MW-4A	GW	10	M, V	A	✓	✓	✓	-	Update: centerline geochemical parameters
MW-M17	GW	10	M	S	✓	✓	-	-	SAP Section 2.2.1
MW-M17	GW	10	M	A	✓	✓	-	-	Update: annual sampling
MW-M20D	GW	14	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
MW-M20D	GW	14	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
MW-M21	GW	12	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
MW-M21	GW	12	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
MW-M22	GW	11.5	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
MW-M22	GW	11.5	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
MW-M23	GW	11.5	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
MW-M23	GW	11.5	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
NA-0	GW	8.5	M, V	A	✓	✓	-	✓	SAP Section 2.2.1
NA-0	GW	8.5	M, V	A	✓	✓	✓	✓	Update: centerline geochemical parameters
NA-1	GW	11.5	M, V	A	✓	✓	-	-	SAP Section 2.2.1
NA-1	GW	11.5	M, V	A	✓	✓	✓	-	Update: centerline geochemical parameters

Table 3. Annual Modifications to Sampling and Analysis Plan (Continued)

Well ID	Matrix	Depth[(a)] (ft bgs)	Monitoring DQO	Monitoring Frequency	Analytical Group: BTEX, MTBE	Analytical Group: DO	Analytical Group: Sulfate, Iron, and Nitrate	Analytical Group: TBA, TBF	Sampling SOP Reference or SAP Section/Comments
Biosparging Monitoring Wells									
957-MW1	GW	12.9	M, V	Q	✓	✓	-	✓	SAP Section 2.2.1
957-MW1	GW	12.9	M, V	Q	✓	✓	✓	✓	Update: centerline geochemical parameters
NA-6	GW	12	M, V	Q	✓	✓	-	✓	SAP Section 2.2.1
NA-6	GW	12	M, V	Q	✓	✓	✓	✓	Update: centerline geochemical parameters
PG-MW1	GW	15	M, R, V	Q	✓	✓	-	✓	SAP Section 2.2.1
PG-MW1	GW	15	M, R, V	Q	✓	✓	✓	✓	Update: centerline geochemical parameters
PZ-1	GW	12	M, V	Q	✓	✓	-	✓	SAP Section 2.2.1
PZ-1	GW	12	M, V	Q	✓	✓	✓	✓	Update: centerline geochemical parameters
Leading Edge Monitoring Wells									
IT-EW-91-1	GW	25.5	M, C	A	✓	✓	✓	-	SAP Section 2.2.1
IT-EW-91-1	GW	25.5	M, C	S	✓	✓	✓	-	Update: semi-annual sampling
MW-M26S	GW	9.5	M	Q	✓	✓	✓	-	SAP Section 2.2.1
MW-M26S	GW	9.5	M	A	✓	✓	✓	-	Update: annual sampling
MW-M27D	GW	17.5	M	Q	✓	✓	✓	-	SAP Section 2.2.1
MW-M27D	GW	17.5	M	A	✓	✓	✓	-	Update: annual sampling
MW-M27S	GW	7.5	M	Q	✓	✓	✓	-	SAP Section 2.2.1
MW-M27S	GW	7.5	M	A	✓	✓	✓	-	Update: annual sampling

A = annually BTEX = benzene, toluene, ethylbenzene, xylenes
C = confirmation of conceptual site model in the Leading Edge Area of the MTBE plume as described in Table 1-3 of Updated SAP.
DO = dissolved oxygen GW = groundwater
M = monitored natural attenuation as describe in Table 1-2 of Updated SAP.
MTBE = methyl tert butyl ether R = monitoring for residual source as described in Table 1-4 of Updated SAP.
Q = quarterly S = semi-annually
TBA = tert-butyl alcohol TBF = tert-butyl formate
V = monitoring for verification of effects of treatment system as described in Table 1-5 of Updated SAP.
(a) The pump intake for low flow purging and sampling should be positioned at or near the mid-point of the well screen (ASTM, 2002). Therefore, the values presented here are the mid-points of the well screens for each monitoring well.
Shaded cells identify proposed changes to the Updated SAP.

Section 7.0: REFERENCES

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