Remedy Optimization Team Report for the Bethpage Groundwater Plume Remedy

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EXECUTIVE SUMMARY

In order to evaluate the effectiveness of the ongoing remedy for the Bethpage plume and recommend potential future steps for optimizing the remedy, the Navy requested an optimization review of the Bethpage plume remedy by a team of independent nationally-recognized experts in chlorinated solvent impacts to groundwater. As part of the review, this Technical Team recognized that many of the tools (e.g., tracer testing or solute transport modeling) used routinely at smaller sites are subject to considerable limitations at a particularly large and complex site, such as Bethpage. Therefore, the Technical Team has used its best scientific judgment and experience to provide strategic recommendations that identify technical areas to *avoid* and technical areas to *emphasize* in future efforts. The Technical Team has not attempted to pinpoint exact locations for additional monitoring wells/vertical profile borings or determine exact locations and pumping rates of new extraction wells. Rather, the Technical Team leaves it to the project representatives to determine efficient methods that accomplish the technical objectives and guidance provided by the Technical Team members.

The Technical Team's key conclusions and recommendations are summarized as follows:

1. The general strategy of on-site source containment and off-site plume monitoring has succeeded in reducing the impacts to down-gradient public supply wells. However, the hot spot in the (Operable Unit 3) OU-3 Plume contains much higher volatile organic compound (VOC) concentrations than the rest of the off-site plume. This hot spot needs to be effectively contained to reduce future impacts to the down-gradient aquifer.
2. The hot spot in the OU-3 Plume can be contained in one of two ways:
    a. Use new extraction wells upgradient of the Bethpage public supply wells to capture a substantial portion of the hot spot. In this strategy, the VOC impacts to the Bethpage supply wells will decrease over time, but low VOC levels are expected to persist in the near future (next 20 or 30 years) due to residual contamination in the aquifer matrix.
    b. Supplement the ongoing capture in Bethpage public supply wells with new extraction wells (if required) that capture additional horizontal or vertical intervals to prevent the hot spot from migrating further down-gradient. This strategy has the potential to leverage existing infrastructure, for example, by operating the Bethpage supply wells at maximum capacity throughout the year. If this strategy is followed, then additional protective measures (such as including sufficient factors of safety in the treatment design) are necessary in the Bethpage public supply wells to ensure that impacted groundwater is treated at all times and does not leave the plant above levels that the water district considers safe.
3. The Technical Team agrees with the general assessment of the USGS's technical memorandum (Misut, 2010) and report (Misut, 2011) outlining the inadequacies of the current groundwater model for the site. The Technical Team adds that some of these modeling inadequacies can be addressed by improved modeling techniques, but some of the inadequacies are likely to remain inherent limitations of any modeling effort at this large and complex site. Capturing the variations in aquifer properties at a scale

conducive to reliable modeling predictions of plume arrival times and concentrations in public water supply wells will continue to be a challenge. However, a well-constructed and properly calibrated model is likely to be useful in addressing a number of important questions, including:

   a. Evaluation of the capture zones of public supply wells that would enable decision makers to better locate outpost (sentry) wells and manage impacts to drinking water;

   b. Validation of capture by the extraction wells in the On-Site Containment System and Interim Remedial Measure to help determine effectiveness of source containment; and

   c. Design of alternatives for capturing the OU-3 Plume hot spot to help protect down-gradient public supply wells.

4. The off-site monitoring network needs to be augmented with vertical profile borings and multi-level monitoring wells at selected locations in order to:

   a. Better quantify hydrogeologic parameters critical for improved groundwater flow modeling and particle tracking through the collection and analysis of time dependent water level or pressure transducer data;

   b. Better evaluate the on-site containment of sources by the On-Site Containment System and the Interim Remedial Measure, especially in the deeper aquifer zones;

   c. Better evaluate contributions to the plume from other non-Navy, non-Northrop Grumman Corporation sources;

   d. Better understand the overall plume's eastern and western boundaries and its leading edge; and

   e. Better monitor the plume's progress beyond its current leading edge.

5. The Technical Team recommends that an evaluation be conducted of the technical and economic feasibility of plume containment at its leading edge and of other alternatives, such as the potential future installation of treatment plants in currently un-impacted public water supply wells.

6. A comprehensive conceptual site model needs to be developed based on an integrated analysis of all available OU-2 Plume and OU-3 Plume information, kept updated, and used as a dynamic tool to guide each successive monitoring, modeling, and treatment step.

ACRONYMS AND ABBREVIATIONS

CNO	Chief of Naval Operations
DNAPL	dense non-aqueous phase liquid
NAVFAC	Naval Facilities Engineering Command
NRC	National Research Council
NWIRP	Naval Weapons Industrial Reserve Plant
NYSDEC	New York State Department of Environmental Conservation
ppb	parts per billion
ROD	Record of Decision
TCE	trichloroethene
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

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1.0 BACKGROUND

The Naval Facilities Engineering Command (NAVFAC) Headquarters and the NAVFAC Mid-Atlantic requested an independent technical optimization study of the groundwater remedy at the Former Naval Weapons Industrial Reserve Plant (NWIRP) and Former Northrop Grumman Corporation in Bethpage, New York. Groundwater at Bethpage is impacted by volatile organic compounds (VOCs), primarily trichloroethene (TCE). The impacted groundwater at this site has been commonly referred to as the Bethpage Plume. The Navy is committed to implementing a remedy that protects Long Island's drinking water supplies and continues to implement the Operable Unit 2 (OU-2) remedy in accordance with the signed Record of Decision (ROD) [1]. Northrop Grumman Corporation is managing Operable Unit 3 (OU-3). The VOC-impacted groundwater originating from OU-2 has generally been called the OU-2 Plume. The VOC-impacted groundwater originating from OU-3 has generally been called the OU-3 Plume.

Northrop Grumman Corporation has prepared a computerized model of the impacted aquifer to aid in understanding groundwater flow and plume migration. Recently, concern was voiced by United States Senator Charles E. Schumer, based on input from Massapequa Water District, questioning the accuracy of the current groundwater model and the sufficiency of this remedy for protecting groundwater supply wells. Therefore, the Southeast Nassau Water Committee requested the Navy to look further into these concerns. The Navy itself has an established policy of conducting remedy optimization evaluations. The Chief of Naval Operations (CNO) Environmental Readiness Division has established a Navy/Marine Corps policy for optimizing remedial and removal actions under the Navy Environmental Restoration Program [2]. This policy requires that at each phase of the cleanup, an evaluation of available data be done to ensure that all remedies are continually optimized. One of the tools that the Navy has used to implement this policy is the formation of a third-party independent optimization team that draws upon expertise from industry, academia, other government agencies, and the Navy. These optimization teams and their recommendations have been well received by regulatory agencies and other stakeholders in the past at several remediation sites.

In compliance with the Navy's optimization policy and in response to requests from Senator Schumer and the Southeast Nassau Water Committee, the Navy initiated an Optimization Evaluation of the Bethpage remedy and assembled a Technical Team of nationally-renowned experts in chlorinated solvent impacts to groundwater, VOC fate and transport, remediation technologies, groundwater modeling, and hydrogeology. The goal of this team is to provide an independent evaluation of the groundwater remedy at the Bethpage site and recommend potential steps to optimize the remedy's implementation. The team is charged with making recommendations to Navy leadership on how best to evaluate (a) the effectiveness of previous and ongoing treatments and (b) the effectiveness of the current well network in monitoring the progress of the plume. Appendix A lists the team members and brief descriptions of their professional experience.

A separate and more thorough evaluation of the computerized groundwater model of the VOC-impacted aquifer was concurrently conducted by the United States Geological Survey (USGS) and U.S. Environmental Protection Agency (U.S. EPA), and the results were considered during the development of this report.

The Technical Team met for a site visit and discussions from February 8-10, 2011 in Bethpage, NY. Prior to the meeting, the team members reviewed key documents including, but not limited to, the Record of Decision (ROD) for OU-2, the Remedial Investigation and draft Feasibility Study for OU-3, Quarterly and Annual Monitoring Reports, documents relating to the On-Site Containment System and hot spot treatment at well GM-38, correspondence regarding the USGS/U.S. EPA task to review Northrop Grumman Corporation's computerized groundwater model, and the USGS report [3] on its findings from the model review.

The Technical Team held weekly conference calls during January and early February 2011 to discuss initial findings and to begin development of preliminary recommendations. In these early calls, the Technical Team decided to take a holistic look at groundwater impacts from both OU-2 and OU-3 because there could be benefits to taking an integrated look at the impacts and management strategy for the composite Bethpage Plume.

The first day of the on-site February meeting was used for information sharing among all stakeholders. Therefore, in addition to the technical team members, participants also included representatives from New York State Department of Environmental Conservation (NYSDEC), U.S. EPA Region 2, Northrop Grumman Corporation and their consultants from Arcadis and EMAGIN, and NAVFAC Headquarters. In the morning, this group visited the Navy and Northrop Grumman Corporation properties, several of the water district supply wells and associated wellhead treatment systems, some of the outpost monitoring wells, the On-Site Containment System at OU-2, the Interim Remedial Measure treatment system at OU-3, and the GM-38 hot spot treatment system in the OU-3 Groundwater Plume. In the afternoon, the Technical Team presented its progress to date. Then, Northrop Grumman Corporation and its consultants presented their conceptual understanding of the plume, data from the On-Site Containment System and Interim Remedial Measure system, modeling strategy, and the OU-3 recommended remedy.

The Technical Team members met on the second and third days following the site visit to develop conclusions and discuss recommendations. Discussions focused on four main topics: 1) evaluation of the on-site remedy, 2) evaluation of the remedy for the off-site hot spot and plume, 3) evaluation of the effectiveness of the monitoring network for the off-site plume, and 4) role of groundwater models and modeling. The Technical Team convened again on a conference call on March 31, 2011 to discuss and finalize the draft report, which was sent to stakeholders including U.S. EPA, NYSDEC, Northrop Grumman Corporation, the Water Districts' representative, and NAVFAC Headquarters for review. The Technical Team reconvened on a conference call on June 9, 2011 to discuss the stakeholders' comments, review the team's responses, and finalize the report. The final report here first presents general observations on the progress of the remedy to date (Section 2.0) and general conclusions and recommendations on a future strategy for managing the Bethpage Plume (Section 3.0). Then, the report discusses the four main topics related to the remedy (Sections 4 to 7) and ends with a summary of the conclusions (Section 8). Appendices B and C provide supporting graphics and hand calculations, respectively. Appendix D contains the stakeholders' comments on the draft report and the Technical Team's responses.

2.0 GENERAL OBSERVATIONS ON PAST PROGRESS AT THE SITE

The Technical Team noted that this large and deep plume in a highly complex geologic setting has posed and will continue to pose relatively unique challenges for decision makers. Figure B-1 provides the general site layout at Bethpage such as locations of the Navy's and Northrop Grumman Corporation's former facilities as well as current remedy locations. Although the "Bethpage Plume" is often referred to as a single plume, there are multiple plumes and/or plume fingers due in part to the permeability contrasts resulting from heterogeneous geology involved (see conceptual depiction of a typical plume and plume fingers in Figure B-2). The Technical Team noted that the east-west geologic cross-section C-C' is strikingly similar to the dispersed plume concept presented in Figure B-2 (see geologic cross-sections shown in Figures B-3 to B-6). Instead of a single, contiguous plume, there are multiple widely dispersed plumes or fingers. If finer resolution (and adequate plume characterization) were possible, several more fingers might become apparent in these already dispersed plumes. Given the size and depth of the impacted aquifer, there are inherent limitations at this site in adequately delineating and managing the plume. These inherent limitations create uncertainties for any plume monitoring, modeling, or capture efforts, whether in the northern portion near source areas or in the southern portion near the leading edge. These limitations need to be taken into account in planning plume management strategies. Although there are other sites (e.g., Hill Air Force Base or Massachusetts Military Reservation) with relatively large VOC plumes, the unique combination of a deep aquifer, large plume, geologic complexities, persistent dense non-aqueous phase liquid (DNAPL), multiple sources, and proximity to public water supply wells make this site somewhat unique. As with many other sites with DNAPL, the solvent phase itself has not been observed in source areas at either OU-2 or OU-3. However, the presence of DNAPL is strongly indicated by the persistence of TCE in containment wells and by the strength of the downgradient plumes.

A National Research Council (NRC) classification of impacted groundwater sites based on difficulty of cleanup would place the Bethpage site in Category 4 [4]. Category 4 sites, which are characterized by the type of heterogeneous geologic layers and DNAPL sources present at Bethpage, are the most difficult to clean up. Of the 42 sites in this category that the NRC panel examined, none had been able to achieve cleanup goals (usually drinking water standards). A NRC panel also concluded that "typical methods used to calculate clean-up time often result in underestimates because they neglect processes that can add years, decades, or even centuries to cleanup" [5]. These challenges have since been reinforced by other researchers, the most recent being Payne et al. [6], who have described the inherent limitations of delineating heterogeneous sites and the consequent implications for monitoring, modeling, and managing groundwater plumes. The difficulties of gaining access to land, operating large drill rigs, and installing monitoring wells for recurring sampling in primarily residential areas are major challenges. The Technical Team is mindful of these challenges and acknowledges the difficulties they pose for any future strategy.

While discussing options for paths forward, the Technical Team took note of the progress that has been made in the past in managing this large Bethpage plume under complex hydrogeologic conditions.

- The Technical Team appreciated past efforts made by the Navy and Northrop Grumman Corporation to protect the public water supply systems. Useful measures taken so far include construction of the On-Site Containment System for the OU-2 Plume and the Interim Remedial Measure for the OU-3 Plume, the pump-and-treat system at GM-38, the water treatment plants installed at public supply wells, and the significant monitoring efforts (especially more recent ones) involved in delineating the plume.

- The removal of 13,000 lbs in 2009 (and 150,000 lbs cumulative since 1998) of source VOC mass from the aquifer by the OU-2 Plume On-Site Containment System is a significant achievement. Operation of this system has reduced the VOC mass loading to the down-gradient plume.
- Bethpage Water District responded and installed well-head treatment facilities at its Plants 4, 5, and 6 for the protection of public health.
- Outpost groundwater monitoring wells (warning wells or "sentry" wells) at both South Farmingdale Water District Plant 1 and Plant 3 served their purpose and provided sufficiently early warning of the approaching plume, enabling the water districts to plan for well-head treatment in advance of VOC impacts to public supply wells. This indicates that the outpost wells, although not foolproof, have succeeded in providing early warning in some cases.
- The Navy's increased reliance on gathering and using intensive field data (instead of relying solely on modeling) to direct future activities has been valuable in navigating some of the complexities of the site (see Figures B-3 to B-6). Although this empirical process could be improved, the several detailed vertical profile borings conducted in the field have helped site representatives better identify and manage the heterogeneously distributed plume.
- The time-series graphs for monitoring wells and the geologic cross-sections constructed by both Tetra Tech (Navy's contractor) and Arcadis (Northrop Grumman Corporation's contractor) are useful representations of field data and contributed greatly to the Technical Team's understanding and analysis of subsurface conditions and On-Site Containment System effectiveness.
- The recent and increasingly deeper vertical profile borings have greatly expanded the site decision-makers' understanding of the nature and depth of the Lower Magothy and Upper Raritan formations. Clay layers in the Raritan formation are now understood to be deeper than previously thought in this region.

3.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS ON A FUTURE STRATEGY

After much discussion, the Technical Team arrived at several broad conclusions and recommendations that relate to the future approach at this site. Further discussion of these general conclusions can be found in Sections 4 to 7 of the report.

1) Although the hydrogeologic system on a regional scale (Long Island footprint) is relatively well understood and has been discussed in USGS publications, the complexities on a local scale (Bethpage Plume footprint or smaller) are not well characterized, have posed a challenge in the past, and could continue to pose a challenge in the future. Even at smaller sites, heterogeneous porosity and permeability distributions that drive plume migration are difficult to understand, despite extensive characterization. These difficulties are magnified at this site with its large and deep volume of impacted aquifer and complex geology. Variable hydrologic stresses, including changes in pumping rates of the supply wells over time, exert considerable influence on groundwater flow and plume migration and add complexity to the site. Therefore, estimating the velocity and strength of groundwater flow and plume migration will continue to be a challenge at the Bethpage site.

2) Given the relative proximity of OU-2 and OU-3 and the possible intermingling of the OU-2 and OU-3 Plumes down-gradient, a more technically integrated approach among various stakeholders for managing groundwater impacts in OU-2 and OU-3 could provide many advantages at this site. Plumes from neighboring sources, such as Hooker/RUCO and American Dry Cleaners, could also possibly be mingling with the composite "Bethpage Plume" and should be taken into account in an overall strategy for the site (see Figure B-7). Some of these smaller plumes, such as the perchloroethylene plume (possibly from the American Dry Cleaners site), are apparent in geologic cross-section C-C' that slices through the composite Bethpage Plume and could have an impact on the public water supply wells. The Technical Team recommends that a comprehensive conceptual site model be described in a report for the entire site, including OU-2 and OU-3 Plumes (and any other comingling plumes), and used as a dynamic tool for future decision making. As more vertical profile borings and monitoring wells are installed, the conceptual site model should be updated periodically.

3) There is a lack of plume delineation in certain areas and this increases the challenge of developing an integrated strategy. The plume currently is not well defined along its eastern and western boundaries, especially down-gradient of the On-Site Containment System (see Figures B-8 and B-9 for shallow and deep TCE plumes). Better definition of the width of the plume immediately down-gradient of the OU-2 Plume On-Site Containment System would provide better guidance for down-gradient plume management. On the southern boundary (near the leading edge of the plume), understanding of the plume has been growing due to the recent vertical profile borings that have been drilled into much deeper zones than in the past. The Navy appears to already have planned additional vertical profile borings near the leading edge of the plume in an effort to determine additional outpost well locations for South Farmingdale Water District Plants 3 and 6.

4) The Technical Team recommends more coordination of data collection and sharing among various stakeholders to improve information exchange and decision making. For example, site-wide standard operating procedures could be developed for common items, such as monitoring well installation. A site-wide sampling and analysis plan could be developed and utilized by both Navy and Northrop Grumman Corporation to standardize sampling procedures and, perhaps, to synchronize certain site-wide monitoring events (e.g., water levels). The influent VOC analysis data collected by the water districts should be communicated to Navy and Northrop Grumman Corporation on a regular basis, as soon as it is acquired.

5) Groundwater modeling has been applied in the past at this site for a variety of purposes, including design of the On-Site Containment Systems at OU-2 and OU-3 and prediction of plume arrival times and concentrations at downgradient wells. The Technical Team notes that the modeling methods, calibration, and reporting used by site representatives could be improved, but that a relatively high degree of uncertainty will remain for many modeling predictions. The large size of the impacted aquifer makes it unlikely that the spatial variations in aquifer properties will be understood and captured in a model well enough to enable more reliable predictions of plume arrival times and concentrations in water supply wells. There is a practical limit to the number of vertical profile borings and monitoring wells that can be drilled to characterize this large, deep aquifer that underlies dense residential areas. On the other hand, there are certain applications for which modeling can be used more reliably at this site. The Technical Team recommends that a well-structured and well-calibrated model be set up and used for evaluating the capture zones of plume containment wells and water supply wells. This will enable site representatives to better evaluate the effectiveness of ongoing containment systems, better design new containment, and better determine appropriate locations for outpost wells.

Recommendations that elaborate on these general conclusions are in the following sections.

4.0 EVALUATION OF THE ON-SITE REMEDY

The On-Site Containment System for the OU-2 Plume and the Interim Remedial Measure for the OU-3 Plume consists of five and four extraction wells, respectively, and associated water treatment plants (see Figure B-1 in Appendix B). The purpose of both systems is to prevent VOC-impacted water from leaving the source zone and migrating south in the direction of groundwater flow. The remedial action objectives and accepted remedy for OU-2 are described in the OU-2 ROD. The proposed remedial action objectives and proposed remedial alternatives for OU-3 are described in the draft Feasibility Study for OU-3.

The Technical Team reviewed the available data on the performance of these containment systems and arrived at the following conclusions and recommendations.

1) Available down-gradient monitoring data show that the On-Site Containment System for the OU-2 Plume is reducing plume concentrations. The reduction in concentrations in immediately down-gradient wells (including well GM-75) indicates that upgradient sources have been considerably contained by the On-Site Containment System, particularly in the shallower portions of the aquifer. The Interim Remedial Measure for the OU-3 Plume has only been operating since 2009 (with periodic shutdowns for maintenance), so it is too early to evaluate its performance.

2) Containment of on-site sources is a critical component of the remedy. Although the Technical Team recognizes that the On-Site Containment System and Interim Remedial Measure are removing considerable VOC mass, their performance in deeper portions of the aquifer has not been established. Elevated VOC levels have been found in recent vertical profile borings/wells (VPB-126, GM-34D, and GM-34D2) in deeper aquifer zones in the off-site plume. Although the On-Site Containment System and Interim Remedial Measure extraction wells probably draw water both horizontally and vertically from the surrounding aquifer (thus extending their capture to depths deeper than their screened intervals), additional performance monitoring in deeper portions of the aquifer (immediately down-gradient of the containment systems) is required to determine whether or not the OU-3 and OU-2 Plume sources are being adequately contained. Horizontally, the extent of both the plume and its capture along its western edge of the OU-2 Plume and eastern boundary of the OU-3 Plume should be better defined to improve identification of down-gradient plume monitoring needs.

   To better evaluate on-site containment, the Technical Team recommends additional studies to better define the capture zones for the extraction wells that constitute the On-Site Containment System and the Interim Remedial Measure. These studies should involve a combination of hydrogeologic measurements (e.g., water levels or pressure transducers in surrounding wells) and groundwater flow modeling. The U.S. EPA [7] published a detailed scientific protocol titled "A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems". The Technical Team recommends that the Navy and Northrop Grumman apply the principles in this document to better understand the performance of the source containment wells. While Northrop Grumman may, in fact, be following several or all of the systematic steps to evaluate capture described in the U.S. EPA report, incomplete reporting of the comparison of water level data and modeling calculations enabled only limited peer review of their work. Capture analysis methodology and validation of modeling results with field data must be documented more thoroughly (see also Recommendations 1 and 2 in Section 7 that describes the role of modeling).

The Technical Team also recommends additional multi-level monitoring points (clustered wells or multi-level monitoring wells) immediately down-gradient of the flow divides at the On-Site Containment System and Interim Remedial Measure to better evaluate effectiveness of containment, especially in the deeper zones in the aquifer (below 500 ft below ground surface). The objective of this program would be to verify that the on-site sources have been contained laterally and at all depths in the Magothy Aquifer. The recommended starting point for locating these monitoring points are computational tools developed for the Department of Defense that are designed to answer questions concerning the distance and time of stabilization at sites where the concentrations of VOCs leaving a source area are reduced through engineered remedial action. It was noted that one potentially important VOC mass transport process called matrix diffusion (transport of VOCs trapped in less-permeable silts and clays into more-permeable soils) may delay the development of a down-gradient "clean" front for several years as VOCs that have diffused into clay and silt layers slowly bleed out. Therefore, the data from these new monitoring points should be interpreted carefully.

3) Source remediation (aggressive in-situ treatment of DNAPL sources) above and beyond the On-Site Containment System in the OU-2 source areas is not recommended. Source reduction will not be sufficient to remove the need for the On-Site Containment System in the near term (within 30 to 50 years). In addition, there is considerable uncertainty pertaining to the location of DNAPL sources at OU-2. The Technical Team noted the continuously elevated concentrations in containment wells and the technical impracticability of source investigation and remediation due to buildings and urban infrastructure. Historical experience at other similar sites indicates that in-situ source reduction is rarely successful at restoring VOC source zones to pre-release conditions (drinking water levels) [5, 8-10]. The inability to restore source zones is due to several factors, the most important of which is that an aquifer is a geologically complex (heterogeneous) matrix that (a) traps and stores VOCs (via "sorption" and "matrix diffusion"); and (b) prevents effective contact between VOCs and injected treatment chemicals or other groundwater treatment measures. Also, source reduction projects will have no effect on plume migration at the leading edge of the plume (where the plume is a result of dissolved VOCs that left the source as many as 60 to 70 years ago). Therefore, source reduction is unlikely to provide any additional benefit above that already provided by the source containment systems.

   Source reduction currently planned in the OU-3 Feasibility Study targets shallower sources in the vadose zone and the uppermost region of the saturated zone, where there is potential risk to on-site surface or near-surface activities, such as recreation or construction. For this reason, the limited source treatment planned in the Feasibility Study will provide on-site benefits and should be done. The proposed thermal treatment remedy is a technology with a reasonably good track record of success in environments with shallow impacts and limited infrastructure constraints. Historically, removal (treatment) of discrete and well-delineated VOC source mass from the subsurface has resulted in reduced VOC mass flux and mass discharge from the source zone to the groundwater plume. However, from a down-gradient plume management perspective, source reduction may not eliminate the need for the Interim Remedial Measure in the near term. As with many other sites, treating VOC levels higher than the DNAPL threshold concentrations (greater than 10,000 mg/kg in soil or 10,000 µg/L in water planned to be treated in the Feasibility Study) will still leave some source mass behind once the thermal application is complete. The assumption that DNAPL sources have been well delineated has proved optimistic at many other sites and may be especially uncertain at this relatively complex site. Any remaining source mass, therefore, will necessitate source containment in the foreseeable future (next 30 to 50 years) in OU-3 as well.

4) As discussed in other sections of the report, appropriate measures will be necessary to maintain and achieve substantial containment of both OU-2 and OU-3 sources. For example, the OU-2 Plume On-Site Containment System well RW-19 is currently recovering substantial VOC mass and is still showing an increasing trend in VOC concentrations in the groundwater that is being extracted. Alternative 3 in the OU-3 Feasibility Study [11] suggests scaling back the extraction rate of this well, in conjunction with increased capture of the plume further down-gradient (in the proposed new well RW-21). The Technical Team recommends that the pumping rate of RW-19 not be reduced in the near term (next 5 or 10 years), unless concentrations in this well drop significantly. The substantial VOC mass recovery in RW-19 is a current certainty, whereas potential tradeoffs between a lowered pumping rate in RW-19 and higher pumping rate in RW-21 currently are less clear to the Technical Team.

5.0 EVALUATION OF REMEDY FOR OFF-SITE HOT SPOT AND PLUME

This section addresses the VOC plume beyond the property boundaries. Multiple sources have contributed to this composite plume and include the OU-2 source areas, the OU-3 source areas, and other assorted sources (see Figure B-7 that shows other possible CERCLA/RCRA sources that may be contributing to the composite plume). This makes tracking the plume and evaluating the off-site remedy very challenging. Some of these challenges and possible approaches for resolving them are presented in this section.

Within the composite plume, reference is made in this report to a "hot spot", which is the portion of the OU-3 Plume down-gradient of the Interim Remedial Measure and upgradient of Bethpage Water District Plants 4, 5, and 6. This hot spot has elevated VOC levels, reaching more than 10,000 parts per billion (ppb) in some places (compared to the typical drinking water standard for such VOCs of 5 ppb).

The Technical Team's conclusions and recommendations for the hot spot and plume are described below.

1) It will not be possible to reduce concentrations throughout the existing plume to drinking water levels within a short timeframe (20 to 30 years) and prevent further impacts to public water supply wells in the region. The sheer size of the TCE plume footprint (approximately 2,350 acres based on the 5 microgram per liter concentration contour) renders complete aquifer cleanup unachievable within a reasonable timeframe, even with the benefit of unlimited economic resources. Experience at other sites shows that geologic heterogeneities, plume migration, and matrix diffusion are significant technical constraints that will likely make large-scale, rapid restoration of groundwater in the down-gradient plume to pre-plume conditions impossible (for example, see [10]). Therefore, impacts to public water supply wells are unavoidable.

2) The hot spot in the OU-3 Plume is a relatively higher-concentration portion of the off-site plume that the Technical Team believes should be prevented from moving further south, as it represents substantially higher concentrations of VOCs than in the rest of the plume. Although any off-site treatment is likely to involve significant challenges, the Technical Team recommends substantial treatment or containment of this hot spot. Reduction in VOC mass discharge by at least 90% should be a functional goal of the hot spot containment. Mass discharge is the mass (in grams per day) of VOCs moving with groundwater through a vertical cross-section of the aquifer proximally upgradient of the Bethpage Water District Plants 4, 5, and 6 and spanning the OU-3 Plume. This can be accomplished in one of two ways:

    a) Demonstrate in a detailed report that the proposed new extraction well (RW-21) or wells will substantially contain the OU-3 Plume hot spot and reduce mass discharge across a vertical cross-section spanning the width and depth of the entire OU-3 Plume at this location by at least 90%. If the current solute transport model is employed for this task, the model must first be calibrated to historical plume concentration data (see Recommendation 5 in Section 7). An alternative and recommended approach is quantifying mass discharge reduction using a well-calibrated groundwater flow model and particle tracking to demonstrate that the capture zone would extend horizontally and vertically across the portion of a well-characterized plume cross-section that represents 90% of the mass discharge through the width and depth of the OU-3 Plume. This would require adequate delineation of the hydraulic flow parameters (gradient and permeability distribution) and plume concentrations in the vicinity of the new containment well with the help of existing and (if required) new multi-level monitoring wells and the public water supply wells. The report should clearly explain how the model was set up, which field measurements were used for calibration, which field measurements were used to define the plume horizontally and vertically, and the pumping scenarios and associated target capture zones. Once this strategy is implemented, the Technical Team recommends that an adaptive process be used on a regular basis (e.g., quarterly or annually) to recalibrate the model based on new monitoring data. Annual reports should include all monitoring data collected, as well as an update on any model recalibration (and associated changes to target capture zones).

b) Demonstrate in a detailed report that the existing Bethpage Water District Wells (Plants 4, 5, and 6) or some combination of the proposed new extraction well (RW-21) or wells and Plants 4, 5, and 6 would capture at least 90% of the VOC mass discharge from a vertical cross-section proximally upgradient of the three supply wells and spanning the width and depth of the OU-3 plume at this location. As mentioned in (a) above, the report should utilize a combination of enhanced plume delineation, a well calibrated flow model, and particle tracking. All the modeling, reporting, and adaptive process recommendations in (a) apply to this approach, too. If this approach is used, the report should also describe steps that will be taken to install sufficient safeguards in Plants 4, 5, and 6 to prevent exposure of the receiving population. These safeguards should include adequate safety factors in the design of the wellhead treatment, as well as engineering controls to ensure that VOC-laden water does not leave the plants above levels that the water district considers safe. The annual report should include monthly VOC data and pumping rate information provided by Bethpage Water District. In general, through a combination of the On-Site Containment System, Interim Remedial Measure and OU-3 Plume Hot Spot containment, the Team recommends that VOC mass discharge to the down-gradient plume be substantially reduced.

3) Ways to leverage existing treatment plant infrastructure should be carefully explored. Reducing the extraction rate of On-Site Containment System well RW-19 may not be the best way to achieve desired efficiencies. The pumping rates of any new extraction wells (e.g., RW-21), GM-38, and Bethpage Water District Plants 4, 5, and 6 wells could be leveraged to obtain optimum capture of the OU-3 Plume and meet the goal of 90% reduction in mass discharge. For example, the technical merits of maintaining the pumping rate of Plants 4, 5, and 6 at summer (maximum) levels throughout the year should be evaluated, and the feasibility of this approach should be explored with the Bethpage Water District.

4) "Arrival time" hand calculations by the Technical Team provided an estimated plume velocity of 285 ft/yr (see Appendix C). This estimate is based on the first arrival of the plume in 2007 in the Aqua New York supply well (approximately 3 miles from the suspected source areas and an estimated 57 years after the original VOC releases in the

source areas). Assuming that the plume progresses with this same flow rate beyond its current leading edge, the plume could arrive in the Massapequa District wells in approximately 20 years. Assuming that uncertainties (and unknowns) in these rough calculations are of the order of a factor of 2, the plume could be approximated to arrive in Massapequa supply wells, potentially between 10 to 40 years. This calculation contains a large assumption – that the geology, hydraulic gradient, and physical stressors encountered by the plume in its future trajectory are the same (spatially and temporally) as those on the last 3 miles covered by the current plume. This assumption may not hold. Another assumption that would have to hold is that the plume bypasses capture by Aqua and South Farmingdale Water District supply wells and continues to migrate downgradient with enough strength to sustain plume expansion over the next 2 or 3 miles and reach the next major group of wells. The objective of this hand calculation is to emphasize that, given the lack of monitoring data to the south of the Aqua and South Farmingdale Water District supply, more rigorous groundwater flow and particle tracking modeling is unlikely to provide considerably more reliable estimates of arrival times and concentrations (discussed further in Recommendation 6 of Section 7). South Farmingdale Water District Plants 3 and 6 are closer to the leading edge of the plume and were not part of this calculation. Whether or not or when the plume arrives at these South Farmingdale Water District wells depends on local heterogeneities on a scale that is still being mapped.

In summary, this hand calculation indicates that there is some possibility that the plume could reach Massapequa Water District supply wells sometime between the next 10 to 40 years. This possibility was a factor in the Technical Team's Recommendation 5 in this section (evaluation of the technical and economic merits of a containment system along the leading edge of the current plume and other alternatives) and in Recommendation 4 in Section 6 (additional monitoring wells midway between the current edge of the plume and the Massapequa supply wells).

5) The Technical Team recommends an evaluation be conducted of the technical and economic feasibility of a containment and treatment system, in conjunction with existing public water supply wells, at the current leading edge of the plume to prevent further plume expansion and impacts to currently non-affected public water supply wells. The technical feasibility and cost of this containment system should be evaluated in relation to other alternatives, such as eventual installation of treatment plants in down-gradient (currently non-impacted) public water supply wells. The possibility of leveraging existing public water supply wells (e.g., Aqua New York and South Farmingdale Water District Plants 3 and 1) by operating them at full capacity year–round could be discussed with the water districts. Lower pumping rates in winter months may be one reason why the plume has evaded greater capture by the supply wells so far.

Monitored natural attenuation is a remediation approach where naturally-occurring processes are relied upon for long-term treatment of VOCs. However, there has been no focused analysis of the effectiveness of monitored natural attenuation at this site through analysis of relatively easily measured parameters, such as total organic carbon, redox conditions, and by-products generation. In general, several attenuating mechanisms are likely to impact VOC concentrations near the leading edge of the plume that may serve to limit or slow further southward progress of the plume. These attenuation mechanisms include capture by the public water supply wells, diffusion into clay lenses, biotic and abiotic degradation, dispersion, and sorption on organic carbon. At some point in the future, understanding the rate of attenuation of the VOCs in the leading edge of the plume is of interest. The progress of the plume beyond its current leading edge will be the net result of these natural attenuation processes. The Technical Team feels that additional study of natural attenuation processes at the leading edge of the plume would be beneficial at some point, but does not see it as an immediately imperative.

6.0 EVALUATION OF EFFECTIVENESS OF MONITORING NETWORK FOR OFF-SITE PLUME

The monitoring network for the off-site plumes (OU-3 and OU-2) covers an area approximately 3 miles long and 1.5 miles wide, down-gradient of the OU-2 and OU-3 sources. In this large area, the Technical Team evaluated the existing monitoring network within and near the plume boundaries, as well as the strategy for selecting outpost monitoring well locations and their screened intervals. Several conventional and innovative tools (such as geophysics, multi-level samplers, pressure transducers, etc.) were discussed for their potential applicability at this site. Although numerous monitoring wells and vertical profile borings have been installed in the last two decades within and near the boundaries of the plume, the large distances and depths involved are a challenge for effectively monitoring the progress of the plume.

The Technical Team's conclusions and recommendations are discussed below.

1) Although there are numerous monitoring points (vertical profile borings and monitoring wells) throughout the site, plume delineation is lacking along the western and eastern boundaries, especially in the northern half of the plume. Contribution to the OU-2 Plume from the Hooker/RUCO Superfund site also is not well defined. Along the southern boundary, efforts seem to be underway to improve the definition of the leading edge of the plume. The further away from the source, the more difficult plume definition becomes, as the plume fingers become more isolated and dispersed. The outpost wells have served their purposes in some cases (South Farmingdale Plants 1 and 3), but not in others (Aqua New York), where the plume appears to have bypassed Bethpage Outpost Well (BPOW) 3-1 and 3-2, before being detected in the Aqua New York supply wells. A recent vertical profile boring (VPB-126) was installed specifically for determining why the Bethpage outpost wells did not identify the approaching plume. The data from this boring indicate the presence of a plume finger below the screened intervals of the outpost wells, indicating that the outpost wells were screened at depth intervals that did not anticipate this deeper plume finger (leading to a "vertical miss"). More recently, vertical profile borings have been drilled to greater depths and future outpost wells are expected to include screened intervals at greater depths, if required. Therefore, the enhanced vertical definition of the plume is expected to result in better performance of future outpost wells. The Technical Team recommends an evaluation of cost-effective methods for incorporating multiple sampling depths in future outpost wells. Westbay Packers® or a string of passive diffusion bag samplers were discussed as possibilities that could be explored (could potentially be more cost efficient than well clusters).

2) Hydrogeologic understanding of the site should be improved through coordinated data collection and analysis that includes the public water supply wells, On-Site Containment System wells, Interim Remedial Measure wells, vertical profile borings (current and planned), and monitoring wells (current and planned). Data collection from these sources should include geologic data (boring logs), hydrologic data (any historical pump test data, hydraulic gradient data), and chemistry data (both VOCs and native geochemical parameters). In particular, the use of pressure transducers in multi-level monitoring wells located near public water supply wells should be implemented to collect time dependent water level data during periods when pumping is either increased or decreased. A

coordinated data analysis effort (discussed further in Recommendations 1 and 2 of Section 7) is required to:

a) Improve the groundwater flow model. Hydrogeologic parameters critical for improved simulation of groundwater flow (transmissivity, vertical hydraulic conductivity and aquifer storage parameters) can be quantified using time dependent water level data. These data can also be used as a means of better quantifying horizontal and vertical gradients in the impacted aquifer.

b) Analyze the capture zones of public supply wells. The capture zones of the public supply wells are an important planning and decision-making tool but are not well understood. Groundwater flow modeling can be used in conjunction with hydrogeologic data to evaluate capture zones. Because of limited water level data in the vicinity of the public water supply wells and the leading edge of the plume, the existing groundwater flow model is only a suitable starting point. Recommendation 2a and the U.S. EPA [7] scientific protocol for the evaluation of capture zones should be followed to improve capture zone analysis.

c) Appropriately locate outpost wells using the capture zone analysis performed as part of the above recommendation (6.2.b). A supply well's capture zone is an important component of determining the location of future outpost wells. Additional outpost monitoring wells should be planned for South Farmingdale Plants 6 and 4 at locations indicated by the improved hydrogeologic analysis in Item 1 and improved understanding from the planned vertical profile borings in this area. Outpost wells installed in the future should incorporate sampling of permeable zones throughout the entire vertical section of the aquifer and not just the currently VOC-impacted zones.

3) Non-Navy, non-Northrop Grumman sources of the groundwater plume are located within and near the Bethpage plume boundaries. Monitoring of any shallow or deep plumes resulting from these sources and mingling with the composite Bethpage plume is necessary, so that outpost well locations and screened intervals can be appropriately designed. An additional monitoring well on the western edge of the plume immediately down-gradient of the OU-2 Plume source zones should be considered as a means of evaluating possible VOC bypass around the OU-2 Plume On-Site Containment system and/or contribution from the Hooker/RUCO plume. A similar well on the eastern boundary should be considered to evaluate potential bypass (or additional sources) around the Interim Remedial Measure wells.

4) At least three additional multi-level monitoring wells should be installed approximately midway between Massapequa supply wells and the currently identified leading edge of the plume, to serve as an additional indicator of plume migration. The Southern State Parkway may provide potential access for such wells, which would be installed across a transverse (approximately east-west) cross-section along the potential path of the plume. These wells would supplement other efforts to monitor plume migration towards the next major series of public water supply wells (Massapequa Water District). Given the rough approximation of estimated arrival times described in Section 5 (Item #4), the halfway point between the current leading edge of the plume and the Massapequa supply wells would represent a conservative 5-year travel window.

7.0 ROLE OF MODELS AND MODELING

A Northrop Grumman Corporation managed computerized groundwater flow and solute transport model has been used at Bethpage for over a decade to predict plume trajectory, arrival times, and concentrations. Due to concerns regarding the model's ability to predict arrival time at outpost and public water supply wells, the USGS and the U.S. EPA have a parallel effort under way to review the current model used at the site. As part of this model review, USGS has prepared a technical memorandum [12] and a report [3] containing its evaluation of the groundwater model, as described in relevant site reports [11, 13]. The USGS memo and report seek to provide an assessment of factors contributing to inaccurate predictions of arrival times, including:

1) Lack of adequate calibration of the flow and solute transport models;
2) Limited representation of aquifer heterogeneity; and
3) Absence of techniques to model changes in hydrologic stress over time (the current model assumes "steady state" groundwater flow conditions).

The Technical Team agrees with this general assessment and adds that some of these inadequacies could be addressed, but some may be inherent limitations of any modeling effort at this large and complex site.

The Technical Team's conclusions and recommendations on the modeling approach at the site are described below.

1) Groundwater flow models can usually be calibrated well enough in the field to determine groundwater (and plume) flow path or trajectory. Therefore, a well-calibrated flow model (or models) combined with best practices for modeling groundwater flow will serve as a valuable tool to address the following objectives:
   a) Determining the target capture zones of On-Site Containment System and Interim Remedial Measure wells so that the effectiveness of source containment can be evaluated.
   b) Determining the target capture zone of any new extraction wells planned (e.g., RW-21 and the recently installed GM-38) so that the effectiveness of hot-spot treatment can be evaluated.
   c) Determining the target capture zones of public water supply wells so that outpost sentry wells can be appropriately located and decision makers can better anticipate potential impacts to the supply wells.
2) To achieve all items in Recommendation 1 above, additional monitoring locations and innovative monitoring strategies (multi-level wells, pressure transducers, etc.) are recommended by the Technical Team in Sections 4, 5, and 6. These would improve the calibration and validation of the groundwater flow model particularly in the vicinity of the public water supply wells. The Technical Team was unclear from the site reports reviewed as to how much of the recently collected vertical profile boring information had been incorporated into the model. Recent vertical profile borings have been drilled

deeper than in the past and the resulting geologic data would be important to use in calibrating and validating the model.

3) The current steady-state modeling approach assumes that hydraulic "stresses" are constant (e.g., a model that assumes a single annual pumping rate for public water supply wells). The variability in pumping rates at the public water supply wells to meet demand will cause changes in the direction that VOCs migrate in the groundwater in the vicinity of the pumping wells. This variability must be accounted for to reduce the current uncertainty associated with flow model interpretations (i.e., capture zone analyses).

4) Several recent publications [6, 14, and 15] have emphasized the need to have realistic expectations about what solute transport modeling can and cannot do. These experts have asserted that small-scale heterogeneities that control the rate and extent of groundwater plume migration are extremely difficult to characterize in the field at sites associated with large plumes and/or relatively heterogeneous aquifers. In other words, the average permeability and average hydraulic gradient measurements collected at most field sites do not adequately capture the small-scale flow and plume migration factors that ultimately determine plume arrival times and concentrations. This is especially true at Bethpage, where the goal in the past has been to predict the first arrival of extremely low solute concentrations (0.5 ppb of total VOC) in distant wells (up to 3 miles distant from the source).

5) Calibrating the solute transport model to historical plume concentration data would improve confidence in the modeling results associated with the OU-3 feasibility study and could be one way of evaluating mass discharge (and mass discharge reduction from any OU-3 Plume hot spot capture efforts). Modeling results were used to evaluate several strategies for the OU-3 Plume [16]. However, the OU-3 report indicates that the solute transport model was never evaluated relative to current site conditions. This is a fundamental step in any modeling investigation [17] to demonstrate the validity of the site model to simulate VOC concentrations in groundwater. As such, the Technical Team recommends an adaptive process used on an annual basis to recalibrate the model based on new monitoring data to reduce uncertainty and improve performance of the remedy. Regardless of these improvements, however, the limitations of adequately characterizing such a large and complex site may still make the predicted VOC concentrations in capture wells and downgradient public water supply wells relatively unreliable (see also, Recommendation 4 in Section 5).

6) Use of modeling to predict plume travel time and concentrations, especially beyond the leading edge of the plume (towards Massapequa wells), is not recommended. There are several reasons for this:

    a) The leading edge of the plume cannot be clearly defined in this large and complex aquifer (at a distance of 3 miles from the source, the "plume" probably is present in the form of several dispersed fingers).

    b) Data for calibrating the groundwater flow and solute models will always be limited, given the size of the plume. Particularly at this site, the scale of the desired modeling volume (several miles of a 700-ft deep aquifer) does not lend itself well to capturing the driving heterogeneities of the site and predicting the arrival of 0.5-ppb level trigger VOC concentrations. Even if the model is calibrated to the known extent of the current plume, it is unlikely that the geologic and hydrologic complexities beyond the current plume extent can be characterized and captured in a model well enough to provide an accurate prediction.

7) The use of a solute transport model for estimating cleanup times (e.g., due to pumping of RW-21 or GM-38) is not recommended, especially if the goal is to achieve extremely low target levels (0.5 ppb of total VOCs). A solute transport model is likely to provide optimistic estimates of cleanup time because: a) it does not entirely account for potential matrix diffusion effects, which become significant when VOC concentrations fall below approximately 100 ppb; and b) the factors described in Recommendation 4 above. More complex modeling approaches (such as a dual-domain modeling technique that has been recently employed at the site) might ameliorate some of the problems discussed in this section, but cleanup time and concentration predictions will still be uncertain.

8.0 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The Technical Team's key conclusions and recommendations are summarized as follows:

1. The general strategy of on-site source containment and off-site plume monitoring has succeeded in reducing the impacts to down-gradient public supply wells. However, the hot spot in the OU-3 Plume contains much higher VOC concentrations than the rest of the off-site plume. This hot spot needs to be effectively contained to reduce future impacts to the down-gradient aquifer.

2. The OU-3 Plume hot spot can be contained in one of two ways:

    a. Use new extraction wells upgradient of the Bethpage public supply wells to capture a substantial portion of the hot spot. In this strategy, the VOC impacts to the Bethpage supply wells will decrease over time, but low VOC levels are expected to persist in the near future (next 20 or 30 years) due to residual contamination in the aquifer matrix.

    b. Supplement the ongoing capture in Bethpage public supply wells with new extraction wells (if required) that capture additional horizontal or vertical intervals to prevent the hot spot from migrating further down-gradient. This strategy has the potential to leverage existing infrastructure, for example, by operating the Bethpage supply wells at maximum capacity throughout the year. If this strategy is followed, then additional protective measures (such as including sufficient factors of safety in the treatment design) are necessary in the Bethpage public supply wells to ensure that impacted groundwater is treated at all times and does not leave the plant above levels that the water district considers safe.

3. The Technical Team agrees with the general assessment of the USGS's technical memorandum [12] and report [3] outlining the inadequacies of the current groundwater model for the site. The Technical Team adds that some of these modeling inadequacies can be addressed by improved modeling techniques, but some of the inadequacies are likely to remain inherent limitations of any modeling effort at this large and complex site. Capturing the variations in aquifer properties at a scale conducive to reliable modeling predictions of plume arrival times and concentrations in public water supply wells will continue to be a challenge. However, a well-constructed and properly calibrated model is likely to be useful in addressing a number of important questions, including:

    a. Evaluation of the capture zones of public supply wells that would enable decision makers to better locate outpost (sentry) wells and manage impacts to drinking water;

    b. Validation of capture by the extraction wells in the On-Site Containment System and Interim Remedial Measure to help determine effectiveness of source containment; and

    c. Design of alternatives for capturing the OU-3 Plume hot spot to help protect down-gradient public supply wells.

4. The off-site monitoring network needs to be augmented with vertical profile borings and multi-level monitoring wells at selected locations) in order to:

a. Better quantify hydrogeologic parameters critical for improved groundwater flow modeling and particle tracking through the collection and analysis of time dependent water level or pressure transducer data;

b. Better evaluate the on-site containment of sources by the On-Site Containment System and the Interim Remedial Measure, especially in the deeper aquifer zones;

c. Better evaluate contributions to the plume from other non-Navy, non-Northrop Grumman Corporation sources;

d. Better understand the overall plume's eastern and western boundaries and its leading edge; and

e. Better monitor the plume's progress beyond its current leading edge.

5. The Technical Team recommends that an evaluation be conducted of the technical and economic feasibility of plume containment at its leading edge and of other alternatives, such as the potential future installation of treatment plants in currently un-impacted public water supply wells.

6. A comprehensive conceptual site model needs to be developed based on an integrated analysis of all available OU-2 Plume and OU-3 Plume information, kept updated, and used as a dynamic tool to guide each successive monitoring, modeling, and treatment step.

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GLOSSARY OF TERMS

Conceptual Site Model (CSM) – a characterization, basic description or diagram of the key overall dynamics of a site which provide the necessary understanding of the site as a basis for remedial strategy development; the model identifies source and release information; contaminant distribution, transport, and fate; geologic and hydrogeologic information; and receptors, pathways, and other risk-related information.

Feasibility Study (FS) – (1) the analysis of a proposal's practicality, often of proposed cleanup alternatives for a specific site. A recommendation for a cost-effective alternative is commonly included. The FS is often begun jointly with the Remedial Investigation (RI), and they are often referred to jointly as the RI/FS; (2) a small-scale investigation to determine whether a proposed research approach is likely to provide useful data.

Heterogeneous – nonuniform, consisting of dissimilar items (geologic units).

Interim Remedial Action (IRA) – a response action under CERCLA to mitigate fire and safety hazards and to prevent further migration of the contaminant(s). It may be identified and implemented at any time during the study or design phase; limited in scope and addresses only areas or media for which a final remedy will be developed by the RI/FS process; should be consistent with the final remedy for a site.

Mass discharge – the total mass of any solute conveyed by a plume at a given location per time. Mass discharge is a scalar quantity, expressed as mass/time.

Matrix Diffusion – contaminant diffusion into and out of the aquifer matrix.

Monitored Natural Attenuation (MNA) – a remedial option that monitors the naturally occurring physical, chemical, and biological processes which reduce contaminant levels to effectively protect human health and the environment and ultimately achieves remedial goals within a time frame that is reasonable compared to alternative technologies, without human intervention.

Perchloroethylene (PCE) – chlorinated solvent used for a variety of operations such as degreasing, maintenance, and dry cleaning.

Record of Decision (ROD) – an official U.S. EPA final remedial action plan for a site or operable unit that records the decisions and rationales for selecting specific remediation processes for a contaminated site(s). An ROD summarizes the problems posed by the conditions at a site, the alternative remedies considered for addressing those problems, the comparative analysis of those alternatives against nine evaluation criteria, and the selected remedy and rationale for selection.

Sampling and Analysis Plan (SAP) – a document that combines a field sampling plan and a quality assurance protection plan.

Solute Transport Model – a numerical model which simulates contaminant fate and transport.

Sorption – (1) the process whereby dissolved contaminants partition to the solid matrix (i.e., soil, rock) in contact with the groundwater, resulting in the slowing (retardation) of the contaminant movement relative to the rate of groundwater flow; (2) a general term used to encompass the processes of adsorption, absorption, desorption, ion exchange, ion exclusion, ion retardation, chemisorption, and dialysis; (3) the slowing or attenuation of a moving contaminant plume due to sorption onto soil solids.

Steady State Groundwater Flow Model – a numerical model which solves the governing groundwater flow equation using site specific boundary conditions and framework geometry. A steady state groundwater model is used to analyze sites where the flow field is independent of time.

Transient Groundwater Flow Model – a numerical model which solves the governing groundwater flow equation using site specific boundary conditions and framework geometry. A transient groundwater model is used to analyze time-dependent situations.

Trichloroethene (TCE) – chlorinated solvent used for a variety of operations such as degreasing, maintenance, and dry cleaning.

Volatile Organic Compound (VOC) – an organic compound that is best identified and quantified by using U.S. EPA SW-846 Method 8260B.

Appendix A

TECHNICAL TEAM MEMBER BIOSKETCHES

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EDUCATION
BS, Chemical Engineering, 1984
MS, Environmental Science/Technology, 1986

RELEVANT PROFESSIONAL EXPERIENCE

25 years of experience in soil and groundwater remediation with particular expertise in DNAPL and chlorinated solvent plumes, an area in which Mr. Gavaskar has led several large cleanup and innovative technology demonstration projects, authored several publications, and served on expert panels at high-profile sites, such as Hill Air Force Base, Kelly Air Force Base, and former Naval Air Station Brunswick

2008 – Current. Head, Technology Sciences Branch, Environmental Restoration Department, Naval Facilities Engineering Command Atlantic, Norfolk, VA

- Supervise technical support to Navy's field engineering commands in continental U.S.
- Provided technical and regulatory expertise at over 60 CERCLA and RCRA sites across the country on issues, with particular expertise in DNAPL/chlorinated solvent contamination
- Member of Interstate Technologies Regulatory Commission's (ITRC) Permeable Barriers Workgroup. Authored section on longevity of permeable barriers in ITRC's 2011 guidance.

1985-2008. Associate Manager, Environmental Restoration Product Line, Battelle, Columbus, OH.

- Supervised a staff of 30 engineers, geologists, and chemists involved in environmental restoration support to the US EPA, Army, Navy, Air Force, NASA, DOE, and private industries.
- Project manager for several large soil, groundwater, and sediment remediation projects at sites, such as NWS Seal Beach, Cape Canaveral Air Station, and Dover Air Force Base.
- Chaired the International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA) in 2000, 2002, and 2004.

AWARDS

- NAVFAC Atlantic's Employee of the Year 2010 award at the ER Conference, Oxnard, CA.
- NASA's Honor Award 2003 for Groundwater Treatment Technology Development.
- US EPA's STAR Award, 1996 for the antifreeze recovery technology development project.

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Phone: 805-982-2636, E-mail: karla.harre@navy.mil

EDUCATION

B.E., Vanderbilt University, Civil and Environmental Engineering, 1992

M.B.A., Graziadio School of Business and Management, Pepperdine University, 2001

RELEVANT PROFESSIONAL EXPERIENCE

2010 - Current. Head, Environmental Restoration Technology Applications Branch, Naval Facilities Engineering Service Center (NAVFAC ESC), Port Hueneme, CA

- Oversee ten engineers, geologists, and biologists to provide assistance to remedial project managers across NAVFAC with technical challenges, disseminate information on innovative technologies, and optimize planned and existing remedies.
- Principle Investigator for an ESTCP project on Quantifying Life Cycle Environmental Footprints of Soil and Groundwater Remedies.
- Member of the Federal Remediation Technologies Roundtable.

2003-2010. Team Lead, Environmental Restoration Technology Transfer, NAVFAC ESC

- Facilitated clean-up review teams and conducted optimization evaluations for over 15 sites.
- Developed NAVFAC's strategic plan to overcome barriers to the use innovative environmental remediation technologies.
- Led the NAVFAC Optimization Workgroup and Alternative Restoration Technology Team (ARTT). These teams are responsible for developing guidance, tools, and case studies on optimizing remedial actions and innovative technologies.
- Principal Investigator for two ESTCP projects. One project to demonstrate software for improving effectiveness of long term monitoring programs. The other project to assess the benefits of using computer algorithms for optimizing groundwater flow and transport models.
- Active team member with the Interstate Regulatory Technology Council (ITRC) Remedial Process Optimization (RPO) and Remedial Risk Management (RRM) teams.

2001-2003. Team Lead, Environmental Acquisitions, NAVFAC ESC. Led a 5-member team in contracting for $10M per year in environmental services for the Environmental Restoration Division.

1994-2001. Environmental Engineer, NAVFAC ESC. Coordinated pilot demonstrations and technical evaluations of innovative environmental technologies. Resolved concerns of community members, Navy project managers, and federal and state regulators.

SELECT CONFERENCE PAPERS / PRESENTATIONS

Harre, K. and Chaudhry, T. Optimizing Remedial Action Operations and Long Term Management Programs, *Navy CECOS Course on Optimizing Remedy Selection and Site Closeout, 2003 – Present.*

Harre, K. et al. Adaptive Long-Term Monitoring at Environmental Restoration Sites - LTM Optimization Workshop, *Partners In Environmental Technology Technical Symposium and Workshop, December 2009.*

Greenwald, R., Y. Zhang, K. Harre, L. Yeh, K. Yager, D. Becker, B. Minsker, C. Zheng, and R. Peralta. Results of Transport Optimization Demonstration Project for Three DoD Sites. *2003 MODFLOW and More: Understanding through Modeling, Golden, Colorado, September 2003.*

RICHARD W. HUMANN, P.E., V.P.

EDUCATION

- B.S., Mechanical Engineering, New York Institute of Technology, 1991
- Certificate in Technical Writing, New York Institute of Technology
- Trained in Dynflow, Dyntrack and Dynplot groundwater modeling software, 2002

RELEVANT PROFESSIONAL EXPERIENCE

- Chief Water Resources Engineer for H2M (employed for 23 years) and responsible for managing the water resources division. Client manager for several of H2M's water supply clients, including the Bethpage Water District. Duties include water system and aquifer evaluation, planning and studies, design of source supply and treatment systems, and assessment of groundwater quality for drinking water.

- Extensive experience in hydrogeology, groundwater and aquifer assessments, water quality and regulatory requirements including:

  - VOC Removal Systems: Treatment system designs for public water supplies of Bethpage, Dix Hills, Garden City, Garden City Park, Greenlawn, Hicksville, Plainview, South Farmingdale, South Huntington and West Hempstead. Responsibilities included groundwater and aquifer contamination assessments, review of available remedial engineering studies, reports, and plans, engineering report preparation, treatment system design, and regulatory permits.

  - Groundwater Modeling: Managed several groundwater modeling projects, including evaluation of new well locations and evaluation of groundwater contamination plumes impacting public supply wells in Bethpage, Garden City, Hicksville, Manhasset-Lakeville, Plainview and South Farmingdale.

PROFESSIONAL ASSOCATIONS and CERTIFICATIONS

- Licensed Professional Engineer: New York (1998), New Jersey (2000)
- American Consulting Engineers Counsel, National Society of Professional Engineers
- American Society of Civil Engineers, American Society of Heating, Refrigeration and Air Conditioning Engineers
- American Society of Mechanical Engineers
- American Water Works Association (AWWA), New York Section Program Committee Member
- Long Island Water Conference, Drinking Water Standards and Comprehensive Planning Committee Member
- National Groundwater Association

AUTHORED PRESENTATIONS

- "Dealing with Groundwater Plumes – What to Know", presented to the Edwin C. Tifft, Jr. Water Supply Symposium, New York State Section AWWA, November 2008
- "Water Treatment System O&M – Lessons Learned", presented to the New York State Section AWWA, April 2008
- "Pilot Program for Nitrate Treatment Technology", presented to the New York State Section AWWA April 2007
- "Water Supplies Collaborate to Investigate Perchlorate Treatment", presented to the New York State Section AWWA, April 2006
- "Approaches for Treatment of MTBE Groundwater Contamination", presented to the New York State Section AWWA, April 2004
- "UV Disinfection of Groundwater Supplies", presented to the Long Island Water Conference, December 2002
- "Optimizing Treatment Efficiencies of VOC Treatment Systems", presented to the New York State Section AWWA, October 2001

EXPERT TESTIMONY

- Index No. 9975/01 – Supreme Court – State of New York, Plainview Water District, Plaintiff vs. Exxon Mobil Corporation, f/k/a Exxon Corporation,…, Defendants – 2007
- Case No. 07-cv-5244 – United States District Court – Eastern District of New York, Inc. Village of Garden City, Plaintiff vs. Genesco, Inc., and Gordon-Atlantic Corp., Defendants – USEPA Superfund Site 150 Fulton Avenue, Garden City Park,

Paul Misut
U. S. Geological Survey
2045 Rt. 112
Coram, NY 11727
Phone: 631 736 0783
E-mail: pemisut@usgs.gov

EDUCATION

B.S., Cornell University, Philosophy and Mathematics, 1988
M.S., SUNY Stony Brook, Earth and Space Sciences, 1991
M.E., Cooper Union, Civil Engineering, 1995

RELEVANT PROFESSIONAL EXPERIENCE

DATES: From: 02/2008 To:present
PROJECT TITLE: Estimation of Hydraulic Properties at Well Fields, Suffolk County, N.Y.
BACKGROUND: Suffolk County Water Authority supplies ground water to over 1 million people on Long Island. Improved understanding aquifer hydraulics near wellfields benefits supply management.
RESULTS: A scientifc investigations report documented one of the aquifer tests conducted during this study; other tests were placed in an aquifer test archive. This project is described further at http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-BEE00.html

DATES: From: 10/2009 To:10/2010
PROJECT TITLE: Evaluation of Manufactured Gas Plants, Suffolk County, N.Y.
BACKGROUND: A massive manufactured gas plant in Bayshore, New York was being remediated with oxygen injection. The local department of health voiced concerns about the saftey of these operations.
RESULTS: For the first time in North America, OxyPAHs were established in groundwater samples. The USGS toxic substances hydrology program provided funding to present these results at a national conference. This project is described further at http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-BEE00.html

DATES: From: 02/2001 To: present
PROJECT TITLE: Simulation of Ground-Water Flow and Chemistry to Evaluate Water-Management Alternatives in Kings and Queens Counties, New York
BACKGROUND: New York City experiences exceptional problems of water supply to its 8 million people, most living on islands. Water is mainly sourced from upstate reservoirs; however, novel approaches to integration with groundwater resources are treated in this project with complex research methods. Methods included application of coupled geochemical/ solute transport modeling to evaluate feasibility of storage and recovery in a previously-unexplored deep aquifer. Deep cores were obtained and subject to mineralogical and and microbiological analysis.
RESULTS: Highly controversial and novel results were nationally publicized in *The New York Times.* This project is described further at http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-A3K-2.html

DATES: From: 02/2009 To:10/2011
PROJECT TITLE: Simulation of saltwater intrusion, Manhasset Neck, Nassau County, N.Y.
BACKGROUND: The Manhasset Neck Peninsula has experienced intrusion of salt water. New modeling techniques were applied to predict future salt water intrusion.
RESULTS: Acceptable saltwater intrusion predictions were generated for a highly complex site which was previously unyielding.This project is described further at http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-BEE00.html

SELECT CONFERENCE PAPERS / PRESENTATIONS

Misut, P.E., 2011, Simulation of groundwater flow in a Volatile Organic Compound-contaminated area near Bethpage, Nassau County, New York-A discussion of modeling considerations: U.S. Geological Survey Open-File Report 2011-1128

Misut, P.E., and Busciolano, R., 2010, Hydraulic Properties of the Magothy and Upper Glacial Aquifers at Centereach, Suffolk County, New York, USGS SIR 2009-5190, 22p.

Yager, R.M., Misut, P.E., Langevin, C.D., and Parkhurst, D.L., 2009, Brine migration from a flooded salt mine in the Genesee Valley, Livingston County, New York: Geochemical modeling and simulation of variable-density flow: U.S. Geological Survey Professional Paper 1767, 59 p.

Misut, P.E. and Voss, C.I., 2007, Freshwater-saltwater transition zone movement during aquifer storage and recovery cycles in Brooklyn and Queens, New York City, USA: Journal of Hydrology.

Misut, P.E., and Feldman, S., 1995, Simulation of sources of water to wells in central Suffolk County, N.Y., USGS OFR 95-703.

Misut, P.E., and Brown, C.J., 1996, Solute transport along ground-water flowpaths near the Nassau/Suffolk County border, Long Island, New York, in “Hydrology and Hydrogeology of Urban and Urbanizing Areas, AIH.

Charles J. Newell, Ph.D., P.E., BCEE

GSI Environmental Inc.

2211 Norfolk, Suite 1000, Houston, TX 77098; Phone: (713) 522-6300; Fax: (713) 522-8010; Email: cjnewell@gsi-net.com

Education

Ph.D., Environmental Engineering, Rice University, Houston, Texas, 1989.

M.S., Environmental Engineering, Rice University, Houston, Texas, 1981.

B.S., Chemical Engineering, Rice University, Houston, Texas, 1978.

Professional Background

Vice President - Environmental Engineer, GSI Environmental Inc., Houston, Texas. 1989 – present.

Adjunct Professor of Environmental Science and Engineering, Rice University. 1993 – present.

Office Manager-Project Engineer, F. X. Browne Associates, Kansas City. 1980 – 1984.

Selected Professional Affiliations / Awards

American Academy of Environmental Engineers.

Certified Ground Water Professional, Association of Ground Water Scientists and Engineers.

2001 Wesley W. Horner Award, American Society of Civil Engineers (awarded for paper in ASCE journal).

Hanson Excellence of Presentation Award, American Association of Petroleum Geologists, 1996

Outstanding Presentation Award, American Institute of Chemical Engineers, June 1994, Denver, Colorado.

2008 Outstanding Engineering Alumni Award, Rice University.

Areas of Expertise

Site characterization, groundwater modeling, groundwater vulnerability, surface water impacts, non-aqueous phase liquids, risk assessment, natural attenuation, remediation performance, bioremediation, matrix diffusion, non-point source studies, environmental software development, environmental decision making, and long-term monitoring optimization.

Selected Publications

Bedient, P. B., H.S. Rifai, C.J. Newell, 1999. Groundwater Contamination: Transport and Remediation, 2nd Edition, Prentice-Hall, 1999.

McGuire, T.M., J.M. McDade, and C.J. Newell, 2006. "Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent-Impact Sites", Ground Water Monitoring and Remediation, Vol 26, No. 1, pg 73-84.

Newell, C.J., and R.R. Ross, 1992. *Estimating Potential for Occurrence of DNAPL at Superfund Sites*, U.S. Environmental Protection Agency, R.S. Kerr Environmental Research Laboratory, January 1992.

Newell, C.J., H.S. Rifai, J.T. Wilson, J.A. Connor, and J.J. Aziz, M.P. Suarez, 2002. *Calculation and Use of First-Order Rate Constants For Monitored Natural Attenuation Studies*, U.S. EPA Remedial Technology Fact Sheet, U.S. Environmental Protection Agency. EPA/540/S-02/500, Nov. 2002.

Newell, C.J. and C.E. Aziz, 2004. "Long-Term Sustainability of Reductive Dechlorination Reactions at Chlorinated Solvents Sites", Biodegradation, 15: 387-394, 2003.

U.S. Environmental Protection Agency; 2003. *The DNAPL Remediation Challenge: Is There a Case for Source Depletion?* National Risk Mgt. Research Laboratory, Ada, OK, EPA/600/R-03/143, Dec. 2003.

Wiedemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.W., 1999. Natural Attenuation of Fuels and Chlorinated Solvents, John Wiley & Sons, New York

Other Information

Selected by Federal Judge (Judge Marcia Crone, U.S. District Court for Eastern District of Texas) as the Court's independent expert for groundwater litigation matter (Lyondell Chemical Co. v. Occidental Chemical Corp).

Principal Investigator or Co-Principal Investigator for 45 research/development/tech transfer projects for Dept. of Energy, Dept. of Defense, U.S. EPA, and others. Cumulative funding: $12 million.

Project coordinator for two multi-party projects: Galveston Bay Estuary Program Mgt. Plan & Los Angles LNAPL Workgroup.

Author/co-author of 15 peer-reviewed articles, 9 environmental software tools, 2 patents, 5 US EPA publications, and 2 books.

Heather Veith Rectanus, Ph.D.
Principal Research Scientist
Battelle

Education

Ph.D. Civil Engineering, Geoenvironmental Emphasis, Virginia Tech, October 2006
Co-Advisors: John T. Novak and Mark A. Widdowson
M.S. Civil Engineering, Geoenvironmental Track, Virginia Tech, Dec 2000
Co-Advisors: John T. Novak and Mark A. Widdowson
B.S. Nuclear Engineering and **B.A. German,** Kansas State University, May 1998

Professional Experience and Qualifications

Ten (10) years experience in environmental research and development projects for government and industrial clients specializing in bioremediation and monitored natural attenuation remedial strategies at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Underground Storage Tank (UST) hazardous waste sites.

Co-chair for the Tenth International In Situ and On-Site Bioremediation Symposium (May 2009).

Remediation Innovative Technology Seminars (RITS)

- Manages task orders (TO) for outreach support and development of Environmental Restoration technology transfer efforts in concert with NAVFAC ESC. Task orders exceed $1.8M across three sets of seminar series.

Clean Up Review Teams (CURTs)

- Managed CURT for MCAS Cherry Point OU1 Chlorinated Solvent Plume to identify additional site characterization data and evaluate technologies for addressing a chlorinated solvent groundwater plume over a mile long.
- Managed CURT for the evaluation of treatment options to address 1,4-dioxane in the 100 ppb range as well as volatile organic compounds in the Eastern Groundwater Plume at Naval Air Station Brunswick, Maine.

Sustainability of reductive dechlorination at chlorinated solvent contaminated sites: Methods to evaluate biodegradable natural organic carbon

- Developed and validated a method to estimate the potentially bioavailable organic carbon in sediments as Ph.D. Research Assistant at Virginia Tech under ER-1349
- Developed and maintained anaerobic consortium for bioaugmentation of laboratory scale microcosms to monitor organic carbon utilization and reductive dechlorination

Fellowships

Graduate Assistance in Areas of National Need (GAANN) Fellowship for Biogeochemistry, 2002-2004
National Science Foundation Fellowship, 1998-2001

Selected Presentations and Publications

Rectanus, H.V., C.A. Kelly, M.A. Widdowson, J.T. Novak and F.H. Chapelle. “Evaluation of potentially bioavailable organic carbon at a chloroethene-contaminated site.” Remediation of Chlorinated and Recalcitrant Compounds, May 19-22, 2008, Monterey, CA.

Rectanus, H.V., Widdowson, M.W., Chapelle, F.H., Kelley, C.A., and J.T. Novak. 2007. Investigation of Reductive Dechlorination Supported by Natural Organic Carbon. Groundwater Monitoring and Review. 27: 53-62.

H.V. Rectanus, C.A. Kelly, M.A. Widdowson, J.T. Novak and F.H. Chapelle. “Application of Potentially Bioavailable Organic Carbon at Active Reductive Dechlorination Sites” Oral presentation, Ninth International In Situ and On-Site Bioremediation, May 2007, Baltimore, MD.

H.V. Rectanus, M.A. Widdowson, J.T. Novak and F.H. Chapelle. “Method Development for Quantifying Bioavailable Organic Carbon in Aquifer Sediments.” Poster presentation, Eighth International In Situ and On-Site Bioremediation, June 2005, Baltimore, MD.

M.A. Widdowson, F. H. Chapelle, **H.V. Rectanus**, and J.S. Brauner. “Relationship Between NAPL Mass and Remediation Time Using Monitored Natural Attenuation.” First International Congress on Petroleum Contaminated Soils, Sediments & Water, August 2001, London, England.

Mark A. Widdowson

EDUCATION

Ph.D., Civil Engineering, Auburn University, 1987.
MS, Water Resources Engineering, University of Kansas, 1984.
BSCE, Civil Engineering, University of Cincinnati, 1982.

PROFESSIONAL EXPERIENCE

The Charles E. Via, Jr. Department of Civil & Environmental Engineering, Virginia Tech

- Professor of Civil Engineering, Virginia Tech, 2004 - present
- Assistant Department Head, , 2009 - present
- Coordinator, Environmental & Water Resources Engineering Graduate Program, 2004 - 2008
- Associate Professor of Civil Engineering (with tenure), Virginia Tech, 1993 – 2004

Professional Engineer Registration, #14257, South Carolina, 1991.
Assistant Professor, Department of Civil Engineering, University of South Carolina, 1988-92.
Post-Doctoral Fellow/Instructor, Department of Civil Engineering, Auburn University, 1988.

PROFESSIONAL ACTIVITIES, HONORS AND NOTABLE RECOGNITIONS

American Society of Civil Engineers; National Ground Water Association
Samuel Arnold Greeley Award, ASCE, 2011
College of Engineering Teaching Award, Virginia Tech, 2011
Outstanding Civil Engineering Faculty, ASCE Student Chapter, 1996
Graduate Summer Fellowship, University of Kansas, 1983

PATENTS AND SOFTWARE PUBLISHED

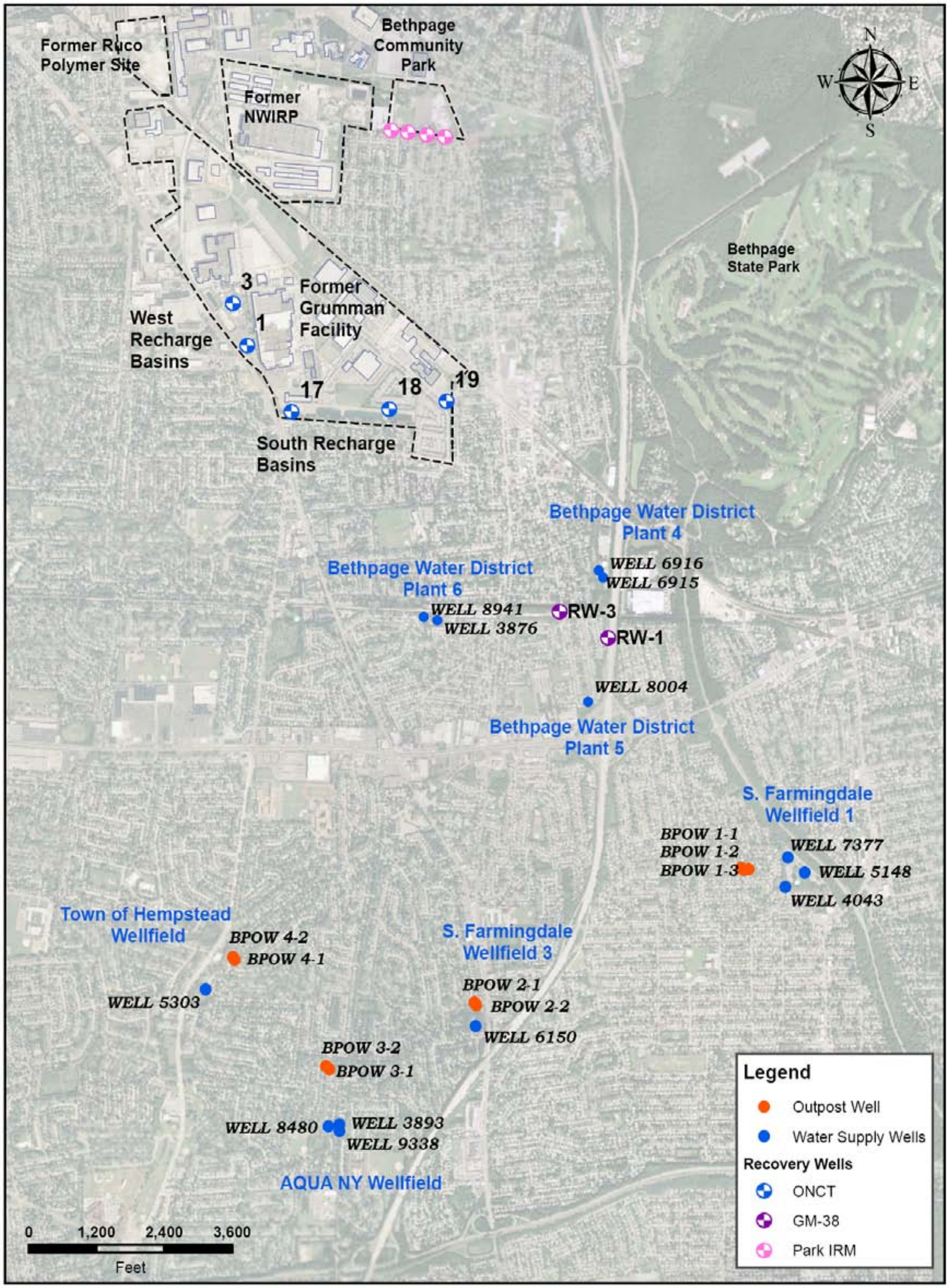
NAS: Natural Attenuation Software, 2002.
SEAM3D: Sequential Electron Acceptor Model for 3D Transport, 2000.
U.S. Patent No. 5,293,931, "Modular Multi-Level Sampling Device", 1994.

SELECTED PUBLICATIONS

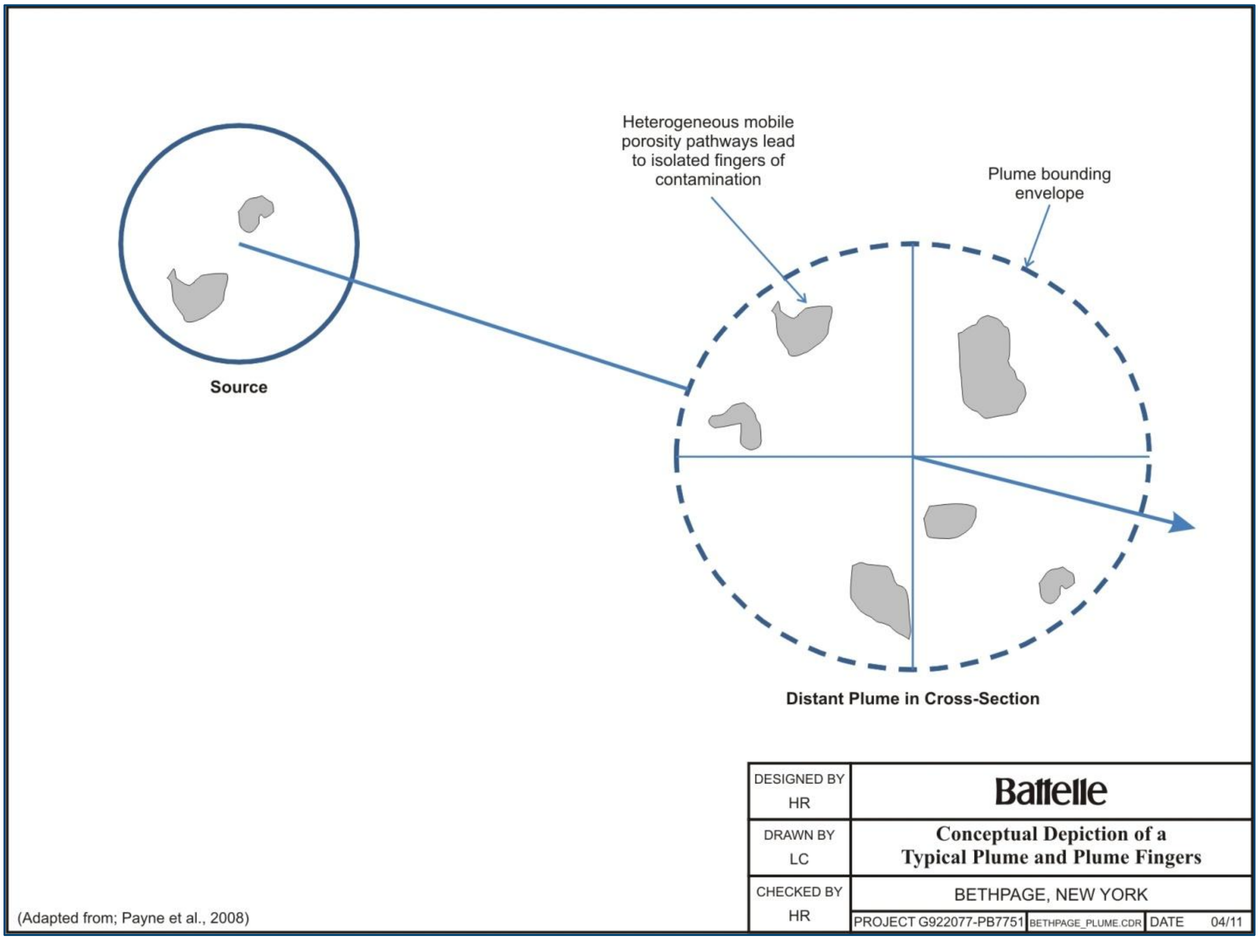
1. Parker, J.C, Kim, U., Widdowson, M., Kitanidis, P., and Gentry, R. "Effects of model formulation and calibration data on uncertainty in predictions of DNAPL source dissolution rate", *Water Resources Research,* in press.
2. Chaplin, B.P., Schnobrich, M.R., Widdowson, M.A., Semmens, M.J., and Novak, P.J. "Stimulating in situ hydrogenotrophic denitrification with membrane-delivered hydrogen under passive and pumped groundwater conditions", *ASCE Journal of Environmental Engineering* 135(8), 666-676, 2009.
3. Rectanus, H.V., M. Widdowson, F. Chapelle, C. Kelly, and J. Novak. "Investigation of reductive dechlorination supported by natural organic carbon", *Ground Water Monitoring and Remediation*, 27(4), 53-62, 2007.
4. Chapelle, F.H., J.T. Novak, J.C. Parker, B.B. Campbell and M.A. Widdowson. "A framework for assessing the sustainability of monitored natural attenuation", accepted for publication by the U.S. Geological Survey Circular Series, C-1303, 2007.
5. Widdowson, M.A., S. Shearer, R. Andersen, J.T. Novak. "Remediation of polycyclic aromatic hydrocarbon compounds in groundwater using poplar trees", *Environmental Science and Technology*, 39(6), 1598-1605, 2004.
6. Widdowson, M.A. "Modeling natural attenuation of chlorinated ethenes under spatially-varying redox conditions". *Biodegradation*, 15, 435-451, 2004.
7. Waddill, D.W. and M.A. Widdowson. "A three-dimensional model for subsurface transport and biodegradation", *ASCE J. of Environmental Engineering*, 124(4), 336-344, 1998.

Appendix B

FIGURES



General site layout at Bethpage such as locations of the Navy's and Northrop Grumman Corporation's former facilities as well as current remedy locations (Source: Northrop Grumman Optimization Presentation, February 8, 2010).



Conceptual Depiction of a Typical Plume and Plume Fingers
(Adapted from Payne et al. 2008)

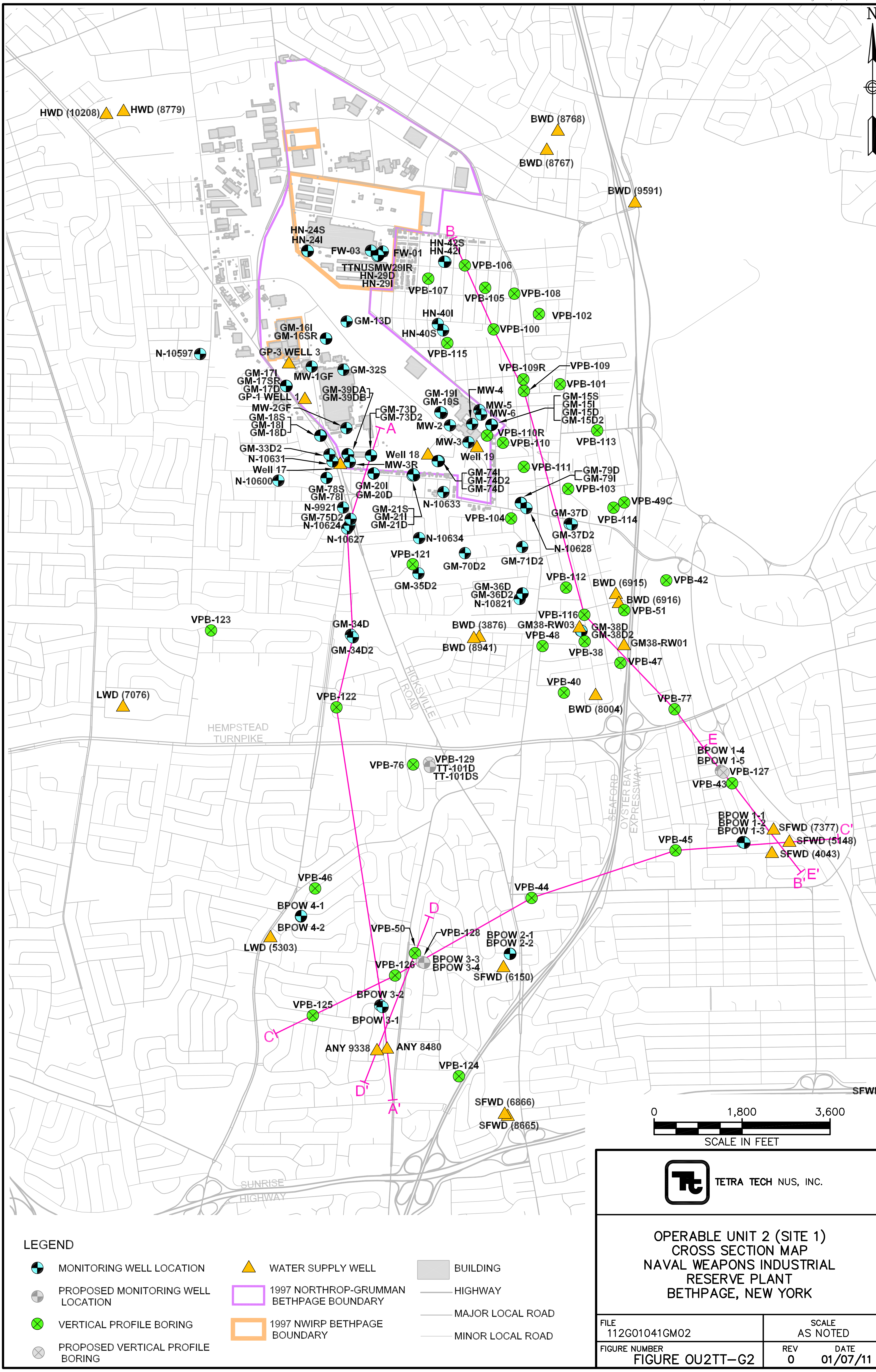
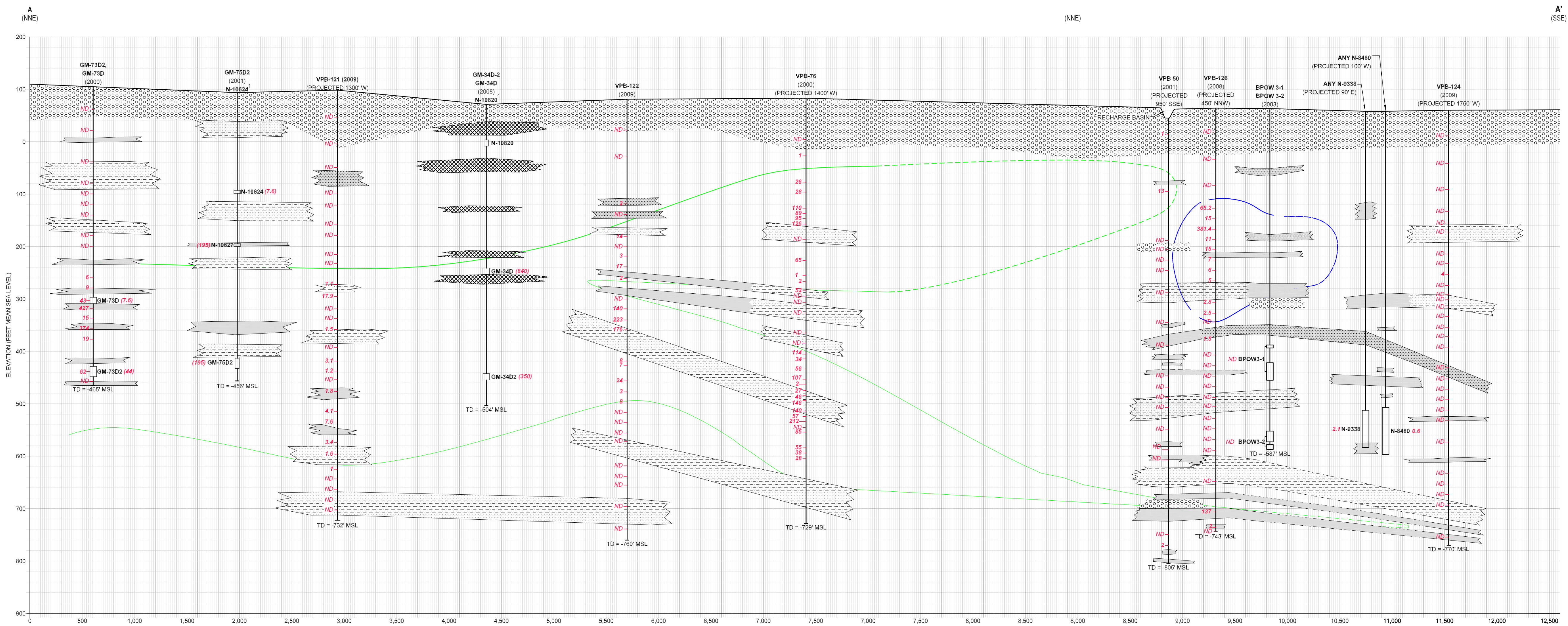
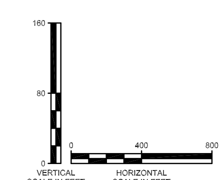

N
HWD (10208)
HWD (8779)
BWD (8768)
BWD (8767)
BWD (9591)
HN-24S
HN-24I
FW-03
FW-01
HN-42S
HN-42I
VPB-106
TTNUSMW29IR
HN-29D
HN-29I
VPB-107
VPB-105
VPB-108
VPB-102
HN-40I
HN-40S
GM-13D
VPB-100
VPB-115
GM-16I
GM-16SR
N-10597
GP-3 WELL 3
GM-32S
MW-1GF
GM-17I
GM-17SR
GM-17D
GP-1 WELL 1
GM-39DA
GM-39DB
VPB-109R
VPB-109
VPB-101
MW-4
GM-19I
GM-19S
MW-5
MW-6
GM-15S
GM-15I
GM-15D
GM-15D2
MW-2GF
GM-18S
GM-18I
GM-18D
GM-73D
GM-73D2
MW-2
VPB-110R
VPB-110
VPB-113
A
MW-3
Well 19
GM-33D2
N-10631
Well 17
N-10600
Well 18
MW-3R
VPB-111
GM-79D
GM-79I
GM-74I
GM-74D2
GM-74D
VPB-103
GM-78S
GM-78I
GM-20I
GM-20D
N-10633
VPB-49C
N-9921
GM-75D2
N-10624
GM-21S
GM-21I
GM-21D
VPB-104
GM-37D
VPB-114
N-10627
N-10634
GM-37D2
N-10628
VPB-121
GM-70D2
GM-71D2
GM-35D2
VPB-112
BWD (6915)
VPB-42
GM-36D
GM-36D2
N-10821
BWD (6916)
VPB-51
VPB-116
VPB-123
GM-34D
BWD (3876)
GM38-RW03
GM-38D
GM-38D2
VPB-48
GM38-RW01
GM-34D2
BWD (8941)
VPB-38
VPB-47
HICKSVILLE ROAD
VPB-40
LWD (7076)
VPB-122
VPB-77
BWD (8004)
HEMPSTEAD TURNPIKE
E
BPOW 1-4
BPOW 1-5
VPB-76
VPB-129
TT-101D
TT-101DS
VPB-127
VPB-43
SEAFORD OYSTER BAY EXPRESSWAY
BPOW 1-1
BPOW 1-2
BPOW 1-3
SFWD (7377)
C'
SFWD (5148)
VPB-45
SFWD (4043)
E'
B'
VPB-46
VPB-44
BPOW 4-1
BPOW 4-2
D
LWD (5303)
VPB-50
VPB-128
BPOW 2-1
BPOW 2-2
VPB-126
BPOW 3-3
BPOW 3-4
SFWD (6150)
BPOW 3-2
VPB-125
BPOW 3-1
C
ANY 9338
ANY 8480
VPB-124
D'
SFWI
A'
SFWD (6866)
SFWD (8665)
SUNRISE HIGHWAY
0
1,800
3,600
SCALE IN FEET
B
LEGEND
MONITORING WELL LOCATION
PROPOSED MONITORING WELL LOCATION
VERTICAL PROFILE BORING
PROPOSED VERTICAL PROFILE BORING
WATER SUPPLY WELL
1997 NORTHROP-GRUMMAN BETHPAGE BOUNDARY
1997 NWIRP BETHPAGE BOUNDARY
BUILDING
HIGHWAY
MAJOR LOCAL ROAD
MINOR LOCAL ROAD
TETRA TECH NUS, INC.
OPERABLE UNIT 2 (SITE 1)
CROSS SECTION MAP
NAVAL WEAPONS INDUSTRIAL
RESERVE PLANT
BETHPAGE, NEW YORK
FILE
112G01041GM02
SCALE
AS NOTED
FIGURE NUMBER
FIGURE OU2TT-G2
REV
0
DATE
01/07/11

Figure B-3





LEGEND

- SAND AND GRAVEL
- F-M SAND WITH VARYING AMOUNTS OF SILT, CLAY, AND C. SAND

CONFINING UNITS

- INTERBEDDED CLAY AND SAND
- SANDY CLAY
- CLAY
- CONFINING UNIT FROM ARCADIS CROSS-SECTION, NO SPECIFIC LITHOLOGY GIVEN
- 1 ARCADIS CROSS SECTION (2004)
- * TVOC DATA FROM ARCADIS

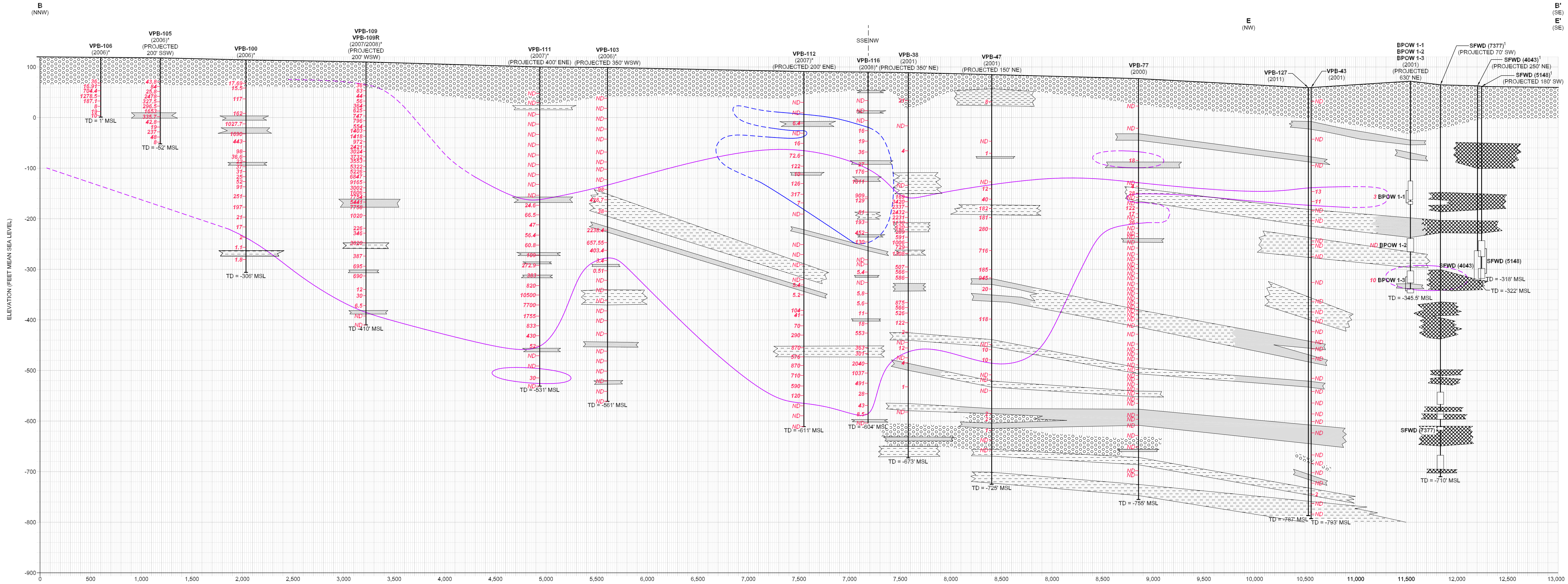
BPOW 3-2	MONITORING WELL ID
(2003)	INSTALLATION YEAR
(PROJECTED 450' ESE)	PROJECTION
	CONFINING UNIT (DASHED WHERE INFERRED)
	MONITORING WELL SCREEN
374	VERTICAL PROFILE BORING TVOC RESULTS IN ug/L
ND	NOT DETECTED
	MIXED VOC PLUME (5 µg/L CONTOUR LINE)
	PCE PLUME (5 µg/L CONTOUR LINE)
TD = -743' MSL	TOTAL DEPTH (MEAN) SEA LEVEL

Figure B-4

TETRA TECH NUS, INC.

CROSS SECTION A – A'
SOUTH FARMINGDALE WATER DISTRICT
NAVAL WEAPONS INDUSTRIAL
RESERVE PLANT
BETHPAGE, NEW YORK

FILE	SCALE	
112G01041GS03	AS NOTED	
FIGURE NUMBER	REV	DATE
FIGURE OU2TT–G3	0	01/26/11



LEGEND

SAND AND GRAVEL

F-M SAND WITH VARYING AMOUNTS OF SILT, CLAY, AND C. SAND

CONFINING UNITS

INTERBEDDED CLAY AND SAND

SANDY CLAY

CLAY

CONFINING UNIT FROM ARCADIS CROSS-SECTION, NO SPECIFIC LITHOLOGY GIVEN

1 ARCADIS CROSS SECTION (2004)

* TVOC DATA FROM ARCADIS

BPOW 3-2 MONITORING WELL ID

(2003) INSTALLATION YEAR

(PROJECTED 450' ESE) PROJECTION

CONFINING UNIT (DASHED WHERE INFERRED)

MONITORING WELL SCREEN

374 VERTICAL PROFILE BORING TVOC RESULTS IN ug/L

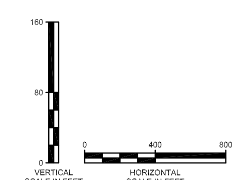
ND NOT DETECTED

MIXED VOC PLUME (5 µg/L CONTOUR LINE)

PCE PLUME (5 µg/L CONTOUR LINE)

TD = -743' MSL TOTAL DEPTH (MEAN) SEA LEVEL

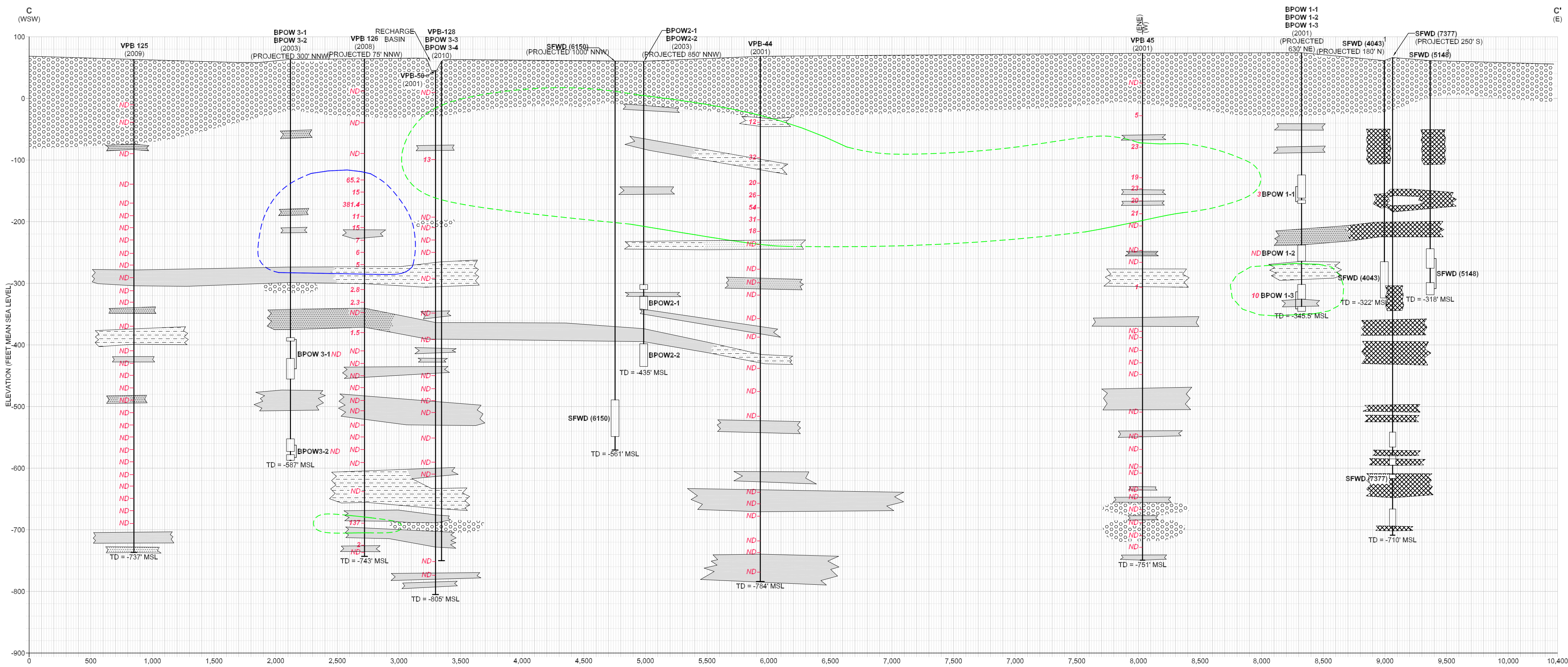
Figure B-5



TETRA TECH NUS, INC.

CROSS SECTIONS B – B' AND E – E'
SOUTH FARMINGDALE WATER DISTRICT
NAVAL WEAPONS INDUSTRIAL
RESERVE PLANT
BETHPAGE, NEW YORK

FILE	SCALE	
112G01041GS02	AS NOTED	
FIGURE NUMBER	REV	DATE
FIGURE OU2TT–G4	0	01/26/11



LEGEND

- SAND AND GRAVEL
- F-M SAND WITH VARYING AMOUNTS OF SILT, CLAY, AND C. SAND

CONFINING UNITS

- INTERBEDDED CLAY AND SAND
- SANDY CLAY
- CLAY
- CONFINING UNIT FROM ARCADIS CROSS-SECTION, NO SPECIFIC LITHOLOGY GIVEN
- 1 ARCADIS CROSS SECTION (2004)
- * TVOC DATA FROM ARCADIS

BPOW 3-2	MONITORING WELL ID
(2003)	INSTALLATION YEAR
(PROJECTED 450' ESE)	PROJECTION
	CONFINING UNIT (DASHED WHERE INFERRED)
BPOW 3-2	MONITORING WELL SCREEN
374	VERTICAL PROFILE BORING TVOC RESULTS IN μg/L
ND	NOT DETECTED
	TCE PLUME (5 μg/L CONTOUR LINE)
	PCE PLUME (5 μg/L CONTOUR LINE)
TD = -743' MSL	TOTAL DEPTH (MEAN) SEA LEVEL

Figure B-6

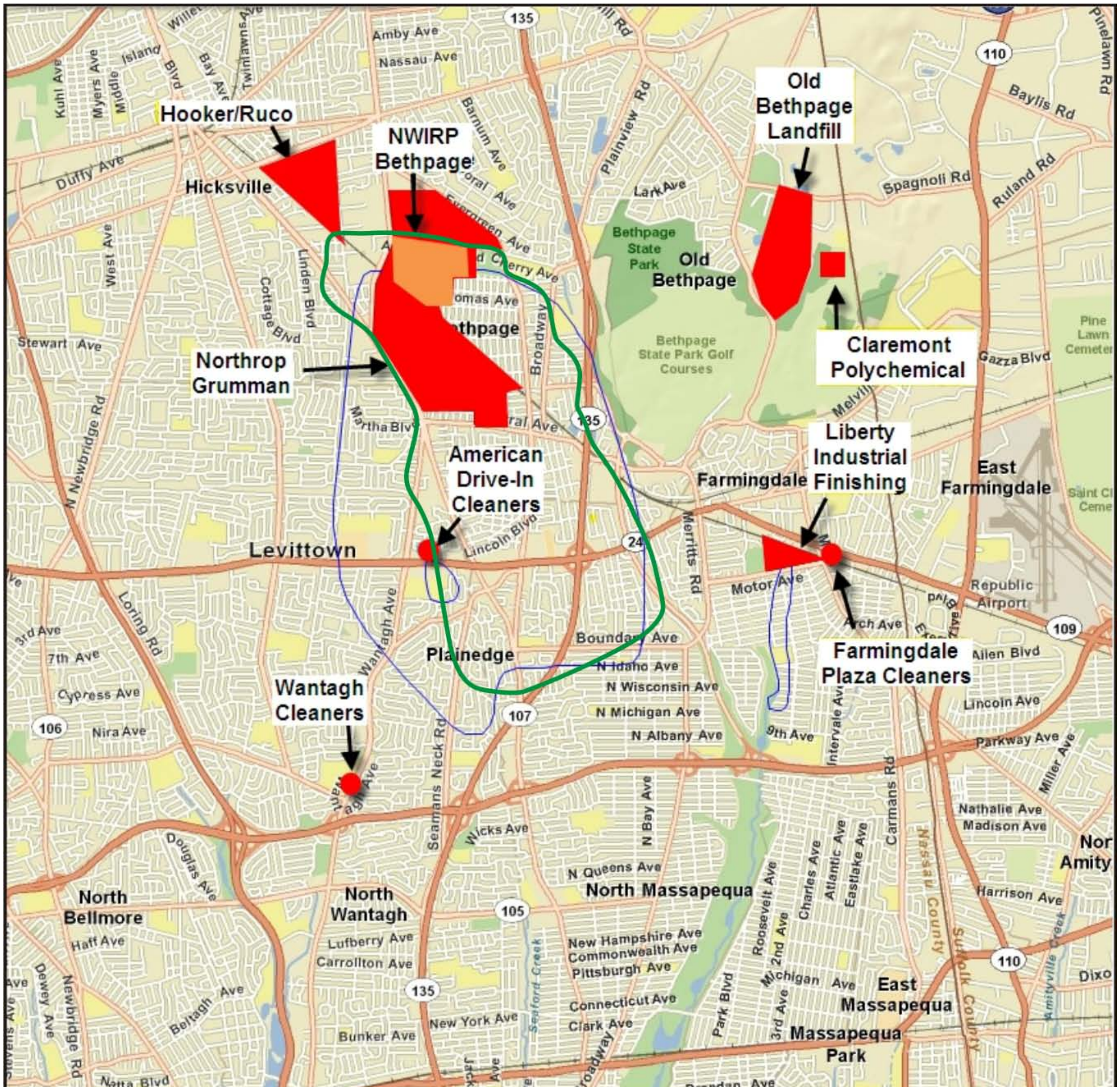
VERTICAL SCALE IN FEET

HORIZONTAL SCALE IN FEET

TETRA TECH NUS, INC.

CROSS SECTION C – C'
SOUTH FARMINGDALE WATER DISTRICT
NAVAL WEAPONS INDUSTRIAL
RESERVE PLANT
BETHPAGE, NEW YORK

FILE	SCALE	
112G01041GS06	AS NOTED	
FIGURE NUMBER	REV	DATE
FIGURE OU2TT-G5	0	01/26/11



N

0 0.5 1
APPROXIMATE SCALE IN MILES

Explanation

- ~5 ppb VOC Concentration Contour in Groundwater (OU2 and OU3)
- Plume from Other Sources
- NWIRP Bethpage
- Potential Sources of Contamination in the Bethpage Area

DESIGNED BY HR	Battelle		
DRAWN BY LC	NWIRP Bethpage Potential Sources of Contamination		
CHECKED BY HR	BETHPAGE, NEW YORK		
	PROJECT G922077-PB7751	BETHPAGE.CDR	DATE 04/11

Figure B-7

P: GIS files/Bethpage/MapDocs/BP OU2 2011 BP TCE DEEP 01192011 MMC 02072011

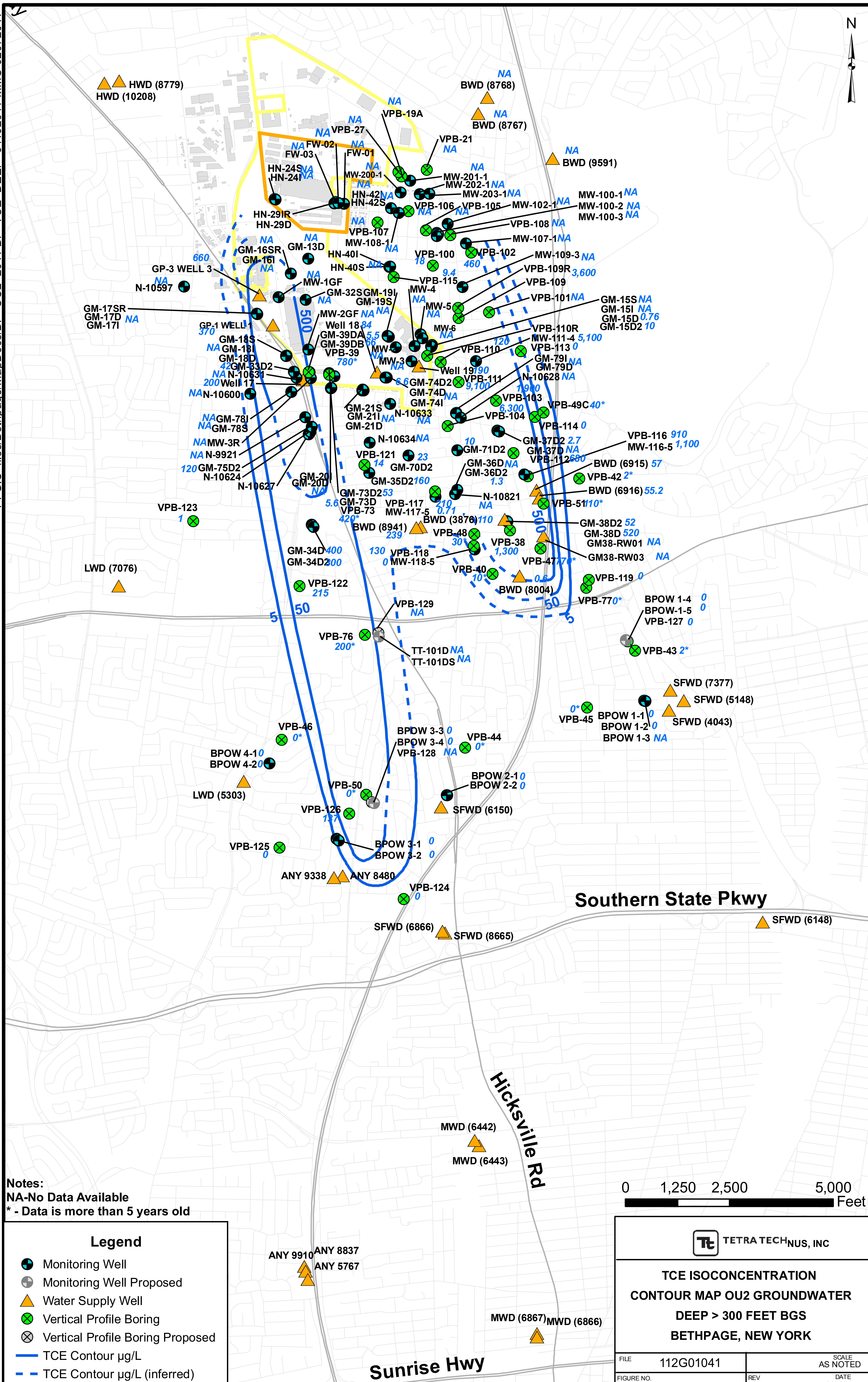


Figure B-8

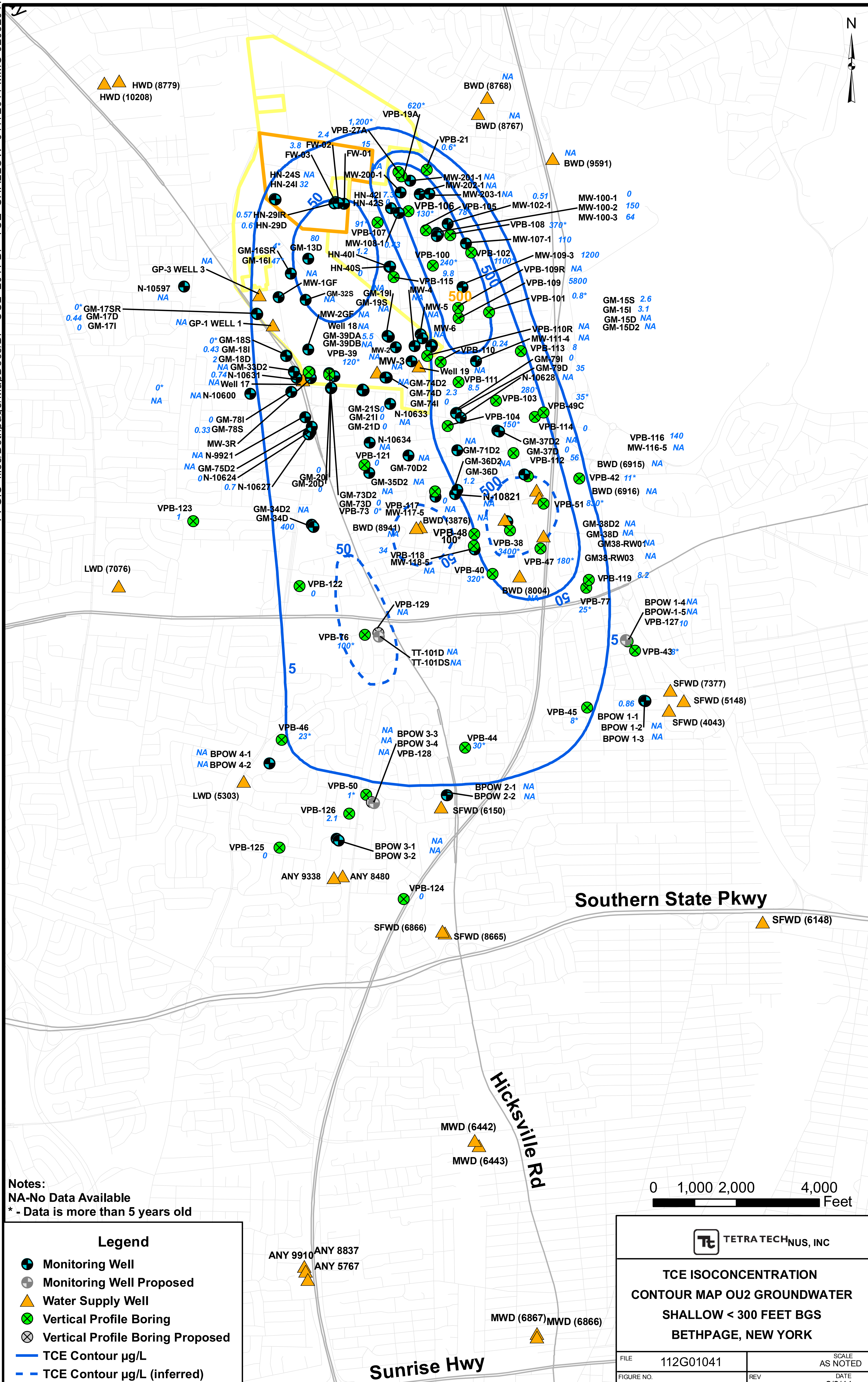

P: GIS files/Bethpage/MapDocs/BP OU2 2011 BP TCE SHALLOW 01172011 MMC 02032011
N
HWD (8779)
HWD (10208)
BWD (8768)
BWD (8767)
BWD (9591)
VPB-19A 620*
VPB-27A 1,200*
FW-02 2.4
FW-03 3.8
FW-01 15
VPB-21 0.6*
HN-24S NA
HN-24I 32
MW-200-1
MW-201-1 NA
MW-202-1 NA
MW-203-1 NA
HN-42I 7.3
HN-42S 0
VPB-106 130*
VPB-105 78
MW-102-1 0.51
MW-100-1 0
MW-100-2 150
MW-100-3 64
HN-29IR 0.57
HN-29D 0.6
VPB-107 91*
VPB-108 370*
MW-107-1 110
GM-13D 80
MW-108-1 0.23
GM-16SR 4*
GM-16I 47
HN-40I 1.2
HN-40S 0
VPB-100 240*
VPB-102 1100*
MW-109-3 1200
VPB-109R NA
VPB-109 5800
VPB-101 0.8*
VPB-115 9.8
GP-3 WELL 3 NA
N-10597 NA
MW-1GF NA
GM-32S NA
GM-19I NA
GM-19S NA
MW-4 NA
MW-5 NA
MW-6 NA
500
50
GM-15S 2.6
GM-15I 3.1
GM-15D NA
GM-15D2 NA
GM-17SR 0*
GM-17D 0.44
GM-17I 0
GP-1 WELL 1 NA
MW-2GF NA
Well 18 NA
GM-39DA 5.5
GM-39DB NA
VPB-39 120*
MW-2 NA
MW-3 NA
VPB-110R NA
MW-111-4 NA
VPB-110 0.24
VPB-113 8
GM-79I 0
GM-79D 35
N-10628 NA
GM-18S 0*
GM-18I 0.43
GM-18D 2
GM-33D2 NA
N-10631 0.74
Well 17 NA
N-10600 NA
Well 19 NA
VPB-111 8.5
GM-74D2 NA
GM-74D 2.3
GM-74I 0
VPB-103 280
VPB-49C 35*
GM-21S 0
GM-21I 0
GM-21D 0
N-10633 NA
VPB-104 150*
VPB-114 0
GM-78I 0
GM-78S 0.33
MW-3R
N-9921 NA
GM-75D2 NA
N-10624 0
N-10627 0.7
N-10634 NA
VPB-121 0
GM-70D2 NA
GM-35D2 NA
GM-20I 0
GM-20D 0
GM-37D2 NA
GM-37D 0
VPB-112 56
GM-71D2 NA
GM-36D2 NA
GM-36D 1.2
VPB-116 140
MW-116-5 NA
BWD (6915) NA
VPB-42 11*
BWD (6916) NA
GM-73D2 NA
GM-73D 0
VPB-73 0*
VPB-117 0
MW-117-5 NA
N-10821 NA
VPB-51 830*
VPB-123 1
GM-34D2 NA
GM-34D 400
BWD (8941) NA
BWD (3876)
VPB-48 100*
VPB-38 3400*
GM-38D2 NA
GM-38D NA
GM38-RW01 NA
GM38-RW03 NA
VPB-47 180*
VPB-118 34
MW-118-5 NA
VPB-40 320*
VPB-119 8.2
LWD (7076)
VPB-122 0
BWD (8004) NA
VPB-77 25*
VPB-129 NA
BPOW 1-4 NA
BPOW-1-5 NA
VPB-127 10
VPB-76 100*
TT-101D NA
TT-101DS NA
VPB-43 8*
5
SFWD (7377)
SFWD (5148)
SFWD (4043)
VPB-45 8*
BPOW 1-1 0.86
BPOW 1-2 NA
BPOW 1-3 NA
VPB-46 23*
BPOW 3-3 NA
BPOW 3-4 NA
VPB-128 NA
VPB-44 30*
BPOW 4-1 NA
BPOW 4-2 NA
LWD (5303)
VPB-50 1*
BPOW 2-1 NA
BPOW 2-2 NA
SFWD (6150)
VPB-126 2.1
VPB-125 0
BPOW 3-1 NA
BPOW 3-2 NA
ANY 9338
ANY 8480
VPB-124 0
Southern State Pkwy
SFWD (6148)
SFWD (6866)
SFWD (8665)
Hicksville Rd
MWD (6442)
MWD (6443)
0 1,000 2,000 4,000 Feet
Notes:
NA-No Data Available
* - Data is more than 5 years old
Legend
Monitoring Well
Monitoring Well Proposed
Water Supply Well
Vertical Profile Boring
Vertical Profile Boring Proposed
TCE Contour µg/L
TCE Contour µg/L (inferred)
ANY 9910
ANY 8837
ANY 5767
MWD (6867)
MWD (6866)
Sunrise Hwy
TETRA TECH NUS, INC
TCE ISOCONCENTRATION
CONTOUR MAP OU2 GROUNDWATER
SHALLOW < 300 FEET BGS
BETHPAGE, NEW YORK
FILE 112G01041
SCALE AS NOTED
FIGURE NO.
REV
DATE 2/3/11

Figure B-9

Appendix C

HAND CALCULATED ILLUSTRATION OF PLUME ARRIVAL TIME ESTIMATES

GSI Job No. G-3619
Issued: 9 June 2011

PRELIMINARY

MEMORANDUM

TO: The Technical Team for Optimization of the Bethpage Plume Remedy

FROM: C. J. Newell

RE: Hand Calculation for Plume Travel Time, Bethpage Groundwater Plume, New York

EXECUTIVE SUMMARY

An evaluation of historical groundwater plume travel distance and travel time suggests a plume travel velocity of about **285 feet per year**. Using this value and an estimated distance from the edge of the current plume to the Massapequa supply wells (~ 6300 feet) suggests a travel time of about 20 years from now. Because of uncertainties in hydrogeology, capture zones, and other factors the range of expected arrival times is between **10 and 40 years from now**.

DATA

- Approximate location of Bethpage Source Zone contributing to OU-2 plume: Near well **HN-24 wells** ("most contaminated well on-site was the intermediate depth well of the HN-24 well cluster"; NYSDEC Record of Decision, 2001).
- Distance from HN-24 well cluster to Aqua New York well 4S (8480): **~ 16,300 feet** (see attached figure).
- Distance from edge of plume to Massapequa supply well**: ~6300** feet (see attached figure)
- Date source began: Assume **1950**, based on NYSDEC ROD (2001) Site History section chlorinated or liquid wastes being used since the early 1950s for several disposal activities. In addition, Waddell (2007) describes plume age being 57 years in 2007.
- Date TCE arrived at Aqua New York Wells: late 2006 – early 2007 (Arcades, 2010). For this calculation assume **2007.**

CALCULATION

- Approximate plume velocity: (16,300 feet) ÷ (2007 – 1950 years) = **285 feet per year** (rounded)
- Range of estimated plume velocity: 142 feet per year to 570 feet per year
- Travel time to nearest Massapequa well (high end): (6300 feet) ÷ 285 feet per year = 22 years – **round to 20 years**.
- Range of estimated arrival times time to nearest Massapequa well: **from 10 to 40 years**.

REFERENCES

Arcadis, 2010. 2009 Annual Groundwater Monitoring Report, Operable Unit 2, Northrup Grumman Systems Corporation, Bethpage, New York, March 29, 2010.

NAVFAC, 2007. Technical Issues and Overview of Arcadis Groundwater Flow And Transport Model, Naval Facilities Engineering Command, Powerpoint presentation by D. Waddill, May 9, 2007.

NYSDCE, 2001. Record of Decision, Operable Unit 2 Groundwater, Northrop Grumman and Naval Weapons Industrial Reserve Plant Sites Nassau County, Sites Numbers 1-30-002A &B.

Appendix D

RESPONSE TO COMMENTS TABLE

Response to Comments

Bethpage Optimization Report

Comment Number	Comments	Response
	Comments from Kent Smith, Northrop Grumman Systems Corporation	
1	**1A: Better definition of the western boundary of the regional plume ("Bethpage plume") is needed.** We agree that better definition of the western boundary of the regional plume is needed. The impacts of the former Hooker/RUCO site, a known significant source of groundwater contamination located on the far western plume boundary, have not been adequately characterized in this area and should be the focus of any additional investigations. Please revise the Optimization Report to reflect this information.	Comment noted. See also EPA comment in this table, which suggests that a copy of this Optimization Report be provided to the stakeholders at the Hooker-Ruco site and a work plan be developed to firmly establish the impacted area from Hooker-Ruco sources. However, the main focus of this recommendation is on the plume originating from OU-2 sources. The western boundary of the OU-2 plume needs better definition to verify that the On-Site Containment System is effective along its westernmost edge.
2	**1B: Better definition of the eastern boundary of the regional plume is needed.** Regarding the investigations conducted by Northrop Grumman, we disagree that the plume is not well defined along its eastern boundary. Northrop Grumman delineated the horizontal and vertical extent of impacted groundwater on and downgradient of the Bethpage Community Park (Park) during the OU3 remedial investigation (RI), as shown in Figure 5-7 in the Site Area RI Report and Figure 4 in the Study Area RI Report. During the RI, five vertical profile borings (VPBs) were drilled along the eastern boundary of the plume and groundwater was sampled from multiple discrete intervals (110 to 804 feet below land surface) for analysis of volatile organic compounds (VOCs). Data from two VPBs drilled by the Navy were also used. We request that the referenced data be further evaluated and that the Optimization Report be revised to reflect that: 1) Northrop Grumman has adequately delineated the eastern portion of the regional plume and 2) any additional definition of contamination along the eastern boundary should be directed at known sources of groundwater contamination in that area, such as those identified in Figure B7 in the Optimization Report. **Upon request from the Technical Team, Northrop Grumman provided the following additional information**: "NG considers the source areas at the Park to be well defined along the eastern boundary. Source areas at the Park are defined in the RI and FS reports as where TVOCs are found at concentrations greater than 10 parts per million (ppm) in shallow groundwater and vadose zone soil. Data provided in the Site Area RI form the basis for NG's interpretation of the extent of the sources in groundwater. As shown in the RI Report, the eastern extent of the groundwater source area is defined by VP-1, VP-3B, VP-10, VP-18, and other VPBs. As observed by the Navy,	The Technical Team has reviewed the comment and the additional information from Northrop Grumman, including the VPBs mentioned in this comment, but still sees a need for better definition of the OU-3 Plume (and associated sources) boundary, especially in deeper portions of the aquifer. For example, VPB-119, the deepest boring is too far downgradient (further downgradient from the BWD supply wells). VPB-101 with a maximum depth of 507 ft shows no elevated VOCs and could have been a possible boundary boring for the plume. However, VPB-103, the next downgradient boring shows much elevated VOC levels at 660 ft bgs. The possibility of a deeper plume and deeper sources needs to be further evaluated. The current conceptual model that shallow on-site sources lead to a plume that is shallow on-site and dips deeper off-site may not be correct. Additional VPBs will be required to define both the horizontal and vertical extent of the OU-3 source areas and plume.

Comment Number	Comments	Response
	these VPBs (and most other on-site borings) were only on the order of 100 feet deep (e.g., 75-150 feet). Nevertheless, the observed patterns of TVOCs in groundwater, plus data on the lithology and hydrogeology, support the Navy's conceptual site model (CSM) that TVOC sources are shallow at the Park and that contamination migrates deeper as it moves downgradient. This CSM finding is also supported by the results of the deeper VPBs on the site (VP-8 and VP-9, both completed to 301 feet below land surface), which show the highest TVOC impacts to be limited to the upper 100 feet. NG considers the plume to be well defined along the eastern boundary in the downgradient direction, based on multiple samples collected during the RI (and by the Navy) at discrete depth intervals - VP-7 (total depth [TD] 110 ft bls) , VP-8 (TD 300 ft bls), VP-101 (TD 507 ft bls), VP-113 (TD 492 ft bls), VP-114 (TD 494 ft bls), and VP-119 (804 ft bls); and Navy locations VP-42 (TD 541 ft bls) and VP-49 (TD 542 ft bls). As with the Park sources, the observed patterns of TVOCs at depth, plus lithologic and hydrogeologic information, support the Navy's CSM. We recognize that addition of monitoring wells will be necessary along the eastern boundary to maintain the plume definition over time, because VPBs provide data as one-time events. Applicable long-term monitoring needs will be determined following remedy selection."	
3	**1C: Better definition of the impacts to the regional plume by parties other than the Navy and Northrop Grumman is needed.** We agree that the impacts from sources other than the Navy and Northrop Grumman need to be fully characterized. This broader evaluation of potential sources is crucial to an understanding of the nature of the regional plume and to developing a comprehensive area-wide approach to groundwater remediation. The Optimization Report identities a number of neighboring CERCLA and RCRA sites whose impacts on regional groundwater should be better characterized. Northrop Grumman has also undertaken an effort to identify potential sources of impacts to the regional plume and will provide that information to the Remedy Optimization Team in the future.	Comment noted.

Response to Comments

Bethpage Optimization Report

Comment Number	Comments	Response
4	**1D: Data collection should be coordinated among the various parties involved in evaluating the regional plume.** Northrop Grumman agrees that coordinated data collection and data sharing with other parties should be exercised to the extent practicable. We have historically shared, and continue to share, data collection and the resulting environmental data with the Navy, regulatory agencies, and water districts.	Comment noted.
5	**2A: Better definition of vertical groundwater capture in deeper groundwater is needed downgradient of the On-site Containment System (ONCT) and Park Groundwater Interim Remedial Measure (IRM) recovery wells to determine whether on-site sources are being contained.** The performance of the Park Groundwater IRM does not need to be established in deeper portions of the aquifer. As demonstrated during the Site Area AI, the groundwater impacts at the Park are shallow. The vertical distribution of VOCs along the southern boundary of the Park (and adjacent Plant 24 Access Road) was defined using 15 VPBs, as presented in Figure 5-16 in the Site Area RI Report. The VPB data show that the vertical extent of the Park VOC plume is limited to shallow groundwater (a maximum depth of approximately 80 teet below the water table). Based on the results of the VPB drilling, the Park lRM was designed to hydraulically contain VOCs in shallow groundwater. Please revise the Optimization Report to reflect these facts and that there is no need to establish the lRM's performance in deeper portions of the aquifer. The response to the next comment addresses definition of vertical capture at the ONCT system. **Upon a request from the Technical Team, Northrop Grumman provided the following additional information**: “Regarding the ONCT, we are currently evaluating the sufficiency of the monitoring well network to demonstrate horizontal and vertical hydraulic capture. The results of our evaluation will be presented in the next annual operation, maintenance, and monitoring (OM&M) report for the ONCT; we would appreciate having this reflected in the Optimization Report. Regarding the Park Groundwater IRM, we do not believe that its performance needs to be established in deeper portions of the aquifer. This	Comment noted, but as described in the response to Comment #2 above, the Technical Team finds the existing VPBs inadequate to characterize the OU-3 source areas and plume Possibility of deeper sources needs to be investigated and new deeper VPBs both upgradient and downgradient of the IRM are a high priority to verify that the OU-3 sources remain well contained, both horizontally (to the east and west) and vertically.

Comment Number	Comments	Response
	opinion is based on NG's and the Navy's interpretations of the CSM that indicate the presence of shallow sources (e.g., VP-9, VP-27, and VP-3C) and that contamination migrates deeper downgradient (see response to Comment 1B). That being said, we are currently evaluating the sufficiency of the IRM monitoring well network to demonstrate that the design hydraulic capture is being achieved and maintained. The results of our evaluation will be presented in the next annual OM&M report for the Park Groundwater IRM; we would appreciate having this reflected in the Optimization Report."	
6	**2B: Better definition of vertical groundwater capture in deeper groundwater is needed downgradient of the On-site Containment System (ONCT) and Park Groundwater Interim Remedial Measure (IRM) recovery wells to determine whether on-site sources are being contained.** We agree that the impacts from sources other than the Navy and Northrop Grumman need to be fully characterized. The broader evaluation of potential sources is crucial to an understanding of the nature of the regional plume and to developing a comprehensive area-wide approach to groundwater remediation. The Optimization Report identifies a number of neighboring CERCLA and RCRA sites whose impacts on regional groundwater should be better characterized. Northrop Grumman has also undertaken an effort to identify potential sources of impacts to the regional plume and will provide that information to the Remedy Optimization Team in the future.	Comment noted. The Technical Team does mention in the report the need to identify and characterize non-Navy, non-Northrop Grumman sources. But the main thrust of the Technical team's statement is that evaluating the potential of deeper sources in both OU-2 and OU-3 is a high priority need, for which new deeper VPBs will be required immediately downgradient and/or upgradient of the ONCT and IRM, Recent VPBs in the downgradient plumes originating from both OU-2 and OU-3 show much deeper components of the plume than were initially conceptualized. The possibility that these deeper plume fingers originate from deeper on-site sources (sources that are possibly deeper than the current capture depth of the containment wells) needs to be investigated on a high priority basis.
7	**2C: Do not reduce the pumping rate of RW-19 In the near term to allow a higher pumping rate in proposed RW-21 (unless concentrations drop significantly) because the tradeoff in VOC mass recovery is not clear.** The current pumping rate for Well 19 was determined during design of the ONCT system to capture the eastern portion of the identified on-site OU2 plume. During design, it was determined that the Well 19 capture zone extended well beyond what was needed to capture the eastern portion of the OU2 plume. Addition of Well RW-21 discharge to the OU2 treatment plant will require a reduction in Well19's pumping rate (from 700 gallons per minute [gpm] to 200 gpm). However, groundwater modeling conducted during the Study Area FS indicated that the combination of RW-21 pumping at 1,000 gpm and Well19 pumping at a reduced rate to 200 gpm will result in effective capture of the eastern portion of the OU2 plume, without loss of on-site containment. In terms	Comment noted. The Technical Team still recommends maintaining the current pumping rate in RW-19 for two reasons. Firstly, the capture zone of RW-19 extends certain distances both east and west. Reducing the pumping rate would reduce the size of the capture zone in both the western and eastern directions, impacting the substantial capture that it is now causing of VOCs emanating potentially from both OU-2 and OU-3 sources. Secondly, the Technical Team's preference would be for less reliance on solute transport modeling (which has proved uncertain in the past) and more reliance on additional field data collection and groundwater flow modeling to determine the ongoing extent of capture in both ONCT and IRM systems, as per Section 4, Recommendation 2. The Technical Team does not see why "addition of Well RW-21 discharge to the OU-2 treatment plant will require a reduction in Well 19's pumping rate". Although it is one consideration, existing treatment plant capacity should not be the driving factor for designing the pumping rate of RW-21.

Comment Number	Comments	Response
	of tradeoffs in VOC mass recovery, RW-21 is designed to capture the highest VOC concentrations observed anywhere in the offsite regional groundwater plume. RW-21's contribution to the overall VOC mass recovery from groundwater is expected to far exceed that associated with Well 19. Please revise the Optimization Report to reflect these facts.	
8	**3: Develop an area-wide CSM to identify multiple sources of contamination and use it as a tool to guide future work.** We agree that developing an area-wide CSM would provide a valuable tool for use in identifying and characterizing multiple sources of contamination and supporting a regional groundwater solution.	Comment noted. Although identifying the contribution of other regional sources would be one component, the primary aim of an improved CSM would be to gather all the available data for OU-2 and OU-3 to better understand the horizontal and vertical extent of the Bethpage plume and sources, the hydrogeological setting that drives VOC migration, and the data gaps that would drive additional investigations.
9	**4A: Multiple sources contribute to the composite off-site plume, which makes tracking the plume and evaluating off-site remedies challenging.** We agree that multiple sources contributing to the regional plume create significant challenges to effective characterization of impacted groundwater and development of remedial approaches. As discussed in our previous comments, better characterization of these multiple sources and use of a well conceived area-wide CSM should make these tasks more manageable and yield improved results.	Comment noted. Although an evaluation of other regional sources is needed to complete the understanding of the Bethpage plume and should be done, the main focus of the Technical Team's recommendations is on plumes originating from OU-2 and OU-3 sources.
10	**4B: Treatment or containment of the OU3 "hotspot" should reduce 90 percent of the mass discharge moving through a vertical aquifer cross section downgradient of the recovery system.** The OU3 "hot spot" is recognized as a portion of the regional groundwater plume characterized by high VOC concentrations (over 5,000 parts per billion [ppb]) and located upgradient of Bethpage Water District's Plants 4, 5 and 6. The location (both horizontally and vertically) and pumping rate associated with proposed remedial well RW-21 were developed to maximize containment and cleanup of this "hot spot". A rigorous data evaluation and groundwater capture zone analysis were conducted when developing the proposed RW-21 remedy. Based on the current plume configuration and the results of the capture zone analysis, we estimate that proposed RW-21 will contain at least 90 percent of the mass flux through a plume cross section in the RW-21 area. This estimate is based on the fact that the proposed remedy was designed to capture not only the plume core (i.e., the "hotspot") but also a substantial portion of the plume upgradient of the proposed RW-21 location. Work conducted as part of the final RW-21 design will include additional aquifer characterization (e.g., vertical	The 90% reduction in mass discharge goal originated in discussions among the Technical Team members as summarized below. 1) There was a need to reduce mass discharge towards Bethpage supply wells, in order to: 1) reduce the risks associated with exceeding the capacity of the treatment system, and 2) to minimize the effect of any treatment system operational problems. In other words the Team determined that it was not prudent to rely on the Bethpage supply wells alone to manage the high-concentration groundwater flowing downgradient from the hotspot. Because elevated VOC concentrations can persist downgradient of any capture or treatment for a variety of reasons (e.g., back diffusion from silty clay lenses), mass discharge was proposed as a more relevant goal. A mass discharge or mass flux reduction goal is consistent with current thinking and recent research in the remediation community and is generally measurable in the relatively shorter term (5 to 10 years). 2) Mass discharge reduction can be measured and evaluated using capture zone analysis and/or more detailed monitoring (e.g., using a fence of multi-level wells or flux meters across the containment cross-section of the plume). While the solute transport modeling work did provide predictions

Comment Number	Comments	Response
	profile borings, well and piezometer installation) and additional flow modeling and particle tracking to optimize plume containment and mass removal (estimated to be greater than 90 percent). Please revise the Optimization Report to reflect the information provided above. It would also be helpful if the Optimization Report provided an understanding of the basis for the recommended 90 percent reduction in mass discharge.	of the reduction in concentration from pumping the proposed RW-21 well, the Team found that the solute transport model results have some issues with reliability (the site has experienced considerable uncertainty in the past from solute transport model concentration vs. time predictions at supply wells). Therefore the Team determined that mass discharge reduction based on capture zone analysis and/or more monitoring was a more measurable, reliable, and relevant goal. The Technical Team recommends additional deeper VPBs that span the entire width of the OU-3 plume at the location of the desired containment cross-section as a good way of determining mass flux. Monitoring wells screened at multiple depths would be left in place in key VPBs in this cross-section to allow periodic monitoring of the progress of hot-spot containment efforts. 3) The Technical Team's consensus, based on the team members' collective experience, was that a 90% reduction in mass discharge was a specific and attainable goal (whereas reducing groundwater concentrations in the impacted supply wells and surrounding aquifer to sub-MCL concentrations was not likely to be attainable in any reasonable time frame).
11	**4C: Delineate water levels and water quality near the recovery system.** Additional aquifer characterization (via vertical profile borings, well and piezometer installation) will be conducted as part of the final RW-21 design. After system start up, water levels and water quality will be monitored routinely as part of the system effectiveness monitoring program. Please revise the Optimization Report to reflect this information.	Comment noted.
12	**4D: Conduct routine flow modeling and particle tracking, with regular model recalibration and reporting, to confirm the effectiveness of the recovery system.** As described above, the final RW-21 design will include additional flow modeling and particle tracking. However, once Well RW-21 is operational, the effectiveness of the recovery system will be based primarily on collection and graphical evaluation of field data (e.g., water level contouring to evaluate the capture zone, water quality trends in key monitoring wells, evaluation of vertical gradients). Please revise the Optimization Report to reflect this information and to acknowledge that routine modeling and particle tracking are not the only means of confirming the effectiveness of the recovery system.	Comment noted. The Team emphasizes the need for proper model calibration prior to undertaking this analysis. Proper model calibration will require additional field characterization with good horizontal and vertical definition of the geology and the plume across a cross-section spanning the width of the plume emanating from OU-3 sources (See Team's response to Comment #10 above). In addition, the Team recommends that a more detailed modeling report be prepared that provides the project stakeholders with enough detail to enable a good peer review (see Team's response to Comment #14).

Comment Number	Comments	Response
13	**5A: There is a need for realistic modeling expectations and recognition of the inherent limitations of using solute transport modeling to predict plume travel time, arrival concentrations, and cleanup times at such a large and complex site.** Northrop Grumman agrees with the conclusion that there are inherent limitations in any modeling effort at such a large and complex site, particularly solute transport modeling. Solute transport modeling has played a limited role in Northrop Grumman's remedial activities; however, as acknowledged in the Optimization Report, certain water districts and local politicians have used the findings of the recently issued USGS report on the Bethpage model to argue that the model is under-predicting travel times and contaminant concentrations. The Bethpage model represents state-of-the-art groundwater computer modeling for such a complex site and has served as a valuable tool (along with empirical data) to design and implement remedies to protect groundwater; the Optimization Report should reflect this information.	Comment noted. Comment noted. The uncertainties of predicting plume arrival times and concentrations at large sites have been well documented in the scientific literature. However, the Technical Team does see value in the use of a well-constructed and well-calibrated model for The Technical Team would recommend that a detailed report describing the model setup, assumptions, calibration, and modeling scenarios be made part of the public record and available for peer review (see response to Comment #14 below).
14	**5B: Flow modeling and particle tracking should be used to determine the capture zones of the ONCT and IRM systems and new remedial well(s).** Northrop Grumman used groundwater flow modeling and particle tracking to determine the capture zones of the ONCT and IRM systems during their design. For the ONCT system, particle tracking was used to determine the target capture zones of various recovery well remedial scenarios (using existing Northrop Grumman production wells and proposed new recovery wells). Particle tracking was also used to determine the location, depth, pumping rates, and resulting capture zones of the Park Groundwater IRM recovery wells. The modeling results, capture zone determinations, and resulting remedial system designs for the ONCT and IRM were submitted to, and approved by, NYSDEC. Flow modeling and particle tracking were also used to determine the location, depth, and pumping rate for proposed new recovery well RW-21. Prior to recommending RW-21 in the Study Area FS as the off-site plume remedy, various other pumping well configurations were also evaluated using flow modeling and particle tracking. The conceptual design for RW-21 was approved by NYSDEC in the Study Area FS. Please revise the optimization Report to reflect these facts.	Comment noted. The Technical Team did not see enough detail about the modeling exercise leading to the conceptual design of RW-21 in the available documents. For groundwater modeling relevant to site related decisions (design of a new containment well, evaluation of capture zones of supply wells or containment wells, etc.), the Technical Team recommends that sufficient documentation of the model and particle tracking be provided in a report to enable peer review (or replication of the results by others). This report should include information on the following: 1. How the model was constructed. Detailed model grid information, boundary conditions, inflow/sources (recharge rates, etc.), output/sinks (pumping rates, etc.), hydraulic conductivity and other MODFLOW inputs. Also, which version of MODFLOW was used. 2. How the model was calibrated. Field data from which VPBs or monitoring wells were used for calibration and for which sampling events. Water level data sets used for calibration, statistical results of each calibration (assuming that the model was tested using multiple data sets), and global mass balance results. 3. How the modeling scenarios were developed and what assumptions were made. The next groundwater modeling report should also address how the recent EPA/USGS modeling review memorandum is being addressed.
15	**6: Lithological Cross Sections (Appendix B)**	Comment noted. The Technical Team agrees that limited spatial data are leading to uncertain interpretations of geologic units. This has been and will continue to be one

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	A number of the interpretations of low-permeability units appear to be inaccurate and not consistent with the depositional environment of the Magothy formation or the findings of the USGS and others that zones of low permeability are, for the most part, laterally discontinuous. For example: 1) some low permeability units show no dip; 2) other units show a steep dip; 3) other units arch upward; 4) various lithologic descriptions are correlated as one continuous low- permeability unit; and 5) relatively thin units are interpreted to be continuous over considerable distances. Also, the cross sections present an overly-simplified plume depiction. More detailed contouring of VOC concentrations may lead to a better understanding of plume stratification and potential sources, especially on Section B-B'. The Study Area RI Report provides a detailed analysis of VOC concentrations along a line of section similar to Section B-B' (Figure 5). Also, as stated in the Navy Work Plans, the objective of drilling to depth and mapping the upper surface of the Raritan Confining unit does not appear to have been achieved.	of the inherent limitations in understanding and/or modeling the groundwater flow and VOC transport at this large and complex site. The following additional information was provided by Tetra-Tech, the Navy contractor: "We acknowledge the general theory on the depositional history of soils on Long Island, as well as the general basis for the formation of low permeability units. This general theory provides a good starting point for understanding groundwater flow in the area. However, based on site-specific information, many localized variations in the general theory have been identified. In particular, based on very detailed work done on Navy property, clay units have been identified as flat (especially when viewed along the strike), steep, or even upward. The low-permeability units presented on the cross section are based on a very detailed evaluation of site-specific information and provide a good basis for understanding potential and actual groundwater and contaminant flow through the area. Where multiple borings show the same lithological signature, the units are shown as connected on the cross section. We recognize that this level of granularity would seriously limit the ability to accurately model groundwater and contaminant transport in the area, but present it because of the need to identify potential contaminant migration. The level of detail on the VOC contouring is likewise accurate based on the data available. This evaluation utilizes the location of known contamination and potential groundwater flow. In addition, where groundwater data are conflicting or variable, the mapping uses a conservative approach, especially where the presence of VOCs may vary based on time. For example, a water district supply well may pull contaminated groundwater from the east, west, or even south under a continuous, semi-confined seasonal pumping scenario. This condition was documented during the testing of GM-38 System, Recovery Well No. 2, where the pumping test was affected by the operation of BWD Plant No. 4."
	Comments from Carol A. Stein, P.E., EPA Region 2	
1	**General Summary:** EPA Region 2 has reviewed the Navy's Draft Optimization Team Report for the Bethpage Groundwater Plume Remedy, dated April 29, 2011. Overall, it is a well-executed report which provides a good basis for discussing and planning the steps needed to verify the effectiveness of the current remedial actions.	Comment noted. The Technical Team appreciates all the information support and guidance provided by EPA during the introductory conference call and subsequent site visit in February 2011.
2	**Comment 1:** I have attached a comment memo from Rob Alvey, the EPA geologist involved in this project. I concur with the four comments noted in the attached memo from Mr. Alvey.	Comment noted.
3	**Comment 2 Background (page 1) -** Regarding the discussion on the first	Comment noted. Reference to Navy Policy for Optimization Reviews has been

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	two paragraphs about the formation of the optimization team, perhaps one or more sentences could be added to describe how the optimization review normally falls into the remediation process. For instance, is there a criteria that can be cited under the Navy's environmental remediation guidance, which specifies the optimization review process? If the optimization process is similar to EPA's 5-year review process for Superfund remedies, my understanding is that it probably would have been planned regardless of whether concern was voiced by U.S. Senator Charles Schumer's office.	included in the introductory paragraph.
4	**Comment 3:** As the optimization review evaluates the conclusions of the ROD issued in January 2003, it would be useful if more specific reference to recommendations of the ROD were noted. For instance, in the portion of the ROD summary pertaining to the *Groundwater Remedial Program* (p.3), the ROD recommends "additional groundwater investigation in the vicinity of well GM-75D2, or other areas identified as requiring additional groundwater investigation …. to further determine if a contaminant mass removal program similar to the GM-38 area, is necessary". The optimization report states in Section 4.0 (Evaluation of the On-Site Remedy) recommendation #3, that "source remediation (aggressive in-situ treatment of DNAPL sources) above and beyond the On-Site Containment System in the OU-2 Plume source areas is not recommended." Although I assume that this statement applies to the GM-75D well cited in the ROD, it would be helpful for the lay reader if the optimization report were to indicate whether GM-75D was among the wells included in this category.	Comment noted. Since the 2003 ROD, VOC levels in GM-75D have declined. If sustained, this could indicate a beneficial effect of source containment by the On-Site Containment System, at least in the relatively shallower portions of the aquifer where the GM-75D is screened. This would indicate that the GM-75 area is responsive to containment of sources occurring upgradient. However, the Technical Team took a broader view of the GM-75D region and recommended a study of the entire southern boundary of the On-Site Containment System, including deeper zones that are not yet adequately characterized (Section 4, Recommendation #2). The objective would be to verify both the horizontal and vertical capture efficiency of the On-Site Containment System across more than just the GM-75D location. This study would indicate whether there are horizontal or vertical gaps in the ongoing containment (causing any elevated VOC levels in nearby downgradient regions, such as GM-75D) that would need to be addressed in some fashion. In Section 4, Recommendation #3, the statement "source treatment above and beyond the On-Site Containment System in the OU-2 Plume source areas is not recommended" refers only to aggressive mass removal through in-situ treatment of the source areas north of the On-Site Containment System. This sentence has now been changed in the report to read "Operable Unit 2 source areas" instead of "OU-2 Plume" source areas.
5	**Comment 4:** Perhaps there can be further clarifications in Section 5 (Evaluation of Remedy for Off-Site Hot Spot and Plume). Recommendation #1 (page 10) states that "geologic heterogeneities, etc., will likely make large-scale, rapid restoration of groundwater plume to pre-plume conditions impossible" within 20 to 30 years. Whereas recommendation #5 on page 12 proposes the evaluation of "a containment and treatment system… at the current leading edge of the plume to prevent further plume expansion and impacts to currently non-affected public water supply wells." According to recommendation #5, this could be done by "operating them [affected water supply wells] at full capacity year round". It would be helpful if further explanation were given regarding whether or not gearing up the pumping in the vicinity of the affected water supply treatment systems should be able to remediate the aquifer to drinking water concentrations at a distance down-	1. Comments noted. These are all good questions and are the reason why the Team recommends that the evaluation be done. The current water supply wells would be just one part of the plume capture. Additional extraction wells would be required to supplement their capture.

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	gradient. Or, if down-gradient water supply wells would still need treatment, would there be value to significantly gearing up the pumping of the affected Aqua NY and S. Farmingdale wells? Also, if it is not beyond the scope of this assignment, perhaps there could be a discussion/ recommendation of where the additional pumped water from the supply wells could be discharged if pumping were done at full capacity year round.	
Comments from Rob Alvey, US EPA		
1	**General Summary:** In my opinion, the draft report provides a very good basis for discussion and planning on steps needed to verify the effectiveness of the current remedial actions. I note that the Technical Team also states agreement with the general assessment of the USGS's technical memorandum (report) on the groundwater model.	Comment noted. Thank you.
2	**Comment 1:** Full characterization of contaminated groundwater ultimate extent. The optimization addresses the potential impact to public supply wells, but does not fully discuss the ultimate extent to which the groundwater contamination can be expected to reach. There is a data gap as to if it will ultimately discharge to the shore or if natural resource damage is anticipated.	Agreed. The optimization did focus on potential impacts to public supply wells. There wasn't enough information to determine the ultimate extent of the plume. Predictions based on groundwater flow and transport modeling have proved uncertain in the past . Recommendation 4 in Section 5 illustrates that sophisticated modeling may provide no better prediction than a hand calculation. Ultimately, the full extent of the plume will depend on a complex interaction of many factors that are difficult to adequately map out in the large and deep impacted aquifer. These factors are likely to include geologic heterogeneities, degree of capture by containment and supply wells, advection dispersion, sorption, and diffusion. Recent research indicates that especially diffusion into low-permeability strata (such as those found in the Bethpage site aquifer) plays a big role in the fate and transport of dissolved VOCs in groundwater.
3	**Comment 2:** The western edge of the plume is somewhat uncertain, and includes an area under the responsibility of the Hooker/Ruco Polymers Superfund Site. I suggest a copy of the optimization report be provided to the EPA RPM and a meeting held to develop a workplan to firmly establish the impacted area from Hooker/Ruco and better delineate specifically what part of the impacted groundwater is being addressed by this PRP under Superfund.	Comment noted. This would be a good step.
4	**Comment 3:** The draft report contains indications that the On-Site containment may not be fully effective. This needs to be addressed immediately so that further migration of VOCs from this area does not occur.	Agreed. The technical team has recommended that further evaluation of the effectiveness of the on-site containment systems, especially in deeper portions of the aquifer be done as a high priority.
5	**Comment 4:** The eastern edge of the impacted groundwater needs to be better delineated.	Agreed. The Technical Team too has made this recommendation.
Comments from Steve Sharf, NYSDEC		
1	**General Summary:** The New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Health (NYSDOH) have reviewed this report. Overall, this report was well written,	Comment noted. The Technical Team appreciates the information support and guidance provided by NYSDEC during the introductory conference call and subsequent site visit in February 2011.

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	the recommendations are generally sound and it made objective comments regarding the optimization of the Northrop Grumman (130003A) and Naval Weapons Industrial reserve Plane (NWIRP 130003B) Sites Operable Unit 2 (OU2) groundwater remedy.	
2	**General:** This report is somewhat atypical of a remedy optimization study as it goes beyond evaluating and improving the in-place remedy, more commonly referred to as the OU2 plume. In fact much of this report is focused on the eastern plume, largely impacted by OU3 rather than the OU2 plume which the report was supposed to address.	Comment noted. As stated by the Technical Team at the Ad-Hoc Team meeting in February 2011, the Team took a holistic approach to understanding the VOC-impacted groundwater emanating from the OU2 and OU3source zones. The Team also recognized that as the VOC-impacted groundwater migrates downgradient, the OU-2 and OU-3 Plumes possibly comingle. Both OU2 and OU3 sources (and the OU-2 and OU-3 Plumes) have been scrutinized equally by the Team and many of the Team's recommendations apply to both. For example, Recommendation #2 in Section 4 (better evaluation needed of the ongoing capture efficiency of the on-site containment systems, especially in deeper zones) applies to both OU2 and OU3.
3	**General:** It is assumed that when the report discusses the western plume, the contaminated groundwater emanating from OU2 is being discussed and when the eastern plume is mentioned, the report is referring to the OU3 groundwater plume. The eastern plume hot spot in the GM 38 area that is OU2 contamination also has potentially impending impacts from the OU3 plume. This all should be clarified in the report.	As noted in response to Comment #1 above (and further clarified in the report), the Team recognized that VOC-impacted groundwater originating from OU2 and OU3 possibly comingles downgradient. The Team's understanding is that when the GM 38 extraction and treatment was designed and installed, OU3 had not been identified and delineated and the entire off-site plume was referred to as the OU-2 Plume. Now that OU-3 source areas and OU-3 Plume hot spot have been identified, the respective contributions from OU2 and OU3 to the groundwater impacts at various downgradient locations (e.g., BWD Plant 6 and GM 38) will have to be determined through the additional characterization recommended by the Team, so that the current Conceptual Site Model and the plume management strategy can be improved. In the report, we are now consistently using the term OU-2 and OU-3 plumes, instead of Western and Eastern plumes, respectively.
4	**Executive Summary, Recommendations 1 and 2:** Since the remedy has not been selected for the eastern plume that contains the OU3 contamination, the comments may be useful to the NYSDEC in the preparation and finalizing of the impending Proposed Remedial Action Plan for OU3.	Comment noted.
5	**Recommendation 3:** While the NYSDEC disagrees with the characterization of the modeling effort as inadequate by the previously released draft USEPA memorandum, the NYSDEC does agree that several identified activities and input parameters could be implemented and/or modified to potentially improve the modeling effort.	Comment noted. The Team did not attempt to duplicate the USEPA and USGS Team's modeling review. Rather the Team reviewed the available modeling reports and the USGS review memo and identified areas where modeling can be made more reliable and can be most beneficial (namely, in evaluating the target capture zones of containment wells and supply wells) and areas where modeling is likely to be the least reliable and provide limited benefits (namely, in predicting plume arrival times and concentrations at supply wells or, correspondingly, cleanup times and post-cleanup concentrations resulting from containment wells). The Technical Team hopes this guidance will be useful to the project stakeholders.
6	**Page iv, Recommendation No.5 Executive Summary and Page 12, Item 5:** the report recommends that an evaluation of the technical and economic	Comment noted. These are all good points. The Technical team agrees that downgradient plume containment has been evaluated and found deficient in the past

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	feasibility of plume containment be evaluated. The evaluation already exists in the Feasibility Study for OU2 and, to the extent feasible, for OU3. The NYSDEC included the evaluation of the plume containment option for the OU2 ROD and the outcome of that evaluation identified that this option was not feasible. a. The full plume containment recommendation is also at odds with some of the core conclusions reported by the Technical team such as page 10, item 1 that states: "*measures beyond the current plume containment are likely to be costly and ineffective*," and "*impacts to the public water supply wells are unavoidable*." b. Potential future treatment at a currently un-impacted water supply well(s) is already a part of the approved OU2 Wellhead Treatment Contingency Plan. The report needs to clearly state this. c. Since the optimization Report includes discussion of full OU2 plume containment, it may be useful for the Navy to do such an evaluation. This full plume containment review must be completely separate from the Optimization Report. Should the Navy decide to undertake this evaluation, the effort should include an evaluation of the Massapequa Water District report entitled "Massapequa Water District Case in Opposition to the Navy OU2 ROD."	during previous remedy selection efforts at the site. However, additional data have been gathered near the plume's edge in recent years, especially through the new VPBs that the Navy has installed. The Team's view is that the concern expressed by the water districts merits another look at recently collected data and reevaluation of plume containment.
7	**Page 3, Section 2:** a. Dense Non-Aqueous Phase Liquid, or DNAPL, though likely present for OU2, has never been positively identified in the formation at the 600 acre former Grumman Complex. b. First Bullet: The first bullet in section 2.0 should include the GM-38 Area pump and treatment system.	Comments noted. a. It is correct that DNAPL (or solvent phase) has not been directly verified at OU2 or OU3. As has been observed at many other DNAPL sites, the Technical Team's view is that presence of DNAPL at both OU2 and OU3 is strongly indicated by persistently high concentrations of TCE in the containment wells and by the strength of the downgradient plumes. This has been further clarified in the text of the report. b. Agreed. The pump-and-treat system at GM-38 will be added to the first bullet in Section 2.
8	**Page 5, Section 3, Item 2:** a. The American Dry Cleaners correct site information is as follows: American Drive-In Cleaners Site NYSDEC Site ID No. 130049 3801 Hempstead Turnpike Levittown, New York 11756 b. The American Drive-In (ADIC) Cleaners site is located within southwest corner of the Bethpage plume study area. The site is several miles further south of the Northrop Grumman-NWIRP source area(s) and the Glacial Aquifer is only 35 feet deep in the ADIC location. However, the ADIC site geotechnical and analytical	Comments noted. a. Thank you for supplying the dry cleaner site information. b. The Team appreciates NYSDEC's offer of cooperation in evaluating other (non-Navy, non-Northrop Grumman sites). c. This information would be valuable to the Navy and Northrop Grumman project teams. Thank you.

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	information can be included in the any new model calibrated or developed. The OXY Hooker Ruco National Priorities List site also has a multitude of information available. Should additional field work at these two or other location(s) be included in future field work, the NYSDEC can review these proposed location(s) in any upcoming work plan. c. The RI, FS and sampling reports from the ADIC site can be made available. This also includes monitoring well locations and removal action reports from ADIC.	
9	**Page 12-13, Last Paragraph, Section 5.0:** This section proposes monitored natural attenuation for long-term management of the source area and plume. The section should include "plume monitoring" and not "monitored natural attenuation." Monitored natural attenuation is not part of the selected OU2 remedy.	Comment noted and reference to MNA as part of the remedy at OU2 has been removed from the last paragraph in Section 5.
Comments from Kim Parker Brown, NAVFAC HQ		
1	Include a conclusion about the groundwater model in Section 2, General Observations.	Comment noted and a conclusion on modeling has been added to Section 2.
Comments from Richard Mach, NAVFAC HQ		
1	Add a recommendation/conclusion about the groundwater model in Section 2, General Observations.	Comment noted and a conclusion on modeling has been added to Section 2.
2	Add a reference to Figure B-1 to make sure that the IRM is not confused with as GM-75 in the opening paragraph of Section 4.0.	Reference to Figure B-1 has been added to opening text of Section 4.0.
3	Add a closing section to the report.	New closing section summarizing the conclusions and recommendations has been added to the report.