N00158.AR.000282
NAS WILLOW GROVE
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FOCUSED FEASIBILITY STUDY
for
SITE 1 – PRIVET ROAD COMPOUND GROUNDWATER (OU 3)

NAVAL AIR STATION
JOINT RESERVE BASE
Willow Grove, Pennsylvania

Naval Facilities Engineering Command
Mid-Atlantic

Contract Number N62472-03-D-0057
Contract Task Order 003

January 2008

TETRA TECH NUS, INC.

PHIL-21434

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for
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GROUNDWATER (OU 3)

NAS JRB WILLOW GROVE,
PENNSYLVANIA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Naval Facilities Engineering Command Mid-Atlantic
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CONTRACT NO. N62472-03-D-0057
CONTRACT TASK ORDER 003

JANUARY 2008

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1.0 INTRODUCTION AND BACKGROUND INFORMATION

Tetra Tech NUS (TtNUS), submits this focused feasibility study (FFS) report for Site 1 at the Naval Air Station Joint Reserve Base (NAS JRB) Willow Grove in response to Contract Task Order (CTO) No. 003 under Contract Number N62472-03-D-0057, Comprehensive Long-Term Environmental Action Navy (CLEAN). This work is part of the Navy's Installation Restoration Program (IRP), which is designed to identify and characterize contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures as appropriate.

This FFS was prepared consistent with requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and the National Oil and Hazardous Substance Contingency Plan (NCP). Preparation of this report followed the Interim Final Guidance for Conducting Feasibility Studies Under CERCLA (EPA. October 1988).

The remedial alternatives developed will be used by the Navy and the United States Environmental Protection Agency (EPA) to select a preferred remedy to deal with contaminated groundwater at NAS JRB Willow Grove Site 1 – Privet Road Compound. The preferred remedy will be presented in the Proposed Remedial Action Plan (PRAP) that will be presented to the local community during a public meeting and will be subject to a 30-day public comment period. After consideration of comments, the selected remedy will be documented in a Record of Decision (ROD) according to the prescribed process.

Section 1.0 presents an overview of NAS JRB Willow Grove military operations and the regional environmental setting. A summary of previous investigative activities and a discussion of human health and ecological risks for the site have also been presented. For a full understanding of site conditions, the required document is the Remedial Investigation (RI) Report for Site 1 – Privet Road Compound (TtNUS, July 2002), which was prepared as part of the prescribed RI/FS development process and is the essential companion document to this FFS.

Section 2.0 provides a discussion of potential chemical-specific, location-specific, and action-specific Applicable or Relevant and Appropriate Requirements (ARARs) and criteria to be considered (TBCs). This section also addresses remedial action objectives (RAOs), preliminary remedial goals (PRGs), and general response actions. RAOs and PRGs are addressed on a site-specific basis for the identification, screening, and evaluation of remedial technologies and process options. Selected remedial options are also presented.

Remedial alternatives for Site 1 groundwater are developed in Section 3.0. The rationale for selection of the alternatives and a description of each alternative, including a no-action alternative, are presented.

Section 4.0 provides a detailed analysis and comparison of the alternatives developed in Section 3.0.

1.1 SITE DESCRIPTION AND HISTORY

NAS JRB Willow Grove, Pennsylvania (formerly NAS, Willow Grove) is located in Horsham Township, Montgomery County in southeastern Pennsylvania, approximately 15 miles north of the city of Philadelphia (Figure 1-1). The Base occupies approximately 1,000 acres of flat to slightly rolling terrain and is generally bounded by State Route 611 to the east, State Route 463 to the southwest, and Keith Valley Road to the north.

The primary mission of NAS JRB Willow Grove is to provide support for operations involving aviation activities and to train Navy reservists. NAS JRB Willow Grove supports other tenants such as the Marines, the Air Force, and the Army. The Base provides facilities, services, materials, and training in direct support of all assigned units. These units include antisubmarine warfare squadrons, a helicopter squadron, a fleet logistic support squadron, and other Navy and Marine units. The Willow Grove Air Reserve Station (ARS) occupies approximately 162 acres of land in the northeastern section of the NAS JRB and shares common facilities with the NAS JRB.

The Privet Road Compound is a fenced area that is approximately ½ acre in size and is located west of Building No. 6 (Figure 1-2). The compound was constructed to serve as a transfer station for wastes after closure of the Ninth Street Landfill (Site 3) in 1967. Between 1967 and 1975 the compound was used as an open disposal area where appreciable quantities of waste were burned and buried. The suspected waste-handling area extends beyond the limits of the fenced compound and covers more than 2 acres, including the present location of the bowling alley and the parking area. Materials reported to have been disposed at the site include general refuse, sewage sludge, industrial pretreatment plant sludge, oil and grease emulsion, paint wastes, trichloroethylene (TCE), and polychlorinated biphenyl (PCB) fluids from transformers. The site was fenced in 1972 and much of the accumulated waste was removed from the site for off-base disposal. Since 1981 the site has been used as a staging area for dumpsters maintained for the disposal of items not accepted by the regular trash pickup, such as metal scrap, wood crates, and bundled cardboard.

The Privet Road Compound lies within a heavily developed section of the NAS JRB adjacent to Privet Road and the Air Reserve and Pennsylvania National Guard facilities. The bowling alley and associated parking area cover a significant portion of the ground surface south of the compound. The compound area contains

scattered piles of miscellaneous construction materials. The ground surface slopes at a grade of approximately two- percent toward the northwest.

1.1.1 Geology

NAS JRB Willow Grove is located within the Triassic Basin of southeastern Pennsylvania. The geologic interpretation of the former Fire Training Area is based on the subsurface data (boring logs and geophysical logs) obtained during the multiple phases of the site investigation.

The overburden at the Site 1 consists of sandy silt, silty sand, and silty clay. The thickness of the overburden (or the depth to the top of the weathered bedrock) ranges from approximately 4 feet in the vicinity east of Privet Road (01MW04) to about 9 feet in the northeastern corner of the compound (01MW01). Gravel-rich fill material was encountered within 2 feet of the surface at most locations within the former compound but was not encountered beyond the limits of the suspected waste area.

The bedrock underlying the site consists of the middle arkose member of the Stockton Formation, which locally is about 5,000 feet thick and is unconformably underlain by Ordovician to PreCambrian-age basement rocks. The maximum depth of the monitoring well boreholes at Site 1 is 100 feet. The bedrock to this depth typically consisted of alternating sequences of siltstone and fine- to medium-grained sandstone. Thin beds of shale and claystone were inconsistently encountered within the compound and the northern portion of the site area.

Driller's boring logs for Navy Supply Well No. 1 (396 feet deep) and Navy Supply Well No. 2 (351 feet deep) and the results of the borehole geophysical logging program (USGS, 2001) indicate that the lithology below the depth of investigation of the monitoring well network also is consistent with the regional geology and is generally similar to the lithology described from the shallower monitoring well boreholes. Overall, the rock becomes somewhat coarser grained with increasing subsurface depth, and the thickness of the individual lithologic units increases, especially below a subsurface depth of about 200 feet.

1.1.2 Hydrogeology

The major source of groundwater in the vicinity of NAS JRB Willow Grove is the fractured bedrock of the Stockton Formation (Earth Data, Incorporated, 1985). These rocks form a multi-aquifer system of relatively discrete water-bearing zones separated by less permeable zones. Transmissivity and groundwater movement within water-bearing zones are greater parallel to bedding than across bedding.

Although significant amounts of groundwater may be held in storage within the primary porosity of the fine- to medium-grained sandstones, groundwater migration is chiefly through the secondary porosity created by fractures and joints and along bedding-plane partings. The finer grained shale and siltstone beds typically have very low permeabilities. In addition, fractures and joints are typically not as well developed in these finer grained beds. Consequently, the shale and siltstone units often act as confining layers to groundwater flow.

Groundwater beneath the site occurs under unconfined and confined conditions. The transition from unconfined to confined conditions occurs between subsurface depths of approximately 40 feet to 70 feet. The confined conditions do not appear to result from a laterally extensive aquiclude or aquitard, but are believed to be the result of the weathering and resultant lower permeability of the shallower, fine-grained lithologic units. Vertical or nearly vertical fractures that cut across bedding and the weathering of various beds are expected to permit varying degrees of leakage between individual water-bearing zones, particularly at shallower depths.

Seven monitoring wells were installed during the Phase II RI investigation to further delineate the nature and horizontal and vertical extent of groundwater contamination at the site and to provide the additional hydraulic head data to refine the hydrogeologic interpretation of the site. Site 1 monitoring well locations are illustrated in Figure 1-3. Construction details for all existing monitoring wells are listed in Table 1-1.

1.1.3 Groundwater Occurrence and Flow Characteristics

The depth to groundwater throughout the site generally ranges from about 5 to 30 feet below the ground surface.

The groundwater flow directions in the vicinity of the site are influenced by the pumping of the two Navy supply wells, NSW1 and NSW2, which are located approximately 500 feet east and 500 feet southeast of the site, respectively. Under non-pumping conditions, groundwater flows in a generally north to northwestward direction in both the unconfined and the confined aquifers. Under pumping conditions, a large, laterally extensive drawdown cone is formed that captures groundwater from beneath the compound. The stagnation line for the drawdown cone is located near the northwestern boundary of the compound. Figures 1-4 and 1-5 show the potentiometric surface maps for unconfined and confined aquifers under non-pumping conditions, and Figures 1-6 and 1-7 show the potentiometric surface maps for the unconfined and the confined aquifers under pumping conditions.

Under non-pumping conditions the hydraulic head is higher in the confined aquifer than in the unconfined aquifer and the gradient between the two aquifers is upward. Under pumping conditions, however, the

hydraulic head is lowered in the confined aquifer so that in the vicinity of the compound the gradient between the two aquifers becomes downward. Groundwater in the unconfined aquifer may infiltrate the confined aquifer under pumping conditions.

1.1.4 Hydrology

NAS JRB Willow Grove is situated within an upland area that forms a local drainage divide between the Little Neshaminy Creek drainage basin to the north and the Pennypack Creek drainage basin to the south. Both of these local drainage basins lie within the regional drainage basin of the Delaware River.

Although a significant portion of the ground surface in the area of the site is covered by impermeable paving material, much of the precipitation during normal weather conditions is believed to infiltrate, due to the relatively gentle slope, intermittent vegetated areas, and the rutted and uneven nature of the ground surface in the compound area. Storm drainage swales parallel the northeastern and southeastern sides of the compound and intersect at the northern corner of the site. Runoff is prevented from entering the site from the south by grading and a storm drainage channel located along the southern side of Privet Road. Runoff from the compound that enters the drainage swales discharges to the Air Reserve Station storm water detention basin. Water flow from the storm water detention basin follows an unnamed tributary to Park Creek and enters the Little Neshaminy Creek drainage basin. Little Neshaminy Creek is stocked with trout.

The natural environment at NAS JRB Willow Grove has been altered by development since the facility was first commissioned as a military air station in 1942. Prior to becoming a military base, the facility served as an airport and was a center of private flight development operations. Buildings and paved roadways are concentrated mainly in the eastern portion of the facility. Due to the development on the Base, the land has not retained a natural vegetation cover. The vegetative communities that remain are limited and generally include lawn areas maintained by Base personnel, old field, immature forest, and wetland.

Wetland habitat is rare within the Base area. According to the National Wetlands Inventory map of this area (United States Department of Interior, undated); five wetlands exist on the Base. None of the wetlands is located in the immediate vicinity of Site 1.

1.2 PREVIOUS ENVIRONMENTAL INVESTIGATIONS AND RESPONSE ACTIONS

A complete discussion of the Site 1 groundwater investigations prior to, and including the Phase II Remedial Investigation can be found in the RI Report for Site 1 – Privet Road Compound (TtNUS, 2002). The results of the subsequent, follow-on investigations are each documented in their respective RI

Addendum reports. The following subsections present a brief summary and overview of the groundwater investigations.

1.2.1 Preliminary Assessment (PA) and Site Inspection (SI)

The Privet Road Compound was initially investigated in 1986 as part of a preliminary assessment (PA), formerly identified as the Initial Assessment Study (IAS), of NASJRB Willow Grove that was conducted under the Department of the Defense Installation Restoration Program (IRP). The Privet Road Compound was one of a total of nine potentially contaminated sites at NAS Willow Grove investigated during the PA, which consisted of a records search, personnel interviews, and a site reconnaissance. The sites were evaluated based on waste characteristics, potential migration pathways, and potential contaminant receptors. The Privet Road Compound was one of five sites recommended for a site inspection. The recommendation was based on the disposal of toxic substances at the site, the existence of a migration pathway for those substances, and the existence of contamination in the Base supply wells located 500 feet from the site. Sampling of the three Base supply wells (NW1, NW2, and AFW3) in 1984 revealed TCE concentrations ranging from 6.2 ug/l to 36.3 ug/l, PCE concentrations from 3.9 ug/l to 92.4 ug/l, and 1,1,1-TCA concentrations from 0.3 ug/l to 2 ug/l.

A Site Inspection (SI) was performed at the Privet Road Compound in 1989 (EA Engineering, 1990). Four monitoring wells were installed and sampled; three sediment samples were collected from drainage ditches bordering the northern and eastern boundaries of the site; and subsurface soil samples were collected from two soil borings and from the four monitoring well borings. All of the samples were analyzed for full TCL/TAL parameters, cyanide, TOC, and TPH. The groundwater samples contained TCE (up to 8 ug/l) and PCE (up to 110 ug/l) at concentrations above MCLs, and low concentrations of 1,1,1-TCA, 1,1-DCE, and 1,1-DCE. PCBs, dieldrin, and total lead were also detected in the groundwater samples. The soil samples contained PCBs, dieldrin, and DDT. The sediment samples contained PCBs and dieldrin; however, PCBs were also detected in the upstream sample. There were no VOCs detected in the subsurface soil samples or the sediment samples. The SI report recommended that an RI/FS be performed at the site based on the presence of groundwater contamination at levels above potential ARARs.

1.2.2 Phase I Remedial Investigation

A Remedial Investigation (RI) of Site 1 was conducted in two phases between 1991 and 2000. The purposes of the RI were to characterize the nature and extent of contaminants at Site 1, gain additional understanding of the physical parameters affecting contaminant fate and transport, and assess the current and potential human health and environmental risks associated with the site.

The Phase I RI activities were performed at Site 1 by Halliburton NUS in 1991 (HNUS, 1993). Eight additional monitoring wells, 01MW02I, 01MW04I, 01MW05S, 01MW05I, 01MW06S, 01MW06I, 01MW07S, and 01MW07I were installed. A total of twelve monitoring wells and four supply wells were sampled for TCL VOCs and TAL inorganics. Five surface water samples and five sediment samples were collected. The surface water samples were analyzed for TCL VOCs and TAL metals and the sediment samples were analyzed for TCL VOCs, TCL Pesticides/PCBs, and TAL inorganics.

1.2.3 Phase II Remedial Investigation

Phase II RI activities were performed by Brown and Root Environmental in 1996 (Brown and Root Environmental, 1997). A long term water level study was conducted to determine the effect of the pumping of the Navy potable supply wells on the groundwater flow regime. Seven additional wells, 01MW01SO, MW01S, MW01I, MW03I, MW08SO, MW08S, and MW08I were drilled and installed. The newly drilled boreholes were geophysically logged. Twenty-one monitoring wells and two production wells were sampled for TCL VOCs. Surface and subsurface soil samples were obtained from 28 locations and analyzed for TCL semivolatiles, dioxin, TCL PCBs, or PCBs using a field kit immunoassay depending on the data requirements for specific locations. Sediment samples were collected from five locations and analyzed for TCL semivolatiles, TOC, and grain size. Background surface soil, surface water, and sediment samples were also collected and analyzed.

All RI results are presented and discussed in the Site 1 RI report (TtNUS, February 2002).

1.2.4 Additional Investigations

In 1999, the Navy performed a soil removal action for PCB-contaminated soils. Soil was excavated and removed from an area 70 feet wide by 155 feet long adjacent to the bowling alley on Privet Road and from six nearby smaller contaminated areas. All soils containing PCBs at a concentration above 1ppm were removed.

Long term water level measurements and groundwater quality investigations in the Navy production wells were led by the United States Geological Survey in 2002.

1.3 NATURE AND EXTENT OF CONTAMINATION

This section evaluates all sampling data from the 1991 Phase 1 RI and the 1997 Phase II RI. Details of the samples collected (number of samples, location, sample identifier) during each phase are presented. Data were compared to ARARs and background, as detailed in Section 3.1 of the Draft Phase II RI report.

Twelve monitoring wells and four supply wells were sampled for TCL VOCs and TAL inorganics during the Phase I RI, and 21 monitoring wells and 2 supply wells were sampled for TCL VOCs during the Phase II RI. Table 1-2 presents the occurrence and distribution of inorganic and organic chemicals detected in groundwater samples and compares them to background. Table 1-3 presents the background comparison tests. Table 1-4 presents a comparison of detected compounds to ARARs and TBCs for selection of compounds of potential concern (COPCs). Figure 1-8 shows sample locations and concentrations of compounds that exceed human health risk-based screening levels.

1.3.1 Inorganics

During Phase I, several unfiltered groundwater samples exceeded regulatory criteria for various metals. A comparison of the unfiltered sample results with the filtered sample results revealed that most of these concentrations were the result of suspended solids and were not due to contamination of the groundwater. For the filtered samples, beryllium exceeded ARARs in five shallow zone wells and three intermediate zone wells (at concentrations ranging from 3 ug/l to 4 ug/l), manganese exceeded ARARs in one shallow zone well (981 ug/l), and arsenic and lead exceeded ARARs in one intermediate zone well (2 J ug/l and 17 ug/l, respectively). Arsenic and beryllium were also detected in production wells at concentrations exceeding ARARs and similar to the monitoring well concentrations. Statistical tests indicated that these inorganics were not present at levels above background, however.

1.3.2 Organics

Several VOCs were detected in the groundwater samples obtained during both phases of the RI. The most frequently detected compounds were PCE, ranging from 2 ug/l to 53 ug/l in 11 samples, and TCE, ranging from 1 ug/l to 120 ug/l in 26 samples. Figure 1-9 and 1-10 show the distribution of TCE concentrations in the unconfined and confined aquifers, respectively, and Figures 1-11 and 1-12 show the distribution of PCE concentrations in the unconfined and the confined aquifers, respectively.

In the shallow wells, only low levels of TCE (1 ug/l) and PCE (up to 5 ug/l) were detected, except for a TCE concentration of 18 ug/l detected in 01MW03S in 1991. During the Phase II sampling, however, TCE was not detected in this well. The highest concentrations of VOCs in the intermediate wells were at wells 01MW03I (TCE, 16 ug/l), 01MW06I (PCE, 11 ug/l; TCE 8 J ug/l) and 01MW07I (TCE, 37 ug/l). The intermediate well at the Air Force Reserve facility (01MWWW1B) showed the highest levels of TCE (22 ug/l) detected in that portion of the facility. The shallow well at that location showed 8 J ug/l.

The deeper portion of the confined aquifer is accessed by the Navy supply wells. The grab samples from Supply Well No. 1 (01MWNW1) contained concentrations of PCE at 36 ug/l and TCE at 6 J ug/l (Phase II), and PCE at 53 ug/l and TCE at 13 ug/l (Phase I). Supply well No. 2 (01MWNW2) contained TCE at 3 J ug/l and PCE at 2 J ug/l (Phase II) and TCE at 6 L ug/l and PCE at 4 J ug/l (Phase I). Packer tests conducted by the USGS results indicate that contamination is not evenly distributed throughout the boreholes. The deeper portions of both wells (below a subsurface depth of 182 feet bgs) are significantly more contaminated than the shallow portions.

1.4 CONTAMINANT FATE AND TRANSPORT

The principal contaminants associated with Site 1 groundwater are the VOCs TCE and PCE. Since these compounds were detected infrequently and at low concentrations in the site soils, the site does not appear to be a contributing source of the groundwater contamination at the present time. The actual source of the groundwater contamination is difficult to trace due to the complex hydrogeology and the effect of intermittent pumping of the two supply wells on the direction of groundwater flow. Based on the analytical and hydrogeological data gathered to date, however, it appears that the principal source is located upgradient of Site 1 and off-Base.

1.5 OFF-SITE GROUNDWATER CONDITIONS

The RI reviewed off-site groundwater conditions in order to determine whether site-related groundwater contamination had migrated to off-site receptors or if the site and the supply wells are being impacted by off-site groundwater contamination that is migrating on Base either through the ambient hydraulic gradient or by capture by the pumping of the Base supply wells. The review revealed that groundwater adjacent to the Base was contaminated with VOCs, primarily PCE, TCE, and 1,1,1-TCA, and that these contaminants occurred at concentrations and ratios similar to those found in the Navy supply wells. It was also discovered that the area geology and hydraulic gradients permit the migration of the VOC contaminants from the off-site locations toward the capture zone of the Navy supply wells, but conversely, it is not possible for any groundwater contamination that might originate at the Privet Road Compound to migrate toward and impact the areas where off-site contamination has been detected. Site 1 RI Addendum 5 - Groundwater Continuing Investigation (TtNUS (Draft) July 2007) presents an exhaustive discussion of the results obtained to date that implicate an off-Base source of PCE and TCE.

In 2005, the Navy performed an additional investigation to determine the quality of the groundwater migrating onto the base from upgradient, off-Base locations. Three new monitoring wells, 01MW09S, 01MW10S, and 01MW10D, were installed. 01MW09S was installed at a location in a direct line between the former Kellett facility and the Navy supply wells. 01MW10S and 01MW10D were installed at a

location geologically downdip of the former Kellett facility and generally along bedrock strike from the Navy supply wells. The wells were sampled for VOCs. The analytical results confirmed the RI conclusion that the VOCs detected in the Navy supply wells are not related to Site 1, but are migrating onto the station property from an upgradient, off-Base location. The full discussion of the results is contained in the Site 1 RI Addendum 5 - Groundwater Continuing Investigation (TtNUS, January 2008).

The ARS is a Department of Defense (DOD) Air Force facility that is contiguous with the NAS JRB and lies within the installation's fenced boundaries. Although EPA provides regulatory oversight to the ARS and the NAS JRB as a common Superfund site, these activities are operated by different defense services, Air Force and Navy, respectively. The ARS is not part of the NAS JRB, and is therefore considered to be off-Base relative to the Navy's property.

The ARS Site SD-4 (Aircraft Wash Rack/Trickling Filter Site) lies several hundred feet west of the Privet Road Compound (Figure 1). Unlike the Privet Road Compound Site where no historic investigation detected Target Compound List (TCL) VOCs contamination in subsurface soils, an ESI at ARS SD-4 detected PCE at 1 mg/kg in a subsurface soil sample. PCE and its breakdown product TCE have historically been detected in the monitoring wells at Site SD-4. The ground water extent of contamination at the ARS Site SD-4 and the impact to the Navy Supply wells from this source are unknown, at this time. Therefore, ARS SD-4 cannot be eliminated as a present or historic off-Base contributor of ground water contamination to the underlying aquifer.

1.6 SOURCE DELINEATION

Based on an analysis of the distribution of contamination in the unconfined and confined aquifers and on the interpreted groundwater flow directions under pumping and non-pumping conditions, the RI concluded that at least 3 (possibly 4) individual plumes may coalesce beneath the Privet Road Compound. The most significant source of VOCs is an off-Base source southeast of the Privet Road Compound, possibly in the vicinity of the former Kellett Aircraft Facility. This source creates a mixed TCE and PCE plume contributing to the deeper (>160 feet) groundwater contamination detected in the Navy supply wells. Three potential minor, on-Base sources of VOCs were identified:

- A potential source of PCE and TCE in the vicinity of Supply Well No. 1 or the Public Works Building.
- A possible minor source of TCE at the Privet Road Compound.
- A potential minor source of TCE southwest of the compound, in the vicinity or upgradient of the Navy Fuel Farm.

The delineation of potential sources in the vicinity of the Navy fuel Farm and the Public Works Building was constrained by the absence of monitoring wells at some locations. In 2003, the Navy installed additional monitoring wells to address these data gaps. Monitoring wells 10MW27 and 10MW28 were installed northeast of the Privet Road Compound in the immediate vicinity of Supply Well No. 1, and monitoring wells 10MW24, 10MW25 and 10MW26 were installed in the vicinity of the Navy fuel Farm. These wells were sampled for VOCs in June 2003 and September 2004. The interpretation of the analytical data from the new wells indicated that the source of the PCE in the unconfined aquifer at Site 1 was not in the vicinity of Supply Well No. 1 or the Public Works Building, and that the Fuel Farm is not a significant source of TCE. The interpretation supported the conclusion of the RI that the contamination in the confined aquifer at Site 1 is due to an upgradient, off-Base source, in the general vicinity of the former Kellett Aircraft facility. The full discussion of the results is contained in the Site 1 RI Addendum 3 for Groundwater – Privet Road Compound (TtNUS, 2005).

Due to the complex hydrogeology and the existence of multiple plumes, it is very doubtful that additional investigation would yield the identification or delineation of a Site 1-sourced plume, if one exists. In addition, even if Site 1 is, in fact, a minor contributor of VOCs, it would not be feasible (either technically or logistically) to treat the groundwater impacted by just this site.

The area of groundwater contamination that will be addressed by this FS is indicated in Figure 1-13. This consists of the area of the Base interpreted to be impacted by the contaminant plume that originates at the off-Base source.

1.7 RISK ASSESSMENT

A baseline human health risk assessment (HHRA) for the site was conducted in 1997 and included in the RI Report for Site 1 – Privet Road Compound (TtNUS, 2002) in order to characterize the potential risks to likely human receptors under current and potential land use. Potential receptors identified and retained in the HHRA for quantitative evaluation included current occupational workers, current adolescent and adult trespassers, future excavation workers, future recreational children, and future residents. This section summarizes the baseline human health risk assessment for Site 1 groundwater. Details of the methodologies and techniques used in the human health risk assessment for Site 1 can be found in Section 3 of the Site 1 RI Report (TtNUS, 2002).

A review and limited update of the 1997 HHRA was performed in 2005 and presented in the Site 1 RI Addendum 2 for Groundwater Technical Memorandum of Risk Assessment Evaluation (TtNUS, 2005). The review identified changes in the risk assessment methodology since the 1997 HHRA was prepared and discussed, in general, the impact the changes would have on the risk estimates presented in the

1997 HHRA. The review concentrated on the changes in the methodology for evaluating risks to hypothetical residents since these receptors were identified as the critical receptors in the 1997 HHRA. The list of Chemicals of Potential Concern (COPCs) for groundwater was updated using current USEPA Region 3 Risk Based Concentrations (RBCs) and USEPA Maximum Contaminant Levels (MCLs). The risk estimates for hypothetical residents exposed to groundwater were re-calculated following current risk assessment guidance.

1.7.1 Groundwater Chemicals of Potential Concern

The COPCs were selected in accordance with the protocol established in Section 3 of the Site 1 RI Report. Only those chemicals found to be of potential concern were considered for evaluation in the quantitative risk assessment. A discussion of those chemicals identified as COPCs is provided in this section. The following chemicals were selected as COPCs in groundwater:

Inorganics	Organics
Arsenic	Carbon tetrachloride
Barium	Chloroform
Chromium	TCE
Lead	PCE
Manganese	

The occurrence and distribution, COPC selection results, background comparisons, reference criteria comparisons, and representative concentrations for chemicals detected in Site 5 groundwater are presented in Table 1-4.

1.7.2 1997 Baseline Human Health Risk Assessment

A human health risk assessment was prepared as part of the Phase II RI to estimate the risks to human health resulting from the presence of contamination at the site. A human health risk assessment was not performed for surface water since no COPCs were identified for this medium.

Both carcinogenic and noncarcinogenic risks were assessed. Generally, carcinogenic risks between 10^{-4} and 10^{-6} are considered acceptable. A cumulative incremental cancer risk (ICR) greater than 1×10^{-4} generally indicates that some degree of remediation may be required, and a cancer risk below 1×10^{-6} normally will not result in remedial efforts. A cancer risk of 1×10^{-6} indicates one additional cancer case developing from 1,000,000 exposures under the defined scenario. Noncarcinogenic risk was assessed

using the concept of hazard quotients (HQs) and hazard indices (HIs). HIs were generated by summing individual HQs for contaminants of potential concern. An HQ exceeding unity (1) indicates that there may be potential noncarcinogenic health risks associated with exposure.

Two types of exposures were evaluated for the human health risk assessment. The reasonable maximum exposure (RME) represented the high end, but not usually worst-case, exposure in a given medium of concern. The central tendency exposure (CTE) represented the average exposure to receptors in a given medium of concern. CTE analyses were only performed for exposure pathways where the estimated RME cancer risk exceeded 1×10^{-4} and the RME non-cancer risk HI based on the same target organ group was above 1.

TCE and PCE are the risk-based organic chemicals of potential concern (COPCs) for contaminated groundwater. Arsenic, barium, beryllium, lead, and manganese also were at risk-based levels of concern and could not be conclusively attributed to background during the RI.

The potential receptor for exposure to groundwater at Site 1 consisted of hypothetical future adult residents for carcinogenic risk and hypothetical future adult and hypothetical future child residents for noncarcinogenic risk. Exposures to groundwater through direct ingestion, dermal contact while showering/bathing and inhalation of volatiles while showering/bathing were evaluated. Groundwater at Site 1 is currently used for human consumption (after VOC stripping tower treatment).

The RME and CTE carcinogenic risks for groundwater (untreated groundwater) for a future residential receptor were calculated as 4E-04 and 9E-05, respectively, both of which exceed or equal the EPA guideline maximum cancer risk range of 1E-04 to 1E-06. Beryllium and arsenic are the main contributors to the RME and CTE groundwater carcinogenic risk at Site 1 for the future residential receptor. The estimated RME and CTE HIs for the future adult resident were 1.58 and 1.11, respectively, and for the future residential child were 3.68 and 2.71, respectively. These non-cancer risks were primarily due to manganese via ingestion.

1.7.3 Updated Groundwater Risk Assessment

A review and limited update of the 1997 human health risk assessment of Site 1 groundwater was performed in 2005. The review identified changes in risk assessment methodology since the 1997 HHRA was prepared and recalculated the risk estimates for hypothetical residents exposed to groundwater following current risk assessment guidance.

The chemicals selected as COPCs for the updated assessment consisted of the VOCs carbon tetrachloride, chloroform, PCE, and TCE, and the inorganics arsenic, barium, chromium, lead, and manganese. These chemicals were chosen as COPCs if the maximum detected concentration exceeded the lesser of the USEPA Region 3 RBC and USEPA MCL. Concentrations of carbon tetrachloride, chloroform, arsenic, barium, chromium, and manganese exceeded the USEPA Region 3 RBCs but were less than the USEPA MCLs.

The cancer risk under the RME scenario for child residents (8E-05) was within USEPA's guideline maximum risk range of 1E-04 to 1E-06, that for adult residents (1E-04) was equal to the upper bound of the range, and that for the lifelong resident (2E-04) exceeded the maximum guideline risk range. Arsenic and PCE were the major contributors to the cancer risks for lifelong residents. The cancer risk under the CTE scenario for the child resident (2E-05), adult resident (2E-05), and lifelong resident (4E-05) were within the USEPA's guideline risk range.

The HI for adult residents (HI = 1) under the RME scenario was equal to the acceptable level of 1; the HI for child residents (HI = 3) exceeded unity although the HQs for the individual target organs were all less than unity. The HI for adult residents (HI = 0.6) under the CTE scenario was less than the acceptable level of 1; the HI for child residents exposed to groundwater (HI = 2) exceeded unity although the HQs for the individual target organs were all less than unity.

Hypothetical future residential exposures to lead in groundwater were evaluated using the Integrated Exposure and Uptake Biokinetic (IEUBK) lead model. The lead modeling results did not exceed the USEPA goal described in the 1994 OSWER Directive of no more than 5 percent of children exceeding a 10 ug/dL blood lead level.

The following are the main differences between the 1997 HHRA and the update:

- The cancer risks for lifelong residents are lower in the updated assessment. This is primarily because beryllium is no longer evaluated as a carcinogen for the digestion and dermal exposure pathways. (Beryllium was not chosen as a COPC for the updated assessment.)

- The HIs for child and adult residents are slightly lower in the updated assessment as a consequence of changes in exposure assumptions, exposure point concentrations, and toxicity criteria.

1.7.4 Ecological Risk Assessment Screening

Groundwater from Site 1 does not encounter surface water and has no impact on Site 1 ecology.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Remedial alternatives are developed by assembling combinations of technologies, applicable to the media to which they would be applied, into an appropriate range of alternatives that address site contamination, risks, or threats. This section presents the preliminary phase of the remedial alternatives development process, which consists of identification and screening of remedial technologies, and includes the following:

- Developing remedial action objectives (RAOs) that are protective of human health and the environment with regard to the contaminants and media of concern, exposure pathways, and the preliminary remediation goals (PRGs), which permit a range of treatment and containment alternatives to be developed.

- Developing general response actions for each medium of interest that define measures that may be taken singly or in combination to satisfy the RAOs for the site.

- Identifying the numbers, volumes, or areas of media to which the general response actions might be applied.

- Identifying and screening the technologies applicable to each general response action.

Section 2.1 presents a preliminary list of ARARs and other TBCs in the development of RAOs for Site 1 - Privet Road Compound. Section 2.2 briefly presents the overall approach used to develop RAOs. Section 2.3 summarizes the overall approach used in development of PRGs. Section 2.4 identifies the general response actions that may be implemented for NAS JRB Willow Grove Site 1 groundwater. The site-specific development of RAOs, PRGs, and general response actions and screening of remedial technologies and process options for Site 1 are presented in Section 2.6.

2.1 POTENTIAL ARARs AND TBCs

ARARs are promulgated, enforceable federal and state environmental or public health requirements that are determined to be legally applicable or relevant and appropriate to the hazardous substances, remedial actions, or other circumstances at a CERCLA site. The NCP Section 300.430 states that on-site remedial actions at CERCLA sites must meet ARARs unless there are grounds to invoke a waiver. A waiver is required if ARARs cannot be achieved. The two classes of ARARs, "applicable" and "relevant and appropriate," are defined below.

- **Applicable Requirements** - Section 300.5 of the NCP defines applicable requirements as those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. For example, if a new municipal landfill is being considered, then regulatory requirements that specifically govern its construction, operation, and closure are applicable.

- **Relevant and Appropriate Requirements** - Section 300.5 of the NCP defines relevant and appropriate requirements as those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. For example, a municipal landfill that was constructed and operated prior to the promulgation of landfill regulations may be closed in accordance with the "relevant and appropriate" requirements of those regulations that identify activities needed to close the landfill.

TBCs are non-promulgated advisories or guidance issued by federal or state governments that are not legally binding but may be considered during development of remedial alternatives. For example, EPA Health Advisories and reference doses are non-promulgated criteria that are used to assess health risks from contaminants present on CERCLA sites.

ARARs and TBCs are divided into three categories: chemical-specific, location-specific, and action-specific. In Sections 2.1.1.2 through 2.1.1.4, these categories are briefly described and general types of potential ARARs and TBCs that may be applied to the site are identified. The detailed discussions of the potential ARARs and TBCs for specific remedial alternatives are provided in Section 4.0.

2.1.1 Identification of ARARs and TBCs

Tables 2-1, 2-2, and 2-3 present a list of potential federal and state (i.e., commonwealth) of Pennsylvania chemical-, location-, and action-specific ARARs and TBCs that may be applicable to the selection and/or implementation of remedial measures at Site 1. Most of these ARARs and TBCs provide some medium-specific guidance on acceptable or permissible concentrations of contaminants.

Currently, the only enforceable federal regulatory standards for exposure to groundwater are EPA Maximum Contaminant Levels (MCLs). However, MCLs have not been specified for some of the compounds of potential concern (COPCs) encountered in Site 1 groundwater. Therefore, other

regulatory guidelines may be used for comparative purposes to determine health risks and environmental impacts. Federal relevant regulatory guidelines that are referenced include Maximum Contaminant Level Goals (MCLGs), Ambient Water Quality Criteria (AWQCs), and EPA Drinking Water Health Advisories (DWHAs). Pennsylvania relevant regulatory standards that are referenced include ACT 2 Human Health Standards for soils (residential and non-residential ingestion of soil and soil to groundwater pathway) and groundwater (groundwater aquifer ingestion) and Pennsylvania Code Title 25 Chapter 16 Water Quality Toxics Management Strategy (fish and aquatic life continuous criteria concentration and human health criteria).

Maximum Contaminant Levels (MCLs)

MCLs are enforceable standards promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with lifetime exposure (70 years) of an average adult (weighing 70 kilograms) consuming 2 liters of water per day, but they also reflect technical limits on removing the contaminant from water. These enforceable standards are also based upon the amount of toxicant that can be absorbed by the gastrointestinal tract.

Ambient Water Quality Criteria (AWQC)

AWQC were developed under the Clean Water Act and are not enforceable federal regulatory guidelines but are of primary utility in assessing the potential for toxic effects in aquatic organisms and human receptors. AWQC consider acute and chronic human health effects from ingestion of both water (2 liters per day) and aquatic organisms (6.5 grams per day). The AWQC may also be adjusted to consider ingestion of water alone (2 liters per day). The AWQC for protection of human health for carcinogenic substances is based on EPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 100,000 to 10,000,000 persons and is generally based on older toxicological data.

Clean Air Act

Clean Air Act - National Emissions Standards for Hazardous Air Pollutants (40 CFR, Part 61) set forth standards promulgated for air emissions from specific source categories. This act is related to any emissions from treatment equipment such as air strippers and soil treatment equipment.

Pennsylvania Regulatory Standards and Guidelines

Pennsylvania Safe Drinking Water Regulations (PA Code, Title 25, Chapter 109) set forth drinking-water-quality standards at least as stringent as the federal drinking water standards. MCLs that are promulgated by EPA are automatically incorporated in the Pennsylvania SDWA. If an MCL does not exist for a contaminant, the Pennsylvania SDWA requires the maximum allowable concentration to be determined in the following order: the concentration that EPA has proposed to set or is considered setting as a primary MCL for the contaminant; the concentration associated with a lifetime cancer risk of 10^{-6} for carcinogenic contaminants or the lifetime drinking water health advisory concentration for noncarcinogenic contaminants, provided that this concentration is equal to or greater than the practical quantitation level and the level achievable through the use of available treatment technology; or the lowest concentration achievable considering the practical quantitation level and available treatment technology.

Pennsylvania Land Recycling and Environmental Standards Act (ACT 2) is the primary law establishing the land recycling program and provides the foundation for standards, procedures, clean-up liability limits, and funding for environmental studies and cleanups. Persons who propose or are required to respond to the release of a regulated substance at a site and who wish to be eligible for clean-up liability protection must select and attain one or more of the environmental standards in ACT 2. The three types of clean-up standards are background, statewide health, and site-specific standards. Background is the concentration of a regulated substance that is present at a site but is not related to the release of regulated substances at the site. Statewide health standards consist of all numerical residential and non-residential standards adopted by the Pennsylvania Department of Environmental Protection (PADEP) and the federal government. Groundwater in aquifers intended for drinking or agricultural purposes is required to comply with the MCL or Health Advisory Level established for drinking water, except where naturally occurring groundwater has concentrations of total dissolved solids greater than 2,500 mg/L. Site-specific standards are developed using specific risk factors. For site remediation managed under Act 2, a Notice of Intent to remediate and public notice are required for cleanups planned to achieve background, statewide health, and site-specific standards. In addition, for cleanups to site-specific standards, there is a public comment period and public involvement.

During data evaluation for the draft RI report, interim Act 2 standards issued by PADEP (revision dated November 1996) were applied for comparison purposes. When available, final promulgated standards will supersede the interim PADEP guidelines.

Pennsylvania Water Quality Standards (PA Code, Title 25, Chapter 93) are based upon water uses that are to be protected and considered by PADEP in its regulation of discharges to surface water. The standards may be applicable for actions involving the discharge of pollutants to surface water.

Pennsylvania Water Quality Toxic Management Strategy - Statement of Policy (PA Code, Title 25, Chapter 16) specifies guidelines and procedures for the development of criteria for toxic substances and lists those limits that have been developed to date. The water quality criteria in Chapter 16 are the numeric limits for stream conditions that need to be maintained or attained to prevent or eliminate pollution and are designed to protect the water uses listed in Chapter 93.

Values of the available regulatory standards and guidelines are presented in Table 2-4. This table presents values for the COPCs that are human, probable human, or possible human carcinogens, for chemicals having only noncarcinogenic effects, and for chemicals having both carcinogenic and noncarcinogenic effects.

2.1.1.1 Potential Chemical-Specific ARARs and TBCs

Chemical-specific ARARs and TBCs are usually health- or risk-based numerical values that are used to establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the environment. In general, chemical-specific requirements are set for a single chemical or a close related group of chemicals. These requirements do not consider the mixture of chemicals. Typical chemical-specific ARARs are federal and state drinking water standards. Summaries of the potential federal and state chemical-specific ARARs and TBCs and their consideration in the FS are provided in Table 2-1.

Groundwater at Site 1 is currently used for drinking water by NAS JRB Willow Grove after treatment to remove VOC contamination. Groundwater for private and public water supplies is extracted from the aquifer in the vicinity of the Base. Federal chemical-specific ARARs such as the Safe Drinking Water Act (SDWA) MCLs [40 CFR 141], Clean Water Act (federal AWQCs for the Protection of Aquatic Life) [33 U.S.C. §1314], Clean Air Act (National Emissions Standards for Hazardous Air Pollutants) [40 CFR 61], and the EPA MCLs may be relevant and appropriate requirements in establishing groundwater clean-up levels. Non-zero MCLGs are non-promulgated health-based drinking water supply limits that are to be considered during the development of groundwater clean-up goals. EPA reference doses, carcinogen potency factors, and health advisories, when available, are all factors used to assess potential risks and can be used to derive risk-based clean-up limits. The disposal of contaminated soils may be restricted by Resource Conservation and Recovery Act (RCRA) Land Disposal Restrictions [40 CFR 268], which may potentially be applicable.

The following are TBC regulations that may affect remediation objectives: the Integrated Risk Information System (IRIS), Health Effects Assessments, EPA Health Advisories on Drinking Water, and the EPA Region 3 Risk-Based Concentration Tables.

IRIS is an EPA database containing up-to-date health risk and EPA regulatory information for numerous chemicals. IRIS contains only those reference doses (RfDs) and cancer slope factors that have been verified by the RfD or Carcinogen Risk Assessment Verification Endeavor Workgroups and is the preferred source of toxicity information. Health Effects Assessments determine the chemical-specific health effects that are based on non-enforceable toxicity data. The EPA Health Advisory on Drinking Water is a set of non-enforceable guidelines for public water supply systems. The EPA Region 3 Risk-Based Concentration Tables are non-enforceable guidelines primarily used for chemical screening during baseline risk assessments.

2.1.1.2 Potential Location-Specific ARARs and TBCs

Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because the substances or activities are in specific areas. The general types of location-specific ARARs that may be applied to the sites are briefly described below. Summaries of the potential location-specific ARARs and TBCs and their consideration in this FS are provided in Table 2-2.

Several federal and state regulations govern activities in wetlands and floodplains that may result in their degradation or impairment of their functions. Potential location-specific ARARs include Executive Orders 11990 and 11988 for wetlands and floodplains, respectively; the RCRA Location Standards governing the siting of treatment, storage, and disposal facilities in a 100-year floodplain; the Delaware River Basin Commission Ground Water Protected Area Regulations; National Environmental Policy Act; and the Clean Water Act. A potential location-specific TBC is the Ground Water Protection Strategy of 1984 [EPA 440/6-84-002].

The Endangered Species Act of 1978 [16 U.S.C. 1531; 50 C.F.R. Part 402] is a potential ARAR that protects wildlife and endangered species (if present or encountered) during remediation.

If historic or archeological artifacts are encountered during remediation, then the Archeological and Historic Preservation Act of 1974 [16 U.S.C. 469] may be a potential ARAR that would be invoked to prevent the loss of significant scientific, historical, or archeological data.

A cultural resources survey was conducted for the Navy at NAS JRB Willow Grove in April 1996. The objectives of the study were to evaluate Air Station buildings in terms of significance to the National Register of Historical Places Criteria for Evaluation and to assess the potential impact of Navy property to contain prehistoric and historic period archeological resources. The cultural resources study was performed under Contract N62472-94-D-1397. No buildings were found to be candidates for protection under the National Register of Historical Places and no prehistoric or historic period archeological resources were found.

The National Environmental Policy Act [40 C.F.R. Part 6 Appendix A] is a potential ARAR that may affect remediation within wetland areas. This act requires that any activity that may adversely affect wetlands will not be permitted unless there is no practicable alternative.

Another ARAR that may impact site remediation is the Delaware River Basin Commission (DRBC) Ground Water Protected Areas Regulations (GWPA) [18 C.F.R. Part 430]. The DRBC regulations establish requirements for the extraction of groundwater within the Delaware River Basin. Approval from the DRBC is necessary for all projects with groundwater extraction of 10,000 gallons per day in a groundwater-protected area (GWPA). All of Montgomery County is designated as a GWPA in accordance with DRBC Resolution No. 80-18.

The Ground Water Protection Strategy of 1984 identifies groundwater quality to be achieved during remedial actions based on aquifer characteristics and use.

2.1.1.3 Potential Action-Specific ARARs and TBCs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are generally focused on actions taken to remediate, handle, treat, transport, or dispose of hazardous wastes. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how certain activities within the alternative must be achieved. Summaries of the potential action-specific ARARs and TBCs and their consideration in the FS are provided in Table 2-3.

If site soils, sediments, buried materials, or treatment residues are determined to be hazardous by characteristic or are listed wastes (per RCRA Identification and Listing of Hazardous Waste [40 CFR 261]), then these action-specific ARARs may potentially be applicable to the how they are treated, stored, or disposed or to the treatment processes that are considered. These ARARs include federal regulations governing the off-site transport of hazardous wastes [40 CFR 262 and 263], general facility standards [40 CFR 265 Subpart B], preparedness and prevention [40 CFR 265 Subpart C],

contingency plan and emergency procedures [40 CFR 265 Subpart D], manifesting and recordkeeping [40 CFR 265 Subpart E], closure and post-closure of municipal landfills [40 CFR 258 Subpart F], land treatment [40 CFR 265 Subpart P], thermal treatment [40 CFR 265 Subpart X], and miscellaneous treatment units [40 CFR 264 Subpart X].

2.2 METHOD USED FOR DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

The development of the medium-specific RAOs for a site is typically based on the risks posed by site-related contaminants to human and ecological receptors, threats to or continued degradation of groundwater, and comparison of detected contaminant levels to available regulatory standards.

Generally, human health RAOs are formulated to prevent exposure to site-related contaminants that result in excess carcinogenic and non-carcinogenic health risks or to contaminants that exceed regulatory requirements (e.g., MCLs in potable water).

Ecological RAOs are formulated to reduce or prevent the detrimental effects of site-related contaminants on environmental media (e.g., degradation of groundwater quality) or to address contaminant concentrations that exceed regulatory standards.

RAO development for Site 1 is presented in Section 2.6.

2.3 METHOD USED FOR DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

The determination of numerical remediation goals is an iterative process beginning with the development of a range of medium- and chemical-specific contaminant levels that would be protective of human health or the environment if present in site soils and groundwater. Remediation goals that establish acceptable contaminant levels or ranges of levels that must be achieved under the remedial action are ultimately chosen from the range of PRGs when the remedy is selected.

Remediation goals for Site 1 groundwater were developed based on the RI human health risk assessment results of COPC selection and a comparison to chemical-specific ARARs. Additionally, background concentrations of COPCs and analytical detection limits were identified as potential PRGs to ensure selection of clean-up goals that are reasonably attainable and measurable. Typically, a promulgated regulated ARAR is selected as the proposed goal unless background levels or the analytical detection limit is higher. If no ARAR is available, then the higher of either the risk-based value or the maximum background value (inorganic) was selected, assuming that value was higher than the detection limit.

2.4 METHOD USED FOR DEVELOPMENT OF GENERAL RESPONSE ACTIONS

The RAOs were used to develop general response actions that describe medium-specific measures that will satisfy the RAOs. General response actions presented in Office of Solid Waste and Emergency Response (OSWER) Directive No. 9355.3-01, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, were evaluated for their applicability to each site's specific conditions, environmental media, the nature of the contaminants, and how the potential risks would be mitigated.

General response actions specific to Site 1 are presented in Sections 2.6 of this FS. General response actions that may be applicable to the contaminated groundwater include the following:

- No action
- Limited action (institutional controls)
- Containment actions
- Collection and discharge (clean groundwater only)
- Collection, treatment, and discharge actions
- In-Situ treatment

2.5 METHOD USED FOR IDENTIFICATION, SCREENING, AND EVALUATION OF REMEDIAL TECHNOLOGIES

During this phase of alternatives formulation, preliminary screening is performed to reduce the universe of potentially applicable technology types and process options. The purpose of screening is to investigate all available technologies and process options and to eliminate those obviously not applicable to specific conditions at each site, based on the established remedial action objectives and general response actions. The technology identification considers the demonstrated performance of each technology with site conditions and contaminants.

Potential remedial technologies and process options are identified and screened according to their overall applicability (technical implementability) to the media (soils, groundwater, etc.), primary contaminants of concern (volatile organic compounds), and conditions present at the site, including heterogeneous soils, leaching of contaminants to underlying groundwater, erosion and runoff of contaminated materials, vertical hydraulic gradients, etc.

A detailed evaluation of technologies and process options retained in the preliminary screening step is conducted to further focus the alternatives development process. In this step, process options are evaluated with respect to other processes in the same technology category. One representative process option is selected, if possible, for each technology type to simplify the subsequent development and evaluation of

alternatives without limiting flexibility during remedy selection or remedial design. The evaluation of technologies and process options utilizes three criteria: effectiveness, implementability, and relative cost. The Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (Interim Final), (EPA, 1988) suggests that this evaluation focus on the effectiveness criterion, with less emphasis directed at the implementability and relative cost criteria. Brief definitions of effectiveness, implementability, and relative cost, as they apply to the evaluation process, follow:

- Effectiveness - This criterion focuses on the potential effectiveness of process options in handling the estimated volume of media and meeting the remediation goals; the potential impacts to human health and the environment during construction and implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the site.

- Implementability - The implementability evaluation encompasses both the technical and institutional feasibility of implementing a process. Technical implementability was used in developing general response actions as an initial screen of technology types and process options, to eliminate those that are clearly ineffective or unworkable at a site. Therefore, this subsequent, more detailed evaluation of process options places greater emphasis on the institutional aspects of implementability, such as the ability to obtain permits, availability of treatment, storage, and disposal services, and availability of necessary equipment and resources.

- Cost - Cost plays a limited role in this screening. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to the other options in the same technology type. If there is only one process option, costs are compared to other candidate technologies.

2.6 SITE 1 TECHNOLOGY SCREENING

The selection of viable remedial technologies and process options for assemblage into remedial alternatives for Site 1 is presented in this section.

2.6.1 Site 1 Remedial Action Objectives

The results of the RI, previous investigations, and the human health and ecological risk assessments for Site 1 were evaluated to determine the remedial actions that may be needed to protect human health and the environment and then to develop the site-specific RAOs.

Human Health Protection Considerations

Exposure to contaminated groundwater may pose excess health risks to humans. Risk assessment results indicate that, under a future residential land use scenario, exposure to contaminated groundwater through ingestion, dermal contact, and inhalation poses potential risks that exceed the EPA's target risk range of 1 E-06 to 1 E-04 carcinogenic risk for the hypothetical lifelong resident. Therefore, preventative measures may be needed to mitigate potential human health risks through exposure to contaminated groundwater.

The site does not currently pose a threat to public health, since the site is under military control and the water drawn from the two Navy potable supply wells is treated by air stripping to remove VOCs. After Base closure, however, Site 1 may be considered for residential or commercial land use, which may lead to the unrestricted use of groundwater.

Ecological Receptors Risk Considerations

Contaminants transported in groundwater to surface water can be deposited subsequently in sediment or surface water and can potentially accumulate in the tissues of aquatic organisms. Groundwater beneath the site flows to the north or northwest towards Park Creek, which is approximately 5000 feet from the site. There is no evidence from the RI that groundwater discharges to Park Creek. Surface water samples collected downgradient from the Site 1 do not show site-related compounds. Therefore, ecological risk as a result of groundwater is very low.

Environmental Media Protection Considerations

Groundwater is contaminated with VOCs at concentrations in excess of health-based criteria, but the degree to which Site 1 is responsible for this contamination, if it is responsible at all, cannot be ascertained. The data indicate that most of the observed groundwater contamination is migrating from a source upgradient from Site 1, possibly located in the area of the former Kellett Aircraft Facility. The site itself is not a current source of groundwater contamination, although it cannot be ruled out as a potential historical source. Since it is not feasible technically or logistically to treat only that part of the contaminant plume caused by Site 1, and any action in that regard would not be effective unless the source of the contamination was adequately controlled, remedial actions involving treatment are not being considered as part of this FS. It should also be noted that, without source remediation, natural attenuation alone is not a viable option for contaminant mitigation.

RAOs Selection

Based on the reasons provided, the following remedial action objective has been selected:

Protection of Human Health RAO:

- Protect potential future receptors (potable water supply) from regular ingestion of groundwater contaminated with chlorinated hydrocarbons at concentrations greater than ARARs.

2.6.2 Site 1 Preliminary Remediation Goals (PRGs)

Since clean-up measures or monitoring are not being considered in this FS, PRGs are not applicable and were not developed. Site 1 COPCs from Table 1-4, and the ARARs were reviewed to determine the extent of contaminated groundwater requiring institutional control. Only groundwater is a concern, no COPCs for soils were identified since site-related contaminants are not present in soil at concentrations that pose human health or ecological risks. The organics and metal contaminants in groundwater that would contribute to excess human health carcinogenic risk (greater than 1 E-04 total) or HI (greater than 1.0) were selected as human health risk-based COPCs. PRGs for groundwater contaminants used the applicable numerical values, risk-based groundwater concentrations that do not result in carcinogenic risks exceeding 1 E-06 or HI greater than 0.1, and maximum detected background concentrations. A set of proposed Site 1 COPCs for groundwater is presented in Table 2-4, along with the basis for their selection. These proposed groundwater COPCs can be used to delineate the volume of contaminated groundwater that may need to be evaluated for proposed remedial action.

2.6.3 Site 1 General Response Actions

The following general response actions were selected based on the RAO for Site 1.

- No action
- Institutional controls (limited action)

General response actions considered were confined to those that address potential human exposure to groundwater. General response actions that include remediation of contaminated groundwater or the prevention of migration of contaminated groundwater were not considered.

2.6.4 Site 1 Identification and Screening of Technologies and Process Options

Table 2-5 presents a summary of potential remedial technologies and process options that apply to the Site 1 RAO and general response actions. Screening of the remedial technologies considered their overall applicability to the media of concern, primary contaminants (VOCs), known site conditions, and planned use of the site. During the screening step, process option and entire technology types were eliminated from further consideration on the basis of technical implementability. Site conditions that were considered included the presence of a VOC plume in groundwater underlying a portion of the Base in the vicinity of Site 1. The preliminary focused screening and evaluation of groundwater response technologies is presented in Table 2-5.

2.6.5 Summary of Site 1 Selected Remedial Technologies and Process Options

Table 2-5 identifies the remedial technologies that were retained after the focused evaluation process. Technologies and process options that are not likely to be implementable or effective or that would result in higher implementation costs were eliminated from further consideration. Site-specific considerations were also factors in the elimination of candidate technologies and process options. For contaminated groundwater, the following technology types and process options were retained:

- No action
- Limited action
  - Deed restrictions

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

The purpose of the alternative development and screening process is to assemble an appropriate range of possible remedial options to achieve the RAOs identified for the site. In this process, technically feasible technologies retained for further evaluation from Section 2 are combined to form remedial alternatives that provide varying levels of risk reduction.

3.1 SITE 1 - DEVELOPMENT AND SCREENING OF ALTERNATIVES

Section 3.1.1 presents the rationale for development of remedial action alternatives for Site 1. Section 3.1.2 describes the assembled alternatives. Section 3.1.3 presents the screening of alternatives. Detailed evaluations and costing of the retained alternatives are presented in Section 4.0.

3.1.1 Site 1 - Rationale for Development of Alternatives

Factors considered in formulating the remedial alternatives to address the RAOs for Site 1 are discussed below:

Protection of Human Health Considerations - The RAO for protection of human health specifies preventing human exposure to contaminated groundwater. This objective has been addressed in the formulation of remedial alternatives.

Protection of the Environment Considerations – There is no RAO for protection of the environment because Site 1 has no impact on groundwater contamination in the area.

Navy/Marine Corps policy (as stated in the Installation Restoration Manual) dictates that the procedures outlined in the National Oil and Hazardous Substances Contingency Plan (NCP, 40 CFR 300.430) be followed for all IR sites. In accordance with this policy, alternatives development for Site 1 was conducted in compliance with statutory requirements of the NCP and in consideration of the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final) (RI/FS Guidance), OSWER Directive No. 9355.3-01, EPA/540/G-89/004, October 1988.

The NCP and the EPA RI/FS guidance present a broad framework for the formulation, evaluation, and selection of remedial alternatives for uncontrolled hazardous waste sites. The NCP encourages development of a range of treatment alternatives, including one or more engineering control alternatives (such as containment), one or more innovative treatment alternatives, and the baseline no-action alternative. Treatment technologies are favored to address principal threats and engineering controls are favored to address relatively low long-term threats. In this case, since the source of groundwater contamination is known to be off-Base, a focused set of response actions has been developed.

3.1.2 Site 1 - Remedial Alternatives Descriptions

This section presents detailed descriptions of the remedial alternatives for Site 1. The key components of the two alternatives are identified on Table 3-1.

3.1.2.1 Alternative 1: No Action

The no-action alternative is developed as a baseline case, as required by the NCP. The only activity conducted under this alternative is a review of site conditions and risks every 5 years.

The purpose of the no-action alternative is to evaluate the overall human health and environmental protection provided by the site in its present state. Under this alternative, no remedial actions would be taken to protect human health or the environment. No measures would be implemented to remove or contain the groundwater VOC plume, to prevent potential human exposure to site groundwater, or to mitigate contaminant migration in the environment. Key components of Alternative 1 are identified on Table 3-1 and described below. The cost estimate for Alternative 1 is provided in Appendix A.

Existing Features - Currently, site features offer limited protection of human health and the environment. The primary protective features are that the site is under military control and the groundwater underlying Site 1 is treated to remove contamination prior to its use as a potable water supply. As a result, there is currently no pathway for human exposure to VOC-contaminated groundwater. However, following Base closure, site groundwater could conceivably be used as a potable water supply without being treated, posing a potential excess human health risk.

Five-Year Reviews - Since contaminants remain on the site, a review of site conditions and risks would be conducted every 5 years, as required by CERCLA. The reviews would consist of evaluation of analytical and hydrogeologic data, assessing whether contaminant migration has increased, and determining whether human or biological receptors or natural resources are at risk.

3.1.2.2 Alternative 2: Limited Action

Alternative 2 was developed as an alternative that involves no treatment but provides protection to human health through the establishment of land use controls to limit human exposure to contaminants. The activities that would be conducted under this alternative include the implementation of institutional controls and a review of site conditions and risks every 5 years. Key components of Alternative 2 are identified in Table 3-1. The cost estimate for Alternative 2 is provided in Appendix A.

Institutional Controls - Land use restrictions would be incorporated by local Base Instruction to restrict the use of site groundwater prior to the closure of the Base and transfer of the property.

In the event that the affected property is transferred to another federal agency, this institutional control would be included in the Department of Defense Form 1354, Transfer and Acceptance of Military Real Property. This agreement transfers care and custody of real property owned by the Department of Defense to other federal agencies. The receiving agency would be bound by the same environmental restrictions as the Navy. These restrictions will be identified in an Environmental Summary Document, which will be incorporated by reference into the transfer agreement.

Institutional controls would consist of deed restrictions that would prohibit the use of untreated groundwater for drinking if the property is transferred to a non-Federal entity.

Five-Year Reviews - Since contaminants remain on site, a review of site conditions and risks would be conducted every 5 years, as required by CERCLA. This requirement would be transferred to the property recipient upon transfer.

3.1.3 Site 1 - Alternatives Screening

In the screening process, alternatives are evaluated generally with regard to effectiveness, implementability, and cost. The purpose of the evaluation is to control the number of alternatives that will undergo a more thorough and extensive analysis so that the detailed evaluation in Section 4 focuses on the most plausible array of remedial alternatives. If possible, the alternatives carried forward for detailed evaluation should include the full range of alternatives recommended in the NCP and EPA RI/FS Guidance: no action, treatment, and containment.

The alternative screening process for Site 1 resulted in both of the identified alternatives being retained for further evaluation. The complete results of the alternatives screening evaluation for Site 1 are presented in Table 3-2.

4.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives developed in Section 3.0 were analyzed in accordance with the NCP and EPA guidance. The evaluation criteria according to the NCP are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs and TBCs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

Under the NCP, the selection of the remedy is based on the nine evaluation criteria, which are categorized into three groups:

- Threshold Criteria – These criteria must be satisfied in order for an alternative to be eligible for selection. The threshold criteria are overall protection of human health and the environment and compliance with ARARs.

- Primary Balancing Criteria – The balancing criteria are used to weigh the relative merits of alternatives. The five criteria that are included are long-term effectiveness and permanence, the reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, implementability, and cost.

- Modifying Criteria – State acceptance and community acceptance are considered to be modifying criteria that must be considered during remedy selection. These last two criteria cannot be evaluated in this FS until a preferred remedy has been presented.

Brief, general discussions of the evaluation criteria are presented in the following text. Detailed analyses of the remedial alternatives using seven of the evaluation criteria and a comparative analysis of the remedial alternatives are presented in this section.

4.1 DESCRIPTION OF EVALUATION CRITERIA

Overall Protection of Human Health and the Environment

Alternatives must be assessed for adequate protection of human health and the environment. Overall protection draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. The evaluation focuses on whether a specific alternative achieves adequate protection, how risks are eliminated, reduced, or controlled, and whether remedial action objectives would be achieved.

Compliance with ARARs AND TBCs

Alternatives must be assessed to determine whether they attain applicable and appropriate requirements under federal and state environmental laws or facility siting laws. If one or more regulations that are applicable cannot be complied with, then a waiver must be invoked. Grounds for invoking a waiver would depend on the following circumstances:

- The alternative is an interim measure and will become part of a total remedial action that will attain the ARAR.
- Compliance will result in greater risk to human health and the environment.
- Compliance is technically impracticable from an engineering perspective.
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.
- A state requirement has not been consistently applied or the state has not demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other remedial actions within the state.

Long-Term Effectiveness and Permanence

Alternatives must be assessed for the long-term effectiveness and permanence they offer, along with the degree of certainty that the alternative will prove successful. Factors that will be considered as appropriate are as below:

- Magnitude of Residual Risk – Assesses the risk posed by untreated waste or treatment residuals at the conclusion of the remedial activities. The characteristics of residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- Adequacy and Reliability of Controls – Assesses controls such as containment systems and institutional controls that are necessary to manage treatment residuals or remaining untreated wastes and their reliability, in particular the uncertainties associated with land disposal for providing long-term protection from residuals, the assessment for the potential need to replace technical components of the alternative, and the potential exposure pathways and risks posed should the remedial action need replacement.

Reduction of Toxicity, Mobility, or Volume through Treatment

The degree to which the alternative employs recycling or treatment that reduces the toxicity, mobility, or volume will be assessed, including how treatment is used to address the principal threats posed by the site. Factors that are considered, as appropriate, include the following:

- The treatment processes that the alternative employs, the media they would treat, and threats addressed.

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled.

- The degree of expected reduction in toxicity, mobility, or volume as a result of treatment.

- The degree to which the treatment is irreversible.

- The type and quantity of residuals that would remain following treatment, considering the persistence, toxicity, mobility, and bioaccumulation capacity of the contaminants of concern and impacted media.

- The degree to which treatment reduces the inherent hazards posed by principal threats at the site.

Short-Term Effectiveness

The assessment of short-term effectiveness during construction or implementation until the RAOs are met includes consideration of the following factors:

- Short-term risks that might be posed to the community during implementation.

- Potential impacts to and protection of the workers during remedial actions.

- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation.

- Time until the RAOs are achieved.

Implementability

The ease or difficulty of implementing the alternatives will be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions).

- Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; and availability of prospective technologies.

Cost

A detailed cost analysis is performed for each alternative to assess the net present-worth cost to implement the remedial action. The analysis includes an estimation of capital costs (direct and indirect), annual operation and maintenance (O&M) costs, and the net present value of the capital and O&M costs. Typically, the cost estimate accuracy range is plus 50 percent to minus 30 percent.

State Acceptance

PADEP has been providing input during the RI phase and will continue during the FS and public comment period. The state's concerns that must be assessed include the following:

- The state's position and key concerns related to the preferred alternative and other alternatives.
- State comments on ARARs or the proposed use of waivers.

These concerns cannot be evaluated at this time in the FS until the Navy issues the Proposed Plan and the state has reviewed and commented on the RI/FS. State concerns may be discussed, to the extent possible, in the Proposed Plan to be issued for public comment.

Community Acceptance

This criterion refers to the community's comments on the remedial alternatives under consideration. NAS JRB Willow Grove has an active Restoration Board (RAB) that consists partly of community representatives, that meets regularly to review developments of the Installation Restoration (IR) Program. RAB members have the opportunity to review documents and presentations from Navy and regulatory representatives during the EPA-prescribed RI/FS process. Comments from community RAB members are encouraged and these comments are considered in the development of RI/FS documents. In addition, general public community concerns or comments will be addressed after the public comment period, which follows the release of the RI/FS report and the Proposed Plan. As a result, this FS does not provide any discussion regarding the community acceptance of the remedial alternatives.

4.2 INDIVIDUAL ANALYSIS OF SITE 1 ALTERNATIVES

Detailed evaluations of the two Site 1 remedial alternatives retained for further evaluation are presented in this section. Detailed cost estimates and assumptions for each alternative are presented in Appendix A.

4.2.1 Alternative 1: No Action

The no-action alternative was developed as a baseline case, as required by the NCP. The only activity conducted under this alternative is a review of site conditions and risks every 5 years.

Overall Protection of Human Health and the Environment

The no-action alternative would provide only limited protection of human health and the environment. The site does not currently pose a threat to human health since groundwater use is restricted to the Navy potable water supply system, in which groundwater is treated to remove VOCs. Under a future residential or commercial land use scenario, however, exposure to untreated contaminated groundwater would pose potential carcinogenic and non-carcinogenic risks exceeding EPA's target risk range (carcinogenic risk greater than 1 E-04 and HI greater than 1.0). Alternative 1 does not include implementation of institutional controls to restrict use of contaminated groundwater in the event of future change in land or groundwater use. Long-term review would make it possible to evaluate site conditions and risks on a regular basis.

Compliance with ARARs and TBCs

This alternative would not comply with chemical-specific ARARs or TBCs because no action would be taken to reduce contaminant concentrations. Groundwater contaminant levels beneath the site would continue to exceed federal and state drinking water criteria and no actions would be taken to restrict use or obtain a waiver for technical impracticability of groundwater restoration. No action- or location-specific ARARs or TBCs are applicable because no remedial actions would be taken.

Long-Term Effectiveness and Permanence

This alternative would have limited long-term effectiveness or permanence since it would not remedy the underlying aquifer or prevent on-site exposure to contaminated groundwater. Because no institutional controls would be implemented to prohibit use of untreated contaminated groundwater, the risk to potential future residential users of the groundwater would remain. Five-year reviews would be required to assess whether threats or risks are increasing or abating with time in light of future land use or changes in the conditions at the site.

No controls would be used to manage Site 1 groundwater under the no-action alternative; therefore, the evaluation of the adequacy and reliability of controls is not applicable.

Reduction of Toxicity, Mobility, or Volume through Treatment

The no-action alternative would not reduce the toxicity, mobility, or volume of contamination through treatment, since no treatment is used to address the contaminated groundwater. For reasons previously discussed, however, treatment is not considered an applicable remedial action alternative for this site.

Short-Term Effectiveness

Short-term effectiveness is not relevant to this alternative since no remedial action would be performed that could create additional short-term risks to the community or future on-site workers. Current risks would remain unchanged.

Implementability

Since no response activities would occur, the no-action alternative is readily implementable. The technical feasibility criteria, including constructability, operability, and reliability, are not relevant to this alternative. Five-year reviews would pose no implementability concerns. Additional actions can be easily implemented in the future, if warranted.

Permits would not be required under Alternative 1. Coordination with other agencies may be required as part of the 5-year review process.

Regulatory personnel and environmental specialists are readily available to perform the 5-year reviews effectively.

Cost

No capital costs are associated with the no-action alternative. The cost for 5-year reviews is $20,000 per event. Over a 30-year period, the net present-worth cost is $43,156 (at a 7 percent discount rate).

4.2.2 Alternative 2: Limited Action

Alternative 2 is a low-cost remedial alternative that aims to protect human health through institutional controls. Under this alternative, institutional controls would be implemented to prevent exposure to contaminated groundwater. Because contaminants remain on site, a review of site conditions and risks would be conducted every 5 years, as required by the NCP.

Overall Protection of Human Health and the Environment

The site does not currently pose a threat to human health since groundwater use is restricted to the Navy potable water system, in which groundwater is treated to remove VOCs. Institutional controls restricting future groundwater use would be protective of human health by preventing unacceptable risks to residents from direct exposure to contaminated groundwater. The effectiveness of this protection would

depend entirely upon adequate enforcement. If groundwater use restrictions were not adequately enforced, there would be potential health risks.

Compliance with ARARs

This alternative would not comply with chemical-specific ARARs or TBCs because no action would be taken to reduce contaminant concentrations. Groundwater contaminant levels beneath the site would continue to exceed federal and state drinking water criteria and no actions would be taken obtain a waiver for technical impracticability of groundwater restoration. No action- or location-specific ARARs or TBCs are applicable because no remedial actions would be taken.

Long-Term Effectiveness and Permanence

Alternative 2 should provide adequate long-term effectiveness and permanence. Although groundwater COCs concentrations would not be actively reduced, risks to human health would be minimized through institutional controls. The long-term effectiveness of institutional controls, including deed notices and local ordinances, would be based on the ability to enforce these controls on the part of the municipal authorities.

Because contaminants would remain in groundwater, 5-year reviews would be required to assess contaminant migration, changes in site conditions, and changes in risks.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 would not reduce the toxicity, mobility, or volume of contamination through treatment because treatment is not employed. As a result, no hazardous substances would be specifically treated, recycled, or destroyed. Natural attenuation would continue mitigating contaminant concentrations since the off-site source of the contamination has not been remediated.

Alternative 2 would not satisfy the statutory preference for remedies that employ treatment as a principal element. For reasons previously discussed, however, treatment is not considered an applicable remedial action alternative for this site.

Short-Term Effectiveness

Implementation of institutional controls would not adversely impact the surrounding community or the environment. The RA objective would be achieved upon implementation of institutional controls.

This alternative would be implemented shortly after signing the Record of Decision.

Implementability

Alternative 2 is readily implementable. While the Base is operational, incorporating land use restrictions into the Base Master Plan should not be difficult to implement and enforce, since the site is part of an active Navy facility and coordination with other agencies and property owners would not be necessary.

After Base closure, deed restrictions would not be difficult to implement. The enactment and enforcement of local ordinances regarding the installation and use of private wells would depend on local municipalities.
Regulatory personnel and environmental specialists are readily available to perform effective 5-year reviews.

Cost

The capital costs for implementing Alternative 2 total an estimated $6,897. The cost for 5-year reviews is estimated at $20,000 per event. Over a 30-year period, the net present-worth cost is estimated to be $50,054.

4.2.3 Comparative Analysis of Site 1 Alternatives

As part of the detailed analysis, comparisons of the remedial alternatives are made to identify differences between the alternatives and how site contaminant threats are addressed. The two alternatives are compared with respect to each of the evaluation criteria, and differences are identified. Table 4-1 presents summaries of the comparative analysis for each alternative.

Overall Protection of Human Health and the Environment

Alternative 1 would provide little additional protection of human health or the environment because no actions would be taken to prevent human exposure to groundwater or to mitigate migration of contaminated groundwater.

Alternative 2 would provide protection of human health through implementation of groundwater use restrictions. The effectiveness of this alternative for interim protection of human health would be dependent on enforcement of institutional controls.

Compliance with ARARs

Neither of the alternatives would comply with the ARARs for attainment of groundwater quality criteria; however, Alternative 2 would implement institutional controls on the use of groundwater from Site 1 to prevent the use of untreated groundwater.

Because no wetlands, floodplains, water bodies, or other sensitive receptors are believed to be present at Site 1, no location-specific ARARs were identified for this site.

Because no actions would be implemented, no action-specific ARARs were identified for either of the two alternatives.

Long-Term Effectiveness and Permanence

Alternative 1 would provide little additional protection of human health. Alternative 2 offers long-term protection of human health through the use of institutional controls that place limitations on use of contaminated groundwater as drinking water. The effectiveness of these controls depends on enforcement. If groundwater use restrictions were not enforced, protection of human health would not be achieved.

5-year reviews would be required for both alternatives to assess changes in site conditions and groundwater use.

Reduction of Toxicity, Mobility, or Volume through Treatment

Neither Alternative 1 nor Alternative 2 would reduce groundwater contamination through treatment. Until the contaminant source has been remediated, the reduction of groundwater contamination through natural processes would continue.

Short-Term Effectiveness

Since no active response actions would be implemented under Alternative 1, no additional short-term impacts would be anticipated for this option. The implementation of institutional controls and monitoring under Alternative 2 would not adversely impact the surrounding community or the environment.

Implementability

Since no response activities would occur, Alternative 1 is simplest to implement. The deed notices and local ordinances under Alternative 2 are relatively easy to develop, but implementing and consistently enforcing institutional controls may be difficult.

For both alternatives, regulatory and technical personnel are available to perform the 5-year reviews effectively.

Cost

The costs associated with each alternative are provided in Table 4-1. Alternative 2 would cost only slightly more to implement than Alternative 1.

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TABLES

TABLE 1-1
WELL CONSTRUCTION DETAILS
SITE 1 – PRIVET ROAD COMPOUND
NAS JRB WILLOW GROVE, PENNSYLVANIA

Monitoring Well	Well Depth (feet bgs)	Screen Interval (feet bgs)
01MW01SO	18	8 – 18
01MW01S	33	23 – 33
01MW01I	85	75 – 85
01MW02S	27	7 – 27
01MW02I	88	78 – 88
01MW03S	26.5	6.5 – 26.5
01MW03I	79	69 - 79
01MW04S	35	15 – 35
01MW04I	90	80 – 90
01MW05S	38.5	18.5 – 38.5
01MW05I	85	75 – 85
01MW06S	26	6 – 26
01MW06I	84.5	74.5 – 84.5
01MW07S	26	6 – 26
01MW07I	84	74 – 84
01MW08SO	17	7 – 17
01MW08S	34	24 – 34
01MW08I	86	76 – 86
01MWWW1	29	9 – 29
01MWWW1B	100	80 – 100
01MWW2	21.7	? – 21.7 (toc)
01MWW3	21.95	? – 21.95 (toc)

TOC = Top of casing bgs = Below ground surface
* = Wells installed as part of the Site 3 RI, but also applicable to Site 5.

Table 1-2
Occurrence and Distribution of Organics and Inorganics in Groundwater, Site 1
NAS JRB Willow Grove, Pennsylvania

	Background Data					Site-Related Data					
Substance	Freq. of Detection	Range of Positive Detection Min.	Range of Positive Detection Max.	Mean of All Data	Sampling Round and Location of Maximum	Freq. of Detection	Range of Positive Detection Min.	Range of Positive Detection Max.	Mean of All Data	Sampling Round and Location of Maximum	Representative Concentration
aluminum		-				4/11	85 -	3430	405	09/23/9 01MW05S-F	1760
arsenic		-				2/14	4 -	4.2	1.44	10/08/9 01MWNW1B	1.88
barium		-				13/13	17 -	287	122	09/30/9 01MWNW2B	287
beryllium		-				6/6	3 -	4	3.67	09/24/9 01MW07I-F	4
calcium		-				16/16	12400 -	45400	31400	10/08/9 01MWNW1A	35800
chromium		-				1/10	18 -	18	4.95	09/23/9 01MW05I-F	6.95
cobalt		-				2/16	10 -	17	6.06	09/23/9 01MW05S-F	7.07
copper		-				1/1	37 -	37	37	09/23/9 01MW05S-F	37
iron		-				2/2	247 -	576	412	09/24/9 01MW02I	576
lead		-				11/16	1 -	18	2.92	09/23/9 01MW04I	6.08
magnesium		-				16/16	3780 -	27300	12100	10/08/9 01MWNW1A	15800
manganese		-				12/12	6 -	981	208	09/23/9 01MW05S-F	981
nickel		-				2/6	14 -	26	10.7	09/23/9 01MW04S-F	24.8
potassium		-				9/16	2180 -	38700	5750	09/23/9 01MW05I-F	11200
sodium		-				16/16	9840 -	28500	16100	09/24/9 01MW06S-F	18500
zinc		-				5/5	2 -	65	32	09/23/9 01MW05S-F	59.2
1,1,1-trichloroethane		-				2/39	1 -	3	3.95	09/24/9 01MW06I	3
1,1-dichloroethane		-				1/39	2 -	2	3.96	09/24/9 01MW03S	2
carbon tetrachloride		-				3/39	2 -	7	4.06	09/24/9 01MW07I	4.56
tetrachloroethene		-				11/33	2 -	53	7.94	10/07/9 01MWNW1A	9.2
toluene		-				5/39	1 -	6	4.04	09/23/9 01MW04I	4.63
trichloroethene		-				26/39	1 -	120	9.59	09/24/9 01MW07I	12

Notes:

Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95 % UCL, which is presented in a separate table.
Frequency of detection refers to number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.

Table 1-3
Background Comparison Tests - Groundwater Data for Site 1
NAS JRB Willow Grove, Pennsylvania

Name of Test:		Detection Freq: Z or Fisher				95 % Upper Tolerance Limit (UTL)							Upper Ranks				Mann-Whitney/Gehan				Student's or Satterthwaite T-test					Bartlett's Test for Equal Standard Deviations						
Question Posed:		Site Freq. > Back.Freq.?				Site Maximum > UTL for Background Data ?							Majority are site?				Ranks of Site > Back?				Site Mean > Back. Mean ?					Site Standard Deviation =Background Std.Dev.?						
Assumptions Valid:		#ND & Pos.>=5 or use Fisher				Back. lognorm. or norm. If not, #b>18 for Quantile Test							# Site (s) in Top r				<40% ND or use Gehan				#s>2,#b>2,>=85% Pos; both norm/log					#s>2,#b>2, site & back both normal or both lognorm.						
Test Criterion:		P value <= 0.05 ?				Max >95% UTL (parametric). Or, Max >95% Quantile							P<=0.05 that #s>=k				P value <=0.05 ?				t-Value > t-Table					F-Value<=F-Table (Students T). If not, Satterthwaite						
Conclusion: Site > Back?	YN	Back.	Site	P	YN	Back.	Std.Dev.	t	L,N	Back.	Site	YN	r	k	P	YN	P	Test	Used	YN	Back.	Site	t	t	YN	Back.	Site	Std.Dev.	Std.Dev.	F	F	YN
Substance		Freq.	Freq.	Value		Mean@	Back.@	Value	Q	UTL	Max.				Value		Value				Mean@	Mean@	Value	Table		Distrib.	Distrib.	Back.@	Site@	Value	Table	
aluminum	N	0/0	4/11		NA						3430	NA				NA				NA		405			NA		nonpar.					NA
arsenic	N	0/0	2/14		NA						4.2	NA				NA				NA		1.44			NA		nonpar.					NA
barium	N	0/0	13/13		NA						287	NA				NA				NA		4.37			NA		lognor.		1.06			NA
beryllium	N	0/0	6/6		NA						4	NA				NA				NA		3.67			NA		nonpar.					NA
calcium	N	0/0	16/16		NA						45400	NA				NA				NA		31400			NA		normal					NA
chromium	N	0/0	1/10		NA						18	NA				NA				NA		4.95			NA		nonpar.					NA
cobalt	N	0/0	2/16		NA						17	NA				NA				NA		6.06			NA		nonpar.					NA
copper	N	0/0	1/1		NA						37	NA				NA				NA		37			NA		unknow.					NA
iron	N	0/0	2/2		NA						576	NA				NA				NA		412			NA		unknow.					NA
lead	N	0/0	11/16		NA						18	NA				NA				NA		2.92			NA		lognor.					NA
magnesium	Y	0/0	16/16		NA						27300	NA				NA				NA		9.3			NA		lognor.		0.485			NA
manganese	N	0/0	12/12		NA						981	NA				NA				NA		4.24			NA		lognor.		1.68			NA
nickel	N	0/0	2/6		NA						26	NA				NA				NA		10.7			NA		nonpar.					NA
potassium	N	0/0	9/16		NA						38700	NA				NA				NA		5750			NA		nonpar.					NA
sodium	Y	0/0	16/16		NA						28500	NA				NA				NA		9.65			NA		lognor.		0.29			NA
zinc	N	0/0	5/5		NA						65	NA				NA				NA		32			NA		normal					NA
tetrachloroethene	N	0/0	7/23		NA						36	NA				NA				NA		6.48			NA		nonpar.					NA
trichloroethene	N	0/0	14/23		NA						37	NA				NA				NA		7.3			NA		lognor.					NA

Notes: Units are ug/L.
A statistical significance level (P value) of 0.05 is used for all tests that directly compare site to background. A two-sided significance level of 0.1 is used for Bartlett's test for equal variance.
UTL is the expected value for the upper 95 % quantile of the background population; there is an equal chance of the population's true 95 % quantile being either below or above this estimate.
For each test, a YES or NO decision is presented only if all assumptions are met. The overall decision (is site > background) for each chemical appears at the left and is based on four criteria:
(1) Overall decision is YES if any one of the UTL, Mann-Whitney/Gehan, Upper Ranks Test, or T-Test is YES, regardless of other test results.
(2) Overall decision is NO if at least one of UTL, Mann-Whitney/Gehan, Upper Ranks Test, or T-Test is NO, and none of the aforementioned tests are YES.
(3) Overall decision is YES/NO if Z/Fisher Test is YES/NO, respectively, and other tests are NA. Z-test is treated as lowest priority since it relies on detection frequency, not magnitude of results.
(4) Overall decision is NA if all tests are NA. (Chemicals assigned NA are still included in human health risk-based screening and/or risk assessment.)

Abbreviations:

# NDs or # Pos.	Number of non-detected (ND) or positive (Pos.) results in data set, not including rejected data or blank-qualified data.
# s or # b	Number of site (s) or background (b) samples, not including rejected data or blank-qualified data.
s = b	Standard deviation of site results must not be different from the standard deviation of background results.
P value	Probability or significance level is defined as the chance of a false positive. If P <= 0.05 then test determines site > background with 95 % confidence.
L, N, or Q	UTL is based on 95 % upper limit (using t-value) when data are lognormal (L) or normal (N). Otherwise, an upper 95 % quantile (Q) is used if there are > 18 back. points.
% ND	Mann-Whitney test used if < 40% of data Non-Detected and detect. limits uniformly below the range of positive values. If not, the Gehan Test is used.
@	Mean and standard deviations are shown of log-transformed data when distributions are of this type; ie., if an (L) code appears for the UTL test or if site and background distributions both match lognormal, and both T-test and Bartlett's test are applicable. (Arithmetic mean and normal standard deviation are shown only for illustration in the event that these tests are NA.)
r,k	The upper ranks test calculates the probability that k or more samples from the top r ranks of the combined site and background data set are comprised of site data if both populations are in fact equal.

TABLE 1-4
OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN - GROUNDWATER
SITE 1 - PRIVET ROAD COMPOUND
NASJRB WILLOW GROVE, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum Concentration[1]	Maximum Concentration[1]	Units	Sample with Maximum Concentration	Frequency of Detection	Range of Nondects[2]	Concentration Used for Screening[3]	Above Background Concentration[4]	EPA Region 3 RBCs for Tap Water[5]	Potential ARAR/TBC[6]	Potential ARAR/TBC Source[6]	COPC Flag	Rationale for Contaminant Deletion or Selection[7]
Site 1	**Volatile Organic Compounds**														
	71-55-6	1,1,1-Trichloroethane	0.5 J	6	ug/L	10MW27	2/25	10	6	NA	320 N	200	MCL	No	BSL
	75-34-3	1,1-Dichloroethane	0.2 J	0.8 J	ug/L	10MW27-D	2/25	10	0.8	NA	90 N	NA	NA	No	BSL
	75-35-4	1,1-Dichloroethene	0.1 J	4	ug/L	10MW27	2/25	10	4	NA	35 N	7	MCL	No	BSL
	56-23-5	**Carbon Tetrachloride**	0.2 J	0.2 J	ug/L	10MW27-D	1/25	1 - 10	0.2	NA	**0.16 C**	5	MCL	**Yes**	ASL
	67-66-3	**Chloroform**	0.1 J	0.2 J	ug/L	10MW27, 10MW28	2/25	10	0.2	NA	**0.15 C**	80	MCL	**Yes**	ASL
	127-18-4	**Tetrachloroethene**	2 J	36	ug/L	01MWNW1_19970708	8/25	1 - 10	36	NA	**0.1 C**	**5**	MCL	**Yes**	ASL
	540-59-0	Total 1,2-Dichloroethene	0.2 J	5 J	ug/L	01MW07I_19970627	3/25	1 - 10	5	NA	5.5 N	NA	NA	No	BSL
	79-01-6	**Trichloroethene**	0.1 J	37	ug/L	01MW07I_19970627	16/25	10	37	NA	**0.026 C**	**5**	MCL	**Yes**	ASL
	Semi-Volatile Organic Compounds														
	117-81-7	Bis(2-Ethylhexyl)Phthalate	2 J	2 J	ug/L	10MW28	1/2	6 - 9	2	NA	4.8 C	6	MCL	No	BSL
	Inorganics														
	7429-90-5	Aluminum	19.1	3430	ug/L	01MW05S_19910923-F	6/18	8.6 - 135	3430	NA	3700 N	NA	NA	No	BSL
	7440-36-0	Antimony	0.81 K	0.98	ug/L	10MW27	2/18	45	0.98	NA	1.5 N	6	MCL	No	BSL
	7440-38-2	**Arsenic**	3.6	4.2	ug/L	01MWNW1B_19911007	2/18	0.85 - 3.2	4.2	NA	**0.045 C**	10	MCL	**Yes**	ASL
	7440-39-3	**Barium**	15	474	ug/L	10MW28	15/18	20 - 155	474	NA	**260 N**	2000	MCL	**Yes**	ASL
	7440-41-7	Beryllium	0.16	4	ug/L	5 SAMPLES	7/18	0.05 - 9	4	NA	7.3 N	4	MCL	No	BSL
	7440-70-2	Calcium	12300	56500	ug/L	10MW28	18/18	---	56500	NA	NA	NA	NA	No	NUT
	7440-47-3	**Chromium**	1.3	18	ug/L	01MW05I_19910923-F	3/18	7 - 11	18	NA	**11 N[8]**	100	MCL[9]	**Yes**	ASL
	7440-48-4	Cobalt	10	17	ug/L	01MW05S_19910923-F	2/18	0.15 - 10	17	NA	73 N	NA	NA	No	BSL
	7440-50-8	Copper	0.49	37	ug/L	01MW05S_19910923-F	3/18	6 - 35	37	NA	150 N	1300	MCL[10]	No	BSL
	7439-89-6	Iron	23.6	576 J	ug/L	01MW02I_19910924	4/18	14.6 - 177	576	NA	1100 N	NA	NA	No	BSL
	7439-92-1	**Lead**	1	18	ug/L	01MW04I_19910923	11/18	0.5 - 1	18	NA	**15 [11]**	**15**	MCL[10]	**Yes**	ASL
	7439-95-4	Magnesium	3780	27500	ug/L	01MWNW1A_19911007-D	18/18	---	27500	NA	NA	NA	NA	No	NUT
	7439-96-5	**Manganese**	2.3	981	ug/L	01MW05S_19910923-F	14/18	1 - 2	981	NA	**73 N[12]**	NA	NA	**Yes**	ASL
	7440-02-0	Nickel	3.1	26	ug/L	01MW04S_19910923-F	4/18	12 - 26	26	NA	73 N	NA	NA	No	BSL
	7440-09-7	Potassium	1490 J	38700	ug/L	01MW05I_19910923-F	11/18	2140	38700	NA	NA	NA	NA	No	NUT
	7782-49-2	Selenium	1.1	1.2	ug/L	10MW27-D	2/16	0.85 - 20	1.2	NA	18 N	50	MCL	No	BSL
	7440-23-5	Sodium	9840	28500	ug/L	01MW06S_19910924-F	18/18	---	28500	NA	NA	NA	NA	No	NUT
	7440-62-2	Vanadium	0.58	0.58	ug/L	10MW28	1/9	0.12 - 4	0.58	NA	3.7 N	NA	NA	No	BSL
	7440-66-6	Zinc	2	187	ug/L	10MW27	7/18	2 - 47	187	NA	1100 N	NA	NA	No	BSL

Footnotes

1 - Sample and duplicate are considered as two separate samples when determining the minimum and maximum concentrations.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - No background data are available for groundwater.
5 - The EPA Region 3 tap water screening level is presented. Value represents the risk based tap water screening level divided by 10 to correspond to a target hazard quotient of 0.1 for noncarcinogens (denoted with a "N" flag), or an incremental cancer risk of 1.0E-6 for carcinogens (denoted with a "C" flag) (USEPA Region III, April 2005).
6 - USEPA Primary Drinking Water Standard (USEPA, Winter 2004). The values presented are based on MCLs or SMCLs and are presented for reference purposes only.
7 - The chemical is selected as a COPC if the maximum detected concentration exceeds the risk-based COPC screening level. Chemicals selected as COPCs are indicated by shaded chemical names.
8 - The RBC for tap water for hexavalent chromium is presented. The RBC for trivalent chromium is 55,000 ug/L.
9 - Value presented is for total chromium.
10 - The MCL for this parameter is actually a treatment technique. The SDWA action level (at the tap) has been presented.
11 - No RBC is available. The Action Level promulgated under the Safe Drinking Water Act is used for screening purposes.
12 - The RBC for tap water calculated using the RfDo for manganese nonfood is presented.

Definitions:

ARAR/TBC = Applicable or Relevant and Appropriate Requirements To Be Considered
C = Carcinogen
COPC = Chemical Of Potential Concern
J = Estimated value
K = Value estimated with a high bias
MCL = Maximum Contaminant Level
N = Noncarcinogen
NA = Not Applicable/Not Available
RBC = Risk Based Concentration

Rationale Codes:

For selection as a COPC:
ASL = Above Screening Level and site background.

For elimination as a COPC:
BSL = Below Screening Level
NUT = Essential Nutrient

Associated Samples

01MW01I_19970707	01MW02S_19970627	01MW05I_19970627	01MW07I_19910924	01MWNW2A_19910927
01MW01S_19910924	01MW03I_19970707	01MW05S_19910923	01MW07I_19910924-F	01MWNW2B_19910927
01MW01S_19910924-F	01MW03I_19970707-D	01MW05S_19910923-F	01MW07I_19970627	01MWNW2_19970708
01MW01S_19970627	01MW03S_19910924	01MW05S_19970627	01MW07S_19910924	01MWWW1_19970709
01MW01SO_19970627	01MW03S_19970627	01MW06I_19910924	01MW07S_19910924-F	01MWWW1_19970709-D
01MW02I_19910924	01MW04I_19910923	01MW06I_19910924-F	01MW07S_19970627	01MWWW1B_19970709
01MW02I_19970627	01MW04I_19970627	01MW06I_19970627	01MW08I_19970707	01MWWW2_19970709
01MW02I_19970627-D	01MW04S_19910923	01MW06S_19910924	01MW08S_19970630	01MWWW3_19970708
01MW02S_19910924	01MW04S_19910923-F	01MW06S_19910924-D	01MWNW1A_19911007	10MW27
01MW02S_19910924-D	01MW04S_19970627	01MW06S_19910924-F	01MWNW1A_19911007-D	10MW27-D
01MW02S_19910924-F	01MW05I_19910923	01MW06S_19910924-F-D	01MWNW1B_19911007	10MW28
01MW02S_19910924-F-D	01MW05I_19910923-F	01MW06S_19970627	01MWNW1_19970708	

TABLE 2-1
SUMMARY OF CHEMICAL-SPECIFIC ARARs AND TBCs FOR POTENTIAL USE AT OU 3
NAS JRB WILLOW GROVE, PENNSYLVANIA

ARAR OR TBC	RATIONALE FOR USE AT SITE
Safe Drinking Water Act (SDWA) – Maximum Contaminant Levels (MCLs) (40 CFR 141)	Maximum Contaminant Levels have been promulgated for a number of organic and inorganic contaminants to regulate the concentration of these compounds in public drinking water. MCLs are relevant to groundwater at the site because it is currently used as a drinking water aquifer.
Clean Water Act – Ambient Water Quality Criteria (AWQC)	Ambient water quality criteria are TBCs (i.e., non-promulgated) that have been developed for carcinogenic and non-carcinogenic compounds for the protection of human health and aquatic life. AWQC may be used to assess need for remediation of discharges to surface water or to use as benchmarks during long-term monitoring at the site.
Commonwealth of Pennsylvania Water Quality Standards (25 PA Code 93)	Surface water quality standards promulgated for protection of human health and aquatic life. These may be used to assess need for remediation of discharges to surface water or to use as benchmarks during long-term monitoring.
Commonwealth of Pennsylvania Water Quality Toxics Management Strategy (25 PA Code 16)	Water quality criteria for various toxic substances promulgated for protection of human health and aquatic life. These may be used to assess need for remediation of discharges to surface water or to use as benchmarks during long-tem monitoring.
Commonwealth of Pennsylvania Land Recycling Program (i.e., Act II) (25 PA Code 250)	Medium-specific concentrations (MSCs) for inorganic and organic substances in groundwater and soil promulgated for site remediation.
EPA Groundwater Protection Strategy (EPA, 1984)	Guidance on determining the classification and restoration goals for groundwater based on its value and vulnerability to contamination.
EPA Region III Risk-Based Concentrations (RBCs)	TBCs for soil and tap water that may be used for selecting contaminants for risk assessment and/or fate and transport modeling.
EPA Soil Screening Levels (SSLs) Guidance and Generic Levels	Guidance that provides a methodology to calculate risk-based, site-specific soil screening levels (SSLs) for contaminants in soil that may be used to identify areas needing further investigation. Also provides generic SSLs for a number of contaminants in soil.
Clean Air Act (42 CFR 85) of 1970	Promulgated national primary and secondary ambient air quality standards for air pollutants for protection of public health. May be applicable in design of treatment processes.
Pennsylvania Air Pollution Control Act (25 PA Code 131) of 1971	Ambient air quality standards for discharges of air pollutants. Potentially applicable to remedial design and implementation.
Pennsylvania Safe Drinking Water (25 PA Code 109)	Potentially applicable to site groundwater that is used as drinking water source.

TABLE 2-2
SUMMARY OF LOCATION-SPECIFIC ARARs AND TBCs FOR POTENTIAL USE AT OU 3
NAS JRB WILLOW GROVE, PENNSYLVANIA

ARAR OR TBC	RATIONALE FOR USE AT SITE
Protection of Wetlands and Floodplains (Executive Orders 11990 and 11988)	Potentially applicable to any remedial actions conducted within wetlands and/or floodplains.
Federal Water Pollution Control Act (40 CFR 116.3) (33 USC 26)	Potentially applicable to any discharges at the site.
Fish and Wildlife Coordination Act (16 USC 661)	Potentially applicable if surface water is diverted or disturbed during remedial actions.
Fish and Wildlife Improvement Act of 1978 (16 USC 742)	This Act protects fish and wildlife against impacts that may affect their protected habitats. May be potentially applicable for discharge of treated water.
Fish and Wildlife Conservation Act of 1980 (16 USC 2901)	May be potentially applicable for discharge of treated water.
Endangered Species Act of 1973 (50 CFR Part 200)	Potentially applicable if any endangered or threatened species or habitats are present where remediation activities may occur.
National Historic Preservation Act of 1966 (16 USC 470 et. Seq.)	Action will be taken to recover and to preserve historic artifacts that may be threatened as the result of land alteration. Potentially applicable if historic artifacts are encountered during active site remediation activities.
National Archeological and Historic Preservation Act of 1974 (132 CFR 229)	Action will be taken to recover and to preserve scientific, prehistoric, historic, or archaeological artifacts that may be threatened as the result of land alteration. Potentially applicable if artifacts are encountered during active site remediation activities.
Delaware River Basin Commission-Ground Water Protected Area Regulations, Southeastern Pennsylvania (Resolution No. 80-18)	Regulations to assure the effective management of water withdrawals to avoid depletion of natural stream flow and groundwater and to protect the quality of such water.

TABLE 2-3
SUMMARY OF ACTION-SPECIFIC ARARs AND TBCs FOR POTENTIAL USE AT OU 3
NAS JRB WILLOW GROVE, PENNSYLVANIA

ARAR OR TBC	RATIONALE FOR USE AT SITE
Resource Conservation and Recovery Act (RCRA) – Hazardous Waste Generator and Transporter Requirements (40 CFR Parts 262 and 263)	Establishes responsibilities of generators and transporters of hazardous waste in the handling, transportation, and management of waste. Potentially applicable for disposal of sediments or wastes produced by groundwater treatment processes.
Department of Transportation (DOT) – Hazardous Materials Transport (49 CFR Parts 107 and 171-179)	Regulations for the transportation of hazardous materials including packaging, marking, labeling, and transportation methods. Off-site shipments of any contaminated materials (i.e., sediments, spent carbon canisters) from the site would have to comply with these regulations.
Clean Water Act – Natural Pollutant Discharge Elimination System (NPDES)	These requirements are potentially applicable to any alternatives that include a water discharge.
National Environmental Policy Act of 1970 (NEPA) (42 USC 4321)	Requires federal agencies to evaluate the environmental impacts associated with major actions that they fund, support, permit, or implement. Alternatives could constitute significant activities, thereby making NEPA requirements ARARs.
Occupational Health and Safety Act (29 USC 651-678) of 1970	Regulates worker health and safety during implementation of remedial actions. Applicable to any investigative or remedial tasks conducted at the site.
Pennsylvania National Pollutant Discharge Elimination System (25 PA Code 92)	Potentially applicable to any remedial actions that would involve discharge of water.
Pennsylvania Stormwater Management Act of 1978 (Act No. 167)	Requires the implementation of measures to control stormwater runoff. Potentially applicable for certain remedial activities.
Pennsylvania Erosion Control Regulations (25 PA Code 102)	Requires the implementation of measures to control erosion and stormwater runoff. Potentially applicable for certain remedial activities.
Pennsylvania Drilling Water Wells (17 PA Code 47)	Requirements for the installation and construction of groundwater wells. Potentially applicable for alternatives involving well installation.
Pennsylvania Hazardous Substances Transportation Regulations (PA Code, Title 13 and 15)	Regulations that govern the transport of flammable liquids and solids, oxidizing materials, poisons and corrosive liquids. Potentially applicable to any off-site shipments of hazardous materials.

TABLE 2-4
COMPARISON OF GROUNDWATER CONCENTRATIONS TO REGULATORY CRITERIA
SITE 1- PRIVET ROAD COMPOUND
NASJRB WILLOW GROVE, PENNSYLVANIA

COC	MAXIMUM DETECTION (ug/l)	LOCATION OF MAX. DETECTION	FEDERAL SDWA (ug/l)[1]	PADEP MSC (ug/l)[2]	RBC VALUE (ug/l)[3]
Arsenic	4.2	01MWNW1B	50 (MCL)	50 (MCL)	0.045
Barium	474	10MW28	2000 (S)	2000 (S)	260
Chromium	18	01MW05I	100 (MCL)	100(MCL)	11
Lead	18	01MW04I	15 (AL)	5	15[4]
Manganese	981	01MW05S	--	--	73
Carbon Tetrachloride	0.2J	10MW27-D	5 (MCL)	5	0.16
Chloroform	0.2J	10MW27, 10MW28	--	100	0.15
PCE	36	10MWNW1	5 (MCL)	5 (MCL)	0.1
TCE	37	01MW07I	5 (MCL)	5 (MCL)	0.026

[1] Federal Maximum Contaminant Levels (MCLs). Source: National Primary Drinking Water Regulations, 40 CFR Parts 141.61 and 141.62. SDWA = Safe Drinking Water Act; S = Secondary MCL; AL = Action Level.

[2] Pennsylvania Department of Environmental Protection (PADEP) Medium-specific concentrations (MSCs), November 24, 2001 for used aquifers, residential land use, and total dissolved solids (TDS) less than 2,500 ug/l. MCL = Maximum Contaminant Level; H = Lifetime Health Advisory Level; G = Ingestion; N = Inhalation; S = Aqueous solubility cap. With Periodic Updates and Changes.

[3] EPA Region 3 Risk-Based Concentrations for Tap Water. Source: EPA Region 3 RBC Table, April 2006. The RBC values for tap water are based on maximum carcinogenic risk of 1E-6 or Hazard Quotient of 1.0.

[4] No RBC is available. The action Level promulgated under the Safe Drinking Water Act is used for screening purposes.

Bold = Risk-based Compound of Concern for site-related groundwater.
ug/l = microgram per liter.

TABLE 2-5
PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
FOR SITE 1 GROUNDWATER (OU 3)
NAS JRB WILLOW GROVE, PENNSYLVANIA

General Response Action	Technology	Process Options	Description	Screening Comment
No Action	None	Not applicable	No remedial activities conducted to address contamination. Long-term monitoring program to monitor groundwater levels.	Retained for baseline comparison purposes in accordance with NCP 40CFR Section 300.430(e).
Limited Action	Institutional controls	Deed restrictions and notices. County health department and PADEP well permit process to preclude new wells in the area.	Administrative action used to restrict future and current water extraction activities at site and at individual properties. Installation of private wells and use of untreated groundwater in the area of contamination may be restricted.	Retained.

TABLE 3-1

REMEDIAL ALTERNATIVE COMPONENTS
SITE 1 GROUNDWATER (OU 3)
NAS JRB WILLOW GROVE, PENNSYLVANIA

	ALTERNATIVE	KEY COMPONENTS OF ALTERNATIVE
1	No Action	• Five-year reviews.
2	Limited Action	• Institutional Controls (land use restrictions). • Five-year reviews.

TABLE 3-2
SITE 1 GROUNDWATER - SCREENING OF REMEDIAL ALTERNATIVES
NAS JRB WILLOW GROVE, PENNSYLVANIA

	ALTERNATIVE	EFFECTIVENESS	IMPLEMENTABILITY	COST	COMMENTS
1	No Action: (5 year reviews)	Provides protection of human health and the environment through regulatory agency review. Does not reduce potential for human exposure to groundwater contaminants. Does not reduce contaminant migration in the environment. No reduction in toxicity, mobility, or volume of contaminants.	Readily implementable. No technical or administrative difficulties.	Capital: none O&M: low	Retained as baseline alternative in accordance with NCP. Retained.
2	Limited Action: (Institutional controls, 5-year reviews)	Provides protection of human health and the environment through regulatory agency review. Groundwater use would be restricted. Does not reduce contaminant migration to the environment. No reduction in toxicity, mobility, or volume of contaminants.	Readily implementable. No technical or administrative difficulties.	Capital: low O&M: low	Compared to Alt. 1, provides additional protectiveness for moderate additional cost. Retained.

TABLE 4-1
SITE 1 GROUNDWATER (OU 3) COMPARATIVE ANALYSIS OF REMEDIAL ACTION ALTERNATIVES
NAS JRB WILLOW GROVE, PENNSYLVANIA

CRITERION:	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: LIMITED ACTION
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT		
Prevent Human Exposure to Contaminated Groundwater	Would provide little additional protection against human exposure to contaminated groundwater. Long-term periodic review would provide the Navy and regulatory bodies the opportunity to review site conditions and perform additional remedial actions if they become warranted.	Institutional controls would minimize potential exposure to site groundwater by prohibiting its use as drinking water. Long-term periodic review would provide the Navy and regulatory bodies the opportunity to review site conditions and perform additional remedial actions if they become warranted.
Mitigate Migration of VOC Contaminated Groundwater	No actions taken to reduce migration of contaminated groundwater.	Same as Alternative 1.
COMPLIANCE WITH ARARS		
Chemical-Specific ARARs	Would not comply with state or federal groundwater quality standards or statutory requirements. No institutional controls to protect potential (future) receptors would be implemented.	Institutional controls to protect potential receptors would be implemented.
Location-Specific ARARs	Not applicable.	Not applicable.
Action-Specific ARARs	Not applicable.	Not applicable.
LONG-TERM EFFECTIVENESS AND PERMANENCE		
Magnitude of Residual Risk	Existing risks would remain.	Implementation and enforcement of institutional controls would reduce risks from exposure to site groundwater to acceptable levels.
Adequacy and Reliability of Controls	No new controls implemented.	Long-term enforcement of institutional controls would be required to ensure their effectiveness for preventing use of contaminated groundwater.
Need for 5-Year Review	Review would be required since groundwater contaminants would be left in place.	Review would be required since groundwater contaminants would be left in place and institutional controls would be implemented.

TABLE 4-1
SITE 1 GROUNDWATER (OU 3) COMPARATIVE ANALYSIS OF REMEDIAL ACTION ALTERNATIVES
NAS JRB WILLOW GROVE, PENNSYLVANIA

CRITERION:	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: LIMITED ACTION
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT		
Treatment Process Used	None.	None.
Amount Treated or Destroyed	None.	None.
Reduction of Toxicity, Mobility, or Volume Through Treatment	No reduction, since no treatment would be employed.	Same as Alternative 1.
Irreversible Treatment	Not applicable.	Not applicable.
Statutory Preference for Treatment	No.	No.
SHORT-TERM EFFECTIVENESS		
Community Protection	No significant risk to community anticipated.	Same as Alternative 1.
Worker Protection.	Not applicable.	Same as Alternative 1.
Environmental Impacts	No adverse impacts to the environment anticipated.	Same as Alternative 1.
Time Until Action is Complete	Not applicable.	Not applicable.
IMPLEMENTABILITY		
Ability to Construct and Operate	No construction or operation involved.	Same as Alternative 1.
Ease of Doing More Action if Needed	Additional actions would be easily implemented if required.	Same as Alternative 1.
Ability to Monitor Effectiveness	5-year reviews would provide assessment of changes in site conditions.	Same as Alternative 1.
Ability to Obtain Approvals and Coordinate with Other Agencies	Coordination for 5-year reviews may be required and would be obtainable.	Same as Alternative 1.
Availability of Treatment, Storage Capacities, and Disposal Services	None required.	Same as Alternative 1.
Availability of Equipment, Specialists, and Materials	Personnel and equipment available for implementation of 5-year reviews.	Personnel and equipment available for placement of institutional controls and implementation of 5- year reviews.
Availability of Technology	Not required.	Not required.

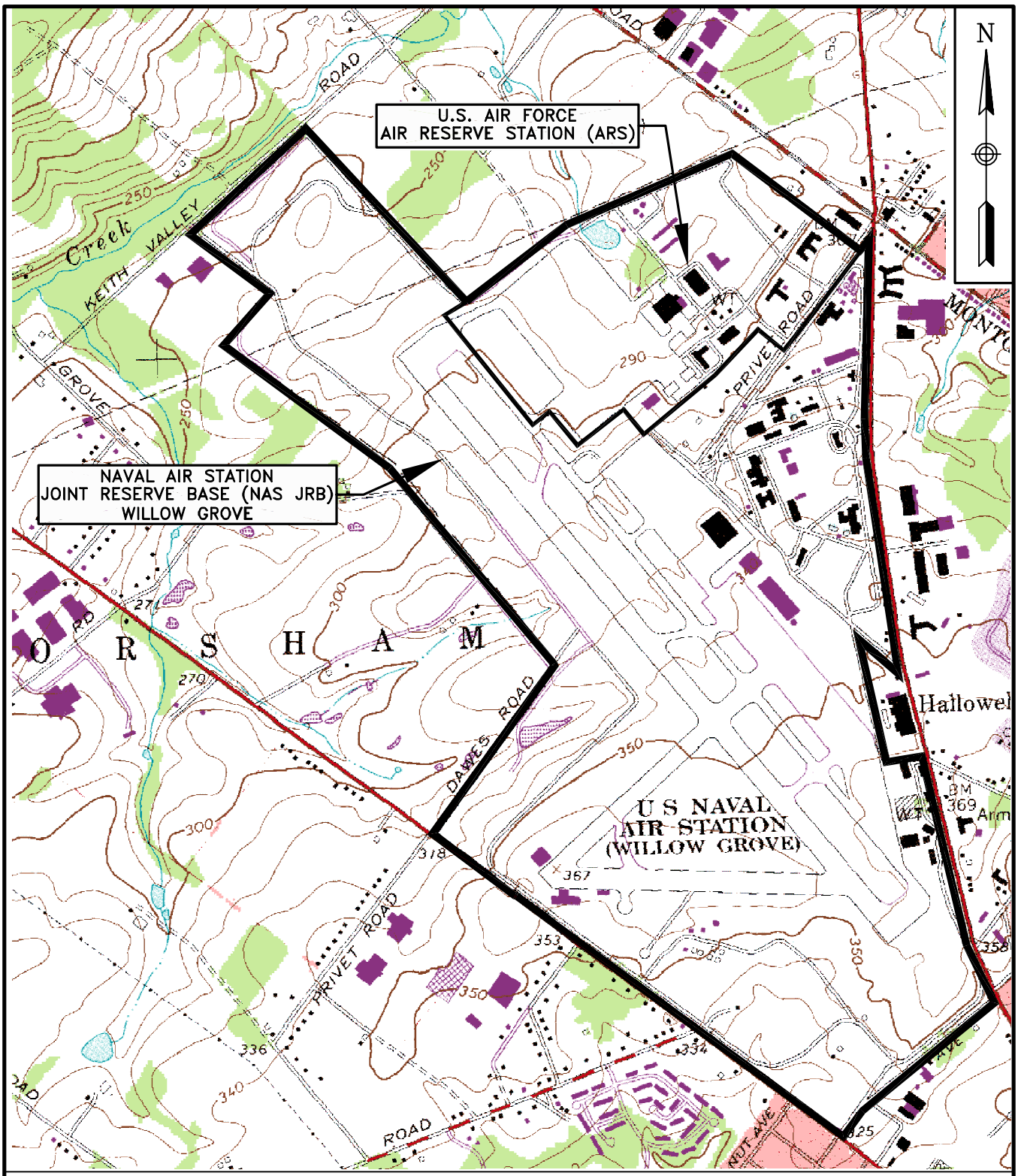
TABLE 4-1
SITE 1 GROUNDWATER (OU 3) COMPARATIVE ANALYSIS OF REMEDIAL ACTION ALTERNATIVES
NAS JRB WILLOW GROVE, PENNSYLVANIA

CRITERION:	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: LIMITED ACTION
COST		
Capital Cost	0	$6,897
First-Year Annual O&M Cost	0	0
Five-Year Reviews	$20,000	$20,000
Present Worth Cost*	$43,156	$50,054

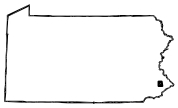
*Present worth cost is based on discount rate of 7%

FIGURES

2192 WillowGrove\1140\2192GM02.DWG 08/03/07 MKB



BASE MAP IS A PORTION OF THE AMBLER, PA U.S.G.S. 7.5 MINUTE QUADRANGLE MAP, DATED 1963, PHOTOREVISED IN 1983.



QUADRANGLE LOCATION

0 1500 3000

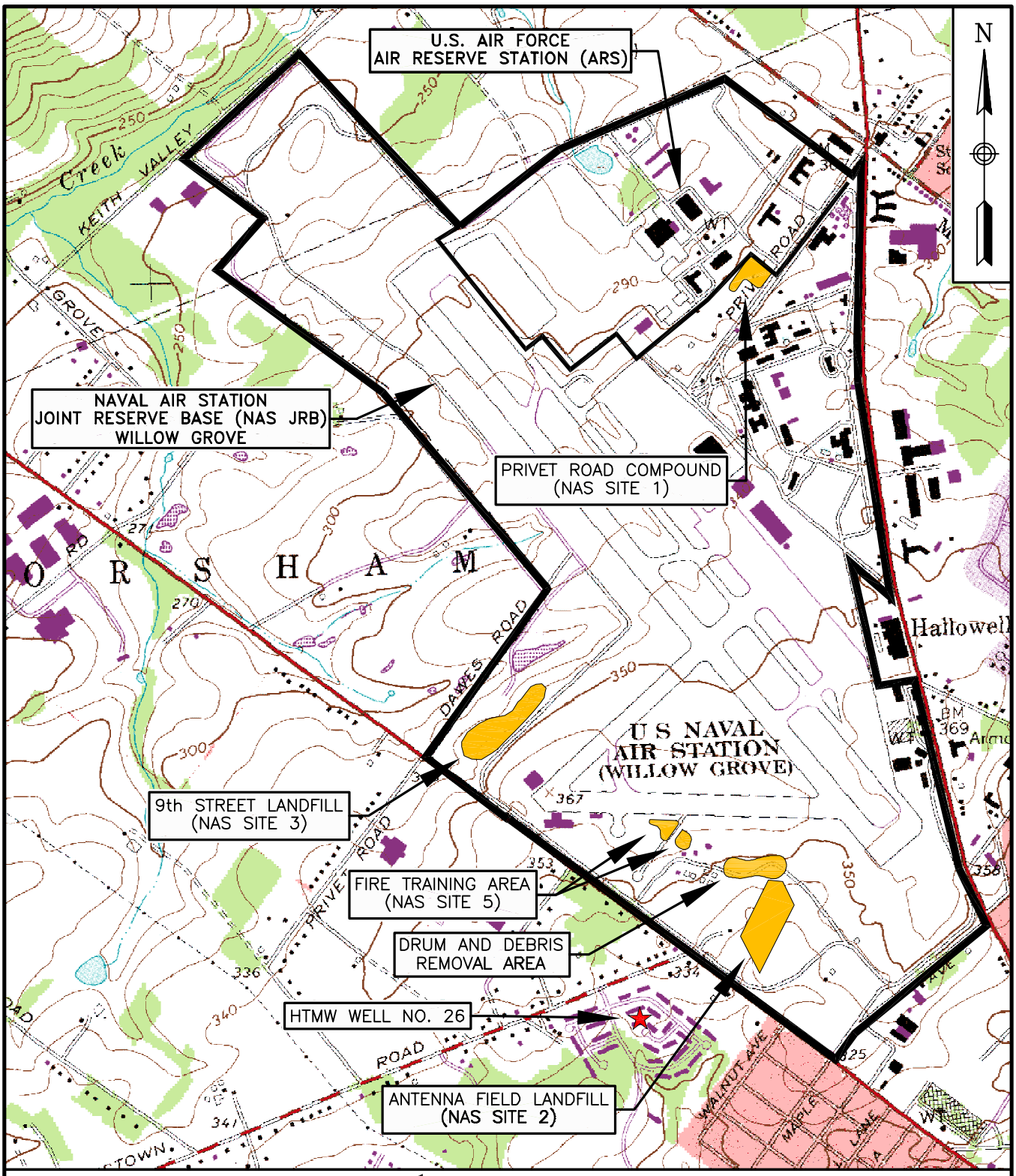
SCALE IN FEET

TETRA TECHNUS, INC.

LOCATION MAP
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

SCALE	AS NOTED
FILE	2192GM02.DWG
REV	0
DATE	08/03/07
FIGURE NUMBER	FIGURE 1–1

2192 WillowGrove\1140\2192GM01.DWG 08/03/07 MKB



BASE MAP IS A PORTION OF THE AMBLER, PA U.S.G.S. 7.5 MINUTE QUADRANGLE MAP, DATED 1963, PHOTOREVISED IN 1983.

QUADRANGLE LOCATION

0 1500 3000

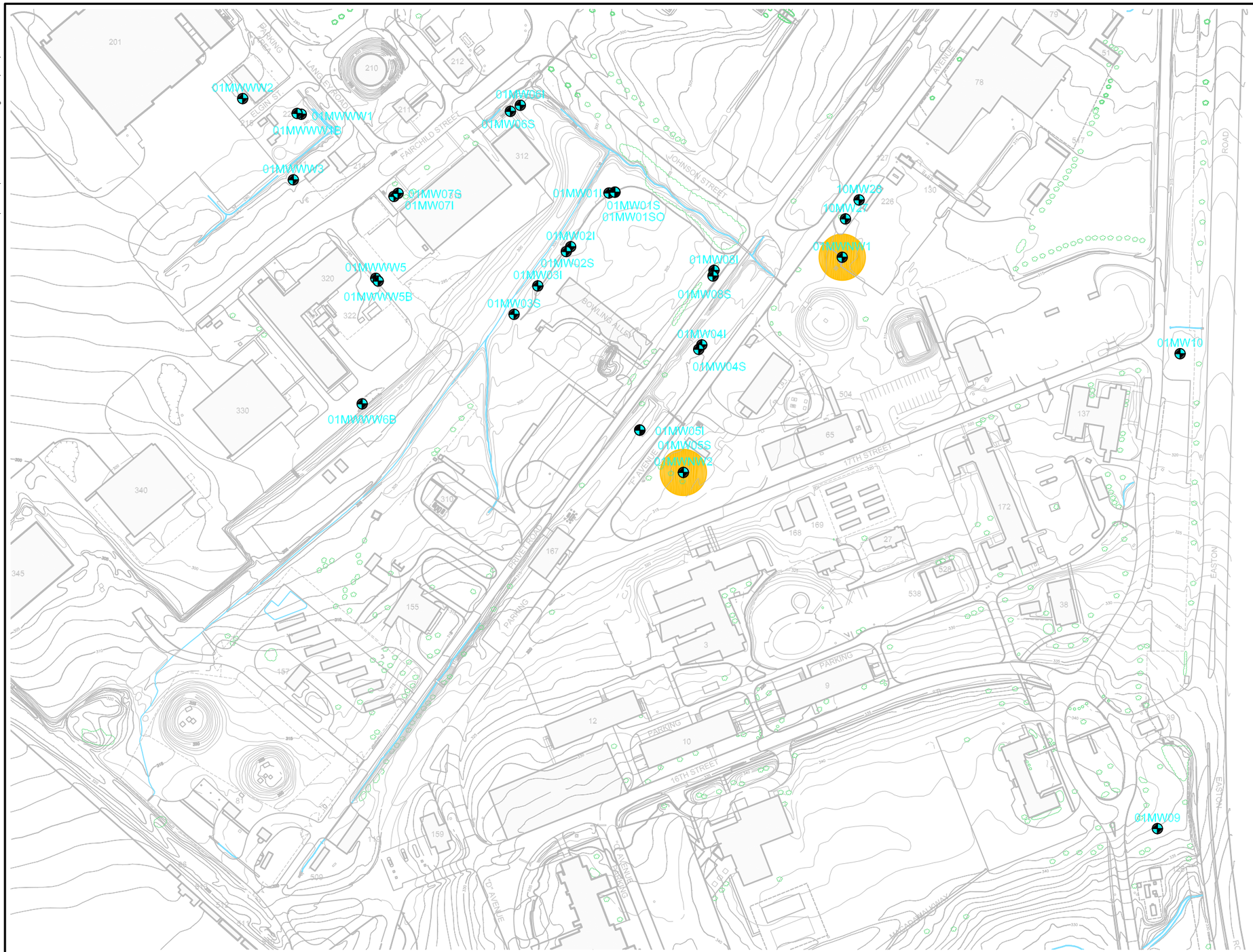
SCALE IN FEET

TETRA TECHNUS, INC.

LOCATION OF RI SITES
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

SCALE	AS NOTED
FILE	2192GM01.DWG
REV	0
DATE	08/03/07
FIGURE NUMBER	FIGURE 1–2

2192 Willow Grove\1140\2192GM03-1.dwg 08/03/07 MKB



N

0 200 400

SCALE IN FEET

LEGEND

MONITORING WELL LOCATION

NAVY SUPPLY WELL LOCATION

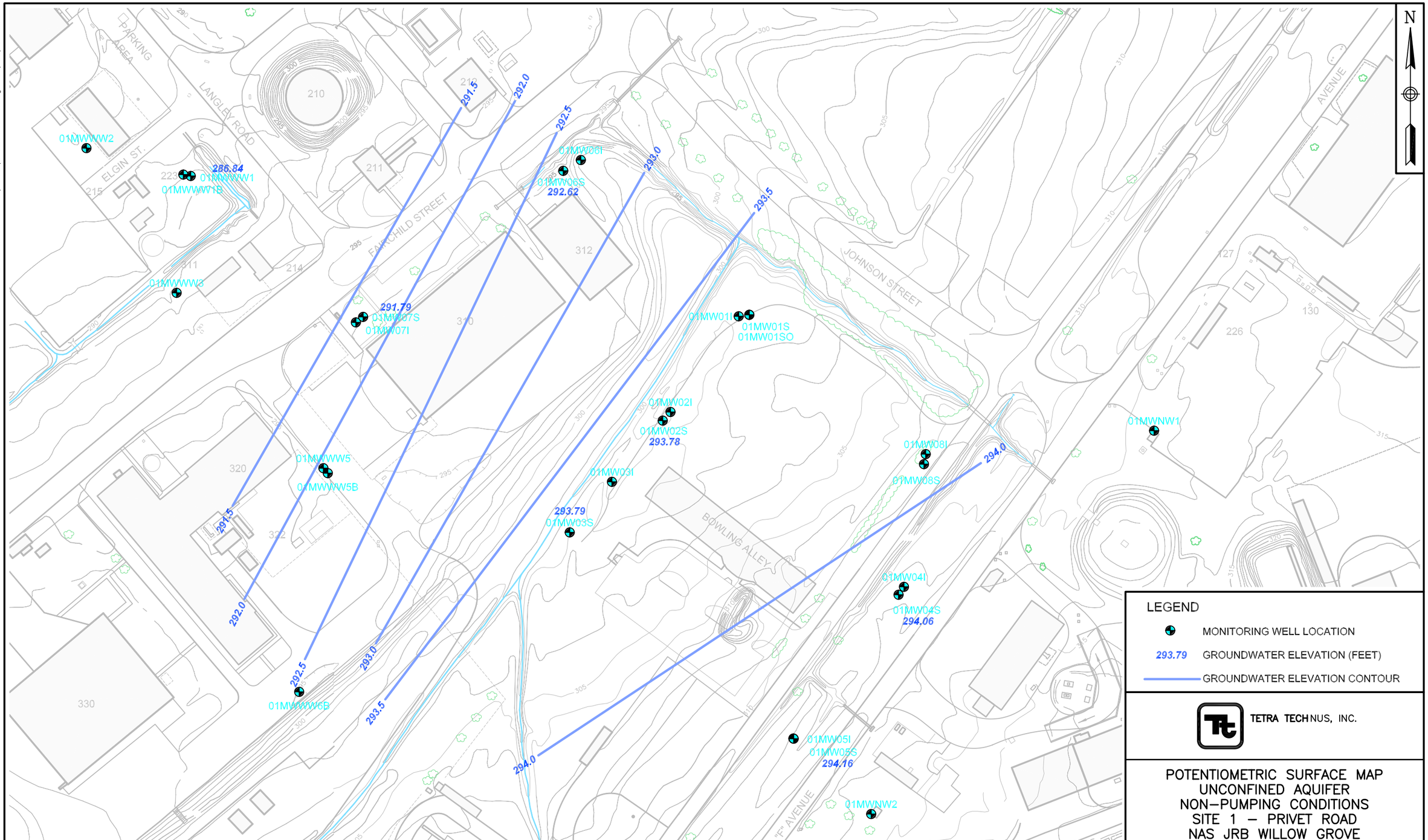
TETRA TECHNUS, INC.

MONITORING WELL LOCATION MAP
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM03-1.DWG	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 1-3	0	08/03/07

2192 Willow Grove\1140\2192GM05-1.dwg 08/03/07 MKB



LEGEND

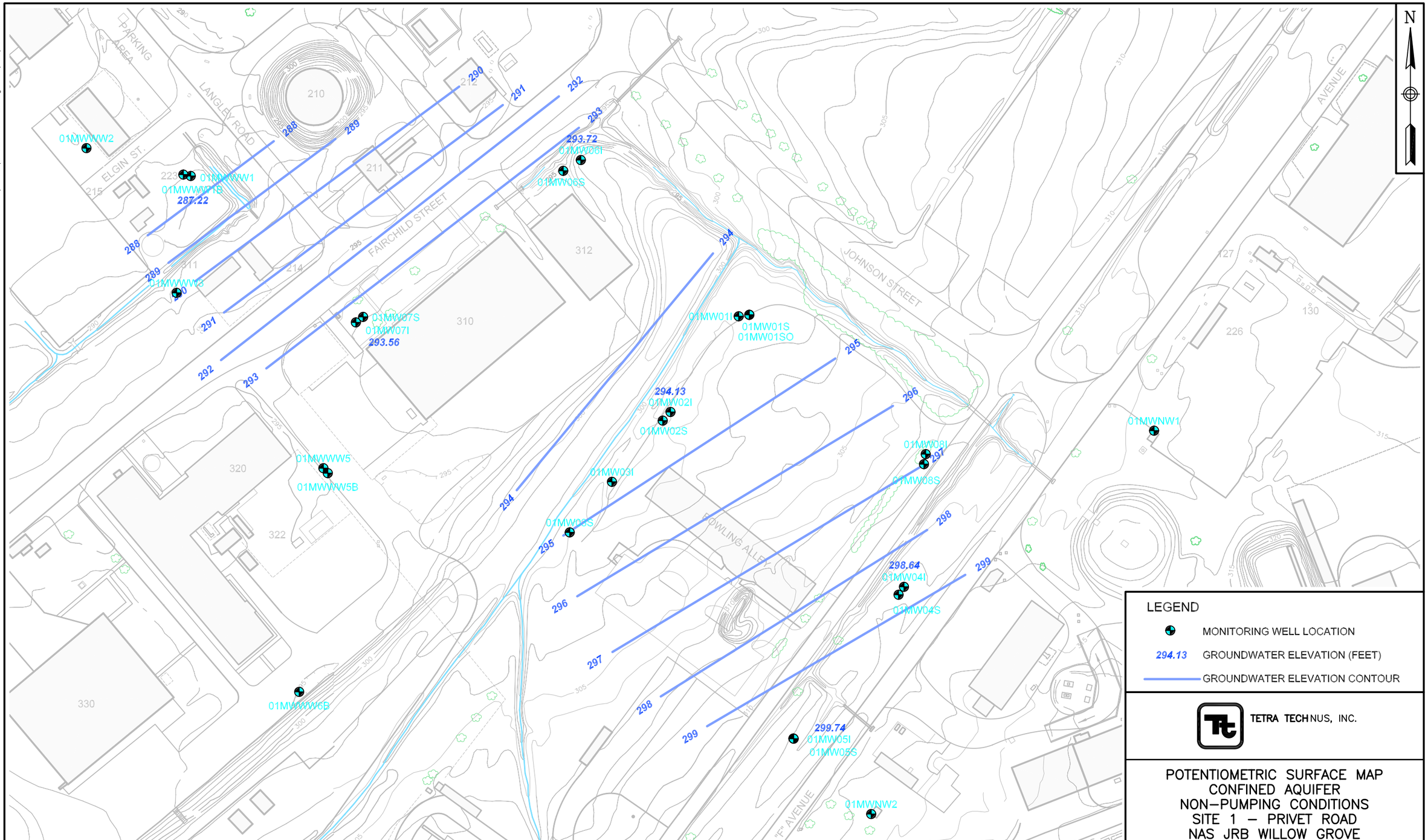
- MONITORING WELL LOCATION
- 293.79 GROUNDWATER ELEVATION (FEET)
- GROUNDWATER ELEVATION CONTOUR

TETRA TECH NUS, INC.

POTENTIOMETRIC SURFACE MAP
UNCONFINED AQUIFER
NON-PUMPING CONDITIONS
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM05-1.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1-4	0 / 08/03/07

2192 Willow Grove\1140\2192GM05-2.dwg 08/03/07 MKB



LEGEND

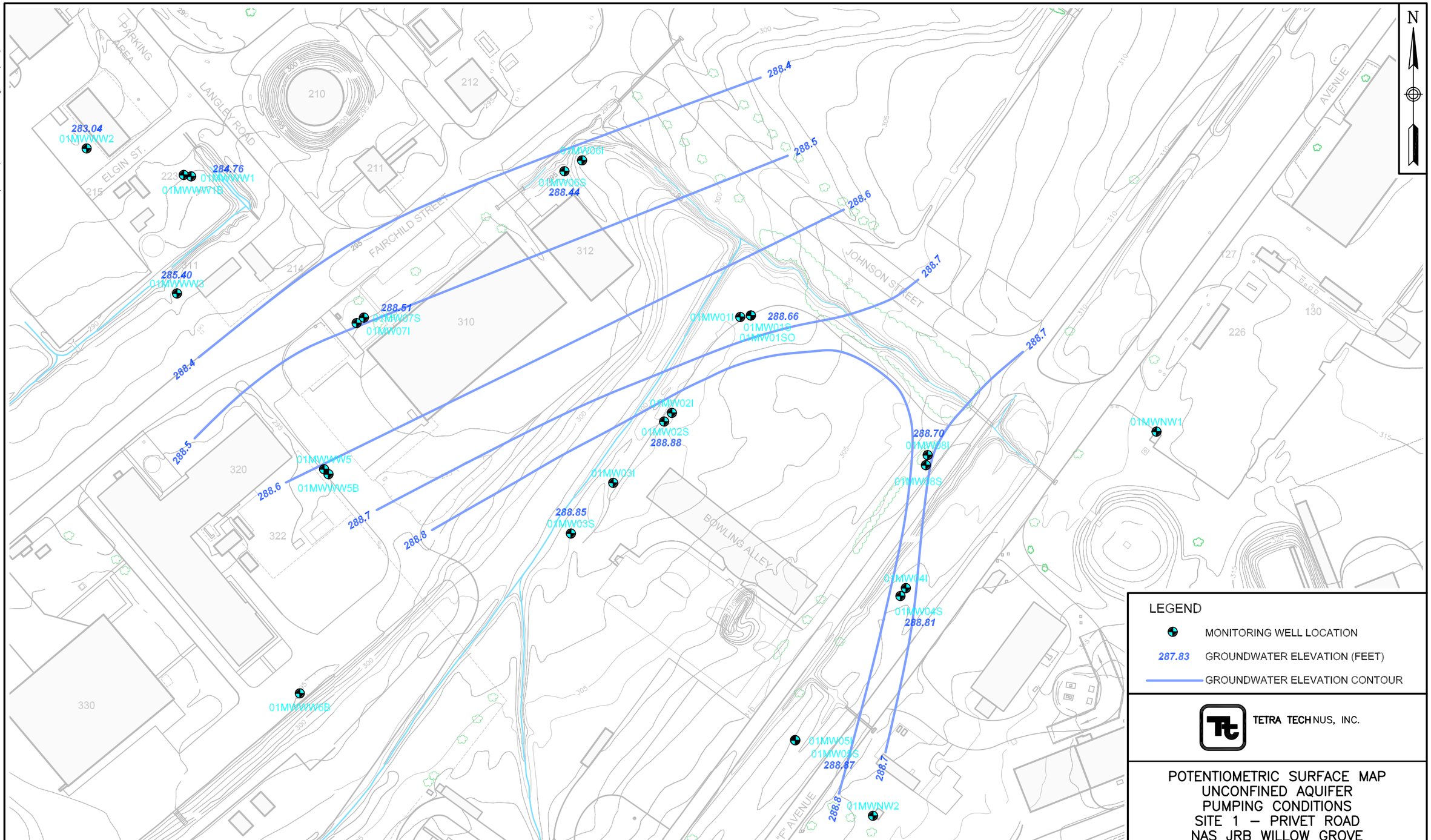
- MONITORING WELL LOCATION
- 294.13 GROUNDWATER ELEVATION (FEET)
- GROUNDWATER ELEVATION CONTOUR

TETRA TECH NUS, INC.

POTENTIOMETRIC SURFACE MAP
CONFINED AQUIFER
NON-PUMPING CONDITIONS
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM05-2.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1-5	0 / 08/03/07

2192 Willow Grove\1140\2192GM05-3.dwg 08/03/07 MKB



LEGEND

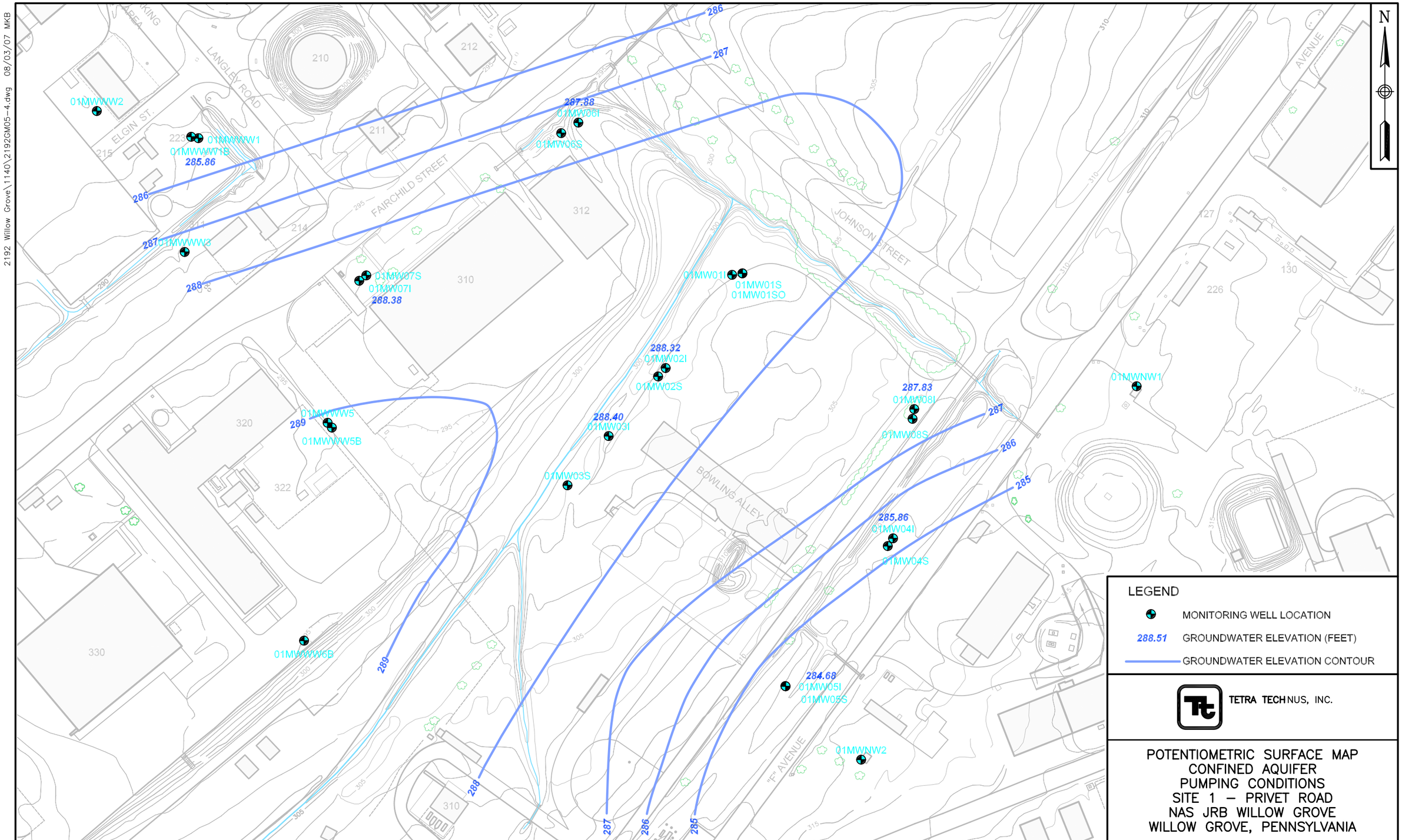
- MONITORING WELL LOCATION
- 287.83 GROUNDWATER ELEVATION (FEET)
- GROUNDWATER ELEVATION CONTOUR

TETRA TECH NUS, INC.

POTENTIOMETRIC SURFACE MAP
UNCONFINED AQUIFER
PUMPING CONDITIONS
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM05-3.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1-6	0 / 08/03/07

2192 Willow Grove\1140\2192GM05-4.dwg 08/03/07 MKB



LEGEND

MONITORING WELL LOCATION

288.51 GROUNDWATER ELEVATION (FEET)

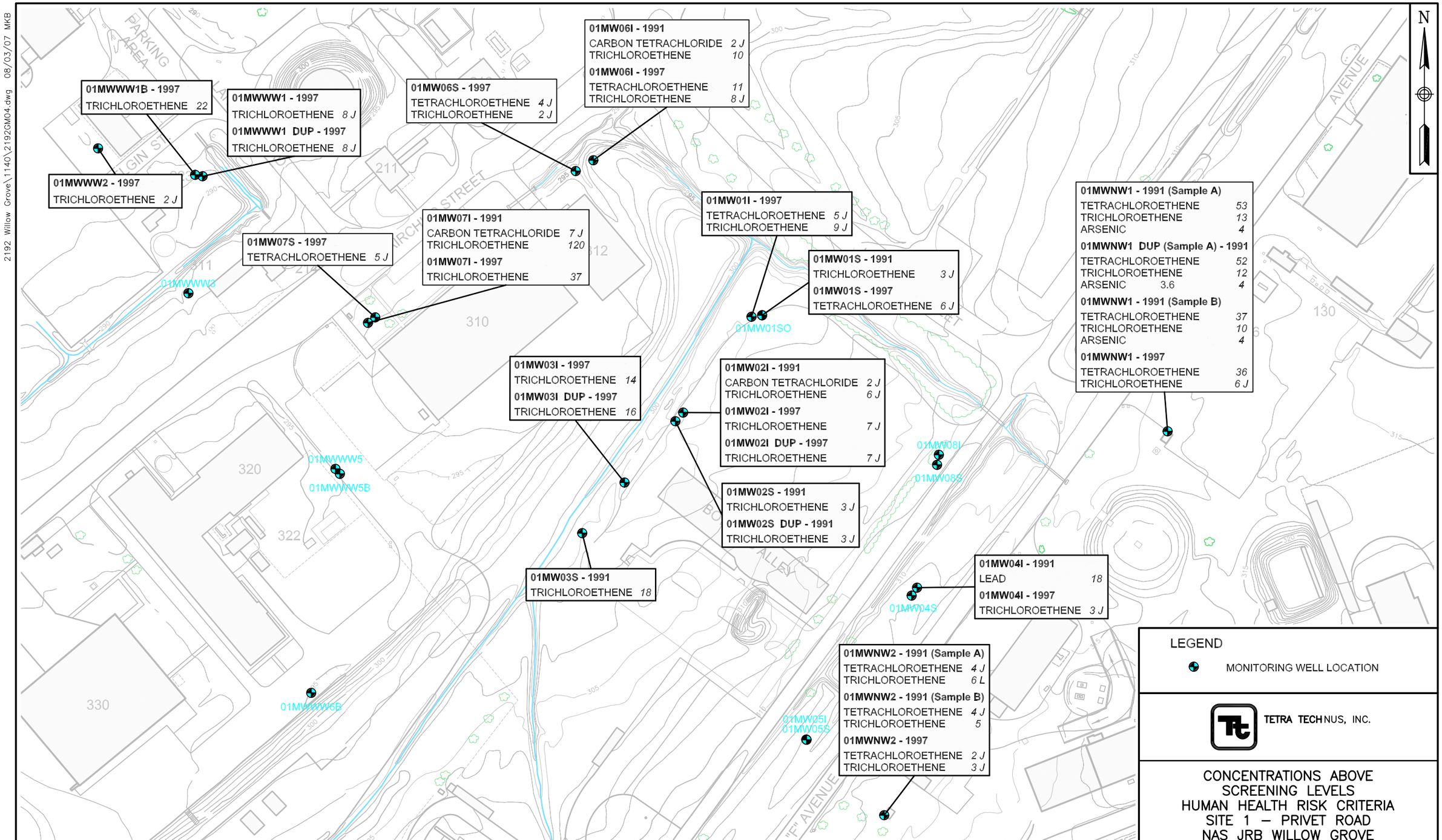
GROUNDWATER ELEVATION CONTOUR

TETRA TECH NUS, INC.

POTENTIOMETRIC SURFACE MAP
CONFINED AQUIFER
PUMPING CONDITIONS
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM05-4.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1-7	0 / 08/03/07

2192 Willow Grove\1140\2192GM04.dwg 08/03/07 MKB



LEGEND

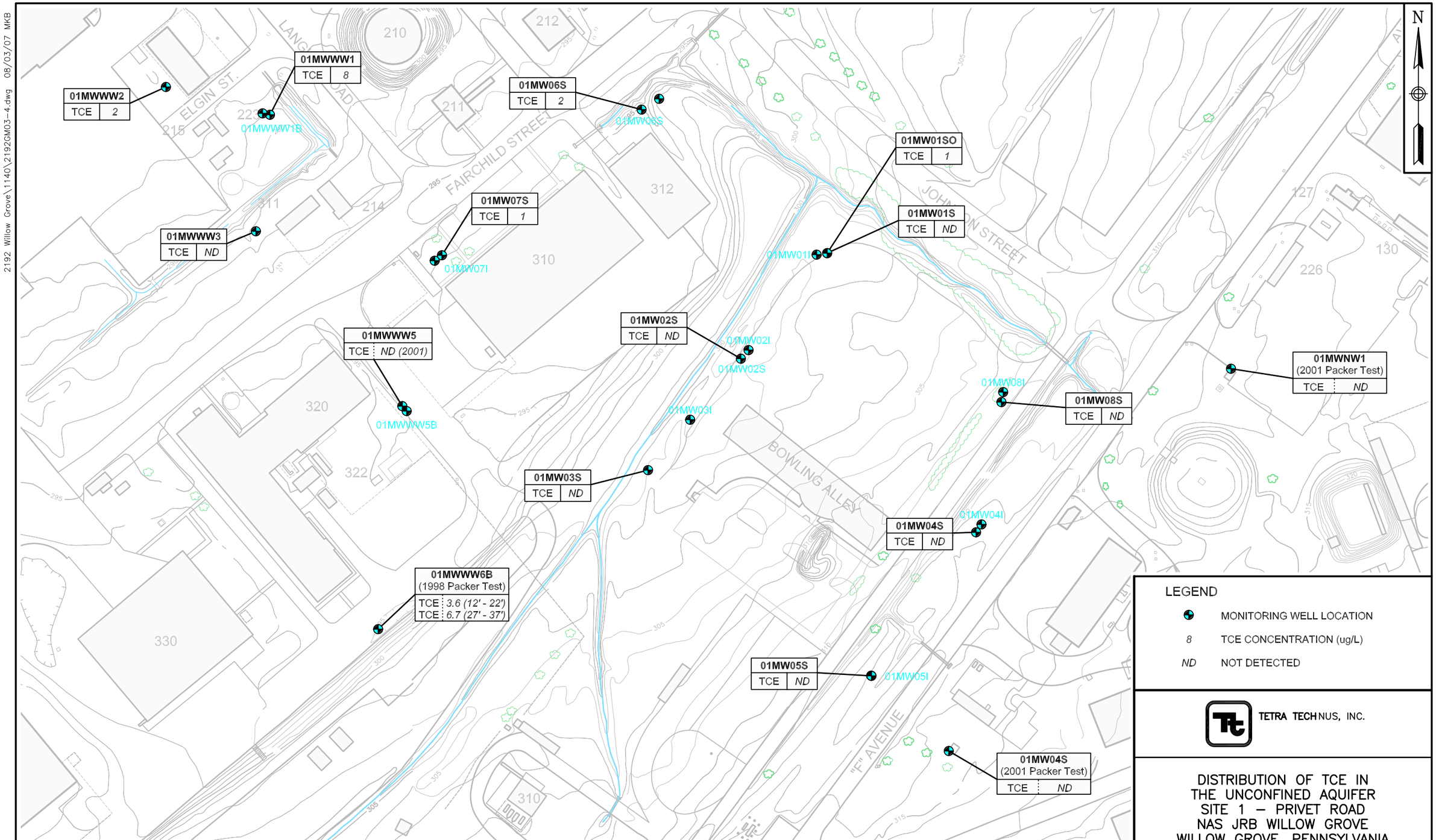
MONITORING WELL LOCATION

TETRA TECH NUS, INC.

CONCENTRATIONS ABOVE
SCREENING LEVELS
HUMAN HEALTH RISK CRITERIA
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM04.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1–8	0 / 08/03/07

2192 Willow Grove\1140\2192GM03-4.dwg 08/03/07 MKB



LEGEND

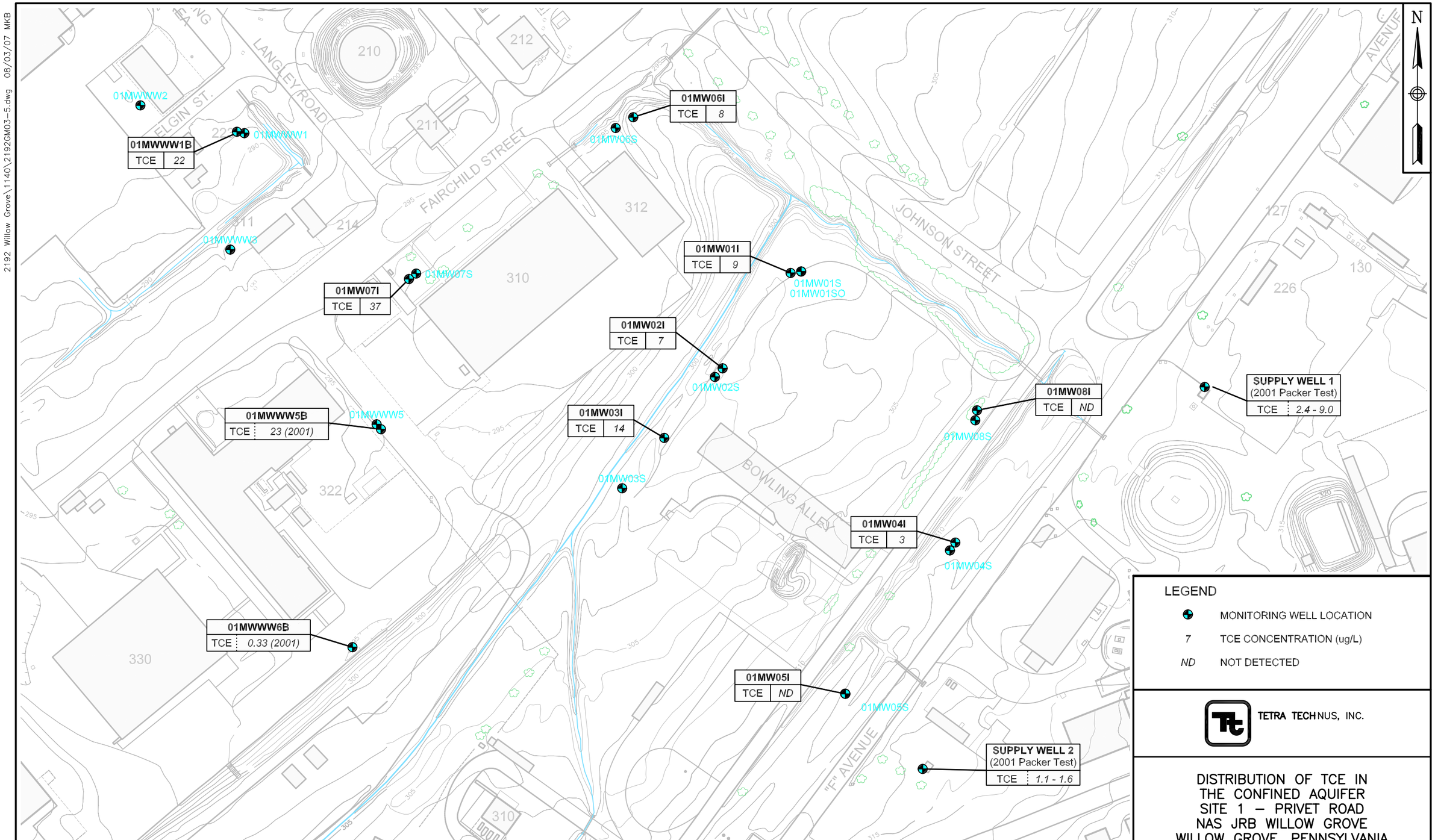
⊕	MONITORING WELL LOCATION
8	TCE CONCENTRATION (ug/L)
ND	NOT DETECTED

TETRA TECH NUS, INC.

DISTRIBUTION OF TCE IN
THE UNCONFINED AQUIFER
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE 2192GM03-4.DWG	SCALE AS NOTED
FIGURE NUMBER FIGURE 1-9	REV 0 / DATE 08/03/07

2192 Willow Grove\1140\2192GM03-5.dwg 08/03/07 MKB



LEGEND

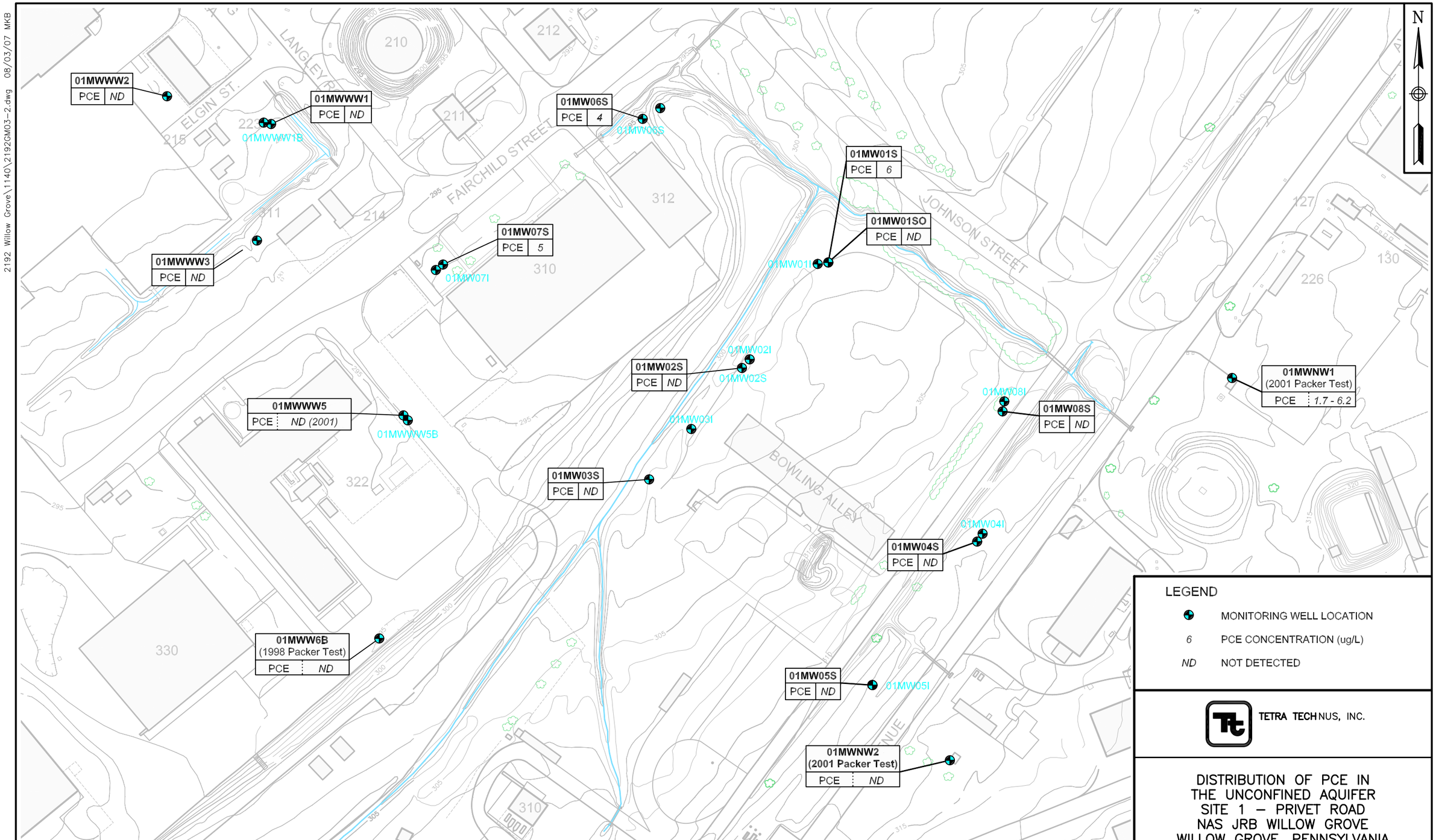
◆	MONITORING WELL LOCATION
7	TCE CONCENTRATION (ug/L)
ND	NOT DETECTED

TETRA TECHNUS, INC.

DISTRIBUTION OF TCE IN
THE CONFINED AQUIFER
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM03-5.DWG	AS NOTED
FIGURE NUMBER: FIGURE 1-10	REV: 0 / DATE: 08/03/07

2192 Willow Grove\1140\2192GM03-2.dwg 08/03/07 MKB



LEGEND

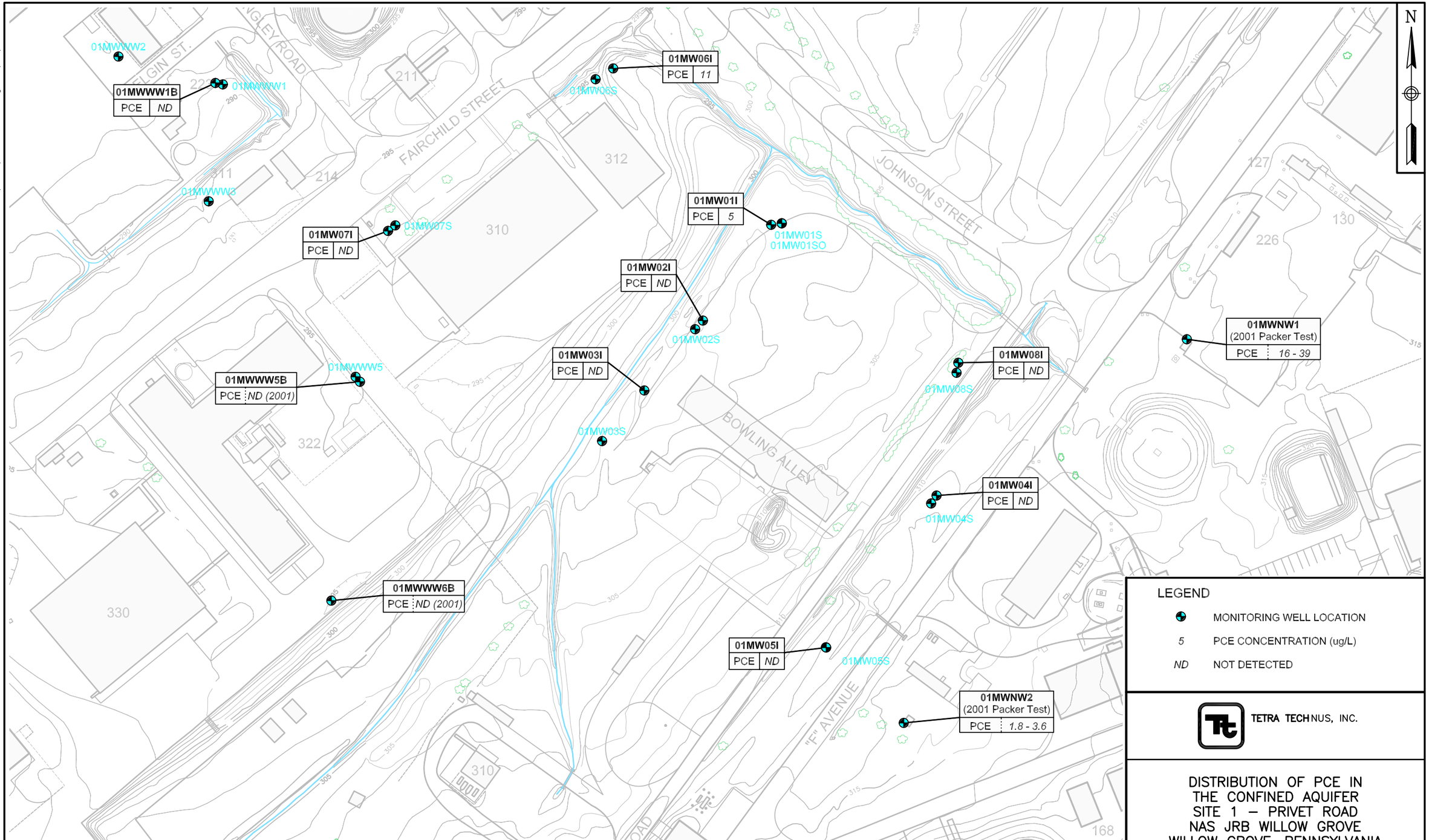
●	MONITORING WELL LOCATION
6	PCE CONCENTRATION (ug/L)
ND	NOT DETECTED

TETRA TECHNUS, INC.

DISTRIBUTION OF PCE IN
THE UNCONFINED AQUIFER
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE 2192GM03-2.DWG	SCALE AS NOTED
FIGURE NUMBER FIGURE 1-11	REV 0 DATE 08/03/07

2192 Willow Grove\1140\2192GM03-3.dwg 08/03/07 MKB



LEGEND

⊕	MONITORING WELL LOCATION
5	PCE CONCENTRATION (ug/L)
ND	NOT DETECTED

TETRA TECH NUS, INC.

DISTRIBUTION OF PCE IN
THE CONFINED AQUIFER
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE 2192GM03-3.DWG	SCALE AS NOTED
FIGURE NUMBER FIGURE 1-12	REV 0 / DATE 08/03/07

2192 Willow Grove\1140\2192GM03-6.dwg 08/03/07 MKB

0 200 400

SCALE IN FEET

LEGEND

MONITORING WELL LOCATION

AREA OF GROUNDWATER CONTAMINATION

TETRA TECH NUS, INC.

ESTIMATED AREA OF
GROUNDWATER CONTAMINATION
SITE 1 – PRIVET ROAD
NAS JRB WILLOW GROVE
WILLOW GROVE, PENNSYLVANIA

FILE	SCALE
2192GM03-6.DWG	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE 1-13	0 / 08/03/07

APPENDICES

APPENDIX A

PRESENT WORTH ANALYSIS
ALTERNATIVE 1 - NO ACTION
SITE 1 FEASIBILITY STUDY
NASJRB WILLOW GROVE, PENNSYLVANIA

YEAR	PRESENT WORTH FACTOR	CAPITAL COSTS	O & M COSTS	5-YEAR REVIEWS	PRESENT WORTH
0	1.000	$0	-		$0
1	0.935		$0		$0
2	0.873		$0		$0
3	0.816		$0		$0
4	0.763		$0		$0
5	0.713		$0	$20,000	$14,260
6	0.666		$0		$0
7	0.623		$0		$0
8	0.582		$0		$0
9	0.544		$0		$0
10	0.508		$0	$20,000	$10,167
11	0.475		$0		$0
12	0.444		$0		$0
13	0.415		$0		$0
14	0.388		$0		$0
15	0.362		$0	$20,000	$7,249
16	0.339		$0		$0
17	0.317		$0		$0
18	0.296		$0		$0
19	0.277		$0		$0
20	0.258		$0	$20,000	$5,168
21	0.242		$0		$0
22	0.226		$0		$0
23	0.211		$0		$0
24	0.197		$0		$0
25	0.184		$0	$20,000	$3,685
26	0.172		$0		$0
27	0.161		$0		$0
28	0.150		$0		$0
29	0.141		$0		$0
30	0.131		$0	$20,000	$2,627

TOTAL PRESENT WORTH = $43,156

Discount rate of 7% per OSWER Directive No. 9355.3-20, June 1993

PRESENT WORTH ANALYSIS
ALTERNATIVE 2 - LIMITED ACTIONS
SITE 1 FEASIBILITY STUDY
NASJRB WILLOW GROVE, PENNSYLVANIA

YEAR	PRESENT WORTH FACTOR	CAPITAL COSTS	O & M COSTS	5-YEAR REVIEWS	PRESENT WORTH
0	1.000	$6,897			$6,897
1	0.935		$0		$0
2	0.873		$0		$0
3	0.816		$0		$0
4	0.763		$0		$0
5	0.713		$0	$20,000	$14,260
6	0.666		$0		$0
7	0.623		$0		$0
8	0.582		$0		$0
9	0.544		$0		$0
10	0.508		$0	$20,000	$10,167
11	0.475		$0		$0
12	0.444		$0		$0
13	0.415		$0		$0
14	0.388		$0		$0
15	0.362		$0	$20,000	$7,249
16	0.339		$0		$0
17	0.317		$0		$0
18	0.296		$0		$0
19	0.277		$0		$0
20	0.258		$0	$20,000	$5,168
21	0.242		$0		$0
22	0.226		$0		$0
23	0.211		$0		$0
24	0.197		$0		$0
25	0.184		$0	$20,000	$3,685
26	0.172		$0		$0
27	0.161		$0		$0
28	0.150		$0		$0
29	0.141		$0		$0
30	0.131		$0	$20,000	$2,627

TOTAL PRESENT WORTH = $50,054

Discount rate of 7% per OSWER Directive No. 9355.3-20, June 1993