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Feasibility Study Report
for
Groundwater in Areas A, B and D

Naval Air Warfare Center (NAWC)
Warminster, Pennsylvania

Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 252

June 1996

Brown & Root Environmental

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FEASIBILITY STUDY REPORT
FOR
GROUNDWATER IN AREAS A, B AND D

NAVAL AIR WARFARE CENTER (NAWC)
WARMINSTER, PENNSYLVANIA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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EXECUTIVE SUMMARY

This Feasibility Study for the Area A, B, and D groundwater sites at the Naval Air Warfare Center (NAWC) located in Warminster, Pennsylvania has been prepared for the Northern Division , Naval Facilities Engineering Command as authorized under Contract Task Order (CTO) No. 252 under Contract N62472-90-D-1298. This work is part of the Navy's Installation Restoration Program (IRP), which is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures, as needed. This report also serves to meet the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

PURPOSE

The purpose of this FS is to present remedial alternatives for groundwater at Areas A, B, and D that has been contaminated due to hazardous substance releases by NAWC Warminster. The Phase II Remedial Investigation (RI) Report (HNUS, 1992) for Operable Unit 1 (OU-1), the Area B Hydrogeologic (ABH) Report (HNUS, 1996), and the Focused RI for Groundwater (FRG) (HNUS, 1996) identify the known nature and extent of contaminated groundwater and the risk to human health associated with this groundwater at NAWC Warminster. The Focused Feasibility Study Report for OU1 (HNUS April 1993) describes the interim actions evaluated for Areas A and B. Based on the available information, it has been determined that final remedial alternatives for Areas A and B and interim remedial alternatives for Area D at NAWC Warminster can be evaluated at this time. This FS has been prepared as part of the remedy selection process for these areas.

REMEDIAL ACTION OBJECTIVES

Contaminated groundwater attributable to NAWC Warminster at Areas A, B, and D presents an unacceptable risk to human health (see baseline Risk Assessment discussions within the Phase II RI report and within the FRG report). The general objectives for all three areas is to eliminate the unacceptable risk associated with exposure (or potential exposure) to groundwater contaminants attributable to these areas and to minimize or control the migration of contaminants from these areas.

Based on the information in the Phase II RI, the FRG, and the ABH reports, there is sufficient information to identify a final remedy for all groundwater zones for Areas A and B. There is uncertainty regarding the full nature and extent of contaminated groundwater attributable to Area D. Data gaps associated with this area will be addressed by studies to be conducted in and adjacent to Area D. As a result, there remains uncertainty in regard to the most appropriate final remedy selection for Area D. However, the available data provide an adequate basis for selecting an interim remedy to minimize the migration of NAWC Warminster-related contaminants within Area D groundwater while additional investigations are being conducted to fully define the nature and extent of contamination in these aquifers and to identify a final remedy.

Accordingly, this FS develops final remedial alternatives for Areas A and B and an interim remedial alternative for Area D. The remedial objectives are defined as follows:

- Minimize migration and prevent exposure to contaminants in groundwater at Areas A and B.

- Restore affected groundwater, where feasible, in Areas A and B to beneficial uses and to the clean-up goals as required by Applicable or Relevant and Appropriate Requirements (ARARs) to be established in the Record of Decision (ROD) for both of these areas.

- Minimize migration of contaminated groundwater attributable to Area D.

REMEDIAL ALTERNATIVES DEVELOPMENT

This Feasibility Study was prepared based on data obtained through previous investigations at NAWC, using EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (OSWER Directive 9355.3-01, October 1988), the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300, March 1990), EPA Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (OSWER Directive 9283.1-2, December 1988), and the Navy/Marine Corps Installation Restoration Manual (February 1992).

Based on site contaminants, characteristics, response objectives, and general response actions, technologies and process options were identified. The technologies and options were screened for effectiveness, implementability, and relative cost. Remedial alternatives were assembled using those technologies and options that passed the screening. In addition, CERCLA and the

NCP require that the "No Action" alternative be evaluated as a baseline alternative. The alternatives that were assembled are briefly described below by area of concern:

Area A Alternatives (Final Remedy)

Alternative A1: No Action: Under this alternative no remedial action would be undertaken to address contaminated groundwater attributable to Area A.

Alternative A2: Institutional Controls and Monitoring: This alternative would consist of implementing institutional controls to prevent use of groundwater for domestic purposes and to monitor the quality of that groundwater. Monitoring would include sampling from selected monitoring wells on a monthly and then quarterly basis and the performance of 5-year reviews. This alternative would also include the preparation of deed restrictions that would be in effect before any change in the ownership of the site.

Alternative A3: Extraction, Treatment at the Existing Treatment System, Discharge at Outfall 001: In this alternative, the contaminated Area A groundwater would be extracted, treated at the existing Treatment System, and discharged to the unnamed tributary of Neshaminy Creek at existing Outfall 001. Minor modifications would be required to the existing Treatment System, to effectively treat increased Volatile Organic Compound (VOC) levels. This alternative would also include the continued operation of the off-site Warminster Township Municipal Authority Well 26 (WTMA26) from which groundwater is currently pumped, treated by air stripping and chlorination, and delivered to the municipal water supply system. Long-term groundwater monitoring and 5-year reviews would be performed as part of this alternative. This alternative would include the preparation of deed restrictions to be in effect before any change in the ownership of the site. Institutional controls would also be implemented to prevent groundwater use for domestic purposes.

Area B Alternatives (Final Remedy)

Alternative B1: No Action: Under this alternative no remedial action would be undertaken to address contaminated groundwater attributable to Area B.

Alternative B2: Natural Attenuation with Institutional Controls and monitoring: Under this alternative no active measures would be taken to remedy the contamination of Area B groundwater. However, control measures would be instituted to prevent use of groundwater for

domestic purposes. Long-term groundwater monitoring would be performed to determine contaminant concentrations; assess the effectiveness of natural attenuation mechanisms such as biodegradation, and volatilization; and to monitor contaminant migration. This alternative would also include the preparation of deed restrictions and the performance of 5-year reviews.

Alternative B3: Extraction, Local Treatment, Reinjection: Under this alternative groundwater would be pumped from selected locations within Area B, treated for removal of the VOCs of concern by air stripping and vapor-phase Granular Activated Carbon (GAC) adsorption at a new local treatment system, and reinjected into the aquifer. This alternative would also include the implementation of institutional controls to prevent groundwater use for domestic purposes, the preparation of deed restrictions before any change in the ownership of the site, the performance of long-term groundwater monitoring, and 5-year reviews.

Alternative B4: Extraction, Treatment at Existing Treatment System, Discharge to Outfall 001: Under this alternative groundwater would be pumped from selected locations within Area B, transferred to the existing Treatment System through a pipeline, treated by air stripping and vapor- and liquid-phase GAC adsorption, and discharged via existing Outfall 001. This alternative would also include the implementaion of institutional controls to prevent groundwater use for domestic purposes, the preparation of deed restrictions before any change in the ownership of the site, the performance of long-term groundwater monitoring, and 5-year reviews.

Area D Alternatives (Interim Remedy)

Alternative D1: No Action: This alternative would not involve any remedial action. No monitoring would be conducted to assess the off-site migration of contaminants.

Alternative D2: Institutional Controls and Monitoring: Under this alternative, actions would consist of establishing institutional controls to prevent use of groundwater for domestic purposes and performing long-term monitoring of groundwater quality. Monitoring results would be used to evaluate the contaminant concentrations, migration, and risks, and to direct future actions. This alternative would also include preparation of deed restrictions, before any change in the ownership of the site, and 5-year reviews.

Alternative D3: Extraction, Treatment at the Existing Treatment System, Discharge at Outfall 001: Under this alternative the groundwater would be pumped from selected locations within Area D, transferred by pipeline to the existing Treatment System, treated in this system, and discharged

via existing Outfall 001. Modifications would be required to the existing Treatment System to accommodate contaminant levels and flow rate. This alternative would include the continued operation of the off-site WTMA26 well system from which groundwater is currently pumped, treated by air stripping and chlorination, and delivered to the municipal water supply system. This alternative would also include the implementation of institutional controls to prevent groundwater use for domestic purposes, the preparation of deed restrictions in case of change in the ownership of the site, the performance of long-term groundwater monitoring, and 5-year reviews.

EVALUATION OF REMEDIAL ALTERNATIVES

Each alternative was evaluated using seven of the nine criteria specified in the NCP and the previously referenced EPA guidance. These criteria include Overall Protection of Human Health and the Environment; Compliance with ARARs; Long-Term Effectiveness and Permanence; Reduction of Toxicity, Mobility, or Volume Through Treatment; Short-Term Effectiveness; Implementability; and Cost. The other two criteria, State Acceptance and Community Acceptance, will be applied after comments are received on a Proposed Plan and in public meetings. Section 4.0 of this report presents the results of this evaluation process.

A comparative analysis of each alternative for the three separate areas, (A, B, and D), was completed. This comparative analysis was performed with respect to specific factors for each of the seven above-mentioned criteria and differences among the alternatives were identified. The results of this analysis are presented in Section 5.0. The costs associated with each alternative are also presented in Section 5.0. The estimated costs for each alternative are as follows:

Area A	Capital Costs	First Year/Annual Costs	Present Worth
Alternative A1	$0	$0	$0
Alternative A2	$0	$81,350/$42,200	$742,000
Alternative A3	$748,000	$122,000/$82,500	$2,109,000
Area B			
Alternative B1	$0	$0	$0
Alternative B2	$0	$98,400/$32,800	$290,000
Alternative B3	$466,900	$153,900/$69,500	$864,000
Alternative B4	$1,046,800	$152,600/$68,200	$1,438,000
Area D			
Alternative D1	$0	$0	$0
Alternative D2	$0	$61,750/$32,200	$579,000
Alternative D3	$675,200	$79,600/$50,000	$1,528,000

There will be an additional $20,000 every fifth year for Alternatives A2, A3, B2, B3, B4, D2, and D3. This is the cost associated with the 5-year reviews that will be conducted for these alternatives. The present worth cost presented above, includes this cost.

The development and evaluation of these alternatives reflect the needs of the entire facility and take into consideration the effects of one alternative on the other. The cost estimates reflect the potential for the use of the existing Treatment System for all three areas. Although an integrated approach was taken in this analysis, each alternative was developed to allow for the independent selection of any given alternative and as such, each alternative presented for an area is independent from the selection of any alternative for another area. The specific modifications that would be required to maintain treatment levels by the addition of contaminated groundwater from any one of these areas are detailed in Section 4.0 and have been included in the cost estimate under the appropriate alternative.

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

In response to Contract Task Order 252 under Contract N62472-90-D-1298, Brown & Root Environmental is submitting this feasibility study (FS) report for the Naval Air Warfare Center (NAWC) (formerly the Naval Air Development Center), Warminster, Pennsylvania. This work is part of the Navy's Installation Restoration Program (IRP), which is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures as needed.

IRP activities are typically performed in four distinct phases. The first phase consists of a preliminary assessment (PA), which is followed by the site inspection (SI). The third phase is a remedial investigation/ feasibility study (RI/FS), which is intended to characterize physical and chemical parameters and risks associated with the facility. The fourth phase consists of remedial action, designed to control and mitigate contamination. This report is prepared under Phase III IRP activities.

The purpose of this FS is to present remedial alternatives for groundwater at Areas A, B, and D that has been contaminated due to hazardous substance releases by NAWC Warminster. The Phase II Remedial Investigation (RI) Report (HNUS, 1992) for OU-1, the Area B Hydrogeologic (ABH) Report (HNUS, 1996), and the Focused RI for Groundwater (FRG) (HNUS, 1996) identify the known nature and extent of contaminated groundwater and the risk to human health associated with this groundwater at NAWC Warminster. Interim remedial actions for contaminated groundwater associated with Areas A and B were addressed in the Focused Feasibility Study (HNUS 1993) for OU1. Based on the available information, it has been determined that final remedial alternatives for Areas A and B and interim remedial alternatives for Area D at NAWC Warminster can be selected at this time. This FS has been prepared as part of the remedy selection process for these areas.

Feasibility studies for other media and other areas affected by the facility will be performed upon completion of additional RI work. These feasibility studies will be performed to facilitate the selection of additional remedial actions necessary to protect human health and the environment.

1.2 ORGANIZATION OF REPORT

This report presents the remedial alternatives for groundwater contamination attributable to NAWC Warminster in the vicinity of Areas A (Sites 1, 2, and 3), B (Sites 5, 6, and 7), and D (Main Building Complex). Groundwater contamination attributable to NAWC in the vicinity of Area C has been addressed through the evaluation of remedial alternatives presented in Focused Feasibility Study Report for Operable Unit 3 (HNUS, August 1994).

- Section 2.0 discusses remedial action objectives, applicable or relevant and appropriate requirements (ARARs) pertaining to groundwater at Areas A, B, and D and the identification and screening of technologies and process options.

- Section 3.0 presents the development of remedial alternatives.

- Section 4.0 presents the detailed analysis of each remedial alternative.

- Section 5.0 presents a comparative analysis of the remedial alternatives.

- Appendix A contains detailed cost estimates for remedial alternatives.

- Appendix B contains supporting information for groundwater modeling conducted for Area B.

- Appendix C contains conceptual design calculations for remedial alternatives.

The Phase II RI Report for OU-1, the Area B Hydrogeologic Report, and the Focused RI for Groundwater contain descriptions of the facility, regional and local hydrogeology, groundwater use, the known nature and extent of overburden and shallow bedrock groundwater contamination, and a risk assessment for this groundwater. Pertinent information from these documents is summarized in this FS (see Sections 1.3 and 1.4).

This FS was prepared using EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (OSWER Directive 9355.3-01, October 1988), the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300, March 1990), EPA Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (OSWER Directive 9283.1-2, December 1988), and the Navy/Marine Corps Installation Restoration Manual (February 1992).

1.3 SITE BACKGROUND

NAWC Warminster is located in the township of Warminster, Bucks County, Pennsylvania. The facility can be found on the United States Geological Survey (U.S.G.S.) Hatboro 7.5-minute topographic Figure 1-1 quadrangle map, a portion of which is reproduced as Figure 1-1. The total area of NAWC Warminster is approximately 734 acres. The facility lies in a populated suburban area surrounded by private homes, various commercial/industrial activities, and a golf course. On-site areas include various buildings and other complexes connected by paved roads, the runway and ramp area, mowed fields, and a small wooded area.

Commissioned in 1944, NAWC Warminster's main mission has been research, development, testing, and evaluation of naval aircraft systems. NAWC Warminster also conducts studies in anti-submarine warfare systems and software development. Historically, wastes were generated during aircraft maintenance and repair, pest control, firefighting training, machine and plating shop operations, spray painting, and various materials research and testing activities in laboratories. These wastes included paints, solvents, sludges from industrial wastewater treatment, and waste oils.

EPA officially recognized the NAWC Warminster sites as possibly needing investigation in September 1979. In November 1979, EPA completed a PA. In 1980, the Department of the Navy began its environmental investigative work at NAWC Warminster.

On October 4, 1989, NAWC Warminster was placed on the final National Priority List (NPL). The same year, EPA submitted a draft Interagency Agreement to the Navy for formalizing and scheduling remedial activities. The contents of this agreement were negotiated in 1990. In 1991, B&R Environmental was tasked to complete RI/FS activities at the facility.

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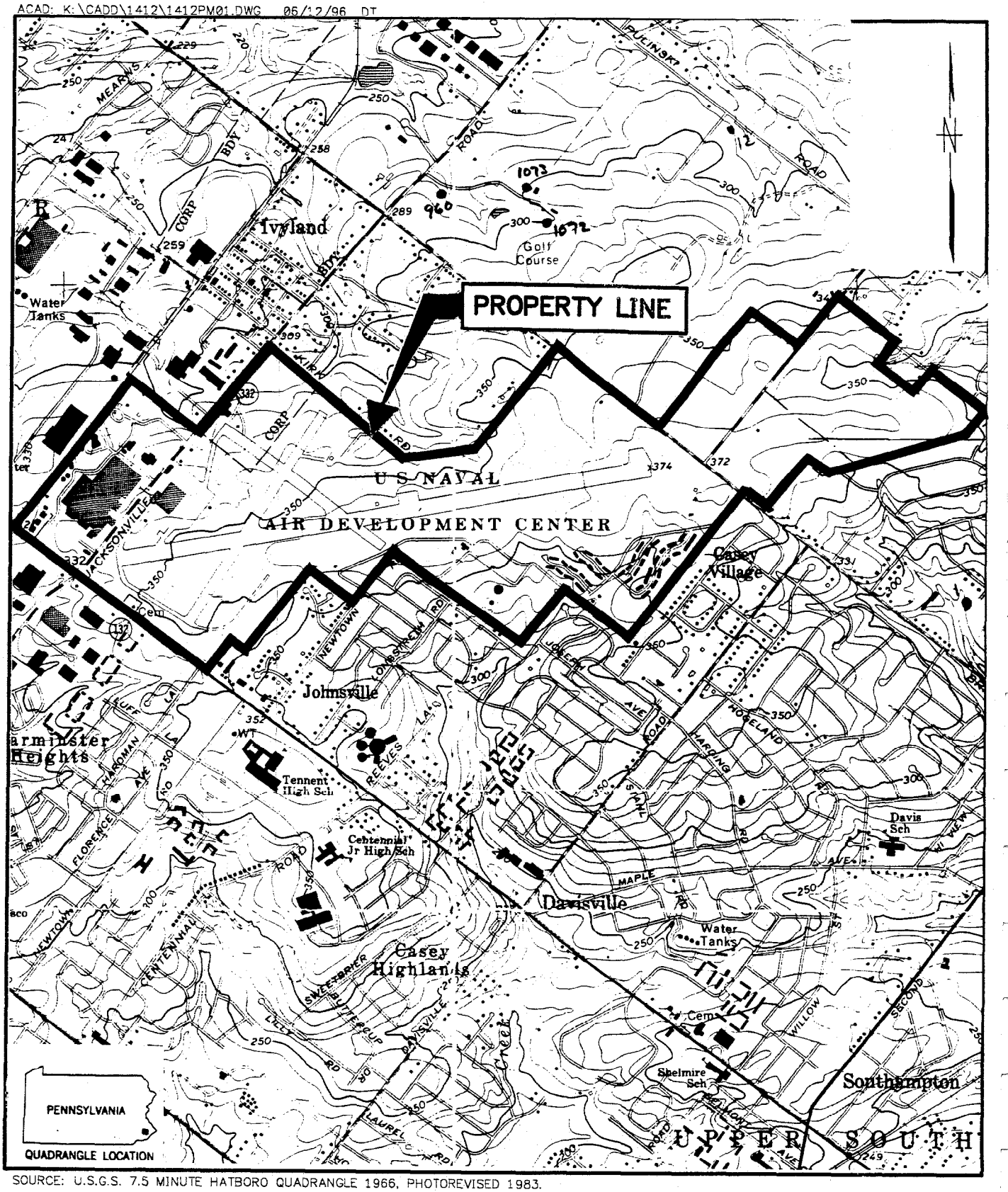

SOURCE: U.S.G.S. 7.5 MINUTE HATBORO QUADRANGLE 1966, PHOTOREVISED 1983.

FIGURE 1-1

SITE LOCATION MAP
NAWC WARMINSTER, PA

0 2000 4000
SCALE IN FEET

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NAWC Warminster is scheduled for realignment under the Base Realignment and Closure (BRAC) Program managed by the Department of Defense. The facility is tentatively scheduled to be closed by September 30, 1996. The future use of the NAWC Warminster property has not been finalized. This report has been prepared as part of the remedy selection process for contaminated groundwater attributable to Areas A, B, and D at the NAWC Warminster facility (see Figure 1-2).

Site Description

NAWC Warminster is located in an upland area lying across two local drainage basins. The longest runway, which is currently the only active runway, is generally located along the topographically highest area at the facility.

The majority of the facility drains toward the north into an unnamed tributary of Little Neshaminy Creek, and the remaining drainage flows southward to Southampton Creek. Both local drainage basins lie within the regional drainage basin of the Delaware River. Local drainage is controlled primarily through natural flow to ephemeral streams and constructed drainage; runoff is influenced locally by surface grading, pavement, constructed ditches, and storm sewer lines.

Surface soils in the vicinity of the facility are generally fine-textured, predominantly silty loams, with moderate to low permeabilities. The soils are commonly underlain by saprolite (extensively weathered bedrock) at an approximate depth of four to 10 feet. The soils and saprolite are underlain by the middle arkose member of the late Triassic age Stockton Formation. The Stockton Formation is underlain by Ordovician to Precambrian age basement rocks.

The middle member of the Stockton Formation consists of fine- to medium-grained arkosic sandstone interbedded with red shale, siltstone, and conglomerate. Bedding layers strike from southwest to northeast and dip to the northwest. The Stockton Formation is extensively faulted and is cut by a well-developed joint system.

Groundwater within the Stockton Formation is transmitted through primary porosity and along bedding planes and fractures. Shales and siltstone units commonly restrict vertical movement of groundwater due to their low primary porosity and poorly developed secondary porosity. The well-sorted, fine- to medium-grained sandstone units form the best aquifers within the formation. Groundwater in the unconsolidated overburden and shallow bedrock layers typically occurs under water-table (unconfined) conditions. Groundwater within the deeper bedrock layers can occur under both unconfined and confined conditions.

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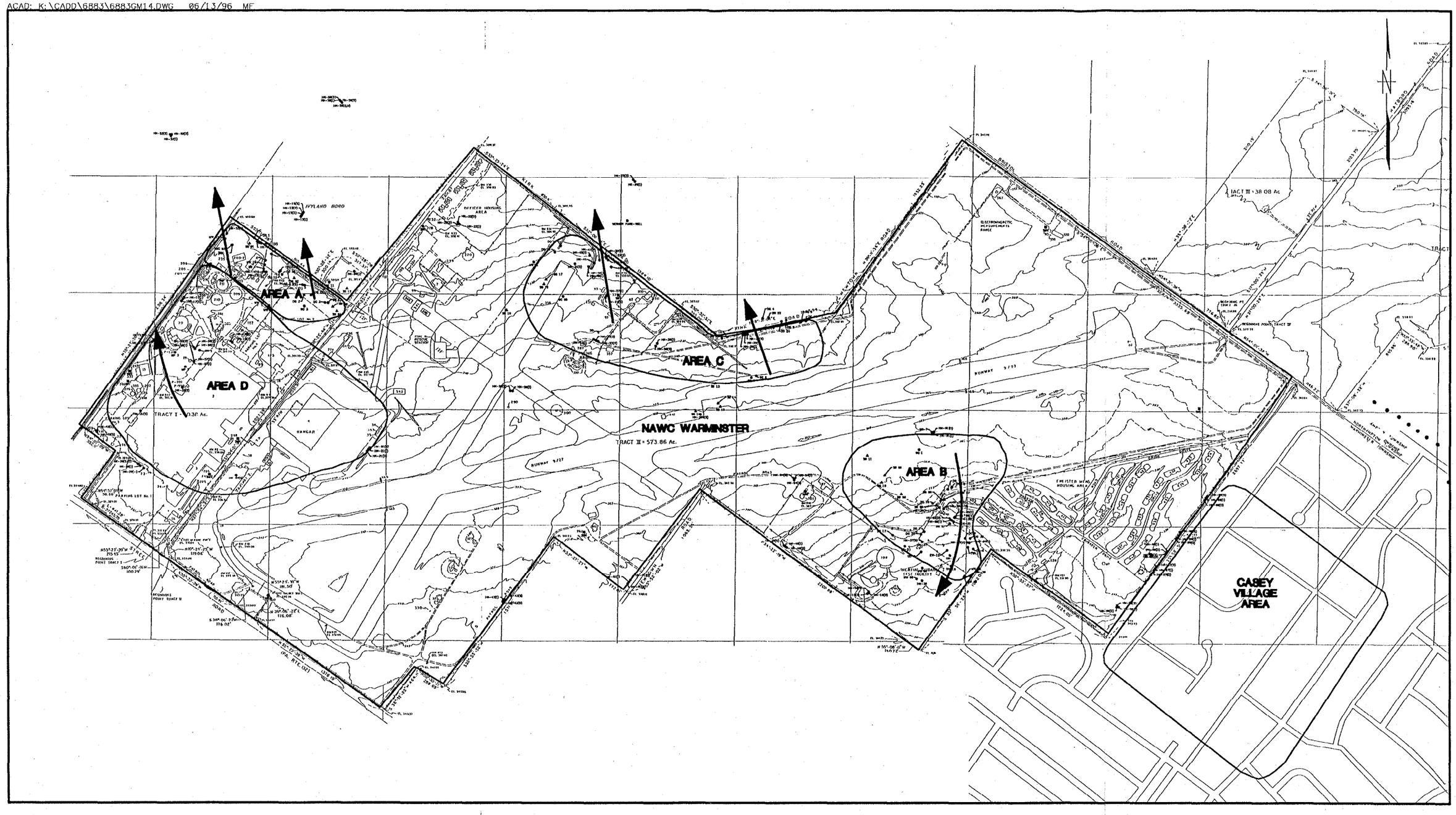

LEGEND

GROUNDWATER FLOW DIRECTIONS

FIGURE 1-2

0 800 1600
SCALE IN FEET

LOCATION MAP FOR GROUNDWATER AREAS OF CONCERN
NAWC WARMINSTER, PA.

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419D012

1.3.1 Areas A/D

Areas A and D, although under two separate actions because of potential source areas, are described together in general terms in this section. These two areas are adjacent to each other and share physical and environmental features.

1.3.1.1 Description/Location

Area A consists of the groundwater associated with Sites 1, 2, and 3 (see Figure 1-2). Site 1 is located on a portion of the facility lying northwest of Jacksonville Road and is adjacent to the wastewater treatment plant. The site is within 1,000 feet of an off-site food processing facility and within 300 feet of an unnamed tributary that flows to Little Neshaminy Creek. Site 1 was operated as a burn pit within an eroded ravine from 1940 to 1955. Various wastes such as paints, oils, asphalt, roofing material, solvents, scrap metals, and unspecified chemicals were burned within this pit. The quantity of wastes deposited or burned is unknown. The estimated area of Site 1 is approximately 2,500 square feet.

Site 2 is located southeast of Site 1 and received wastewater sludges from 1965 to 1970. The site consisted of two disposal trenches; each trench was approximately 12 feet wide by 200 feet long by eight feet deep. The total area of the site may be 20,600 square feet.

Site 3 is adjacent to Site 2. The site was used from 1955 to 1965 as a burn pit for solvents, paints, roofing materials, and other unspecified chemicals. The pit was approximately 20 feet wide by 30 feet long by 10 feet deep. Residue from the pit was occasionally removed and deposited at an unknown area at NAWC Warminster.

Area D generally consists of base property west of Jacksonville Road in the vicinity of the main building complex at NAWC Warminster (Figure 1-2). An industrial park lies to the west of this area and a residential neighborhood is located to the southwest.

Buildings 1, 2, and 3 were built in 1942 by Brewster Aeronautical Corporation, and form the current building complex west of Jacksonville Road. According to the EBS report (EA Engineering, 1995), Buildings 1 and 2 contain numerous labs and shops, while Building 3 is primarily administrative office space. Detailed descriptions of the numerous labs and shops located within Buildings 1 and 2 are presented in the EBS report. Prior to its conversion to largely a lab facility in the 1960's, Building 2 consisted primarily of open space. Aerial photos from the time period up to the mid 1960's show airplanes

parked in an open area between Building 2 and Jacksonville Road, indicating that Building 2 was probably used for aircraft manufacturing, testing, repairs, etc.

In addition to the main building complex and the adjacent open area, a number of smaller structures exist in the general vicinity of Area D. These structures include two 90-day hazardous waste storage areas, an above-ground waste oil tank, a former underground firing range (since removed), a meter house, an elevated water tank, and the main electrical switching station for the base.

On-base supply wells SW-1 and SW-2 are located west of Building No. 2 and along the western NAWC Warminster property line. SW-1 is 247 feet deep and SW-2 is 246 feet deep. Both wells are constructed as open boreholes below their surface casing, which in each instance was set to a depth of about 30 feet. On-base supply wells SW-3 and SW-4 (570 and 591 feet deep, respectively) are located east of and generally upgradient from Area D.

1.3.1.2 Geology

The geology of Areas A/D consists of alternating coarse and fine grained sedimentary bedrock units of the Stockton Formation underlying a thin veneer of clayey residual soils. The soils consists primarily of silt and clay, with minor amounts of sand and rock fragments. Typically, the soils grade into weathered bedrock at depths of about 8-10 feet below ground surface, and to competent bedrock at a depth of about 15 feet. The transition from soils to weathered bedrock to competent bedrock occurs gradually and varies somewhat in depth across Areas A/D.

The bedrock units of the Stockton Formation dip gently to the north-northwest. Lithologic units vary in thickness from less than a foot to about 40 feet typically, with some coarser grained packages of rock units locally reaching thicknesses of up to about 80 feet. The fine grained lithologic units are described as mudstones and typically consist primarily of red-brown siltstones and shales. The coarser grained rock units typically consist of fine to coarse grained arkosic sandstones, ranging from well defined, gradational sequences to fairly abrupt lithologic transitions.

The bedrock units strike north 64° east (N64E) and dip 7° to the northwest, based on boring log data from Areas A and D wells. The dip direction of the bedrock units generally follows topography in this area, thus the bedrock units that outcrop or occur at shallow depths within Areas A and D are encountered at greater depths in areas farther to the north-northwest.

Fractures were encountered at varying depths in the well borings drilled in Areas A and D. The fractures were encountered both at lithologic contacts (bedding plane fractures) and within lithologic units (cross bedding fractures). Both sandstones and mudstones were observed to be fractured to varying degrees.

No bedrock outcrops were encountered within or adjacent to NAWC Warminster during the field investigation, thus no direct measurements of fracture orientations could be made. According to Rima, et.al. (1962), the most frequently occurring joint sets within the Stockton Formation occur parallel and perpendicular to strike, with minor sets aligned approximately 50° from strike.

The bedrock surface across Areas A and D generally slopes to the north and northwest, following the ground surface slope.

1.3.1.3 Hydrogeology

Groundwater within and adjacent to Areas A and D occurs primarily within the underlying bedrock units. Groundwater is encountered in discrete fractures within the rock mass. Interconnected networks of fractures within the bedrock serve as the primary groundwater migration pathways. Some minor primary (intergranular) permeability may exist within the bedrock, however it is insignificant in comparison to the secondary (fracture) permeability.

Within the bedrock, the sandstone units function as the primary water transmitting units, while the fine-grained mudstone units act as semiconfining layers to groundwater flow. Both sandstones and mudstones are fractured to varying degrees, however fractures in the sandstones in general tend to have higher yields and the sandstone units act as preferential zones of groundwater flow. Below a depth of about 80-100 feet, groundwater occurs under semiconfined conditions, with significantly higher hydraulic heads in deeper portions of the bedrock in comparison to hydraulic heads in the shallow bedrock.

The soils overlying bedrock also contain minor amounts of water in places, primarily along the northern edge of Area A near the base boundary. Due to the limited extent of the saturated soils and the clayey nature and resulting low permeability of the soils, this groundwater migration pathway is of minor significance in comparison to the bedrock groundwater flow systems.

The Stockton Formation is used as a source of domestic, municipal, and commercial water supply in the vicinity of Areas A and D.

Groundwater Flow Directions

Groundwater flow directions across Areas A and D were evaluated based on water level data gathered from on-site and off-site monitoring wells.

Shallow groundwater flow directions were defined based on water level data from bedrock wells with monitored intervals generally less than 90 feet deep. The overall shallow bedrock groundwater flow direction across Areas A and D, as shown in Figure 1-3, is to the north-northwest, with an average gradient of approximately 0.02. This direction of groundwater flow is similar to the ground surface slope, towards several unnamed tributaries to Little Neshaminy Creek.

Based on a comparison between the staff gauge water level measurements for the stream that borders Area A and the shallow groundwater flow map, water levels in the stream appear to be higher than groundwater levels within the overburden and shallow bedrock across most of Area A and in the downstream area as far as staff gauge No. 3. This indicates that shallow groundwater is not discharging to the stream in this area. Near Jacksonville Road, groundwater and surface water levels are similar, suggesting a higher potential for localized groundwater discharge to the stream.

Locally in Area D, the shallow groundwater flow gradient is somewhat lower than occurs within Area A and the adjacent property across Jacksonville Road. This localized area of lower gradient may be related to the presence of the building complex. The presence of the large building within Area D may act to minimize precipitation recharge locally and lessen the shallow groundwater flow gradient.

Intermediate depth groundwater flow is also to the north-northwest following ground surface slope and bedrock dip, as shown in Figure 1-4. The lateral groundwater flow gradient in the intermediate flow system is 0.025. As with the shallow wells, the local flow gradient in Area D is lower than in Area A and east of Jacksonville Road, however the reason for the decrease in flow gradient may be due to different reasons than for the shallow flow system. The intermediate depth wells within Area D are affected by cyclical pumping of nearby wells SW-3 and SW-4. The periodic withdrawal of water from this depth zone by the production wells likely acts to reduce the flow gradient locally in Area D.

Within the deepest zone of investigation, groundwater flow is to the north-northwest across Area D, gradually changing to a north-northeast flow direction across Area A and downgradient as shown in Figure 1-5. The mechanisms causing this flow pattern, and the area of low gradient between areas A and D, are not clearly defined but may be tied in part to the pumping of base production wells SW-3 and SW-4. In addition, SW-10 is located further south and updip of areas A and D. The shallow strata intersected by

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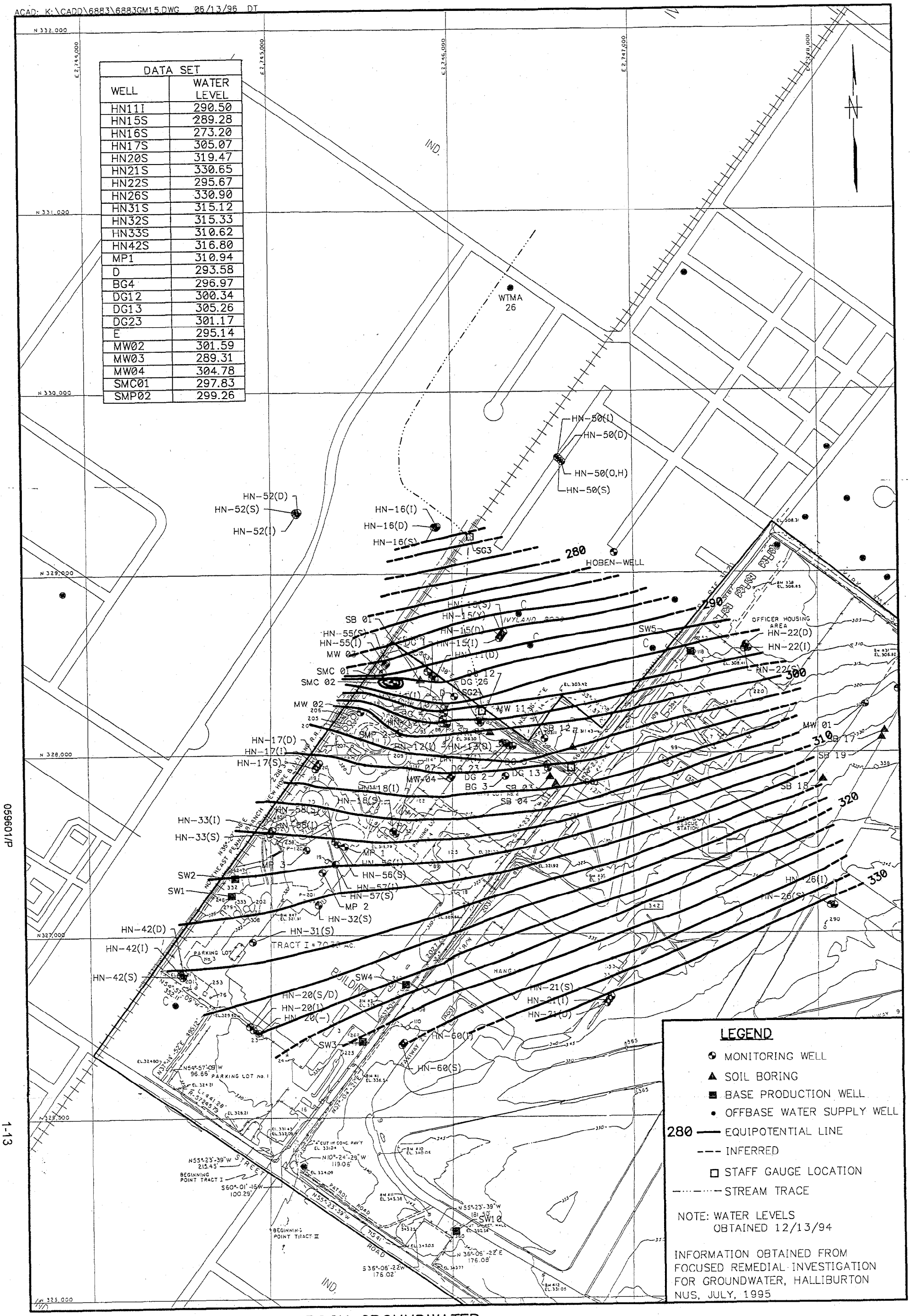

DATA SET	
WELL	WATER LEVEL
HN11I	290.50
HN15S	289.28
HN16S	273.20
HN17S	305.07
HN20S	319.47
HN21S	330.65
HN22S	295.67
HN26S	330.90
HN31S	315.12
HN32S	315.33
HN33S	310.62
HN42S	316.80
MP1	310.94
D	293.58
BG4	296.97
DG12	300.34
DG13	305.26
DG23	301.17
E	295.14
MW02	301.59
MW03	289.31
MW04	304.78
SMC01	297.83
SMP02	299.26

SHALLOW BEDROCK GROUNDWATER
FLOW MAP
AREAS A/D
NAWC WARMINSTER, PA

0 500 1000
SCALE IN FEET

FIGURE 1-3

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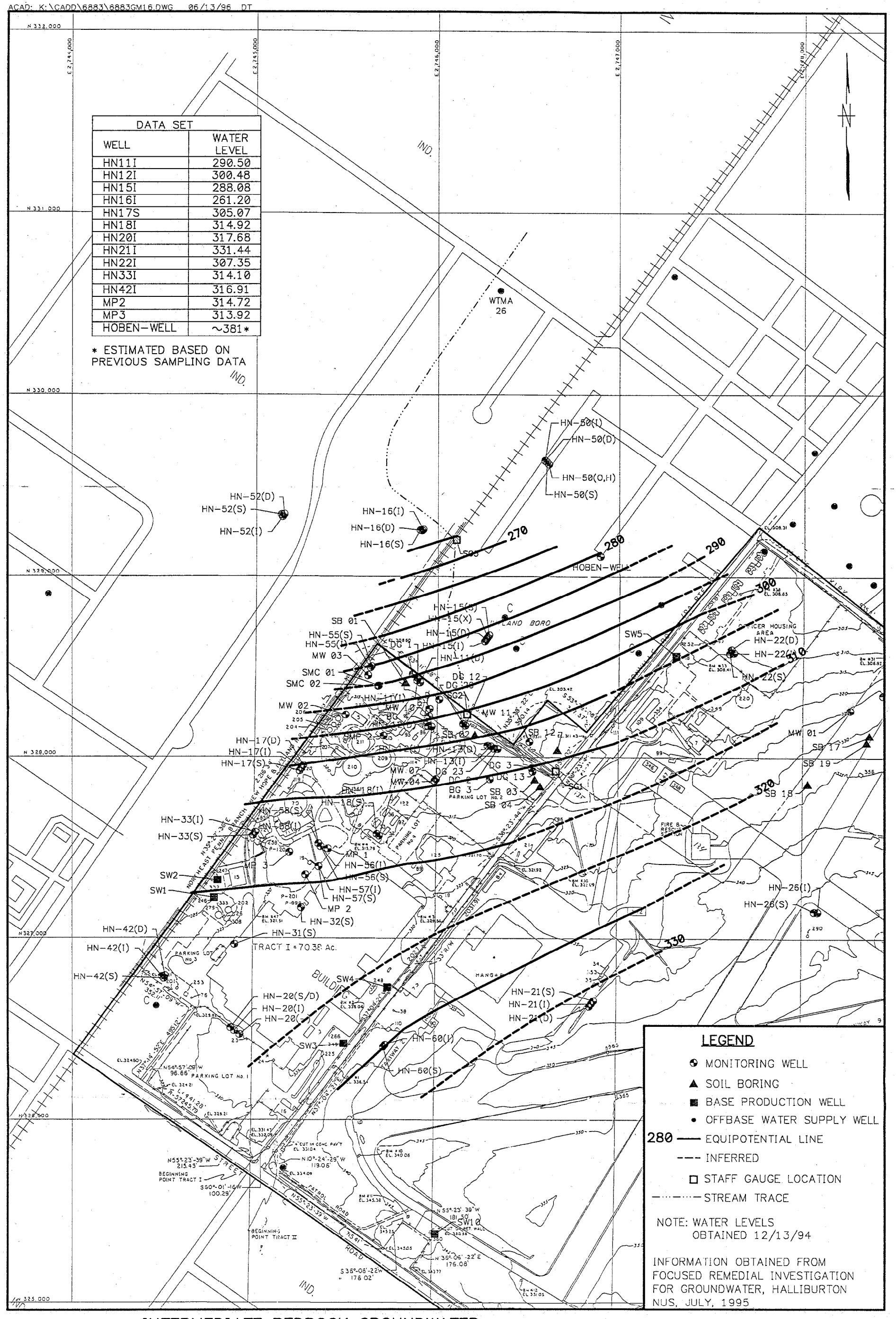

DATA SET	
WELL	WATER LEVEL
HN11I	290.50
HN12I	300.48
HN15I	288.08
HN16I	261.20
HN17S	305.07
HN18I	314.92
HN20I	317.68
HN21I	331.44
HN22I	307.35
HN33I	314.10
HN42I	316.91
MP2	314.72
MP3	313.92
HOBEN-WELL	~381*

* ESTIMATED BASED ON PREVIOUS SAMPLING DATA

INTERMEDIATE BEDROCK GROUNDWATER FLOW MAP
AREAS A/D
NAWC WARMINSTER, PA

0 500 1000
SCALE IN FEET

FIGURE 1-4

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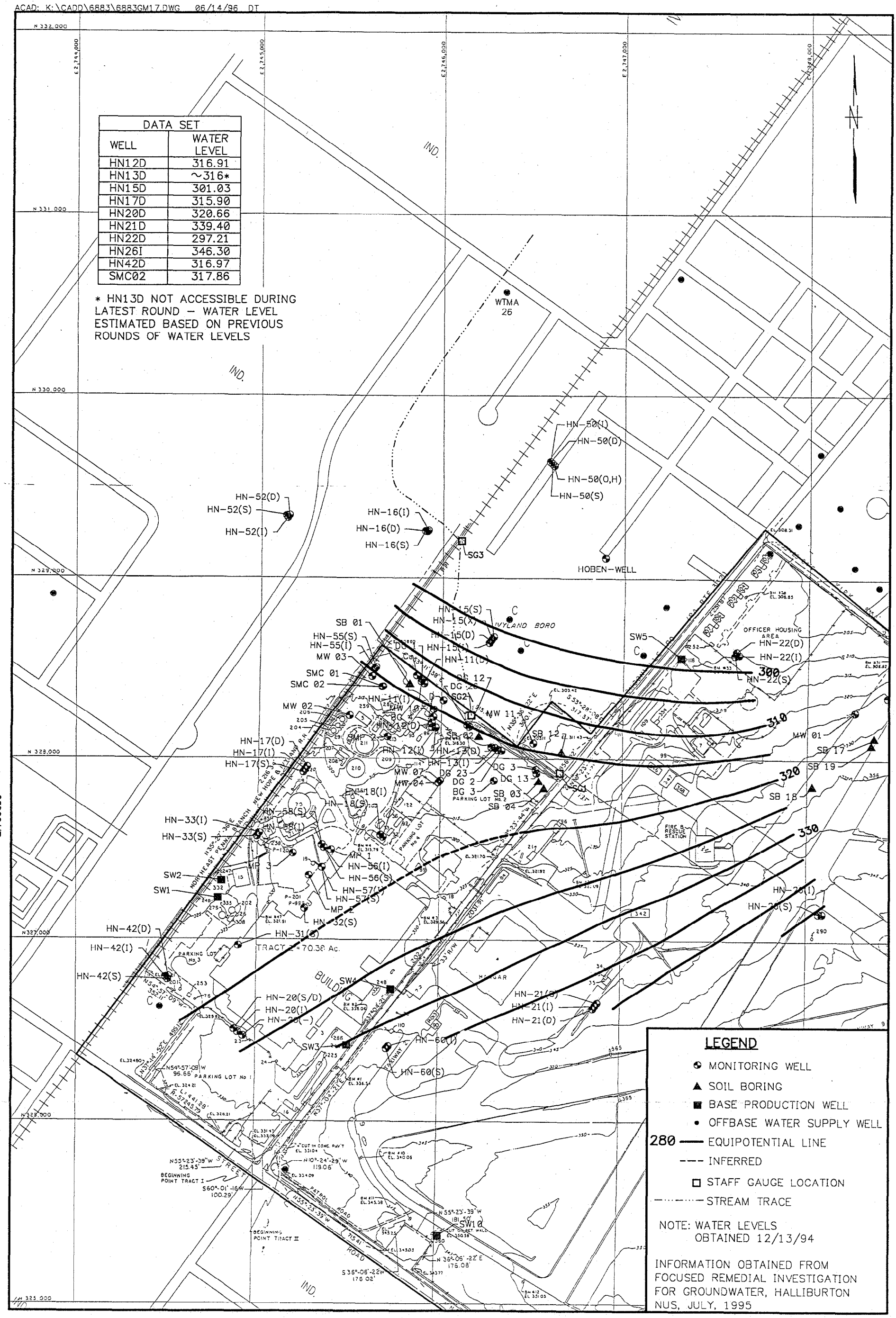

DATA SET	
WELL	WATER LEVEL
HN12D	316.91
HN13D	~316*
HN15D	301.03
HN17D	315.90
HN20D	320.66
HN21D	339.40
HN22D	297.21
HN26I	346.30
HN42D	316.97
SMC02	317.86

* HN13D NOT ACCESSIBLE DURING LATEST ROUND – WATER LEVEL ESTIMATED BASED ON PREVIOUS ROUNDS OF WATER LEVELS

DEEP BEDROCK GROUNDWATER FLOW MAP
AREAS A/D
NAWC WARMINSTER, PA

0 500 1000
SCALE IN FEET

FIGURE 1-5

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this high-yielding production well may be intersected by the deep wells within Areas A and D, and the pumping of SW-10 may act to reduce the flow gradient in the deep flow system somewhat.

Vertical groundwater flow gradients are generally upward, from deeper flow zones to shallow flow zones across Areas A and D. Upward vertical head differentials between shallow and deep wells ranged from a maximum of approximately 20 feet to a minimum of about 0.2 feet. Typically, within clusters, the intermediate well water level was higher than the shallow water level and lower than the deep water level, but there were exceptions to this general trend. One notable exception to the pattern of increasing heads with depth is at well cluster HN16. In this cluster, the intermediate depth well has a significantly lower water level (10+ feet) than both the deep and the shallow wells. Overall, the deep well has the highest water level within this cluster. The reason for this distribution of hydraulic heads is not clear but may be related to groundwater pumping conditions in the area.

The overall pattern of vertical head differentials indicates that groundwater in the bedrock exists under semiconfined conditions. As described previously, the laterally persistent mudstone units within Areas A and D act as semiconfining layers to groundwater flow, creating the large head differentials seen.

Bedrock Aquifer Hydraulic Characteristics

The characteristics of the bedrock aquifer were investigated through the performance of a long-term pumping test in Area D. Monitoring well MP-1 was selected as the pumping well for the test, because of its relatively high yield and its monitored interval (18-101 feet), which corresponds roughly to the depth range within which the most significant groundwater impacts have been noted at the base.

An average transmissivity (T) of 733 ft^2/day and storativity (S) of 2.3×10^{-2} was obtained from time-drawdown analyses of the test data. The distance-drawdown analysis yielded an average T of 705 ft^2/day. This transmissivity is somewhat higher than was observed during the Area A, Area B, and Area C pumping tests, and may be related in part to an increased sandstone/mudstone ratio for the sequence of strata pumped, in comparison to the subsurface conditions present in the areas of the other pumping tests at the base.

Geologic/Hydrogeologic Controls on Contaminant Migration

Migration of contaminants in groundwater in and out of Areas A and D will be influenced by several factors. Groundwater (and contaminant) migration is expected to occur primarily within interconnected networks of fractures within the rock mass. Lateral migration of shallow groundwater is to the north-

northwest through the shallow bedrock units that underlie Areas A and D, following the groundwater flow gradient and the direction of ground surface slope. Large volume pumping of groundwater from production wells north of Area A (i.e., WTMA26) may influence the local groundwater flow pattern somewhat, depending on the location, depth and pumping rate of the well(s). Warminster Township Municipal Well 26 (WTMA26) is located approximately 1,800 feet due north of Area A along Ivyland Road. This 10-inch-diameter well is 250 feet deep, is cased to a depth of 70 feet, and pumps at an average rate of 236 gallons per minute, with a maximum capacity of approximately 250 gpm. The static water level is above ground surface, and the pumping water level is 150-175 feet below ground surface. The reported average daily withdrawal rate is 339,400 gallons.

The vertical migration of dissolved contaminants within the bedrock aquifer is expected to be limited by the presence of semi-confining units of siltstone/mudstone that are laterally persistent on a local scale, and the presence of significant upward vertical gradients between deeper and shallow zones of preferential flow (primarily sandstone units). In the vicinity of Areas A and D, significant vertical migration of dissolved contamination found within the shallow bedrock to deeper geologic/hydrogeologic horizons is not expected.

The structural dip of the bedrock in Areas A and D to the north-northwest would influence the migration of any DNAPL present. To date, there is some evidence to suggest that DNAPL may be present within the northwest corner of Area A.

The overburden groundwater is expected to either recharge the bedrock groundwater flow system or discharge to local surface water drainages thus migration distances within the overburden are likely to be restricted. The low overall permeability and minor saturated thickness of the overburden also suggests that significant quantities of groundwater are not transported laterally through this flow system.

1.3.1.4 Nature and Extent of Contamination

This section of the FS report summarizes the nature and extent of contamination for Areas A and D groundwater. The conclusions presented in this section are based primarily on the analytical results for groundwater sampling which was performed during 1994-1995 field investigation activities, and discussed in more detail in the Focused RI for Groundwater (1996). Supplemental discussion of groundwater quality conditions in the area north of Area A is based on more recent perimeter monitoring activities.

Because of hydrogeologic conditions at the site, the discussion is segregated to address contamination detected in the shallow and intermediate depth wells apart from the deep monitoring wells. A generally

pronounced upward vertical hydraulic gradient from deeper to shallow water bearing zones within the Stockton Formation has limited the vertical extent of contaminant migration. All deep monitoring wells are screened at depths greater than 150 feet below ground surface.

1994 Sampling Results

Shallow/Intermediate Groundwater

Shallow and intermediate groundwater monitoring wells in Area A exhibit the highest amount of groundwater contamination observed at NAWC Warminster. Trichloroethene is detected at the highest concentrations and with the greatest frequency of all target compounds. Tetrachloroethene, chloroform, and carbon tetrachloride are also detected in multiple wells. In Area A, the majority of the organic contamination appears to be centered immediately north of the wastewater treatment lagoons, at the location of Site 1. In Area D, the higher concentrations of organic compounds were generally detected along the northwest side of Building 2.

The extent of contamination in Area A shallow/intermediate depth groundwater, based on 1994 data, is presented in Figure 1-6. All but two monitoring wells (MW-11 and DG-23) contain detectable amounts of volatile organic compounds. The highest amounts of organics are detected in the monitoring wells in cluster HN-11, including monitoring wells C, DG-1, HN-11I, and HN-11D. The sample collected in 1994 from HN-11I contained the highest concentrations of chloroform (370 µg/L), carbon tetrachloride (2,600 µg/L), and trichloroethene (100,000 µg/L) detected in the investigation area. The trichloroethene detection of 100,000 µg/L is approximately 10 percent of the solubility limit for this compound, which is considered indicative of potential DNAPL presence. Later samples, obtained as part of the base perimeter sampling program, had lower TCE concentrations ranging from 17,500 to 72,000 µg/L. The highest concentration of tetrachloroethene was detected at Monitoring Well D (320 µg/L). Based on the screened depths of wells HN-11I (70 to 80 feet BGS) and D (35 to 40 feet BGS), most on-base contamination appears to be located within the shallow bedrock portion of the aquifer. Chemicals sometimes associated with the degradation of trichloroethene and tetrachloroethene (i.e., 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, and 1,2-dichloroethene) were detected during the Focused RI in monitoring wells C, D, E, BG-4, HN-15S, HN-16S, HN-32S, HN-33S, SMP-02, DG-01, DG-03, DG-13, and MW-04. These wells are screened over depths of 13 to 84 feet BGS. Vinyl chloride and chloroethane were not detected in any of the groundwater samples in Area A.

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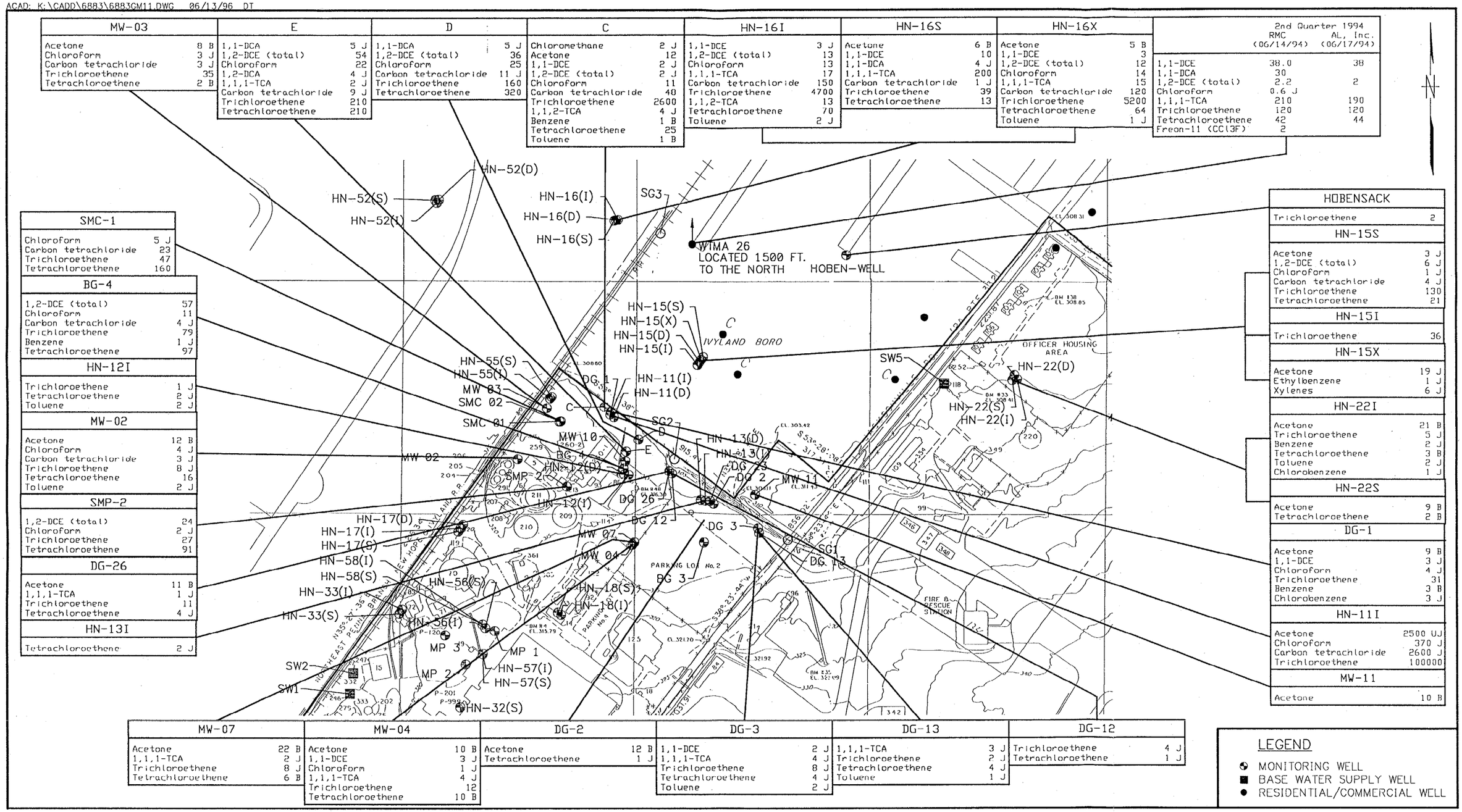

MW-03	
Acetone	8 B
Chloroform	3 J
Carbon tetrachloride	3 J
Trichloroethene	35
Tetrachloroethene	2 B

E	
1,1-DCA	5 J
1,2-DCE (total)	54
Chloroform	22
1,2-DCA	4 J
1,1,1-TCA	2 J
Carbon tetrachloride	9 J
Trichloroethene	210
Tetrachloroethene	210

D	
1,1-DCA	5 J
1,2-DCE (total)	36
Chloroform	25
Carbon tetrachloride	11 J
Trichloroethene	160
Tetrachloroethene	320

C	
Chloromethane	2 J
Acetone	12
1,1-DCE	2 J
1,2-DCE (total)	2 J
Chloroform	11
Carbon tetrachloride	40
Trichloroethene	2600
1,1,2-TCA	4 J
Benzene	1 B
Tetrachloroethene	25
Toluene	1 B

HN-16I	
1,1-DCE	3 J
1,2-DCE (total)	13
Chloroform	13
1,1,1-TCA	17
Carbon tetrachloride	150
Trichloroethene	4700
1,1,2-TCA	13
Tetrachloroethene	70
Toluene	2 J

HN-16S	
Acetone	6 B
1,1-DCE	10
1,1-DCA	4 J
1,1,1-TCA	200
Carbon tetrachloride	1 J
Trichloroethene	39
Tetrachloroethene	13

HN-16X	
Acetone	5 B
1,1-DCE	3
1,2-DCE (total)	12
Chloroform	14
1,1,1-TCA	15
Carbon tetrachloride	120
Trichloroethene	5200
Tetrachloroethene	64
Toluene	1 J

	2nd Quarter 1994 RMC (06/14/94)	AL, Inc. (06/17/94)
1,1-DCE	38.0	38
1,1-DCA	30	
1,2-DCE (total)	2.2	2
Chloroform	0.6 J	
1,1,1-TCA	210	190
Trichloroethene	120	120
Tetrachloroethene	42	44
Freon-11 (CCl3F)	2	

SMC-1	
Chloroform	5 J
Carbon tetrachloride	23
Trichloroethene	47
Tetrachloroethene	160

BG-4	
1,2-DCE (total)	57
Chloroform	11
Carbon tetrachloride	4 J
Trichloroethene	79
Benzene	1 J
Tetrachloroethene	97

HN-12I	
Trichloroethene	1 J
Tetrachloroethene	2 J
Toluene	2 J

MW-02	
Acetone	12 B
Chloroform	4 J
Carbon tetrachloride	3 J
Trichloroethene	8 J
Tetrachloroethene	16
Toluene	2 J

SMP-2	
1,2-DCE (total)	24
Chloroform	2 J
Trichloroethene	27
Tetrachloroethene	91

DG-26	
Acetone	11 B
1,1,1-TCA	1 J
Trichloroethene	11
Tetrachloroethene	4 J

HN-13I	
Tetrachloroethene	2 J

HOBENSACK	
Trichloroethene	2

HN-15S	
Acetone	3 J
1,2-DCE (total)	6 J
Chloroform	1 J
Carbon tetrachloride	4 J
Trichloroethene	130
Tetrachloroethene	21

HN-15I	
Trichloroethene	36

HN-15X	
Acetone	19 J
Ethylbenzene	1 J
Xylenes	6 J

HN-22I	
Acetone	21 B
Trichloroethene	5 J
Benzene	2 J
Tetrachloroethene	3 B
Toluene	2 J
Chlorobenzene	1 J

HN-22S	
Acetone	9 B
Tetrachloroethene	2 B

DG-1	
Acetone	9 B
1,1-DCE	3 J
Chloroform	4 J
Trichloroethene	31
Benzene	3 B
Chlorobenzene	3 J

HN-11I	
Acetone	2500 UJ
Chloroform	370 J
Carbon tetrachloride	2600 J
Trichloroethene	100000

MW-11	
Acetone	10 B

MW-07	
Acetone	22 B
1,1,1-TCA	2 J
Trichloroethene	8 J
Tetrachloroethene	6 B

MW-04	
Acetone	10 B
1,1-DCE	3 J
Chloroform	1 J
1,1,1-TCA	4 J
Trichloroethene	12
Tetrachloroethene	10 B

DG-2	
Acetone	12 B
Tetrachloroethene	1 J

DG-3	
1,1-DCE	2 J
1,1,1-TCA	4 J
Trichloroethene	8 J
Tetrachloroethene	4 J
Toluene	2 J

DG-13	
1,1,1-TCA	3 J
Trichloroethene	2 J
Tetrachloroethene	4 J
Toluene	1 J

DG-12	
Trichloroethene	4 J
Tetrachloroethene	1 J

LEGEND

- MONITORING WELL
- BASE WATER SUPPLY WELL
- RESIDENTIAL/COMMERCIAL WELL

0 400 800
SCALE IN FEET

VOLATILE ORGANICS
1994 SAMPLING RESULTS
SHALLOW AND INTERMEDIATE WELLS
AREA A
NAWC, WARMINSTER, PA

FIGURE 1-6

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CTO 252

419 D032

Detections of monocyclic aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylenes) are less frequent and of lower concentrations that those for chlorinated volatile organic compounds. Area A detections of these compounds during the Focused RI were limited to MW-02 (toluene at 2 µg/L), HN-12I (toluene at 2 µg/L), HN-15X (ethylbenzene at 1 µg/L and xylenes at 6 µg/L), DG-03 (toluene at 2 µg/L), DG-13 (toluene at 1 µg/L), and BG-4 (benzene at 1 µg/L). These concentrations are all less than respective MCLs and quantitation limits, and are not believed to be indications of significant groundwater impacts.

Downgradient off-base monitoring, residential, and municipal wells have also been impacted by organic contamination. During the Focused RI, monitoring well clusters HN-15 and HN-16, located 350 feet and 700 feet, respectively, from the installation boundary, contained significant amounts of tetrachloroethene (HN-15S only), trichloroethene (all wells), and carbon tetrachloride (HN-15S and HN-16I only) which exceeded MCLs. Other detected chemicals in these wells included benzene, toluene, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, chloroform, 1,1,1-trichloroethane, 1,2-dichloroethene, and acetone (a suspected laboratory artifact). The TCE level in HN-16I was 7,300 µg/L immediately after development, 4,700 µg/L after the well stabilized several weeks later, and has ranged from 5,700 to 2,400 µg/L during the perimeter sampling rounds since late 1994.

The high concentration of 1,1,1-trichloroethane (TCA) detected in the shallow bedrock well at cluster HN-16 (HN-16S at 200 µg/L) relative to the intermediate well (HN-16I, 17 µg/L), in combination with a low concentration of trichloroethene in HN-16S (39 µg/L) relative to HN-16I (4,700 µg/L), suggests a local source for the TCA detected in this well. Several NPL and CERCLA sites which are confirmed to have experienced halogenated solvent releases are noted in the immediate vicinity of Areas A and D (EA, Basewide Environmental Baseline Survey, November 1994).

The well at the Hobensack residence contains only trichloroethene at 2 µg/L, which is below the MCL for this compound. A municipal well (Warminster Township Municipal Authority Well #26 - WTMA 26) which is located approximately 2,000 feet north of Area A has been impacted by organics, with detections of trichlorofluoromethane, 1,1-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethene, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, tetrachloroethene, and styrene reported during routine monitoring. Detected concentrations of 1,1-dichloroethene, 1,1-dichloroethane, and 1,1,1-trichloroethane in WTMA 26 exceeded the highest concentrations found in Area A/D monitoring wells, suggesting an alternate source for these compounds. MCLs for 1,1-dichloroethene, trichloroethene, and tetrachloroethene are consistently exceeded in this municipal well, and one reported result for 1,1,1-trichloroethane (from the June 1994 monitoring period) also exceeds the MCL.

Analyses for TAL inorganic constituents were also performed during the Focused RI on a number of the monitoring well samples. Metals analyses were conducted for groundwater samples from monitoring wells HN-11I, HN-11D, HN-12I, HN-12D, HN-13I, HN-13D, HN-15X, HN-15S, HN-15I, HN-15D, HN-16S, HN-16I, and HN-16D.

All but four of the maximum positive results within and around Area A were associated with groundwater samples from cluster HN-15. This well cluster is located off base and downgradient of the eastern portion of Area A, approximately 350 feet from the installation boundary. The highest groundwater concentrations for cobalt (40.0 µg/L), copper (43.6 µg/L), iron (56,600 µg/L), manganese (12,800 µg/L), nickel (75.5 µg/L), and vanadium (74.7 µg/L) are noted at HN-15X, an overburden well. Monitoring well HN-15I contained maximum concentrations of aluminum (120,000 µg/L), arsenic (27.1 µg/L), barium (4,210 µg/L), beryllium (11.1 µg/L), calcium (84,800 µg/L), lead (154 µg/L), magnesium (28,500 µg/L), and zinc (340 µg/L). HN-15S had the highest detection of chromium, at 134 µg/L.

Other maximum concentrations of inorganics in Area A groundwater are noted in HN-13D (mercury at 0.13 µg/L), HN-16I (potassium at 43,000 µg/L), and HN-16D (dissolved cadmium at 3.5 µg/L and total thallium at 4.1 µg/L). The dissolved cadmium result was the only positive detection reported for this analyte in wells located within and near Area A

The groundwater within and downgradient of Area A does not appear to have been impacted by releases of inorganics at the base. The highest concentrations of metals are predominantly detected in one cluster of monitoring wells which are located over 300 feet from the base boundary. The pattern of detections is inconsistent, in that results for the overburden and intermediate depth wells are not reflected by the shallow and deep bedrock wells. Suspended material in the samples with the highest metals concentrations could account for some of the elevated detections. Comparison of dissolved metals data to total metals data for these samples provides support for this explanation.

Monitoring wells in Area D include well clusters HN-17, HN-18, HN-20, HN-33, and HN-42; single monitoring wells HN-31S, HN-32S, MP-1, MP-2, MP-3, and production wells SW-1 and SW-2. The pattern of volatile organic groundwater contamination within Area D suggests discrete source areas for various contaminants (Figure 1-7). Trichloroethene is pervasive throughout the site, with detections noted at all shallow and intermediate monitoring locations except HN-18I, HN-20S, and SW-1. The detections are primarily shallow and intermediate depth wells. TCE levels in HN-17I and HN21I were below MCLs. TCE levels in HN-42S and HN-42I were initially slightly above MCLs, however during subsequent perimeter sampling rounds the TCE levels in these wells had dropped to maximum levels of 2 µg/L and 1 µg/L, respectively. Tetrachloroethene was detected during the Focused RI in one isolated pocket consisting of

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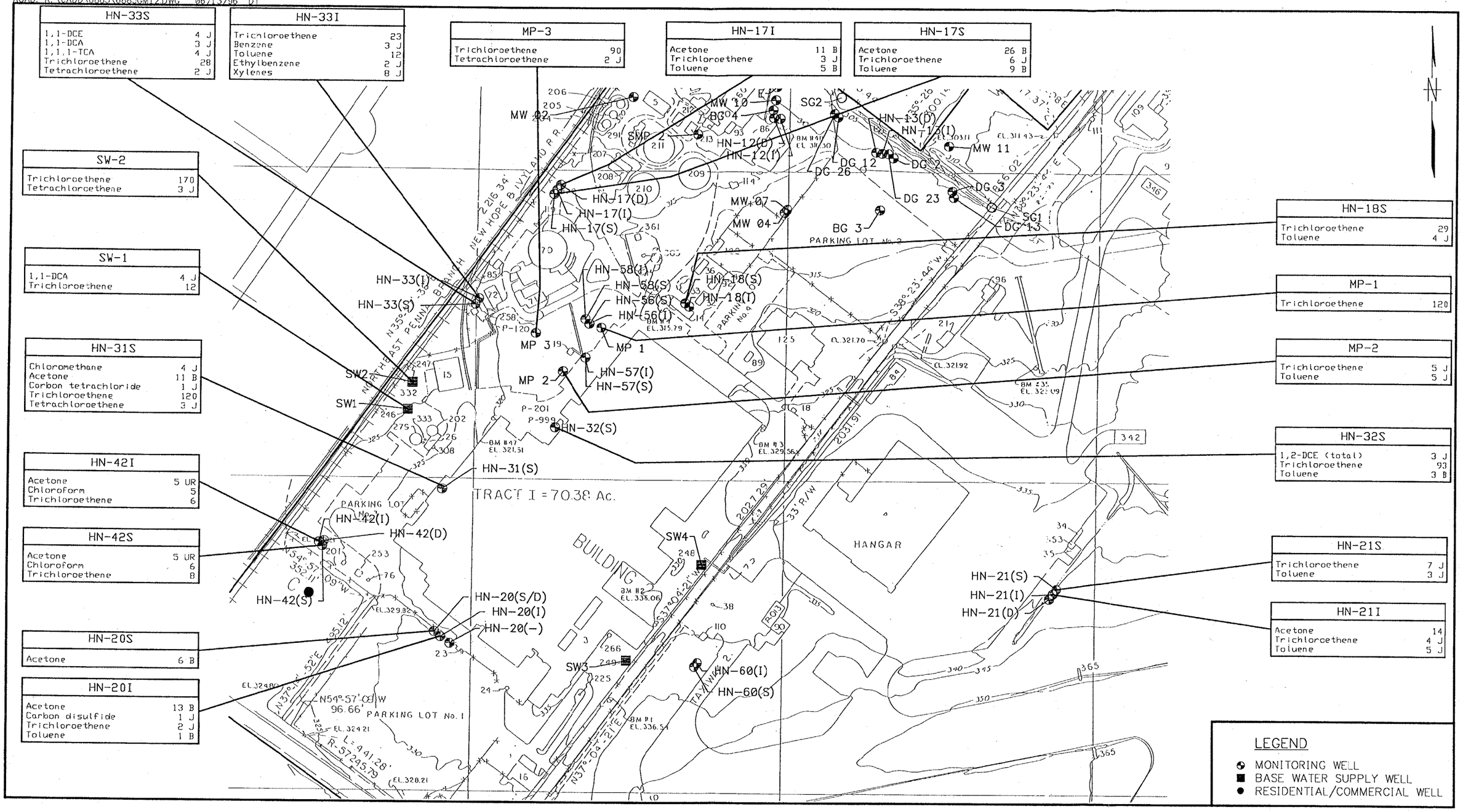

VOLATILE ORGANICS
1994 SAMPLING RESULTS
SHALLOW AND INTERMEDIATE WELLS
AREA D
NAWC, WARMINSTER, PA

0 300 600
SCALE IN FEET

FIGURE 1-7

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HN-31S, SW-1, SW-2, and HN-33S, at levels below MCL's (<5 µg/L). Halomethanes (chloromethane, chloroform, and/or carbon tetrachloride) detections are localized to HN-31S and trace detections in the HN-42 cluster, suggesting a minor release at the southern end of the main building complex. Trichloro- and dichloro- ethene and ethane detections are noted in monitoring wells HN-31S, HN-32S, SW-1, SW-2, MP-1, MP-3, and HN-33S, which suggests releases throughout the building complex. Finally, monocyclic aromatics (BTEX) are detected only in monitoring wells MP-2, HN-18S, and HN-33I, all of which are located at the northern end of the building complex. The BTEX compounds were all detected at concentrations below MCLs.

The highest concentration of trichloroethene detected in Area D during the Focused RI was at SW-2 (170 µg/L), with additional hits above 100 µg/L at HN-31S (120 µg/L) and MP-1 (120 µg/L). The locations of these wells, two near the middle (SW-2 and HN-31S) and the other near the northern end (MP-1) of the building complex, may indicate two release points. The maximum detection of tetrachloroethene (4 µg/L) was at HN-31S, as was the maximum carbon tetrachloride result (2 µg/L). BTEX detections were primarily limited to HN-33I, which is located along the base boundary nearest the railroad. These compounds were not detected in nearby well MP-3, which is located between HN-33 and Building 2.

Inorganic results for 11 monitoring wells in Area D indicate that no significant metallic contamination is present in the groundwater.

Deep Groundwater

The majority of deep groundwater monitoring wells are located within and downgradient of Area A. As detailed in the Focused RI for Groundwater (1996), confining pressures were observed in the majority of these wells. These observed pressures result in significant upward hydraulic gradients. Downward migration of dissolved contaminants from shallow portions of the bedrock aquifer at these locations is not likely.

During the Focused RI, all deep groundwater monitoring wells contained trace amounts of chlorinated organics, except HN-21D (Figure 1-8). The greatest amount and variety of contaminants were in the sample from HN-16D, which contained 1,1,1-trichloroethane (13 µg/L), trichloroethene (15 µg/L), and trichlorofluoromethane (7 µg/L). Trichloroethene is the most pervasive deep groundwater contaminant, also detected (at levels below MCLs) in samples collected from HN-12D (1 µg/L), HN-15D (2 µg/L), HN-17I (3 µg/L), and HN-17D (3 µg/L). Detections of toluene and tetrachloroethene were limited to HN-12D (2 µg/L and 2 µg/L, respectively) and SMC-02 (2 µg/L and 4 µg/L, respectively). These concentrations are all below MCL's. Both of these wells are located at the downgradient edge of Area A.

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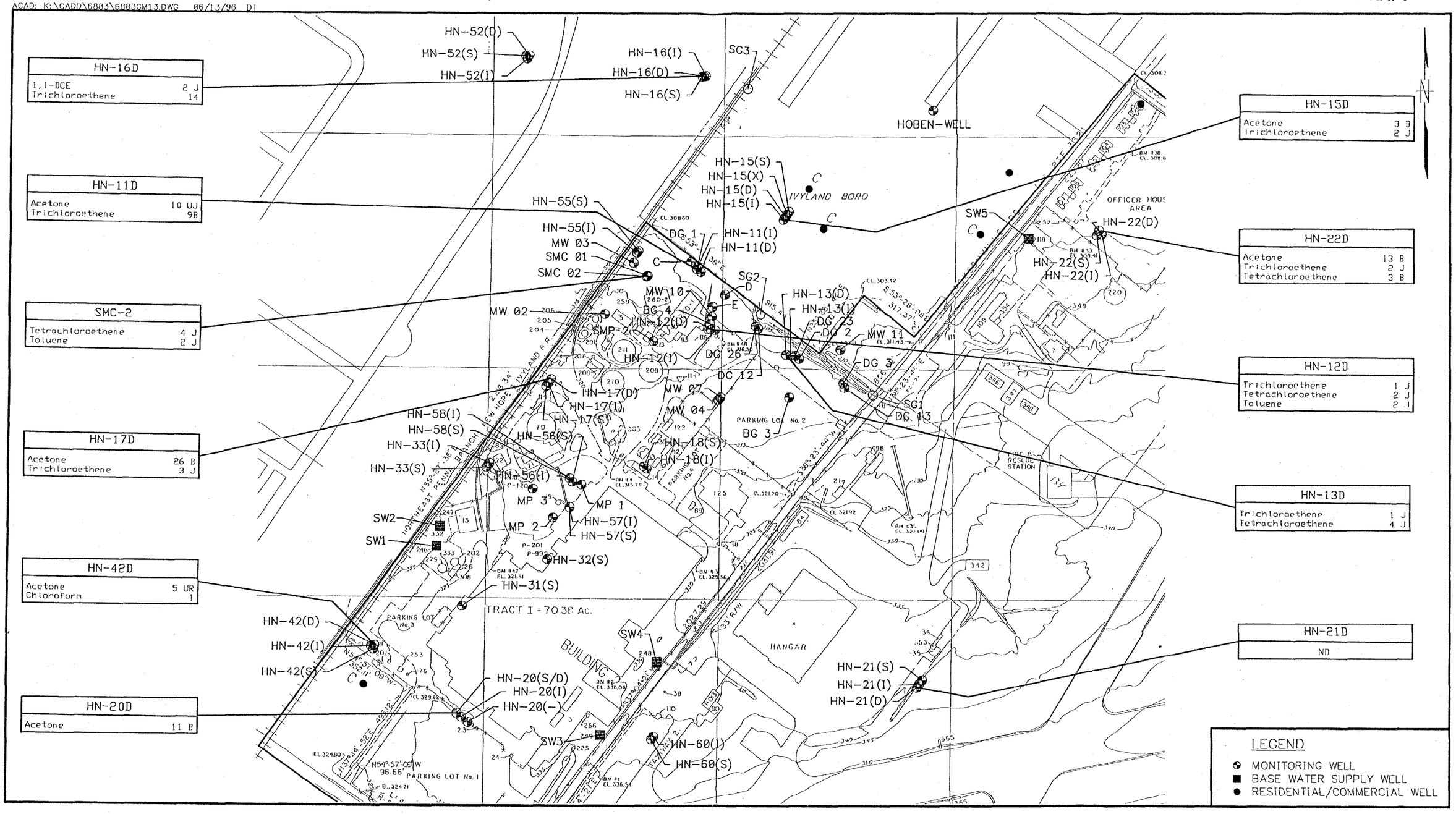

VOLATILE ORGANICS
1994 SAMPLING RESULTS
DEEP WELLS
AREA A AND D
NAWC, WARMINSTER, PA

FIGURE 1-8

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CTO 252

419 D052

The inorganic analytical data for deep groundwater samples in Areas A and D does not show any discernible pattern which might suggest groundwater contamination. Analytical results for detected metals are all comparable (within an order of magnitude) to upgradient concentrations reported for HN-21D.

1995 Perimeter Sampling Results

Subsequent to the sampling performed for the draft Focused RI for Groundwater Report, additional off-site monitoring well clusters were installed north and northwest of Area A. These clusters are periodically sampled as part of the Navy's ongoing perimeter monitoring program for NAWC. Figure 1-9 shows the results of the September 1995 round of perimeter monitoring, which is the most recent round that includes all of the off-site monitoring wells. As is evident in the figure, well clusters HN-11, 16, 50, 52, and 55, the Wagner production well, and WTMA Well No. 26 have TCE concentrations in the hundreds to thousands µg/L range, indicating significant on-base and off-base TCE contamination. Other compounds found at concentrations well above regulatory levels include PCE, 1,1-DCE, 1,1,1-TCA, and carbon tetrachloride.

The patterns of contaminant detections in the off-base monitoring well clusters suggest multiple sources for the contaminants. For example, well HN-16S has high levels of 1,1,1-TCA but almost no TCE; the reverse is seen in well HN-16I. At well cluster HN-52, the shallow well contains high levels of 1,1-DCE, 1,1-DCA, 1,1,1-TCA, and TCE while the intermediate and deep wells contain little or no 1,1-DCE, 1,1-DCA, or 1,1,1-TCA but high TCE levels. At cluster HN-50, the source of the high TCE concentrations in the shallow and intermediate wells is not clear, based on both contaminant distribution and groundwater flow patterns.

1.3.2 Area B

1.3.2.1 Description/Location

Area B consists of Sites 5 (South Runway Landfill), 6 (Waste Pit No. 3), and 7 (Sludge Disposal Pits). The general layout of Area B is shown in Figure 1-2. Site 5 is located under Housing Unit 401 in NAWC Warminster's enlisted men's housing area. Site 6 is south of the main runway and north of the patrol road near the eastern end of the facility. The location of Site 7 is uncertain, as historical information is sketchy and site investigation work performed to date has not positively identified the site.

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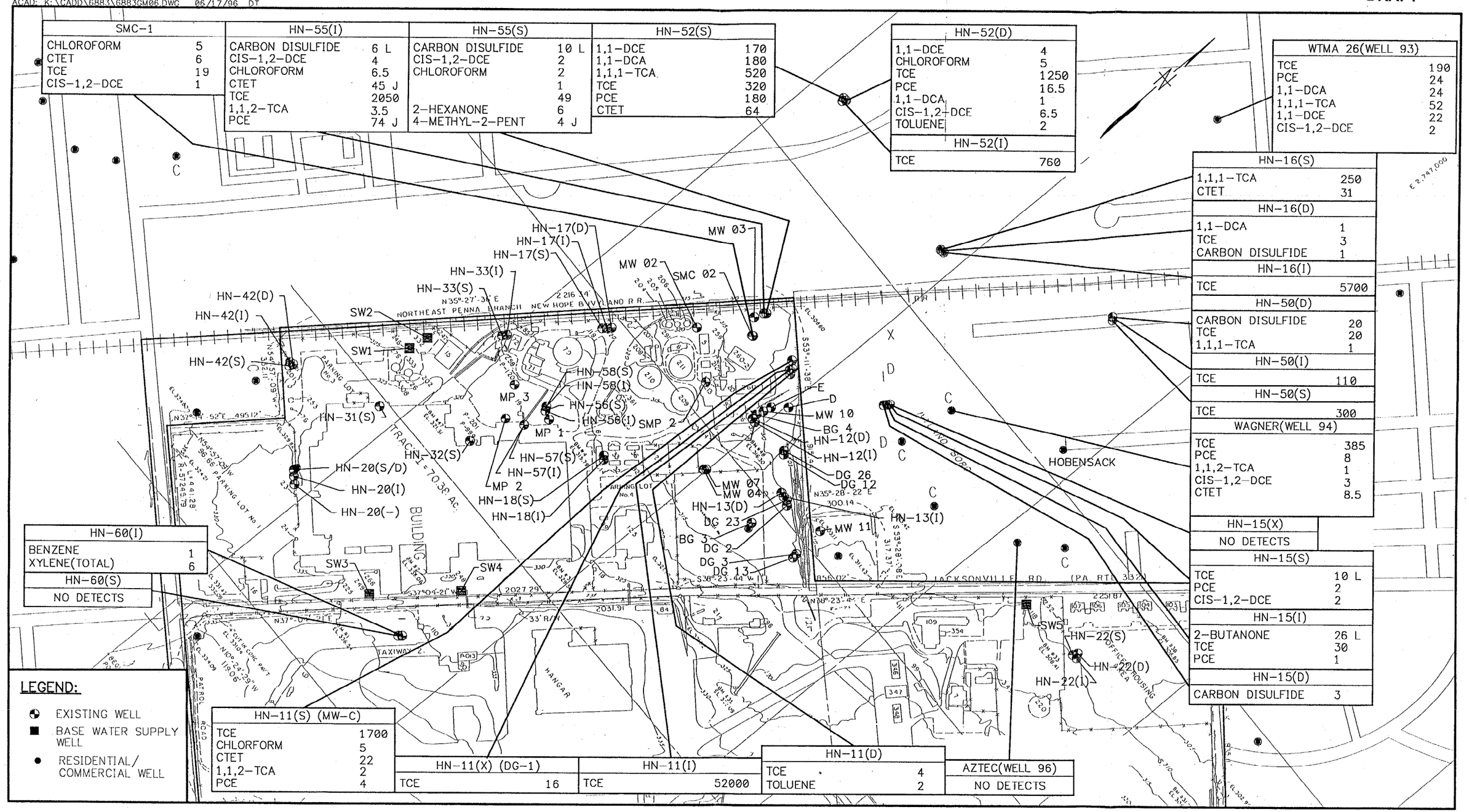

FIGURE 1-9

AREA A/OFFBASE MONITORING WELL SAMPLING RESULTS(µg/L)
SEPTEMBER 1995 PERIMETER SAMPLING ROUND
NAWC, WARMINSTER, PA

0 400 800
SCALE IN FEET

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CTO 252

South Runway Landfill - Site 5

Site 5 is located south of the main runway and adjacent to a baseball field at NAWC Warminster. The site reportedly operated from 1955 to 1970 and was rediscovered during construction for the foundation of a housing unit (Unit 401). It is currently not known what, if any, removal of wastes occurred subsequent to this discovery. Site 5 reportedly consisted of up to six to eight disposal trenches in which paints, solvents, scrap metal, demolition debris, and asphalt were disposed of. Each trench was reportedly 12-feet wide by 70-feet long and eight-feet deep.

Waste Pit No. 3 - Site 6

Site 6 reportedly consists of an unknown number of disposal pits or trenches on the northern side of the patrol road and the south side of the main runway. Site 6 is north of Site 5 and northeast of Site 7. This site allegedly received paint, solvents, demolition waste, waste oils, flammable waste, and grease trap waste from 1960 to 1980. The site is currently wooded and construction debris has been observed on ground surface. The site covers an areas of about 70,000 square feet.

Sludge Pits - Site 7

Site 7 reportedly consisted of two disposal trenches that were used from 1950 to 1955 to receive sludge from the wastewater treatment plant. The site is located south of the main runway.

The trenches were reportedly 100-feet long by 12-feet wide and eight-feet deep. The trenches were reportedly backfilled with fill after each dumping episode. Upon site closure in 1955, the trenches were covered with two feet of soil, regraded, and reseeded.

1.3.2.2 Geology

The geology of Area B consists of a thin veneer of residual soils overlying sedimentary bedrock of the Stockton Formation. The bedrock surface slopes across Area B to the south and southeast, mimicking ground topography. The soils consist primarily of silt and clay, with some sand, and extend to an average depth of about 10 feet below ground surface.

The bedrock of the Stockton Formation consists of alternating sequences of fine- and coarse-grained, gently dipping rock units. Lithologic units vary in thickness from less than a foot to a maximum observed

thickness of about 60 feet within Area B. The fine-grained lithologies are described as mudstones and consist primarily of siltstones and shales. Coarser-grained rock units include fine- to coarse-grained arkosic sandstones.

Bedding within the Stockton Formation strikes approximately north 71 degrees east (N71E) and dips approximately 5 degrees to 8 degrees to the northwest. This dip of the rock units is approximately opposite the overall topographic slope of the ground surface within Area B.

Individual rock units vary both in thickness and in aerial extent, with some lithologies extending for significant distances across Area B and others pinching out within relatively short distances. Thicker beds typically extend laterally for greater distances than the thinner beds, which tend to be localized in aerial extent.

Fractures were encountered at varying depths of the well borings drilled in and around Area B. The fractures included both bedding plane fractures and cross-formation joints. Fractures were observed within both the sandstone and mudstone units, with the fractures in the sandstones more likely to yield significant quantities of water.

1.3.2.3 Hydrogeology

Groundwater within Area B is primarily encountered within the Stockton Formation. The overlying residual soils contain minor amounts of water in places; however, the saturated thickness is generally limited to a few feet or less, and, due to the low permeability of the soils, the volumetric groundwater flow rate within the soils is minor. Groundwater within the Stockton Formation is primarily encountered within and moves through interconnected networks of fractures that on a local scale form discrete flow zones related to lithology but on a larger scale are part of a complex, hydraulically interconnected, groundwater flow system. Primary permeabilities of the rock units that comprise the Stockton Formation are considered negligible in comparison to the secondary (fracture) permeability.

The coarser-grained rock units within the Stockton Formation act as preferential flow zones for groundwater, and the finer-grained mudstone units generally act as semiconfining layers to groundwater flow.

The nearest historic groundwater users are located approximately 1,600 feet from and sidegradient (east) of Area B (Casey Village residences). Due to water quality problems within Casey Village, the residences in this area have recently been connected to municipal water and no longer use domestic wells as water

sources. Groundwater users are also located approximately 1/2 mile south and southwest of Area B but are not considered to be receptors of groundwater from Area B.

Groundwater Flow Directions

The overall direction of groundwater flow across Area B is to the south. Figure 1-10 shows groundwater flow directions at depths of approximately 60 to 100 feet within the Stockton Formation, in and around Area B. The stream trace of one of the headwaters of Southampton Creek appears to exert some control over groundwater flow directions, as shown by the convergence of flow along the southern boundary of Area B and the accompanying change in flow direction parallel to the stream trace to the southwest. In general, groundwater flow directions within the upper portions of the Stockton Formation were observed to mimic the ground surface topography and are expected to be controlled by topography and the locations of streams in the area.

Lateral groundwater flow gradients are generally steepest along the flank of the east-west-trending ridge upon which the runway is situated, along the northern edge of Area B. Across the ball field that is located adjacent to Site 5 and directly downgradient of Site 6, the groundwater flow gradient flattens out, as does the topography. Based on the intermediate groundwater flow map (Figure 1-10), the average flow gradient along the hillslope area is approximately 0.045. In the downgradient portion of Area B, the gradient flattens out to an average of approximately 0.01.

Bedrock Aquifer Hydraulic Characteristics

The hydraulic characteristics of the shallow portion of the Stockton Formation in Area B were investigated through a long-term pumping test. From the test evaluation, an average transmissivity of 139 square feet per day was obtained. Assuming an average thickness of the sandstone unit being pumped of about 25 feet, this yields an average bulk hydraulic conductivity (K) value of about 5 to 6 feet per day. An average storativity in the 10^{-5} range was calculated.

Drawdown responses in the observation wells indicated that pumping effects are projected laterally, along bedding and out, much more so than vertically, across bedding.

In addition to the pumping test described above, a pumping test was performed on extraction well EW-12 as part of the predesign studies for interim remedial action for Area B groundwater. Based on time-drawdown analyses, a range of transmissivity from 178 to 406 square feet per day was obtained. Extraction well EW-12 is open over a depth interval from 20 to 100 feet as opposed to the more restricted

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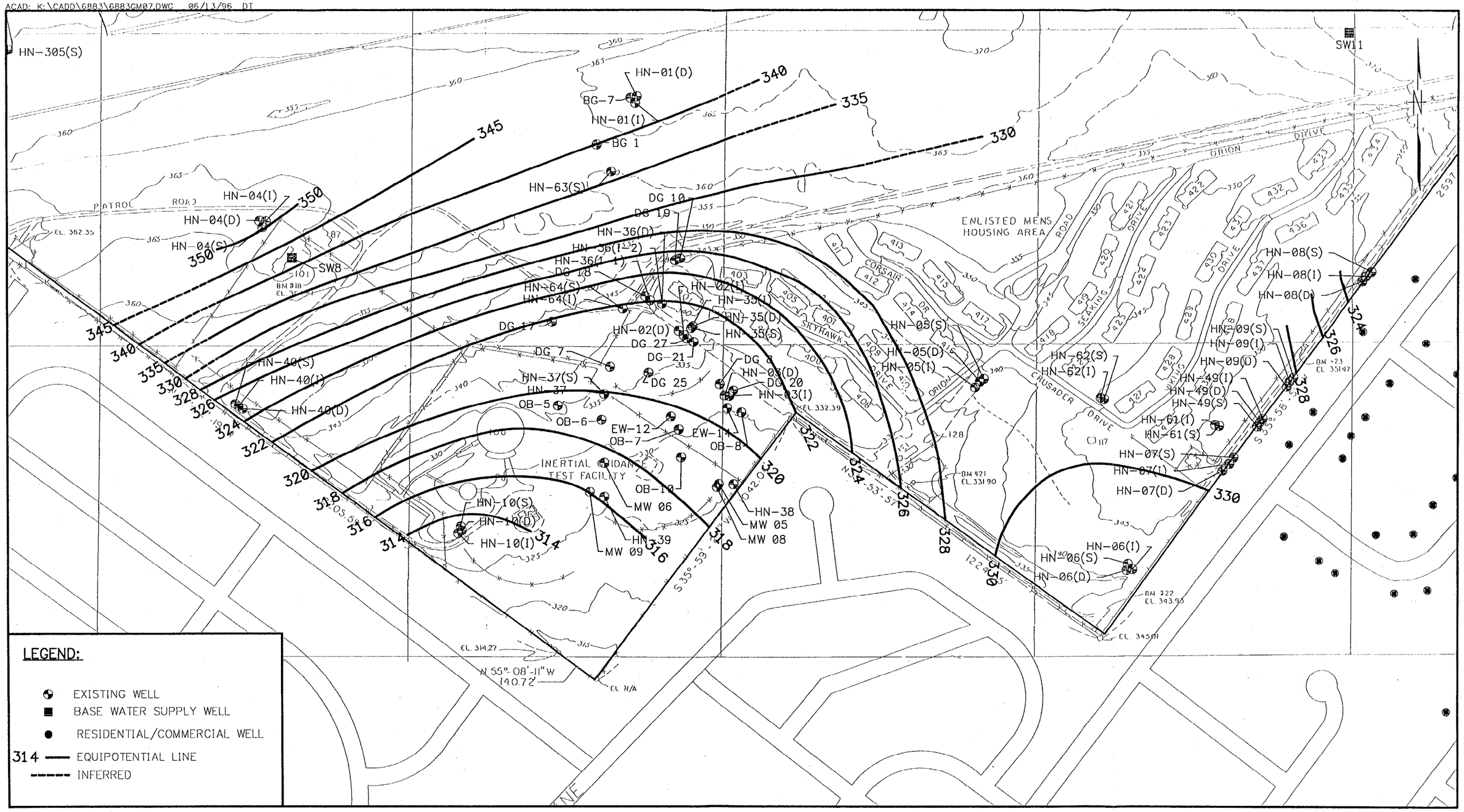

INTERMEDIATE BEDROCK (60–100 FEET)
GROUNDWATER FLOW MAP
AREAB
NAWC, WARMINSTER, PA

0 300 600
SCALE IN FEET

FIGURE 1–10

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open interval of HN-02I (85 to 104 feet), thus the discrepancy in transmissivity values obtained in the two tests is likely a function of the vertical extent of the aquifer pumped rather than local variations in hydraulic characteristics.

Geologic Controls on Contaminant Migration

The migration of contaminants in groundwater across Area B is influenced by several factors. Groundwater primarily moves through interconnected networks of fractures within the bedrock. Lateral groundwater (and contaminant) migration directions are to the south across Area B and are controlled by topography and by the presence of the tributary of Southampton Creek south of Area B. It is expected that groundwater from Area B will eventually discharge within the Southampton Creek drainage.

Groundwater flow follows the slope of the ground surface topography across Area B, flowing against the dip direction of the bedrock units.

Fine-grained mudstone beds act as semiconfining layers to groundwater flow, restricting but not preventing the vertical movement of groundwater across bedding. Based on sampling results, contamination appears to be limited to the top 100 to 150 feet of the bedrock aquifer.

There are no known groundwater users that influence groundwater flow directions within Area B.

1.3.2.1 Nature and Extent of Contamination

Low concentrations of contaminants were detected in some monitoring wells within Area B, primarily along the downgradient (southern) edge of Site 6. Organic chemicals detected in Area B groundwater include low concentrations of chlorinated organics, mono- and polycyclic aromatic hydrocarbons, phthalate esters and pesticides. Positive results have been reported in at least one sample for all Total Analyte List (TAL) metals except cadmium, chromium, cobalt, and selenium. Of the detected compounds within and downgradient of Area B, only trichloroethene (TCE) (maximum 12 µg/L) and benzene (maximum 20 µg/L) slightly exceed their respective Maximum Contaminant Levels (MCLs). Figures 1-11, 1-12, and 1-13 show analytical results for shallow, intermediate, and deep groundwater in Area B, based on 1993-1995 data.

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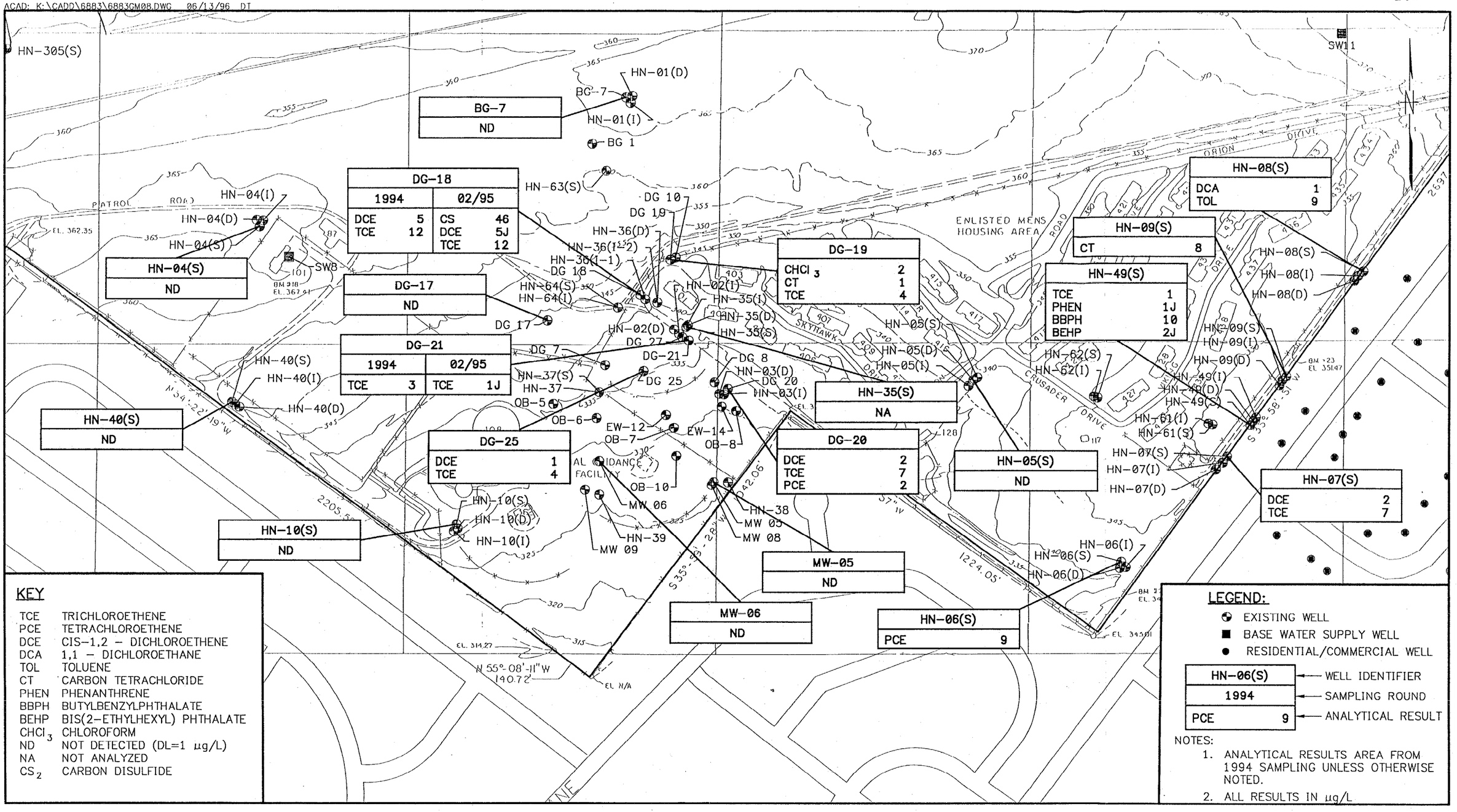

1994-1995 BROWN & ROOT ENVIRONMENTAL
GROUNDWATER SAMPLING RESULTS
AREA B - SHALLOW GROUNDWATER
NAWC, WARMINSTER, PA

0 300 600
SCALE IN FEET

FIGURE 1-11

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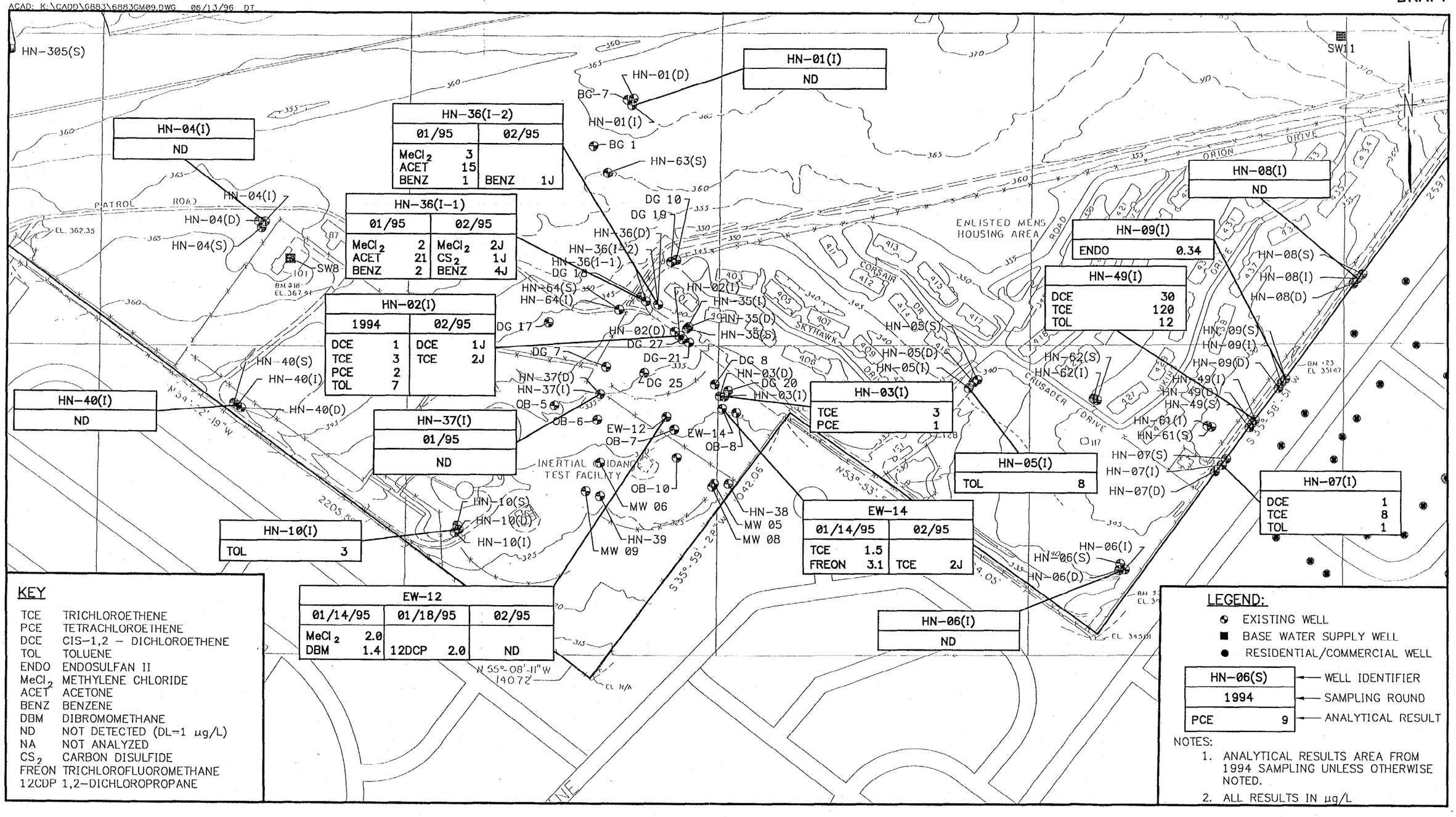

1994-1995 BROWN & ROOT ENVIRONMENTAL
GROUNDWATER SAMPLING RESULTS
AREA B - INTERMEDIATE GROUNDWATER
NAWC, WARMINSTER, PA

0 300 600
SCALE IN FEET

FIGURE 1-12

Brown & Root Environmental

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CTO 252

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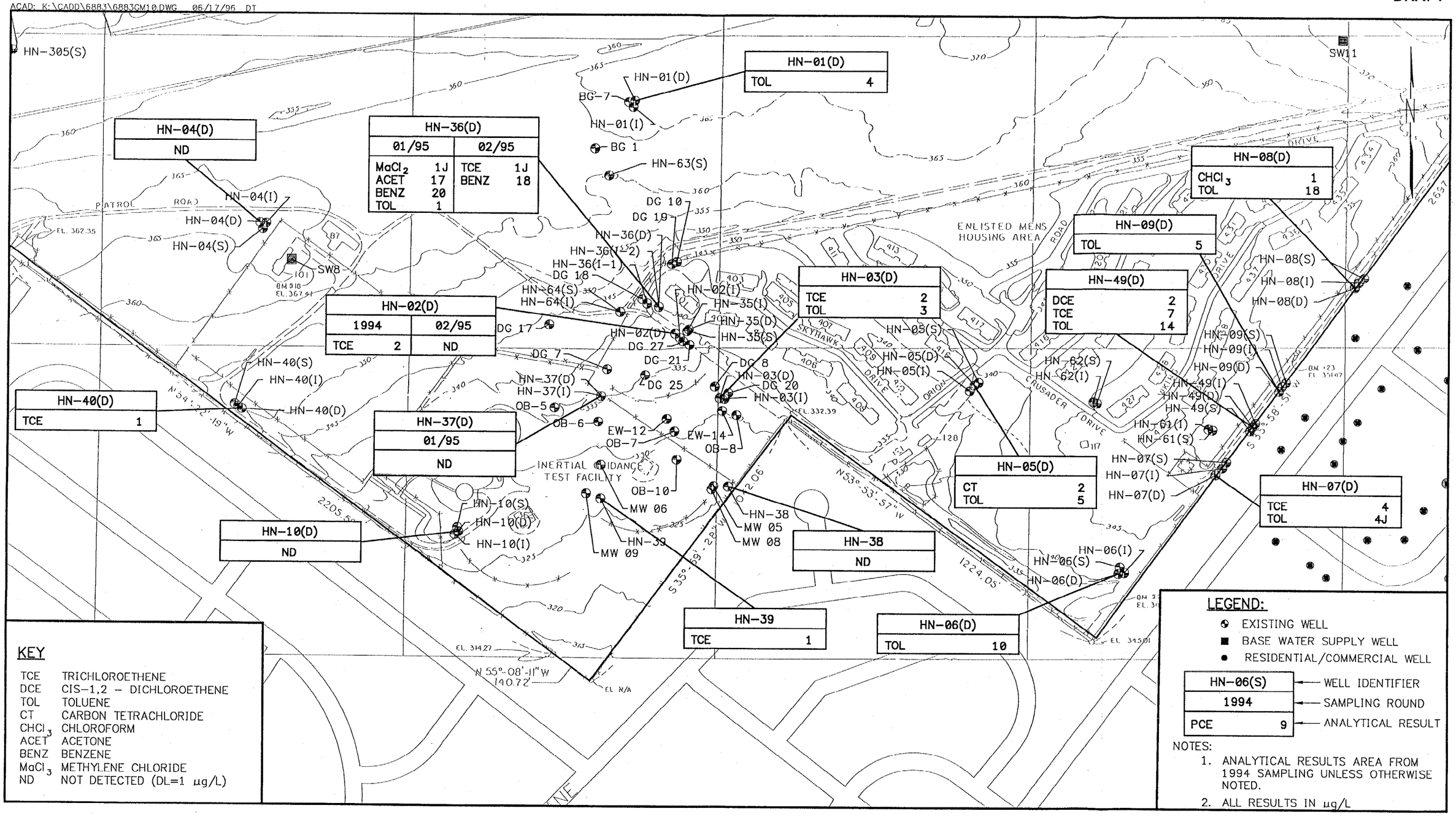

1994-1995 BROWN & ROOT ENVIRONMENTAL
GROUNDWATER SAMPLING RESULTS
AREA B - DEEP GROUNDWATER
NAWC, WARMINSTER, PA

FIGURE 1-13

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CTO 252

The maximum detected concentrations of volatile organics in monitoring wells within Area B include 1,1-dichloroethane (1,1-DCA, 1 µg/L), cis-1,2-dichloroethene (1,2-DCE, 5 µg/L), chloroform (2 µg/L), carbon tetrachloride (8 µg/L), trichloroethene (TCE, 12 µg/L), tetrachloroethene (PCE, 2 µg/L), benzene (20 µg/L), and toluene (7 µg/L). The maximum concentrations of 1,2-DCE and TCE were found in the sample collected from monitoring well DG-18, located immediately downgradient of Site 6. The maximum concentration of benzene was found in HN-36D, also located along the downgradient edge of Site 6. DG18 and HN-36D were the only two wells in Area B with contaminant detections above MCLs.

A second area of groundwater impacts detected along the Casey Village/southeast base boundary is evidenced by data from monitoring well clusters HN-06S/I/D, HN-07S/I/D, HN-08S/I/D, HN-09S/I/D, and HN-49S/I. This plume primarily comprises TCE (maximum 120 µg/L), PCE (maximum 9 µg/L), carbon tetrachloride (maximum 8 µg/L), and DCE isomers (maximum 30 µg/L). The shallow groundwater flow pattern around this plume and contaminant distribution data indicate an off-base source (in Casey Village). Area B is not considered to be a potential source for this contamination. Well HN-49I, which had the highest detections of TCE and DCE, is located in close proximity to the residential wells with the highest reported detections of TCE (1,200 µg/L) and DCE (530 µg/L).

Although several inorganic analytes were detected in groundwater samples collected in Area B, no significant patterns of contamination were noted. Based on comparison to upgradient data, positive results for metals exceed background concentrations for at least one parameter in either total or dissolved sample analyses in every sample. However, the exceedences are neither consistent for every parameter in an individual sample nor is there a pattern of exceedence in a group of sample locations. The results appear to be characteristic of the normal variation in inorganics that would be expected in groundwater.

OHM Extraction Well Sampling Results

Two extraction wells installed on the downgradient edge of Sites 5 and 6 in Area B (EW-12 and EW-14), were sampled in January 1995 while pumping tests of varying duration were performed. Trace levels of methylene chloride, 1,2-dichloropropane, and dibromomethane were detected in well EW-12, at concentrations of 2 µg/L, 2 µg/L, and 1.4 µg/L, respectively. TCE and trichlorofluoromethane were detected in the sample collected from EW-14 at concentrations of 1.5 µg/L and 3.1 µg/L, respectively.

Area B Contaminant Trends Over Time

Data from previous investigations were compared to 1994-1995 sampling results to identify contaminant trends over time.

Results of analyses for past (1991 and 1992) and present (1994 and 1995) sampling of monitoring wells MW-05, BG-7, and DG-17 (see Figure 1-11) indicate no detectable amounts of volatile organic compounds (VOCs) in these wells. Groundwater collected from MW-06 contained a positive detection of PCE in 1991 (4 µg/L) and nondetects for all volatiles in the 1994 sample.

Groundwater sample analyses for monitoring well DG-18 detected the presence of 1,2-dichloroethene and TCE in both sampling rounds at concentrations that are not significantly variant over time. The results for 1,2-DCE (7 µg/L in 1991, 8 µg/L in 1992, and 5 µg/L in 1994) and TCE (8 µg/L in 1991, 13 µg/L in 1992, and 12 µg/L in 1994) have not shown any significant change over time. Carbon tetrachloride, detected at a concentration of 0.3 µg/L in 1991, was not detected in the 1992 or 1994 sampling rounds.

Similar organics were detected in DG-20 over the 1991-1994 time period. PCE (ND in 1991, 3 µg/L in 1992, and 2 µg/L in 1994), 1,2-DCE (2 µg/L in 1991 and 1994 and 3 µg/L in 1992), and TCE concentrations (6 µg/L in 1991, 8 µg/L in 1992, and 7 µg/L in 1994) do not vary over time.

Groundwater samples collected from DG-25 contained 1,2-DCE (2 µg/L in 1991 and 1992 and 1 µg/L in 1994) and TCE (6 µg/L in 1991 and 1992, and 4 µg/L in 1994). These results are noted to decline marginally over the 3-year period. Carbon tetrachloride was detected in 1991 (1 µg/L) but not in 1992 or 1994.

In conclusion, the detected concentrations of VOCs in the Area B groundwater appear to have decreased or remained stable over the 3- to 4-year period between sampling rounds. The analytical data indicate that the plume has not migrated beyond the affected area identified in the Phase II RI Report and that additional contamination has not entered the groundwater.

1.4 DEVELOPMENT OF REPRESENTATIVE DATA

In order to examine the feasibility of technologies and alternatives, it was necessary to derive representative data for each area. To this end, several wells were chosen from each area to represent the contamination present in those areas.

For each area, the extent of contamination was determined by first compiling all of the available data for each chosen well from 1994 to present. The data for each well were then averaged over time for each contaminant to yield an arithmetic mean value for each well. For the purpose of calculating these values, any non-detect result was treated as a zero. Finally, the individual well values for each contaminant were

averaged to yield a representative value for the presence of the contaminant throughout the area. Table 1-1 summarizes the contaminant profiles at Area A. Tables 1-2 and 1-3 summarize the contaminant profiles for Areas B and D, respectively. The maximum detected concentrations and locations of the maximum are presented along with the representative (estimated average) for each constituent. The contaminant profile is compared against the Federal Safe Drinking Water Act Maximum Contaminant Levels (MCLs) or Pennsylvania's Statewide Human Health Standards for (ingestion of) Groundwater to provide a base-line for determining the significance of the contaminant concentrations.

TABLE 1-1

SUMMARY OF CONTAMINANT CONCENTRATIONS DETECTED IN AREA A GROUNDWATER

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

	Average Result(1)	Maximum Result	Maximum Location	MCL (µg/L)
TCL Volatiles (µg/L)				
1,1-Dichloroethene	0	3	DG1	7
1,2-Dichloroethene (total)	10	57	BG4	70
Chloroform (as total trihalomethanes)	9	370	HN11I	100
2-Butanone	2	200	MW-C	none
1,1,1-Trichloroethane	1	4	DG3	200
Carbon Tetrachloride	52	2600	HN11I	5
Trichloroethene	3694	100000	HN11I	5
4-Methyl-2-Pentanone	1	100	MW-C	none
2-Hexanone	18	1500	HN11I	none
Tetrachloroethene	51	320	MW-D	5
TAL Metals (µg/L)(2)				
Calcium	35650/30300	40600/30400	HN11I	none
Iron	299/ND	598/ND	HN11I	none
Lead	0/ND	1/ND	HN11I	15(4)
Manganese	104/62	148/101	HN11I	50(3)
Mercury	ND/0	ND/0.28	ND	2

ND Not detected.
1 Consists of wells BG4, DG1, DG3, DG12, DG13, DG26, HN11I, HN12I, MW-02, MW-03, MW-55S, MW-55I, MW-C, MW-D, MW-E, and SMC1 averaged for samples collected from 9/94 to 1/96.
2 Metals are reported as Total concentration/Dissolved concentration.
3 Secondary MCL.
4 Action Level.

TABLE 1-2

SUMMARY OF CONTAMINANT CONCENTRATIONS DETECTED IN AREA B GROUNDWATER

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

	Average Result	Maximum Result	Maximum Location	MCL
TCL Volatiles (µg/L)(1)				
1,2-Dichloroethene (total)	1	5	DG18	70
Trichloroethene	3	12	DG18	5
Benzene	6	20	36D	5
Acetone	8	21	36I1	none
Toluene	0	1	36D	1000
Methylene chloride	1	3	3612	5
Carbon disulfide	12	46	DG18	none
TAL Metals (µg/L)(2)(3)				
Aluminum	5590/ND	13,100/ND	HN-01D	200
Arsenic	NA	8.3/4.3	HN-01D	50
Chromium	NA	41.3/ND	HN-49S	100
Copper	8.8/ND	41.1/ND	HN-49S	1000
Iron	7120/B	42,300/B	HN-49S	none
Manganese	232/196	897/517	HN-49S	50(4)
Mercury	NA	0.22/ND	HN-01D	2
Lead	13.5/ND	19.3/ND	HN-01D	15(5)
Zinc	83.2/17.9	99.4/44.4	HN-49S	5000

NA Not applicable, contaminant was detected only in one sample..
ND Not detected.
B Blank contamination (range reported: 12 to 155 µg/L).
1 Using data from wells DG18, HN36I1, HN36I2, and HN36D collected from 1994 to 1/96.
2 Average from available data (positive detections) from other monitoring wells on site, as noted below: HN-01, HN-02, HN-03, HN-05, HN-07, HN-09, HN-10, HN-40, and HN-49, including shallow, intermediate, and deep well in each cluster of wells as appropriate.
3 Metals are reported as Total concentration/Dissolved concentration.
4 Secondary MCL.
5 Action Level.

TABLE 1-3

SUMMARY OF CONTAMINANT CONCENTRATIONS DETECTED IN AREA D GROUNDWATER

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

	Average Result(1)	Maximum Result	Maximum Location	MCL (µg/L)
TCL Volatiles (µg/L)				
1,1-Dichloroethene	0	4	HN33S	7
1,2-Dichloroethene (total)	1	3	HN32S	70
Chloroform	0	1	HN17S	100
2-Butanone	0	3	HN33S	none
1,1,1-Trichloroethane	0	4	HN33S	200
Carbon Tetrachloride	0	1	HN31S	5
Trichloroethene	47	170	SW2	5
4-Methyl-2-Pentanone	0	0	ND	none
2-Hexanone	0	1	HN33S	none
Tetrachloroethene	1	3	HN31S SW2	5
TAL Metals (µg/L)(2)				
Aluminum	885/12	8540/74	HN33S	200
Arsenic	0/0	3.9/4	SW2	50
Calcium	54340/52220	98800/96000	HN31S	none
Chromium	11/5	54/42	HN31S	100
Copper	3/1	13/8	HN33S	1000
Iron	9285/ND	58800/ND	MP1	none
Lead	2/ND	19/ND	HN33S	15(3)
Manganese	252/112	717/354	HN33S	50(4)
Mercury	0/0	0.22/1.5	MP1	2
Zinc	35/14	101/73	SW2	5000

1 Consists of wells HN17S, HN18S, HN31S, HN32S, HN33I, HN33S, HN56I, HN57I, MP1, MP3, SW1, and SW2 averaged for samples collected from 9/94 to 1/96.
2 Metals are reported as Total concentration/Dissolved concentration.
3 Action Level
4 Secondary MCL.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 INTRODUCTION

In this section, the following actions of the feasibility study process are performed:

- Establish remedial action objectives (Section 2.2).
- Discuss review of recent literature and available data bases for identification of potential remedial technologies.
- Identify remedial technologies and process options under each general response action with emphasis on permanent solutions. Screen these remedial technologies and process options based on effectiveness and implementability considerations (Section 2.4).

2.2 REMEDIAL ACTION OBJECTIVES

Contaminated groundwater attributable to NAWC Warminster at Areas A, B, and D presents an unacceptable risk to human health (see baseline Risk Assessment discussions within the Phase II RI report and within the FRG report).

Based on the information in the Phase II RI, the FRG, and the ABH reports, there is sufficient information to identify a final remedy for Areas A and B. An ongoing study at Area A that is occurring outside the NAWC Warminster property line and a limited on-site study at Area B may result in modifications to the design of the remedy, but these studies are not anticipated to affect the conclusions developed herein.

The full nature and extent of contaminated groundwater attributable to Area D. Data gaps associated with this area will be addressed by studies to be conducted in and adjacent to Area D. As a result, there remains uncertainty in regard to the most appropriate final remedy selection for Area D. However, the available data provide an adequate basis for selecting an interim remedy to minimize the migration of NAWC Warminster-related contaminants within Area D groundwater while additional investigations are being conducted to fully define the nature and extent of contamination in these aquifers and to identify a final remedy.

Accordingly, this FS develops final remedies for Areas A and B and an interim remedy for Area D. The remedial objectives are defined as follows:

- Minimize migration and prevent exposure to contaminants in groundwater at Areas A and B.
- Restore affected groundwater, where feasible, in Areas A and B to beneficial uses and to the clean-up goals to be established in the Record of Decision (ROD) for both of these areas.
- Minimize migration of contaminated groundwater attributable to Area D.

2.2.1 Applicable or Relevant and Appropriate Requirements (ARARs) and "To Be Considered (TBC) Criteria"

Tables 2-1 and 2-2 present a summary of potential federal and state ARARs and TBCs for any remedial actions undertaken for OU-1 at NAWC Warminster.

The definition of ARARs is as follows:

- Any standard, requirement, criterion, or limitation under federal environmental law.
- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-siting law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

One of the primary concerns during the development of remedial action alternatives for hazardous waste sites under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or Superfund, is the degree of human health and environmental protection afforded by a given remedy. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent federal and state environmental requirements.

TABLE 2-1

POTENTIAL FEDERAL ARARs AND TBCs

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Contaminant-Specific Requirements	Rationale
Safe Drinking Water Act (42 USC 300) MCLs (40 CFR Part 141), SMCLs (40 CFR Part 143), and MCLGs (42 USC 300.430)	Remedial actions may include groundwater cleanup to MCLs, MCLGs, and/or SMCLs
Clean Water Act (33 USC 1251-1376) Federal Ambient Water Quality Criteria (AWQCs) (40 CFR 131)	Remedial actions may result in surface water discharges that could impact aquatic life
Clean Air Act (42 USC 7401)	
National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50)	Remedial alternatives may result in emissions to the atmosphere
National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61.60-61.71)	Remedial alternatives may result in hazardous chemical emissions
New Source Performance Standards (NSPS) (40 CFR Part 60)	Remedial alternatives may result in emissions to the atmosphere
Air Emissions for Non-Attainment Areas (OSWER Directive 9355.0-28)	Remedial alternatives may result in air emissions
Reference Doses (RfDs), EPA Office of Research and Development Cancer Slope Factors, EPA Environmental Criteria and Assessment Office, EPA Carcinogen Assessment Group Health Advisories, EPA Office of Drinking Water Health Effects Assessments	Considered in the human health risk assessment
Threshold Limit Values, American Conference of Governmental Industrial Hygienists	May be applicable to air concentrations during remedial activities
Identification and Listing of Hazardous Wastes (40 CFR Part 261)	Remedial alternatives may result in the generation of hazardous wastes

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TABLE 2-1 (Continued)
POTENTIAL FEDERAL ARARs AND TBCs
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Location-Specific Requirements	Rationale
Federal Protection of Wetlands Executive Order (E.O. 11990)	Wetland or floodplain resources may be affected by remedial action
Endangered Species Act of 1978 (16 USC 1531) (40 CFR 502)	Considered in the environmental assessment
Fish and Wildlife Coordination Act of 1980 (16 USC 661) Fish and Wildlife Conservation Act (16 USC 2901) Fish and Wildlife Improvement Act of 1978 (16 USC 742a)	Remedial alternatives may affect fish and wildlife habitat
Groundwater Protection Strategy (EPA, 1991)	Remedial alternatives may be determined by specific category
Executive Order on Floodplain Management (E.O. 11988)	Floodplain resources may be affected by remedial action

Action-Specific Requirements	Rationale
Hazardous Waste Generator Requirements (40 CFR Part 262)	Standards applicable to generators of hazardous wastes that may be generated during remedial action
Hazardous Waste Transportation Requirements (40 CFR Part 263)	Remedial alternatives may require transportation of hazardous materials off site for treatment/disposal
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, or Disposal (TSD) Facilities (40 CFR Part 264) Interim Status Standards for Owners and Operators of Hazardous Waste or TSD Facilities (40 CFR Part 264)	Remedial alternatives may involve hazardous waste treatment, storage, and disposal facilities
Land Disposal Restrictions (40 CFR Part 268)	Standards for the land disposal of hazardous wastes
Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257)	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health and thereby constitute prohibited open dumps.

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TABLE 2-1 (Continued)
POTENTIAL FEDERAL ARARs AND TBCs
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Action-Specific Requirements	Rationale
Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR) Parts 107, 171-179)	Remedial alternatives may include transport of waste for off-site treatment and disposal
National Environmental Policy Act	Requires consideration of environmental effects due to Federal actions
Clean Water Act (40 CFR Part 122) National Pollutant Discharge Elimination System (NPDES)	Remedial actions may involve discharge to surface waters
Clean Air Act (42 USC 7401) NAAQS (40 CFR Parts 50 and 53), NESHAPs (40 CFR Part 61), and NSPS (40 CFR Part 60)	Treatment technologies for emissions to air (incineration, surface impoundments, waste piles, landfills, and sources of fugitive emissions)
Occupational Safety and Health Act (29 USC 651-678)	Regulates worker health and safety
Revised Procedures for Planning and Implementing Offsite Actions (OSWER Directive 9834.11)	Establishes procedures for off-site response actions
Guidance for Evaluating the Technical Impracticability of Groundwater Restoration (guidance)	Establishes EPA's approach for determination of technical impracticability of groundwater cleanups, alternative measures, and overall framework for decision making.
Superfund Groundwater RODs: Implementing Change This Fiscal Year, July 31, 1995 (memorandum)	Requires written justification at sites where technical impracticability waivers are not used.
DRBC/USEPA Region III Memorandum of Agreement, October 23, 1991	EPA will notify DRBC of remediation activities within the Delaware River Basin that involve withdrawal or discharge of groundwater. DRBC relegates oversight of such remediation activities to USEPA Region III, provided they do not conflict with DRBC planning.

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TABLE 2-2
POTENTIAL STATE ARARs AND TBCs
FEASIBILITY STUDY FOR

AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Contaminant-Specific Requirements	Rationale
Pennsylvania Water Quality Standards (25 PA Code, Chapter 93)	Remedial actions may include discharge to surface waters
Pennsylvania Air Pollution Regulations (25 PA Code, Chapters 121-143)	Remedial actions may include technologies with atmospheric emissions
Pennsylvania Water Quality Toxics Management Strategy (25 PA Code, Chapter 16)	Remedial actions may include discharge to surface waters
Pennsylvania Safe Drinking Water Regulations (25 PA Code, Chapter 109)	State MCLs and treatment technologies

Location-Specific Requirements	Rationale
Pennsylvania Water Quality Standards (25 PA Code, Chapter 93.9)	Provides designation to local streams that may be useful in determining designated uses and water quality criteria.

Action-Specific Requirements	Rationale
Pennsylvania Hazardous Waste Management (25 PA Code, Article VII)	Remedial actions may include treating, storing, and disposing of hazardous wastes
Pennsylvania Solid Waste Disposal Regulations (25 PA Code, Chapter 75)	Remedial actions may include treating, storing, and disposing of solid wastes
Pennsylvania Pollutant Discharge Elimination System (NPDES) Rules 25 PA Code, Chapter 92)	Remedial actions may include discharge to surface waters
Pennsylvania Wastewater Treatment Requirements (25 PA Code, Chapter 95)	Remedial actions may include treatment and discharge to surface waters

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TABLE 2-2 (Continued)
POTENTIAL STATE ARARs AND TBCs
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Action-Specific Requirements	Rationale
Pennsylvania Industrial Waste Management Regulations (25 PA Code, Chapter 97)	Remedial actions may include treatment and discharge to surface waters
Pennsylvania Stormwater Management Act (Act No. 167)	Requires measures to control stormwater runoff during remedial alternatives or development of land
Pennsylvania Special Water Pollution Regulations (25 PA Code, Chapter 101)	Applicable for permitted solid waste disposal facilities
Pennsylvania Erosion Control Regulations (25 PA Code, Chapter 102)	Soil disturbance during proposed remedial actions may require erosion and sedimentation control measures
Pennsylvania Hazardous Substances Transportation Regulations PA Code Title 13 (Flammable Liquids and Flammable Solids) and Title 15 (Oxidizing Materials, Poisons, and Corrosive Liquids)	Applicable to wastes generated during a remedial action that would be shipped off site for analysis, treatment, or disposal
Pennsylvania General Provisions (25 PA Code, Chapter 91)	Standards for the reinjection of treated groundwater
Pennsylvania Construction, Modification, Reactivation and Operation of Sources Regulations (25 PA Code, Chapter 127)	Standards for the operation of air pollution controls at a potential source
Pennsylvania Hazardous Waste Regulations (25 PA Code, Chapter 264)	Establishes procedures to measure the background groundwater quality
Land Recycling and Environmental Remediation Standards Act/Technical Manual: Pennsylvania's Land Recycling Program.	Establishes three types of cleanup standards: background, statewide health, and site specific standards. Standards are to be used for all mandatory site cleanups in Pennsylvania. Technical manual provides numerical values for standards.

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TABLE 2-2 (Continued)
POTENTIAL STATE ARARs AND TBCs
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Action-Specific Requirements	Rationale
Hazardous Waste and Petroleum Products Contamination Cleanup Projects (guidance)	Requires plan approval and BAT for air strippers and other equipment designed to remove volatile contaminants.
Air Quality Permitting Criteria for Remediation Projects Involving Air Strippers and Soil Decontamination Units (guidance)	Provides a permit exemption for remediation projects involving the Bureau of Air Quality Control.

Definitions of the two types of ARARs, as well as other TBC criteria, are given below:

- Applicable Requirements means those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements means those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at the CERCLA site, that their use is well suited (appropriate) to the particular site.

- To Be Considered" (TBC) Criteria are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing remedial action, or necessary for determining what is protective to human health and/or the environment. Examples of TBC criteria include EPA Drinking Water Health Advisories, Carcinogenic Potency Factors, and Reference Doses.

Section 121(d)(4) of CERCLA allows the selection of a remedial alternative that will not attain all ARARs if any of six conditions for a waiver of ARARs exist. These conditions are as follows:

- The remedial action is an interim measure whereby the final remedy will attain the ARAR upon completion.

- Compliance will result in greater risk to human health and the environment than other options.

- Compliance is technically impracticable.

- An alternative remedial action will attain the equivalent of the ARAR.

- For state requirements, the state has not consistently applied the requirement in similar circumstances.

- Compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the availability of Superfund money for response at other facilities (fund balancing).

The first condition applies to remedial alternatives developed in this FS for Area D, since the objective is to implement an interim action.

ARARs fall into three categories, based on the manner in which they are applied:

- Contaminant Specific: Health-/risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples of contaminant-specific ARARs include MCLs and Clean Water Act (CWA) water quality criteria. Contaminant-specific ARARs govern the extent of site cleanup.

- Location Specific: Restrictions based on the concentration of hazardous substances or the conduct of activities in specific locations. These may restrict or preclude certain remedial actions or may apply only to certain portions of site. Examples of location-specific ARARs include RCRA location requirements and floodplain management requirements. Location-specific ARARs pertain to special site features.

- Action Specific: Technology- or activity-based controls or restrictions on activities related to management of hazardous waste. Action-specific ARARs pertain to implementing a given remedy.

2.2.1.1 Contaminant-Specific ARARs and TBCs

This section presents a summary of federal and state contaminant-specific ARARs and TBC criteria of potential concern in the case of Areas A, B, and D. All ARARs and TBC criteria provide some medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants. Table 2-3 contains federal regulatory requirements and dose response parameters for contaminants of concern at NAWC Warminster.

The Safe Drinking Water Act (SDWA) promulgated National Primary Drinking Water Standard MCLs (40 CFR Part 141). MCLs are enforceable standards for contaminants in public drinking water supply systems. They consider not only health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary MCLs (SMCLs) (40 CFR Part 143) are not

TABLE 2-3

FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN

FEASIBILITY STUDY FOR AREAS A, B, AND D GROUNDWATER NAWC WARMINSTER WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Benzene	0.005	0	1-Day/Child: 0.2 10-Day/Child: 0.2	NA	1.71×10^{-3}	2.9×10^{-2}	2.9×10^{-2}	A	0.0012	0.071
Tetrachloroethene	0.005	0	1-Day/Child: 2.0 10-Day/Child: 2.0 Longer-Term/Child: 1.0 Longer-Term/Adult: 5.0	1×10^{-2}	NA	5.2×10^{-2}	NA	NA	0.0008	0.00885
1,1,1-Trichloroethane	0.2	0.2	1-Day/Child: 100 10-Day/Child: 40 Longer-Term/Child: 40 Longer-Term/Adult: 100 Lifetime: 0.2	9.0×10^{-2}	3×10^{-1}	NA	NA	D	3.1	170
Carbon tetrachloride	0.005	0	1-Day/Child: 4.0 10-Day/Child: 0.2 Longer-Term Child: 0.07 Longer-Term Adult: 0.3	7×10^{-4}	5.71×10^{-4}	1.3×10^{-1}	5.25×10^{-2}	B2	0.00025	0.0044
1,2-Dichloropropane	0.005	0	10-Day/Child: 0.09	NA	1.14×10^{-3}	6.8×10^{-2}	NA	B2	0.00052	0.039
1,1-Dichloroethane	NA	NA	NA	1×10^{-1}	1.43×10^{-1}	NA	NA	C	NA	NA
Chloroform (Trihalomethanes)	0.1	0	1-Day/Child: 4.0 10-Day/Child: 4.0 Longer-Term/Child: 0.1 Longer-Term/Adult: 0.4	1×10^{-2}	NA	6.1×10^{-3}	8.05×10^{-2}	B2	0.0057	0.470

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
1,2-Dichloroethane	0.005	0	1-Day/Child: 0.7 10-Day/Child: 0.7 Longer-Term/Child: 0.7 Longer-Term/Adult: 2.6	NA	2.86×10^{-3}	9.1×10^{-2}	9.1×10^{-2}	B2	0.00038	0.099
Trichloroethene	0.005	0	NA	6.0×10^{-3}	NA	1.1×10^{-2}	6.0×10^{-3}	B2	0.0027	0.081
cis-1,2-Dichloroethene	0.07	0.07	1-Day/Child: 4.0 10-Day/Child: 3.0 Longer-Term/Child: 3.0 Longer-Term/Adult: 11.0 Lifetime: 0.07	1×10^{-2}	NA	NA	NA	D	NA	NA
trans-1,2-Dichloroethene	0.1	0.1	1-Day/Child: 20.0 10-Day/Child: 2.0 Longer-Term/Child: 2.0 Longer-Term/Adult: 6.0 Lifetime: 0.1	2×10^{-2}	NA	NA	NA	D	0.7	140
1,1-Dichloroethene	0.007	0.007	1-Day/Child: 2.0 10-Day/Child: 1.0 Longer-Term/Child: 1.0 Longer-Term/Adult: 4.0 Lifetime: 0.007	9×10^{-3}	NA	6×10^{-1}	1.75×10^{-1}	C	5.7×10^{-5}	0.0032
2-Butanone	NA	NA	1-Day/Child: 80.0 10-Day/Child: 8.0 Longer-Term/Child: 3.0 Longer-Term/Adult: 9.0 Lifetime: 0.2	6×10^{-1}	2.86×10^{-1}	NA	NA	(under review)	NA	NA

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Chloromethane	NA	NA	1-Day/Child: 9.0 10-Day/Child: 0.4 Longer-Term/Child: 0.4 Longer-Term/Adult: 1.0 Lifetime: 0.003	NA	NA	1.3×10^{-2}	6.3×10^{-3}	C	0.0057	0.47
1,2-Dichlorobenzene	0.6	0.6	1-Day/Child: 9.0 10-Day/Child: 9.0 Longer-Term/Child: 9.0 Longer-Term Adult: 30.0 Lifetime: 0.6	9×10^{-2}	4.0×10^{-2}	NA	NA	D	2.7	17
Ethylbenzene	0.7	0.7	1-Day/Child: 30.0 10-Day/Child: 3.0 Longer-Term/Child: 1.0 Longer-Term/Adult: 3.0 Lifetime: 0.7	1×10^{-1}	3×10^{-1}	NA	NA	D	3.1	29
Toluene	1.0	1.0	1-Day/Child: 20.0 10-Day/Child: 2.0 Longer-Term/Child: 2.0 Longer-Term/Adult: 7.0 Lifetime: 1.0	2×10^{-1}	1.14×10^{-1}	NA	NA	D	6.8	200
Trichlorofluoro-methane	NA	NA	1-Day/Child: 7.0 10-Day/Child: 7.0 Longer-Term/Child: 3.0 Longer-Term/Adult: 10.0 Lifetime: 2.0	3×10^{-1}	2×10^{-1}	NA	NA	D	NA	NA

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence [4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Vinyl Chloride	0.002	0	1-Day/Child: 3.0 10-Day/Child: 3.0 Longer-Term/Child: 0.01 Longer-Term/Adult: 0.05	NA	NA	1.9×10^{0}	3×10^{-1}	A	0.002	0.525
Methylene chloride	0.005	0	NA	6×10^{-2}	8.6×10^{-1}	7.5×10^{-3}	1.6×10^{-3}		0.0047	1.6
Acetone	NA	NA	NA	1×10^{-1}	NA	NA	NA		NA	NA
Carbon disulfide	NA	NA	NA	1×10^{-1}	2×10^{-1}	NA	NA		NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA	NA		NA	NA
4-Methyl-2-pentanone	NA	NA	NA	8×10^{-2}	2.29×10^{-2}	NA	NA		NA	NA
Xylenes (Total)	10	10	1-Day/Child: 40.0 10-Day/Child: 40.0 Longer-Term/Child: 40.0 Longer-Term/Adult: 100.0 Lifetime: 10.0	2.0×10^{0}	NA	NA	NA	D	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA	NA	7.3×10^{-1}	6.1×10^{-1}	B2	2.8×10^{-6}	3.1×10^{-5}
Benzo(a)pyrene	0.002	0	NA	NA	NA	7.3×10^{0}	6.1×10^{0}	B2	2.8×10^{-6}	3.1×10^{-5}
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	7.3×10^{-1}	6.1×10^{-1}	B2	2.8×10^{-6}	3.11×10^{-5}
Benzo(g,h,i)perylene	NA	NA	NA	NA	NA	NA	1.29×10^{-1}	D	NA	NA
Butylbenzylphthalate	NA	NA	NA	2.0×10^{1}	NA	NA	NA	C	3	5.2
Chrysene	NA	NA	NA	NA	NA	7.3×10^{-3}	6.1×10^{-3}	B2	2.8×10^{-6}	3.11×10^{-5}

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence [4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Dibenz(a,h) anthracene	NA	NA	NA	NA	NA	7.3×10^{0}	6.1×10^{0}	B2	2.8×10^{-6}	3.11×10^{-5}
Diethylphthalate	NA	NA	Lifetime: 5.0	8×10^{-1}	NA	NA	NA	D	23	120
Di-n-octylphthalate	NA	NA	NA	2×10^{-2}	NA	NA	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	4×10^{-2}	NA	NA	NA	D	0.3	0.37
Indeno(1,2,3-cd) pyrene	NA	NA	NA	NA	NA	7.3×10^{-1}	6.1×10^{-1}	B2	2.8×10^{-6}	3.11×10^{-5}
Phenanthrene	NA	NA	NA	NA	NA	NA	NA	D	NA	NA
Pyrene	NA	NA	NA	3×10^{-2}	NA	NA	NA	D	0.96	11
Arsenic	0.05	NA	NA	3×10^{-4}	NA	1.5×10^{0}	1.51×10^{1}	A	0.000018	0.00014
Cadmium	0.005	0.005	1-Day/Child: 0.04 10-Day/Child: 0.04 Longer-Term/Child: 0.005 Longer-Term/Adult: 0.02 Lifetime: 0.005	5×10^{-4}	5.71×10^{-5}	NA	6.3×10^{0}	B1	0.016	0.17
Chromium (total)	0.1	0.1	1-Day/Child: 1.0 10-Day/Child: 1.0 Longer-Term/Child: 0.2 LongerpTerm/Adult: 0.8 Lifetime: 0.1	1×10^{-0}(tri) 5×10^{-3}(hex)	5.7×10^{-7} (tri)	NA	4.2×10^{1} (hex)	D (tri) A (hex)	NA	NA
Cobalt	NA	NA	NA	6.0×10^{-2}	NA	NA	NA	NA	NA	NA
Lead	0.015[8]	0	NA	NA	NA	NA	NA	B2	0.05	NA

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence [4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Manganese	NA	NA	NA	5×10^{-3}	1.43×10^{-5}	NA	NA	D	NA	NA
Nickel	0.1	0.1	1-Day/Child: 1.0 10-Day/Child: 1.0 Longer-Term/Child: 0.5 Longer-Term/Adult: 1.7 Lifetime: 0.1	2×10^{-2}	NA	NA	8.4×10^{-1} (refinery dust)	D	0.61	4.6
Thallium	0.002	0.0005	1-Day/Child: 0.007 10-Day/Child: 0.007 Longer-Term/Child: 0.007 Longer-Term/Adult: 0.02 Lifetime: 0.0004	7.0×10^{-5} (thallic oxide)	NA	NA	NA	NA	0.0017	0.0063
Aluminum	0.05-0.2[13]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium	2.0	2.0	Lifetime: 2.0	7×10^{-2}	1.4×10^{-4}	NA	NA	D	NA	NA
Copper	1.3	1.3	NA	3.7×10^{-2}	NA	NA	NA	D	1.3	NA
Mercury	0.002	0.002	Longer-Term/Adult: 0.002 Lifetime: 0.002	3×10^{-4}	8.6×10^{-5}	NA	NA	D	1.4×10^{-4}	1.5×10^{-4}
Silver	0.05[13]	NA	1-Day/Child: 0.2 10-Day/Child: 0.2 Longer-Term/Child: 0.2 Longer-Term/Adult: 0.2 Lifetime: 0.1	5×10^{-3}	NA	NA	NA	D	0.105	65
Vanadium	NA	NA	NA	7×10^{-3}	NA	NA	NA	D	NA	NA

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TABLE 2-3 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Zinc	5.0[13]	NA	Lifetime: 2.0	3×10^{-1}	NA	NA	NA	D	NA	NA

NA Not Available.
(1) Safe Drinking Water Act, 40 CFR 141/142/143.
(2) EPA, Drinking Water Regulations and Health Advisories, EPA 822-R-96-001, February 1996.
(3) EPA, 1992a.
(4) IRIS October, 1995.
(5) EPA, 1992b.
(6) EPA, 1990b. Based on protection of human health.
(7) Calculated from LD_{LO}.
(8) Action level, EPA, 1991b.
(9) RfD has been revoked pending review of carcinogenicity.
(10) EPA, 1991a.
(11) Heast, 1994 Annual.
(12) Memorandum on Carcinogenicity of Benzo(a)pyrene and PAHs, Pei-Fing Hurst, March 22, 1991.
(13) Secondary MCL.

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enforceable but are intended as guidelines for contaminants that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and may deter public acceptance of drinking water provided by public water systems.

The SDWA also established Maximum Contaminant Level Goals (MCLGs) for several organic and inorganic compounds in drinking water. MCLGs are set at levels of no known or anticipated adverse health effects, with an adequate margin of safety. The National Contingency Plan (NCP) [40 CFR Part 300.430(e)(2)(i)] states that MCLGs that are set at levels above zero shall be attained by remedial actions for groundwaters or surface waters that are current or potential sources of drinking water [where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in Section 300.400(g)(2) of the NCP]. If an MCLG is found not to be relevant and appropriate, the corresponding MCL shall be achieved where relevant and appropriate to the circumstances of the release. For MCLGs that are set at zero, the MCL promulgated for that contaminant under the SDWA shall be attained by the remedial actions. In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in a cumulative cancer risk in excess of 10^{-4}, criteria in paragraph (e)(2)(i)(A) of Section 300.430 (i.e., risk-based criteria) may be considered when determining the clean-up level to be attained. The NCP explains that clean-up levels set at zero (generally the case for carcinogens) are not appropriate because CERCLA does not require complete elimination of risk and because "true zero" cannot be detected.

SDWA requirements may be relevant and appropriate to remedial actions involving groundwater. Table 2-3 contains available federal SDWA standards for the contaminants of concern identified during the previous studies conducted at NAWC Warminster.

The Clean Water Act (CWA) sets EPA Ambient Water Quality Criteria (AWQCs) that are non-enforceable guidelines developed for pollutants in surface waters pursuant to Section 304(a)(1) of the CWA. Although AWQCs are not legally enforceable, they have been used by many states to develop enforceable water quality standards; they should be considered as potential ARARs, as specified by CERCLA. AWQCs are available for the protection of human health from exposure to contaminants in surface water as well as from ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. AWQCs may be considered for actions that involve groundwater treatment and/or discharge to nearby surface waters.

The Clean Air Act (CAA) (42 USC 7401) consists of three programs or requirements that may be ARARs: National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50), National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61), and New Source Performance Standards (NSPS) (40 CFR Part 60). NESHAPs, which are emission standards for source types (i.e., industrial categories)

that emit hazardous air pollutants, are not likely to be applicable or relevant and appropriate for NAWC Warminster because they were developed for a specific source.

EPA requires the attainment and maintenance of primary and secondary NAAQS, shown in Table 2-4, to protect public health and public welfare, respectively. These standards are not source specific but rather are national limitations on ambient air quality. States are responsible for assuring compliance with the NAAQS. Requirements in the EPA-approved State Implementation Plan (SIP) for the implementation, maintenance, and enforcement of NAAQS are potential ARARs.

NSPS are established for new sources of air emissions to ensure that the new stationary sources minimize emissions. These standards are for categories of stationary sources that cause or contribute to air pollution that may endanger public health or welfare. Standards are based upon the best demonstrated technology (BDT). NSPS are generally not applicable to CERCLA remedial actions but may be relevant and appropriate to NAWC Warminster if the pollutant(s) emitted (e.g., from an air stripping tower) and the technology employed during the clean-up action are sufficiently similar to the pollutant and source category regulated by an NSPS and are well suited to the circumstances at the site.

OSWER Directive 9355.0-28 is a TBC that guides the control of air emissions from air strippers at Superfund groundwater remediation sites. For sites located in areas that are not attaining the NAAQS for ozone, add-on emission controls are required for an air stripper with an actual emission rate in excess of 3 pounds per hour or 15 pounds per day, or a potential (i.e., calculated) rate of 10 tons per year of total VOCs. This TBC may be relevant and appropriate in meeting risk management guidelines because NAWC Warminster is located in an area that is not attaining the NAAQS for ozone.

EPA Health Advisories are nonenforceable guidelines (TBCs) developed by the EPA Office of Drinking Water for chemicals that may be intermittently encountered in public water supply systems. Health advisories are available for short-term, longer-term, and lifetime exposures for a 10-kilogram child and/or a 70-kilogram adult. Health advisories may be pertinent for remedial actions involving groundwater, especially for contaminants that are not regulated under the SDWA.

Reference Dose (RfD), as defined in the EPA Integrated Risk Information System (IRIS), is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are developed for chronic and/or subchronic human exposure to hazardous chemicals and are based on the assumption that thresholds exist for certain toxic effects. The RfD is usually expressed as an acceptable dose (mg) per unit body weight (kg) per unit time (day). The RfD is derived

TABLE 2-4

CLEAN AIR ACT - NATIONAL AMBIENT AIR QUALITY STANDARDS

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Parameter	Primary Standard ($\mu g/m^3$)	Secondary Standard ($\mu g/m^3$)
Carbon monoxide	10,000 (8-hour)[1] 40,000 (1-hour)[1]	10,000 (8-hour)[1] 40,000 (1-hour)[1]
Lead	1.5 (90-day)[2]	1.5 (90-day)[2]
Nitrogen oxides	100 (1-year)[3]	100 (1-year)[3]
Ozone	235 (1-hour)[1]	235 (1-hour)[1]
Particulate matter (expressed as PM-10)	150 (24-hour)[1] 50 (1-year)[3]	150 (24-hour)[1] 50 (1-year)[3]
Sulfur Dioxide	365 (24-hour)[1] 80 (1-year)[3]	1,300 (3-hour)[1]

Primary: Protection of public health
Secondary: Protection of public welfare
(1) Maximum concentration not to be exceeded more than once per year
(2) Maximum arithmetic mean averaged over a calendar quarter
(3) Annual arithmetic mean

by dividing the no-observed-adverse effect level (NOAEL) or the lowest-observed-adverse effect level (LOAEL) by an uncertainty factor (UF) times a modifying factor (MF). The use of uncertainty factors and modifying factors is discussed in the EPA Office of Research and Development (ORD) Health Effects Assessment Summary Tables, Fourth Quarter FY1989 [October 1989-ORD(RD-689)] (EPA, 1989a). RfDs are TBCs for NAWC Warminster.

Cancer Slope Factors (CSFs) are used for estimating the lifetime probability (assumed 70-year lifespan) of human receptors contracting cancer as a result of exposure to known or suspected carcinogens. These factors are generally reported in units of kg-day/mg and are derived through an assumed low-dosage linear relationship and an extrapolation from high to low dose responses determined from human or animal studies. Cancer risk and CSFs are most commonly estimated through the use of a linearized multistage mathematical extrapolation model applied to animal bioassay results. The value used in reporting the slope factor is the upper 95 percent confidence limit. CSFs are TBCs for NAWC Warminster.

Hazardous Waste Identification and Listing Regulations (40 CFR Part 261) define those solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262 to 265 and Parts 124, 270, and 271.

Pennsylvania Water Quality Standards (PA Code, Title 25, Chapter 93) are based upon water uses that are to be protected and will be considered by the Pennsylvania Department of Environmental Protection (PADEP) in its regulation of discharges to surface water. The standards may be applicable for actions involving the discharge of pollutants to surface water. Chapter 93.5 specifies the procedures for applying water quality criteria for discharge of pollutants including design conditions (i.e., the use of stream flow rates) that are potentially applicable to discharge of treated groundwater from the sites.

Table 2-5 provides state water quality standards applicable to surface waters in Pennsylvania. Chapter 93.9 provides designations to site-specific surface waters based on drainage areas of river basins in question. Little Neshaminy Creek is designated as a second generation tributary of the Delaware River. This designation may be potentially useful for applying the designated water use and specific water quality criteria (if any) for treatment requirements prior to discharge of site groundwater.

Pennsylvania Air Pollution Control Regulations (PA Code, Title 25, Chapters 121 through 143) govern air emissions from remedial actions. The regulations provide for the control and prevention of air pollutants and guidance for the design and operation of air pollution sources. Potential sources of air pollution at the site may include on-site remedial actions that involve air stripping. Pennsylvania has adopted the NAAQS presented in Table 2-4 and has air quality standards for five additional constituents as shown in Table 2-6.

TABLE 2-5

PENNSYLVANIA WATER QUALITY STANDARDS AND AMBIENT WATER QUALITY CRITERIA

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Parameter	Water Quality Standard[1]	Ambient Water Quality Criteria for Protection of Aquatic Life[2] (µg/L)		Ambient Water Quality Criteria for Protection of Human Health[2] (µg/L)	Statewide Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
		Continuous Concentration	Maximum Concentration		
Aluminum	0.1 of the 96-hour LC_{50}	NP	NP	NP	200 / 20000
Arsenic	NP	190[8]	360[8]	50	50 / 5000
Barium	NP	4,100	20,500	1,000	2000 / 200000
Cadmium	NP	1.0[3][8]	3.7[3][8]	10	5 / 500
Chromium	NP	10[7][8]	15[3][7][8]	NP[7]	100 / 10000[6]
Cobalt	NP	19	95	NP	None
Copper	NP	11[3][8]	17[3][8]	1,000	1000 / 100000
Iron	1.5 mg/L (total); 0.3 mg/L (diss.)	NP	NP	NP	None
Lead	NP	2.5[3][8]	65[3][8]	50	5 / 500
Manganese	1.0 mg/L	NP	NP	NP	50 / 5000
Mercury	NP	0.012	2.1[8]	0.144	2 / 200
Nickel	NP	160[3][8]	1,400[3][8]	600	100 / 10000
Silver	NP	NP	3.5[3][8]	200	100 / 10000
Thallium	NP	13	65	2	2 / 200
Vanadium	NP	103	515	NP	None
Zinc	NP	100[3][8]	110[3][8]	5,000	5000 / 500000

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TABLE 2-5 (Continued)
PENNSYLVANIA WATER QUALITY STANDARDS AND AMBIENT WATER QUALITY CRITERIA
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Parameter	Water Quality Standard[1]	Ambient Water Quality Criteria for Protection of Aquatic Life[2] (µg/L)		Ambient Water Quality Criteria for Protection of Human Health[2] (µg/L)	Statewide Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
		Continuous Concentration	Maximum Concentration		
Benzene	NP	128	640	1	5 / 500
Tetrachloroethene	NP	139	695	0.7	5 / 500
Trichloroethene	NP	450	2,250	3	5 / 500
cis-1,2-Dichloroethene	NP	NP	NP	NP	70 / 7000
trans-1,2-Dichloroethene	NP	1,350	6,750	700	100 / 10000
1,1-Dichloroethene	NP	1,492	7,460	0.06	7 / 700
1,1,1-Trichloroethane	NP	605	3,025	1,000	200 / 20000
2-Butanone	NP	32,200	161,000	2,000	None
Carbon tetrachloride	NP	556	2,780	0.3	5 / 500
Chloroform	NP	389	1,945	6	100 / 10000 (as total trihalomethanes)
1,2-Dichloropropane	NP	2,165	10,825	NP	5 / 500
1,1-Dichloroethane	NP	NP	NP	NP	None
Chloromethane	NP	5,500	27,500	NP	3/300
1,2-Dichlorobenzene	NP	164	820	400[4]	600 / 60000
1,2-Dichloroethane	NP	3,088	15,440	0.4	5 / 500
Ethylbenzene	NP	580	2,900	3,000	700 / 70000
Toluene	NP	330	1,650	3,000	1000 / 100000
Trichlorfluoromethane	NP	NP	NP	NP	2000/200000
Vinyl chloride	NP	NP	NP	0.02	2 / 200

TABLE 2-5 (Continued)
PENNSYLVANIA WATER QUALITY STANDARDS AND AMBIENT WATER QUALITY CRITERIA
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Parameter	Water Quality Standard[1]	Ambient Water Quality Criteria for Protection of Aquatic Life[2] (µg/L)		Ambient Water Quality Criteria for Protection of Human Health[2] (µg/L)	Statewide Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
		Continuous Concentration	Maximum Concentration		
4-Methyl-2-pentanone	NP	5,000	26,000	2,000	None
2-Hexanone	NP	4,280	21,400	NP	None
Acetone	NP	86,000	446,000	4,000	None
Methylene chloride	NP	2,368	11,840	5	5 / 5000
Xylenes	NP	211	1,055	300	10000 / 1000000
Benzo(a)anthracene	NP	0.1	0.5	0.003	None
Benzo(a)pyrene	NP	NP	NP	0.003	0.2 / 20
Benzo(b)fluoranthene	NP	NP	NP	0.003	None
Benzo(ghi)perylene	NP	NP	NP	NP	None
Butylbenzylphthalate	NP	35	140	300	None
Chrysene	NP	NP	NP	0.003	None
Dibenz(ah)anthracene	NP	NP	NP	0.003	None
Diethylphthalate	NP	800	4,000	20,000	5000 / 500000
Di-n-octylphthalate	NP	NP	NP	NP	None
Fluoranthene	NP	40	200	300	None
Indeno(1,2,3-cd)pyrene	NP	NP	NP	0.003	None
Phenanthrene	NP	1	5	NP	None
Pyrene	NP	NP	NP	1,000	None

(1) 25 PA Code, Chapter 93.

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TABLE 2-5 (Continued)
PENNSYLVANIA WATER QUALITY STANDARDS AND AMBIENT WATER QUALITY CRITERIA
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

(2) 25 PA Code Chapter 16
(3) Based on assumed hardness of 100 μg/L, must be evaluated on a site-specific basis for receiving stream(s) of concern.
(4) Total dichlorobenzenes
(5) Technical Manual, Pennsylvania's Land Recycling Program, 1995.
(6) Value for total chromium.
(7) Value for Chromium VI.
(8) Dissolved criteria.
TDS Total Dissolved Solids.
NP Not promulgated.

TABLE 2-6

PENNSYLVANIA AMBIENT AIR QUALITY STANDARDS

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Parameter	Standard
Settled particulate	0.8 $mg/cm^2/mo$ (1-year average) 1.5 $mg/cm^2/mo$ (30-day average)
Beryllium	0.01 $\mu g/m^3$ (30-day average)
Sulfates (as H_2SO_4)	10 $\mu g/m^3$ (30-day average) 30 $\mu g/m^3$ (24-hour average)
Fluorides (total soluble as HF)	5 $\mu g/m^3$ (24-hour average)
Hydrogen sulfide	0.005 ppm (24-hour average) 0.1 ppm (1-hour average)

Source Code: PA Code Title 25, Chapter 131

Pennsylvania Water Quality Toxics Management Strategy (PA Code, Title 25, Chapter 16) contains water quality criteria for toxics. Values for toxics of concern are shown in Table 2-5.

Pennsylvania Safe Drinking Water Regulations (PA Code, Title, 25 Chapter 109) set forth drinking water quality standards at least as stringent as the National Primary Drinking Water Regulations. MCLs that are promulgated by EPA are automatically incorporated into 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 considering 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.

2.2.1.2 Location-Specific ARARs and TBCs

Federal Protection of Wetlands Executive Order (E.O. 11990) requires federal agencies, in carrying out their responsibilities, to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. According to the published definition of national wetlands, federal Register 40 CFR Appendix C, several small areas of palustrine forested wetlands are present along intermittent tributaries to Little Neshaminy Creek or Southampton Creek. This ARAR has been retained in the event that wetland areas may be affected.

The Endangered Species Act of 1978 (16 USC 1531) (40 CFR Part 502) provides for consideration of the impacts on endangered and threatened species and their critical habitats. This act requires federal agencies, in consultation with the Secretary of the Interior, to ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. A review of the available information indicates that no state or federally listed endangered or threatened species are known to permanently or seasonally reside in the vicinity of NAWC Warminster. For this reason, the Endangered Species Act of 1978 is not applicable or relevant and appropriate to actions taken at the site.

The Fish and Wildlife Coordination Act (16 USC 661) provides for consideration of the impacts on wetlands and protected habitats. The act requires that federal agencies, before issuing a permit or undertaking federal action for the modification of any body of water, consult with the appropriate state

agency exercising jurisdiction over wildlife resources to conserve those resources. Consultation with the United States Fish and Wildlife Service is also required.

The Fish and Wildlife Improvement Act of 1978 (16 USC 742a) and The Fish and Wildlife Conservation Act of 1980 (16 USC 2901) provide for consideration of the impacts on wetlands and protected habitats.

EPA's Groundwater Protection Strategy (EPA, 1984) policy is to protect groundwater for its highest present or potential beneficial use. This policy (TBC) will be incorporated into future regulatory amendments. The strategy designates three categories of groundwater:

- Class I - Special Groundwaters: Waters that are highly vulnerable to contamination and are either irreplaceable or ecologically vital sources of drinking water.

- Class II - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses: Waters that are currently used or that are potentially available.

- Class III - Groundwater Not a Potential Source of Drinking Water and of Limited Beneficial Use. Class III groundwater units are further subdivided into two subclasses.

  - Subclass IIIA includes groundwater units that are highly to intermediately interconnected to adjacent groundwater units of a higher class and/or surface waters. They may, as a result, be contributing to the degradation of the adjacent waters. They may be managed at a similar level as Class II groundwaters, depending upon the potential for producing adverse effects on the quality of adjacent waters.

  - Subclass IIIB is restricted to groundwater characterized by a low degree of interconnection to adjacent surface waters or other groundwater units of a higher class within the Classification Review Area. These groundwaters are naturally isolated from sources of drinking waters in such a way that there is little potential for producing adverse effects on quality. They have low resource values outside of mining or waste disposal.

Groundwater beneath and adjacent to NAWC Warminster is designated as a Class II aquifer.

Federal Floodplain Management Executive Order (E.O. 11988) requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the extent possible, the adverse impacts associated with direct and indirect development of a floodplain.

2.2.1.3 Action-Specific ARARs and TBCs

RCRA Subtitle C regulates the treatment, storage, and disposal of hazardous waste from its generation until its ultimate disposal. In general, RCRA Subtitle C requirements for the treatment, storage, or disposal of hazardous waste will be applicable if

- The waste is a listed or characteristic waste under RCRA.
- The waste was treated, stored, or disposed of (as defined in 40 CFR 260.10) after the effective date of the RCRA requirements under consideration.
- The activity at the CERCLA site constitutes current treatment, storage, or disposal as defined by RCRA.

RCRA Subtitle C requirements may be relevant and appropriate when the waste is sufficiently similar to a hazardous waste and/or the on-site remedial action constitutes treatment, storage, or disposal and the particular RCRA requirement is well suited to the circumstances of the contaminant release and site. RCRA Subtitle C requirements may also be relevant and appropriate when the remedial action constitutes generation of a hazardous waste. On-site activities, mandated by a federally ordered Superfund cleanup, must comply with the substantive requirements of RCRA Subtitle C but not with the administrative requirements (i.e., permits) of RCRA. All RCRA Subtitle C requirements must be met if the cleanup is not under federal order and/or when the hazardous waste moves off site.

An exemption from the hazardous waste rules is provided for wastewater treatment units that are tank systems discharging via regulated outfalls (40 CFR 264.1(g)(6), 25 PAC 264.1(c)(8), 40 CFR 260.10, 25 PAC 260.2). An exclusion from permitting is provided for such facilities under 40 CFR 270.1(c)(2)(4) for owners and operators of wastewater treatment units and permit-by-rule is provided under 25 PAC 270.1(c). Accordingly, permit requirements do not apply to this facility.

The following requirements included in the RCRA Subtitle C regulations may pertain to the NAWC Warminster:

- Hazardous waste generator requirements (40 CFR Part 262).
- Transportation requirements (40 CFR Part 263).
- Standards for owners and operators of hazardous waste treatment, storage, and disposal (TSD) facilities (40 CFR Part 264).
- Interim status standards for owners and operators of hazardous waste TSD facilities (40 CFR Part 265).
- Land Disposal Restrictions (40 CFR Part 268)

A generator that treats, stores, or disposes of hazardous waste on site must comply with RCRA Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262). These standards include manifest, pre-transport (i.e., packaging, labeling, placarding), recordkeeping, and reporting requirements. The standards are applicable to actions taken at NAWC Warminster that constitute generation of a hazardous waste (e.g., generation of groundwater treatment residues that may be hazardous).

Standards Applicable to Transporters of Hazardous Waste (40 CFR Part 263) are applicable to off-site transportation of hazardous waste from NAWC Warminster. These regulations include requirements for compliance with the manifest and recordkeeping systems and requirements for immediate action and cleanup of hazardous waste discharges (spills) during transportation. Transporters must also have a Pennsylvania transporter permit.

Standards for Owners and Operators of Hazardous Waste TSD Facilities (40 CFR Part 264) are applicable to remedial actions taken at NAWC Warminster and to off-site facilities receiving hazardous waste from the site for treatment and/or disposal and have a RCRA Part B permit. On-site facilities must also have a RCRA Part B permit if the site is not a federally ordered CERCLA cleanup. Standards for TSDFs include requirements for preparedness and prevention, releases from solid waste management units (i.e., corrective action requirements), closure and post-closure care, use and management of containers, and design and operating standards for tank systems, surface impoundments, waste piles, landfills, and incinerators.

RCRA Land Disposal Restrictions (LDR) Requirements (40 CFR Part 268) restrict certain wastes from being placed or disposed of on the land unless they meet specific Best Demonstrated Available Technology (BDAT) treatment standards (expressed as concentrations, total or in the TCLP extract, or as specified technologies).

Placement of hazardous waste into underground injection wells constitutes "land disposal" under the LDRs. Furthermore, RCRA Section 3020(a) bans hazardous waste disposal by underground injection into or above an underground source of drinking water. RCRA Section 3020(b), however, exempts from the ban all reinjections of treated contaminated groundwater into such formations undertaken as part of a CERCLA Section 104 or 106 response action, or a RCRA corrective action, if the following conditions are met:

- The contaminated groundwater is treated to substantially reduce hazardous constituents prior to such injection.

- The response action or corrective action is sufficient to protect human health and the environment upon completion.

Therefore, the LDR requirements may not be applicable or relevant and appropriate to reinjection of treated groundwater at NAWC Warminster.

RCRA Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257) establish criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health and thereby constitute prohibited open dumps.

Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR Parts 107 and 171-179) regulate the transport of hazardous materials, including packaging, shipping equipment, and placarding. These rules are considered applicable to wastes shipped off site for laboratory analysis, treatment, or disposal.

The Clean Water Act (CWA), as amended, governs point-source discharges through the National Pollutant Discharge Elimination System (NPDES), discharge or dredge or fill material, and oil and hazardous waste spills to United States waters. NPDES requirements (40 CFR Part 122) will be applicable if the direct discharge of pollutants into surface waters is part of the remedial action.

The Occupational Health and Safety Act (29 USC, Sections 651 through 678) regulates worker health and safety during implementation of remedial actions.

OSWER Directive 9834.11 establishes procedures for planning and implementing off-site response actions.

Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, OSWER Publication 9234.2-25, EPA/540-R-93-080, September, 1993 is a TBC that establishes EPA's approach for determination of technical impracticability (TI) of groundwater cleanups, alternative measures, and an overall framework for decision making. TI determinations are to be based on clear and convincing evidence provided by the operator. A phased approach of investigation and remediation is recommended for dense non-aqueous phase liquids (DNAPL) sites. An expectation is stated that the aqueous plume outside the DNAPL zone will be remediated to required clean-up levels. Geologic constraints to cleanups are recognized: for example, aquifer heterogeneity or fractured bedrock aquifers. Technical concerns that are addressed include exposure control, source control, and plume remediation. Use of next most stringent ARARs as a fallback requirement and the potential to remediate by natural attenuation are addressed in the case of technical impracticability. The TI decision must be incorporated into the site decision document, either before or after the remedy is implemented.

EPA Memorandum: Superfund Groundwater RODs: Implementing Change This Fiscal Year, July 31, 1995 is a TBC that addresses changes in EPA's philosophy regarding DNAPLs. The memorandum speaks to the challenges of restoring sites to drinking water standards where DNAPLs are present, emphasizes flexible, phased approaches to remediation in such circumstances, and emphasizes the general appropriateness of TI waivers with respect to federal and/or state clean-up standards for DNAPL sites. The memorandum also expresses a concern that the TI waivers are not being used to the extent that they should be used and requires written justification at sites where the TI waiver is not used.

Pennsylvania Hazardous Waste Management Regulations (PA Code, Title 25, Article VII) essentially parallel RCRA Subtitle C hazardous waste management regulations. Similar to RCRA Subtitle C regulations, Pennsylvania regulations include requirements for the following:

- Generators of hazardous waste (Chapter 262)
- Transporters of hazardous waste (Chapter 263)
- New and existing hazardous waste management facilities applying for a permit (Chapter 264)
- Interim status hazardous waste management facilities applying for a permit (Chapter 265)

The above regulations may be relevant and appropriate to on-site remedial actions and applicable to the transport of hazardous waste off site.

The corrective action program requirements of Chapter 264 (Section 264.100) require contaminated groundwater to be remediated to background levels. This regulation also establishes procedures to measure background groundwater quality. As stated in the regulation, groundwater remedial actions may be terminated when it can be demonstrated that concentration levels of hazardous constituents in the monitoring wells have remained at background levels for a period of 3 consecutive years.

Pennsylvania Solid Waste Disposal Regulations (PA Code 25, Chapter 75) regulate the disposal of solid wastes including municipal and industrial materials. The regulations set operating and permitting standards for disposal areas and characterize waste materials to achieve proper disposal. Any remedial actions resulting in the generation of waste material for on-site or off-site disposal are governed by these regulations.

Pennsylvania Industrial Waste Management Regulations (PA Code 25, Chapter 97) regulate the disposal of industrial waste materials. The regulations characterize wastes and set permitting and disposal standards. Remedial activities resulting in the generation of industrial waste such as wastewater treatment plant sludges are regulated under this statute.

Pennsylvania NPDES Rules (PA Code, Title 25, Chapter 92) govern point-source discharges to Pennsylvania waters. The rules include requirements for permits, permit applications, permit conditions, and monitoring. These rules may be applicable for remedial actions involving a discharge to surface water. To the extent that Pennsylvania water quality criteria and standards, wastewater treatment requirements, industrial waste treatment, and special water pollution control regulations (PA Code, Title 25, Chapters 16, 93, 95, 97, and 101) pertain to a discharge for which an NPDES permit is required, the provisions of these chapters govern if their application produces a more stringent effluent limitation than would be produced by application of federal standards. The Pennsylvania NPDES rules are generally equivalent to the federal standards.

Table 2-7 shows effluent limitations provided by PADEP for a 130 gpm groundwater flow discharging from NAWC Warminster's existing outfall to an unnamed tributary of Little Neshaminy Creek. These limitations were developed for an Interim Remedial Action addressing Areas A and B.

Pennsylvania Wastewater Treatment Regulations (PA Code, Title 25, Chapter 95) are regulations that are required to maintain water quality and include treatment requirements, effluent limitations based on best

TABLE 2-7

EFFLUENT QUALITY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS FOR OUTFALL TO TRIBUTARY OF LITTLE NESHAMINY CREEK

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

Constituent	Units	Average Monthly	Instantaneous Maximum
Flow	Monitor Only		
pH	Standard Units	6.0 - 9.0	
Total Suspended Solids	mg/L	30	75
Cadmium	μg/L	1.6	4.0
Copper	μg/L	9.5	24.0
Lead	μg/L	4.3	11.0
Zinc	μg/L	63	158
Arsenic	μg/L	0.11	0.28
$Chromium^{6+}$	μg/L	9.3	23.0
Aluminum	μg/L	750	1,875
Total Iron	μg/L	1,440	3,600
Dissolved Iron	μg/L	450	1,125
Total Manganese	μg/L	1,500	3,750
Mercury	μg/L	0.018	0.045
Carbon Tetrachloride	μg/L	1.7	4.3
Tetrachloroethene	μg/L	4.0	10.0
Trichloroethene	μg/L	17	43.0
Vinyl Chloride	μg/L	0.11	0.28
1,1-Dichloroethylene	μg/L	0.34	0.85

Note 1: Limits apply to a flow of 130 gallons per minute.

Note 2: Limits shown were excerpted from PADEP internal memo, Nancy Krickman to Steve O'Neil, dated March 31, 1994, issued within PADEP's Conshohocken office.

Note 3: Limits for vinyl chloride and 1,1-dichloroethylene will be enforced at detection limits of 1 μg/L, per telephone conversation with Nancy Krickman of PADEP on June 21, 1994.

practical control technologies, and waste-load allocations for pollutants for which minimum treatment requirements have not been established. These regulations will be applicable for remedial actions that include a discharge to surface water.

Pennsylvania Stormwater Management Act (Act No. 167) requires measures to control stormwater runoff during remedial alternatives or development of land.

Pennsylvania Special Water Pollution Regulations (PA Code, Title 25, Chapter 101) establish a procedure for mandatory notification of downstream users in the case of an accident in which a toxic substance enters surface waters. These regulations also specify bonding requirements for solid waste facilities that would ensure closure of a permitted site in a manner that would abate or prevent water pollution. The regulations may be applicable for remedial actions that include on-site treatment of solid waste.

Pennsylvania Erosion Control Regulations (PA Code, Title 25, Chapter 102) provides requirements for erosion and sedimentation control plans, permits, etc. These regulations may be potentially applicable if remedial actions involve disturbance of soils at the site.

Pennsylvania General Provisions (PA Code, Title 25, Chapter 91) are applicable if treated groundwater reinjection is a component of the remediation. If reinjection is done off site, it will be necessary to obtain a water quality management permit (Section 91.21). If the reinjection is done on site, then the substantive requirements of Chapter 91 must be met, but a permit would not be required.

Pennsylvania Hazardous Substances Transportation Regulations (PA Code, Title 13 and Title 15) govern the transport of flammable liquids and solids, oxidizing materials, poisons, and corrosive liquids. These regulations may be applicable to certain wastes that are shipped off site for laboratory analysis, treatment, or disposal. These regulations are generally equivalent to federal DOT regulations.

Pennsylvania Construction, Modification, Reactivation, and Operation of Sources Regulations (PA Code, Title 25, Chapter 127) regulate the construction, modification, or reactivation of an air contaminant source as well as the installation of an air cleaning device on an air contamination source. Remedial actions used to remove volatile contaminants from the groundwater at NAWC Warminster are subject to plan approval review under Chapter 127. The various air quality permitting criteria are site specific. Depending on site conditions, air pollution controls may be required for an air stripper at NAWC Warminster.

"Hazardous Waste and Petroleum Products Contamination Cleanup Projects" is a state guidance document and TBC that requires plan approval and BAT for air strippers and other equipment designed to remove volatile contaminants from soil, water, and other materials.

"Air Quality Permitting Criteria for Remediation Projects Involving Air Strippers and Soil Decontamination Units" is a state guidance document and TBC that provides a permit exemption policy for remediation projects involving the Bureau of Air Quality Control.

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 three environmental standards under Act 2. The standards must be used for all mandatory site cleanups in Pennsylvania. 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 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 (HAL) 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. 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.

Regulations under Act 2 are anticipated to be promulgated approximately 1 year after the time of this writing at the earliest. In the interim, the Commonwealth of Pennsylvania has published a Technical Manual, entitled "Pennsylvania's Land Recycling Program" (July 1995). The Commonwealth of Pennsylvania takes the position that the clean-up standards provided in this document are ARARs and supercede those provided in the Pennsylvania Groundwater Protection Strategy (PADEP, 1992).

The statewide health standards for groundwater as published in the Technical Manual are presented in Table 2-3.

2.2.2 Remedial Action Levels

Remedial Action Levels have been selected for the COCs at Areas A, B, and D based on ARARs and TBCs. These levels are provided in the following discussions.

Area A

Table 2-8 summarizes the Remedial Action Levels for Area A. Attempts to achieve these levels will be made, however, because of the possible presence of DNAPL, the Remedial Action Levels may not be attainable. If this is the case then a TI waiver will be requested.

Area D

There are no Remedial Action Levels proposed for Area D because the selected action will be an interim measure. The goal of the remedial action for Area D will be to contain the contaminant plume and minimize off-site migration of contamination.

Area B

Table 2-9 summarizes the Remedial Action Levels for Area B. These levels are based on both state and Federal Drinking Water standards and will therefore be protective of human health once achieved in the aquifer.

2.3 GENERAL RESPONSE ACTIONS

Using the general response actions developed for NAWC Warminster, Section 2.4 will identify the types of technologies and process options associated with these technologies. These will be screened for effectiveness and technical implementability, and a representative process option will be selected for applicable and implementable technologies. The selected process options will then be assembled into remedial alternatives. Listed below are six general response actions that were identified for groundwater at NAWC Warminster.

- No Action
- Institutional Controls
- Containment
- Removal

TABLE 2-8

REMEDIAL ACTION LEVELS FOR CHEMICALS OF CONCERN
AREA A GROUNDWATER

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

	MCL (µg/L)	State[1] Groundwater Standard (µg/L) ≤2500 TDS/>2500 TDS
TCL Volatiles (µg/L)		
Vinyl Chloride	2	2 / 200
1,1-Dichloroethene	7	7 / 700
cis-1,2-Dichloroethene	70	70 / 7000
trans-1,2-Dichloroethene	100	100 / 10000
Chloroform (as total trihalomethanes)	100	100 / 10000
2-Butanone	1900[2]	none
1,1,1-Trichloroethane	200	200 / 20000
Carbon Tetrachloride	5	5 / 500
Trichloroethene	5	5 / 500
4-Methyl-2-Pentanone	2900[2]	none
Tetrachloroethene	5	5 / 500
TAL Metals (µg/L)[2]		
Lead	15 (Action Level)	5 / 500
Manganese	50[3]	50 / 500
Mercury	2	2/ 200

1 Technical Manual, Pennsylvania's Land Recycling Program, 1995.
2 EPA Region III Risk Based Concentrations - Concentration for acceptable tap water concentration.
3 Secondary MCL.

TABLE 2-9

REMEDIAL ACTION LEVELS FOR CHEMICALS OF CONCERN
AREA B GROUNDWATER

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

	MCL	State[1] Groundwater Standards (µg/L) ≤2500 TDS/>2500 TDS
TCL Volatiles (µg/L)		
cis-1,2-Dichloroethene	70	70 / 7000
trans-1,2-Dichloroethene	100	100 / 10000
Trichloroethene	5	5 / 500
Benzene	5	5 / 500
Acetone	3700[2]	none
Toluene	1000	1000 / 100000
Methylene chloride	5	5 / 5000
Carbon disulfide	21[2]	none
TAL Metals (µg/L)[2][3]		
Aluminum	200	200 / 20000
Arsenic	50	50 / 5000
Chromium	100	100 / 10000
Copper	1000	1000 / 100000
Manganese	50[3]	50 / 5000
Mercury	2	2 / 200
Lead	15	5 / 500
Zinc	5000	5000 / 500000

1 Technical Manual, Pennsylvania Land Recycling Program, 1995.
2 EPA Region III Risk Based Concentration - Concentration for acceptable risk for tap water consumption.
3 Secondary MCL.

- Ex-situ Treatment
- In-situ Treatment

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

In this section, the technologies and process options considered under various general response actions are screened and representative process options are selected for groundwater remediation at Areas A, B, and D. The screening process consists of the following steps:

- Identifying remedial technologies and process options based on remedial action objectives and general response actions.
- Screening technologies for technical implementability and effectiveness.
- Evaluating process options considered to be implementable.

2.4.1 Initial Identification and Screening of Technologies and Options

In this step, technologies that may be applicable to groundwater remediation at Areas A, B, and D are identified and are screened to eliminate those that are obviously ineffective or difficult to implement for the given contaminants and site conditions.

In this step, potentially applicable technology types and process options are identified based on remedial action objectives and the general response actions. The list of technologies and process options is reduced by evaluating the options with respect to technical implementability. This is accomplished by using available information from the RI, ABH, and FRG and supplemented through a review of current literature and databases. This step of the screening process is applied to all three areas. However, the relevance of current application of groundwater remedies in DNAPL areas, is particularly relevant to Area A.

To develop a current and complete list of candidate remediation technologies, two recently published comprehensive works on the subject, other technical papers, and vendor supplied information were reviewed. In addition, several databases were searched. The list of remediation technologies and their variants is too lengthy for exhaustive review; accordingly, the technologies were screened for suitability based upon site-specific conditions (e.g., depth of contamination to be addressed; aquifer in heterogeneous, fractured bedrock; possible DNAPL in Area A; very low contamination levels in Area B).

The challenges of treating groundwater, especially refractory compounds in complex subsurface systems are well documented in the literature, and numerous approached have been proposed and investigated over the past several years. Two recent publications offering broad, overall analyses of the state of groundwater remediation technology and the contents of several technical papers are discussed herein to determine current thinking with regard to the implementability and effectiveness of the several technical approaches and numerous variants that are available.

Pankow and Cherry (1996) discuss DNAPL behavior at length and set forth considerations for remediation of DNAPL sites. In general, the analysis by Pankow and Cherry is consistent with the NRC publication cited in this review (1994). Pankow and Cherry report that:

> "Defining the source zone at solvent DNAPL sites on fractured porous media (e.g., fractured clayey deposits or fractured porous sandstone or shale) is complicated because the DNAPL mass initially in the fractures may have been depleted fairly quickly by diffusive transfer to the dissolved and sorbed phases of the matrix .... Therefore, in a fractured porous medium, the size of the subsurface zone in which DNAPL exists can diminish with time. In some cases, the DNAPL can disappear altogether. However, even with total DNAPL disappearance, the initial zone will contain essentially all of the contaminant mass, and will thus represent a long-term source as contaminants are released by diffusion from the matrix to groundwater flowing through the fracture network."

and

> "The restoration of fractured porous media contaminated by DNAPL compounds is a task which is exceptionally difficult, and in many cases, even futile. The difficulty in remediating such sites derives from three main factors: 1) complex fracture networks cause the initial distribution of DNAPL mass to be difficult to predict or locate; 2) dead-end fractures or fractures not well connected to active groundwater flushing impede cleanup by pump-and-treat systems; and 3) the existence of much or nearly all the contaminant mass in the relatively immobile pore water of the matrix as a result of matrix diffusion greatly increases the time for cleanup." (Pankow and Cherry, Dense Chlorinated Solvents and Other DNAPLs in Groundwater: History, Behavior & Remediation by James F. Pankow and John A. Cherry; Waterloo Press, 1996.)

Pankow and Cherry address alternatives for remediation of DNAPL sites that include low-permeability barriers, pump-and-treat, and in-situ treatment. Low-permeability barriers can be used to enclose and isolate, or to reduce or funnel groundwater flow, thereby reducing the plume size. The reference acknowledges that such measures are generally impractical in fractured bedrock. Pump-and-treat is effective for plume containment or source zone containment; however, it is criticized for the length of time

it takes to see results and for a general lack of success at accomplishing remediation. However, it may be the only option available for fractured bedrock.

Two approaches to migration control by *in-situ* treatment methods are discussed: the treatment curtain and the funnel-and-gate system. In both approaches, a plume moves to an emplaced permeable zone that accomplishes treatment through use of reactive media such as iron filings (dehalogenation), volatilization of contaminants, or amendments such as nutrients or cultured bacteria to accomplish bio-degradation. These methods are limited to shallow plumes due to cost and installation difficulties. The impracticality that applies to barrier walls in fractured bedrock would also apply to these technologies in fractured bedrock.

In-situ treatment by pumping of DNAPL pools is considered in this literature and is feasible for large pools. For small pools, DNAPL pumping is discouraged because of the cost of aggressively searching for pools that are difficult to find, the impact of pumping a small pool is minimal, and there is a risk of remobilizing the DNAPL through drilling.

Treatment of the vadose zone by air sparging and soil venting and vacuum extraction is discussed but is not highly recommended and is dismissed as being of minimal benefit as long as a DNAPL source remains below the water table.

Mass removal *in-situ* methods involve the removal or destruction of the DNAPL and the resulting plume through application of chemicals. Removal is accomplished by enhancing the mobility of the DNAPL through use of surfactants or cosolvents. This is a modification of pump-and-treat which is at an early stage of development, and has a risk of enlarging the problem. There are practical problems such as achieving contact of the flushing fluid with the contaminants in low-permeability zones. Destruction can be accomplished by the addition of soluble oxidants such as potassium permanganate or use of enzymes such as vitamin B12, which dehalogenates in strongly reducing conditions. Both of these approaches will have problems achieving contact of the reactant to the DNAPL in low-permeability zones, and much of their effectiveness may be dissipated on destruction of background occurrences of organic carbon. The latter technology requires control of aquifer redox potential, which is of questionable practicality.

Mass removal by *in-situ* biological treatment has also been studied. Such treatment involves building indigenous microorganisms by nutrient and/or oxygen amendments, adding of co-metabolites (chemical analogs to the contaminant that foster the growth of organisms that will degrade both the co-metabolite and the contaminant), and adding of bacteria cultured to disperse readily and to decompose the

contaminant. In general, the *in-situ* biological treatment approach is endorsed for sites with low levels of contamination.

The National Research Council (NRC) (1994) established a committee of experts to evaluate existing information related to subsurface remediation. The product of this evaluation gave greater emphasis to pump-and-treat technology than did Pankow and Cherry, but it identified the same concerns. Subsurface complexity and heterogeneity, the properties and behavior of DNAPL, difficulties in characterizing sites, inaccuracy of available estimating tools for calculating the duration of the cleanup, and the lack of success of cleanups on all but a small number of sites are raised as concerns. Sites are provided a numerical ranking from one to four with respect ease of cleanup (see Table 2-10). Fractured bedrock sites with DNAPLs are identified as the most difficult to remediate.

The publication concludes that pump-and-treat is effective at sites with simple geology and dissolved contaminants or at sites where contaminants are biodegradable, but NAPL-contaminated aquifers take very long periods of time to restore, unless the NAPLs are contained or removed. Cleanup of category 4 sites to health-based standards is unlikely, but the contamination can be mitigated. The NRC report states: "Removal of NAPLs from fractured rock and heterogeneous regions poses the most extreme of technical challenges."

Soil vapor extraction and bioventing are discussed favorably for vadose zone reclamation but not for aquifer restoration, for the same reasons that make pump-and-treat's effectiveness problematic in such applications. In-situ bioremediation through stimulating growth of indigenous microbial populations is presented in an encouraging light for the destruction of petroleum hydrocarbons, fuels, and some of the more readily degradable solvents. The reference is cautious with respect to chlorinated solvents, explaining that in-situ biodegradation is possible but not well documented. The advantages presented include the elimination of a stream to manage on the surface and simplicity of operation. The need for a specific microbial enhancement feasibility study, which includes consideration of site-specific geology and geochemistry, is discussed.

Use of methanotrophic bacteria, through stimulation by addition of methane to the subsurface environment or by introducing cultured methanotrophic bacteria is discussed. This is an aerobic process, whereby chlorinated organics are destroyed by the same metabolic processes that consume methane. Anaerobic processes are also discussed, with the caveat that they are slower and that incomplete decomposition may create a bigger problem than is removed (for example, formation of vinyl chloride from TCE). Creating an anaerobic environment in an otherwise aerobic environment may result in the solubilization of

TABLE 2-10

RELATIVE EASE OF CLEANING UP OF CONTAMINATED AQUIFERS AS A FUNCTION OF CONTAMINANT CHEMISTRY AND HYDROGEOLOGY[1]

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

Hydrogeology	Contaminant Chemistry					
	Mobile, Dissolved (degrades/ volatizes)	Mobile, Dissolved	Strongly Sorbed, Dissolved (degrades/ volatizes)	Strongly Sorbed, Dissolved	Separate Phase LNAPL	Separate Phase DNAPL
Homogeneous, single layer	1[2]	1-2	2	2-3	2-3	3
Homogeneous, multiple layers	1	1-2	2	2-3	2-3	3
Heterogeneous, single layer	2	2	3	3	3	4
Heterogeneous, multiple layers	2	2	3	3	3	4
Fractured	3	3	3	3	3	4

1. From: Alternatives for Groundwater Cleanup, Committee on Groundwater Cleanup Alternatives, Water Science and Technology Board, Board on Radioactive Waste Management, and Commission on Geosciences, Environment, and Resources, pub by National Academy Press, Washington, D.C., 1994

2. Relative ease of cleanup, where 1 is easiest and 4 is most difficult.

nuisance compounds such as iron and manganese. Both require the input of electron donors for energy sources, and delivery of electron donors to the point of need can be problematic.

The NRC publication is more encouraging than Pankow and Cherry concerning the effectiveness of air sparging for the removal of chlorinated volatiles from groundwater. Air sparging at depth is limited by "the uncertain path of the air stream and poor penetration of low-permeability layers within more permeable soils." Air sparging through horizontal wells and in-well sparging are mentioned as promising but unproven technologies. All approaches are faced with the geologic and mass transfer barriers that interfere with the effectiveness of other remediation approaches.

Enhancing the mobility of subsurface contamination through use of surfactants, cosolvents, and heat (generated by radio-frequency or steam) is discussed with cautious optimism. However, all approaches have their limitations and are still being developed. In-situ solidification and vitrification are presented as effective in shallow soils, as are reactive barriers. Support is given for combining technologies, early containment actions, and recognition of technical impracticability for certain sites (see Table 2-10).

The use of technology to improve the characteristics of the subsurface for remediation purposes is addressed in several publications. Pneumatic fracturing uses pressurized hot gas to open up fractures and displace and/or dissolve obstructions and may involve maintaining openings by pumping sand. By creating new openings or widening existing ones, air flow through the subsurface is increased. This increase in air flow can potentially increase the effectiveness of many existing, but formerly inefficient, remediation technologies. Increased air flow could allow for greater volatilization and removal in vapor extraction treatments, enhanced metabolism in bioremediation treatments, or increased volume in pump and treat methods. Vendors claim to have had success at removing TCE in fractured bedrock by using pneumatic fracturing in conjunction with soil vapor extraction. However, when DNAPL is present pneumatic fracturing would likely cause adverse consequences by mobilizing the free product.

The databases reviewed and their sources/sponsors are as follows:

EPA

• VISITT (Vendor Information System for Innovative Treatment Technologies)	This is a database containing specific vendor information. Searches are conducted by indicating a category of technology and the results are profiles of vendors utilizing that technology.

• ATTIC (Alternative Treatment Technology Information Center)	This is a database containing abstracts for EPA publications. Searches are conducted by keyword.
• BFSS (Bioremediation in the Field Search System)	This is a database containing project information for sites where bioremediation is being considered as a remediation option. Searches are conducted by indicating contaminants and media and the results are profiles of corresponding projects.
• ROD (Record of Decision) Database	This is a database containing the full text of EPA ROD. Searches are conducted by indicating contaminant, medium, region, contractor, or treatment method.
DOE	
• ReOpt	This is a database containing information on remediation options and alternatives. Searches are conducted by indicating contaminant, medium, or treatment category. Results are profiles on different treatment methods.
• EM (Office of Environmental Management) Database	This is a database containing vendor and technology profiles. Searches are conducted by keyword. This database draws information from other databases, including VISITT.
DOD	
• Remediation Technologies Screening Matrix and Reference Guide	This is a document containing innovative technologies identified by the Department of Defense for consideration in remedial activities at DOD sites. A four-page summary is provided for each technology.

Keywords used for the searches were "TCE," "DNAPL," and "groundwater." As a general comment, the information contained in the databases was sufficiently detailed to identify obvious inappropriate technologies for the Warminster applications, but the information was not sufficient to meaningfully evaluate apparently suitable applications.

Results of the database search and a review of current technologies and process options are presented in Table 2-11 and discussed in Section 2.4.2. Table 2-11 presents a summary of the initial screening of technologies and process options.

TABLE 2-11

SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
No Action	No Action	No Action	NA	No activities conducted at site to address contamination.	Retain.
Institutional Controls	Institutional Controls	Fencing	4	Barrier used to restrict site access.	Retain.
		Deed Restrictions	4	Administrative action used to restrict future groundwater use.	Retain.
		Monitoring	4	Sampling and analysis of media to assess contaminant migration.	Retain.
		Alternative Water Supply	4	Replacement of contaminated groundwater source with alternative water supply for end user.	Eliminate. Water supply wells currently employ adequate treatment.
Containment	Capping	Synthetic/ Natural	NA	Use of impermeable or semipermeable materials to reduce the vertical migration of contaminants from source areas into groundwater.	Retain.
	Vertical Barriers	Slurry Walls	4, 6	Soil/bentonite or soil/cement walls used to restrict horizontal migration of contaminants in groundwater.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.
		Grout Curtains	4	Use of pressure-injected cement to restrict horizontal migration of contaminants in groundwater.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.
		Sheet Piling	4	Use of barrier sheets driven into the subsurface to mitigate groundwater migration or to provide shoring/erosion control during excavation.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Containment (Continued)	Hydraulic Barriers	Pumping	NA	Discrete pumping wells or a collection trench strategically placed downgradient of the leading edge of a plume to form a hydraulic barrier.	Retain.
Removal	Removal	Extraction Wells	4	Discrete pumping wells used to remove contaminated water.	Retain.
		Subsurface Drains	4	A permeable trench used to intercept and collect groundwater.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.
	Enhanced Removal	Enhanced Removal	1, 5, 6	Hydrofracturing or pneumatic fracturing of bedrock to promote access to groundwater in bedrock fractures.	Retain.
Disposal	Beneficial Re-use	Process Water/ Potable Water	NA	On-site re-use of groundwater in which the contaminants have been removed.	Eliminate. No current users; may be revisited when base re-use utility plan is developed.
	Surface Discharge	Direct Discharge (NPDES)	4	Discharge of collected/treated water to local surface water.	Retain.
		Indirect Discharge	4	Discharge of collected/treated water to a local wastewater treatment plant.	Eliminate. Local POTWs unwilling to accept contaminated groundwater.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Disposal (Continued)	Surface Discharge (Continued)	Offsite Treatment Facility	NA	Treatment and disposal of hazardous or nonhazardous materials at permitted offsite facilities.	Eliminate. No implementable for groundwater because of flow rates and duration of remediation. Would be considered an ancillory option for treatment residues such as sludges and spent activated carbon. Will be used for remedial action treatment plant.
	Subsurface Discharge	Reinjection/ Discharge	4	Use of reinjection, spray irrigation, or infiltration to discharge collected/treated groundwater to underground.	Retain.
Ex-Situ Treatment	Physical	Extraction	1, 4	Separation of contaminants from a solution by contact with an immiscible liquid with a higher affinity for the contaminants of concern.	Eliminate. Not appropriate for low concentration groundwater streams.
		Equalization	NA	Dampening of flow and/or contaminant concentration variation in a large vessel to promote constant discharge rate and water quality.	Retain.
		Sedimentation	4	Gravity settling of suspended solids from water in a vessel. Sedimentation may be used for pretreatment for inorganics removal, if required.	Retain.
		Dewatering	NA	Mechanical removal of free water from wastes using equipment such as a filter press or a vacuum filter.	Retain.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Ex-Situ Treatment (Continued)	Physical (Continued)	Filtration	4, 6	Separation of materials from water via entrapment in a bed or membrane separation. Filtration may be used as pretreatment for inorganics removal, if required.	Retain.
		Flotation	4	Separation of oils and suspended solids less dense than water by flotation methods.	Eliminate. No floating products were detected in the groundwater.
		Reverse Osmosis	4	Use of high pressure and membranes to separate dissolved materials, including certain organics and inorganics from water.	Retain.
		Volatilization	4, 6	Contact of contaminated water with air to remove volatile compounds. Air stripping or steam stripping methods are typically employed.	Retain.
		Adsorption	1, 4, 6	Adsorption of contaminants onto activated carbon, resins, or activated alumina.	Retain.
		Evaporation	NA	Change from the liquid to the gaseous state at a temperature below the boiling point.	Eliminate. Typically not applicable to dilute aqueous streams.
		Distillation	NA	Vaporization of a liquid followed by condensation of the vapors by cooling.	Eliminate. Typically not applicable to dilute aqueous streams.
		Electrodialysis	1	Recovery of anions or cations using special membranes under the influence of an electrical current.	Eliminate. Does not apply to the contaminants of concern; applicable to inorganics.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASABILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Ex-Situ Treatment (Continued)	Physical (Continued)	Freeze Crystallization	4	Process in which contaminated water is cooled to produce ice crystals that can be removed by filtration, yielding nearly pure water.	Eliminate. Typically not applicable to dilute aqueous streams.
		Pyrolysis	1, 4	Process in which compounds are thermally decomposed and volatilization occurs. Off-gases are combusted in an afterburner.	Eliminate. Not applicable to aqueous streams.
	Biological	Aerobic	1, 3, 4, 6	Suspended growth or fixed film process employing aeration and biomass recycle to decompose organic contaminants.	Eliminate. Field-scale applications are limited because of typically long hydraulic retention times required for the process. Other physical treatment technologies are better demonstrated for chlorinated VOCs.
		Aerobic/ Anaerobic	1, 3	Suspended growth facultative process in pond or basin employing long detention times and aerobic/anaerobic biomass to decompose organic contaminants.	Eliminate. Field-scale applications are limited because of typically long hydraulic retention times required for the process. Other physical treatment technologies are better demonstrated for chlorinated VOCs.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASABILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Ex-Situ Treatment (Continued)	Biological (Continued)	Anaerobic	1, 3, 4, 6	Suspended growth or fixed film process employing anaerobic biomass to decompose organic contaminants.	Eliminate. Field-scale applications are limited because of typically long hydraulic retention times required for the process. Other physical treatment technologies are better demonstrated for chlorinated VOCs.
	Chemical	Ion Exchange	6	Process in which ions, held by electrostatic forces to charged functional groups on the ion exchange resin surface, are exchanged for ions of similar charge in a water stream.	Eliminate. Does not apply to the contaminants of concern; typically applicable to inorganics.
		Electrolytic Recovery	NA	Passage of an electric current through a solution with resultant ion recovery on positive and negative electrodes.	Eliminate. Does not apply to the contaminants of concern; applicable to inorganics.
		Enhanced Oxidation	1, 4, 6	Use of strong oxidizers, such as ultraviolet light, ozone, peroxide, chlorine, or permanganate, to chemically oxidize materials.	Retain.
		Reduction	NA	Use of strong reducers, such as sulfur dioxide, sulfite, or ferrous iron, to chemically reduce the oxidation state of materials. Reduction may be used as pretreatment for removal of inorganics, if required.	Eliminate. Inorganics of concern do not require reduction.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
Ex-Situ Treatment (Continued)	Chemical (Continued)	pH Adjustment	4	Use of acids or bases to counteract excessive pHs or to adjust pH to optimum for a given technology.	Retain.
		Coagulation/ Flocculation	4, 6	Use of chemicals to neutralize surface charges and promote attraction of colloidal particles to facilitate settling. Flocculation/coagulation may be used as pretreatment for removal of inorganics, if required.	Retain.
		Precipitation	NA	Use of reagents to convert soluble constituents into insoluble forms. Precipitation may be used as pretreatment for removal of inorganics, if required.	Retain.
	Off-Gas Treatment	Physical	NA	Removal of VOCs from vapor phase by adsorption on activated carbon.	Retain.
		Thermal	NA	Destruction of VOCs in vapor phase by catalytic or high-temperature oxidation.	Retain.
		Biological	5	Biodegradation of VOCs in vapor phase by biofiltration.	Eliminate. Not a proven technology for chlorinated VOCs.
In-Situ Treatment	Chemical/ Physical	Treatment Barriers	1	Use of innocous (e.g., zero valent iron) materials to remove chlorine from chlorinated compounds.	Retain.
		Soil Flushing	1	Flushing of contaminants using an injection/extraction well system and above-ground treatment system.	Eliminate. Results in fractured bedrock would be unpredictable; groundwater flow would be difficult to model.

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TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
In-Situ Treatment (Continued)	Chemical/ Physical (Continued)	Air Sparging/Vapor Extraction	1, 5, 6	Removal of volatile contaminants by injection of air into saturated zone and extraction of vapors from the vadose zone.	Eliminate. Results in fractured bedrock would be unpredictable; groundwater flow would be difficult to model.
		Volatilization	1, 6	Use of hot water or steam, via injection wells, to volatilize VOCs. Vaccuum extraction can be used to remove vaporized contaminants.	Eliminate. Results in fractured bedrock would be unpredictable; groundwater flow would be difficult to model.
		Enhanced Extraction	NA	Use of additives, such as surfactants, to make DNAPLs more accessible or extractable.	Eliminate. Ineffective in fractured bedrock due to limited contact between additive and contaminant.
		Electro-Thermal Gasification	1	Use of electrodes to heat the subsurface and volatilize or combust the contaminants.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.
	Biological	Subsurface Reclamation	1, 5, 6	Enhancement of in-place biodegradation by addition of nutrients and control of environment.	Eliminate. Difficult to supply nutrients and control the process in fractured bedrock geology.
		Cometabolism	2, 5, 6	Process in which enzymes produced to oxidize a primary substrate (such as methane) also oxidize the contaminant as a secondary substrate.	Eliminate. Difficult to supply nutrients and control the process in fractured bedrock geology.

TABLE 2-11 (Continued)
SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

General Response Action	Technology	Process Options	Database(s) Cited	Description	General Screening Comments
In-Situ Treatment (Continued)	Biological (Continued)	Phytoremediation	NA	Use of deep-rooted trees to absorb contaminants from groundwater and enzymatically oxidize them to form innocuous products.	Eliminate. Difficult to implement in bedrock; unrealistic for depth of contamination.

NOTES:

1. VISITT (Vendor Information System for Innovative Technologies)
2. ATTIC (Alternative Treatment Technology Information Center)
3. BFSS (Bioremediation in the Field Search System)
4. ReOpt
5. EM (Office of Environmental Management) Database
6. Remediation Technologies Screening Matrix and Reference Guide

NA Not Applicable, no data base cited.

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2.4.2 Screening of Technologies and Process Options which Passed Initial Screening

Further screening of the technologies and process options that passed the initial screening can be evaluated in accordance with criteria established in EPA guidance for Feasibility Studies. The evaluation criteria for detailed screening of technologies and process options that have been retained after the preliminary screening in Section 2.4.1 are effectiveness, implementability, and cost. The following provides items to be considered under each of the evaluation criteria:

- Effectiveness
  - Protection of human health and environment; reduction in toxicity, mobility, and volume; and permanence of solution.
  - Ability of the technology to address the estimated areas or volumes of contaminated medium.
  - Ability of the technology to meet the remediation goals identified in the remedial action objectives.
  - Technical reliability (innovative versus well-proven) with respect to contaminants and site conditions.
- Implementability
  - Overall technical feasibility of implementation at the site.
  - Availability of equipment and resources, including vendors, mobile units, and storage and disposal services.
  - Administrative feasibility such as permitting requirements.
  - Special, long-term maintenance and operation requirements.

- Cost (Qualitative)
  - Capital cost.
  - Operation and maintenance (O&M) costs.

All of the items listed above may not apply directly to each technology and, therefore, are addressed as appropriate in the evaluation of each technology. Screening evaluations at this stage generally focus on effectiveness and implementability, with less emphasis on cost evaluations. Technologies whose use would be precluded by waste characteristics and inapplicability under the given site conditions are screened and eliminated from further consideration. At this stage, no technologies are eliminated based on cost. A process option within a technology category, however, may not be carried through if an equally effective process option under that technology is available at a lower cost. Each technology presented in this section is not necessarily intended to be implemented alone, as it may be combined with other technologies into remedial action alternatives.

2.4.3 Detailed Screening of Technologies

2.4.3.1 No Action

No action is a general response action wherein status quo is maintained at the site. No activities would be conducted at the site to address contamination.

Effectiveness: There is no effectiveness, as no remedial action would occur.

Implementability: There are no implementability concerns, as no remedial action would occur.

Cost: There are no costs associated with No Action.

Conclusion: No Action is normally retained during an FS to provide a baseline for comparison with other technologies. No Action is retained for further consideration for Areas A, B, and D.

2.4.3.2 Institutional Controls

Fencing, deed restrictions and monitoring are the options that may be considered under institutional controls for implementation by NAWC Warminster.

Currently the facility is fenced prohibiting access to unauthorized personnel. The fencing could be maintained, thus minimizing the possibility of trespassers. Since the NAWC Warminster is a Federal facility, deed restrictions at the site would potentially take the form of a requirement in the Master Plan of the Warminster complex prohibiting or restricting the use of the groundwater as a drinking-water source. Future land use after transfer of the property to private ownership, would be restricted under the deed accompanying the sale of the land.

Monitoring would consist of sampling of groundwater and surface water at the site followed by analysis for the contaminants of concern. Monitoring would help assess the migration of contaminants in the environment and provide direction for future remedial actions.

Effectiveness: Contaminants may continue to migrate in the groundwater. Fencing would be effective in minimizing unauthorized personnel from entering the NAWC Warminster. Deed restrictions (or recordation in the Master Plan) would minimize the potential for human exposure to the contaminants in the surficial aquifer and potentially achieve the remedial action objective of protection of human health. Deed restrictions on the site for potential private ownership would be required to protect human health. Monitoring would be used to determine whether groundwater concentrations are changing. Further remedial action may be necessary based on evaluation of monitoring results. Institutional controls must be incorporated in any remedial action until remedial action objectives are achieved in order to minimize the effects of any exposure to humans or the environment.

Implementability: There are no implementability concerns for institutional controls. Fencing is currently in place and could easily be maintained. Deed restrictions (groundwater use restrictions) are implemented relatively easily at federal facilities. These deed restrictions must accompany any sale of property to private users according to applicable local regulations. Monitoring is easily implemented.

Cost: The main costs associated with deed restrictions are attorney's fees for property transfer. The main operating costs would be associated with monitoring; such cost are typically low. Cost for maintaining the fencing around NAWC Warminster would also be low.

Conclusion: Institutional Controls are retained for further consideration for Areas A, B, and D.

2.4.3.3 Containment

Capping

Capping consists of the placement of an impermeable or semi-permeable barrier over the surface of a contaminant source. The purpose of a cap in groundwater remediation is to eliminate or minimize infiltration into the source of groundwater contamination, such as from contaminated vadose-zone soils or an unconfined waste disposal area. A cap placed over the source of contamination would minimize further contribution of contaminants from the source by reducing infiltration.

Caps may consist of synthetic materials such as polyethene, polypropylene, polyvinyl chloride, etc., or natural materials such as clay. The selection of the type of material depends on a variety of factors such as the allowable level of permeability, compatibility with the wastes, etc.

Effectiveness: Caps made of compacted clay or HDPE can offer adequate reduction of infiltration into the sources of groundwater contamination. However, in order for capping to be effective, the areas of contamination that are known to be the sources must be adequately delineated and above the water table. At NAWC Warminster, the contaminant sources are not well defined, may be beneath the water table or have been addressed through removal actions. Therefore, the applicability of capping at Areas A, B and D is questionable.

Implementability: Installation of a cap would be relatively easy to implement. Caps require long-term inspection for integrity to ensure that natural forces (photochemical degradation, wind, rain, etc.) or artificial intrusion do not compromise the impermeability of the barrier. They would require maintenance on a periodic basis. The use of caps would not allow unrestricted use of the property in the event that NAWC releases the land for private use.

Costs: Synthetic caps are more expensive than natural caps. However, capital costs for both types of caps are moderate. Long-term monitoring and maintenance costs are moderate.

Conclusion: Eliminate capping because of questionable effectiveness and implementability concerns.

Hydraulic Barriers

A hydraulic barrier can be used to capture water naturally passing through contaminated subsurface soil before it migrates to downgradient areas. Typically, the hydraulic barrier consists of a line of extraction

wells serving as an intercepting "wall". The pumping well system, composed of a series of wells completed in an aquifer, would be used to control the off-site migration of contaminated groundwater by collecting the groundwater. The wells used in the capture system are designed and located to provide optimum efficiency in capturing contaminated groundwater while minimizing the collection of uncontaminated groundwater. Groundwater extracted in the pumping well system would require treatment prior to discharge as with typical groundwater pump-and-treat systems. However, pumping rates may differ significantly because the hydraulic barrier is meant to control migration of groundwater off site rather than restore the aquifer .

Effectiveness: Extraction well placement and extraction rate must be designed for the hydraulic barrier to adequately capture groundwater migrating off site. Sufficient hydrogeological data are necessary for the design of the system. The dips and fractures within the bedrock at Warminster causes concern with regards to effectiveness in collecting all of the contaminant plumes. It is anticipated that sufficient site knowledge exists to design an effect hydraulic barrier, however monitoring would be necessary to verify the effectiveness.

Additional concerns, such as the impact of pumping on off-site plumes (e.g., drawing contamination on site from off-site sources) or the risks of mobilizing and further dispersing existing DNAPL etc., will impact the system design and the feasibility of achieving clean-up goals because these may increase the rate and amount of groundwater that requires extraction to adequately contain the contaminated plume.

One of the limitations to the use of extraction wells includes the presence of viscous or reactive chemicals, which could clog well screens, drains, and coagulate material. Conditions that favor the formation of iron, manganese, or calcium carbonate deposits may also limit the effectiveness of these systems.

Implementability: Installation of extraction wells and extraction, treatment, and discharge for hydraulic barriers are generally readily implementable. In general, there are no implementability concerns associated with installing hydraulic barriers at NAWC.

Costs: Costs of extraction well systems for hydraulic barriers can vary greatly from site to site. Some of the factors that determine these costs are the geology, the characteristics of the contaminated and naturally occurring groundwater, the extent of contamination, the periods and duration of pumping, and the electrical power required.

The depth and number of wells determine the capital cost of installation. If a large number of wells are required, such as in a low yielding aquifer, then the capital costs are high because more pumps will be in

operation. Installation costs depend primarily on the depth of excavation, stability of soils, extent of rock fragmentation required, and groundwater flow rates. The principal material costs include pipes, gravel, manholes, and pumps and other accessories.

Because of the fractured bedrock and depth of contamination (up to 100 feet) at NAWC, the costs are considered to be moderate to install a hydraulic barrier.

Conclusion: Hydraulic barriers are retained for further consideration for Areas A, B, and D.

2.4.3.4 Removal

Extraction

Groundwater pumping by extraction wells allows for active manipulation and management of groundwater to contain or remove a plume. For this application, the wells would be used to remove the contamination sources. The selection of the appropriate well system design depends upon the depth of contamination and the hydrologic and geologic characteristics of the aquifer.

Effectiveness: The location and nature of the contamination source must be well delineated and understood for removal by extraction wells to be effective. Extraction well placement and extraction rate must be designed for the hydrogeologic conditions to optimize removal of the groundwater source. At NAWC Warminster, sufficient hydrogeological data is available for the design of a system that could remove contaminated groundwater and effectively control the contaminated plume.

Additional concerns, such as the impact of pumping on off-site plumes (e.g., drawing contamination on site from off-site sources) or the risks of mobilizing and further dispersing existing DNAPL etc., will impact the system design and the feasibility of achieving clean-up goals because these may increase the rate and amount of groundwater that requires extraction to adequately contain the contaminant plume.

One of the limitations to the use of extraction wells includes the presence of viscous or reactive chemicals, which could clog well screens, drains, and coagulate material. Conditions that favor the formation of iron, manganese, or calcium carbonate deposits may also limit the effectiveness of these systems. This is anticipated to be a minimal concern at NAWC that can effectively be controlled by descaling the system periodically, as necessary.

Implementability: Installation of extraction wells and extraction, treatment, and discharge for removal are generally readily implementable. There are no major implementability concerns with installing and operating a groundwater extraction system at NAWC Warminster.

Cost: Costs of an extraction well system for plume management can vary greatly from site to site. Some of the factors that determine these costs are the geology, the characteristics of the contaminated and naturally occurring groundwater, the extent of contamination, the periods and duration of pumping, and the electrical power required.

The depth and number of wells determine the capital cost of installation. If a large number of wells are required, such as in a low-yielding aquifer, then the capital costs are high because more pumps will be in operation. Installation costs depend primarily on the depth of excavation, stability of soils, extent of rock fragmentation required, and groundwater flow rates. The principal material costs include pipes, gravel, manholes, and pumps and other accessories.

Because of the fractured bedrock and depth of contamination (up to 100 feet), the costs are considered to be moderate to install an extraction system.

Conclusion: Extraction wells for removal of contaminated groundwater are retained for further consideration at Areas A, B, and D.

Enhanced Removal

Enhanced removal consists of using explosives (blasting), high-pressure water (hydrofracturing), or high-pressure air (pneumatic fracturing) to create new fractures or enlarge existing fractures in low yielding aquifers, such as in bedrock. The increase in the number and size of fractures allows for greater air and groundwater flow. This contributes to increased removal rates in extraction wells.

In hydrofracturing and pneumatic fracturing, a well is drilled and the water or air feed system is lowered down the well. The air or water is injected at high pressure and horizontal fractures are formed in a radius extending from the well. The extent of fracturing is measured by surface displacement. After fracturing is complete, the well is used as a typical extraction well.

Effectiveness: Field studies have shown fracturing to be successful at increasing removal rates of TCE in fractured bedrock. However, the published reports of the studies do not refer to the success of fully remediating the test site, so it is unclear if fracturing will allow complete removal of contaminants.

Because fracturing increases the flow through the aquifer, it is possible that, at sites where DNAPL contamination is not completely delineated, fracturing may result in uncontrolled mobilization of the contaminants off site. Uncontrolled mobilization of DNAPL is a major concern for Areas A and D and a lesser concern for Area B. An additional concern at NAWC Warminster would be to mobilize the contamination resulting in downward mobilization causing contamination to spread vertically.

Implementability: Enhanced removal is more difficult to implement than extraction wells and there are not as many qualified contractors available. To perform the fracturing, specialized equipment and personnel are required, but when the fracturing has been accomplished, the well is treated like a normal extraction well.

Costs: As with extraction, the costs associated with enhanced removal vary greatly with site conditions. Site geology is extremely important because the fracturing step adds directly to the cost for extraction. If the site were amenable to fracturing, fewer wells would be required than if the site were resistant to fracturing. Depth and range of contamination would also greatly affect cost because each well would need to be fractured throughout the range. Enhanced removal would have higher costs than extraction at NAWC Warminster.

Conclusion: Due to the potential for uncontrolled mobilization of the contaminants off site, enhanced removal is eliminated from consideration for Areas A and D. Because TCE contamination in Area B is localized, enhanced removal offers no benefit over extraction and is therefore eliminated from further consideration for Area B.

2.4.3.5 Disposal

Two options for disposal of extracted groundwater are considered: local discharge to surface water via existing remedial action treatment system outfall and subsurface discharge by reinjection or spray irrigation into the aquifer.

Surface Discharge

Groundwater that is extracted during remedial action may be discharged to an unnamed tributary of Little Neshaminy Creek or an unnamed tributary of Southampton Creek. Surface flows in Area A drain to the former, Area D drains to both, and Area B drains to the latter. At present, NAWC Warminster discharges treated wastewater under an NPDES permit to an unnamed tributary of Little Neshaminy Creek and discharges stormwater to tributaries of both creeks at several locations. These outfall systems may be

utilized for purposes of discharging treated groundwater subject to permit equivalency requirements. Discharge to these creeks for Area A (and by inference, Area D) would require treatment to meet surface water standards. The preferred discharge point, as indicated by the Design Analysis Report (HNUS, 1994), is the existing wastewater outfall located along an unnamed tributary of Little Neshaminy Creek, 5,000 feet from NAWC along Bristol Road.

Effectiveness: Surface discharge options were determined to be potentially effective for the remedial action system design flow rate of 130 gallons per minute (gpm) and should be equally effective for the additional flows contributed from other areas. The hydraulic capacity and stream quality (unnamed tributary of Little Neshaminy Creek) were determined not to be adversely affected with adequate treatment. Effluent standards were defined for inorganics and VOCs as presented in the Design Analysis Report (HNUS, 1994) and Table 2-7. These standards will be subject to adjustment based on deviation from the 130 gpm flow on which the limits are based.

Discharge standards are more stringent for streams with low or intermittent flows (i.e., periodically non-existent) such as the creek in the vicinity of Area B. These limits will be difficult if not impossible to achieve.

Implementability: Discharge to the tributary of Neshaminy Creek was determined to be implementable for the remedial action flow rate of 130 gpm. If flow rates exceed 130 gpm, this option will need to be revisited but is still expected to be implementable.

Cost: The direct cost of surface discharge is the cost of modifying the existing discharge permit. These costs are expected to be low. Indirect costs associated with each option are mainly the operating/maintenance costs of the treatment/pretreatment plants.

Conclusion: Retain all surface discharge options for further consideration for Areas A and D. Local surface discharge for Area B is a possibility but undesirable because of implementability concerns. Discharge via the existing remedial action treatment plant for Area B is implementable and is also retained.

Subsurface Discharge

Subsurface discharge of any groundwater that may be extracted during remedial action can be accomplished by one of the following options: reinjection, spray irrigation, or infiltration basins. Reinjection directly discharges the water into the aquifer through injection wells. Spray irrigation and

infiltration basins discharge the water to the surface of a site and allow percolation of the water into the aquifer.

Effectiveness: Subsurface discharge is not appropriate when the nature and extent of contamination are not well defined because of the potential of exacerbating the migration of contaminants from the discharge locations in the aquifer. This is especially true if DNAPL is present such as is possible at Areas A and D. Therefore, there are significant concerns with reinjection of groundwater at Areas A and D. The locations of the extraction wells and discharge areas must take into consideration any hydrogeological connection between the aquifer and the surface water bodies, namely tributaries of Little Neshaminy Creek and Southampton Creek, and the discharge system must be designed accordingly. Typically, treatment of the extracted groundwater to meet MCLs, LDRs or state water quality criteria (or background levels) would be required.

Spray irrigation and infiltration basins would be ineffective in low-permeability geological formations such as the bedrock at NAWC Warminster.

Because the contamination at Area B is localized and DNAPL is not anticipated, subsurface discharge would be effective.

Implementability: Typically, more extensive treatment of the extracted groundwater would be required prior to subsurface discharge when compared to discharge to a surface water. The existing groundwater treatment facility would require evaluation to determine if upgrades or a new facility would be required to achieve the discharge limits. Spray irrigation and infiltration basins would require large areas of clean vadose zone soils for discharge of the treated groundwater to prevent further addition of contaminants into the aquifer from the source area soils. Especially large surface areas are required because of the low permeability of the bedrock at NAWC Warminster. Additionally, these large areas used for infiltration basins would detract from selling the property. Injection wells would be easier to implement at Area B compared to surface discharge; however, injection wells are maintenance intensive.

Cost: The direct capital and operation/maintenance costs of spray irrigation are low, compared to infiltration basins, and compared to injection wells which are the highest. Indirect costs (operation/maintenance) can be high. Overall, subsurface discharge has a high cost compared to surface discharge at Areas A and D because a discharge system is currently in place. For Area B, cost for subsurface discharge is moderate when compared to surface discharge.

Conclusion: Eliminate infiltration basins and spray irrigation from further consideration because of effectiveness and implementability concerns. Eliminate reinjection wells from further consideration for Areas A and D because of effectiveness concerns associated with DNAPL. Retain reinjection wells for further consideration for Area B.

2.4.3.6 Ex-Situ Treatment

The options for ex-situ treatment of contaminated groundwater at NAWC Warminster have been discussed at length in two previous documents for this site: the Focused Feasibility Study Report for Operable Unit 1 (HNUS, April 1993) and the Focused Feasibility Study Report for Operable Unit 3 (HNUS, August, 1994). These documents contributed to the technology selection represented in the existing groundwater treatment plant, which has been constructed as part of groundwater Remedial Actions for Areas A and C and is soon to go on line. This facility is located in Area A, northwest of Jacksonville Road.

The applicable technologies selected for the treatment system consist of the following unit operations and processes:

- Equalization, pH adjustment, and chemical oxidation/alkaline precipitation
- Coagulation/flocculation/sedimentation
- Sand filtration
- Neutralization
- Air stripping with off-gas treatment using granular activated carbon adsorption
- Aqueous-phase granular activated carbon adsorption
- Discharge to unnamed tributary of Neshaminy Creek
- Sludge thickening and dewatering followed by off-site disposal

The treatment process is designed to treat the groundwater for VOCs such as carbon tetrachloride, PCE, TCE, and 1,2-DCE. The treatment plant is also designed to remove certain inorganic contaminants and fouling constituents such as dissolved iron and manganese and any other metals that are expected to be present at concentrations that marginally exceed discharge standards. In addition, an aqueous-phase activated carbon adsorber is provided for removal of any residual organic contaminants.

The NPDES limits that were established for contaminants of concern for discharge of the treated groundwater from the interim action system are presented in Table 2-7.

Enhanced photochemical oxidation was considered for this application, but was rejected after a treatability study. The study showed that certain contaminants would not be treated to the extent necessary. (See Bench-Scale Photochemical Oxidation Treatability Study Report for Operational Unit 1 Remedial Design, HNUS, June 1994.)

The existing groundwater treatment system is designed to address a number of potential groundwater quality scenarios. Accordingly, every unit process is not necessarily essential for all groundwater to be remediated at the site (e.g., clarification). For certain groundwater with volatile organics and minimal suspended solids, air stripping alone may be feasible, or aqueous phase activated carbon adsorption alone may be feasible. An existing (165 gpm) air stripper has operated on Supply Wells 1 and 2 in Area D at NAWC Warminster and is available to treat flows in Area D. Alternately, groundwater from wells with low levels of contaminants could be introduced at intermediate points in the existing Remedial Action treatment process to minimize unnecessary loading on upstream unit operations.

The existing Remedial Action groundwater treatment system was originally designed to treat 130 gpm. This figure includes an 86 gpm projected composite flow rate from Areas A and B, plus approximately 50 percent of reserve capacity. Space has been provided in the floor plan to add a second treatment train, effectively doubling the treatment capacity, if necessary.

Since the design was prepared, a decision was made to bring in flows from Area C, and the projected flows from Area B have been reduced. The result has been a net loss of capacity; therefore, use of the existing Remedial Action treatment system for Area D flows may require some upgrading of existing facilities.

A municipal supply well (WTMA26) located approximately one-half mile downgradient of Area A has been operating as an extraction well for contaminated groundwater. The supply well is equipped with a stripper which provides adequate treatment that allows the well to continue to function as a supply well.

Off-site treatment facilities will be used to dispose of dewatered sludge and spent activated carbon.

Effectiveness: The technologies used in the interim treatment facility are all effective. The existing stripper unit at MTWA26 is effective.

Implementability: The ex-situ treatment technologies are readily implementable and, in fact, have been implemented as part of the existing Remedial Action treatment facility.

Costs: Costs will be low, since most of the capital cost has already been expended, except that required for the upgrades necessary to accommodate additional flow.

Conclusion: Retain the existing Remedial Action treatment system, the SW1/2 air stripper, and the MTWA26 stripper and well for further consideration. Eliminate enhanced photochemical oxidation from further consideration.

Reverse Osmosis

Reverse osmosis uses a semi-permeable barrier that will pass only certain components of a solution. The membrane is permeable to water but impermeable to most dissolved substances, both organic and inorganic. The driving force is an applied pressure gradient to overcome the osmotic pressure of the contaminated solution. Relatively clean water is produced on the downflow side of the membrane, whereas the larger, rejected organic and inorganic compounds remain on the upflow side as a concentrated reject stream (for further treatment of disposal).

Reverse osmosis systems are operationally sensitive. Therefore, close monitoring of the temperature, pressure, and pH of the contaminated solution is necessary. In addition, the chemical and physical structure of the membrane must be closely monitored because the contaminants in the solution may react with it and reduce its integrity.

Effectiveness: Reverse osmosis may be used to concentrate dilute solutions of many inorganic and organic solutes. Reverse osmosis reduces excess dissolved solids, reduces or removes many organics and metals, and produces almost turbidity-free water. At NAWC Warminster, the primary contaminants are chlorinated organics, which may degrade the reverse osmosis unit membranes. Additionally, the reject stream would consist of a concentrated mixture of organics and some metals requiring additional treatment.

Implementability: Although equipment and resources are specialized, the reverse osmosis process is commercially available. General construction permits and a TSD permit may be required for the implementation of reverse osmosis technologies. Reverse osmosis membranes, in general, are subject to deterioration and may require frequent replacement. Pretreatment may be required to optimize pH.

Cost: Capital and O&M costs are high.

Conclusion: Reverse osmosis is eliminated from further consideration because of effectiveness concerns and the availability of other more conventional, effective, and economical technologies (such as air stripping) for organic removal.

Thermal Off-Gas Treatment

Off-gas emissions of VOCs are expected from the treatment of groundwater as a result of active treatment by volatilization.

Incineration and catalytic oxidation are thermal processes. Incineration uses a flame to oxidize the VOCs into relatively less toxic gases, such as carbon dioxide, water vapor, and hydrogen halides, if the VOCs are halogenated. Temperatures as high as 2,000°F may be required, depending on the optimum temperature of reaction of the particular VOCs of concern. Adequate supply of oxygen in the form of a forced draft of air must be ensured to support combustion. Depending on the ability of the VOCs to support combustion and the concentrations of the VOCs, significant quantities of fuel may be required for combustion.

Catalytic oxidation is also used to oxidize the VOCs into less harmful products; however, the temperature required for oxidation is significantly less than that of incineration, typically less than 90°F. Catalytic oxidation consists of the use of a preheater to raise the temperature of the VOC-laden vapor to the required temperature and the passage of the heated gas through a permeable catalyst bed. The catalyst activates the VOC molecules and makes them more reactive to the oxygen, thus obviating the necessity for high temperatures. Therefore, catalytic oxidation can achieve similar results as incineration at lower temperatures.

Effectiveness: Incineration and catalytic oxidation are effective technologies for the destruction of VOCs. Incineration is a proven technology for the destruction of gases containing toxic VOCs. However, incineration is usually cost effective only if the gases requiring treatment are inherently capable of supporting combustion, such as petroleum hydrocarbons or benzene, toluene, ethylbenzene, and xylenes (BTEX). Catalytic oxidation is a relatively innovative technology that is proving to be effective in recent applications. The effectiveness of catalytic oxidation is based on a few field-scale applications and several bench- and pilot-scale tests.

Implementability: Incineration and catalytic oxidation require specialized personnel for installation. After initial startup, the operation of both systems must be monitored periodically, although several fail-safe measures and alarm systems would be included in the equipment. The main implementability concerns

for both systems are because of the potential hazards associated with use of high temperatures. Catalytic oxidation systems would require replacement of the catalyst on a regular basis because certain chlorinated VOCs reduce the efficiency of operation of the catalytic material. The treated gases might require further treatment to remove the halogen compounds, if any, followed by disposal of the treatment products.

Cost: Incineration and catalytic oxidation systems have moderate to high capital costs. Incineration has moderate to high or very high O&M costs. Catalytic oxidation has moderate to high O&M costs.

Conclusion: Retain for further consideration.

2.4.3.7 In Situ Treatment

Treatment Barriers

Dechlorination is the process of removal of chlorine atoms from chlorinated alkanes/alkenes to result in relatively innocuous hydrocarbons and chloride ions. Dechlorination by the use of zero-valent iron is an innovative technology wherein the contaminated groundwater is allowed to pass through a bed containing a metal formulation (zero-valent iron) as the active ingredient. During the passage of the groundwater through the bed, the dissolved chlorinated alkanes/alkenes react with the iron and undergo a substitution of the chlorine atoms with hydrogen atoms. The products of this reaction are hydrocarbons such as ethane, ethene and methane, and chloride ions (EnviroMetal Technologies Inc., technical brochure).

Since the contaminants are destroyed in the liquid phase and are not transferred to another phase, this process offers a significant advantage over above-ground technologies such as air stripping and activated carbon adsorption. In this process, the solid waste residues created are minimal over the life of the treatment bed. Typically, gaseous and liquid-phase activated carbon adsorption produces spent carbon that must be replaced frequently. However, the life of the zero-valent iron treatment bed is claimed to be longer, perhaps on the order of several years (Vogan, J., EnviroMetal Technologies, Personal Communication).

This process can be implemented as an in-situ permeable treatment wall or above ground in a packed-bed reactor. In either configuration, the reaction half-lives of the contaminants of concern are important in determining the size of the treatment bed in order to allow sufficient hydraulic retention time for adequate contact between the reactants.

Effectiveness: Reductive dechlorination is a relatively innovative technology, and full-scale applications are few and limited to in-situ applications. Above-ground reactor configurations of reductive dechlorination are limited to pilot-scale studies. The technology has shown promise in various studies to be effective for complete dechlorination of TCE. The process is not proven to be effective in treating DNAPL. Therefore, any free-phase TCE encountered in the groundwater may not be adequately treated. Moreover, high concentrations of TCE require long hydraulic retention times in order to achieve concentrations of micrograms per litre in the effluent. However, this technology may be effective for Area B groundwater. Treatability studies would definitely be required to evaluate the effectiveness of the process for site-specific groundwaters.

Implementability: The technology is implementable in situ for overburden but not for bedrock at depths up to 100 feet, where the contamination at this site is believed to reside. A second implementability concern is innovative and proprietary nature of the technology. Only one company (EnviroMetal Technologies, Ontario, Canada) offers the technology. The materials that the treatment bed is composed of are commonly available. Disposal of the spent material is not expected to be of concern because the technology destroys the hazardous VOCs. The process equipment is relatively simple to operate and maintain. Specially trained operators are not required after start-up.

Costs: The capital and operating costs of this technology are low compared to most other above-ground technologies.

Conclusion: Eliminate dechlorination from further consideration because of implementability concerns with depth of contamination (Areas A, B and D) and because of high concentrations at Areas A and D.

2.5 SUMMARY OF FINAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

The results of the evaluations of technologies and process options, based on effectiveness, implementability, and cost, are summarized in Table 2-12. In this table, the technologies are organized according to the general response actions developed in Section 2.3. The screening results are presented in Table 2-12 individually for each area addressed in this feasibility study.

2.6 SELECTION OF REPRESENTATIVE PROCESS OPTIONS

Process options are selected from the technologies that have been retained in the final screening. These process options are then used for assembly of a focused set of remedial alternatives. Thus, the alternatives may be used to emphasize the significant differences in the effectiveness,

implementability,and costs among categories of competitive technologies. Furthermore, the use of a representative process option allows the flexibility to select equipment offered by different vendors at the time of remedial design or during bid evaluation.

For Areas A and D, No Action, Institutional Controls, and Extraction Wells are retained. Discharge to the existing Remedial Action Treatment Plant has been selected for discharge of the extracted groundwater over discharge to surface water because it is more appropriate to utilize the existing facility rather than develop a new system. The following physical/chemical ex-situ treatment processes are selected: equalization, coagulation/flocculation/sedimentation, dewatering, filtration, volatilization, adsorption, pH adjustment , precipitation, and off-gas treatment. These processes may be required as a treatment train for removal of inorganics and suspended solids prior to volatilization for the removal of VOCs, and they are utilized in the Remedial Action Treatment Plant.

For Area B, No Action, Institutional Controls, and Extraction Wells are selected. Discharge to the Remedial Action Treatment Plant for the extracted groundwater is retained. Also, the physical/chemical ex-situ treatment processes as noted above are retained because of their use at the Remedial Action Treatment Plant. Note that only one or more of these processes may be selected for assembly of an alternative for on-site treatment at Area B, depending on site-specific groundwater constituents. Subsurface discharge using reinjection wells is also selected to be combined with on-site treatment.

For the two process options under off-gas treatment (Physical and Thermal), Physical treatment (activated carbon adsorption) has been selected as the representative process option for Areas A, B, and D. This has been selected because it is easy to implement, effective for contaminants of concern, and is more cost effective than thermal technologies. Moreover, activated carbon adsorption is the chosen off-gas treatment option in the Remedial Action Treatment Plant.

TABLE 2-12

TECHNOLOGIES AND PROCESS OPTIONS SUMMARY OF SCREENING RESULTS, OU1 FS

FEASIBILITY STUDY FOR AREAS A, B, AND D GROUNDWATER NAWC WARMINSTER WARMINSTER, PA

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	CONCLUSIONS		
			AREA A	AREA B	AREA D
No Action	No Action	No Action	✓	✓	✓
Institutional Controls	Institutional Controls	Monitoring	✓	✓	✓
		Fencing	✓	✓	✓
		Deed Restrictions	✓	✓	✓
Containment	Capping	Synthetic/Natural	✗	✗	✗
	Hydraulic Barriers	Pumping	✓	✓	✓
Removal	Removal	Extraction Wells	✓	✓	✓
		Enhanced Removal	✗	✗	✗
Disposal	Surface Discharge	Surface Water	✓	✗	✓
		Existing Remedial Action Treatment Plant	✓	✓	✓
	Subsurface Discharge	Reinjection Wells	✗	✓	✗
		Infiltration Basins	✗	✗	✗
Ex-situ Treatment	Physical	Equalization	✓	✓	✓
		Sedimentation	✓	✓	✓
		Dewatering	✓	✓	✓
		Filtration	✓	✓	✓
		Reverse Osmosis	✗	✗	✗
		Volatilization	✓	✓	✓
		Adsorption	✓	✓	✓
	Chemical	Enhanced Oxidation	✗	✗	✗
		pH Adjustment	✓	✓	✓
		Coagulation/ Flocculation	✓	✓	✓
		Precipitation	✓	✓	✓
	Off-gas Treatment	Physical	✓	✓	✓
		Thermal	✓	✓	✓
In-situ Treatement	Chemical/ Physical	Treatment Barriers	✗	✗	✗

✓ Retained
✗ Eliminated

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 DEVELOPMENT OF ALTERNATIVES

The purpose of this section is to develop and screen remedial alternatives for the groundwater in Areas A, B, and D based upon the representative process options selected in Section 2.5 for each general response action. This section provides a rationale for the assembly of alternatives followed by a brief description of the alternatives.

3.1.1 Assembly of Alternatives

CERCLA requires that a No Action alternative be considered to provide a base-line for comparison of other alternatives.

Institutional controls is an alternative that is used when remedial action objectives (RAOs) may be met by enforcing legal measures to protect human health from exposure to the contaminated groundwater.

For the assembly of remedial alternatives involving treatment, only groundwater extraction, above-ground treatment, and discharge were considered because of the absence of suitable controlled in-situ treatment technologies.

The groundwater extraction systems used for the assembly of remedial alternatives involving treatment typically consist of extraction wells screened in the contaminated aquifer and located so as to remedy or contain groundwater contamination.

The hydraulic and contaminant characteristics in the off-site portions of the Stockton formation are not yet fully defined. Accordingly, the design of groundwater extraction and monitoring proposed in this FS should be considered as conceptual in nature and subject to modification based upon the result of future investigations. In particular, the need to revise the proposed groundwater extraction well locations or to provide additional wells should be evaluated once more data is collected as part of the remedial design effort.

Two above-ground treatment options were used for the assembly of remedial alternatives involving treatment, including:

- Treatment at the existing Treatment System located at Area A and which is scheduled for initial operation with the Area C groundwater in the spring or summer of 1996.

- Treatment at a new local above-ground treatment system. This option was only considered for the assembly of remedial alternatives for the Area B groundwater due to the significant distance between this area and the existing Treatment System.

Use of the existing air stripping systems at the off-site Warminster Township Municipal Authority (WTMA) Well 26 (WTMA26) and at the on-site supply wells SW1 and SW2 was also considered to provide additional remediation in support of the main treatment system. The use of WTMA is included in the remedial alternatives for Area A. The use of SW1 and SW2 extraction wells is not included in the remedial alternative for Area D because the contaminant levels in these two wells have progressively declined and are of minimal levels of concern.

Two treated groundwater discharge options were used for the assembly of remedial alternatives involving treatment, including:

- Surface discharge to unnamed tributary of Neshaminy Creek at existing Outfall 001. This option is used for alternatives with treatment at the existing Treatment System since Outfall 001 has already been established as the discharge location for that system.

- Reinjection into the aquifer. This option was only considered for the assembly of remedial alternatives for the Area B groundwater because suitable surface waters or discharge locations leading to suitable surface waters do not exist in the vicinity of this area.

Note that at Site B, discharge to the local stream (i.e., Southampton Creek) is not included in the alternatives because of implementability concern due to which the option was eliminated in Section 2.5.

In accordance with the above rationale, the following remedial alternatives have been assembled:

Area A Groundwater Alternatives (Final Remedy):

- Alternative A1: No Action
- Alternative A2: Institutional Controls and Monitoring
- Alternative A3: Extraction, Treatment at existing Treatment System, Discharge at Outfall 001

Area B Groundwater Alternatives (Final Remedy):

- Alternative B1: No Action
- Alternative B2: Natural Attenuation with Institutional Controls and Monitoring
- Alternative B3: Extraction, Local Treatment, Reinjection
- Alternative B4: Extraction, Treatment at existing Treatment System, Discharge To Outfall 001

Area D Groundwater Alternatives (Interim Remedy):

- Alternative D1: No Action
- Alternative D2: Institutional Controls and Monitoring
- Alternative D3: Extraction, Treatment at existing Treatment System, Discharge at Outfall 001

3.1.2 Summary Description of Area A Groundwater Alternatives (Final Remedy)

3.1.2.1 Alternative A1: No Action

Under this alternative, no active measures would be taken to remedy the contamination of the Area A groundwater.

3.1.2.2 Alternative A2: Institutional Controls and Monitoring

Under this alternative, no active measures would be taken to remedy the contamination of the Area A groundwater. However, this alternative would differ from the No Action alternative in that control measures would be instituted to prevent use of the Area A groundwater for drinking purposes and monitoring would be performed to periodically assess the degree of groundwater contamination. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring.

3.1.2.3 Alternative A3: Extraction, Treatment at the Existing Treatment System, Discharge at Outfall 001

Under this alternative, active measures would be taken to remedy the contamination of the Area A groundwater. The groundwater would be pumped from selected locations within Area A and treated for removal of the volatile organic compounds (VOCs) of concern, including chloroform, carbon tetrachloride, TCE, and PCE, by the air stripping and vapor- and liquid-phase granular activated carbon (GAC) adsorption unit processes of the existing Treatment System. The treated groundwater would then be discharged via the established Outfall 001 to the unnamed tributary of Little Neshaminy Creek.

This alternative would also include the continued operation of the groundwater extraction and air stripping system at WTMA26.

Control measures would be instituted to prevent use of the Area A groundwater for drinking purposes and monitoring would be performed to periodically assess the degree of groundwater contamination. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring with any change in ownership of the property.

3.1.3 Summary Description of Area B Groundwater Alternatives (Final Remedy)

3.1.3.1 Alternative B1: No Action

Under this alternative, no active measures would be undertaken to remedy the contamination of the Area B groundwater.

3.1.3.2 Alternative B2: Natural Attenuation with Institutional Controls and Monitoring

Under this alternative, no active measure would be undertaken to remedy the contamination of the Area B groundwater. However, this alternative would differ from the No Action alternative in that control measures would be instituted to prevent use of the Area B groundwater for drinking purposes. These measures would remain in effect until the RAOs have been met through natural attenuation. Monitoring would be periodically performed to assess contaminant concentrations, monitor the effectiveness of natural attenuation mechanisms such as decomposition, volatilization, and biodegradation, and check for off-site contaminant migration. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring should property ownership change before RAOs have been met.

3.1.3.3 Alternative B3: Extraction, Local Treatment, Reinjection

Under this alternative, active measures would be taken to remedy the contamination of the Area B groundwater. The groundwater would be pumped from the locations of higher contamination within Area B, treated for removal of the VOCs of concern, including TCE and benzene, by air stripping and vapor-phase GAC adsorption at a new local treatment system, and reinjected into the aquifer.

Until the RAOs have been met, control measures would be instituted to prevent use of the Area B groundwater for drinking purposes and monitoring would be performed to periodically assess the degree of groundwater contamination. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring, should property ownership change before RAOs have been met.

3.1.3.4 Alternative B4: Extraction, Treatment at The Existing Treatment System, Discharge at Outfall 001

Under this alternative, active measures would be taken to remedy the contamination of the Area B groundwater. The groundwater would be pumped from the locations of higher contamination within Area B, transferred to the existing Treatment System located at Area A, and treated for removal of TCE and benzene by the air stripping and vapor- and liquid-phase GAC adsorption unit processes of this system. The treated groundwater would then be discharged via the established Outfall 001 to the unnamed tributary of Little Neshaminy Creek.

Until the RAOs have been met, control measures would be instituted to prevent use of the Area B groundwater for drinking purposes and monitoring would be performed to periodically assess the degree of groundwater contamination. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring.

3.1.4 Summary Description of Area D Groundwater Alternatives (Interim Remedy)

3.1.4.1 Alternative D1: No Action

Under this alternative, no active measures would be taken to remedy the contamination of the Area D groundwater.

3.1.4.2 Alternative D2: Institutional Controls and Monitoring

Under this alternative, no active measures would be undertaken to remedy the contamination of the Area D groundwater. However, this alternative would differ from the No Action alternative in that control measures would be instituted to prevent use of the Area D groundwater for drinking purposes and monitoring would be performed to periodically check for off-site contaminant migration and to assess the degree of groundwater contamination. This alternative would also include preparation of deed restrictions to ensure continuity of controls and monitoring should property ownership change.

3.1.4.3 Alternative D3: Extraction, Treatment at the Existing Treatment System, Discharge at Outfall 001

Under this alternative, active measures would be taken to contain and partially remedy the contamination of the Area D groundwater. The groundwater would be pumped from selected locations along the northwestern NAWC boundary (and optionally at locations of higher contamination within Area D). The extracted groundwater would be treated for removal of the VOCs of concern, including TCE and PCE, by the air stripping and vapor- and liquid-phase GAC adsorption unit processes of the existing Treatment System. The treated groundwater would then be discharged via the established Outfall 001 to the unnamed tributary of Little Neshaminy Creek.

This alternative would also include the continued operation of the groundwater extraction and air stripping system at WTMA26.

Control measures would be instituted to prevent use of the Area D groundwater for drinking purposes and monitoring would be performed to periodically check for off-site contaminant migration and to assess the degree of groundwater contamination. This alternative would include preparation of deed restrictions to ensure continuity of controls and monitoring and limit the use of groundwater.

3.2 SCREENING OF REMEDIAL ALTERNATIVES

Remedial alternatives may be screened based on implementability, effectiveness, and cost to further focus on suitable alternatives for detailed analysis. In this FS report all of the alternatives are being retained for detailed analysis.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section discusses the remedial alternatives outlined in Section 3.0 for the Area A, B, and D groundwater and analyzes these alternatives in detail based on the criteria of the National Contingency Plan (NCP) and the CERCLA guidance.

4.1 EVALUATION CRITERIA

Criteria used in evaluating the remedial alternatives will be those nine established in the NCP which was finalized in a Federal Register notice dated March 8, 1990, pages 8666-8865. The evaluation of the remedial alternatives will be conducted as provided in the NCP and the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (OSWER Directive 9355.3-01, USEPA October, 1988) The nine criteria are as follows:

- Overall Protection of Human Health and The Environment
- Compliance With ARARs and TBCs
- Long-term Effectiveness and Permanence
- Reduction of Mobility, Toxicity, and Volume Through Treatment
- Short-term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

The nine evaluation criteria are grouped into three categories; threshold criteria, primary balancing criteria, and modifying criteria. The threshold criteria include overall protection of human health and the environment and compliance with ARARs. An alternative must achieve these criteria to be considered for selection.

The primary balancing criteria include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. These criteria are used to differentiate between alternatives during the selection process.

The modifying criteria include state and community acceptance. These two criteria are not considered in the FS. The state's concerns are considered after the RI/FS comments are received and the community's concerns are considered after comments on the proposed plan are received.

Overall Protection of Human Health and The Environment:

To the extent possible, remedial alternatives that use permanent solutions to reduce the mobility, toxicity, and/or volume and alternative treatment technologies will be considered. Alternatives shall be assessed to determine whether they adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals. Overall protection of human health and the environment draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance With ARARs and TBCs:

Alternatives will be assessed as to whether they attain legally applicable or relevant and appropriate requirements of Federal and state environmental regulations and public health laws, including:

- Contaminant-specific ARARs and TBCs (e.g., MCLs, Pennsylvania's Statewide Human Health Standards for Groundwater).
- Location-specific ARARs and TBCs (e.g., wetland criteria).
- Action-specific ARARs and TBCs (e.g., Clean Water Act NPDES, Clean Air Act NAAQS).

Long-Term Effectiveness and Permanence

Alternatives will be assessed for the long-term effectiveness and permanence they offer along with the degree of certainty that the remedy will prove successful in attaining the clean-up goals. Factors to be considered include the following:

- Magnitude of residual risks in terms of amounts and concentrations of waste remaining following implementation of a remedial action.
- Type and degree of long-term management required, including monitoring and operation and maintenance.
- Potential for exposure of human and environmental receptors to remaining waste.
- Long-term reliability of the engineering and institutional controls, including uncertainties associated with land disposal of untreated wastes and residuals.
- Potential need for replacement of the remedy.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume will be assessed. Factors that are relevant include the following:

- The treatment or recycling processes the remedies employ and materials they will treat.
- The amount of hazardous materials that will be destroyed, treated, or recycled.
- The degree of expected reduction in toxicity, mobility, and volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring.

- The residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents.

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

Short-Term Effectiveness:

The short-term effectiveness of alternatives will be assessed considering the effects of the alternatives during implementation until remedial action objectives (RAOs) are met. Alternatives will be evaluated with respect to their effect on human health and the environment, considering relevant factors, including:

- Short-term risks that might be posed to the community, workers, or the environment during implementation of an alternative and the effectiveness and reliability of mitigative measures during implementation.

- Time until full protection is achieved.

Implementability:

The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors:

- Degree of difficulty associated with constructing the technology.

- Expected operational reliability of the technology.

- Need to coordinate with and obtain necessary approvals and permits (e.g., NPDES permits) from other offices and agencies.

- Availability of necessary equipment and specialists.

- Available capacity and location of needed treatment, storage, and disposal services.

Cost:

The types of costs that will be assessed include the following:

- Capital costs, including both direct and indirect cost.
- Operation and maintenance (O&M) costs
- Net present worth of capital and O&M costs

For each alternative, the costs will be estimated within a range of -30 percent to +50 percent. The cost analysis will include separate evaluation of capital and operation and maintenance costs such as engineering/design fees, materials and equipment, construction, and off-site treatment or disposal. Operation and maintenance costs will consist of long-term costs associated with operating and monitoring the remedial actions. Capital and annual operation and maintenance costs will be based on the anticipated time necessary for the alternative to achieve cleanup criteria.

4.2 AREA A ALTERNATIVES (FINAL REMEDY)

The alternatives that have been developed and retained after screening for the permanent remediation of the Area A groundwater are the following:

- Alternative A1: No Action
- Alternative A2: Institutional Controls and Monitoring
- Alternative A3: Extraction, Treatment at existing Treatment System, Discharge To Outfall 001

4.2.1 Alternative A1: No Action

This alternative would not involve any remedial action. No monitoring would be conducted to assess the off site migration of contaminants.

Overall Protection of Human Health and The Environment:

This alternative would not be protective of the human health because it would not remedy the Area A aquifer, or contain off-site contaminant migration, or prevent on-site exposure to contaminated groundwater. Although the groundwater at Area A is not currently used for drinking purposes, the health

of potential future users could be adversely affected. No environmental receptors have been identified at Area A and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Specifically, concentrations of volatile organic compounds (VOCs) of concern, including chloroform, carbon tetrachloride, TCE, and PCE would continue to exceed their respective MCLs. No action-specific ARARs would need to be addressed since no remedial action would be performed.

Long-Term Effectiveness and Permanence:

This alternative would have no long-term effectiveness and permanence since no remedial action would occur and the current and future threat to human health and the environment would remain. The Area A aquifer would not be remedied and the VOCs of concern would continue migrating off site. Concentrations of these VOCs would likely remain at levels exceeding MCLs because of the suspected presence of DNAPL, which would continue to be a source of groundwater contamination. Potential future transfer of ownership of NAWC Warminster would be infeasible.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would not actively reduce toxicity, mobility, and volume through treatment. Any reduction in groundwater toxicity and contaminant volume due to natural attenuation, if any, would not be monitored and would likely be offset by the recharging action of the suspected DNAPL. This alternative would not satisfy the statutory preference for treatment to reduce risks posed by the contaminated Area A groundwater.

Short-Term Effectiveness:

Short-term effectiveness is not relevant to this alternative since no remedial action would be performed which could create additional short-term risk to the local community or future on-site workers. Current risks would remain unchanged. None of the RAOs would be met.

Implementability:

Implementability is not relevant to this alternative since it would not involve any remedial action.

Cost:

Capital costs: $0
O&M costs: $0/year
Present-worth: $0

4.2.2 Alternative A2: Institutional Controls and Monitoring

This alternative would consist of implementing institutional controls to prevent use of the Area A groundwater for domestic purposes and conducting long-term monitoring of groundwater quality.

For costing purposes it was assumed that monitoring would consist of sampling groundwater from a set of 16 wells installed in the vicinity of Area A as selected in the design specifications for the existing Treatment System (HNUS, Design Analysis Report, 1994). The actual wells to be used for groundwater monitoring would best be selected after completion of a pre-design off-site groundwater investigation. Groundwater samples would be sampled monthly during the first quarter and quarterly thereafter. The samples would be analyzed for Target Compound List (TCL) volatile organics.

This alternative would also include preparation of deed restrictions to ensure continued implementation of institutional controls and groundwater monitoring, should the site changes ownership, and the possible preparation of other off-site institutional controls and restrictions to limit the use of groundwater..

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and The Environment:

This alternative would provide limited protection of human health since it would not remedy the Area A aquifer or contain off-site contaminant migration but it would nonetheless prevent on-site exposure to contaminated groundwater by prohibiting its use for domestic purposes. This alternative would also

provide limited protection from off-site exposure to downgradient groundwater users by monitoring the groundwater quality which would allow the responsible agency to evaluate contaminant migration, detect potential impacts to downgradient receptors, and take action to mitigate any potential health risks. No environmental receptors have been identified at Area A and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Specifically, concentrations of chloroform, carbon tetrachloride, TCE, and PCE would continue to exceed their respective standards. No action-specific ARARs would need to be addressed since no remedial action would be performed.

Long-Term Effectiveness and Permanence:

This alternative would have limited long-term effectiveness and permanence since it would not remedy the Area A aquifer or contain off-site contaminant migration but it would nonetheless prevent exposure to the contaminated groundwater by prohibiting its on-site use for domestic purposes. This alternative would also monitor groundwater quality which might provide limited protection to downgradient receptors by allowing the responsible agency to evaluate contaminant migration and determine whether future actions are necessary to mitigate risks to downgradient users. Concentrations of VOCs of concern would likely remain at levels exceeding MCLs because of the suspected presence of DNAPL at Area A, which would continue to be a source for groundwater contamination. This alternative would also ensure that monitoring and institutional controls would continue to be implemented if the site changes ownership.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would not actively reduce toxicity, mobility, and volume through treatment. Any reduction in groundwater toxicity or contaminant volume due to natural attenuation, if any, would be assessed by monitoring but would likely be offset by the recharging action of the suspected DNAPL. As with the No-Action alternative, this alternative would not satisfy the statutory preference for treatment to reduce the risks posed by the Area A contaminated groundwater.

Short-Term Effectiveness:

This alternative would involve no remedial action other than monitoring of groundwater quality and potential preparation of deed restrictions. The risks associated with these limited remedial activities would be minimal. Sampling personnel would wear the required personal protective equipment (PPE) and receive the appropriate health and safety training. This alternative could be implemented immediately after the signing of the Record of Decision (ROD). Deed restrictions, if needed, might require up to a year or longer to implement, depending on the properties affected. The RAOs would not be achieved.

Implementability:

This alternative would be readily implementable since it would only involve long-term monitoring of groundwater quality, administration of institutional controls, and potential preparation of deed restrictions if the site changes ownership. As mentioned above, this alternative could be implemented immediately after signing of the ROD although deed restrictions, if needed, might require up to a year or more to implement.

Present-Worth: $742,000 over 30 years

Detail cost estimates are included in Appendix A.

4.2.3 Alternative A3: Extraction, Treatment at existing Treatment System, Discharge at Outfall 001

In this alternative, the contaminated Area A groundwater would be extracted, treated at the existing Treatment System, and discharged to the unnamed tributary of Neshaminy Creek at existing Outfall 001. This alternative would also include the continued operation of the off-site Warminster Township Municipal Authority Well 26 (WTMA26) from which groundwater is currently pumped, treated by air stripping and chlorination, and delivered to the municipal water supply system.

The design for the Area A extraction system considered the following information:

- There is a potential for DNAPL presence in Area A near Site 1, based on historic sampling results.
- Groundwater contamination extends off site of the base to the north-northwest.
- Groundwater contamination above MCL's is present throughout most of the downgradient (north) edge of Area A.
- Most of the groundwater impacts on base within Area A are within the top 60 to 100 feet of the bedrock aquifer. Off-base contamination extends deeper, following the dip of the rock units to some degree.
- Municipal water supply well WTMA No. 26 is located generally north of Area A, and serves as a collection point for contaminated groundwater between the base and the municipal well.

Based on the above factors and site-specific hydrogeologic information, a conceptual remedial design strategy was developed for Area A groundwater. The approach selected is designed to provide on-site hydraulic containment of the Navy source area along the northern edge of the base property west of Jacksonville Road, and use WTMA No. 26 for the collection/containment of the off-site plume attributable to the Navy. This approach prevents further releases of contaminants from Area A, while also providing containment and removal of the residual plume located beyond the limit of the on-site extraction system capture zone. The design is similar to the interim FS design for Area A, with the addition of off-site plume containment/removal via WTMA No. 26. The need for deeper extraction wells on base for the final remedy was considered but rejected due to DNAPL concerns and contaminant distribution data, which suggests that groundwater impacts are limited in depth within Area A.

Within Area A, groundwater extraction will be focused on the upper portion of the bedrock aquifer where DNAPL presence is suspected, both to limit the potential for inducing downward migration of contamination and to focus the pumping within the depth interval where most of the contamination exists. Off base to the north, both shallow and deeper contamination will be collected by the municipal well as it is open to a depth of approximately 250 feet. By limiting the scope of off-site pumping to operating the municipal well, the potential for negatively impacting the municipal well's yield is minimized, while still achieving plume containment and a reasonable estimated single pore volume flushing time (approximately

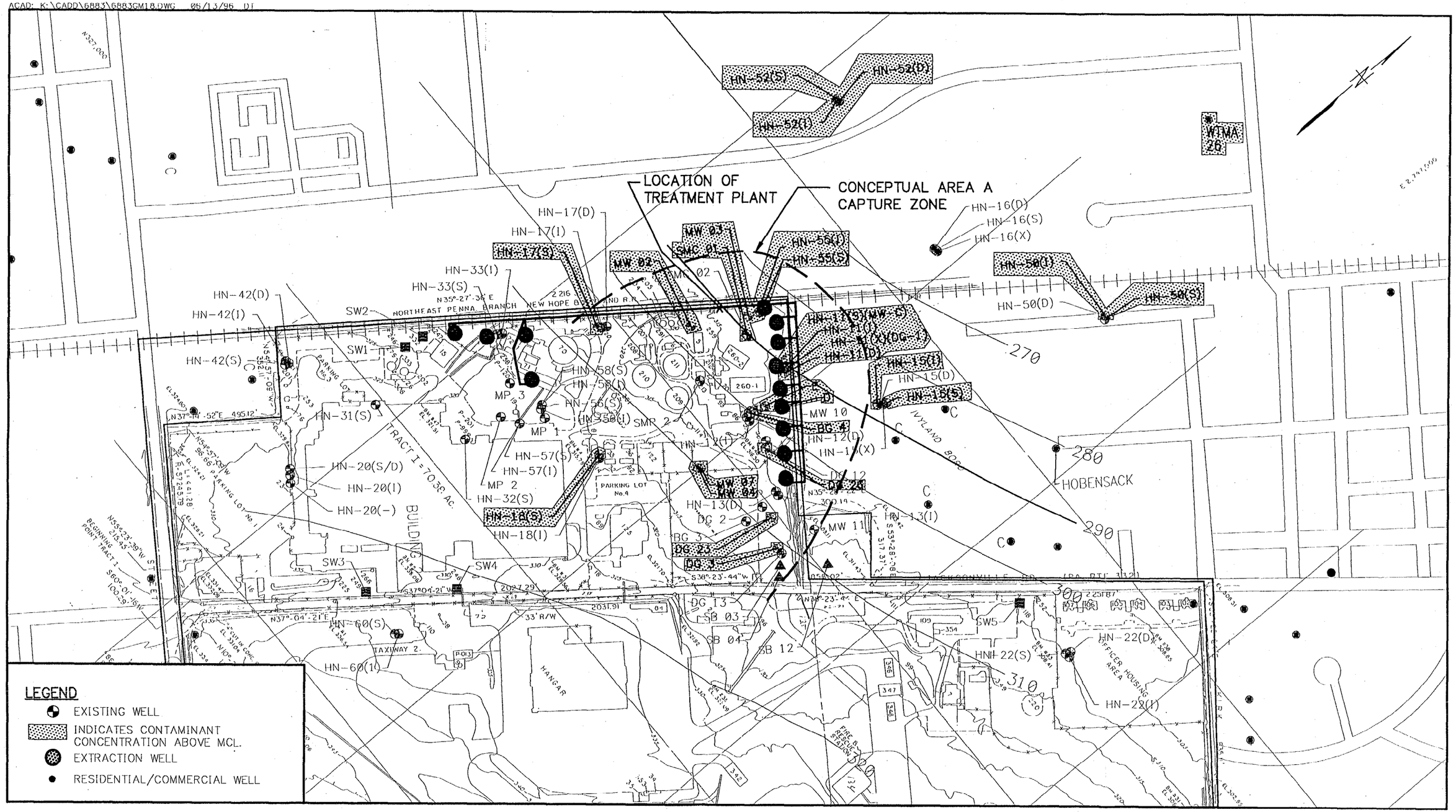
67 days, see Appendix C). Details regarding the design approach and calculations are presented in Appendix C.

A set of 9 extraction wells would be screened within the shallow portion of the aquifer at an average depth of approximately 70 feet. Each well would be 6-inch in diameter and would yield an average approximately 7 gallons per minute (gpm) for a total of 63 gpm. These wells would be installed along the northeastern edge of the NAWC boundary between monitoring well clusters HN-13 and HN-55. These extraction wells would be located in the area exhibiting the greatest and most consistent levels of contamination and could be located immediately downgradient and/or within the area of suspected DNAPL. Details regarding the FS design approach and assumptions, well construction, location, and calculated recovery zone are presented in Appendix C. Figure 4-1 shows the proposed Area A groundwater extraction well layout and its capture zone.

Area A and Area D remediations may constitute an integrated remedial approach to the groundwater at adjacent sites. Therefore, Figure 4-2 that is also presented here shows the proposed Area D groundwater extraction well layout and its capture zone. The conceptual design of the Area D extraction system is presented in Section 4.4.3.

The Area A groundwater would be conveyed to the existing Treatment System by a pipeline featuring double-wall containment and a leak detection system. At the existing Treatment System, the Area A groundwater would be treated along with the Area C groundwater that is scheduled for treatment beginning in the spring or summer of 1996. The Area C groundwater flow rate is expected to be approximately 59 gpm. Thus, the total groundwater flow rate from Areas A and C would be approximately 122 gpm. If groundwater from Areas B and D also has to be treated at the existing Treatment System, a total hydraulic capacity of approximately 170 gpm would be required. As the existing Treatment System is designed for a flow rate of 130 gpm, certain modifications would be required to accommodate the additional 40 gpm. Pending results from ongoing groundwater extraction and treatment actions, the groundwater flow from off-site extraction wells may also have to be treated, requiring further modifications to the existing Treatment System. The existing Treatment System was designed to accommodate duplicate treatment components, therefore it is expected that adequate space will be available for future expansion of this system. Because this existing system was designed to treat groundwater from Areas A and B and later accommodated the groundwater flow from Area C through the implementation of an approved ROD, any modification required to upgrade the hydraulic capacity of the existing Treatment System will be discussed and costed under Alternative D3 for the Area D groundwater in Section 4.4.3.

DRAFT



CONCEPTUAL EXTRACTION WELL AND
CAPTURE ZONE LOCATIONS
AREA A
NAWC, WARMINSTER, PA

0 400 800
SCALE IN FEET

FIGURE 4-1

Brown & Root Environmental

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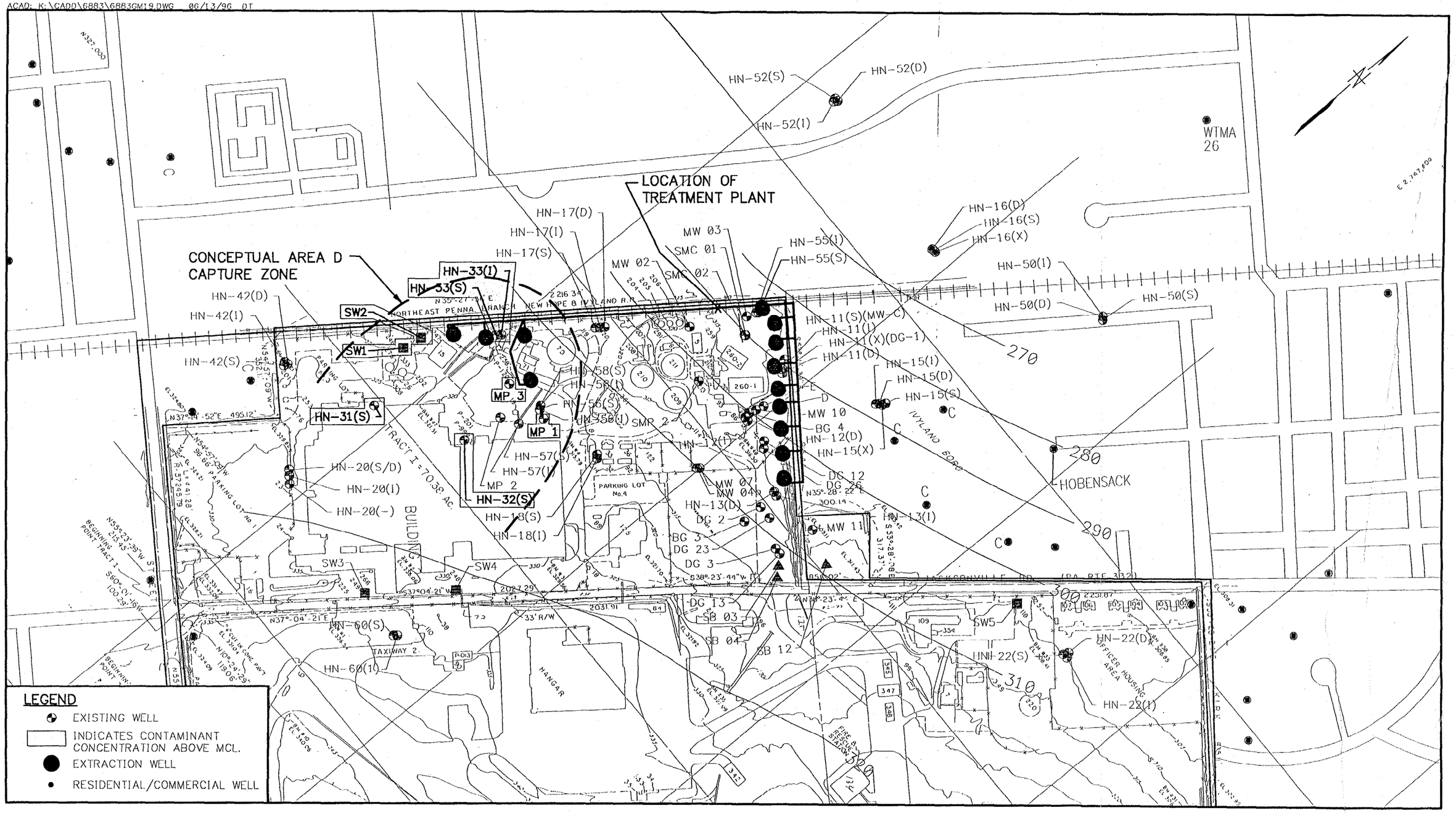

CONCEPTUAL EXTRACTION WELL AND
CAPTURE ZONE LOCATIONS
AREA D
NAWC, WARMINSTER, PA

0 400 800
SCALE IN FEET

FIGURE 4-2

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The maximum and average concentrations of the VOCs of concern for the Area A groundwater are shown on Table 4-1 together with their respective NPDES discharge limits or Pennsylvania's Water Quality Criteria (WQCs) for Toxic Substances. Based upon this comparison, the chloroform, carbon tetrachloride, TCE and PCE content of the extracted Area A groundwater may need to be reduced to achieve their respective discharge limits.

Table 4-2 shows the anticipated concentrations of the Areas A and C groundwater VOCs of concern, including chloroform, carbon tetrachloride, TCE and PCE, as well as an estimate of the concentrations of these VOCs in the composite influent to the existing Treatment System. The composite influent concentrations were obtained by flow-weighted averaging of VOCs concentrations in the groundwater from Areas A and C based upon their respective extraction rates of 63 gpm and 59 gpm. Table 4-2 also compares the composite influent concentrations of VOCs of concern with the design influent concentrations of the existing Treatment System.

Figure 4-3 shows a process flow diagram for the existing Treatment System. The following is the sequence of unit processes for the existing Treatment System:

- Equalization
- Flash Mixing/Flocculation/Clarification
- Continuous Backwash Sand Filtration
- Neutralization
- Tray-Type Low-Profile Air Stripping
- Air Stripping Offgas Treatment With Vapor-Phase Granular Activated Carbon (GAC) Adsorption
- Liquid-Phase GAC Adsorption
- Treated Groundwater Discharge To Outfall 001
- Sludge Dewatering and Off-Site Disposal

Given the composite influent concentrations of VOCs of concern shown on Table 4-2, the unit processes of the existing Treatment System would need to be evaluated for VOC removal efficiency.

The existing Treatment System was designed for the treatment of contaminated groundwater containing VOCs (especially TCE), some minor semi-volatile organic compounds (SVOCs), and inorganics (iron and manganese). However, the VOCs removal was not designed for the average concentrations that have

TABLE 4-1

MAXIMUM AND AVERAGE VOC CONCENTRATIONS IN AREA A GROUNDWATER AND ANTICIPATED DISCHARGE LIMITS

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

VOC	Maximum Concentration (µg/L)	Average Concentration (µg/L)	Anticipated Discharge Limit (µg/L)
1,2-Dichloroethene	57	10	700 (WQC)
Chloroform	370	9	6 (WQC)
2-Butanone	200	2	none
1,1,1-Trichloroethane	4	1	1,000 (WQC)
Carbon tetrachloride	2,600	52	1.3 (average monthly) 3.3 (instantaneous maximum)
Trichloroethene (TCE)	100,000	3,694	13 (average monthly) 33 (instantaneous maximum)
4-Methyl,2-Pentanone	100	1	None
2-Hexanone	1,500	18	None
Tetrachloroethene (PCE)	320	51	0.7 (WQC)

NOTES:

1. WQC: Pennsylvania's Water Quality Criteria for Toxic Substances, Appendix A, Table 1, PA Title 25, Chapter 16, as amended April 30, 1994
2. Anticipated limits for carbon tetrachloride and TCE were estimated by converting their respective limits for a flow rate of 130 gpm (for the interim action system) to those that might be applicable for a flow rate of 170 gpm, assuming the same allowable mass loading for these VOCs.

TABLE 4-2

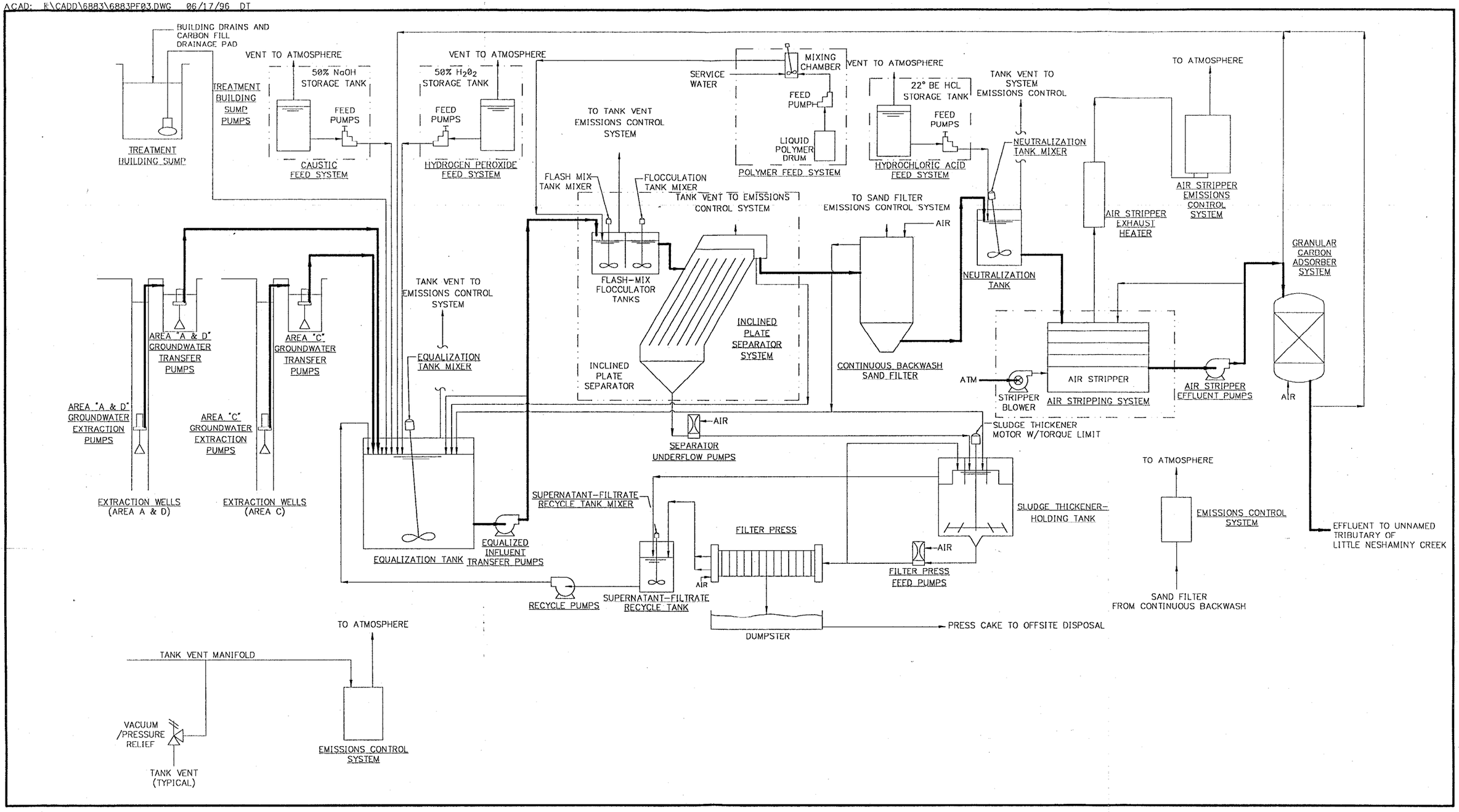
SUMMARY OF VOC CONCENTRATIONS
AREAS A AND C GROUNDWATER
DESIGN INFLUENT CONCENTRATIONS FOR THE INTERIM TREATMENT SYSTEM

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

VOC	Area A Concentration (Max/Ave) µg/L	Area C Concentration (Max/Ave) µg/L	Composite Concentration (Max/Ave) µg/L	Influent Design Concentration[1] (µg/L)
TCE	100,000/3,694	ND/ND	51,639/1,908	300
Chloroform	370/9	ND/ND	191/4.6	9.3
Carbon Tetrachloride	2,600/52	ND/ND	1,343/26.9	11.3
PCE	320/51	29/2	179/27.3	82.5

NOTES :

1. Excerpted from "Concentrations of as-Received at Treatment", Design Analysis Report, HNUS, 1995



ALTERNATIVE A3, B4, AND D3
EXISTING TREATMENT PLANT
PROCESS FLOW DIAGRAM
NAWC WARMINSTER, WARMINSTER, PA.

FIGURE 4-3

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since been detected in the Area A groundwater. Because of this, additional tray elements may have to be added to the air stripper. No other modification of the existing Treatment System should be required.

Alternative A3 would also include the continued operation of WTMA26 as an extraction, treatment, and supply well. The current rate of extraction and treatment of that well provides the necessary capture zone to adequately intercept contaminants in the off-site groundwater. The existing WTMA26 treatment system can accommodate the existing and anticipated levels of contamination without modifications. The cost of continuing to operate the WTMA26 well systems at the current flow rate and level of contamination has been included in the total cost of this alternative.

Long-term groundwater monitoring would be conducted to measure the effectiveness of the remedy and to ensure that off-site migration of the contaminant plume is minimized. Monitoring would consist of sampling from 24 monitoring wells that were selected during the design of the existing Treatment System plus the WTMA26 well. During the first year, the sampling would be conducted monthly to establish a trend in the contaminant levels. After the trend has been established during subsequent years, the sampling frequency would be reduced to a quarterly basis and, eventually, to a semi-annual or even yearly basis.

This alternative would also include the preparation of deed restrictions to ensure the continued implementation of the remedial action, institutional controls, and groundwater monitoring if the site changes ownership.

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and The Environment:

This alternative would be protective of human health by actively remediating the Area A aquifer, containing the off-site migration of VOCs of concern, and preventing on-site exposure to contaminated groundwater by prohibiting its use for domestic purposes. In addition, this alternative would provide long-term monitoring of groundwater quality which would allow the responsible agency to assess the effectiveness of the remedy. No environmental receptors have been identified at Area A and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative might not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs, in areas where suspected DNAPL would act as an ongoing contaminant source. If long-term monitoring indicates that contaminant-specific ARARs are not being approached in the areas of suspected DNAPL, the appropriateness of a Technical Impracticability Waiver would have to be evaluated. This would not be inconsistent with the current approach at DNAPL-contaminated sites. All action-specific ARARs for the discharge of treated groundwater and air emissions would be complied with during the remedial action.

Long-Term Effectiveness and Permanence:

This alternative would have long-term effectiveness and permanence since it would contain off-site migration of the Area A VOCs of concern. It should be noted, however, that residual contaminants might remain in certain areas at concentrations exceeding MCLs because of the recharging action of the suspected DNAPL. However, this alternative would provide groundwater quality monitoring and institutional controls to ensure that on-site exposure to these VOCs does not occur. This alternative would also ensure that the remedial action, monitoring, and institutional controls would continue to be implemented if NAWC Warminster changes ownership.

Reduction of Toxicity, Mobility, and Volume through Treatment:

This alternative would reduce toxicity, through groundwater extraction and treatment with air stripping and vapor- and liquid-phase GAC adsorption. Approximately 3.0 pounds per day (lbs/day) of total VOCs would be removed from the extracted Area A groundwater, based upon average groundwater concentrations and extraction rates. The removed VOCs would ultimately be destroyed (100% irreversibly) during the off-site regeneration of the spent GAC. It should be noted, however, that the VOCs of concern would probably remain at concentrations exceeding MCLs because of the recharging action of the suspected DNAPL. The sludge produced by the unit processes upstream of the air stripper would likely be non-hazardous and could therefore be disposed of safely at an off-site facility. Additional minor quantities of VOCs would be removed by the WTMA26 well treatment system.

Short-Term Effectiveness:

The risks of contaminant exposure would be minimal for the operating personnel of the existing Treatment System and surrounding community since any VOC emission would be captured by the offgas GAC adsorption system and the filter press cake would not be hazardous. Off-site transportation of the spent GAC and filter press cake would not pose an undue threat to the community or the environment. Construction, operation, and monitoring personnel would wear the required PPE and receive the appropriate health and safety training.

Implementability:

This alternative would be readily implementable. The new groundwater extraction system and minor modifications to the existing Treatment System, would be relatively easy to install. The WTMA26 well extraction, treatment, and supply systems are already in operation. All of the new groundwater extraction system, existing Treatment System, and existing WTMA26 well systems unit processes are well-proven and reliable if properly maintained and operated. The substantive requirements of a modified NPDES permit for discharge at the existing Outfall 001 would be met. Long-term monitoring of the groundwater quality would be simple to perform. The administrative and legal services which might be required to prepare deed restrictions if the site is sold would be readily available.

Cost:

Capital Cost: $748,000
O&M Costs: $122,000 for the first year, $82,500/year thereafter
Present-Worth: $2,109,000 over 30 years

Detailed cost estimates are included in Appendix A.

4.3 AREA B ALTERNATIVES (FINAL REMEDY)

The alternatives that have been developed and retained after screening for the permanent remediation of the Area B groundwater are the following:

- Alternative B1: No Action
- Alternative B2: Institutional Controls and Monitoring
- Alternative B3: Extraction, On-site Treatment, Reinjection
- Alternative B4: Extraction, Treatment at existing Treatment System, Discharge To Outfall 001

4.3.1 Alternative B1: No Action

This alternative would not involve any remedial action. No monitoring be performed to assess whether off-site contaminant migration or natural attenuation are occurring.

Overall Protection of Human Health and Environment:

This alternative would not be protective of human health since it would not contain off-site contaminant migration or prevent on-site exposure to the contaminated Area B groundwater. Although the groundwater at Area B is not currently used as a potable water source, the health of potential future users would be adversely affected. No environmental receptors have been identified at Area B and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs:

This alternative would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. No action-specific ARARs would need to be addressed since no remedial action would take place.

Long-Term Effectiveness and Permanence:

This alternative would have no long-term effectiveness and permanence since it would not contain off-site contaminant migration or provide any protection against on-site exposure to contaminated groundwater.

Monitoring would not be conducted and therefore one cannot confirm that off-site migration of contaminants at levels exceeding MCLs does not occur in the future.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would not reduce toxicity, mobility, and volume through treatment. This alternative would therefore not meet the statutory preference for treatment to reduce risks from contaminated groundwater.

Short-Term Effectiveness:

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

Implementability:

Implementability is not relevant to this alternative since it does not involve any remedial action to be implemented.

Cost:

Capital Cost: $0
O&M Cost: $0/year
Present-Worth: $0

4.3.2 Alternative B2: Natural Attenuation With Institutional Controls and Monitoring

This alternative would include the implementation of institutional controls to prevent the use of the Area B groundwater for domestic purposes. There are currently no users of the groundwater on Area B and any potential use while NAWC Warminster is owned by the Navy would be prohibited.

Long-term groundwater monitoring would be conducted to assess contaminant attenuation, quantify certain naturally-occurring biodegradation parameters, and to confirm that future off-site contaminant migration at levels exceeding MCLs does not occur. Approximately 10 wells screened in the shallow,

intermediate, and deep portions of the aquifer within the areas of higher contamination and along the NAWC boundary would be selected for sampling on a quarterly basis. The water samples would be analyzed for Target Compounds List (TCL) VOCs.

The 10 monitoring wells to be sampled would include the following:

- Three wells screened within the shallow, intermediate, and deep aquifers in each of the two hot-spot locations, for a total of six wells

- Two wells screened within the shallow and deep aquifers at two locations along the southern boundary of the site, for a total of four wells

The analytical results would provide data to confirm that natural attenuation of the VOCs of concern is occurring.

Naturally-occurring mechanisms such as dispersion, volatilization, chemical oxidation/reduction, and biodegradation would likely attenuate and decrease the levels of TCE and benzene in the Area B groundwater to below levels of concern.

The natural inflow of less contaminated upgradient groundwater would replenish the naturally occurring degradation and dispersion mechanisms needed to decrease and diminish contaminant levels.

Volatilization due to water table fluctuation could transfer the VOCs into the vapor phase.

Chemical or biological oxidation of benzene could decompose it into carbon dioxide and water. Chemical reduction could de-halogenate TCE into dichloroethenes (DCE), vinyl chloride, and ultimately into ethene. Although TCE is amenable to reductive de-halogenation under methanogenic conditions, the end product, typically vinyl chloride is more toxic and less reactive. However, a mixed consortia of anaerobic bacteria and aerobic methanotrophic bacteria could completely biodegrade TCE into innocuous products such as ethene, carbon dioxide, chlorides, and water.

In order for these mechanisms to occur naturally, suitable nutrients and other minerals, oxidation/reduction potentials, dissolved oxygen levels (or lack thereof), must be present in the aquifer. Typically, variations of levels of metabolic products such as ethene or methane, and indicator parameters such as dissolved

iron (reduced or ferrous iron), biological oxygen demand (BOD), and nitrate could be used to confirm that these mechanisms are actually occurring. However, because the VOCs of concern are only present at very low concentrations in the Area B groundwater (TCE maximum of 12 μg/L and benzene maximum of 20 μg/L), any variations of concentrations of metabolic products or indicator parameters are expected to be difficult to detect. Therefore, it is proposed that only the concentrations of TCE, DCE, vinyl chloride, and benzene be monitored within the TCL VOCs list.

The data available to date indicate that the concentrations of TCE have remained essentially unchanged between the 1992 and 1995 sampling rounds at 13 μg/L and 12 μg/L, respectively (B&R Environmental memo, March 1, 1995). Therefore, currently, the effect of natural attenuation of TCE, if any, may be masked by continued contribution from suspected source(s) at Area B. Benzene was detected only in a newly installed well at 20 μg/L in 1995 (HN36D). A source evaluation and removal action is ongoing at Site 6, within Area B.

Chemical fate and transport modeling (using ECTRAN™) shows that, after the removal of the suspected source(s) (and conservatively assuming no biodegradation), natural dispersion and dilution of the plume would decrease the concentrations of TCE and benzene so that they would attain their respective MCLs of 5 μg/L each within 8 years. A summary of the modeling discussion is presented below and details of the modeling calculations are included in Appendix B.

The model is a multi-layer, unidimensional model that is used to simulate the transport of dissolved contaminants in the saturated zone. The model assumes that the fractured bedrock aquifer can be simulated as an equivalent porous medium (EPM) on a large scale. The model also assumes that the contaminants have migrated over a period of 40 years from an assumed source area from reported dates of waste disposal at Sites 5, 6 and 7 (HNUS, Hydrogeologic Report, 1995). The model uses the current concentrations of contaminants which appear to be at a steady state at a maximum of 12 μg/L of TCE at DG18 and 20 μg/L of benzene at HN36D as sources within the aquifer. The model also assumes that the source of contamination in the vadose zone is removed and allows the concentrations in the aquifer to deplete naturally by advection and dispersion, with no biodegradation, as an added conservative measure.

Under these conditions, the model predicts that the concentrations of TCE and benzene at the locations of higher contamination and downgradient aquifer would be reduced to less than 5 μg/L within approximately 8 years. In the worst-case scenario, assuming that an upgradient and as yet unidentified source exists, the duration of attenuation to attain MCLs (after the source is removed), would be longer. In either case,

the concentrations of TCE or benzene would never exceed MCLs at the downgradient NAWC boundary. Even if the TCE degrades anaerobically to form the more toxic vinyl chloride, the concentration of vinyl chloride would be lower than its MCL of 2 μg/L.

This alternative would also include the preparation of deed restrictions to ensure continued implementation of the institutional controls and groundwater monitoring if the site changes ownership before the RAOs are met.

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and Environment:

This alternative would provide protection of human health since it would prevent on-site use of contaminated groundwater for domestic purposes and provide groundwater quality monitoring to verify that potential off-site contaminant migration at levels exceeding MCLs until the RAOs have been met through natural attenuation. No environmental receptors have been identified at Area B and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would eventually comply through natural attenuation with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Eventual compliance with the contaminant-specific ARARs would be verified through groundwater quality monitoring. No action-specific ARARs would need to be addressed for this alternative since no remedial action would take place.

Long-Term Effectiveness and Permanence:

This alternative would have long-term effectiveness and permanence since it would prevent on-site use of the Area B groundwater for domestic purposes and monitor its quality to verify off-site contaminant migration at levels exceeding MCLs does not occur until attainment of the RAOs through natural attenuation. Modeling predicts that, assuming the removal of the source(s) of contamination, natural attenuation would likely attain remedial action goals within 8 years. Residual risks associated with any

contaminants remaining after that time period would be minimal. This alternative would also ensure that the monitoring and institutional controls would continue to be implemented if the site changes ownership before the RAOs have been met.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would not reduce toxicity, mobility, and volume through treatment. However, reduction in groundwater toxicity would occur through natural attenuation and would be monitored and quantified.

Short-Term Effectiveness:

This alternative would only involve monitoring of groundwater quality, administration of institutional controls, and potential preparation of deed restrictions. The short-term risks associated with these limited remedial activities would be minimal. Sampling personnel would wear the required PPE and receive the appropriate health and safety training. This alternative could be implemented immediately after signing of the ROD. Deed restrictions, if required, might take up to a year or longer to implement, depending on the properties affected. The RAOs would only be met through natural attenuation, which would require approximately 8 years, assuming removal of the source(s) of contamination.

Implementability:

This alternative would be readily implementable since it would only involve the performance of long-term groundwater quality monitoring, the administration of institutional controls, and the potential preparation of deed restrictions if the site changes ownership before the RAOs have been met. As mentioned above, this alternative could be implemented immediately after signature of the ROD, although potential deed restrictions, if required might take up to a year or longer to implement.

Cost:

Capital Cost: $0
O&M Cost: $98,400 for the first year, $32,800/year thereafter
Present-Worth: $290,000 over 30 years

Detailed cost estimates are included in Appendix A.

4.3.3 Alternative B3: Extraction, Local Treatment, Reinjection

This alternative would consist of using two wells installed at locations of higher contamination, namely DG18 (12 μg/L TCE) and HN36D (20 μg/L benzene), to extract contaminated groundwater; followed by above-ground treatment with air sparging, and reinjection of the treated groundwater to the Area B aquifer.

The design for the Area B extraction system considered the following information:

- The area of highest groundwater impacts within Area B appears to be a localized area along the downgradient edge of Site 6, around wells DG-18 and HN-36D.
- Groundwater contamination does not appear to be migrating any significant distance downgradient (to the south) from the vicinity of wells DG-18 and HN-36D.
- The contaminant plume within Area B appears to be in a steady-state configuration both in terms of concentration and areal distribution, with elevated levels of contaminants confined to the Navy property.
- Most of the groundwater impacts onbase within Area B are within the top 150 feet of bedrock aquifer. TCE is found above MCLs only in the shallow <75 feet portion of the bedrock aquifer, while benzene was found above MCLs in one well at a depth of 133-147 feet.

Based on the above factors and site-specific hydrogeologic information, a conceptual remedial design strategy was developed for Area B groundwater. The approach selected is designed to provide focused groundwater extraction from the areas of DG-18 and HN-36D, as these are the two areas of highest groundwater impacts within Area B. This approach prevents further releases of contaminants from these discrete areas of elevated contaminant levels while avoiding the long term pumping of significant quantities of groundwater that has little or no contamination.

Yield testing/sampling of potential extraction wells along the downgradient edge of the Area B plume confirmed that the groundwater contamination above MCLs in Area B is very localized and that extremely low concentration of contaminants would be removed using a containment-type extraction system. In addition, the steady-state nature of the plume suggests that a containment-type approach to groundwater

remediation is not necessary. An extraction system based on selective pumping from discrete areas of highest contaminant levels will provide the highest contaminant removal efficiency and cost effectiveness. Details regarding the design approach and calculations are presented in Appendix C.

The extraction wells would be 6-inch in diameter with an average depth of 85 feet. Submersible centrifugal pumps would be installed in each well and each well would yield on average approximately 5 gpm of groundwater. A total flow rate of 10 gpm of groundwater would be conveyed to the above-ground treatment system that would be located midway between the extraction wells at a distance of approximately 75 feet from either well. Figure 4-4 shows the proposed groundwater extraction system layout. A source area evaluation and removal action is ongoing at Site 6 within Area B.

Treatment would consist of air sparging to volatilize the benzene and TCE in an enclosed equalization tank with off-gas treatment using vapor-phase GAC adsorption. The equalization tank would be a 300-gallon vertical cylindrical tank with closed top. The air sparging equipment would consist of two components:

- An air diffusion system installed at the bottom of the equalization tank and featuring a perforated tube, sock, dome or disc diffuser, or other such device to ensure even distribution of air.

- An air blower to supply a total of approximately 25 cubic feet per minute (cfm) of ambient air to provide adequate mixing and volatilization of the VOCs of concern.

Approximately 17 cfm (at tank mid-depth pressure) of air is theoretically required for achieving 75 percent removal of benzene from a maximum concentration of 20 μg/L to the remedial action goal of 5 μg/L. The residual concentration of TCE would be less than 3 μg/L under these conditions. Figure 4-5 depicts the process flow diagram for this alternative.

The treated groundwater would be reinjected within the shallow portion of the bedrock aquifer to a depth of approximately 100 feet below the surface via two wells. These reinjection wells would be located at a distance of approximately 500 feet away from the extraction wells, towards the northern edge of Site 6 near the runway. This configuration is based on maintaining the maximum practical separation between extraction wells and reinjection wells. The treated groundwater would be conveyed to the reinjection wells by a 10 gpm pump with sufficient hydraulic head for discharge into the aquifer. In order to minimize potential maintenance problems due to clogging (caused by biological growth, iron oxides, etc.), the

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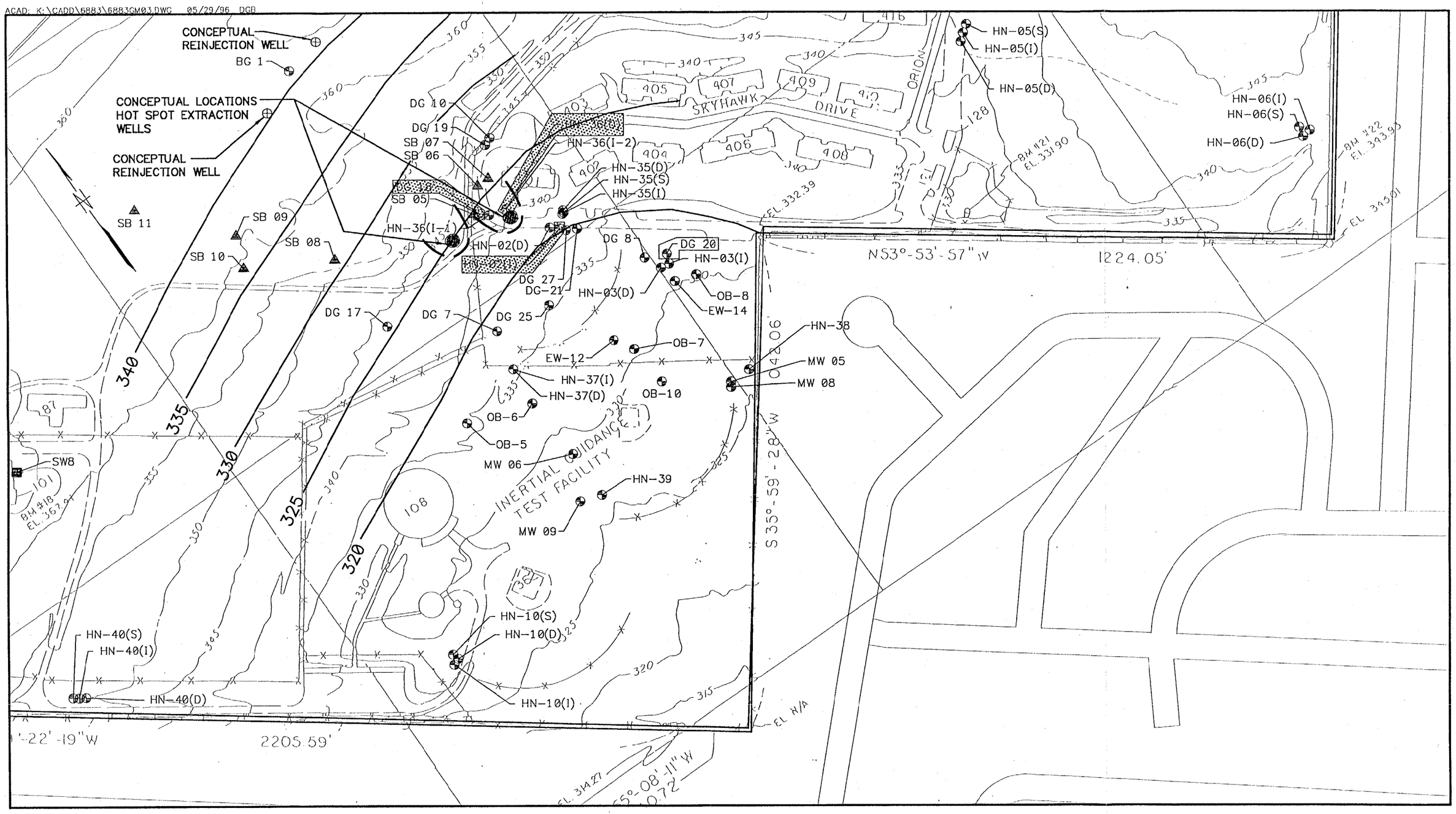

LEGEND

- ⊕ CONCEPTUAL REINJECTION WELL
- EXISTING WELL
- ▲ SOIL BORING
- ■ BASE WATER SUPPLY WELL
- INDICATES CONTAMINANT CONCENTRATION ABOVE MCL.
- EXTRACTION WELL

CONCEPTUAL EXTRACTION WELL AND REINJECTION WELL LOCATIONS ALTERNATIVE B3, AREA B NAWC, WARMINSTER, PA

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FIGURE 4-4

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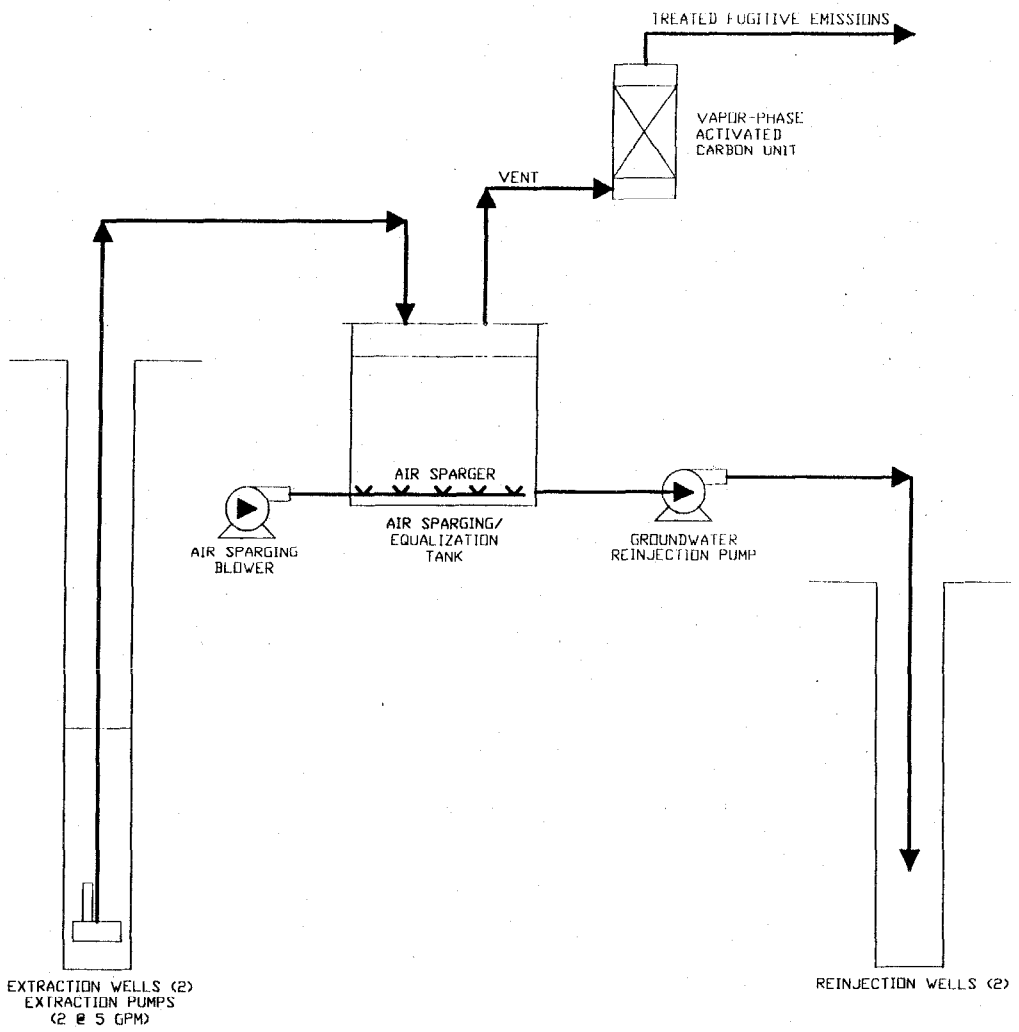

ALTERNATIVE B3, AREA B
EXTRACTION, TREATMENT (AIR SPARGING), REINJECTION
CONCEPTUAL PROCESS FLOW DIAGRAM
NAWC WARMINSTER, WARMINSTER, PA.

FIGURE 4-5

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reinjection wells would feature relatively large gravel pack and screen slot sizes. Figure 4-4 also shows the anticipated locations of the reinjection wells.

The equalization tank would be equipped with a vent and a flexible-hose connection to the lead unit of an off-gas treatment system consisting of two GAC canisters connected in series. When breakthrough of VOCs would be observed in the outlet of the lead canister (based on field instrument readings), it would be replaced by a fresh one. The canister previously in the lag position would be reconnected in the lead position, and the fresh canister would be placed in the lag position. The spent canister would be sent offsite for GAC regeneration. Assuming conservatively that 100 percent of the VOCs are volatilized and based on maximum detected groundwater concentrations, a total of approximately 1.0 lb/day of VOCs (consisting mainly of TCE, benzene, and carbon disulfide) would be captured by the off-gas treatment system. Assuming conservatively an adsorption coefficient of 0.01 pound of VOC captured per pound of GAC, approximately 365 pounds of GAC would be consumed in a year and changeout of a canister containing 200 pounds of GAC would be required about every 6 months.

All of the treatment system's equipment would be installed on a concrete pad within a temperature-controlled building. In order to maintain design conditions for air sparging, the temperature of the ambient air within the building would not be allowed to fall below 50 °F, which is the minimum expected groundwater temperature.

Modeling using ECTRAN™ predicts that, assuming the removal of the source(s) of contamination, restoration of the Area B aquifer for TCE and benzene would be accelerated as compared with natural attenuation and would occur within approximately 5 years, instead of 8. In addition, the active pumping of groundwater would restrict migration of contamination and help control the movement of groundwater in the area. A summary discussion of the model was presented under Alternative B2 in Section 4.3.2.

Conceptual design calculations for the groundwater extraction, treatment, and reinjection systems are presented in Appendix C. Further investigation to delineate the source(s) of contamination and the contaminant plumes are recommended prior to remedial design. Further hydrogeological studies would be necessary during remedial design to confirm the design of the extraction/reinjection system.

Long-term groundwater quality monitoring would be conducted as described under Alternative B2 in Section 4.2.2 to assess the effectiveness of the remedial action.

Institutional controls would be implemented to prevent the on-site use of the Area B groundwater for domestic purposes until the RAOs have been met.

This alternative would also include preparation of deed restrictions to ensure that the remedial action, groundwater monitoring, and institutional controls continue to be implemented if the site changes ownership before the RAOs are met.

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and Environment:

This alternative would be protective of human health by actively remediating the Area B aquifer, confirming that off-site contaminant migration at levels exceeding MCLs does not occur, and prohibiting on-site use of contaminated groundwater for domestic purposes and monitoring its quality until the RAOs have been met. No environmental receptors have been identified at Area B and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would eventually comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. The treated groundwater would likely be suitable for reinjection into the aquifer. This alternative would also comply with action-specific ARARs, including PADEP's policy of not allowing discharge of untreated gaseous emissions to the atmosphere. It must be noted that, even without treatment, the maximum expected emission rate of VOCs from the treatment system would be less than 0.01 lb/day, and therefore far below the OSWER Directive 9355.0-28 limit of 15 lbs/day for air strippers at CERCLA remedial action sites.

Long-Term Effectiveness and Permanence:

This alternative would have long-term effectiveness since it would accelerate the attenuation of TCE and benzene in the Area B aquifer and reduce off-site migration of groundwater contaminants through the use of groundwater extraction at locations of higher contamination. This alternative would also be effective as

it would monitor groundwater quality to verify the effectiveness of the remedy and confirm that off-site migration of these contaminants at levels exceeding MCLs does not occur. Moreover, by implementing institutional controls this alternative would prevent the on-site use of the Area B groundwater for domestic purposes until the RAOs have been met. This alternative would ensure that the remedial action, monitoring, and institutional controls would continue to be implemented if the site changes ownership before the RAOs have been met.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would reduce toxicity, mobility, and volume through treatment. Approximately 0.01 lb/day of VOCs (TCE, benzene, and miscellaneous other VOCs) would be removed from the Area B groundwater with air sparging and vapor-phase GAC adsorption. These VOCs would be ultimately destroyed (100% irreversibly) during the regeneration of the spent GAC. This alternative satisfies the statutory preference for treatment for the reduction of the risks posed by the contaminated groundwater.

Short-Term Effectiveness:

This alternative would be effective in the short term. Remedial action goals are expected to be achieved within approximately five years after initiation of remedial action, assuming that the suspected source(s) of contamination are removed. During the remedial action, the risk of exposure to contaminants would be minimal for the operating personnel of the new groundwater treatment system and the surrounding community since any VOC emissions would be captured by the offgas GAC adsorption system. Off-site transportation of the spent GAC would not pose an undue threat to the community or the environment. Construction, operation, and monitoring personnel would wear the required PPE and receive the appropriate health and safety training.

Implementability:

This alternative would be readily implementable. The unit processes of the new groundwater extraction, treatment, and reinjection systems are of well-proven effectiveness. The materials and equipment for these systems would be readily available and relatively easy to install and operate. Maintenance of equipment would involve checking well screens (especially for the reinjection wells) for periodic cleaning, infrequent replacement of well screens/redrilling, routine maintenance of blowers and pumps, periodic cleaning of the equalization tank air diffusion system, and replacement of spent GAC canisters, none of

which present a major concern. A groundwater reinjection permit would not likely be required from the PADEP.

Cost:

Capital Cost: $466,900
O&M Cost: $153,900 for the first year, $69,500/year thereafter
Present-Worth: $864,000 over 30 years

Detailed cost estimates are included in Appendix A.

4.3.4 Alternative B4: Extraction, Treatment at Existing Treatment System, Discharge To Outfall 001

This alternative would utilize a hot-spot groundwater extraction system identical to the one previously described for Alternative B3 in Section 4.3.3. The extracted groundwater would then be treated in the existing Treatment System located at Area A. The treated groundwater would be discharged at existing Outfall 001.

The extracted groundwater would be conveyed to the existing Treatment System via a transfer pipeline featuring double-wall containment and a leak detection system. Each of the two groundwater extraction wells would be equipped with a submersible centrifugal pump capable of delivering 5 gpm. Figure 4-6 shows the proposed route of the pipeline that would be used for conveying the groundwater from Area B to the existing Treatment System via a connection with existing transfer lines.

At the existing Treatment System, the Area B groundwater would be blended with the groundwater from other NAWC areas and treated for the removal of any inorganics and VOCs. The unit processes of the existing Treatment System are shown on Figure 4-3 and have been described in some detail under Alternative A3 for the Area A groundwater in Section 4.2.3.

The existing Treatment System's design influent concentration of TCE is 300 μg/L. Therefore, with a maximum detected concentration of only 12 μg/L the TCE in the Area B groundwater would be adequately removed by the existing Treatment System. This system's design influent concentrations for the other Area B VOC of concern, benzene, is only 1.3 μg/L whereas the maximum detected concentration of benzene in the Area B groundwater is 20 μg/L. However, the existing Treatment System's unit processes

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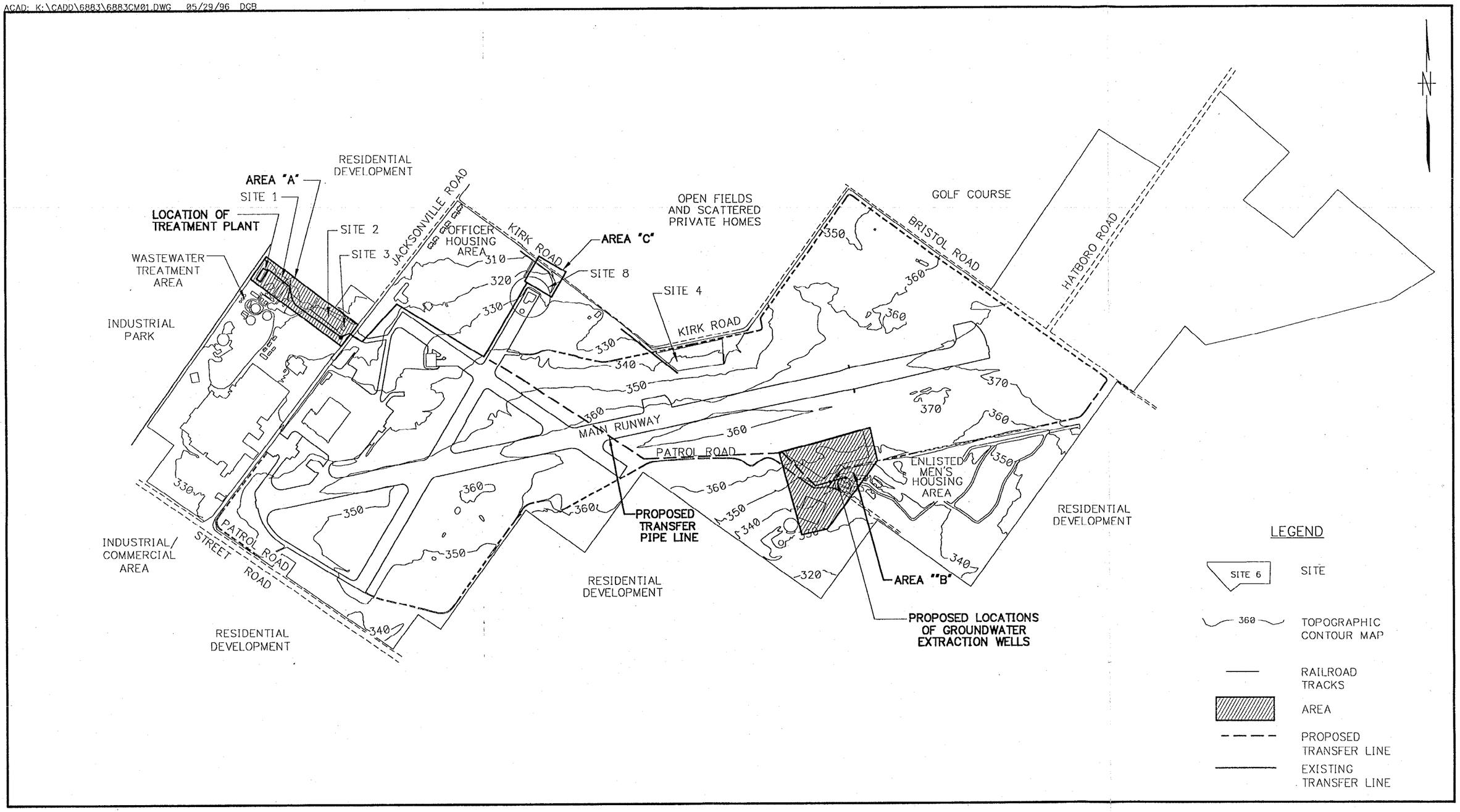

FIGURE 4-6

TRANSFER PIPE LAYOUT FOR ALTERNATIVE B4, AREA B
NAWC, WARMINSTER, PA.

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such as air stripping and liquid-and vapor-phase GAC adsorption would be readily able to achieve adequate removal of benzene from the Area B groundwater and achieve treatment objectives for discharge at the 001 Outfall.

Addition of the Area B groundwater to the existing Treatment System's influent would be feasible since the expected groundwater extraction rate at Area B would only be 10 gpm, which is less than 8 percent of the 130 gpm total design flow rate of the existing Treatment System. It should be noted, however, that, if the Area D groundwater would also be added to the groundwater from Areas A, B, and C for treatment at the existing Treatment System, the hydraulic capacity of that system would be exceeded by about 40 gpm and, therefore, one or more unit processes in the treatment train would have to replaced or appropriately modified. As indicated under Alternative A3 in Section 4.1.3, all costs associated with modification of the existing Treatment System are reported under Alternative D3 for the Area D groundwater in Section 4.4.3.

Modeling using ECTRAN™ predicts that, assuming the removal of the source(s) of contamination, this alternative would accelerate the restoration of the Area B aquifer for TCE and benzene as compared to natural attenuation and would achieve the remedial goals within approximately 5 years instead of 8. A summary discussion of the model was presented under Alternative B2 in Section 4.3.2.

Groundwater quality monitoring would be performed as described for Alternative B3 in Section 4.3.3 to assess the effectiveness of the remedial action.

Institutional controls would be implemented to prevent on-site use of the Area B groundwater for domestic purposes.

This alternative might also include the preparation of deed restrictions to ensure the continued implementation of the remedial action, groundwater monitoring, an institutional controls, if the site changes ownership before the RAOs are met.

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and Environment:

This alternative would be protective of human health by actively remediating the Area B aquifer, confirming that off-site contaminant migration at levels exceeding MCLs does not occur, and preventing on-site use of contaminated groundwater for domestic purposes and monitoring is quality until the RAOs have been met. No environmental receptors have been identified at Area B and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would eventually comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. This alternative would also comply with action-specific ARARs, including the requirements of the NPDES permit limits established for discharge at Outfall 001. The inclusion of the contaminated Area B groundwater would have a minimal impact on the designed capability of the existing Treatment System to meet these discharge limits.

Long-Term Effectiveness and Permanence:

This alternative would have long-term effectiveness and permanence since it would accelerate the natural attenuation of TCE and benzene in the Area B aquifer through the use of groundwater extraction at location of highest contamination. This alternative would also be effective as it would monitor groundwater quality to verify the effectiveness of the remedy and to confirm that off-site migration of contamination at levels exceeding MCLs does not occur. Institutional controls would prevent on-site use of the Area B groundwater for domestic purposes until the RAOs have been met. This alternative would ensure that the remedial action, monitoring, and institutional controls would continue to be implemented if the site changes ownership before the RAOs have been met.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would reduce toxicity, mobility, and volume through treatment. Approximately 0.01 lb/day of VOCs (TCE, benzene, and miscellaneous other VOCs) would be removed from the Area B groundwater in the existing Treatment System with air stripping and vapor- and liquid-phase GAC adsorption. The removed VOCs would ultimately be destroyed (100% irreversibly) during the regeneration of the spent

GAC. This alternative would satisfy the statutory preference for treatment to reduce the risk posed by contaminated groundwater.

Short-Term Effectiveness:

This alternative would be effective in the short-term. Remedial action goals are expected to be achieved within approximately five years after initiation of remedial action, assuming that the suspected source(s) of contamination are removed. During remediation, there would minimal risks of exposure to contaminants for the operating personnel of the existing Treatment System and the surrounding community since VOC emissions would be treated with an offgas GAC adsorption system and since the filter press cake would not likely be hazardous. Off-site transportation of the spent GAC (liquid- and vapor-phase) and filter press cake. The addition of the Area B groundwater would have a minimal impact on the existing Treatment System's efficiency or on the quantity or composition of this system's by-products (spent GAC and filter press cake). Construction, operation, and monitoring personnel would wear the required PPE and receive the appropriate health and safety training.

Implementability:

This alternative would be readily implementable. The equipment and services required for the installation of the new groundwater extraction system are readily available. No modification would be required to the existing Treatment System to accommodate the Area B groundwater. All of the unit processes of this system are well-proven, reliable, and effective for the removal of VOCs when properly operated and maintained. The requirements of a modified NPDES permit would be met for discharge of the treated Area B groundwater at the existing Outfall 001. Long-term monitoring of groundwater quality would be easy to perform. The administrative and legal services which might be required to prepare deed restrictions if the site changes ownership would be readily available.

Cost:

Capital Cost: $1,046,800
O&M Cost: $152,600 for the first year, $68,200/year thereafter
Present-Worth: $1,438,000 over 30 years

Detailed cost estimates are included in Appendix A.

4.4 AREA D ALTERNATIVES (INTERIM REMEDY)

The alternatives that have been developed and retained after screening for the interim remediation of the Area D groundwater are the following:

- Alternative D1: No Action
- Alternative D2: Institutional Controls and Monitoring
- Alternative D3: Extraction, Treatment at existing Treatment System, Discharge To Outfall 001

4.4.1 Alternative D1: No Action

This alternative would not involve any remedial action. No monitoring would be conducted to assess off-site migration of contaminants or natural attenuation, if any.

Overall Protection of Human Health and Environment:

This alternative would not be protective of human health since it would not remedy the Area D aquifer, or prevent off-site contaminant migration, or prevent on-site exposure to contaminated groundwater. Although the groundwater at Area D is not currently used as a potable water source, the health of potential future users would be adversely affected. No environmental receptors have been identified at Area D and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs:

As interim remedies, the Area D groundwater actions are not required to fully comply with ARARs. However, this alternative would not would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Specifically, concentrations of TCE and PCE would continue to exceed their respective standards. No action-specific ARARs would need to be addressed since no remedial action would be performed.

Long-Term Effectiveness and Permanence:

This alternative would have no long-term effectiveness or permanence since it would not remedy the Area D aquifer, or contain off-site contaminant migration, or prevent on-site exposure to contaminated groundwater. Since no remedial action would be performed, the current and future threat to human health and the environment would remain. Since no monitoring would be conducted, the effects of off-site contaminant migration and natural attenuation, if any, would not be determined.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

There would be no reduction of toxicity, mobility, and volume through treatment. Any reduction in groundwater toxicity through natural attenuation of TCE and PCE would not be monitored. This alternative would not satisfy the statutory preference for treatment to reduce the risks posed by contaminated groundwater.

Short-Term Effectiveness:

Short-term effectiveness is not relevant to this alternative since no remedial action would be performed which could create additional short-term risks to the local community or future on-site workers. Current risks would remain unchanged. None of the RAOs would be met.

Implementability:

Implementability is not relevant to this alternative since no remedial action will be implemented.

Cost:

Capital Cost: $0
O&M Cost: $0/year
Present-Worth: $0

4.4.2 Alternative D2: Institutional Controls and Monitoring

This alternative would consist of implementing institutional controls to prevent current and future use of the Area D groundwater for domestic purposes and conducting long-term groundwater monitoring.

Monitoring would consist of sampling groundwater from a set of 8 wells installed in the vicinity of Area D as selected in the specifications of the Interim Action System (HNUS, Design Analysis Report, 1994). The actual wells to be used for monitoring would be selected after evaluation of the results from the ongoing Area D source investigation is completed. Groundwater samples would be sampled monthly during the first quarter and quarterly thereafter. The samples would be analyzed for Target Compound List (TCL) organics.

This alternative would also include preparation of deed restrictions to ensure continued implementation of institutional controls and groundwater quality monitoring if the site changes ownership.

Five-year site reviews would be conducted to assess the status of contamination and to determine the direction of further action.

Overall Protection of Human Health and The Environment:

This alternative would provide limited protection of human health since it would not remedy the Area D aquifer or contain off-site contaminant migration but it would nonetheless prevent on-site exposure to the contaminated Area D groundwater by prohibiting its use for domestic purposes. The groundwater quality monitoring performed with this alternative might also provide limited protection to downgradient groundwater users by allowing the responsible agency to detect potential off-site contaminant migration, evaluate potential impacts to downgradient receptors, and take action to mitigate health risks. No ecological receptors have been identified at Area D and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

As interim remedies, the Area D groundwater actions are not required to fully comply with ARARs. However, this alternative would not comply with Pennsylvania's Statewide Human Health Standards for Groundwater and Federal Safe Drinking Water Act MCLs. Specifically, concentrations of TCE and PCE

would continue to exceed their respective standards. No action-specific ARARs would need to be addressed since no active remedial action, other than monitoring, would take place.

Long-Term Effectiveness and Permanence:

This alternative would have limited long-term effectiveness and permanence since it would not remedy the Area D aquifer or contain off-site contaminant migration but it would nonetheless prevent on-site exposure to contaminated groundwater by prohibiting its use for domestic purposes. This alternative would also monitor groundwater quality which would allow an evaluation of potential off-site contaminant migration and natural attenuation, if any. This alternative would also ensure that monitoring and institutional controls would continue to be implemented if the site changes ownership.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

There would be no reduction of toxicity, mobility, and volume through treatment because no active remediation would take place. Any reduction in the concentration of VOCs of concern through natural attenuation, if any, would be assessed by monitoring. This alternative would not satisfy the statutory preference for treatment to reduce risks posed by the contaminated groundwater.

Short-Term Effectiveness:

This alternative would involve no remedial action other than groundwater quality monitoring, administration of institutional controls, and potential preparation of deed restrictions. The short-term risks associated with these limited remedial activities would be minimal. Sampling personnel would wear the required PPE and receive the appropriate health and safety training. This alternative could be implemented immediately after the signing of the ROD. Deed restrictions, if required, might take up to a year or more to implement, depending on the properties affected.

Implementability:

This alternative would be readily-implementable since it would only involve long-term monitoring groundwater quality, administration of institutional controls, and potential preparation of deed restrictions if NAWC Warminster changes ownership. As mentioned above, this alternative could be implemented immediately after signing of the ROD although deed restrictions, if required, might take up to a year or

more to implement. However, it should be noted that implementation of this alternative may restrict options being considered under a long-term utility plan to be implemented as part of the base closure master plan.

Cost:

Capital costs: $0
O&M costs: $61,750 for the first year, $32,200/year thereafter
Present-Worth: $579,000 estimated over 30 years

Detailed cost estimates are included in Appendix A.

4.4.3 Alternative D3: Extraction, Treatment at existing Treatment System, Discharge at Outfall 001

In this alternative, the contaminated Area D groundwater would be extracted, treated at the existing Treatment System, and discharged to the unnamed tributary of Neshaminy Creek at existing Outfall 001. This alternative would also include the continued operation of off-site well WTMA26, from which groundwater is currently pumped, treated by air stripping and chlorination, and delivered to the municipal water supply system.

The design for the Area D extraction system considered the following information:

- The area of highest groundwater impacts within Area D appears to be located near the northwestern edge of the building complex.
- The off-base extent groundwater contamination to the north-northwest is unknown at this time.
- Groundwater contamination appears to be only marginally above MCL's along the downgradient (northwest) edge of Area D.
- Most of the groundwater impacts on base within Area A are within the top 100 to 130 feet of the bedrock aquifer.

- Municipal water supply well WTMA No. 26 is located generally north of Area D, and serves as a collection point for contaminated groundwater between the base and the municipal well.

Based on the above factors and site-specific hydrogeologic information, a conceptual remedial design strategy was developed for Area D groundwater. The approach selected is designed to provide on-site containment of the Navy source area along the northwestern edge of Area D. This approach prevents further releases of contaminants from Area D while the potential need for additional off-site extraction wells is evaluated as a part of ongoing off-site groundwater investigation work. Details regarding the design approach and calculations are presented in Appendix C.

A modification to a strict hydraulic containment-type approach that should also be considered during the remedy selection process is to focus the groundwater extraction efforts within discrete hot spot areas of groundwater impacts within Area D (i.e., near wells MP-1, HN-31, HN-32). This modification would better focus groundwater extraction and contaminant removal efforts within Area D, while still providing some plume containment. Repositioning of the wells to focus on hot spots could be achieved with the same pumping rate as was calculated in Appendix C for plume containment.

The groundwater extraction system for this alternative would consist of 4 wells screened within the deeper portion of the aquifer at an average depth of approximately 100 feet. Each well would be 6-inch in diameter and would yield on average approximately 9 to 9.5 gpm, for a total groundwater extraction flow rate of approximately 37 gpm. These wells would be installed along the northwestern edge of the NAWC boundary in the vicinity of monitoring well clusters HN-33, HN-17, and SW1/SW2. Well SW2 was considered as a potential option for all extraction wells; however, the contaminant levels in this well have not been consistent and have decreased over recent sampling events. In addition, this well was constructed as an open boring and its use as an extraction well would require further hydrologic studies and possible sealing or casing-off of portions of the well to optimize extraction zones. The use of SW2 alone would not provide the lateral spacing necessary to provide an effective recovery zone. For these reasons and considering the current use of SW2 to provide water for fire protection systems, this well has not been included in the conceptual design used to evaluate and cost this alternative.

Figure 4-2 shows the proposed lay-out of the Area D groundwater extraction wells and their capture zone. At the time of remedial design, review of additional groundwater monitoring data may suggest advantages to relocating some or all of the Area D groundwater extraction wells in the vicinity of monitoring wells MP 1, HN-31S, HN-32S, and MP 3 to capture groundwater from areas of higher contamination. At that

time, the composite influent concentrations to the existing treatment plant must be taken into consideration to evaluate the efficiency of the air stripper, and perform any upgrades as necessary. Any off-site contaminant migration attributable to Area D would be captured and treated by the WTMA26 groundwater extraction and air stripping system.

The Area D groundwater would be conveyed to the existing Treatment System located at Area A by means of a pipeline featuring double-wall containment and a leak detection system. At the existing Treatment System, the Area D groundwater would be blended with the groundwater from other NAWC areas and treated for the removal of inorganics and VOCs of concern.

A process flow diagram of the existing Treatment System is shown on Figure 4-3. The unit processes of the existing Treatment System have been previously described in some detail under Alternative A3 for the Area A groundwater in Section 4.2.3.

The maximum and average concentrations of the VOCs of concern for the Area D groundwater are shown on Table 4-3 together with their respective NPDES discharge limits or Pennsylvania's WQCs for Toxic Substances.

Based upon the comparison shown on Table 4-3, the TCE and PCE concentration of the Area D groundwater may need to be reduced through treatment to achieve their respective discharge limits.

Table 4-4 presents the anticipated concentrations of VOCs, including chloroform, carbon tetrachloride, TCE, and PCE in the groundwater from Areas A, C, and D and an estimate of the concentrations of these VOCs in the composite influent to the existing Treatment System. The composite influent concentrations were obtained by averaging the concentrations of VOCs in Areas A, C, and D groundwater, and using their extraction rates of 63 gpm, 59 gpm and 37 gpm, respectively. Table 4-4 also compares the composite influent concentrations of VOCs of concern with the design influent concentrations of the existing Treatment System.

It should be noted that Area B groundwater has not been included in the composite, because the minor concentrations of VOCs exceeding MCLs (TCE at maximum 12 μg/L and benzene at maximum 20 μg/L) would reduce the conservatively high concentrations of the composite. However, the Area B groundwater flow rate of 10 gpm was included to yield a total influent flow rate of 170 gpm to yield a conservatively high hydraulic loading.

TABLE 4-3

MAXIMUM AND AVERAGE VOCs CONCENTRATIONS OF VOCs IN AREA D GROUNDWATER AND ANTICIPATED DISCHARGE LIMITS

FEASIGILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

VOC	Maximum Concentration (µg/L)	Average Concentration (µg/L)	Anticipated Discharge Limit (µg/L)
1,2-Dichloroethene	3	1	700 (WQC)
Chloroform	3	ND	6 (WQC)
2-Butanone	3	ND	None
1,1,1-Trichloroethane	4	ND	1000 (WQC)
Carbon Tetrachloride	1	ND	1.3 (average monthly) 3.3 (instantaneous maximum)
Trichloroethene (TCE)	170	47	13 (average monthly) 33 (instantaneous maximum)
4-Methyl, 2-Pentanone	ND	ND	None
2-Hexanone	1	ND	None
Tetrachloroethene (PCE)	3	1	0.7 (WQC)

NOTES:

1. ND: Non-Detect at method detection limit
2. WQC: Pennsylvania's Water Quality Criteria for Toxic Substances, Appendix A, Table 1, PA Title 25, Chapter 16, as amended April 30, 1994
3. Anticipated limits for carbon tetrachloride and TCE were estimated by converting their respective limits for a flow rate of 130 gpm (for the interim action system) to those that might be applicable for a flow rate of 170 gpm, assuming the same allowable mass loading for these VOCs. Based on the comparison shown in the above table, the groundwater from Area D would contribute the following VOCs that may need to be treated to achieve their respective discharge limits: TCE and PCE.

TABLE 4-4

SUMMARY OF VOCs CONCENTRATIONS FOR AREAS A, C, AND D GROUNDWATER AND INTERIM TREATMENT SYSTEM INFLUENT DESIGN CONCENTRATIONS

FEASIBILITY STUDY FOR
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

VOC	Area A Concentration (Max/Ave) µg/L	Area C Concentration (Max/Ave) µg/L	Area D Concentration (Max/Ave) µg/L	Composite Concentration (Max/Ave) µg/L	Design Influent Concentration[1] (µg/L)
TCE	100,000/3694	ND/ND	170/47	39,414/1,465	300
Chloroform	370/9	ND/ND	1/ND	146/3.5	9.3
Carbon Tetrachloride	2600/52	ND/ND	1/ND	1,024/20.5	11.3
PCE	320/51	29/2	3/1	138/21	82.5

NOTES:

1. Excerpted from "Concentrations of as-Received at Treatment", Design Analysis Report, HNUS, 1995

Given the composite influent concentrations of VOCs of concern shown on Table 4-4, and an additional flow rate of 40 gpm over the existing Treatment System's design flow rate of 130 gpm, the critical unit operations and processes of this system would need to be analyzed for VOC removal efficiency and adequate hydraulic capacity. The most critical unit processes used for VOCs removal and the available design information on these are as follows:

- A low-profile tray-type air stripper with a design maximum hydraulic capacity of 140 gpm (Delta Cooling Towers, facsimile, April 15, 1996)

- A vapor-phase GAC adsorption system with a design maximum gas-flow rate of 1650 cfm (HNUS, memorandum, May 24, 1995)

The liquid-phase GAC adsorption system downstream of the air stripper is designed as a polishing stage for removal of SVOCs and residual VOCs in the effluent of the air stripper, if any. Since SVOCs are very efficiently adsorbed on activated carbon, the increase in flow rate would probably not impact adversely the function of the liquid-phase activated carbon adsorption system.

The major modifications that are required for upgrading the existing Treatment System to accommodate the additional flow rate and improve the VOC removal efficiency would therefore be as follows:

- Provide an air stripper with a design hydraulic flow rate of 170 gpm and featuring additional tray elements for improved VOCs removal efficiency.

- Provide a vapor-phase GAC adsorption system with a design gas flow rate of 2200 cfm.

Use of the existing air stripper at supply wells SW1/SW 2 was also considered as an option to increase the capacity of the existing Treatment System. Design drawings and technical specifications were reviewed for this air stripper and a site inspection was conducted. This review and inspection revealed that, while the SW1/SW2 air stripper appeared to be in satisfactory condition and has a design water flow rate of 350 gpm, it would be unsuitable for the purpose of treating the Area D groundwater, since its minimum design throughput of 100 gpm would be almost three times greater than the 37 gpm extraction rate of the Area D groundwater. The SW1/SW2 air stripper also lacks any pretreatment systems for the removal of suspended solids and inorganic contaminant and offgas treatment system for the capture of VOC emission from the stripper. These auxiliary systems would therefore have to be provided, which

would offset any cost benefit the use of the SW1/SW2 air stripper might have provided. The future use of this air stripper and the possible use of SW2 as a component of future permanent long-term groundwater extraction and treatment systems should be considered after completion of ongoing investigations. The formulation of final remedial alternatives should evaluate the possible use of both of these wells as extraction recovery wells and should evaluate the feasibility of maintaining them and the associated contaminant treatment components as part of the long-term utilities plan to be implemented with base closure and transfer.

The other existing Treatment System unit processes upstream of the air stripper that are designed for a flow rate of 130 gpm are : (1) Equalization, (2) Flash-mixing/Flocculation/Clarification, (3) Transfer Tank, and (4) Continuous Backwashing Sand Filtration. These components are capable of accommodating the additional flow rate of 30 gpm because adequately conservative design bases (i.e., hydraulic detention times and hydraulic flux rates) have been employed in their sizing. Unless otherwise determined from review of the as-built design information for the existing Treatment System which is in progress, these unit processes should not require modification.

For costing purposes, it was assumed that the modification of the existing Treatment System would only include replacement of the current air stripper and vapor-phase GAC adsorption system with the larger above-mentioned units. It is not anticipated that any of the piping or vapor ducts would need to be increased in size.

Institutional controls would be implemented to prevent the use of the Area D groundwater for domestic purposes.

Long-term groundwater monitoring would be conducted to ensure that off-site migration of the contaminant plumes is minimized. Monitoring would consist of sampling from 18 monitoring wells that were selected during the interim action treatment system design. During the first year, the sampling would be conducted monthly to establish a trend in the contaminant levels. After the trend has been established during subsequent years, the sampling would be conducted on a quarterly basis.

This alternative would also include preparation of deed restrictions to ensure continued implementation of the institutional controls and groundwater monitoring if the site changes ownership.

Although not an essential or integral component of this alternative, the effect of continued operation of upgradient supply wells (SW3 and SW4) should be evaluated as part of the ongoing groundwater investigations for Area D. The potential benefits of continued operation of these wells as a long-term mechanism to control and/or maintain current groundwater flow patterns in the area should be evaluated as part of the final remedy for Area D groundwater. This evaluation should consider the strategies and needs identified in the utility plan being developed for base closure and reuse.

Five-year site reviews would be conducted to assess contamination and to determine the necessity and direction of further action.

Overall Protection of Human Health and The Environment:

This alternative would be provide short-term and limited long-term protection of human health by minimizing off-site contaminant migration. Any off-site contaminant migration would be captured and treated by the WTMA26 extraction and treatment system. Institutional controls would prevent on-site use of the contaminated Area D groundwater. Long-term monitoring of the groundwater quality would allow for continued assessment of the area D aquifer until a final remedy is implemented. No environmental receptors have been identified at Area D and, therefore, environmental effects of this alternative are not relevant.

Compliance with ARARs and TBCs:

This alternative would not comply with Pennsylvania's Statewide Human Health Standards for Groundwater and Federal Safe Drinking Water Act MCLs. However, as an interim remedy, this alternative does not have to fully comply with ARARs. It should also be noted that source areas investigations are ongoing at Area D and additional groundwater evaluations are under consideration. If the ongoing investigation and the monitoring results of this alternative indicate presence of DNAPL at Area D, modification of this interim remedy and issuance of a Treatability Impracticability Waiver might satisfy final remedy requirements. All action-specific ARARs for the discharge of treated groundwater and discharge of air emissions would be achieved.

Long-Term Effectiveness and Permanence:

This alternative would be effective in minimizing the off-site migration of VOCs of concern from Area D. Some remediation of the Area D aquifer would also occur if a few of the groundwater extraction wells are relocated in the areas of higher contamination. Institutional controls would be implemented to prevent on-site use of the contaminated groundwater for domestic purposes and long-term groundwater monitoring would be conducted to check for off-site contaminant migration. Residual on-site contamination would remain. However, this would be acceptable since this alternative is an interim remedy.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

This alternative would reduce mobility and, to a lesser extent, toxicity and volume through treatment. Approximately 0.02 lb/day of total VOCs would be removed from the Area D groundwater through extraction and treatment with air stripping and vapor- and liquid-phase GAC. The removed VOCs would ultimately be destroyed (100% irreversibly) during the off-site regeneration of the spent GAC. This alternative would satisfy the statutory preference for treatment to reduce the risks posed by the contaminated groundwater.

Short-Term Effectiveness:

During remediation, there would be minimal risks to the operating personnel of the existing Treatment System and the surrounding community since VOC emissions would be treated by the offgas GAC adsorption system and the filter press cake would not likely be hazardous. Off-site transportation of the spent GAC (liquid- and vapor-phase) and filter press cake would not pose an undue threat to the community or the environment. Construction, operating, and sampling personnel would wear the required PPE and receive the appropriate health and safety training.

Implementability:

This alternative would be readily implementable. The equipment and services required for the installation of the new groundwater extraction system and the modification of the existing Treatment System would be readily available. All of the proposed groundwater extraction system components, and the existing Treatment System unit processes are well proven, reliable, and effective for the removal of VOCs when properly maintained and operated. The requirements of a modified NPDES permit would be met for

discharge of the treated Area D groundwater at existing Outfall 001. Long-term groundwater monitoring would be easy to perform. The administrative and legal services which might be required to prepare deed restrictions if the site changes ownership are readily-available.

Cost:

Capital Cost:	$675,200
O&M Costs:	$79,600 for the first year, $50,000/year thereafter
Present-Worth:	$1,528,000 over 30 years

Detailed cost estimates are included in Appendix A.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

In this section the alternatives of the Area A, B, and D groundwater as evaluated in Section 4.0 are compared to each other using the seven criteria that were used for the detailed analysis.

5.1 AREA A ALTERNATIVES (FINAL REMEDY)

The alternatives for the Area A groundwater are as follows:

- Alternative A1: No Action
- Alternative A2: Institutional Controls and Monitoring
- Alternative A3: Extraction, Treatment at Existing Treatment System, Discharge To Outfall 001

These three alternatives are compared with respect to specific factors for each evaluation criterion and differences are identified. Table 5-1 and the following text summarizes this comparison.

Overall Protection of Human Health and The Environment:

Alternative A1 would not be protective of human health. Alternative A2 would provide minimal protection of human health since it would not stop migration of groundwater contaminants from Area A but would prevent use of the Area A groundwater for domestic purposes and provide groundwater quality monitoring. Alternative A3 would be protective of human health by actively remediating the Area A groundwater, preventing its use for domestic purposes, and monitoring its quality. The extraction well network would minimize any migration of the contaminant plume. Area A groundwater would be treated to meet stream discharge and drinking water standards.

Compliance with ARARs and TBCs:

Alternatives A1 and A2 would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Alternative A3 might eventually comply with these contaminant-specific ARARs if the suspected DNAPL does not recharge groundwater contaminants as anticipated. Alternatives A1 and A2 would not need to comply with any action-specific ARARs since no remedial action would be performed. Alternative A3 would comply with all action-specific ARARs for the discharge of treated groundwater and air emissions and the disposal of treatment residues.

TABLE 5-1

SUMMARY OF COMPARATIVE ANALYSIS FOR AREA A REMEDIAL ALTERNATIVES
AREAS A, B, AND D GROUNDWATER FEASIBILITY STUDY
NAWC WARMINSTER - WARMINSTER, PA

CRITERION	ALTERNATIVE A1: NO ACTION	ALTERNATIVE A2: INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE A3: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT			
Prevent Human Exposure to Contaminated Groundwater	Would not be protective	Institutional controls would provide minimal protection by limiting groundwater use.	Contaminated groundwater would be extracted and treated. Institutional controls would prevent future use and long-term monitoring would monitor effectiveness.
Minimize Migration of Contaminated Groundwater	Would not prevent migration	Long-term monitoring would allow for control of groundwater use but would not minimize migration.	Extraction well network would minimize migration.
COMPLIANCE WITH ARARs			
Chemical and Location Specific ARARs	Would not comply with contaminant-specific ARARs.	Same as Alternative A1.	May comply with contaminant-specific ARARs. DNAPL sources may prevent compliance throughout entire area.
Action-Specific ARARs	No action-specific ARARs would apply.	Same as Alternative A1.	Would comply with action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE			
Magnitude of Residual Risk	Existing risks remain.	Same as Alternative A1.	Existing risks would be decreased in source and far-reaching plume areas. DNAPL may limit restoration and recharge residual contaminants in source area.
Adequacy and Reliability of Controls	No controls in place. Risk and contaminant volume may increase.	Long-term monitoring and institutional controls would provide minimal control.	Extraction well network would effectively minimize migration. Use of WTMA26 would provide long-term effective removal and treatment. Long-term monitoring and deed restrictions would provide additional controls.
Need for 5-Year Review	Residual contamination would remain. However, five-year reviews would not be conducted.	Residual contamination would remain. Five-year reviews would be required.	Residual contaminant levels would remain. Five-year reviews would be required.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT			
Treatment Process Used	None	None	Air stripping and vapor- and liquid- phase GAC adsorption.
Amount Destroyed or Treated	None	None	Remove and destroy 3.0 lbs/day of VOCs from source area. Additional treatment provided by WTMA26 system in far-reaching plume area.

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TABLE 5-1 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA A REMEDIAL ALTERNATIVES
NAWC WARMINSTER
AREAS A, B, AND D GROUNWATER
FEASIBILITY STUDY
WARMINSTER, PA

CRITERION	ALTERNATIVE A1: NO ACTION	ALTERNATIVE A2: INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE A3: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
Irreversible Treatment	None	None	Contaminants removed would be completely destroyed.
Statutory Preference for Treatment	No treatment provided.	No treatment provided.	Achieves statutory preference for treatment.
SHORT-TERM EFFECTIVENESS			
Community Protection	No risk reduction.	Institutional controls would provide limited protection from exposure but not from migration. Implementation would present minimal risks.	Same as Alternative A2 with additional protection through control of migration and removal and treatment of contaminants. Implementation would present minimal risks.
Worker Protection	Not applicable.	Monitoring would present minimal risks.	Installation and operation of systems and monitoring would present minimal easily controllable risks.
IMPLEMENTABILITY			
Ability to Construct and Operate	No construction or operation is involved.	No difficulties are anticipated.	No difficulties are anticipated. The existing Treatment System could be easily modified to accommodate additional loading.
Ability to Monitor Effectiveness	No monitoring would be conducted.	Monitoring would provide assessment of potential exposures, contaminant concentrations, and migration.	Same as Alternative A2.
Availability of Technology	No remedial technology is involved.	No remedial technology is involved. Institutional controls are commonly used to limited exposure to site contaminants.	Well proven treatment processes. A new extraction system and minor modifications to existing treatment systems would be required. Technology for complete destruction of recovered contaminants is in-use. Institutional controls are commonly used to limit exposure.
COST			
Capital Cost	$0	$0	$748,000
First Year and Annual O&M Cost	$0	$81,350 $42,200	$122,000 $82,500
30-Year Present-Worth Cost	$0	$742,000	$2,109,000

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Long-Term Effectiveness and Permanence:

Alternative A1 would have no long-term effectiveness and permanence. Alternative A2 would have limited effectiveness and permanence since it would not remedy the Area A aquifer or stop migration of groundwater contaminants from Area A but it would nonetheless monitor the quality of the Area A groundwater and prevent its use for domestic purposes. Alternative A3, although it might not achieve complete aquifer remediation in the areas of suspected DNAPL accumulation, would provide long-term effectiveness and permanence through active remediation and containment of the Area A groundwater contaminants coupled with controls to prevent its use for domestic purposes and monitoring to assess its quality.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

Alternatives A1 and A2 would not actively reduce toxicity, mobility, and volume through treatment. Alternative A2 would monitor and quantify contaminant concentrations and migration but neither alternative would actively reduce the risks associated with the Area A groundwater. Alternative A3 would actively reduce toxicity, mobility, and volume through groundwater extraction and treatment with air stripping and vapor- and liquid-phase GAC adsorption. Alternative A3 would remove approximately 3.0 lbs/day of VOCs from the Area A groundwater and these VOCs would ultimately be destroyed (100% irreversibly) during regeneration of the spent GAC. It should be noted, however, that the DNAPL suspected to be present in the Area A aquifer might offset a significant part of the reduction in groundwater toxicity and contaminant volume achieved by Alternative A3 by recharging the Area A aquifer with VOCs. The Alternative A3 groundwater extraction well network would contain and continuously capture any such recharge for treatment at the existing Treatment System. Residual contamination outside of the plume recovery area would also be extracted and treated.

Short-Term Effectiveness:

Alternative A1 would not be effective in the short-term. There would be no risks or concerns associated with remedial action activities under Alternative A1 since none would take place. Alternative A2 would offer minimal short-term effectiveness since it would not clean-up the Area A aquifer or stop migration of groundwater contaminants from Area A . It would nonetheless immediately reduce the risk of exposure by monitoring the Area A groundwater quality and prohibiting its use for domestic purposes. The risks associated with the monitoring activities performed under Alternative A2 would be minimal. Alternative A3 would offer limited short-term effectiveness. It would immediately prevent the risk of exposure by containing groundwater contaminants within Area A and prohibiting its use for domestic purposes, actively

removing approximately 3.0 lbs/day of VOCs from the plume source area, monitoring of the Area A groundwater quality, and intercepting and treating of the far-reaching plume area. Although the plume source area would be contained, restoration of the Area A aquifer may be slowed down by contaminant recharge from suspected DNAPL. For Alternative A3, there would be minimal risks associated with the installation and operation of the new groundwater extraction system, the operation of the existing Treatment System, and the transportation and disposal/reprocessing of the residues generated by this system (filter press cake and spent GAC).

Implementability:

Implementability is not relevant to Alternative A1 since no activities would be implemented. The institutional controls and groundwater monitoring activities associated with Alternative A2 would be readily implementable. Alternatives A2 and A3 would require administrative and legal services for preparation of deed restrictions in case of change in the ownership of NAWC Warminster. The groundwater extraction system used for Alternative A3 would be relatively easy to install. The Treatment System proposed for treatment of the Area A groundwater under Alternative A3 already exists and the minor modifications required to accommodate the additional contaminant load from the Area A groundwater would be easy to implement. The unit processes of this system are well-proven and effective for the removal of VOCs. The modification of the existing NPDES permit for Alternative A3 would be readily-implementable and no modification of the WTMA26 extraction and treatment system would be required.

Cost:

The following table summarizes and compares the estimated capital cost, O&M cost, and 30-year present worth costs of Alternatives A1, A2, and A3 for the Area A groundwater:

Alternative	Capital ($)	Operation & Maintenance ($/year)	Present Worth ($)
Alternative A1	$0	$0	$0
Alternative A2	$0	$81,350 - Year 1 $42,200 - Years 2 to 30	$742,000
Alternative A3	$748,000	$122,000 - Year 1 $82,500 - Years 2 to 30	$2,109,000

5.2 AREA B ALTERNATIVES (FINAL REMEDY)

The alternatives for the Area B groundwater are as follows:

- Alternative B1: No Action
- Alternative B2: Natural Attenuation with Institutional Controls and Monitoring
- Alternative B3: Extraction, Local Treatment, Reinjection
- Alternative B4: Extraction, Treatment at Existing Treatment System, Discharge To Outfall 001

These four alternatives are compared with respect to specific factors for each evaluation criterion and differences are identified. Table 5-2 and the following text summarizes this comparison.

Overall Protection of Human Health and The Environment:

Alternative B1 would not be protective of human health. Alternative B2 would provide limited protection of human health since it would not actively contain migration of groundwater contaminants from Area B. It would nonetheless prevent use of the Area B groundwater for domestic purposes and provide groundwater quality monitoring until the RAOs have been achieved through natural attenuation. Alternatives B3 and B4 would be protective of human health by actively containing contaminant migration and remediating the Area B aquifer, prohibiting use of the Area B groundwater for domestic purposes, and monitoring its quality until the RAOs have been achieved.

Compliance with ARARs and TBCs:

Alternative B1 would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Alternative B1 would not need to comply with any action-specific ARARs since no remedial action would take place. Alternative B2 would eventually comply with contaminant-specific ARARs through natural attenuation. Alternative B2 would not need to comply with any action-specific ARARs, since no remedial action would take place, except for implementation of institutional controls and groundwater monitoring. Alternatives B3 and B4 would comply with contaminant-specific ARARs through active remediation. Alternatives B3 and B4 would comply with all action-specific ARARs for the discharge of treated groundwater and air emissions and the disposal of treatment residues.

TABLE 5-2

SUMMARY OF COMPARATIVE ANALYSIS FOR AREA B REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER - WARMINSTER, PA

CRITERION	ALTERNATIVE B1: NO ACTION	ALTERNATIVE B2: NATURAL ATTENUATION WITH INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE B3: EXTRACTION, ON-SITE TREATMENT, REINJECTION	ALTERNATIVE B4: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT				
Prevent Human Exposure to Contaminated Groundwater	Would not be protective	Limited protection. Monitoring would assess natural attenuation. Institutional controls would limit groundwater use.	Contaminated groundwater would be extracted and treated. Institutional controls would limit groundwater use and long-term monitoring would monitor effectiveness.	Same as Alternative B3.
Minimize Migration of Contaminated Groundwater	Would not prevent migration	Long-term monitoring would allow for control of groundwater use but would not minimize migration.	Extraction well network would minimize migration.	Same as Alternative B3
COMPLIANCE WITH ARARs				
Chemical and Location Specific ARARs	Would not comply with contaminant-specific ARARs.	Contaminant-specific ARARs would be achieved through natural processes.	Would comply with contaminant-specific ARARs.	Same as Alternative B3.
Action-Specific ARARs	No action-specific ARARs would apply.	Same as Alternative B1.	Would comply with action-specific ARARs.	Same as Alternative B3.
LONG-TERM EFFECTIVENESS AND PERMANENCE				
Magnitude of Residual Risk	Existing risks remain.	Existing risks would be decreased to RAOs. Assumes source removal.	Existing risks would be decreased to RAOs.	Same as Alternative B3.

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TABLE 5-2 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA B REMEDIAL GROUNDWATER FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

CRITERION	ALTERNATIVE B1: NO ACTION	ALTERNATIVE B2: NATURAL ATTENUATION WITH INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE B3: EXTRACTION, ON-SITE TREATMENT, REINJECTION	ALTERNATIVE B4: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
Adequacy and Reliability of Controls	No controls in place. Risk and contaminant volume may increase.	Long-term monitoring and institutional controls would provide minimal control.	Extraction well network would effectively minimize migration. Long-term monitoring and deed restrictions would provide additional controls.	Same as Alternative B3.
Need for 5-Year Review	Residual contamination would remain. However, five-year reviews would not be conducted.	Residual contamination would remain. Five-year reviews would be required.	Same as Alternative B2.	Same as Alternative B3.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT				
Treatment Process Used	None	Natural processes.	Air stripping and vapor- phase GAC adsorption.	Same as Alternative B3, along with liquid Phase GAC adsorption.
Amount Destroyed or Treated	None	Would vary according to natural conditions.	Would remove and destroy 0.01 lb/day of VOCs from source area.	Same as Alternative B3.
Irreversible Treatment	None	Contaminants would be altered by natural processes.	Contaminants removed would be completely destroyed.	Same as Alternative B3.
Statutory Preference for Treatment	No treatment provided.	No active treatment pursued.	Satisfies statutory preference for treatment.	Same as Alternative B3.

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TABLE 5-2 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA B REMEDIAL GROUNDWATER
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

CRITERION	ALTERNATIVE B1: NO ACTION	ALTERNATIVE B2: NATURAL ATTENUATION WITH INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE B3: EXTRACTION, ON-SITE TREATMENT, REINJECTION	ALTERNATIVE B4: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
SHORT-TERM EFFECTIVENESS				
Community Protection	No risk reduction.	Institutional controls would provide limited protection from exposure but not from contaminant migration. Implementation would present minimal risks.	Same as Alternative B2 with additional protection through control of migration and removal and treatment of contaminants. Implementation would present minimal risks.	Same as Alternative B3.
Worker Protection	Not applicable.	Monitoring would present minimal risks.	Installation and operation of systems and monitoring would present minimal easily controllabl risks.	Same as Alternative B3.
IMPLEMENTABILITY				
Ability to Construct and Operate	No construction or operation is involved.	No difficulties are anticipated.	No difficulties are anticipated. The extraction, treatment, and reinjection system can be easily constructed. Treatment and reinjection system would require minimal maintenance.	No difficulties are anticipated. The existing treatment and discharge permits would require minimal modifications.
Ability to Monitor Effectiveness	No monitoring would be conducted.	Monitoring would provide assessment of potential exposures, contaminant concentrations, and migration.	Same as Alternative B2.	Same as Alternative B3.

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TABLE 5-2 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA B REMEDIAL GROUNDWATER
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

CRITERION	ALTERNATIVE B1: NO ACTION	ALTERNATIVE B2: NATURAL ATTENUATION WITH INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE B3: EXTRACTION, ON-SITE TREATMENT, REINJECTION	ALTERNATIVE B4: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
Availability of Technology	No remedial technology is involved.	Remedial technology requires analytical monitoring using available methods. Institutional controls are commonly used to limit exposure to site contaminants.	Well-proven treatment processes. Extraction, treatment, and reinjection systems would be required. Technology offers complete destruction of recovered VOCs. Institutional controls are commonly used to limit exposure.	Well-proven treatment processes. Extraction and transfer systems would be required. Complete destruction technology is readily available. Institutional controls are commonly used to limit exposure.
COST				
Capital Cost	$0	$0	$466,900	$1,046,800
First Year and Annual O&M Cost	$0	$98,400 $32,800	$153,900 $69,500	$152,600 $68,200
Present-Worth Cost	$0	$290,000	$864,000	$1,438,000

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Long-Term Effectiveness and Permanence:

Alternative B1 would not offer any long-term effectiveness and permanence since it would not contain contaminant migration or provide any protection against on-site exposure to the contaminated groundwater. Alternative B2 would offer limited long-term effectiveness and permanence since it would not contain contaminant migration but it would nonetheless achieve the RAOs through natural attenuation and provide protection through monitoring and institutional controls until these RAOs are met. Alternatives B3 and B4 would offer long-term effectiveness and permanence by actively containing contaminant migration, remediating the Area B aquifer, and providing protection against exposure to contaminated groundwater through monitoring and institutional controls until the RAOs have been met.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

Alternatives B1 and B2 would not actively reduce toxicity, mobility, and volume through treatment. Alternative B2 would monitor and quantify reduction in groundwater toxicity and contaminant volume through natural attenuation whereas Alternative B1 would not. Alternatives B3 and B4 would actively reduce toxicity, mobility, and volume through groundwater extraction and treatment with air stripping and GAC adsorption. Alternatives B3 and B4 would remove approximately 0.01 lb/day of VOCs from the Area B groundwater and these VOCs would ultimately be destroyed (100% irreversibly) during regeneration of the spent GAC.

Short-Term Effectiveness:

Alternative B1 would have no short-term effectiveness since it would not contain contaminant migration or provide any exposure protection or monitoring. There would be no risks or concerns associated with remedial action activities under Alternative B1 since none would take place. Alternative B2 would have limited short-term effectiveness since it would not contain contaminant migration but would nonetheless immediately reduce the risk of exposure to the Area B groundwater by monitoring groundwater quality and prohibiting its use for domestic purposes until remedial goals have been met through natural attenuation. Assuming removal of the contaminant source(s) and no significant changes in the Area B aquifer hydrological regime and contaminant migration rate as monitored by this alternative, the RAOs would be met within approximately 8 years. The risks associated with the monitoring activities performed under Alternative B2 would be minimal. Alternatives B3 and B4 would have short-term effectiveness as they would actively reduce the risk of exposure to the Area B groundwater by remediating it within 5 years, assuming removal of the source(s) of contamination. Alternative B3 and 7 would also immediately prevent the risk of exposure to the Area B groundwater by monitoring its quality and prohibiting its use for

domestic purposes until the RAOs have been met. There would be minimal risks and concerns associated with the installation and operation of the new groundwater extraction system for Alternatives B3 and B4, the installation and operation of the new treatment system for Alternative B3, and the operation of the existing Treatment System for Alternative B4. There would also be minimal risks associated with the transportation and disposal/reprocessing of the treatment residues generated either by the new treatment system for Alternative B3 (spent GAC) or the existing Treatment System for Alternative B4 (filter press cake and spent GAC).

Implementability:

Implementability is not relevant to Alternative B1 since no activities would be implemented. The institutional controls and groundwater monitoring activities associated with Alternative B2 would be readily implementable. Alternatives B2, B3, and B4 would require administrative and legal services for preparation of deed restrictions in case of change in site ownership. The groundwater extraction system used for Alternatives B3 and B4 and the new local groundwater treatment and reinjection systems for Alternative B3 would be relatively easy to install. The Treatment System proposed for use under Alternative B4 already exists and would require no modification to accommodate the Area B groundwater flow. The unit processes of both the new treatment system for Alternative B3 and the existing Treatment System for Alternative B4 are well-proven and effective for the removal of VOCs. A groundwater reinjection permit would not likely be required for Alternative B3 and the modification of the existing NPDES permit for Alternative B4 would be readily attainable.

Cost:

The following table summarizes and compares the estimated capital cost, O&M cost, and 30-year present-worth for Alternatives B1, B2, B3, and B4:

Alternative	Capital ($)	Operation & Maintenance ($/year)	Present Worth ($)
Alternative B1	$0	$0	$0
Alternative B2	$0	$98,400 - Year 1 $32,800 - Years 2 to 8	$290,000
Alternative B3	$466,932	$153,900 - Year 1 $69,500 - Years 2 to 5	$864,000
Alternative B4	$1,046,800	$152,600 - Year 1 $68,200 - Years 2 to 5	$1,438,000

5.3 AREA D ALTERNATIVES (INTERIM REMEDY)

The alternatives for the Area D groundwater are as follows:

- Alternative D1: No Action
- Alternative D2: Institutional Controls and Monitoring
- Alternative D3: Extraction, Treatment at Existing Treatment System, Discharge To Outfall 001

These three alternatives are compared with respect to specific factors for each evaluation criterion and differences are identified. Table 5-3 and the following text summarizes this comparison.

Overall Protection of Human Health and The Environment:

Alternative D1 would not be protective of human health. Alternative D2 would provide limited protection of human health since it would not contain contaminant migration but it would nonetheless prevent use of the Area D groundwater for domestic purposes and provide groundwater quality monitoring. Alternative D3 would be protective of human health by actively containing groundwater contamination within Area D, preventing use of the Area D groundwater for domestic purposes, and monitoring groundwater quality.

Compliance with ARARs and TBCs:

As interim remedies, Alternatives D1, D2, and D3 are not required to and would not comply with contaminant-specific ARARs, including the Pennsylvania Statewide Human Health Standards for Groundwater and the Federal Safe Drinking Water Act MCLs. Alternatives D1 and D2 would not need to comply with any action-specific ARARs since no remedial action would be performed for Alternative D1 and remedial action would be limited to implementation of institutional controls and groundwater monitoring for Alternative D2. Alternative D3 would comply with all action-specific ARARs for the discharge of treated groundwater and air emissions and the disposal of treatment residues.

Long-Term Effectiveness and Permanence:

Alternative D1 would have no long-term effectiveness and permanence. Alternative D2 would have limited effectiveness and permanence since it would not contain contaminant migration or actively remedy the Area D aquifer but it would nonetheless prevent use of contaminated groundwater for domestic purposes and would monitor groundwater quality. Alternative D3, although it would not achieve restoration of the

TABLE 5-3

SUMMARY OF COMPARATIVE ANALYSIS FOR AREA D REMEDIAL ALTERNATIVES
AREAS A, B, AND D GROUNDWATER FEASIBILITY STUDY
NAWC WARMINSTER - WARMINSTER, PA

CRITERION	ALTERNATIVE D1: NO ACTION	ALTERNATIVE D2: INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE D3: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT			
Prevent Human Exposure to Contaminated Groundwater	Would not be protective	Institutional controls would provide minimal protection by limiting groundwater use.	Contaminated groundwater would be extracted and treated. Institutional controls would prevent future use and long-term monitoring would monitor effectiveness.
Minimize Migration of Contaminated Groundwater	Would not prevent migration	Long-term monitoring would allow for control of groundwater use but would not minimize migration.	Extraction well network would minimize migration.
COMPLIANCE WITH ARARs			
Chemical and Location Specific ARARs	No active remediation. Would not comply with contaminant-specific ARARs.	Same as Alternative D1.	Interim remedy, would not comply with contaminant-specific ARARs. Would minimize migration and would be consistent with future remedial response actions.
Action-Specific ARARs	No action-specific ARARs would apply.	Same as Alternative D1.	Would comply with action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE			
Magnitude of Residual Risk	Existing risks remain.	Same as Alternative D1.	Existing risks would be decreased in source and far-reaching plume areas. Interim action is consistent with long-term response actions.
Adequacy and Reliability of Controls	No controls in place. Risk and contaminated volume may increase.	Long-term monitoring and institutional controls would provide minimal control.	Extraction well network would effectively minimize migration. Use of WTMA26 would provide long-term effective removal and treatment. Long-term monitoring and deed restrictions would provide additional controls.
Need for 5-Year Review	Residual contamination would remain. However, five-year reviews would not be conducted.	Residual contamination would remain. Five-year reviews would be required.	Residual contaminant levels would remain. Five-year reviews would be required.

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TABLE 5-3 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA D REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

CRITERION	ALTERNATIVE D1: NO ACTION	ALTERNATIVE D2: INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE D3: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT			
Treatment Process Used	None	None	Air stripping and vapor- and liquid- phase GAC adsorption.
Amount Destroyed or Treated	None	None	Remove and destroy 0.2 lbs/day of VOC contaminants from source area. Additional treatment provided in far-reaching plume area.
Irreversible Treatment	None	None	Contaminants removed would be completely destroyed.
Statutory Preference for Treatment	No treatment provided.	No treatment provided.	Achieves statutory preference for treatment.
SHORT-TERM EFFECTIVENESS			
Community Protection	No risk reduction.	Institutional controls would provide limited protection from exposure but not from migration. Implementation would present minimal risks.	Same as Alternative D2 with additional protection through control of migration and removal and treatment of contaminants. Implementation would present minimal risks.
Worker Protection	Not applicable.	Monitoring would present minimal risks.	Installation and operation of systems and monitoring would present minimal easily controllable risks.
IMPLEMENTABILITY			
Ability to Construct and Operate	No construction or operation is involved.	No difficulties are anticipated.	No difficulties are anticipated. The existing Treatment System could be easily modified to accommodate additional loading.
Ability to Monitor Effectiveness	No monitoring would be conducted.	Monitoring would provide assessment of potential exposures, contaminant concentrations, and migration.	Same as Alternative D2.

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TABLE 5-3 (CONTINUED)
SUMMARY OF COMPARATIVE ANALYSIS FOR AREA D REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
AREAS A, B, AND D GROUNDWATER
NAWC WARMINSTER
WARMINSTER, PA

CRITERION	ALTERNATIVE D1: NO ACTION	ALTERNATIVE D2: INSTITUTIONAL CONTROLS AND MONITORING	ALTERNATIVE D3: EXTRACTION, TREATMENT AT EXISTING TREATMENT SYSTEM, DISCHARGE TO OUTFALL 001
Availability of Technology	No remedial technology is involved.	No remedial technology is involved. Institutional controls are commonly used to limited exposure to site contaminants.	Well-proven treatment processes. A new extraction system and minor modifications to existing treatment systems would be required. Technology for complete destruction of recovered contaminants is in-use. Institutional controls are commonly used to limit exposure.
COST			
Capital Cost	$0	$0	$675,200
First Year and Annual O&M Cost	$0	$61,750 $32,200	$79,600 $50,000
30-Year Present-Worth Cost	$0	$579,000	$1,528,000

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Area D aquifer, would still provide long-term effectiveness for an interim through active containment of the Area D groundwater coupled with prevention of its use for domestic purposes and monitoring of its quality.

Reduction of Toxicity, Mobility, and Volume Through Treatment:

Alternatives D1 and D2 would not actively reduce toxicity, mobility, and volume through treatment. Alternative D3 would actively reduce mobility and, to a lesser extent, toxicity and volume through groundwater extraction and treatment with air stripping and vapor- and liquid-phase GAC adsorption. Alternative D3 would remove about 0.02 lbs/day of VOCs from the Area D groundwater and these VOCs would ultimately be destroyed (100% irreversibly) during regeneration of the spent GAC.

Short-Term Effectiveness:

Alternative D1 would not be effective in the short-term. There would be no risks or concerns associated with remedial action activities under Alternative D1 since none would take place. Alternative D2 would offer minimal short-term effectiveness. It would immediately reduce the risk of exposure to contaminated groundwater by monitoring the quality of the Area D groundwater and prohibiting its use for domestic purposes but it would not contain contaminant migration nor would it capture or remove contaminants from the source area. The risks associated with the monitoring activities performed under Alternative D2 would be minimal. Alternative D3 would have limited short-term effectiveness since it would not clean up the Area D aquifer but would nonetheless immediately prevent risk of exposure to the Area D groundwater by actively containing contaminant migration, removing approximately 0.02 lbs/day of VOCs, monitoring groundwater quality, and prohibiting its use for domestic purposes. For Alternative D3, there would be minimal risks associated with the installation and operation of the new groundwater extraction system, the operation of the existing Treatment System, and the transportation and disposal of the residues generated by this system (filter press cake and spent GAC).

Implementability:

Implementability is not relevant to Alternative D1 since no activities would be implemented. The institutional controls and groundwater monitoring activities associated with Alternative D2 would be readily implementable. Alternatives D2 and D3 would require administrative and legal services for preparation of deed restrictions in case of change in the ownership of site. The groundwater extraction system used for Alternative D3 would be relatively easy to install. The Treatment System proposed under Alternative D3 already exists and could readily be modified to accept the additional hydraulic and contaminant load from the Area D groundwater. The unit processes of the existing Treatment System are well-proven and

effective for the removal of VOCs. Modification of the existing NPDES permit for Alternative D3 would be readily-attainable.

Cost

The following table summarizes and compares the estimated capital cost, O&M cost, and 30-year present-worth for Alternatives D1, D2, and D3:

Alternative	Capital ($)	Operation & Maintenance ($/year)	Present Worth ($)
Alternative D1	$0	$0	$0
Alternative D2	$0	$61,750 - Year 1 $32,200 - Years 2 to 30	$579,000
Alternative D3	$675,200	$79,600 - Year 1 $50,000 - Years 2 to 30	$1,528,000

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APPENDIX A

COST ANALYSIS FOR ALTERNATIVES

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Institutional Controls, Monitoring,
Alternate No. A2
(OMNWA2)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY/ QUARTERLY YEAR 1	ITEM $ QUARTERLY YEAR 2-30	ITEM $ COST PER 5 YEARS	NOTES
1. Sampling	35000.00	20000.00		16 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	28350.00	16200.00		18 groundwater samples, per sampling period. 1st year monthly for 4 months, then quarterly for remaining 30 years (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5,10,15,20,25,30
TOTAL ANNUAL COST	81350.00	42200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Institutional Controls, Monitoring,
Alternate No. A2
(PWANWA2) 6/13/96
742

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	0											
2. O & M COSTS		81.4										
3. ANNUAL COSTS	0	81.4	42.2	42.2	42.2	62.2	42.2	42.2	42.2	42.2	62.2	42.2
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	0	77	38	36	35	49	31	30	29	27	38	25

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	42.2	42.2	42.2	62.2	42.2	42.2	42.2	42.2	62.2	42.2	42.2	42.2
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	24	22	21	30	19	18	18	17	23	15	14	14

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	42.2	62.2	42.2	42.2	42.2	42.2	62.2	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	13	18	12	11	11	10	14	742

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment plant
Alternate No. A3
(NAWA4S)

6/13/96

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	0	5000	5000	10000
2) EQUIPMENT	138600	31800	5400	0	175800
3) PIPING & INSTRUMENTATION	0	35014	44333	585	79932
4) FOUNDATION & STRUCTURAL	0	5000	4400	3600	13000
5) ELECTRICAL	0	40560	33665	0	74225
	138600	112374	92798	9185	352957
Burden @ 30% of Labor Cost			27839		27839
Labor @ 10% of Labor Cost			9280		9280
Material @ 10% of Material Cost		11237			11237
Subcontract @ 10% of Sub. Cost	13860				13860
Total Direct Cost	152460	123611	129917	9185	415174
Indirects @ 75% of Total Direct Labor Cost			97438		97438
Profit @ 10% Total Direct Cost					41517
Total Field Cost					554129
Contingency @ 20% of Total Field Cost					110826
Engineering @ 15% of Total Field Cost					83119
Total Cost This Page					748074

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. A3
(NAWA4)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			2000.00	2000.00			2000	2000	4000	
2) Clearing And Grubbing	1	AC			3000.00	3000.00			3000	3000	6000	
							0	0	5000	5000	10000	
EQUIPMENT												
1) Extraction Wells (Area "A")	630	LF	220.00				138600				138600	9 @ 70'
2) Extraction Well Pumps (Area "A")	9			2200.00	400.00			19800	3600		23400	7 gpm
3) Transfer Pumps (Area "A")	2			3500.00	400.00			7000	800		7800	63 gpm
4) Upgrade Existing Tray Stripper		LS		5000.00	1000.00			5000	1000		6000	
							138600	31800	5400	0	175800	
PIPING & INSTRUMENTATION												
1) Area "A" Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	630	LF		2.30	7.60			1449	4788		6237	
b) 4"	900	LF		7.00	12.75	.30		6300	11475	270	18045	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	900	LF			7.95	4.78			7155		7155	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	900	LF		1.30	1.89			1170	1701		2871	
D) Revegetation	9	MSF		50.00	11.00	9.00		450	99	81	630	
2) Area "A" Transfer Sump To Interim Action Treatment Plant												
A) Piping												
a) 4"	600	LF		7.00	12.75	.30		4200	7650	180	12030	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	600	LF			7.95	4.78			4770		4770	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	600	LF		1.30	1.89			780	1134		1914	
D) Revegetation	6	MSF		50.00	11.00	9.00		300	66	54	420	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. A3
(NAWA4)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
3) Plug Valves												
a) 1-1/2"	9			110.00	20.00			990	180		1170	
b) 4"	2			350.00	120.00			700	240		940	
4) Check Valves												
a) 1-1/2"	9			95.00	20.00			855	180		1035	
b) 4"	2			200.00	90.00			400	180		580	
5) Ball Valves - 1/2"	11			45.00	15.00			495	165		660	
6) Level Control System	10			1500.00	400.00			15000	4000		19000	
7) Pressure Gauges	11			175.00	50.00			1925	550		2475	
							0	35014	44333	585	79932	
FOUNDATION & STRUCTURAL												
1) Transfer Station	1			5000.00	4400.00	3600.00		5000	4400	3600	13000	
							0	5000	4400	3600	13000	0
ELECTRICAL												
1) Motor Starter #1	11			1730.00	705.00			19030	7755		26785	
2) Disconnect Switch	11			240.00	80.00			2640	880		3520	
3) Conduit, Cable, Control	11			340.00	700.00			3740	7700		11440	
4) Well Pump Feeder Cable	900	LF		1.00	1.20			900	1080		1980	
5) Instrument Control Loop	10			500.00	700.00			5000	7000		12000	
6) Grounding	11			250.00	250.00			2750	2750		5500	
7) Miscellaneous Wiring	11			500.00	500.00			5500	5500		11000	
8) Outdoor Lighting		LS		1000.00	1000.00			1000	1000		2000	
							0	40560	33665	0	74225	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. A3
(OMNWA4)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY/ QUARTERLY YEAR 1	ITEM $ QUARTERLY YEAR 2-30	ITEM $ COST PER 5 YEARS	NOTES
1. Sampling	35000.00	20000.00		16 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	28350.00	16200.00		18 groundwater samples, per sampling period. 1st year monthly for 4 months, then quarterly for remaining 30 years (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5,10,15,20,25,30
TOTAL ANNUAL COST	81350.00	42200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. A3
(OMNWA4a)
6/13/96

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTES
1. Energy					
a. Electric	130647	KW-HR	.065	$8492	Well Pumping Sys
b. Electric	97985	KW-HR	.065	$6369	Well #26
2. Maintenance				$15000	3% of Capital Co incl. Well#26
3. Operator	520	HR	20.00	$10400	2 Hour/5 Days/We incl. Well #26
TOTAL ANNUAL COSTS				$40261	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "A"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. A3
(PWANWA4) 6/13/96
2109

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	748.1											
2. O & M COSTS		121.6										
3. ANNUAL COSTS	748.1	121.6	82.5	82.5	82.5	102.5	82.5	82.5	82.5	82.5	102.5	82.5
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	748	116	75	71	68	80	62	59	56	53	63	48

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	82.5	82.5	82.5	102.5	82.5	82.5	82.5	82.5	102.5	82.5	82.5	82.5
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	46	44	42	49	38	36	34	33	39	30	28	27

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	82.5	102.5	82.5	82.5	82.5	82.5	102.5	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	26	30	23	22	21	20	24	2109

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Institutional Controls, Monitoring,
Natural Attenuation
Alternate No. B2
(OMNWB2)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY YEAR 1	ITEM $ QUARTERLY YEAR 2-8	ITEM $ COST PER YEAR 5	NOTES
1. Sampling	48000.00	16000.00		10 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	32400.00	10800.00		12 groundwater samples, per sampling period. (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5
TOTAL ANNUAL COST	98400.00	32800.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 8

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Institutional Controls, Monitoring,
Natural Attenuation
Alternate No. B2
(PWANWB2) 6/13/96
290

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	0											
2. O & M COSTS		98.4										
3. ANNUAL COSTS	0	98.4	32.8	32.8	32.8	52.8	32.8	32.8	32.8	0	0	0
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	0	94	30	28	27	41	24	23	22	0	0	0

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	0	0	0	0	0	0	0	0	0	0	0	0

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	0	0	0	0	0	0	0	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	0	0	0	0	0	0	0	290

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(NAWB3S)

6/13/96

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	4200	9600	9000	22800
2) EQUIPMENT	69400	14600	3000	0	87000
3) PIPING & INSTRUMENTATION	0	10344	14472	50	24866
4) FOUNDATION & STRUCTURAL	12000	6000	11400	600	30000
5) ELECTRICAL	0	18980	14615	0	33595
	81400	54124	53087	9650	198261
Burden @ 30% of Labor Cost			15926		15926
Labor @ 10% of Labor Cost			5309		5309
Material @ 10% of Material Cost		5412			5412
Subcontract @ 10% of Sub. Cost	8140				8140
Total Direct Cost	89540	59536	74322	9650	233048
Indirects @ 75% of Total Direct Labor Cost			55741		55741
Profit @ 10% Total Direct Cost					23305
Total Field Cost					312094
Contingency @ 20% of Total Field Cost					62419
Premedial Design Study					30000
Engineering @ 20% of Total Field Cost					62419
Total Cost This Page					466932

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(NAWB3)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			3000.00	3000.00			3000	3000	6000	
2) Clearing And Grubbing	2	AC			3000.00	3000.00			6000	6000	12000	
3) Access Road	600	SY		7.00	1.00			4200	600		4800	
							0	4200	9600	9000	22800	
EQUIPMENT												
1) Extraction Wells	170	LF	220.00				37400				37400	2 @ 85'
2) Reinjection Wells	200	LF	160.00				32000				32000	2 @ 100'
3) Extraction Well Pumps	2			2200.00	400.00			4400	800		5200	5 gpm
4) Equalization Tank w/ Air Sparging System	1			1200.00	400.00			1200	400		1600	300 gallon
5) Air Blower	1			1000.00	400.00			1000	400		1400	
6) Activated Carbon Adsorber - Vapor	1			1000.00	200.00			1000	200		1200	200#
7) Reinjection Pumps	2			3500.00	600.00			7000	1200		8200	10 gpm
							69400	14600	3000	0	87000	
PIPING & INSTRUMENTATION												
1) Area B Extraction Wells To Equal. Tank												
A) Piping												
a) 1-1/2"	320	LF		2.30	7.60			736	2432		3168	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	150	LF			7.95	4.78			1193		1193	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	150	LF		1.30	1.89			195	284		479	
D) Revegetation	1.5	MSF		50.00	11.00	9.00		75	17	14	105	
2) Area B Equal. Tank To Reinjection Wells												
A) Piping												
a) 1-1/2" C.S	600	LF		2.30	7.60			1380	4560		5940	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	400	LF			7.95	4.78		0	3180		3180	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	400	LF		1.30	1.89			520	756		1276	
D) Revegetation	4	MSF		50.00	11.00	9.00		200	44	36	280	
3) Treatment Plant Piping												
a) 1-1/2"	50	LF		9.75	5.25			488	263		750	
4) Plug Valves												
a) 1-1/2"	7			110.00	20.00			770	140		910	
5) Check Valves												
a) 1-1/2"	4			95.00	20.00			380	80		460	
6) Ball Valves - 1/2"	5			45.00	15.00			225	75		300	
7) Level Control System	3			1500.00	400.00			4500	1200		5700	
8) Pressure Gauges	5			175.00	50.00			875	250		1125	
							0	10344	14472	50	24865	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(NAWB3)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
FOUNDATION & STRUCTURAL												
1) Treatment Building	400	SF	30.00				12000				12000	20' x 20'
2) Treatment Building Foundation	30	CY		200.00	380.00	20.00		6000	11400	600	18000	
							12000	6000	11400	600	30000	
ELECTRICAL												
1) Motor Starter #1	5			1730.00	705.00			8650	3525		12175	
2) Disconnect Switch	5			240.00	80.00			1200	400		1600	
3) Conduit, Cable, Control	5			340.00	700.00			1700	3500		5200	
4) Well Pump Feeder Cable	150	LF		1.00	1.20			150	180		330	
5) Control Panel	1			1000.00	150.00			1000	150		1150	
6) Instrument Control Loop	3			500.00	700.00			1500	2100		3600	
7) Grounding	5			250.00	250.00			1250	1250		2500	
8) Miscellaneous Wiring	5			500.00	500.00			2500	2500		5000	
9) Security	400	SF		.70	.65			280	260		540	
10) Outdoor Lighting		LS		750.00	750.00			750	750		1500	
							0	18980	14615	0	33595	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(OMNWB3)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY YEAR 1	ITEM $ QUARTERLY YEAR 2-5	ITEM $ COST PER YEAR 5	NOTES
1. Sampling	60000.00	20000.00		16 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	48600.00	16200.00		18 groundwater samples, per sampling period. (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5
TOTAL ANNUAL COST	126600.00	42200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 5

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(OMNWB3a)
6/13/96

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTES
1. Energy					
a. Electric	26130	KW-HR	.065	$1698	Treatment Plant
2. Maintenance				$8000	3% of Capital Cost
3. Operator	832	HR	20.00	$16640	2 Day/Week
4. Activated Carbon					
a. Gases	365	LB	2.50	$913	
TOTAL ANNUAL COSTS				$27251	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Groundwater Treatment,
Reinjection
Alternate No. B3
(PWANWB3) 6/13/96
864

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	466.9											
2. O & M COSTS		153.9										
3. ANNUAL COSTS	466.9	153.9	69.5	69.5	69.5	89.5	0	0	0	0	0	0
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	467	147	63	60	57	70	0	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	0	0	0	0	0	0	0	0	0	0	0	0

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	0	0	0	0	0	0	0	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	0	0	0	0	0	0	0	864

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Discharge To Interim Action
Groundwater Treatment plant
Alternate No. B4
(NAWB4S)

6/13/96

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	0	2500	2500	5000
2) EQUIPMENT	37400	8000	1200	0	46600
3) PIPING & INSTRUMENTATION	0	93841	150902	44360	289103
4) ELECTRICAL	0	48320	28670	0	76990
	37400	150161	183272	46860	417693
Burden @ 30% of Labor Cost			54982		54982
Labor @ 10% of Labor Cost			18327		18327
Material @ 10% of Material Cost		15016			15016
Subcontract @ 10% of Sub. Cost	3740				3740
Total Direct Cost	41140	165177	256581	46860	509758
Indirects @ 75% of Total Direct Labor Cost			192436		192436
Profit @ 10% Total Direct Cost					50976
Total Field Cost					753169
Contingency @ 20% of Total Field Cost					150634
Premedial Design Study					30000
Engineering @ 15% of Total Field Cost					112975
Total Cost This Page					1046779

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. B4
(NAWB4)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			1000.00	1000.00			1000	1000	2000	
2) Clearing And Grubbing	.5	AC			3000.00	3000.00			1500	1500	3000	
							0	0	2500	2500	5000	
EQUIPMENT												
1) Extraction Wells	170	LF	220.00				37400				37400	2 @ 85'
2) Extraction Well Pumps	2			4000.00	600.00			8000	1200		9200	5 gpm
							37400	8000	1200	0	46600	
PIPING & INSTRUMENTATION												
1) Area B Extraction Wells To Interim Groundwater Treatment Plant												
A) Piping												
a) 1-1/2"	170	LF		2.30	7.60			391	1292		1683	
b) 2"-4" Double Wall Pipe	4000	LF		16.00	13.00	.30		64000	52000	1200	117200	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	4000	LF			7.95	4.78			31800		31800	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	4000	LF		1.30	1.89			5200	7560		12760	
D) Revegetation	40	MSF		50.00	11.00	9.00		2000	440	360	2800	
2) Pipe Jacking	400	LF		46.00	142.00	107.00		18400	56800	42800	118000	
3) Plug Valves												
a) 1-1/2"	2			110.00	20.00			220	40		260	
4) Check Valves												
a) 1-1/2"	2			95.00	20.00			190	40		230	
5) Ball Valves - 1/2"	2			45.00	15.00			90	30		120	
6) Level Control System	2			1500.00	400.00			3000	800		3800	
7) Pressure Gauges	2			175.00	50.00			350	100		450	
							0	93841	150902	44360	289103	
ELECTRICAL												
1) Motor Starter #1	2			1730.00	705.00			3460	1410		4870	
2) Disconnect Switch	2			240.00	80.00			480	160		640	
3) Conduit, Cable, Control	2			340.00	700.00			680	1400		2080	
4) Well Pump Feeder Cable	4000	LF		1.00	1.20			4000	4800		8800	
5) Leak Detection Monitor	4000	LF		8.20	3.00			32800	12000		44800	
6) Leak Detection Loop	8			500.00	700.00			4000	5600		9600	
7) Instrument Control Loop	2			500.00	700.00			1000	1400		2400	
8) Grounding	2			250.00	250.00			500	500		1000	
9) Miscellaneous Wiring	2			500.00	500.00			1000	1000		2000	
10) Outdoor Lighting		LS		400.00	400.00			400	400		800	
							0	48320	28670	0	76990	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. B4
(OMNWB4)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY YEAR 1	ITEM $ QUARTERLY YEAR 2-5	ITEM $ COST PER YEAR 5	NOTES
1. Sampling	60000.00	20000.00		16 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	48600.00	16200.00		18 groundwater samples, per sampling period. (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5
TOTAL ANNUAL COST	126600.00	42200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 5

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. B4
(OMNWB4a)
6/13/96

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTES
1. Energy					
a. Electric	19600	KW-HR	.065	$1274	Treatment Plant
2. Maintenance				$19500	3% of Capital Cost
3. Operator	260	HR	20.00	$5200	1 Hour/5 Days/Week
TOTAL ANNUAL COSTS				$25974	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "B"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. B4
(PWANWB4) 6/13/96
1438

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	1046.8											
2. O & M COSTS		152.6										
3. ANNUAL COSTS	1046.8	152.6	68.2	68.2	68.2	88.2	0	0	0	0	0	0
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	1047	145	62	59	56	69	0	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	0	0	0	0	0	0	0	0	0	0	0	0

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	0	0	0	0	0	0	0	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	0	0	0	0	0	0	0	1438

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Institutional Controls, Monitoring,
Alternate No. D2
(OMNWD2)
6/13/96

Annual Costs

ITEM	ITEM $ MONTHLY/ QUARTERLY YEAR 1	ITEM $ QUARTERLY YEAR 2-30	ITEM $ COST PER 5 YEARS	NOTES
1. Sampling	28000.00	16000.00		8 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	15750.00	10200.00		10 groundwater samples, per sampling period. 1st year monthly for 4 months, then quarterly for remaining 30 yea (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5,10,15,20,25,30
TOTAL ANNUAL COST	61750.00	32200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Institutional Controls, Monitoring,
Alternate No. D2
(PWANWD2) 6/13/96
579

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	0											
2. O & M COSTS		61.8										
3. ANNUAL COSTS	0	61.8	32.2	32.2	32.2	52.2	32.2	32.2	32.2	32.2	52.2	32.2
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	0	59	29	28	27	41	24	23	22	21	32	19

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	32.2	32.2	32.2	52.2	32.2	32.2	32.2	32.2	52.2	32.2	32.2	32.2
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	18	17	16	25	15	14	13	13	20	12	11	10

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	32.2	52.2	32.2	32.2	32.2	32.2	52.2	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	10	15	9	9	8	8	12	579

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment plant
Alternate No. D3
(NAWD4S)
Page 1 of 3
6/13/96

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	0	5000	5000	10000
2) EQUIPMENT	96800	81000	8900	6500	193200
3) PIPING & INSTRUMENTATION	0	28742	40466	476	69684
4) FOUNDATION & STRUCTURAL	0	5000	4400	3600	13000
5) ELECTRICAL	0	22260	18490	0	40750
	96800	137002	77256	15576	326634
Burden @ 30% of Labor Cost			23177		23177
Labor @ 10% of Labor Cost			7726		7726
Material @ 10% of Material Cost		13700			13700
Subcontract @ 10% of Sub. Cost	9680				9680
Total Direct Cost	106480	150702	108158	15576	380917
Indirects @ 75% of Total Direct Labor Cost			81119		81119
Profit @ 10% Total Direct Cost					38092
Total Field Cost					500127
Contingency @ 20% of Total Field Cost					100025
Engineering @ 15% of Total Field Cost					75019
Total Cost This Page					675172

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. D3
(NAWD4)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			2000.00	2000.00			2000	2000	4000	
2) Clearing And Grubbing	1	AC			3000.00	3000.00			3000	3000	6000	
							0	0	5000	5000	10000	
EQUIPMENT												
1) Extraction Wells (Area "D")	440	LF	220.00				96800				96800	4 @ 110'
2) Extraction Well Pumps (Area "D")	4			2400.00	400.00			9600	1600		11200	9.25 gpm
3) Transfer Pumps (Area "D")	2			3200.00	400.00			6400	800		7200	37 gpm
4) Air Stripper (Existing Treatment Plant)	1			45000.00	4500.00	4500.00		45000	4500	4500	54000	
5) Upgrade Existing Pumps		LS		2000.00	800.00			0	0		0	
6) Upgrade Air Stripper Emission Control System (Carbon Adsorber)	1			20000.00	2000.00	2000.00		20000	2000	2000	24000	
							96800	81000	8900	6500	193200	
PIPING & INSTRUMENTATION												
1) Area "D" Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	440	LF		2.30	7.60			1012	3344		4356	
b) 3"	500	LF		4.50	11.30	.25		2250	5650	125	8025	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	500	LF			7.95	4.78			3975		3975	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	500	LF		1.30	1.89			650	945		1595	
D) Revegetation	5	MSF		50.00	11.00	9.00		250	55	45	350	
2) Area "D" Transfer Sump To Interim Action Treatment Plant												
A) Piping												
a) 3"	900	LF		4.50	11.30	.25		4050	10170	225	14445	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	900	LF			7.95	4.78			7155		7155	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	900	LF		1.30	1.89			1170	1701		2871	
D) Revegetation	9	MSF		50.00	11.00	9.00		450	99	81	630	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. D3
(NAWD4)

6/13/96

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
3) Plug Valves												
a) 1-1/2"	4			110.00	20.00			440	80		520	
b) 3"	2			280.00	90.00			560	180		740	
4) Check Valves												
a) 1-1/2"	4			95.00	20.00			380	80		460	
b) 3"	2			130.00	46.00			260	92		352	
5) Ball Valves - 1/2"	6			45.00	15.00			270	90		360	
6) Level Control System	5			1500.00	400.00			7500	2000		9500	
7) Pressure Gauges	6			175.00	50.00			1050	300		1350	
8) Modify Piping Existing Treatment Plant												
a) 4"	100	LF		26.00	14.00			2600	1400		4000	
b) 6"	150	LF		39.00	21.00			5850	3150		9000	
							0	28742	40466	476	69684	
FOUNDATION & STRUCTURAL												
1) Transfer Stations	1			5000.00	4400.00	3600.00		5000	4400	3600	13000	
							0	5000	4400	3600	13000	0
ELECTRICAL												
1) Motor Starter #1	6			1730.00	705.00			10380	4230		14610	
2) Disconnect Switch	6			240.00	80.00			1440	480		1920	
3) Conduit, Cable, Control	6			340.00	700.00			2040	4200		6240	
4) Well Pump Feeder Cable	900	LF		1.00	1.20			900	1080		1980	
5) Instrument Control Loop	5			500.00	700.00			2500	3500		6000	
6) Grounding	6			250.00	250.00			1500	1500		3000	
7) Miscellaneous Wiring	6			500.00	500.00			3000	3000		6000	
8) Outdoor Lighting		LS		500.00	500.00			500	500		1000	
							0	22260	18490	0	40750	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. D3
(OMNWD4)
6/13/96

Annual Costs

ITEM	ITEM $ QUARTERLY YEAR 1	ITEM $ QUARTERLY YEAR 2-30	ITEM $ COST PER 5 YEARS	NOTES
1. Sampling	28000.00	16000.00		8 groundwater samples per sampling period, plus travel, living & shipping costs.
2. Analysis	15750.00	10200.00		10 groundwater samples, per sampling period. 1st year monthly for 4 months, then quarterly for remaining 30 years (inc. blank & duplicate) TCL, VOCs, PH, TOC
3. Reporting	18000.00	6000.00		20 manhours per report plus other direct costs
4. Site Review			20000.00	Analysis Review Performed for Year 5,10,15,20,25,30
TOTAL ANNUAL COST	61750.00	32200.00	20000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. D3
(OMNWD4a)
6/13/96

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTE
1. Energy					
a. Electric	32662	KW-HR	.065	$2123	Treatment Plan
2. Maintenance				$10500	3% of Capital Co
3. Operator	260	HR	20.00	$5200	1 Hour/5 Days/We
TOTAL ANNUAL COSTS				$17823	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "D"
Extraction, Discharge To Interim Action
Groundwater Treatment Plant
Alternate No. D3
(PWANWD4) 6/13/96
1528

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	675.2											
2. O & M COSTS		79.6										
3. ANNUAL COSTS	675.2	79.6	50	50	50	70	50	50	50	50	70	50
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	675	76	45	43	41	55	37	36	34	32	43	29

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	50	50	50	70	50	50	50	50	70	50	50	50
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	28	27	25	34	23	22	21	20	26	18	17	16

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	50	70	50	50	50	50	70	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	16	21	14	13	13	12	16	1528

APPENDIX B

GROUNDWATER MODELING FOR AREA B

Groundwater Modeling to Support the Feasibility Study for Area B, Naval Air Warfare Center Warminster

Groundwater contaminant fate and transport modeling was conducted to support the Feasibility Study(FS) for Area B of the Naval Air Warfare Center in Warminster Pennsylvania (NAWC Warminster). The following sections describe the modeling.

OBJECTIVES

Groundwater modeling was conducted for Area B primarily to estimate the time required for a relatively small area of groundwater contamination ("hot spot") to reduce to MCL levels assuming that the source of contamination has been removed. Trichloroethene (TCE) and benzene are above the MCL levels in this plume, so the cleanup times were estimated for these two chemicals. The times were estimated based on both natural attenuation and based on a conceptual remedial groundwater extraction system design.

CONCEPTUAL MODEL

The conceptual model of contaminant transport represents a simplified interpretation of the complex natural aquifer system and the movement of contaminants within it. The following subsections describe the aquifer system beneath the site and areas of contamination, the modeling tools used to simulate the aquifer, and the assumptions used in this quantitative evaluation.

General Site Conditions

Area B contains three sites (5,6, and 7) which consist of various disposal trenches. The exact location of these trenches is not known with certainty. The sites reportedly began operation between 1950 and 1960. The last site was believed to have ceased operations in 1980 (HNUS, 1995). The source of contamination to the groundwater potentially could have been in place for approximately 40 years (1955 to 1995).

The hydrogeology of Area B is discussed in detail in the *Area B Hydrogeologic Report* (HNUS, 1995). Much of the following discussion of the hydrogeology is based on that report and summarized below. The average depth to groundwater is approximately fifteen feet with the groundwater flow generally to the south. The aquifer beneath Area B consists primarily of fractured bedrock consisting of beds of sandstone and mudstone. The fine grained mudstone beds act as semiconfining layers to the groundwater flow, restricting but not preventing the vertical movement of groundwater across the bedding. The hydraulic heads within the bedrock generally were observed to decrease with increasing depth, indicating that the vertical flow potential is downward. Monitoring wells have been screened in shallow, intermediate and deep portions of the aquifer.

One low-concentration volatile organics plume exists immediately down gradient of Sites 5 and 6 within Area B, centered around well DG-18 and well cluster HN-36. The only compounds detected above MCLs within this plume are TCE and benzene, at levels slightly above MCLs. Through comparisons between sampling results for selected wells across the 1991 to 1995 time frame, it appears that the plume within area B is in a steady state condition. The distributions and concentrations of contaminants within the groundwater appear to be stable, indicating that the plume is neither migrating further down gradient nor increasing in concentration. Based on the groundwater sampling data, the contaminant plume does not extent off site and is not expanding toward the base boundary at this time. With the exception of benzene in well HN-36D, contaminants appear to be confined to the top 100 feet of the bedrock aquifer.

Modeling Tools

The modeling was performed using an analytical porous-media groundwater contaminant fate and transport model. This groundwater model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3.0 and is called ECTran (which stands for Excel-Crystal Ball Transport). The ECTran model (Chiou 1993) is based on straight forward mass-balances and advection/dispersion analytical equations, but can be used to simulate a variety of complex conditions. ECTran is a multi-layer one dimensional model in the unsaturated zone which can then simulate down gradient lateral transport in the saturated zone. It provides a conservative estimate of the contaminant concentration at a receptor location or discharge area down gradient of the source area under different source-loading conditions. The ECTran model estimates the down gradient concentration at the centerline of the contaminant plume. The ECTran model can only directly simulate the fate and transport of dissolved contaminants in the groundwater. The ECTran model can not directly simulate the movement of Non Aqueous Phase Liquids (NAPL). To date, ECTran and its predecessors have been employed at hazardous waste sites in U.S. EPA regions III, V, VI, and X to evaluate soil cleanup goals, cleanup time estimations, and to support baseline risk assessments. It has been used at DOD, DOE, and industrial sites for both RCRA and CERCLA applications.

Based on the hydrogeologic investigation for Area B, it is assumed that the bedrock aquifer behaves as an equivalent porous medium (EPM) on a large scale. Porous media type equations (such as those used in the ECTran model) then apply at the scale appropriate for remedial design and groundwater modeling. The ECTran model simulates vertical contaminant transport with uniform (thickness, concentration, porosity, etc.) layers. Each layer can contain different properties. The model also uses rectangular areas to simulate the model source areas and/or initial areas of contamination. Contaminant transport trough the unsaturated zone is driven by infiltration of water from the surface (into the first layer of the model) based on advection, retardation, and decay. Contaminant transport can then be simulated down gradient in the last layer of the model, based on advection, dispersion, retardation, decay, and mixing with groundwater flow upgradient of the source area.

Modeling Procedures and Assumptions

Layers Modeled

Since the objective of this modeling task is to determine the cleanup times in the aquifer after the source concentrations have been removed, a source loading from the unsaturated zone was not incorporated. The model of the aquifer used one layer with uniform chemical and physical properties. The highest TCE concentration (12 ug/L) was detected in the shallow portion aquifer while the highest concentration of benzene (20 ug/L) was detected in the deep portion of the aquifer. Benzene was not detected in the shallow portion. Since the contamination (of either Benzene or TCE) was not distributed through out the entire aquifer vertically, only the portion of the aquifer where the highest contamination occurred was simulated. Wells are screened in the top 150 feet of the aquifer and are grouped as shallow, intermediate, and deep wells. The shallow groundwater portion of the aquifer was assumed to be 50 feet thick. Similarly, the deep portion of the aquifer was assumed to be 50 feet thick.

Current Plume Conditions and Calibration

The current contaminant plumes are used as the initial condition for this modeling task. The current contaminant plumes were set in the model by assigning a source area in the aquifer where the maximum plume concentration was detected. The maximum sampled concentration was assigned to this source area with the up gradient and down gradient groundwater assumed to be clean. Contaminant migration from the source area was simulated for 40 years to create the current plumes down gradient of the source area. Up gradient flow was assumed to always be clean. The concentration of the source area in the aquifer was held constant for this part of the simulation so that contaminants are loaded to the aquifer down gradient

at a constant rate for 40 years (to simulate a continuing source from the unsaturated zone). The time of 40 years was used because it is the estimated number of years that wastes in the trenches may have contributed to the groundwater plume. The model predicted concentrations down gradient of the source area were compared to current sampling data and model adjustments made until the down gradient plumes matched the sample data.

Cleanup Time for Natural Attenuation

To simulate the time for the aquifer to naturally attenuate to MCL levels, the model source term in the aquifer was allowed to deplete and decay after the initial 40 years of loading. The model simulation was continued until all of the concentrations in the aquifer reached the MCL level.

Cleanup time for Remedial Pumping

To simulate the remedial groundwater pumping scenario, it is assumed that the pumping wells effectively capture all of the contaminants leaving the source area in the aquifer. The remedial pumping scenario essentially collects groundwater as quickly as it naturally flows to the aquifer source area. It does not pull additional groundwater out of the source area than would have moved out of this area under natural conditions. This means that the aquifer source area will not cleanup faster under the pumping scenario, however, the aquifer contaminant source area will no longer contribute contamination to the down gradient plume. The plume down gradient of the source area will then cleanup faster under the pumping scenario than under natural groundwater flow conditions.

INPUT PARAMETERS

The description of the input parameters required for the modeling is discussed in the following two subsections, chemical input and physical input parameters.

Chemical Input Parameters

The primary chemical input parameters include the soil water partitioning coefficient, K_d, initial groundwater concentrations, and chemical and biological decay half-lives. The chemical inputs used in the modeling are discussed below.

Soil/Water Partitioning Coefficient

The soil/water partitioning coefficient is used to estimate each chemical's mobility in the groundwater. The K_d value is the chemical's ratio of its concentration in soil to its concentration in groundwater when the two concentrations are in equilibrium. A high K_d value would be representative of a chemical which has a tendency to bind to the soil and is therefor less mobile in the groundwater. The partitioning coefficients used for TCE and benzene were based on octanol/water (K_{OW}) partition coefficients taken from literature (Handbook of Groundwater Monitoring Constituents, 1992). The K_{OC} (adsorption constant based on organic carbon) can be related to K_{OW} by a common approximation that K_{OC} equal 0.63 multiplied by K_{OW} (Maidment 1990). The K_d value can then be estimated as the K_{OC} value multiplied by the organic carbon fraction of the soil (f_{OC}) (Maidment, 1993). The f_{oc} value was assumed to be 0.002 which is the default value used by U.S. EPA (EPA, 1994) in developing generic Soil Screening Levels. The K_{ow} values used to develop the K_d values for TCE and benzene are 339 and 135, respectively. The corresponding K_d values used in the modeling for TCE and benzene were 0.43 and 0.17 respectively.

Half-life Decay Constants

Decay of organic contaminants can occur by biological and non-biological mechanisms. The decay can be quantified by chemical specific half-life. Half-lives were conservatively chosen from literature sources.

The longest reported half-life for the contaminant in groundwater was chosen from the literature source. The half-life used in the modeling for TCE and benzene was 4.5 and 2 years (Howard, 1991), respectively.

Current Contaminant Concentrations in the Aquifer

The maximum concentration for TCE in the aquifer was 12 ug/L at DG-18. The actual source area is not well defined, however the source area in the aquifer does not appear to be very large because of the surrounding wells do not contain concentrations as high as DG-18. A TCE concentration of 4 ug/L was detected in monitoring well DG-19 which is located approximately 150 feet cross gradient and slightly up gradient from DG-18. A TCE concentration of 3 ug/L was detected in monitoring well DG-21 which is located approximately 150 feet down gradient from DG-18. The maximum concentration was used for the uniform source concentration in the aquifer. Approximately 300 feet down gradient of the plume source area, TCE concentrations ranged from 3 to 7 ug/l (monitoring wells DG-20, DG-21, and DG-25). TCE was not detected down gradient of the source area at the NAWC site boundary (MW-5). The analytical detection limit was 1 ug/l.

The maximum concentration for Benzene in the aquifer was 20 ug/L at HN-36D. The only other detections of Benzene were also detected in monitoring well cluster 36 and not in the adjacent wells. It is reasonable to assume that the benzene plume is fairly small. This concentration was used for the uniform source concentration in the aquifer. Benzene was not detected down gradient of the source in the deep aquifer (monitoring wells HN-03D and HN-38). The detection limit for benzene was 10 ug/L, but estimated values are reported to 1 ug/L.

Physical Input Parameters

The physical input parameters to the ECTran model include layer thicknesses, effective porosity, groundwater seepage velocity, hydraulic conductivity, groundwater gradient, source area size, and infiltration. Many of the required physical input parameters were taken from the conceptual remedial design calculation for the extraction wells. The hydraulic conductivity was estimated from information in the groundwater extraction system design to be 3.29 ft/day. The effective porosity was assumed to be 0.3. The average groundwater gradient from the extraction well design calculation was 0.03. Based on these inputs the groundwater seepage velocity is estimated to be 120 ft/year. As discussed in the model assumptions section, the layer thicknesses used for both the TCE and Benzene were 50 feet. Based on the assumed capture zone in the extraction well design calculation and the locations of the monitoring wells, the source area size was assumed to be 100 feet wide (perpendicular to the flow direction) by 200 feet long (in the flow direction). Infiltration into the ground (and eventually to the groundwater) was assumed to be one fourth of the annual precipitation which falls on the site. The annual precipitation was based on the average of 5 years of data contained in the U.S. EPA's HELP model (Schroeder, 1994) database for the Philadelphia Area. The average precipitation amount from the HELP model database is 43.7 inches per year. The infiltration into the model was assumed to be 10.9 inches per year.

RESULTS

Two cases were run for the initial 40 years of the simulation, one assuming no decay of the contaminants in the aquifer and another assuming the half-lives taken from literature sources. The down gradient model predicted concentrations were then compared to the sampling data to see which case (decay or no decay) fit the sample data better. Two down gradient points were compared for both the TCE and benzene, one 300 feet down gradient and another 700 feet down gradient (at the NAWC boundary). TCE fit the sampling data better with the no decay case. Benzene fit the sample data better incorporating decay. Tables 1 and 2 list the sample concentration data and the model predicted concentrations after the 40 years of constant loading.

Based on the 40 years of constant loading the down gradient concentrations came very close to a steady state condition, which is in agreement with the sampling data. Even with the very conservative no decay case the steady state concentration of both benzene and TCE were below the MCL level of 5 ug/L at the NAWC boundary. Based on the model predictions, the concentration of these contaminants will not exceed the MCL level at the property boundary even if the contaminants do not decay in the groundwater and the source remains in place at its current strength.

Tables 1 and 2 also list the cleanup times for TCE and benzene, respectively. The pumping scenario was simulated for the no decay case since this would produce more conservative results. For natural attenuation and no decay, the maximum cleanup time for TCE and benzene were both 8 years, 300 feet down gradient of the source area. The longest cleanup time occurs down gradient of the source because once the source has been removed, contaminated groundwater between the source and the down gradient point will take some time before it reaches the down gradient point. The source area immediately receives clean flow from up gradient areas.

Under the remedial pumping scenario the longest cleanup time is 5 years. The predicted cleanup time is the same for the source area as in the natural attenuation case, however, the down gradient concentration cleans up quicker as was discussed in the Modeling Assumptions Section. The results of this simulation are also presented in Tables 1 and 2.

All of these simulations assume that the groundwater flow up gradient of the model source areas are clean. Based on the available information this is a reasonable assumption, the model source areas are the areas of highest detected groundwater concentrations and a hot spot was detected very close to these areas during the soil gas survey (Figure 5-14, Phase II RI [HNUS 1993]). If up gradient flow is not clean at these source areas the cleanup times will increase. Little groundwater data is available up gradient of the model aquifer source areas. A worst case scenario was run assuming that the source of contamination was at Trench TR 11/ TR 12 (Figure 1-2 Hydrogeologic Report Area B [HNUS 1995]) in Site 6). If the source of groundwater contamination is located at trench TR 11/ TR 12 the cleanup time for the whole aquifer could be as long as 28 years. Under this worst case scenario, the concentration of benzene and TCE will still never exceed MCL levels at the NAWC boundary.

If TCE does decay in the aquifer, one of the potential decay products is Vinyl Chloride (VC) which has a lower MCL that TCE. The MCL for Vinyl Chloride is 2 ug/L. The predicted steady state concentration of TCE at the NAWC boundary is 2.62 ug/L (no decay). Based on the molecular weights of TCE and VC, the concentration of VC in the aquifer resulting from the TCE would be expected to be about half of the initial TCE concentration. Therefore the concentration of VC if TCE degrades would not be expected to be greater than about 1.3 ug/L, below the MCL level.

The models sensitivity to the f_{oc} value and the effective porosity were evaluated. The f_{oc} value will effect the K_d value and therefor the chemical's mobility in the groundwater. The effective porosity will effect the groundwater seepage velocity which in turn will also effect the speed that the chemical travels in the groundwater.

For the sensitivity analysis the f_{oc} value was assumed to be 0.001. This effectively halves the K_d value. The steady state conditions do not change under this scenario, so that the concentrations at the NAWC boundary still never exceed the MCL value. The aquifer clean up times were shorter with the lower f_{oc} values since the chemical washes out quicker. For the sensitivity analysis, a effective porosity of 0.1 was assumed which effectively tripled the groundwater seepage velocity used originally. This change in effective porosity did not change the steady state conditions but it did decrease the aquifer clean up times. The values used in the modeling are therefore conservative compared to the values tested in this sensitivity analysis.

SUMMARY

An analytical groundwater fate and transport groundwater model called ECTran was used to predict the clean up time for a relatively small volatile organics plume in Area B of NAWC Warminster. TCE and Benzene are the only chemicals to exceed MCL levels in the plume. The plume appears to be in steady state condition (i.e., not migrating or changing in concentration with time) based on sampling data over a four year time span. The maximum detected groundwater concentration was input into the model as a constant source of contamination to the aquifer. Assuming a conservative case in which the chemicals do not decay, the steady state concentration at the NAWC boundary was below the MCL level. The contaminant transport was based on advection, dispersion, and retardation effects.

The primary objective of the modeling was to estimate the groundwater clean up times assuming that the source of contamination to the groundwater has been removed. Two cases were considered. The first case involved natural attenuation and the second involved a remedial pumping system design. To estimate the aquifer clean up times, a constant source in the aquifer was simulated for 40 years (the length of time that waste may have contributed contaminants to the groundwater). After 40 years, the removal of the source of contamination to the groundwater was simulated by allowing the aquifer source area to deplete. Assuming no decay, the predicted cleanup time of the aquifer (once the source has been removed) under natural attenuation is predicted to be 8 years. For the remedial pumping scenario it is predicted to be 5 years.

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Table 1
Summary of TCE Results

Groundwater Sampling Results

	Source Area	300 FT Down Gradient	NAWC Boundary 700 FT Down Gradient
Concentrations	12 ug/L	3-7 ug/L	ND (1)

Model Predicted Results

Case 1, Constant Source for 40-yrs, No Decay, No Pumping,

Steady State Conditions	12 ug/L	5.78 ug/L	2.62 ug/L
Conditions at 40 yrs	12 ug/L	5.78 ug/L	2.52 ug/L
Clean up times (to MCL Level)	5 yrs	8 yrs	NA (2)

Case 2, Constant Source for 40-yrs, With Decay, No Pumping,

Steady State Conditions	12 ug/L	1.94 ug/L	0.262 ug/L
Conditions at 40 yrs	12 ug/L	1.94 ug/L	0.262 ug/L
Clean up times (to MCL Level)	3 yrs	NA	NA

Case 3, Constant Source for 40-yrs, No Decay, With Pumping,

Conditions at 40 yrs	12 ug/L	5.78 ug/L	2.52 ug/L
Clean up times (to MCL Level)	5 yrs	5 yrs	NA

(1) TCE was not detected at the NAWC Boundary [MW-5]
(2) MCL level for TCE is 5 ug/L . Concentration is always below MCL level.

Table 2
Summary of Benzene Results

Groundwater Sampling Results

	Source Area	300 FT Down Gradient	NAWC Boundary 700 FT Down Gradient
Concentrations	20 ug/L	ND (1)	ND

Model Predicted Results

Case 1, Constant Source for 40-yrs, No Decay, No Pumping,

Steady State Conditions	20 ug/L	9.36 ug/L	4.36 ug/L
Conditions at 40 yrs	20 ug/L	9.36 ug/L	4.36 ug/L
Clean up times (to MCL Level)	4 yrs	8 yrs	NA (2)

Case 2, Constant Source for 40-yrs, With Decay, No Pumping,

Steady State Conditions	20 ug/L	2.36 ug/L	0.249 ug/L
Conditions at 40 yrs	20 ug/L	2.36 ug/L	0.240 ug/L
Clean up times (to MCL Level)	2 yrs	NA	NA

Case 3, Constant Source for 40-yrs, No Decay, With Pumping,

Conditions at 40 yrs	20 ug/L	9.36 ug/L	4.36 ug/L
Clean up times (to MCL Level)	4 yrs	5 yrs	NA

(1) Benzene was not detected in the down gradient wells
(2) MCL level for Benzene is 5 ug/L . Concentration is always below MCL level.

APPENDIX C

DESIGN CALCULATIONS

EXTRACTION SYSTEM DESIGN CALCULATIONS FOR AREAS A AND D

CLIENT Navy		JOB NUMBER 6883.1010 (CTO 252)	
SUBJECT FS Extraction System Designs			
BASED ON Site Data		DRAWING NUMBER	
BY JPO	CHECKED BY	APPROVED BY	DATE 3/28/96

NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D

Purpose

Generate FS designs for groundwater remediation for contamination associated with Areas A and D. Consider the following in the design process:

- Potential DNAPL presence in Area A - Do not extract groundwater from depths below suspected DNAPL horizon.
- Areas A and D gw remediation approaches should be compatible and integrated.
- Onsite extraction wells should contain future releases from site source areas.
- Offsite gw extraction should factor in the use of WTMA 26 as a remediation well, also should factor in WTMA needs for water supply from this well (Don't do anything that may substantively impact the well's yield).
- Consider the use of onbase production wells SW 1 and/or SW 2 and monitoring well MP-1 in Area D remediation scheme. Also consider using existing strippers on SW 1 & 2 for groundwater treatment.
- Assume that the bedrock aquifer behaves as an equivalent porous medium (EPM) on a large scale; EPM-type flow equations therefore apply at the scale appropriate for remedial design.

Design Data

Required capture zone widths (W)
- Required Area A onsite capture zone width - ~1,400 ft.
- Required Area D onsite capture zone width - ~1,000 ft

Groundwater flow gradients (i)
- Area A - .024 (based on shallow gw potentiometric surface map)
- Area D - .01 (based on shallow gw potentiometric surface map)

Depth of contamination/remediation
- Area A - Extract gw from shallow depth only, due to potential DNAPL concerns. Use data from Well C/HN11I/D, HN55S/I, BG4/HN12I as basis for setting well depths in Area A. At each cluster, the most contaminated wells are installed within the same shallow sandstone unit. Wells installed below the mudstone unit underlying the sandstone have little or no contamination. Use the base of the shallow sandstone unit as the maximum depth of pumping in the western portion of Area A.
- Depth of shallow sandstone unit varies from 100 feet (northwest corner) to 0 feet (at well DG-23). Projected avg extraction well depth ~65-70 feet, depth range ~35-100 ft.
- In eastern portion of Area A, pump from shallow depth <40 feet) to contain low concentration plume in this area.

CLIENT Navy		JOB NUMBER 6883.1010 (CTO 252)	
SUBJECT FS Extraction System Designs			
BASED ON Site Data		DRAWING NUMBER	
BY JPO	CHECKED BY	APPROVED BY	DATE 3/28/96

NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

- In Area D, focus pumping from water table to ~100-130 ft depth, near NAWC western boundary (based on HN-33I, SW-2, HN- 17S/I). For any wells closer in to the main building complex, pumping should be focused on the depth interval from the water table to about 100 feet.

Saturated thicknesses (B)
- Area A, Average thickness ~50 ft (70 ft depth - 20 ft depth to water)
- Area D, Average thickness ~100 ft (110 ft avg depth - 10 ft depth to water)

Transmissivities (T)
- Area A - 360 ft^2/day (1/2 Area D pumping test T, targeted aquifer thickness ~1/2 that of Area D pumping test aquifer thickness)
  - T from Area A pumping test - 104 ft^2/day, for shallow bedrock well(<50 ft pumping/observation well depths, 25-30 ft saturated thickness) - To be conservative, use 1/2 Area D pumping test results instead of Area A results)
- Area D - 720 ft^2/day (from Area D pumping test)

<u>Required extraction rates</u>

Basic Equation Q = TiW (1)

- For Area A, Q = (360 ft^2/day)(.024)(1400 ft)
  = 12,096 ft^3/day
  = 63 gpm

- For Area D, Q = (720 ft^2/day)(.01)(1000 ft)
  = 7200 ft^3/day
  = 37 gpm

Total pumping rate, Areas A and D - 63 + 37 gpm = 100 gpm

<u>Sustainable per-well pumping rates</u>

Limit individual well drawdowns to approximately 10% of saturated thicknesses, and aggregate per-well drawdowns (including drawdown effects from other extraction wells) to approximately 30% of the saturated thicknesses.

CLIENT Navy		JOB NUMBER 6883.1010 (CTO 252)	
SUBJECT FS Extraction System Designs			
BASED ON Site Data		DRAWING NUMBER	
BY JPO	CHECKED BY	APPROVED BY	DATE 3/28/96

NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

- For Area A, average saturated thickness of zone targeted for active pumping is about 50 feet.
- Individual per-well drawdowns should not exceed approximately 5 feet.

The pumping rate (Q) for a given drawdown (s) can be calculated by:

$Q = (4\pi Ts/2.3)/\log(2.25Tt/r^2S)$, (2)

where $T = 360\ ft^2/day$
$s = 5$ ft
$t = 10$ days
$S = .005$
$r = 0.25$ ft
Q = per-well pumping rate

$Q = 1{,}329\ ft^3/day$
$= 6.9$ gpm, say 7 gpm ($1{,}348\ ft^3/day$)

@ 7 gpm, need 9 wells to pump 63 gpm from Area A

- Optimum well spacing $= 1.2Q/\pi Ti$, (3)

where $Q = 1{,}348\ ft^3/day$
$T = 360\ ft^2/day$
$i = .024$

Optimum well spacing, Area A = 60 ft

- For 9 wells, maximum drawdown seen in center well. To estimate cumulative effects, use superposition concept and equation (2) rearranged as follows:

$s = (2.3Q/4\pi T)\ [\log(2.25Tt/r^2S)]$ (4)

with radial distances of 0.25 ft, 60 ft, 60 ft, 120 ft, 120 ft, 180 ft, 180 ft, 240 ft, and 240 ft. Add the 9 drawdowns (s) together to get the cumulative drawdown effect on the center well.

Cumulative drawdown = 5 ft + 1.8 ft + 1.8 ft + 1.4 ft + 1.4 ft + 1.2 ft + 1.2 ft + 1 ft + 1 ft
= 15.8 ft

15.8 ft/50 ft = 32% of saturated thickness - OK

CLIENT **Navy**		JOB NUMBER 6883.1010 (CTO 252)	
SUBJECT FS Extraction System Designs			
BASED ON Site Data		DRAWING NUMBER	
BY JPO	CHECKED BY	APPROVED BY	DATE 3/28/96

NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

- For Area D, average saturated thickness of zone targeted for active pumping about 100 feet.
- Individual per-well drawdowns should not exceed approximately 10 feet.

$Q = (4\pi Ts/2.3)/\log(2.25Tt/r^2S)$, (2)

where $T = 720\ ft^2/day$
$s = 10$ ft
$t = 10$ days
$S = .005$
$r = 0.25$ ft
Q = per-well pumping rate

$Q = 5{,}102\ ft^3/day$
$= 26.5$ gpm

- Historic monitoring well and extraction well yield data suggests that yields of > 10 gpm are atypical for the shallow portion of the Stockton Formation in the NAWC area. In addition, the use of several extraction wells allows for manipulation/optimization of pumping rates to focus pumping effects in those wells where higher levels of contaminants are present. As a result, revise assumed average per-well pumping rate for Area D downwards to 9 gpm for FS design purposes.

@ 9 gpm, need 4.1 wells to pump 37 gpm from Area D.
Pump each of 4 extraction wells at an average rate of 9.25 gpm (1,781 ft^3/day).

- Optimum well spacing $= 1.2Q/\pi Ti$, (3)

where $Q = 1{,}781\ ft^3/day$
$T = 720\ ft^2/day$
$i = .01$

Optimum well spacing = 94 ft

For 4 wells, maximum drawdown seen in center wells. To estimate cumulative effects, use equation (2) rearranged as follows:

$s = (2.3Q/4\pi T)\ [\log(2.25Tt/r^2S)]$ (4)

with radial distances of 0.25 ft, 94 ft, 94 ft, and 188 ft. Add the 4 drawdowns (s) together to get the cumulative drawdwon effect on the center wells.

Cumulative drawdown = 3.5 ft + 1.15 ft + 1.15 ft + .9 ft
= 6.7 ft

6.7 ft/100 ft = 7% of saturated thickness - OK

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NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

Conceptual Design Summary, Onsite Extraction Well Networks for Areas A and D

- Area A - 9 wells pumping at 7 gpm/well
  - Total extraction rate 63 gpm
  - Average well depth approximately 70 ft
  - Well diameter 6 inches

- Area D - 4 wells pumping at 9.25 gpm/well
  - Total extraction rate 37 gpm
  - Average well depth approximately 110 ft
  - Well diameter 6 inches
  - Use existing wells and air stripping towers for remedial work in Area D to the extent possible. Consider the use of MP-1 and possibly SW-1 for groundwater extraction; consider the use of the air stripping towers on wells SW 1 & 2 for treatment of Area D groundwater.

- Actual well yields can be expected to vary considerably due to the nature of the aquifer targeted for remediation (Stockton Formation; layered, fractured bedrock). The final determinations of per-well pumping rates, the number of wells required, well depths, and well spacings for Areas A and D should be based on actual site conditions encountered, including geologic/hydrogeologic conditions, sustainable yields from well borings, drawdown effects on the aquifer during test pumping, etc.. Conceptual designs showing well locations and per area and aggregate capture zones are shown in the attached figures.

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NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

Evaluation of offsite groundwater extraction and treatment, downgradient of Areas A and D.

- Offsite extraction system designs should factor in the use of WTMA Well No. 26 as a long term extraction well. The need for additional offsite extraction wells will be evaluated based on the premise that the onsite extraction system and WTMA 26 will be operational and upon the premise that the yield of WTMA should not be adversely affected by the operation of any additional offsite extraction wells.

<u>Estimation of WTMA Well Parameters</u>

- Transmissivity - No pumping test data available, use specific capacity (SC) data to estimate T.

$SC = T/2{,}000$, or (6)
$T = SC \times 2{,}000$

where: SC (Q/s) is in gpm/ft of drawdown
T is in gpd/ft

Based on existing information, WTMA 26 pumps at approximately 250 gpm with about 150 ft of drawdown. The specific capacity is calculated as follows:

$SC = 250 \text{ gpm}/150 \text{ ft}$
$= 1.67$ gpm/ft of drawdown

Inserting the SC into (6);

$T = 3340$ gpd/ft
$= 447 \text{ ft}^2/\text{day}$

- Capture zone width (w) of WTMA 26

$w = Q/Ti$,

where $Q = 48{,}128 \text{ ft}^3/\text{day}$ (250 gpm)
$T = 447 \text{ ft}^2/\text{day}$
$i = .024$

$w = 4{,}486$ ft

Based on onsite plume width for Areas A and D of approximately 2,100 ft and the assumed location of WTMA downgradient of the plume, the capture zone of WTMA will encompass the entire NAWC plume (and considerably more). Therefore, additional extraction wells are not required offsite for overall plume capture/containment.

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NAWC Warminster
Feasibility Study groundwater extraction system design - Areas A and D (continued)

Evaluation of offsite groundwater extraction and treatment, downgradient of Areas A and D (cont.)

- Estimation of drawdowns in area between Area A and WTMA 26 - Project drawdowns using distance-drawdown graphs. For Area A, project drawdowns for a single well, multiply by 9 to get cumulative drawdown at any given point. Graphs are attached to calculations.

For HN-16 area,
- WTMA located approximately 1450 ft away, Area A approx. 950 ft away
  - Drawdown due to WTMA 26 estimated at about 8 ft.
  - Drawdown due to Area A extraction wells estimated at about 2 ft (.22 ft x 9).
  - Total drawdown about 10 ft.

Flushing rate estimate, area between base and WTMA 26

- Distance (d) between Area A extraction system capture zone limit and WTMA 26 - approx. 2,000 ft

- Width (w) of WTMA capture zone - est. approx. 4,486 ft

- Avg. thickness (b) of aquifer within capture zone - ~180 ft (well 250 ft deep, factoring in water table depth, bedrock dip (upgradient area of capture zone is updip of WTMA 26)

- Bedrock fracture porosity (n) - assumed at 0.2%

Volume of water (Vw) in WTMA capture zone area between base and well calculated by:
$Vw = dwbn$
$= 3{,}229{,}920\ ft^3$

- @ an extraction rate of 48,128 ft^3/day (250 gpm) for WTMA 26, will require 67 days to pump one fracture pore volume from area between the base and WTMA 26.

Further extraction of groundwater from offbase areas is not recommended due to both the adequacy of the aggregate extraction system without additional offsite wells, and the concerns regarding potential impacts to WTMA 26 yields/capture zone extents. This recommendation is based on the following:

- Projected flushing rates for the area between the base and WTMA 26 appear to be reasonable

- Containment of the source area will be achieved by the onbase extraction system

- Significant drawdown effects are projected in the area between the base and the municipal well due to the pumping of both WTMA 26 and the Area A extraction system

- The operation of the Area A onbase extraction system will by necessity expand the capture zone of WTMA 26

EXTRACTION SYSTEM DESIGN CALCULATIONS FOR AREA B

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BASED ON Site Data		DRAWING NUMBER	
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NAWC Warminster
Feasibility Study groundwater extraction system design - Area B

Purpose

Generate FS design for groundwater remediation for contamination associated with Area B. Consider the following in the design process:

- Groundwater monitoring to date does not show any significant contaminant plume migration from identified areas of groundwater impacts.
- Past containment-type groundwater remediation test pumping indicates that minimal contamination (well below MCL's) is removed in this approach.
- An isolated area of impacted groundwater (TCE 12 ug/l and benzene 20 ug/l) contamination has been identified near a soil gas hot spot.
- Assume that the bedrock aquifer behaves as an equivalent porous medium (EPM) on a large scale; EPM-type flow equations therefore apply at the scale appropriate for remedial design.

Design Data

Assume that two hot spots of groundwater contamination exist that require focused remediation. Based on the lack of contamination in past test pumping of a containment-type system in Area B, do not consider a containment-type approach for plume control/remediation. Remediation approach will be to install extraction well(s) directly into the discrete area(s) of most significant groundwater impacts.

Based on gw monitoring data and soil gas anomaly sizes, assume two areas, approximately 100 feet in width each, require focused gw extraction.

- Required capture zone widths (W) - 100 ft
- Groundwater flow gradient (i) - .03 (based on gw potentiometric surface maps)
- Depth of contamination/remediation - avg. ~100 ft (2 most impacted wells are 27 and 147 ft deep)
- Avg. saturated thickness (b) - ~85 ft (avg depth to water ~ 15 ft)
- Transmissivity (T) - ~ 280 ft^2/day (2x the Area B pumping test T, which resulted from a pumping test that pumped a discrete interval at depth within the Stockton)

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Feasibility Study groundwater extraction system design - Area B (cont.)

Required extraction rate per hot spot

Basic equation Q = TiW

Q = (280 ft^2/day)(.03)(100)
= 840 ft^3/day
= 4.4 gpm, say 5 gpm (963 ft^3/day)

Sustainable per-well pumping rate

Limit drawdown to approximately 10% of saturated thickness to avoid excessive dewatering of aquifer, allow for flexibility to accomodate well-specific variations in yields, allow flexibility to increase pumping rates if later needed.

- For Area B, average saturated thickness of zone targeted for active pumping about 85 feet.
- Individual per-well drawdowns should not exceed approximately 9 feet.

The pumping rate (Q) for a given drawdown (s) can be calculated by:

$Q = (4\pi Ts/2.3)/\log(2.25Tt/r^2S)$, (2)

where T = 280 ft^2/day
s = 9 ft
t = 10 days
S = .005
r = 0.25 ft
Q = per-well pumping rate

Q = 1,883 ft^3/day
= 10 gpm

Therefore, 1 well can pump at 5 gpm without exceeding a drawdown of 9 feet.

Need 1 well to pump 5 gpm from each of 2 areas of focused remediation in Area B.

Conceptual design summary, Area B extraction system

- 2 wells, pumping at 5 gpm each
- Wells located along downgradient edges of discrete hot spots within Area B.
- Wells average 85 ft deep, 6 inches in diameter

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Feasibility Study groundwater extraction system design - Area B (cont.)

Reinjection of pumped/treated groundwater

- Assume wells used for injection of treated water.
- Assume injection well efficiency is 1/2 the efficiency of extraction well efficiency (i.e., the injection head for a given injection rate will be twice as much as the drawdown for the same extraction rate).

Drawdown for a given pumping rate can be calculated by:

$s = (2.3Q/4\pi T)\ [\log(2.25Tt/r^2S)]$ (4)

where $T = 280\ ft^2/day$
$t = 10$ days
$S = .005$
$r = 0.25$ ft
$Q = 963\ ft^3/day$ (5 gpm)

$s = 4.6$ ft

- Assuming 50% efficiency for injection, 9.2 ft of head would be created to inject 5 gpm into the aquifer.
- Assuming an average depth to water of 15 ft, there is sufficient space between the water table and ground surface to use 1 injection well for each 5 gpm extraction well.

Inject water directly upgradient of each extraction well, near runway along north edge of Site 6. Maintain as much separation between the injection and extraction wells as possible.

Injection well design

Construct injection wells similar to extraction wells
- Avg ~ 100 ft deep
- 6 inch diameter
- Maximize gravel pack and screen slot sizes to maximize efficiency, minimize maintenance problems.

EQUIPMENT SIZING CALCULATIONS

PROCESS CALCULATIONS
EQUIPMENT SIZING
By: J.P.Pradeep
Checked By: R. E. Mallowey

Date:5/10/96

DESIGN BASIS

Groundwater contaminants of concern are VOCs

Contaminant profile is shallow, intermediate and deep bedrock aquifers:

Ranges of Concentrations

VOC	Shallow	Intermediate	Deep	Groundwater Standard*
	(ug/L)	(ug/L)	(ug/L)	(ug/L)
Acetone	ND	ND-21	ND-17	None
Benzene	**ND**	**ND-4j**	**ND-20**	5
Carbon tetrachloride	ND-1	ND	ND	5
Carbon disulfide	ND-46	ND	ND	None
Chloroform	ND-2	ND	ND	100 (as total trihalomethanes)
cis 1,2-Dichloroethene	ND-5	ND-1	ND	70
Tetrachloroethene	ND-2	ND-2	ND	5
Toluene	ND	ND-7	ND-4	1000
Trichloroethene	**ND-12**	**ND-3**	**ND-2**	5

Note: Concentrations in bold indicate an exceedance of groundwater quality standards

* Appendix B-1: Statewide Human Health Standards for Groundwater, Pennsylvania's Land Recycling Program, 1995

Assume that reinjection standards are identical to groundwater quality standards

Based on the contaminant concentration ranges provided above, only the maximum concentrations of benzene and TCE are expected to exceed groundwater quality concs.

REMEDIAL SYSTEM COMPONENTS:

1) Groundwater Extraction System
2) Groundwater Treatment System
   - Equalization
   - Air Sparging/Mixing
   - Off-gas Treatment with Vapor-phase Activated Carbon Adsorption
3) Groundwater Reinjection

1.0 Groundwater Extraction System

2x Extraction Wells: 6-inch dia, 85 ft deep
Flow rate: 5 gpm/well
Total: 10 gpm
Provide 2x centrifugal submersible pumps: 5 gpm @ 35 ft TDH: 1/3 H.P.

2.0 Groundwater Treatment System

Equalization

Provide adequate detention time for mixing and volatilization
Assume that mixing and volatilization are simultaneously provided by air sparging
Assume that a 30 min detention time is adequate

Provide tank volume = 300 gal
Tank dimensions: 4 ft dia x 3.5 ft swd + 1.5 ft fb
Closed-top tank with vent to Off-gas Treatment System
For mixing with grid aeration, provide 10-15 cfm/1000 ft^3 air flow/tank volume (Metcalf and Eddy, 1991)
Estimate air-sparger sizing after determining requirement for volatilization

Air Sparger Sizing

(1) To be conservative assume only mass transfer by bubble aeration, ignore surface aeration
Note that for shallow basins (i.e. depth < 9 ft) removal by surface aeration can be significant
Actual aeration requirement may be only 50% of the estimate provided here.

(2) Estimate for removal of Benzene and TCE assuming maximum concentrations

Benzene =	20 ug/L, discharge goal =	5 ug/L
TCE =	12 ug/L, discharge goal =	5 ug/L

(3) Estimate using model prepared by Roberts, et al., 1984

I) Estimate saturation parameter (FO2) for oxygen under given conditions

FO2 = - ln [(Cge- ClxHco2)/(Cgi-ClxHco2)

Where:

Cge = Effluent gas conc of O2
Cl = Ave aqueous conc of O2 in tank = 2 mg/L or g/m^3 (= gw diss O2 conc)
Hco2 = Dimensionless Henry's Law Coefficient for O2 = 33 at 283 oK
Cgi = influent gas conc of O2 (in ambient air converted to mid-tank depth pressure)

Cge = (1-0.1)xCgi assuming 10% efficiency using coarse/fine bubble diffusers
Cgi = y x Pz/2 x M/(RT)

where:

y = molefraction of oxygen in ambient air = 0.209
Pz/2 = pressure at mid-diffuser depth = (1 + 0.1Depth/2) atm
Depth of diffuser = 1 ft = 0.30 m
R = Universal Gas Constant = 8.206 x 10^-5 atm.m^3/mol/K)
T = temperature of water = 50 oF = 283 oK
M = molecular wt of oxygen = 32 g/gmol

Cgi = 292.38 g/m^3
Cge = 263.14 g/m^3

FO2 = 0.14

II) Estimate saturation parameter for VOC using FO2

Fvoc = Si x FO2 x Hco2/Hcvoc
where:
Si = mass transfer rate proportionality constant for VOC = 0.675 for TCE
(Kyosai and Rittmann, 1991)

Si for other two-carbon aliphatics reported to be = 0.5 to 0.7
Assume Si for other VOCs = 0.6
Hctce = Dimensionless Henry's Law Constant for TCE = 0.42 (mean)
(Kyosai and Rittmann, 1991)

Ftce = 7.37 for TCE

Hcben = 2.37E-01 for benzene
Fbenz = 11.63 for benzene

III) Estimate required air flow rate to achieve adequate reduction of VOC conc
Qg = %R/(1-%R) x Ql/Hcvoc x (1/[1-e^(-Fvoc)])
where:
%R = percentage removal of VOC = 75% (assuming benzene reduction from 20 ug/L to 5 ug/L)
Ql = water flow rate = 10 gpm (= 1.3 cfm)
Hcvoc as listed above
Fvoc as calculated above
Qg = 9.56 cfm @ tank mid-depth pressure for TCE
Qg = 16.95 cfm @ tank mid-depth pressure for benzene

Choose highest air flow rate required for adequate removal of any one VOC
Therefore, required air flow rate = 16.95 cfm for benzene removal

Pressure at diffuser depth = 3.5 ft = 1.52 psig
Additional pressure drop through piping and diffusers = say = 2 psi
Total pressure differential = 3.52 psi
Air flow rate at mid-diffuser depth converted to standard conditions:
= actual flowx (14.7 + pressure at diffuser depth/2)/14.7
= 18.7 scfm

Provide air sparge blower:25 scfm @ 4 psig: 1.5 H.P
Provide porous dome/disc/tube type, fine-bubble air diffusers
Provide 1 or diffusers with common header, placed @ 3 ft depth

Off-gas Treatment System

Provide granular activated carbon adsorption for off-gas treatment
Assume 100% removal of TCE, benzene and carbon disulfide from aqueous stream to vapor
Assume adsorption coefficient of 1% (lb VOC/lbGAC) because of low concs expected in air

TCE =	12 ug/L
Benzene =	20 ug/L
Cdisulfide	46 ug/L

Total VOCs emission rate = 9.36E-03 lb/day
GAC consumption rate = VOC emission rate/0.01
= 0.936 lb/day
= 341.64 lb/yr

3.0 Groundwater Reinjection

Provide two horizontal centrifugal pumps: 5 gpm @ 35 ft TDH each: 1/3 H.P.
Provide 1.5 inch-dia, 250 ft transfer pipeline each to reinjection location
Provide 2x Injection wells: 6-inch dia, 100 ft deep; maximum gravel pack and screen slot sizes