FEASIBILITY STUDY REPORT

Northrop Grumman Bethpage Facility (Operable Units 2 and 3)

&

Naval Weapons Industrial Reserve Plant (Operable Unit 2)

(NYSDEC Site # 130003A and 130003B)

NYSDEC STANDBY ENGINEERING CONTRACT

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PREPARED FOR

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List of Abbreviations

°C	Degrees Celsius
1,2-DCE	cis-1,2-Dichloroethene
2D	Two-Dimensional/Two Dimensions
3D	Three-Dimensional/Three Dimensions
AOP	Advanced Oxidation Processes
ARAR	Applicable or Relevant and Appropriate Requirement
BCP	Bethpage Community Park
bgs	Below Ground Surface
BPGWCS	Bethpage Park Groundwater Containment System
BWD	Bethpage Water District
CCWPCP	Cedar Creek Water Pollution Control Plant
CERCLA	Superfund or Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfs	Cubic Feet Per Second
CHP	Catalyzed Hydrogen Peroxide
COC	Contaminant of Concern
CVOC	Chlorinated Volatile Organic Compound
DER	Division of Environmental Remediation
DNAPL	Dense Non-Aqueous Phase Liquids
ERH	Electrical Resistance Heating
ESTCP	Environmental Security Technology Certification Program
f_{oc}	Organic Carbon Content of Soil
FRTR	Federal Remediation Technology Roundtable
FS	Feasibility Study
ft/d	Feet Per Day
GABF	Grumman Aerospace-Bethpage Facility
GAC	Granular Activated Carbon
GHB	General Head Boundary
gpm	Gallons Per Minute
GRAs	General Response Actions
GWQS	Groundwater Quality Standards
HDPE	High Density Polyethylene
HDR	Henningson, Durham & Richardson Architecture and Engineering, P.C.
ICs	Institutional Controls
IRM	Interim Remedial Measure
ISCO	*In-Situ* Chemical Oxidation
ISTD	*In-Situ* Thermal Desorption
ITRC	Interstate Technology & Regulatory Council
K_{oc}	Soil Organic Carbon-Water Partitioning Coefficient
LTM	Long-Term Monitoring
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/kg	Milligrams Per Kilogram

MGD	Million Gallons Per Day
MNA	Monitored Natural Attenuation
msl	Mean Sea Level
NaOH	Sodium Hydroxide
NAPL	Non-Aqueous Phase Liquid
Navy	U.S. Navy
NGBF	Northrop Grumman Bethpage Facility
NWIRP	Naval Weapons Industrial Reserve Plant
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O&M	Operation and Maintenance
ONCT	On-site Containment System
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PDF	Portable Document File
PDI	Pre-Design Investigation
pH	Potential of Hydrogen
POTW	Publicly Owned Treatment Works
PRB	Permeable Reactive Barrier
PVC	Polyvinyl Chloride
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROW	Right-of-Way
SCG	Standards, Criteria, and Guidance
SEE	Steam-Enhanced Extraction
SO_4^-	Sulfate Free Radical
SPDES	State Pollutant Discharge Elimination System
SSF	State Superfund Program
SVE	Soil Vapor Extraction
TBC	To Be Considered
TCE	Trichloroethylene
TCH	Thermal Conductive Heating
TCVOC	Total Chlorinated Volatile Organic Compounds
TDS	Total Dissolved Solids
TOGS	Technical and Operational Guidance Series
TSDF	Treatment, Storage, and Disposal Facility
TVOC	Total Volatile Organic Compound
µg/l	Micrograms Per Liter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

UV	Ultraviolet
VOC	Volatile Organic Compound
VPB	Vertical Profile Borings
WA	Work Assignment
ZVI	Zero-Valent Iron

EXECUTIVE SUMMARY

The Northrop Grumman Bethpage Facility (NGBF) and Naval Weapons Industrial Reserve Plant (NWIRP) located in the Town of Oyster Bay, New York have been associated with the aerospace industry since the 1930s. Past handling, storage, and disposal practices resulted in volatile organic compound (VOC) contamination in on-site and off-site groundwater. As a result, the sites were placed on the New York State Registry of Inactive Hazardous Waste Disposal Sites as a Class 2 site in 1983.

Analytical results of groundwater samples collected from public water supply wells and groundwater monitoring wells as part of on-going sampling programs show that six public water supply well fields are impacted or threatened (likely to become impacted) by contaminated groundwater originating at the NGBF and NWIRP sites. Bethpage Water District (BWD) operates three public water supply well fields within the central portion and along the perimeter of the groundwater impacted by the former NGBF and NWIRP operations. Analytical results of groundwater samples collected from BWD public water supply well 6-2 prior to treatment show trichloroethylene (TCE) was detected as high as 1,650 micrograms per liter (μg/l) in April 2017.

The analytical results of groundwater samples collected from public water supply wells and groundwater monitoring wells also show contaminated groundwater originating from NGBF and NWIRP extends off-site approximately four miles to the Southern State Parkway. The responsible parties have implemented on-going remedial measures intended to eliminate or control the on-site sources of groundwater contamination. The responsible parties have either implemented or are planning to implement groundwater remedial measures capable of eliminating or controlling portions of the groundwater plume that contain high (greater than 1,000 μg/l) concentrations of TCE. Despite these efforts, groundwater contamination continues to migrate to the south toward public water supply wells, Great South Bay, and the Atlantic Ocean. After a review of the historical data, the New York State Department of Environmental Conservation (NYSDEC) determined further action is warranted to protect public health and the environment.

Remedial actions that could be completed to protect public health and the environment were evaluated during the completion of the Feasibility Study (FS). This FS report addresses off-site groundwater contamination within what is administratively known as Operable Unit 2 (OU2) and Operable Unit 3 (OU3), identifies technologies, and evaluates remedial alternatives that could be

implemented to remediate the groundwater contamination and achieve the Remedial Action Objectives (RAOs).

The RAOs are goals designed to be protective of human health and the environment, and include:

- Prevent ingestion of groundwater with contaminant levels exceeding State and Federal drinking water standards;
- Prevent contact with contaminated groundwater;
- Restore the groundwater to pre-disposal/pre-release conditions, to the extent practicable;
- Prevent the discharge of contaminants to surface water; and
- Prevent adverse impacts to the quantity or quality of the Nassau-Suffolk Sole Source Aquifer.

The primary objective of the FS is to ensure that appropriate remedial alternatives are identified and evaluated such that relevant information concerning potential remedial actions can be considered and an appropriate remedy selected. The FS relied on a comprehensive groundwater flow model constructed by the United States Geologic Survey (USGS) to compare groundwater extraction alternatives and quantify the daily volume of groundwater that must be extracted, treated, and discharged to achieve the RAOs.

Based on the USGS groundwater flow modeling, a total of eight remedial alternatives were evaluated in this FS, inclusive of the "No Further Action" alternative as a means of comparison. This evaluation included remedial alternatives designed to hydraulically contain and treat groundwater containing contaminants at concentrations exceeding State and Federal standards. These eight alternatives were divided to include options for a centralized treatment plant with centralized aquifer recharge or decentralized treatment with recharge occurring on a local scale. A common element considered for each alternative was the development of an alternate water supply for the BWD. The following alternatives were evaluated based on the results of the USGS groundwater flow modeling:

- Alternative 1 – No Further Action (existing & planned remedial systems);
- Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods;
- Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin;

- Alternative 3A – Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods;
- Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin;
- Alternative 4 – Aquifer Flushing;
- Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods; and
- Alternative 5B – Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin.

The results of the evaluation indicate that Alternative 5B is the most protective of human health and would achieve the RAO of restoring the groundwater quality to pre-disposal/pre-release conditions to the extent practicable in the shortest timeframe. This alternative would hydraulically contain the groundwater plume and include additional extraction wells in the most concentrated areas of the plume to reduce risk to human health and the environment and accelerate the timeframe to reach the RAOs. Alternative 5B would also include the construction of a centralized treatment plant and return the treated water to the aquifer through a newly constructed recharge basin in the vicinity of the treatment plant. A portion of the treated water would also be used for irrigation at Bethpage State Park and to augment stream flow in Massapequa Creek. Alternative 5B can be completed in a manner that would not negatively affect the environment (surface water, wetlands, and the saltwater interface) or the safe yield of the aquifer. Alternative 5B could reduce the concentration of VOCs in impacted water supply wells and could prevent threatened public supply wells from becoming impacted.

1 INTRODUCTION

Henningson, Durham & Richardson Architecture and Engineering, P.C. (HDR) was retained by the NYSDEC to conduct an FS for intercepting and remediating groundwater containing VOCs and 1,4-dioxane originating from the former NWIRP and the NGBF located in the Town of Oyster Bay, Nassau County, New York (Figure 1-1). HDR prepared this FS in general conformance with Section 4 of the Technical Guidance for Site Investigation and Remediation (*DER-10*) (NYSDEC Division of Environmental Remediation [DER], May 3, 2010). This FS report identifies technologies and evaluates remedial alternatives that are capable of achieving cleanup to pre-disposal or unrestricted land use conditions, or alternatives that may achieve a cleanup appropriate for the identified land use of the area. The primary objective of the FS is to ensure that appropriate remedial alternatives are identified and evaluated such that relevant information concerning potential remedial actions can be considered and an appropriate remedy selected.

2 SITE DESCRIPTION AND HISTORY

2.1 General Site Description

The NGBF and NWIRP sites are located in the Hamlet of Bethpage, Town of Oyster Bay, New York (Figure 1-1) and have been associated with the aerospace industry since the 1930s. Activities conducted at these facilities included administration, engineering, research and development, and manufacturing and testing for the U.S. Navy (Navy) and the National Aeronautics and Space Administration. The facility also had an active airfield to support the testing of aircraft. The manufacturing portions of the NGBF and NWIRP are now closed. The facility is surrounded by properties utilized for industrial, commercial, and residential purposes.

Site No.130003, formerly known as the Grumman Aerospace-Bethpage Facility (GABF) Site, consisted of approximately 600 acres and was listed in the Registry of Inactive Hazardous Waste Disposal Sites in New York State in 1983. On March 10, 1993, the GABF Site (130003) was divided into the NGBF Site (130003A) and the NWIRP Site (130003B). The NGBF Site was further divided on March 13, 2000, with 26 acres becoming the Northrop Grumman-Steel Los Plant 2 Site (130003C).

During the early 1990s many portions of the NGBF Site (130003A) were delisted, reducing the originally listed site to nine acres. Based on the investigations that were conducted it was discovered that the Grumman Corporation (a predecessor of Northrop Grumman) had also disposed of wastes in settling ponds on another 18 acre parcel prior to donating this property to the Town of Oyster Bay in 1962 for use as the Bethpage Community Park (BCP). In June 1996 operations at NWIRP ended, at that time the facility occupied 109.5 acres. In 2002, 4.5 acres of the property were transferred to Nassau County followed by another 96 acres in 2008. At this time the remaining 9 acre NWIRP parcel is retained by the Navy for investigation and remediation. Figure 2-1 shows the historical 1997 boundaries for the NGBF and NWIRP sites making up the original approximately 600-acre site along with the additional 18 acre area occupied by the BCP.

2.2 Operable Units

An operable unit (OU) represents a portion of a remedial program that for technical or administrative reasons can be addressed separately to investigate, eliminate, or mitigate a release, threat of release or exposure pathway resulting from contamination. The NGBF and NWIRP sites are divided into three OUs. Soil remediation at the former NGBF and NWIRP manufacturing plants are designated as OU1. Groundwater contamination at and down-gradient of NGBF and NWIRP are designated as OU2. Soil and groundwater at and down-gradient of the Former Grumman Settling Ponds, adjacent areas of the BCP, and the Northrop Grumman Access Road are designated as OU3. Disposal at OU3 also impacted adjacent off-site properties. The following Records of Decision (RODs) have been issued for the NGBF and the NWIRP sites:

- Operable Unit 1 NGBF On-Site Soils Source Area, 1995 (130003A);
- Operable Unit 1 NWIRP On-Site Soils Source Areas, 1995 (130003B);
- Operable Unit 2 Groundwater, 2001 and 2003 (130003A and 130003B); and
- Operable Unit 3 Former Grumman Settling Ponds and Adjacent Areas; On-Site Soils and On-Site and Off-Site Groundwater, 2013 (130003A).

2.2.1 Operable Unit 1

2.2.1.1 Northrop Grumman Bethpage Facility

Established in the 1930s, the NGBF is located on Hicksville Road in an urbanized area of Bethpage, New York. The main activities that occurred at this facility included the research/development, engineering, manufacturing, assembly, and testing of a variety of military and aerospace craft. A remedial investigation (RI) was conducted by Northrop Grumman between 1991 and 1994. The RI included the investigation of chemical and waste storage and disposal areas. Historically, the main source of wastes was the metal finishing process lines, including degreasing, conversion coating, anodizing, and painting. A ROD for source areas (i.e., soil) was issued in March 1995 and required soil remediation, via soil vapor extraction (SVE), at the Plant 15 area and the former TCE tank area at Plant 2. Remediation of the Plant 2 and 15 areas has been completed.

2.2.1.2 Naval Weapons Industrial Reserve Plant

The NWIRP was established within the Northrop Grumman property during the early 1940s. Historically, this facility was a government-owned, contractor-operated facility with the mission of design engineering, research prototyping, testing, fabrication, and assembly of various naval aircraft. The waste source areas that were studied during the Remedial Investigation/Feasibility Study (RI/FS) (Halliburton NUS, 1994) included:

- Site 1 - Former Drum Marshaling Area;
- Site 2 - Recharge Basin Area;
- Site 3 - Salvage Storage Area; and

- HN-24 Area.

The RI for the NWIRP was completed in May 1992 and a ROD for source areas (i.e., soil) was issued in May 1995. The 1995 ROD required excavation of inorganic-contaminated soils, the excavation of polychlorinated biphenyl (PCB) contaminated soil above 10 milligrams per kilogram (mg/kg), the remediation of VOC-contaminated soils via air sparging, and the implementation of deed restrictions for certain areas of the NWIRP (Arcadis Geraghty & Miller, 2000).

2.2.2 Operable Unit 2

The Navy and Northrop Grumman have been implementing a remedy identified in the NYSDEC 2001 ROD and the Navy 2003 ROD for OU2. The RODs call for on-site containment of impacted groundwater from source areas; groundwater extraction and treatment of hotspots (VOCs at concentrations greater than 1,000 μg/l); a public water supply contingency plan for monitoring and potentially providing treatment at down-gradient public water supply wells; and off-site monitoring of groundwater impacted by NGBF and NWIRP. Since the success of these remedies is critical to the overall strategy to contain and remediate the existing groundwater plume, specific details on these efforts are outlined below:

- Northrop Grumman has been operating the OU2 on-site containment system (ONCT) to contain and remediate VOC-impacted groundwater at the southern (down-gradient) edge of the OU2 source areas since 1998. The ONCT consists of five extraction wells (Well 3R [replaced Well 3 in 2013], Well 1, Well 17, Well 18, and Well 19). The water is treated at two on-site treatment systems and discharged to the on-site recharge basins. The location of the ONCT is shown on Figure 2-2. Approximately 6.7 million gallons per day (MGD) of contaminated water is withdrawn from five extraction wells, treated, and returned to the aquifer through recharge basins. Since operation of these systems began in 1998, nearly 200,000 pounds of VOC contamination have been removed from the aquifer.

- Under an agreement with the NYSDEC, the Navy designed, installed, and has been operating a groundwater extraction and treatment system (GM-38 Area) for remediating high (greater than 1,000 μg/l) concentrations of off-site VOC-contaminated groundwater since 2009. Following treatment, the water is returned to the aquifer system via a Town of Oyster Bay recharge basin adjacent to Arthur Avenue. The location of the GM-38 Area groundwater remediation system is shown on Figure 2-2. On average, approximately 1.4 MGD of contaminated water is withdrawn from a single recovery well in the GM-38 Area, treated, and returned to the aquifer through a recharge basin. Since operation of this system began in 2008, approximately 10,000 pounds of VOC contamination has been removed from the aquifer.

- Under an agreement with the NYSDEC, the Navy is currently designing a groundwater extraction and treatment system based on the detection of high (greater than 1,000 µg/l) concentrations of contaminants in groundwater in an area identified as the RE-108 Area. The Navy has divided the RE-108 Area work into two phases that will include three to five groundwater extraction wells. It is anticipated that groundwater will be extracted from the aquifer, treated, and returned to the aquifer through recharge basins. The location of the RE-108 Area is shown in Figure 2-2.

2.2.3 Operable Unit 3

OU3 includes on-site source areas within the BCP-Former Grumman Settling Ponds and adjacent areas of the NGBF. OU3 also includes off-site groundwater. The RI was completed in 2011 and the ROD signed in 2013. Details of the OU3 ROD specific to the groundwater include:

- The existing on-site groundwater extraction and treatment system identified as the Bethpage Park Groundwater Containment System (BPGWCS) will continue to be operated and upgraded as necessary, based on a review of its effectiveness, to assure the capture/containment of the full depth and area of contaminated groundwater leaving the on-site area. The BPGWCS consists of four groundwater extraction wells as shown on Figure 2-2. On average, approximately 0.3 MGD of contaminated water is withdrawn from these four recovery wells, treated, and returned the aquifer through a recharge basin located on the NWIRP property. Since operation of this system began in 2009, approximately 2,200 pounds of VOC contamination has been removed from the aquifer.
- Under an agreement with the NYSDEC, Northrop Grumman has installed three extraction wells and is designing the piping and treatment system to extract high (greater than 1,000 µg/l) concentrations of contaminants in groundwater in an area identified as the RW-21 Area located down-gradient of BCP. It is anticipated that groundwater will be extracted from the aquifer, treated, and returned to the aquifer through recharge basins or injection wells. The location of the RW-21 Area is shown on Figure 2-2.

2.3 Site-Related Contaminants of Concern

The contaminants of concern (COCs) for this FS were identified based on a review of the following four documents:

- 2001 NYSDEC OU2 ROD;
- 2003 Navy OU2 ROD;
- 2013 NYSDEC OU3 ROD; and
- 2003 Public Water Supply Contingency Plan

A list of COCs included in each document is provided below:

OU2 Off-Site Groundwater: The 2001 NYSDEC ROD lists seven VOCs as COCs including (Table 2-1):

1. Tetrachloroethene (PCE)
2. Trichloroethylene (TCE)
3. 1,2-dichloroethene
4. 1,1-Dichloroethene
5. Vinyl Chloride
6. 1,1,1-Trichloroethane
7. 1,1-Dichloroethane

The 2003 Navy OU2 ROD lists five VOCs as COCs including (Table 2-1):

1. PCE
2. TCE
3. 1,2-dichloroethene
4. Vinyl Chloride
5. 1,1,1-Trichloroethane

OU3 Off-Site Groundwater: The 2013 NYSDEC OU3 ROD lists 16 VOCs and three metals (Table 2-1) as COCs listed below:

1. PCE
2. TCE
3. cis-1,2-dichloroethene (1,2-DCE)
4. trans-1,2-dichloroethene

5. 1,1-Dichloroethene
6. Vinyl Chloride
7. 1,1,1-Trichloroethane
8. 1,1,2-Trichloroethane
9. 1,1-Dichloroethane
10. 1,2-Dichloroethane
11. 1,2-Dichloropropane
12. Chloroform
13. Toluene
14. Chlorodifluoromethane (Freon 22)
15. Dichlorodifluoromethane (Freon 12)
16. Trichlorotrifluoroethane (Freon 113)
17. Chromium
18. Nickel
19. Iron

Northrop Grumman and the Navy agreed to develop and implement a Public Water Supply Contingency Plan[1] as stipulated in the 2001 NYSDEC OU2 ROD and the 2003 Navy OU2 ROD. The Public Water Supply Contingency Plan was incorporated into the April 2015 Order on Consent and Administrative Settlement (Index #W1-118-14-2). Sixteen VOCs listed below have been and continue to be monitored as part of the Public Water Supply Contingency Plan:

1. PCE
2. TCE
3. 1,2-DCE
4. trans-1,2-dichloroethene

[1] Note that the compound name for Freon 113 (CAS #76-13-1) that is used in the Water Supply Contingency Plan is "1,1,2-Trichloro-1,2,2,-trifluoroethane," but should be "Trichlorotrifluoroethane."

5. 1,1-dichloroethene
6. 1,1,2,2-tetrachloroethane
7. 1,1,1-trichloroethane
8. 1,1,2-trichloroethane
9. 1,2-dichloroethene
10. 1,2-dichloroethane
11. 1,1-dichloroethane
12. Carbon disulfide
13. Carbon tetrachloride
14. Chlorobenzene
15. Chloroform
16. Trichlorotrifluoroethane (Freon 113)

One additional compound, 1,4-dioxane, has been included on the list of COCs for this FS. Although this emerging contaminant is not included in the four documents outlined above, recent sampling shows it is present in groundwater at concentrations above United States Environmental Protection Agency (USEPA) health based guidance, the 2018 New York State Drinking Water Quality Council MCL recommendation (1 µg/l), and it may be associated with historic solvent usage at the NGBF and NWIRP.

2.4 Applicable Standards, Criteria, and Guidance

SCGs are generally applicable, consistently applied, and officially promulgated standards and criteria that are either directly applicable, or that are not directly applicable but are relevant and appropriate, unless good cause exists why conformity should be dispensed with, and with consideration being given to guidance determined, after the exercise of scientific and engineering judgment, to be applicable. SCGs incorporate both the Superfund or Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) concept of "applicable or relevant and appropriate requirements" (ARARs) and the USEPAs "to be considered" (TBC) category of non-enforceable criteria or guidance.

There are three types of SCGs:

- Chemical-Specific SCGs: numerical standards or guidance for the concentration of COCs in the environment.

- Location-Specific SCGs: restrictions of certain activities based solely because of geographical or land use concerns. Requirements addressing wetlands, historic places, floodplains, or sensitive ecosystems and habitats are potential location-specific SCGs.
- Action-Specific SCGs: restrictions on the conduct of certain activities or operation of certain technologies at a particular site, and are primarily used to assess the feasibility of remedial technologies and alternatives. Regulations that dictate the design, construction, and operating characteristics are examples of action-specific SCGs.

2.4.1 Chemical-Specific SCGs

Chemical-Specific SCGs are either health- or risk-based numerical values or methodologies that establish the acceptable amount or concentration of a chemical that may remain in or be discharged to the ambient environment. Where more than one requirement addressing a contaminant is determined to be an SCG, the most stringent requirement was applied.

Chemical-Specific SCGs include relevant standards derived from NYSDEC Water State Quality Standards (Title 6 of the New York Code of Rules and Regulations), NYSDEC Division of Water Technical and Operational Guidance Series (TOGS 1.1.1), and the New York State Department of Health (NYSDOH) MCLs (NYSDOH Part 5, Subpart 5-1), and the Safe Drinking Water Act Maximum Contaminant Level (MCL), and above zero Maximum Contaminant Level Goals (MCLGs) (40 CFR 141). Currently one COC, 1,4-dioxane, does not have an established standard, so a proposed health-based criterion has been used as a conservative measure within this FS. The criterion for 1,4-dioxane is a USEPA calculated screening level identified as 0.35 µg/l based on a 10^{-6} lifetime excess cancer risk screening level in tap water (EPA, 2013C). This value will be updated when the NYSDOH establishes guidance for (or adopts) a drinking water standard for this compound. In December 2018, the New York State Drinking Water Quality Council recommended that the NYSDOH adopt an MCL of 1 µg/l for 1,4-dioxane, the recommendation is under consideration by the Commissioner of Health. The chemical-specific SCGs for the COCs identified in Section 2.3 are summarized in Table 2-2A.

2.4.2 Location-Specific SCGs

Location-Specific SCGs can be associated with the location of the remedy and include identifying and complying with floodplain and wetlands requirements; historical and cultural resources requirements; or rare, threatened, or endangered species requirements. Floodplains and wetlands may be encountered near Massapequa Creek during the construction of a potential groundwater remedy. State and Federal SCGs associated with protecting floodplains and wetlands during remedial activities are listed in Table 2-2B. Cultural resource surveys may be conducted before remedial activities to ensure that no historic resources will be affected by the activity in accordance with the SCGs listed in Table 2-2B. No State or Federal threatened or endangered species have been identified to date in the vicinity of Massapequa Creek. Additional threatened or endangered species studies may be conducted before remedial activities to ensure that no threatened or endangered species will be affected by the activity in accordance with the SCGs listed in Table 2-2B.

2.4.3 Action-Specific SCGs

Most action-specific SCGs address treatment, transportation, and disposal of hazardous waste that may occur during a remedial action. Table 2-2C includes descriptions of action-specific SCGs that may be associated with potential remedial actions.

2.4.4 Summary of Standards, Criteria, and Guidance

Groundwater SCGs were developed based on the criteria outlined above. The most stringent of the federal MCLs, NYSDEC Part 703.5 Class GA water quality standards, NYSDEC TOGS 1.1.1 water quality standards, and NYSDOH Part 5; Subpart 5-1 MCLs, were selected as the SCGs for the COCs in groundwater (see Table 2-2A). The SCGs for 16 of the 24 COCs shown on Table 2-1 are established by the NYSDOH Part 5 MCLs, while the other eight are based on water quality standards associated with NYSDEC Part 703.5 and TOGS 1.1.1.

2.5 Physical Setting

2.5.1 Topography

The topography in the vicinity of the site is relatively flat, resulting mainly from the advance and retreat of continental ice sheets of the Wisconsin aged glacier during the Pleistocene Epoch, which last retreated approximately 15,000 years ago. The roughly east-west trending ridge that forms the spine of Long Island, located to the north of the site, is an accumulation of glacial deposits that represents the southernmost terminus of the glacier and represents the highest elevations in this area (Buxton and Shernoff, 1999). South of the moraine, in the vicinity of the site, the ground surface dips gently southward from the moraine to the Atlantic Ocean.

2.5.2 Surface Water

Massapequa Creek, and its associated ponds, the Massapequa Park and Massapequa Preserve, and other areas that surround it comprise a mix of woodland, freshwater wetland, tidal wetland, and aquatic environments (Cashin Associates Inc., 2009). The Massapequa Creek drainage basin covers 38.6 square miles and is a major surface water contributor to South Oyster Bay (Figure 2-3) and includes portions of the Incorporated Villages of Farmingdale and Massapequa Park and the neighborhoods and communities of Bethpage, South Farmingdale, North Massapequa, Massapequa, and Biltmore Shores before ending at South Oyster Bay.

Massapequa Creek and surrounding riparian area contain a variety of habitats consisting of coastal streams, ponds, lakes/reservoirs, freshwater and tidal wetlands, and upland wooded areas that support diverse vegetation and wildlife. The majority of Massapequa Creek and the surrounding riparian area are located within the Massapequa Preserve and the boundaries of the South Shore Estuary Reserve. The Creek and its tributaries eventually drain into South Oyster Bay. Figure 2-3 also shows the stream flow for Massapequa Creek from 2006 to 2018. Below are historic stream flow statistics for Massapequa Creek based on a 68-year period of record (http://waterdata.usgs.gov/usa/nwis/uv?01309500).

- Minimum Stream Flow (1995) 0.83 cubic feet per second (cfs)
- 25th Percentile Stream Flow 2.6 cfs
- Median Stream Flow 6.2 cfs
- Mean Stream Flow 8.4 cfs
- 75th Percentile Stream Flow 9.5 cfs
- Maximum Stream Flow (1959) 57 cfs

Bellmore Creek extends from the Southern State Parkway to South Oyster Bay. The channel traverses through highly urban/suburban areas, in some places disappearing as a surface feature. It is also artificially ponded in some areas. The drainage area of Bellmore Creek is over 14.2 square miles. There is a USGS gauge station located on the right bank 40 feet east of the intersection of Valentine Place and Mill Road, in Bellmore, 0.5 miles north of Sunrise Highway, and 0.5 miles northwest of Wantagh.

Two other smaller creeks are also located south of the site including: Seaford and Seamans Creek (Figure 2-3). The creeks occupy much smaller drainage basins than Massapequa and Bellmore Creek and have fewer USGS stream flow measurements. For Seaford Creek, flow measurements ranged from 0.29 to 2.00 cfs while at Seamans Creek the flow ranged from zero (no-flow) to 4.00 cfs. In both cases, the very few field measurements available suggest these two creeks exhibit very low flows and may become seasonally dry. The flow record for Bellmore Creek includes more measurements over a longer time period, and the range of reported flows for Bellmore Creek ranges from 1.54 to 19.7 cfs (http://waterdata.usgs.gov/).

2.5.3 Geology

The NGBF and NWIRP are located in the Atlantic Coastal Plain physiographic province. This region is bordered to the south and east by the Atlantic Ocean and to the north and west by the Piedmont and New England physiographic provinces (Fenneman, 1938). Four distinct geologic units lie beneath the NGBF and NWIRP including deposits associated with the Ronkonkoma and/or Harbor Hill glaciation (upper glacial), the Magothy Formation and Matawan Group (Magothy), a clay member of the Raritan Formation (Raritan clay), and the Lloyd Sand of the Raritan Formation (Lloyd). A stratigraphic column of the geology of Nassau County is shown on Figure 2-4. A generalized hydrogeological cross-section is shown on Figure 2-5 (Isbister, 1966).

The Ronkonkoma ice sheet deposited a mantle of glacial drift on the Cretaceous, Pliocene, and early Pleistocene deposits. The drift ranges from unstratified till to stratified outwash and mainly occurs in three forms; basal drift, terminal moraine, and an outwash plain. South of the Ronkonkoma moraine is a relatively flat outwash plain that generally extends from the center of Long Island to the south shore. This outwash plain is composed of well-rounded coarse-grained sand and gravel (Isbister, 1966).

The Harbor Hill drift covers most of northern Nassau County and consists of outwash and till. Outwash deposits of the Harbor Hill ice sheet often thinly cover and are generally indistinguishable from the Ronkonkoma outwash (from the Ronkonkoma moraine) to the south shore of Long Island. Its surface is generally irregular and it includes numerous kettles, depressions, and small hills (Isbister, 1966).

The NGBF and NWIRP are located on the outwash plain south of the terminal moraines. The material is predominantly brown, medium to coarse-grained sand with minor amounts of fine sand and silt. The glacial outwash extends from ground surface to an unknown depth as the transition between the upper glacial and Magothy is not always distinct but is estimated to be 75 feet below ground surface (bgs) based on published literature (Isbister, 1966). A surficial geologic map of the area showing the geologic units at land surface is presented as Figure 2-6

The Magothy deposits are undifferentiated and lie unconformably on the Raritan clay. The Magothy, like the Lloyd Sand and Raritan clay, are early Cretaceous deposits of continental origin and are mostly deltaic quartzose very fine to coarse-grained sand and silty sand with interbedded silt and clay. The Magothy ranges in thickness from zero at its northern limit to more than 900 feet in southeastern Nassau County. The Magothy's upper surface slopes to the southeast and ranges from 200 feet above mean sea level (msl) to more than 450 feet below msl. The Magothy commonly has a 25 to 50-foot thick coarse sand and gravel layer near its base (Isbister, 1966).

2.5.4 Hydrogeology

Regional groundwater recharge occurs most prominently along the moraine north of the site which serves as not only a deep recharge zone but also as a groundwater divide. Although the moraine area is the most important regional recharge feature, groundwater recharge takes place across most of the land surface of Long Island. In general, groundwater moves away from the recharge area along the central spine of the island toward the coastal areas. The regional groundwater flow direction in the Magothy aquifer can be inferred from the 2016 potentiometric surface map provided by the United States Geological Survey (USGS) (Monti et al., 2017) and is presented as Figure 2-7. Based on the potentiometric surface of the Magothy aquifer, the groundwater flow direction at and down-gradient of the NGBF and NWIRP is to the south to southeast.

Groundwater in the shallow portions of the Magothy aquifer in the vicinity of the NGBF and NWIRP sites occurs as an unconfined aquifer. However, lenses of silt and clay, whose overlapping arrangement produces anisotropy ranging from approximately 36:1 to 120:1, cause a confining effect with depth (Isbister, 1966 and Reilly et al., 1983). The storativity of the Magothy ranges from water table conditions (0.25) to confined conditions (0.0006) depending on the location and depth (Reilly et al., 1983). Hydraulic conductivity estimates for the regional Magothy Formation based on aquifer tests of permeable portions of the aquifer range from approximately 27 feet per day (ft/d) to 150 ft/d with an average of approximately 67 ft/d (Isbister, 1966). Variations in the horizontal and vertical hydraulic conductivity can occur locally due to the presence of lower or higher permeability materials such as silts, clays, or gravels. More recent studies contain average values of hydraulic conductivity for the Magothy Formation to be in the range of 35 to 90 ft/d (Cartwright, 2002; Misut and Feldman, 1996; Smolensky and Feldman, 1995). The horizontal hydraulic gradient in shallow portions of the Magothy can range from 0.0001 to 0.001 feet per foot; however, the hydraulic gradient can be affected by hydraulic stresses such as local pumping, recharge basins, and remediation systems (Busciolano et al, 1998).

The Nassau/Suffolk Aquifer, that includes the upper glacial, Magothy, and Lloyd aquifers, was designated as a Sole Source Aquifer by the USEPA in 1978. The Nassau/Suffolk Aquifer is considered the sole source of drinking water in Nassau County. In the vicinity of the NGBF and NWIRP sites, 27 public drinking water wells operated by five regional water suppliers are either directly affected or have the potential to be affected by the groundwater from NGBF and NWIRP. These drinking water supply wells are screened in the Magothy aquifer and a majority of the wells are between 400 to 600 feet deep.

As an example, one of the five regional water suppliers is the BWD. Three BWD plants (well fields and treatment systems) are immediately down-gradient of NGBF and NWIRP. The BWD provides treatment at the three plants prior to distribution of water to customers. BWD relies on two public water supply wells (Well 4-1 and Well 4-2) at Plant 4. Both wells withdraw water from the Magothy aquifer. Well 4-1 is not in service and Well 4-2 produced 445 million gallons (mg) at an average pumping rate of 850 gallons per minute (gpm) in 2016. There is one public water supply well (Well 5-1) at Plant 5 that withdraws water from the Magothy aquifer. This well produced 180 mg with an average pumping rate of 340 gpm in 2016. There are two public water supply wells at Plant 6 (Well 6-1 and Well 6-2) that withdraw water from the Magothy aquifer. Well 6-1 produced 140 mg with an average annual pumping rate of 275 gpm in 2016, during the same year Well 6-2 produced 215 mg at an average annual pumping rate of 410 gpm.

Based on water demand and operator experience, the water supply wells are typically operated on a routine schedule that has the pumps switching on at a certain time and then off once the operational need is met. As groundwater is extracted from the aquifer during the pumping cycle, the water levels in the aquifer are drawn down (lowered) in response to the pumping. On the contrary, when the pumping stops, the water levels recover (increase) back to the original level.

3 REMEDIAL INVESTIGATION SUMMARY

3.1 Previous Remedial Investigation Summary

The nature and extent of groundwater contamination has been characterized through the drilling, testing, and sampling of monitoring wells and vertical profile borings (VPBs). Groundwater samples are collected from a network of wells on a routine basis to measure the concentration of VOCs over time while groundwater samples collected from VPBs provide a one-time measurement of the concentration of VOCs at multiple depths within the aquifer.

Data collected during the previous RIs shows that groundwater is contaminated with VOCs, primarily TCE, at concentrations that exceed SCGs. At the time of the Navy ROD in 2003 (Navy, 2003), the plume of groundwater (associated with OU2) containing VOCs at concentrations greater than the NYSDOH MCLs was reported to be more than 2,000 acres and extend to a depth of approximately 700 feet. At the time of the NYSDEC 2013 ROD in 2013 (NYSDEC, 2013), the plume of groundwater containing VOCs at concentrations greater than the NYSDOH MCLs was reported to be 5,400 feet in length and at least 550 feet deep with a notable area of high concentrations of VOCs. These investigations also showed groundwater containing VOCs greater than the NYSDOH MCLs comingled down-gradient of NGBF and NWIRP. A detailed discussion on the nature and extent of groundwater contamination can be found in the RI reports and in the OU2 and OU3 RODs.

3.2 2017-18 Supplemental Remedial Investigation Summary

The Conceptual Site Model (CSM) representing the hydrogeology and groundwater contamination that was developed during the previous remedial options work assignment (HDR 2016) was updated to integrate the most recently collected site information and data. The CSM was then used to identify data gaps and assist in the selection of possible VPB locations to confirm the down-gradient extent of COCs above the SCGs. Two data gaps were identified; one on the east side and one on the west side of the down-gradient extent of groundwater containing VOCs greater than the SCGs. Two VPBs were drilled during the summer and fall of 2017 (DEC-VPB-1 and DEC-VPB-2 on Figure 3-1) (HDR 2019). The two locations are approximately 4 miles south of NGBF and NWIRP, and were intended to characterize the down-gradient extent of the COCs above the SCGs. Groundwater samples were collected from the VPBs using a hydro punch sampler and submitted for laboratory analysis (EPA Method 8260C). At the conclusion of the VPB drilling, the USGS completed down-hole geophysical logging including gamma, single-point resistance, short and long normal resistivity, and electromagnetic (EM) conductivity logging. Split spoon soil samples and drill cutting samples were collected during the VPB drilling to characterize subsurface geology.

Groundwater samples were collected from DEC-VPB-1 from 60 to 945 feet bgs. Groundwater samples were collected every 50 feet between 60 and 210 feet bgs and every 20 feet thereafter. Some variation in the spacing of the intervals occurred due to lack of sample recovery at certain sample depths. Only two COCs were detected in the groundwater samples collected during DEC-VPB-1 (Table 3-1). Toluene was detected in groundwater samples collected from roughly 700 to 800 feet bgs with the highest concentration (14 μg/l) detected in the 698 feet bgs sample. Groundwater samples collected from 738 feet and 783 feet bgs also contained toluene at concentrations that slightly exceeded the SCGs. All groundwater samples collected above and below the 700 to 800 foot interval did not contain toluene. Other VOCs were detected in groundwater samples collected from DEC-VPB-1 including carbon disulfide which was distributed sporadically throughout the boring at concentrations much lower than the SCG. TCE or any other chlorinated volatile organic compound (CVOC) were not detected in any groundwater sample collected from DEC-VPB-1.

Groundwater samples were collected from DEC-VPB-2 at 20 foot intervals between 200 and 983 feet bgs. Two COCs were detected in groundwater samples collected from DEC-VPB-2 (Table 3-1). TCE was detected at concentrations below the SCG in samples collected from 148 and 198 feet bgs (maximum concentration = 1.4 μg/l). TCE or other CVOCs were not detected in other groundwater samples collected from VPB-2. Carbon disulfide was detected in groundwater samples at very low concentrations that are below the SCG. No other COCs were detected in groundwater samples collected from DEC-VPB-2.

Based on the results of the two VPBs, three new monitoring wells were installed. Two monitoring wells (DEC1D1 and DEC1D2) were installed adjacent to DEC-VPB-1 while the third well (DEC2D1) was installed near DEC-VPB-2 (Figure 3-1). The screened interval for each well was based on a review of groundwater sampling results, subsurface geology, and down-hole geophysical logging. Well DEC1D1 was screened from 695-715 feet bgs, corresponding with the 698 feet bgs DEC-VPB-1 sample that contained the highest concentration of toluene. Well DEC1D2 was screened between 760 to 780 feet bgs based on the results from the 763 and 783 feet bgs groundwater sampling intervals in DEC-VPB-1 that also contained toluene. Monitoring well DEC2D1 was screened at 180-200 feet bgs and corresponded with the 198 feet bgs sampling interval in DEC-VPB-2 that contained TCE.

Toluene was detected in groundwater samples collected from monitoring well DEC1D1 and from the 698 feet bgs interval in DEC-VPB-1. The concentration of toluene (2.2 μg/l) in the groundwater sample collected from the monitoring well was below the SCG, whereas the concentration of toluene (14 μg/l) in the groundwater sample collected from the corresponding DEC-VPB-1 interval exceeded the SCG. TCE or CVOCs were not detected in groundwater samples collected from DEC1D1 or DEC-VPB-1 (698 feet bgs). Toluene was also detected at low concentrations in the groundwater sample collected from monitoring well DEC1D2 and the groundwater sample collected from DEC-VPB-1 at 763 feet bgs. The concentration of toluene in both groundwater samples (0.37 μg/l from DEC1D2 and 2.4 μg/l from DEC-VPB-1) were below the SCG (Table 3-2).

TCE was the only COC detected in groundwater samples collected from monitoring well DEC2D1 and at 198 feet bgs from DEC-VPB-2. The TCE concentration (1.2 μg/l) in groundwater collected from DEC2D1 was similar with the TCE concentration (1.4 μg/l) in groundwater collected from 198 feet bgs in DEC-VPB-2. Both TCE concentrations are below the SCG.

3.3 Database Compilation

Groundwater quality data associated with the previous investigations, routine long-term monitoring (LTM), and the NYSDEC VPB drilling program were compiled and incorporated into a single comprehensive database. The database was then used as a tool to analyze and evaluate the nature and extent of the groundwater contamination. The database was also used as the source of data for the preparation of three-dimensional (3D) visualizations of the groundwater plumes.

The 3D visualizations are based on groundwater quality data from VPBs, monitoring wells, public supply wells, and groundwater extraction wells associated with the existing remedial systems. Data were provided to HDR from the NYSDEC, Navy, Northrop Grumman, and NCDOH (Table 3-3). Additional information, including well screen intervals, pumping rates, ownership, boring and well construction information, and county identifiers, were obtained from the data providers listed above through reports or direct communication. The data were provided in multiple electronic format types, including electronic data deliverable (EDDs), spreadsheets, or tabular data in portable document format (PDF) files. The data provided in PDF format were manually transcribed into spreadsheets for later assimilation into the database.

The design of the data management system needed to accommodate the wide variety of formats and quantity of data fields contained in the data files (Table 3-4). For this reason, a relatively simple relational database management system was designed using Microsoft Access™ (www.microsoft.com).

The data files varied in the types of information and number of data fields they contained. For example, some EDD formatted files consisted of approximately 145 fields while the data provided in spreadsheet and PDF formats contained as few as six fields. Given these differences, the database was designed to manage at least the minimum amount of data fields necessary to support the plume visualization effort. These data fields were divided into four general categories: 1) locational information; 2) sample properties; 3) sample time; and 4) analytical results. Each data type was stored on its own table with a "one-to-many" relationship defined between each.

After the database's core structure was designed, the compiled data were added to the corresponding fields and tables. Then the data were checked to identify possible duplicate information that entered the database due to slight variations of spelling or nomenclature among the data sources. It was possible for data with more than one name to be duplicated in the database (e.g., "MW-01" and "MW01" could refer to the same well, but the data entered twice because of the inconsistent sample nomenclature). The database was checked to assure that duplication did not occur and in the few instances where duplication was found, it was corrected and a note added to the database.

Standardization of the compiled dataset was necessary for the data from disparate sources to be used together to generate 3D visualizations. Examples of data standardization actions include converting all sample location coordinates to NAD 1927 State Plane New York Long Island FIPS 3104, and unifying analyte names to the same synonym and/or spelling (e.g., trichloroethene instead of trichloroethylene). Prior to exporting the data for use in developing the 3D visualizations, sample information such as depths and coordinates were reviewed and discrepancies and conflicts corrected. If additional discrepancies were discovered during pre-processing or during initial plume visualization development, then those discrepancies were also corrected in the database.

Database queries were designed to extract groundwater concentration data at VPBs, monitoring wells, public water supply wells, and remediation wells in the input format required by the 3D visualization software (Leapfrog Hydro™; ARANZ Geo™; www.aranzgeo.com). These queries were designed to extract groundwater sample data associated with VPBs, and the most recent available groundwater sample data from monitoring wells (January 2013 to March 2017), public water supply wells (June 2013 to June 2017), and extraction wells (June 2013 to June 2017). Data for wells and VPBs without XY coordinates and for intervals without sufficient depth information, were excluded from the queries.

3.4 Groundwater Visualization

Leapfrog Hydro™ software was used to generate 3D visualizations of contaminants in groundwater via the Fast RBF™ algorithm within Leapfrog Hydro™, a mathematical algorithm developed from radial basis functions. Plume 3D visualizations were created using one of two approaches: 1.) "Binary" where the input dataset is assigned into two classes indicating whether each sampling interval concentration is within the plume, or outside of the plume; and 2.) Numeric "interpolant" that uses the concentrations from sampling interval data and performs an interpolation between them. The binary 3D visualizations approach defines classes based on particular concentration thresholds (i.e., above, and equal or below, the concentration of interest or SCG). The interpolant approach can produce plume visualizations at various concentrations without re-classifying the underlying dataset or re-running the interpolation algorithm. Sample concentrations below the detection limit (ND) were assigned a value of "0." The 3D visualizations were constrained where there was a lack of data to define the edges based on upgradient concentrations and particle tracking.

Interpolant visualizations were created for TCE, toluene, 1,1-DCA, Freon, and Total Chlorinated Volatile Organic Compounds (TCVOCs) listed on Table 3-5. Data limitations precluded development of interpolant plumes for a majority of the COCs that were not frequently detected. Once this was completed, the individual plumes were superimposed over each other to form the 3D visualization of COCs that exceed SCGs (including 1,4-dioxane to 0.35 µg/l) (Figure 3-2). Three-dimensional visualizations were also created for a 50 µg/l (Figure 3-3) and 100 µg/l (Figure 3-4) TCVOC plumes.

The volume and mass of groundwater contamination (Tables 3-6 and 3-7) was also determined using Leapfrog Hydro™ and calculations via Microsoft Excel™. The volumes calculated represent the total volume within the 3D space. To identify the volume of affected groundwater, the calculated volumes within 3D visualizations (Table 3-6) were multiplied by the total porosity of the aquifer materials. A total porosity of 0.43 was used as a representative of fine sand (Todd, 1980). The 3D visualization volumes were used to calculate contaminant mass by multiplying the groundwater volumes by the associated concentrations, assuming the middle value of concentration (for each plume volume) was representative of the overall concentration for each interval. For example, the middle value of 75 µg/l was used to represent the 50 to 100 µg/l interval.

3.5 Groundwater Flow Modeling

Groundwater flow modeling has been used successfully in the past at this site to evaluate the migration of VOCs in groundwater (Misut 2011 & 2014, Arcadis 2003). In support of this FS, the NYSDEC tasked the USGS with the lead role in completing the groundwater modeling as a quantitative method of evaluating and comparing alternatives that could be used to remediate groundwater to the SCGs or other criteria (50 and 100 µg/l TCVOC). USGS reports documenting the modeling are in preparation and planned for publication in the near future.

The USGS used MODFLOW and MODPATH to conduct the modeling. Both of these models are considered industry standard for use in simulating complex groundwater flow systems. MODFLOW is a modular hydrologic model that simulates 3D groundwater flow in aquifers while MODPATH is a particle tracking post processing model that calculates the path lines along which a groundwater particle would travel based on the MODFLOW results.

The basis for the groundwater flow model used during the FS is the USGS 2018 Long Island regional groundwater flow model, which is currently under development. This island-wide model is being developed as part of the on-going USGS study on the groundwater sustainability of the Long Island aquifer system. The USGS regional model includes an update to the geologic framework of the island.

The Long Island regional groundwater flow model was completed as a 25-layer model. Since the Long Island regional groundwater flow model is an island-wide model, USGS developed a more defined focus area within the overall model domain for this investigation (Figure 3-5).

3.5.1 Focus Area Model

The 25-layer island-wide regional groundwater flow model was used as the initial framework for the focus area model. Within this smaller focus area, the model grid was re-discretized from the regional model containing 25 layers, 1,309 columns, 348 rows of 500-foot square cells to a focus area model containing 25 layers, 250 columns, and 346 rows of 100-foot square cells. Beyond the focus area of 100-ft square cells, there are square- and rectangular-shaped cells resulting from variable cell spacing (total of 25 layers, 617 columns, and 614 rows). There are five times more cells in the focus area model than the regional model; within the volume of a single regional model cell, there are 25 focus area cells. Vertically, the regional and focus area model grids are coincident and cover the entire depth of unconsolidated material with bedrock used as the lower boundary.

Model layer 1 represents the water table aquifer, mainly an upper glacial aquifer. Model layers 2 through 5 are used to regionally represent the Gardiner's Clay and other local confining units. Layer thickness was defaulted to unit thickness and hydraulic properties set to the underlying layer if a model layer in the regional model was not present in the local area model. Model layers 5 to 23 represent the Magothy aquifer. Model layer 24 represents the Raritan confining unit. Model layer 25 represents the Lloyd aquifer. The size and shape of the Raritan confining unit, Lloyd aquifer, Gardiner's Clay, and moraine/ice contact deposit zones were carried over from the regional to the focus area model. Within the upper glacial and Magothy aquifers, a texture model was used in the regional model to represent heterogeneity based on borehole logs. Within the focus area, additional parameter zones were constructed and used as multipliers of associated regional model values. The additional multiplier parameters included 1.) an upper-Magothy valley fill zone set within the top 5 layers of the Magothy aquifer or regional model layers 5 through 9; 2.) a lower-Magothy gravel zone set in regional model layer 19; and 3.) for model cells not classed as upper-Magothy valley fill or lower-Magothy gravel, subdivisions of regional texture model Kx values into greater than 100 ft/d and less than 100 ft/d categories. The focus area model was calibrated using parameter estimation techniques to solve for groundwater level and stream flow targets.

The 3D visualizations were provided to the USGS for use in the groundwater flow modeling. MODPATH was used to assign particles at the centroid of each model cell within the shell to form a representation of the groundwater plume within the model domain. MODPATH then calculates the forward path along which each particle travels from its origin to its ultimate discharge location.

The modeling was used to refine each remedial alternative to better understand zones of contribution, possible movement of existing hotspots, potential influence on or by the public water supply wells and existing groundwater recovery systems, and the return of the treated water to the aquifer system (i.e., recharge basins and injection wells).

A total of eight remedial alternatives were simulated with the model using an iterative process to conceptualize and refine each alternative. No Further Action is intended to simulate the steady-state condition resulting from the existing and currently planned remedial systems (Alternative 1). The existing and planned remedial systems target only the most highly contaminated groundwater, generally those areas exhibiting concentrations in excess of 1,000 µg/l. At the other end of the possible range, Alternative 2 provides hydraulic containment of groundwater containing COCs above the SCGs (full plume hydraulic containment). This is accomplished with a network of extraction wells capable of intercepting groundwater containing COCs above the SCGs. This alternative was completed using de-centralized (Alternative 2A) and centralized treatment and recharge (Alternative 2B).

The mass flux alternative (Alternative 3) seeks to maximize the removal of contaminant mass by targeting high mass flux zones occurring within the plume area exhibiting a TCVOC concentration greater than 50 µg/l within high permeability aquifer zones. This alternative was completed using de-centralized (Alternative 3A) and centralized treatment and recharge (Alternative 3B).

The aquifer flushing alternative (Alternative 4) seeks to accelerate groundwater movement through strategically placed extraction and injection wells. Alternative 5 is a hybrid approach of Alternative 2 and 3 and includes hydraulic containment of COCs to SCGS and focused extraction of groundwater containing high TCVOC concentration (generally greater than 50 µg/l) within high permeability aquifer zones to accelerate the remedial timeframe. This alternative was completed using de-centralized (Alternative 5A) and centralized treatment and recharge (Alternative 5B).

Once the MODFLOW simulations for each remedial alternative were set up and run, MODPATH was used to show particle tracking of groundwater from within the plume to the extraction wells or other discharge locations. The other discharge locations were commonly one of the existing remedial wells, public supply wells, surface water, or subsea discharge. The number of wells and pumping rates needed to meet the goals for each remedial alternative was determined through a series of modeling iterations.

3.5.2 Simulating the Potential Affects to the Environment

The groundwater flow model was also used to evaluate the potential effects each remedial alternative could have on the environment. These include:

- Evaluating the potential impact to surface water using modeled changes in stream flow;

- Evaluating the potential impact to wetlands using modeled changes to the water table in wetlands;
- Evaluating the potential impact to 13 public water supply wells using modeled changes in water level at each well; and
- Evaluating the potential impact to the freshwater-saltwater interface using modeled changes in subsea discharge.

The parameters outlined above are described in additional detail in the next four sections.

3.5.2.1 Surface Water

Each remedial alternative evaluated using the model has the potential to change stream flow, as changes in groundwater elevation near streams could decrease the amount of groundwater discharging to surface water. Groundwater can naturally seep through the bottom sediments of a lake, pond, or river and represent a portion of the overall water contribution to surface water. Depending on the characteristics of the surface water body and watershed, the portion of overall inflow that is groundwater can vary. Some water bodies are completely disconnected from a groundwater aquifer and receive only water from runoff. The local area groundwater model was used to analyze potential changes in stream flow for each remedial alternative by comparing the stream flow in cfs during each alternative to the stream flow during baseline conditions (Alternative 1). Potential changes in stream flow were assessed for the following streams/creeks:

Massapequa Creek: USGS Stream Gage 01309500

Bellmore Creek: USGS Stream Gage 01310000

Seaford Creek

Seamans Creek

Any increases or decreases in stream flow were assessed at existing USGS stream gages on Massapequa Creek and Bellmore Creek to allow for future direct comparisons to empirical data. Increases or decreases in stream flow were also assessed at Seaford and Seaman Creeks at mid-point stream locations similar to Massapequa Creek and Bellmore Creek. The stream flow assessment locations are shown on Figure 3-6.

3.5.2.2 Wetlands

Each remedial alternative has the potential to affect wetlands since increased groundwater extraction could raise or lower exiting water levels in and around local wetlands. The potential effect to wetlands was evaluated using the USGS groundwater flow model. The potential effect each alternative could have on wetlands was evaluated by assessing the potential change of the water table elevation at three Preserves (Massapequa Creek, Seaford Creek, and Bellmore Creek) along the south shore of Nassau County identified by the National Wetlands Inventory by the US Fish and Wildlife Service. The water table elevation was simulated at the seven locations identified on Figure 3-7 and compared to the baseline water table elevations as assessed by the simulation of Alternative 1. The difference in water table elevation between each alternative and the baseline alternative was identified as the potential water table elevation change at each location.

3.5.2.3 Public Water Supply Wells

Each alternative has the potential to affect public water supply wells since increased groundwater extraction or return of treated water can increase or decrease the existing water level in the aquifer. The potential effect each alternative could have on existing public water supply wells was evaluated using the USGS groundwater flow model. The groundwater flow model was used to evaluate potential water level changes in the public water supply wells by comparing the simulated water level in the well for each alternative to the simulated water level in the baseline alternative (Alternative 1). The difference between the water levels was used to understand the potential changes in water levels in the public supply wells.

3.5.2.4 Saltwater Intrusion

The flow of water exiting, or discharging from the groundwater system of Long Island occurs naturally through streams, along the coast, and as subsea discharge. Potential changes in subsea discharge have the potential to affect the saltwater interface. The potential effect each alternative could have on the saltwater interface in the Magothy aquifer was evaluated with the USGS groundwater flow model. The groundwater flow model was used to quantify the subsea discharge for the upper glacial, Magothy, and Lloyd aquifers under each alternative.

Groundwater flow from the freshwater aquifers into the marine surface water and from marine surface water into freshwater aquifers were assessed by comparing the flow from the active model cells into or out of the general-head model cells. Groundwater flow from active model cells in the aquifer into general-head cells simulates groundwater flow from the aquifers into saline groundwater or marine surface waters. Groundwater flow from general-head cells into active model cells simulates marine surface water or saline groundwater flowing into the freshwater aquifer. The potential for saltwater intrusion was assessed by comparing groundwater through the General Head Boundary (GHB) into and out of the Magothy for each alternative to the groundwater through the GHB into and out of the Magothy for the baseline alternative (Alternative 1).

3.6 Nature and Extent of Groundwater Contamination

A review of the groundwater quality data collected from 2007 to 2018 that was used to create the 3D visualizations shows TCE is the primary contaminant in groundwater. TCE has the highest number of detections that exceed SCGs in groundwater samples used to create the 3D visualizations (Table 3-8). TCE was detected in 1,239 of the roughly 3,000 samples used to create the 3D visualizations, 735 of which exceeded the SCGs, with the highest concentration (11,200 µg/l) in a monitoring well located south of the LIRR near Stewart Avenue near RW-21 (RW-21_MW-3-1). TCE was detected at concentrations ranging from 0.23 µg/l to 11,200 µg/l and was found to exceed the SCGs to a depth of 820 feet bgs.

Cis-1,2-DCE and PCE were also frequently detected in groundwater samples. Cis-1,2-DCE was detected the second most frequently in groundwater samples used to create the 3D visualizations. PCE was detected the third most frequently in groundwater samples used to create the 3D visualizations. Cis-1,2-DCE was detected in 593 of the roughly 3,000 groundwater samples, with 181 samples exceeding the SCG (5 µg/l). The highest cis-1,2-DCE concentration was 3,400 µg/l and was detected in a groundwater sample collected in 2007 from VP-109, which is located near the BCP-Former Grumman Settling Ponds. PCE was detected in 558 of the roughly 3,000 groundwater samples with 186 samples exceeding the SCG (5 µg/l). The highest PCE concentration (620 µg/l) was detected in a groundwater sample collected in 2008 from VPB-116 in the RW-21 area.

Additional chlorinated VOCs, Freon compounds, toluene, and 1,4-dioxane were also detected at concentrations exceeding the SCGs, generally co-mingling with the TCE, PCE, and cis-1,2-DCE. Based on the dataset used to construct the 3D visualizations, 1,4-dioxane was detected in 159 of the 393 samples analyzed for 1,4-dioxane with 145 of the samples exceeding the EPA health-based guidance value 0.35 µg/l used to create the 3D visualizations. One hundred twenty-seven of the 145 samples (88%) contained 1,4-dioxane above the 1 µg/l New York State Drinking Water Quality Council recommended MCL. The detected concentrations for 1,4-dioxane ranged from 0.11 µg/l to 190 µg/l and the highest 1,4-dioxane concentration (190 µg/l) was detected in a groundwater sample collected from RW-21_MW-3-1, the same monitoring well near RW-21 that exhibits the highest measured TCE concentration.

Four of the parameters found on Table 3-8 were detected in only a limited number of samples and did not exceed the SCGs, including 1,1,2,2-terachloroethane (no detections), carbon disulfide (162 detections), chlorobenzene (9 detections), and nickel (one detection).

Data used to create the 3D visualizations were collected from 2007 to 2018. This data range was selected to create the 3D visualizations based on the spatial distribution and the age of the data to create accurate and current visualizations of the data. The comprehensive database includes data from wider date range (2000 to 2018) than the data used to create the 3D visualizations. Groundwater statistics that include all samples in the database are presented on Table 3-9.

The groundwater plume is a 3D volume of contaminated groundwater in the subsurface that varies by location and depth within its overall limits. In order to determine the maximum length and width of the groundwater plume in plan view, the 3D image was projected to two-dimensional (2D) view (Figure 3-8). This projection was completed for the following:

- Areas where COC concentration exceeds its respective SCGs (SCG plume). The COCs included are those listed on Table 2-1 excluding chromium, nickel, and iron because they have different solute transport properties than VOCs and excluding chloroform and carbon disulfide as they are often laboratory contaminants.
- Areas where TCVOC (including only those chlorinated VOCs listed on Table 3-5) concentrations exceed 100 µg/l (100 µg/l plume). The TCVOC list of compounds includes COCs and does not include metals (chromium, nickel, and iron), carbon disulfide, chloroform, carbon tetrachloride, chlorobenzene, 1,2-dichloropropane, toluene, 1,4-dioxane, and Freon listed as COC; and
- Areas where TCVOC (including only those chlorinated VOCs listed on Table 3-5) concentrations exceed 50 µg/l (50 µg/l plume). The TCVOC list of compounds includes COCs and does not include metals (chromium, nickel, and iron), carbon disulfide, chloroform, carbon tetrachloride, chlorobenzene, 1,2-dichloropropane, toluene, 1,4-dioxane, and Freon listed as COC.

The characteristics for each of these three plume representations are summarized below:

SCG Plume: The SCG plume includes groundwater that contains COCs greater than the SCGs. The SCG plume can be divided into the eastern (OU3) and western plumes (OU2). The western plume is approximately 4.3 miles long, extending from the NWIRP property to the Southern State Parkway. The main portion of the eastern plume is approximately 2 miles long, extending from the BCP-Former Grumman Settling Ponds to Hempstead Turnpike. Further to the south, beyond Hempstead Turnpike, a shallower portion of the eastern plume extends to the Southern State Parkway (Figure 3-2). The eastern and western plumes are comingled. The overall SCG plume is approximately 2.3 miles wide at Hempstead Turnpike.

50 µg/l Plume: The concentration of COCs that are CVOCs (Table 3-5) were summed to calculate TCVOCs in each groundwater sample collected from VPBs, monitoring wells, and public water supply wells. These data were used to create a 50 µg/l TCVOC plume. The western plume (Figure 3-3) is approximately 3.7 miles long, extending from the NWIRP property to an area north of the Southern State Parkway. The eastern plume is approximately 2.2 miles long from the BCP-Former Grumman Settling Ponds to Hempstead Turnpike. The two plumes have comingled and the TCVOC plume is approximately 1.6 miles wide (measured in the vicinity of Hempstead Turnpike).

100 µg/l Plume: The concentration of COCs that are CVOCs (Table 3-5) were summed to calculate TCVOCs in each groundwater sample collected from VPBs, monitoring wells, and public water supply wells. These data were used to create a 100 µg/l TCVOC plume. The western portion of the plume is approximately 3.5 miles long and the eastern portion of the plume is approximately 2.15 miles long (Figure 3-4). The two portions of the plume have comingled and the TCVOC plume is approximately 1.5 miles wide.

Cross-sectional views of the eastern and western plumes are shown together on Figure 3-9 (the western plume is the upper section and the eastern plume the lower section). The two cross sections represent slices through the 3D visualizations along the two section lines shown on the figure. The two section lines were selected to illustrate the configuration and concentration gradient of the plume with depth.

The cross-section of the eastern plume shows that the plume is migrating in a southerly direction and is getting progressively deeper to the south. As shown with the orange and red shading on the lower cross-section on Figure 3-9, there is an area where site contaminants are present in off-site groundwater at concentrations exceeding 10,000 µg/l (RW-21 Area). The eastern plume includes a shallower portion of contamination that is located near the GM-38 area.

Similar to the eastern plume, the western plume is migrating in a southerly direction and becomes progressively deeper but does not appear to have a separate portion of shallow contamination. The orange and red shading shown on the upper section of Figure 3-9 shows an area where the western portion of the plume exceeds 1,000 µg/l. This area is referred to as the RE-108 area. The source of the western plume has been contained by the OU2 on-site groundwater remedy. As described in Section 2.2.2, the five remedial wells in the ONCT prevent further off-site migration of elevated concentrations of site related contaminants by extracting, treating, and recharging approximately 6.75 MGD. Since this system has been in operation since 1998, the on-going groundwater monitoring program data show that the groundwater quality is improving immediately down-gradient of the ONCT. The area where the groundwater quality is improving is best illustrated on Figures 3-3 and 3-9 where the western portion of the plume appears to be split into a northern (on-site) and southern (off-site) plume area.

4 REMEDIAL GOALS AND REMEDIAL ACTION OBJECTIVES

4.1 Remedial Goals

The remedial goals for remedial actions undertaken pursuant to the New York State Inactive Hazardous Waste Disposal Remedial Program (State Superfund Program or SSF), are defined by Environmental Conservation Law, Article 27, Title 13. The stated goal of the SSF is to restore a site to pre-disposal conditions, to the extent feasible. At a minimum, the remedy selection process must result in a remedial action that shall eliminate or mitigate all significant threats to public health and the environment posed by the disposal of hazardous wastes at the site.

4.2 Remedial Action Objectives

RAOs are goals set for environmental media (e.g. soil and groundwater) that are intended to provide protection for human health and the environment. RAOs form the basis for the FS by providing overall goals for site remediation. RAOs are developed to define site-specific concerns that must be addressed and to what levels to protect human health and the environment. The RAOs for this FS are presented below.

Groundwater RAOs for Public Health Protection

- Prevent ingestion of groundwater with contaminant levels exceeding drinking water standards; and
- Prevent contact with contaminated groundwater.

Groundwater RAOs for Environmental Protection

- Restore groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable;
- Hydraulically contain the Navy Grumman groundwater plume, reduce its volume and contaminant concentrations, and prevent its further expansion and migration;
- Prevent the discharge of contaminants to surface water; and
- Prevent adverse impacts to the quantity or quality of the groundwater resources associated with the Nassau-Suffolk Sole Source Aquifer.

5 GENERAL RESPONSE ACTIONS

General Response Actions (GRAs) are broad classes of responses or remedies developed to meet the RAOs for the groundwater contamination associated with NGBF and NWIRP. The GRAs consider the nature of the contamination, the COCs, the physical and hydrogeological characteristics, and existing infrastructure. As described in Section 3, groundwater has been impacted by VOCs and 1,4-dioxane at concentrations exceeding SCGs. The primary VOC, TCE, has been detected at concentrations ranging from less than the 5 µg/l to more than 10,000 µg/l over an area that is approximately four miles long, two miles wide, and 900 feet deep.

GRAs that could be applied to address groundwater contamination down-gradient of NGBF and NWIRP include physical and chemical *in-situ* treatments, ex-situ treatments, disposal/discharge, or various combinations thereof. Seven GRAs have been identified for groundwater and are listed in Table 5-1.

- No Further Action
- Institutional Controls (ICs) with LTM
- Monitored Natural Attenuation (MNA) with LTM
- Containment
- *In-Situ* Treatment
- *Ex-situ* Treatment
- Groundwater Disposal/Discharge

5.1 No Further Action

Consideration of a 'No Further Action' response action is required under NYSDEC DER 10. The No Further Action response serves as a baseline against which the performance of other GRAs may be compared. Under the No Further Action response, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminated groundwater beyond what is currently being implemented to contain the on-site contamination and associated hot spots. No ICs for the contaminated groundwater will be implemented as part of the No Further Action GRA. At this particular site, the No Further Action alternative assumes that no additional remedial actions will be taken beyond what has already been implemented or planned in regard to the on-site and off-site groundwater contamination. On-going remedial efforts being conducted by the Navy and Northrop Grumman are described in Section 3, but generally include:

1. Operation of the On-Site Groundwater Containment System (five remediation wells);

2. Operation of the BCP Groundwater Containment System (four remediation wells);
3. Operation of the GM-38 Groundwater Extraction and Treatment System (one remediation well);
4. Future operation of the RW-21 Area Groundwater Extraction and Treatment System (three remediation wells);
5. Future operation of the RE-108 Groundwater Extraction and Treatment System (three or more remediation wells);
6. Continued use of wellhead treatment at six public water supplies; and
7. Continued implementation of the Public Water Supply (PWS) Contingency Plan.

5.2 Institutional Controls with Long-Term Monitoring

ICs are legal or administrative measures designed to prevent or reduce human exposure to hazardous substances when active remedial measures do not achieve cleanup limits. Such measures may include groundwater use restrictions. ICs are often implemented in conjunction with other remedy components. Long-term groundwater monitoring is typically completed to demonstrate compliance with the ICs.

5.3 MNA with Long-Term Monitoring

This GRA relies on natural mechanisms including dispersion, dilution, adsorption, diffusion, volatilization, biodegradation, and chemical reactions with subsurface materials to reduce contaminant concentrations in groundwater. There is no intervention to manipulate the physical, geochemical, or hydrological regime to improve attenuation. Comprehensive long-term groundwater quality monitoring is a required component of this GRA to evaluate and verify the progress of MNA, as is a contingency plan that defines the appropriate response action(s) should MNA not achieve the RAOs as expected.

5.4 Containment

Groundwater containment is typically achieved using physical vertical barriers, surface caps to limit precipitation infiltration, or hydraulic controls (e.g., interceptor trenches and extraction wells). Containment actions are taken to inhibit further migration of contaminated groundwater by minimizing recharge to the groundwater table through surface caps and/or altering the groundwater flow direction through hydraulic controls (i.e., minimizing mobility of contaminants). Containment options typically are not aimed at reducing the volume or toxicity of contaminants;

however, containment that involves groundwater extraction and *ex-situ* treatment will also result in reducing the mass of contaminants in the aquifer. This class of GRAs has been implemented on-site and immediately down-gradient of the site as a means of source hydraulic containment (including the OU2 ONCT and OU3 BPGWCS), as well as at the GM-38 Area located approximately one mile down-gradient of the BCP.

5.5 *In-situ* Treatment

In-situ treatment technologies may be used to reduce contaminant concentrations in-place without removal or containment of groundwater. Many *in-situ* treatment options (e.g., thermal treatment and *in-situ* chemical oxidation [ISCO]) are typically applied for source areas or areas where contaminant concentrations are found to be very high. However, other *in-situ* treatment options (e.g., enhanced biological treatment, in-well air stripping, or in-situ flushing) can also be applied at areas of lower contaminant concentrations.

5.6 *Ex-situ* Treatment

Ex-situ treatment GRAs are typically paired with GRAs involving collection of contaminated groundwater. The goal of *ex-situ* treatment is to reduce concentrations of contaminants in groundwater to levels required for the selected discharge process option(s). *Ex-situ* treatment technologies commonly include biological and physical/chemical processes, as well as transport for off-site treatment.

5.7 Groundwater Disposal/Discharge

Groundwater disposal/discharge GRAs are typically paired with GRAs involving the collection of contaminated groundwater. Extracted groundwater could be transported to a permitted Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal facility (TSDF) or discharged to a publicly owned treatment works (POTW) for treatment. Alternatively, the groundwater could be treated on-site using *ex-situ* treatment and then discharged either to a POTW, to a nearby surface water body, or into the subsurface via recharge basins or injection wells. There may also be opportunities to beneficially re-use the treated water.

Table 5-1 lists each of the GRAs that apply to groundwater. Information for each type of GRA includes an estimate of the areas and volumes of groundwater media to be addressed and remediated, and the identified use of that area of the site, and whether or not the GRA category includes a presumptive remedy. A presumptive remedy is a technology or approach that is appropriate for the remediation of specific types of contamination which, based on historical patterns of remedy selection and NYSDEC scientific and engineering evaluation of performance data, can be used to accelerate the remedy selection process.

6 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The following sub-sections describe technology classes associated with GRAs that are capable of achieving the RAOs. For example, *in-situ* treatment is a GRA that may achieve RAOs using thermal treatment, ISCO, or biological remediation technologies. Specific process options were identified within each technology class. For instance, ISCO, which is a technology class, includes process options related to the type of oxidant selected, such as permanganate, hydrogen peroxide, or sodium persulfate. Applicable process options were selected based on an understanding of the characteristics of the contaminated media and the technologies that are available to address the media.

The universe of potentially applicable technology types and process options were reviewed by screening the technologies and process options with respect to technical feasibility. This was accomplished by using site information regarding site geology and contaminant concentrations and distribution. The major factors that influence the technical feasibility of remedial technologies are the hydrogeologic complexity, aquifer heterogeneity, depth of contamination and the residential and commercial density of the area. Table 6-1 lists the identified technologies and process options and summarizes the outcome of the technical implementability screening. Results of the preliminary screening of technologies and process options identified for each GRA are discussed below. Based on this screening, remedial technologies are retained or not retained for further consideration. The retained technologies and process options are subsequently evaluated based on the NYSDEC DER-10 remedy selection evaluation criteria.

Several databases, guidance documents, and journal articles addressing groundwater remediation were used to identify potentially applicable remedial technologies. The following sources are of particular note:

- Federal Remediation Technologies Roundtable website (http://www.frtr.gov/matrix2/top_page.html)
- USEPA Hazardous Waste Clean-up Information web site (http://www.clu-in.org/)
- A Decision Flowchart for the Use of MNA and Enhanced Attenuation at Sites with Chlorinated Organic Plumes - The Interstate Technology & Regulatory Council (ITRC), Enhanced Attenuation: Chlorinated Organics Team (ITRC, 2007)
- Critical Review of State-of-the-Art *In-situ* Thermal Technologies for DNAPL Source Zone Treatment (Environmental Security Technology Certification Program [ESTCP], 2010)

- Presumptive Response Strategy and *Ex-Situ* Treatment Technologies for Contaminated Ground Water at CERCLA Sites (USEPA, 1996)

As discussed in Section 3, CVOCs and 1,4-dioxane have been detected in groundwater at concentrations greater than the SCGs. The estimated off-site groundwater treatment area is approximately four miles long, two miles wide, and 900 feet thick. This proposed treatment area is heavily urbanized and is fully developed with a few open spaces, such as the Bethpage State Park, existing Nassau County recharge basins, and Right-of-Way (ROW) corridors along major roads, such as Hempstead Turnpike and Southern State Parkway. Technologies requiring extensive area for staging or implementation will not be suitable for this site.

6.1 No Further Action

The No Further Action option is included as a basis for comparison with active groundwater remediation technologies in accordance with Section 4.2 of NYSDEC DER-10. If no further remedial action is taken, contaminants already present in the groundwater down-gradient from the NGBF and NWIRP will remain in place and/or move down-gradient in the direction of groundwater flow. Contaminants of concern, particularly CVOCs, will possibly degrade via natural processes and transform to other compounds over a long time period. At this particular site, the No Further Action alternative assumes that no additional remedial actions will be taken beyond what has already been implemented or planned in regard to the on-site and off-site groundwater contamination. The on-going remedial efforts that include groundwater extraction and treatment in several locations are described in detail in Section 2. Groundwater monitoring shows that No Further Action will fail to achieve the RAO's as groundwater containing COCs above the SCGs will continue to migrate down-gradient, potentially impacting receptors. However, as previously mentioned, this GRA is retained as a basis for comparison.

6.2 Institutional Controls and Long-Term Monitoring

ICs consist of administrative restrictions focused on minimizing potential contact with contaminated groundwater. LTM includes groundwater sampling to demonstrate the effectiveness of groundwater remediation and compliance with the ICs. These process options could be combined with other GRAs to achieve the RAOs; therefore, ICs and LTM have been retained for further evaluation.

6.3 Monitored Natural Attenuation and Long-Term Monitoring

MNA relies on natural mechanisms occurring in the aquifer, including dispersion, dilution, adsorption, diffusion, volatilization, biodegradation, and naturally-occurring chemical reactions with subsurface materials, to reduce contaminant concentrations in groundwater. There is no intervention to manipulate the physical, geochemical, or hydrological regime in the aquifer to promote the natural attenuation of the site contaminants. MNA is always used in combination with LTM to assess the progress, effectiveness, and protectiveness of natural attenuation. Regulatory approval of this option usually requires modeling and evaluation of contaminant degradation rates and pathways, as well as predicting contaminant concentrations at potential down-gradient receptor points over time (ITRC, 2007).

Site modeling is performed to evaluate whether natural processes of contaminant degradation could reduce contaminant concentrations below SCGs before potential exposure pathways are completed or to identify where additional measures (e.g., ICs) may be necessary to protect public health. In addition, LTM must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives and the longer remedial timeframe associated with its use. MNA/LTM has been retained for further evaluation with other remedial technologies, as site conditions (e.g., location in a Sole Source Aquifer and groundwater geochemical conditions) make its use independent of other remedial technologies unlikely.

6.4 Containment

Containment technologies are designed to prevent migration of contaminants to existing or potential down-gradient receptors. Containment technologies include hydraulic control, vertical barriers, and surface caps. These technologies provide containment by preventing the migration of groundwater from a source area. Hydraulic control is accomplished by installing extraction wells for pumping and treating the groundwater to stop contaminated groundwater from migrating past a certain point in the subsurface. Once treated, the water can be recharged to the subsurface, sent to a public sewer, or discharged to surface water. The technology classes and associated process options screened under containment are described below.

6.4.1 Hydraulic Control

Extraction Wells: Hydraulic control may be achieved by controlling the direction of groundwater flow with well capture zones created by pumping wells. These extraction or groundwater pumping wells create points of low hydraulic head to which nearby groundwater flows. When groundwater is pumped from extraction wells, the groundwater potentiometric surface (or generally the groundwater level) is modified and results in changes to the groundwater flow directions near the well. By optimizing the locations of the extraction wells and adjusting the groundwater pumping rates, a potentiometric surface can be manipulated to capture the contaminated groundwater. This capture zone prevents contaminated groundwater from migrating toward down-gradient receptors. This technology has been used at many sites and is technically feasible. The water that is extracted typically requires treatment and management. Hydraulic control using groundwater extraction wells will be retained for further evaluation.

Interceptor Trenches: Interceptor trenches refer to a wide range of lateral groundwater collection systems from tile-drain systems to deep horizontal well installations. Recent technology advances in trench construction methods, such as continuous trenching equipment, use of biodegradable slurries, geotextiles, or plastic shoring materials, and other innovations have led to the more frequent use of interceptor trenches. All of these construction methods involve the installation of a horizontal collection system which intersects a large cross-section of the groundwater system. Groundwater is directed to the interceptor trench as a result of a hydraulic head drop maintained across the length of the trench.

The hydraulic head drop can be a result of gravity drainage (as in a traditional French or tile drain) or can be induced by pumping from a collection sump attached to the trench system. Interceptor trenches are typically used in shallow groundwater collection applications in unconsolidated media. This technology is not feasible for the NGBF and NWIRP sites because the groundwater contamination is more than 800 feet deep, well below the practical limit of trenching. Therefore, interceptor trenches will not be retained for further evaluation.

6.4.2 Vertical Barrier

Vertical barriers (e.g., slurry walls, grout curtains, and sheet pile walls) are used to slow groundwater flow, minimize migration of contaminated groundwater, divert contaminated groundwater from a drinking water intake, and/or provide a hydrodynamic barrier to enhance the efficacy of a hydraulic barrier (i.e., a groundwater pump & treat system). The following are commonly used vertical barriers:

Slurry Wall: Slurry walls consist of a vertically excavated trench that is filled with a low-permeability material to contain the contaminated groundwater. Most slurry walls are constructed of a soil, bentonite, and water mixture. The bentonite slurry is used primarily for wall stabilization during trench excavation. A soil-bentonite backfill material is then placed into the trench (displacing the slurry) to create a cutoff or containment wall. Walls of this composition provide a barrier with low permeability and chemical resistance. Other wall compositions, such as cement/bentonite, pozzolan/bentonite, attapulgite, organically modified bentonite, or slurry/geomembrane composite, may be used if greater structural strength is required or if chemical incompatibilities between bentonite and site contaminants exist. Slurry walls are typically placed at depths up to 100 feet in unconsolidated media and are generally 2 to 4 feet in thickness. This technology is not feasible for the Grumman Site because the groundwater contamination is more than 800 feet deep, well below the practical limit to which a vertical barrier can be installed. The density of buildings, roads, and subsurface utilities within the footprint of the groundwater plume would also make the installation of a slurry wall impractical. Therefore, slurry walls will not be retained for further evaluation.

Grout Curtain: Another method used to create a vertical barrier to groundwater flow is the installation of a grout curtain. Grouting consists of the injection of one of a variety of special fluids (e.g., epoxy or sodium silicate) or particulate grouts (e.g., Portland cement), into the soil matrix under high pressure. Grouting reduces permeability and increases mechanical strength of the grouted zone. When carried out in a linear pattern, grouting can result in a curtain or wall that can be an effective barrier to groundwater flow. The rate of grout injection and the spacing between the injection wells are critical. If the rate of injection is too slow, premature solidification occurs and if the injection rate is too fast, the formation may be fractured. The advantage of grout curtain emplacement is the ability to inject grout through relatively small diameter drill holes at unlimited depths. The main disadvantage of using grout curtains is the uncertainty that complete cutoff is attained.

This technology is not feasible for the Grumman Site because the groundwater contamination is more than 800 feet deep, well below the practical limit to which a vertical barrier can be installed. The density of buildings, roads, and subsurface utilities within the footprint of the groundwater plume would also make the installation of a grout curtain impractical. Grout curtains will not, therefore, be retained for further evaluation.

Sheet Piling: Sheet pile cutoff walls are constructed by driving sheet materials, typically steel, through unconsolidated materials with a pile driver or vibratory drivers. The depth of groundwater contamination greatly exceeds the practical limits for driving sheeting into the aquifer. Sheet piling will not, therefore, be retained for further evaluation.

6.4.3 Surface Capping

Surface capping prevents or reduces infiltration of rainwater to the aquifer. Caps (or covers), which involve installing low-permeability material at the ground surface, are typically constructed of soil and synthetic material, asphalt, or bituminous concrete.

Multimedia Cap: A multimedia cap is typically constructed from low-permeability clay and a synthetic membrane covered by soil to minimize groundwater recharge. A multimedia cap will not achieve the RAOs and is not implementable over the extensive off-site groundwater contamination. Therefore, installation of a multimedia cap will not be retained for further evaluation.

Asphalt or Concrete Cap: This process option involves the installation of a layer of asphalt or a concrete slab to minimize groundwater recharge. An asphalt or concrete cap will not achieve the RAOs and is not implementable over the extensive off-site groundwater contamination. Therefore, installation of an asphalt or concrete cap will not be retained for further evaluation.

6.5 *In-Situ* Treatment

The remedial technologies identified under *in-situ* treatment consist of measures to treat contaminated groundwater *in-situ* (i.e., without removal). The remedial technologies and associated process options screened under this GRA are described below.

6.5.1 *In-Situ* Thermal Treatment

Several thermal treatment technologies are identified that may be applicable. In simplest terms, *in-situ* thermal treatment uses heat to mobilize and recover the contaminants. The only significant difference between the various methods is the way the heat is generated and transferred into the subsurface. The following are three thermal treatment technologies evaluated for the site.

Steam-Enhanced Extraction: Steam-enhanced extraction (SEE) uses an alternating steam injection and vacuum extraction approach to remove volatile and semi-volatile compounds from the subsurface. The steam injection displaces mobile liquids (groundwater and mobile non-aqueous phase liquids [NAPL]) ahead of the advancing steam zone. Liquids displaced by the injected steam are pumped from extraction wells. The vapors containing the volatilized contaminants are captured by vacuum extraction wells installed within the unsaturated zone above the thermal wells. Once above ground, extracted groundwater and vapors are cooled and condensed. The concentrated contaminants are separated from the aqueous steam for recycling or disposal, and process vapors and water are treated before discharge.

Several SEE applications have been completed at large sites and RAOs (below MCL level groundwater concentrations) have been achieved at a few sites. Relatively new thermal treatment schemes involving combinations of SEE with thermal conduction heating (which is discussed below) seek to optimize the use of the lower-energy method (i.e., by enhancing electrical heating projects using steam injection). The close spacing of injection and extraction points necessary to recover contamination are not implementable for this project given the large treatment area and depth (greater than 800 feet) and the highly developed nature of the area. Therefore, SEE will not be retained for further evaluation.

Electrical Resistance Heating: Electrical resistance heating (ERH) involves installation of electrodes in the subsurface for thermal treatment of VOCs. Soil and groundwater are heated by the passage of electrical current between the electrodes. It is the resistance to the flow of electrical current that results in increased subsurface temperatures. The maximum achievable temperature with ERH is the boiling point of water. As the subsurface is heated, contaminants are volatilized and soil moisture and groundwater are converted to steam. Vapors generated by ERH, along with contaminated condensate and entrained water, are captured using vacuum extraction wells installed in the unsaturated zone above the heater wells and then treated using activated carbon or other methods at the surface.

Unlike SEE, ERH does not rely on fluid movement to deliver heat. ERH electrodes are constructed using readily available materials (e.g., steel pipe and sheet piling) and have been used to treat contamination to depths of 100 feet bgs (ESTCP, 2010). Similar to each of the thermal technologies, given the large area and depth of contamination, the high density commercial/residential area, and the fact that most of the VOCs are in the permeable fractions of the aquifer, this technology is not effective or implementable under these hydrogeologic conditions. Therefore, ERH will not be retained for further evaluation.

Thermal Conduction Heating: Thermal conduction heating (TCH), also known as *in-situ* thermal desorption (ISTD), is the simultaneous application of heat and vacuum to the subsurface to remove organic contaminants. Heat is applied by installing electrically powered heaters throughout the zone to be treated. The heat moves out into the inter-well regions primarily via thermal conduction. The boiling of fluids in the aquifer matrix leads to steam formation. The steam is captured by the vacuum applied at each heater boring. TCH may be applicable for higher boiling point organics such as PCBs, polycyclic aromatic hydrocarbons (PAHs), and pesticides because it can heat the subsurface to temperatures exceeding 300 degrees Celsius (°C) assuming that the amount of water in the treatment area can be controlled, because water has a cooling effect on the treatment area. For the same reasons as SEE and ERH, this technology is not effective or implementable under these hydrogeologic conditions. Therefore, ISTD will not be retained for further evaluation.

6.5.2 *In-Situ* Biological Treatment

Bioremediation is a technology in which the physical, chemical, and biological conditions of a contaminated medium are manipulated to accelerate contaminant removal through the natural biodegradation and mineralization processes. Biodegradation is the process whereby microorganisms alter the structure of a chemical, while mineralization is the complete biodegradation of a chemical to carbon dioxide, water, and simple inorganic compounds. In nature, both partial biodegradation and complete mineralization take place; the processes, however, are frequently slow. Biodegradation and mineralization are potentially applicable to VOCs and 1,4-dioxane. Heavier, more chemically complex organic compounds (e.g., pesticides and dioxins/furans) tend to be recalcitrant (resistant) to biodegradation and mineralization.

Biostimulation, bioaugmentation, and *in-situ* adsorption and biodegradation (i.e., Regenesis PlumeStop®) are processes used to enhance the rates of biodegradation and mineralization. Biostimulation involves the addition of amendments such as food-grade carbon substrates and nutrients to stimulate biodegradation. Bioaugmentation involves the addition of selectively cultured naturally occurring microbes that are known to degrade the contaminants of concern. *In-situ* adsorption and biodegradation is composed of very fine particles of activated carbon (1-2 µm diameter) suspended in water through the use of unique organic polymer dispersion chemistry. Once in the subsurface, the material behaves as a colloidal biomatrix binding to the aquifer matrix. Once contaminants are sorbed onto the regenerative matrix, biodegradation processes reportedly achieve complete remediation at an accelerated rate.

The *in-situ* biological treatments listed above are potentially effective and do not require the extraction of the contaminants (and subsequent treatment/disposal) since they will be naturally broken down. However, the large area and depth of contamination would require a highly concentrated grid of multi-depth injection points within the plume footprint to achieve RAOs. Even with a high density of injection points, there is the potential for incomplete degradation of the site contaminants. The highly-developed commercial/residential nature of the area would make it difficult to achieve the necessary injection density and result in significant costs for this alternative; therefore, this technology will not be retained for further evaluation.

6.5.3 *In-Situ* Chemical Oxidation

ISCO involves the delivery and distribution of oxidants and other amendments into the subsurface to transform VOCs into innocuous end products such as carbon dioxide, water, and inorganic compounds. The appropriateness of ISCO technology at a site depends on matching the oxidant and delivery system to the site contaminants and site conditions.

The most common oxidants used for ISCO are permanganate, catalyzed hydrogen peroxide (CHP), and activated persulfate. Each of these oxidants was evaluated as a potentially feasible process option. Permanganate is an oxidizing agent with a unique affinity for oxidizing organic compounds with carbon-carbon double bonds (e.g., TCE and 1,2-DCE). Compared to the other commonly used oxidants, permanganate is more stable in the subsurface. Unlike CHP, permanganate does not degrade naturally and can persist in the subsurface indefinitely (i.e., it is only consumed by interaction with contaminants or natural organic material). CHP involves the injection of hydrogen peroxide under acidic conditions in the presence of a ferrous iron catalyst to form hydroxyl free radicals. Hydroxyl radicals are very effective and nonspecific oxidizing agents. However, they are unstable and have a fairly short active life (i.e., on the order of hours or a few days). Sodium persulfate dissociates in water to form the persulfate anion which, although a strong oxidant, is kinetically slow in oxidizing many organic contaminants. When catalyzed or 'activated' in the presence of high potential of hydrogen (pH) (e.g., via addition of sodium hydroxide [NaOH]), heat (thermal catalyzation), a ferrous salt, or hydrogen peroxide, the persulfate ion is converted to the sulfate free radical (SO4•-). The SO4• is a very potent oxidizing agent that has a greater oxidation potential and can degrade a wider range of environmental contaminants at faster rates than the persulfate anion.

For ISCO to be effective, the oxidant must come into direct contact with VOCs. Accordingly, this remedial approach generally includes several injections over time to ensure contact with the site contaminants accompanied by groundwater sampling and analysis. ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration endpoints. ISCO is potentially effective; however, the large area and depth of contamination would require a highly concentrated grid of multi-depth injection points within the plume footprint to achieve RAOs. The highly-developed commercial/residential nature of the area would make it difficult to achieve the necessary injection density and result in significant costs for this alternative. Therefore, this technology will not be retained for further evaluation.

6.5.4 Permeable Reactive Barriers

Permeable reactive barriers (PRBs) are installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the barrier. These barriers allow the passage of water while inhibiting the movement of contaminants by employing such reactive agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and other reactive media. The majority of installed PRBs use zero-valent iron (ZVI) as the reactive medium for the treatment of chlorinated ethenes. As the iron is oxidized, a chlorine atom is removed from the chlorinated ethene by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades. PRBs are generally intended for long-term operation to control migration of contaminants in groundwater.

Even though PRBs are potentially effective in removing site contaminants, it is not implementable due to the depth of contamination and the high density commercial/residential nature of the area. Therefore, the use of PRBs will not be retained for further evaluation.

6.5.5 *In-Situ* Air Sparging with Soil Vapor Extraction

In-situ air sparging involves injection of a gas (typically air) under pressure into the saturated zone to volatilize groundwater contaminants, and SVE wells are used to capture the contaminants. Volatilized vapors migrate into the vadose zone where they are extracted under vacuum, generally by an SVE system. Air sparging has been used at many sites to treat chlorinated VOCs but not 1,4-dioxane. Successful use of air sparging technology depends on the ability of the system to effectively deliver air to the treatment area and the ability of the subsurface media to transmit the air. Heterogeneous conditions and possible semi-confined groundwater conditions, limit the effectiveness of this technology because of the preferential flow paths for the air. This technology also has a depth limitation since at great depths below the groundwater surface very large pressures are required to force the air into the aquifer. This technology is not feasible because the groundwater contamination is well below the practical limit of sparging. Therefore, *in-situ* air sparging with SVE will not be retained for further evaluation.

6.6 *Ex-situ* Treatment

Ex-situ treatment is required when the selected remedy involves groundwater extraction, and when the groundwater requires treatment prior to recharge, reuse, or disposal. Although the technologies used for treating extracted groundwater are important aspects of a remedy, they have little influence on reducing contaminant levels in the aquifer or minimizing contaminant migration because these factors are more dependent on the associated containment technologies. Therefore, the technologies presented in USEPA's *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (USEPA, 1996) were evaluated.

These presumptive *ex-situ* treatment technologies are well-understood methods that have been used for many years in the treatment of drinking water and/or municipal or industrial wastewater. The presumptive technologies presented below are the technologies retained for the development of remedial alternatives. The presumptive response guidance document serves as the technology screening step (USEPA, 1996) for the *ex-situ* treatment component of a remedy.

The presumptive technologies for treatment of extracted groundwater containing site contaminants, including VOCs and 1,4-dioxane, include the following:

- Air stripping: *Ex-situ* air stripping has been used in conjunction with extraction and treatment systems to enhance performance; it separates VOCs from groundwater by increasing the surface area of the contaminated water exposed to air. Methods include packed towers and diffused aeration.
- Adsorption/Granular Activated Carbon (GAC): The adsorption process consists of passing contaminated groundwater through a sorbent media. Contaminants are adsorbed onto the media, reducing their concentration in the bulk liquid phase. Adsorption mechanisms are generally categorized as physical, chemical, or electrostatic adsorption. Adsorption is a viable technology for treatment of organic constituents in extracted groundwater.
- Advanced Oxidation Processes (AOPs): AOPs including the use of Ultraviolet (UV) radiation, catalytic oxidation, ozone, and/or hydrogen peroxide can destroy organic contaminants in groundwater. AOPs are a viable technology for 1,4-dioxane in water. AOPs use hydroxyl radicals, which are powerful oxidizers, to sequentially oxidize organic contaminants to carbon dioxide, water, and residual chloride. While its high energy requirements limit its cost-effectiveness, it is one of only a few technologies with

commercial viability to treat 1,4-dioxane. AOPs may also be useful as an enhancement to other technologies, if the need to treat other recalcitrant residual contamination arises.

The ex-situ treatment technologies outlined above have been retained for further evaluation.

6.7 Groundwater Discharge

Groundwater discharge will be required if the remedy involves groundwater extraction. The primary options for the management of groundwater include treatment followed by discharge to surface water, aquifer recharge/well injection, irrigation, or transport to an off-site location (e.g., POTW; or RCRA TSDF) for treatment and disposal. These options are described and evaluated below.

6.7.1 Discharge of Water to Publicly Owned Treatment Works

This process option involves the direct discharge of untreated extracted groundwater or treated effluent to a local POTW for treatment and subsequent discharge. In this part of Nassau County, the extracted water/treated effluent would be directed to a wastewater treatment facility operated by the Cedar Creek Water Pollution Control Plant (CCWPCP). A discharge approval would need to be obtained from CCWPCP, and the *ex-situ* treatment system would need to be designed to meet existing discharge limitations. Once treated, the wastewater would be piped to an ocean outfall that is located in the Atlantic Ocean approximately six miles from the plant. Based on discussions with representatives of Nassau County, CCWPCP does not have the future infrastructure capacity to receive the volume of water likely to be discharged as part of a remedy to address the off-site groundwater contamination. The discharge of untreated groundwater or treated effluent to a POTW will not, therefore, be retained as a process option due to the volume of discharge anticipated.

6.7.2 Discharge Untreated Water to RCRA Treatment/Storage/Disposal Facility

This process option involves the transport of extracted groundwater to a licensed RCRA facility for treatment and/or disposal. This process option is not feasible based on the large volumes of water anticipated to be extracted. As part of the technology screening, it was determined that a suitable facility for this process option was not present in the vicinity of the site, the necessary infrastructure (e.g., suitable roadway or rail) are not present, and the overall environmental impact associated with implementing this option would be high. Therefore, this process option will not be retained for further evaluation.

6.7.3 Discharge to Surface Water

This process option involves the discharge of treated groundwater to Massapequa Creek and/or other nearby creeks such as Bellmore, Seaford, and Seamans Creek. Due to the locations of other creeks with respect to the proposed extraction wells and the relatively limited capacity of Bellmore, Seaford, and Seamans Creek to receive significant additional flow, the discharge of treated groundwater to Massapequa Creek only was retained for further evaluation within the FS. The discharge of treated groundwater to Massapequa Creek will be retained for further evaluation.

6.7.4 Discharge to Recharge Basin/Infiltration Galleries

A recharge basin allows treated water to seep through the ground surface in a controlled area. An infiltration gallery includes a subsurface network of perforated pipes in trenches that return the treated water to the subsurface, but above the water table. Numerous recharge basins are present within Nassau County, and many may be able to receive a portion of the treated water discharge. Additional recharge basins and/or galleries may be constructed to assist in handling the potential large volume of discharge water generated as a result of groundwater extraction and *ex-situ* treatment. Recharge basins and infiltration galleries have therefore been retained for further evaluation.

6.7.5 Well Injection

This process option involves the use of injection wells to pump treated water under pressure into the subsurface. The use of injection wells, alone or in combination with recharge basins or infiltration galleries for managing treated water could be a component of overall discharge design. Injection wells may be able to receive a portion of the treated water discharge as one component of the overall discharge design. The use of injection wells will therefore be retained for further evaluation.

6.7.6 Irrigation

Irrigation allows treated water to be discharged through land application or irrigation of vegetation. The use of irrigation could seasonally receive a portion of the discharge flow as one component of the overall discharge design. This process option will be retained for further evaluation.

6.8 Evaluation of Technologies and Selection of Representative Technologies

As listed in Table 6-1, groundwater remedial technologies under each type of GRA were screened for potential applicability, effectiveness, and implementation. In addition to No Further Action, the following technologies pass the screening process and will be further evaluated:

- ICs with LTM
- MNA with LTM
- Containment
    - Hydraulic Control
        - Extraction Wells
- *Ex-Situ* Treatment
    - *Ex-situ* Physical/Chemical Treatment
        - Air Stripping
        - Adsorption
        - Advanced Oxidation Potential
- Groundwater Discharge
    - Discharge to Surface Water
    - Discharge to Recharge Basin
    - Well Injection
    - Irrigation

7 DEVELOPMENT AND ANALYSIS OF ALTERNATIVES

In accordance with NYSDEC's *DER-10: Technical Guidance for Site Investigation and Remediation*, May 3, 2010, remedial alternatives are developed by combining the remedial technologies that have successfully passed the screening stage into a range of alternatives.

NYSDEC's *DER-10* requires a No Further Action alternative and an alternative that will restore the site to "pre-disposal conditions." Other alternatives are to be included based on:

- Current, intended, and reasonably anticipated future use of the site;
- Removal of source areas of contamination; and
- Containment of contamination.

In addition to No Further Action, and as described above, the groundwater remedial technologies retained for further analysis include:

- ICs with LTM
- MNA/LTM
- Containment
    - Hydraulic Containment
        - Extraction Wells
- *Ex-Situ* Treatment
    - *Ex-situ* Physical/Chemical Treatment
        - Air Stripping
        - Adsorption
        - AOP
- Groundwater Discharge
    - Discharge to Surface Water
    - Discharge to Recharge Basin
    - Well Injection
    - Irrigation

LTM is incorporated into each alternative in conjunction with the primary remedial technologies. The LTM network will be used to assess the progress of remediation within the groundwater plume, as well as at the leading edge of contaminated groundwater.

Based on the three plumes defined in Section 3.7, data evaluation, and site-specific conditions, 8 alternatives were developed for analysis with the USGS groundwater flow model. The groundwater flow modeling allowed for a quantitative evaluation of the extraction and discharge options for each alternative. The USGS in consultation with HDR completed the groundwater flow modeling with particle tracking analysis iteratively by adjusting the location and flow rate of each extraction well and recharge basin until the remedial goal of the alternative was met.

Based on the retained remedial technologies, eight groundwater remedial alternatives were developed and summarized in Table 7-1. These eight alternatives are listed below, and described in the following sections:

- Alternative 1 – No Further Action
- Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods
- Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin
- Alternative 3A – Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods
- Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin
- Alternative 4 – Aquifer Flushing
- Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods
- Alternative 5B – Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

7.1 Common Components

The common components across all the groundwater alternatives are the extraction of contaminated groundwater from the aquifer, *ex-situ* treatment, a conveyance system, treated water management, and performance monitoring. The alternatives differ in the options used to achieve each of these components, as well as the target remediation area. The basic assumptions and options evaluated for the common groundwater components are described in detail below:

7.1.1 Groundwater Extraction

Groundwater extraction would be achieved through high capacity extraction wells. The pumping rates, locations, and quantities of extraction wells proposed for each alternative were determined using groundwater flow modeling conducted by the USGS. The location, depth, and flow rate for each of the extraction wells would be further refined during the remedial design. For the purpose of this FS, the proposed extraction wells for each alternative are divided into three depth zones;

- Zone 1 – Extraction wells with completion depths down to 300 feet bgs;
- Zone 2 – Extraction wells with completion depths more than 300 but less than 600 feet bgs; and
- Zone 3 – Extraction wells with completion depths greater than 600 feet bgs.

7.1.2 *Ex-situ* Treatment:

Depending on the alternative, the contaminated groundwater from each extraction well would be treated using one of the following two options:

- Decentralized Treatment Plants: Decentralized groundwater treatment plants are proposed in the vicinity of each extraction well (either individually or in a group) under Alternatives 2A, 3A, 4, and 5A, based on the location and flow rate of each associated extraction well. The real estate area required for constructing the decentralized treatment plants is included within the cost estimates for Alternatives 2A, 3A, 4, and 5A. For the purpose of this FS, it is assumed that an approximately 2,000 to 4,000-square foot groundwater treatment plant building is required in the vicinity of each extraction well. The actual size of the groundwater treatment building is dependent on the groundwater extraction rate and the corresponding volume of water requiring treatment, along with the overall groundwater chemistry. The actual location of each treatment plant would be refined during the remedial design. To the maximum extent practicable, public ROWs, existing state/county-owned recharge basins, and publicly-available real estate would be used when evaluating possible locations for the decentralized treatment plants.

- Centralized Treatment Plants: Centralized treatment plants are proposed for Alternatives 2B, 3B, and 5B. One treatment plant (under Alternatives 2B, 3B, and 5B) would be located within the NGBF and NWIRP boundaries (herein referred to as the north centralized treatment plant); and a second treatment plant (under Alternatives 2B and 5B only) would be in the vicinity of the Southern State Parkway near Massapequa Creek (herein referred to as the south centralized treatment plant). Costs associated with the land required for constructing the north centralized treatment plant have been included in the cost estimates for Alternatives 2B, 3B, and 5B. It may also be necessary to acquire real estate for the construction of well houses and pump stations under these alternatives. The south centralized treatment plant is assumed to be constructed on the existing state/county-owned parcel near Massapequa Creek; therefore, land acquisition for the south centralized treatment plant is not included in the estimated cost. To the maximum extent practicable, public ROWs, existing state/county-owned recharge basins, and publicly-available real estate would be used when evaluating possible locations for the extraction well houses and pump stations.

Although the *ex-situ* treatment options are similar, treatment units would be sized depending on the total influent flow rate and water chemistry at each treatment plant. The typical treatment process would include equalization, filtration, iron removal, removal of VOCs by air strippers, vapor-phase GAC, liquid-phase GAC, and AOP for 1,4-dioxane. A typical schematic of the proposed process treatment of the system is shown on Figure 7-1. The treatment process anticipated for purposes of costing in the FS is described below; however, treatment requirements would be more fully determined during the remedial design.

- Water from an individual extraction well would be pumped to a treatment plant. For the decentralized treatment plant alternatives, groundwater from one or more extraction well(s) would be pumped directly to a decentralized treatment plant located in the vicinity of the well(s). For the centralized treatment plant alternatives, groundwater from the extraction well(s) would be combined together and conveyed to a centralized treatment plant via multiple piping networks or a single larger diameter manifold pipe. Pump stations with appropriately sized pumps would also be used within the piping networks to transfer groundwater to the centralized treatment plant.
- After the pumped groundwater has been metered at the treatment plant(s), it would enter a media filter to remove iron/manganese precipitants. A bag filter unit with an approximate design flow of 1,000 gpm is included for the purpose of the FS. Based on the total flow rate for each alternative, a single bag filter unit or multiple units operated in parallel would be used to remove iron/manganese precipitants from the influent groundwater.
- Groundwater from the bag filter would be transferred into an air stripper for VOC treatment. The vapor phase emitted from the air stripper would be treated by a vapor-phase GAC network. An air stripping unit with a design flow ranging from 500 to 1,000 gpm is included

for the purpose of the FS. Based on the total flow rate for each alternative, a single air stripper unit or multiple units operated in parallel would be used for the removal of VOCs in groundwater. Numerous smaller units in parallel, rather than a single larger unit, are anticipated to accommodate variations in flow rate over time. Process air heaters and blowers, along with the vapor-phase GAC (with carbon capacity of 10,000 pounds), are assumed as part of the air stripping system.

- Liquid effluent from the air stripper would then pass through a liquid-phase GAC network. For the purpose of the FS, liquid-phase GAC units with capacities of approximately 300 to 500 gpm are included. Based on the total flow rate for each alternative, two parallel trains of two 10-foot diameter liquid GAC vessels in series or multi-series of units would be used for the removal of groundwater contaminants. A lead-lag system would be used to allow continuous operation during GAC change-out periods.
- Liquid effluent from the GAC would then pass through AOP treatment for reducing 1,4-dioxane concentrations. For the purpose of this FS, AOP utilizing ozone with hydrogen peroxide is assumed for the removal of 1,4-dioxane in groundwater. Ozone with peroxide is known to accelerate the production of hydroxyl radicals, resulting in faster reactions. Based on the total flow rate for each alternative, a single AOP unit or a series of units in parallel would be used to treat 1,4-dioxane in groundwater. Ozone generator(s) and/or hydrogen peroxide material/storage are also assumed as part of the AOP system.
- After treatment, groundwater would be managed based on the assumptions listed for each alternative.

Pilot testing, bench testing, and field measurements in the pre-design phase of the work would be required to determine if any type of pre-treatment of the groundwater is required prior to passing through the treatment plant. Pre-treatment for iron removal via manganese green sand is also included in the cost estimate based on a review of existing groundwater iron concentrations. Iron concentrations in groundwater within the off-site area have frequently exceeded the Class GA Groundwater Quality Standards (GWQS) for iron of 300 µg/l, ranging from 120 µg/l to more than 1,700 µg/l.

Operation and maintenance (O&M) costs associated with each treatment system would include the following:

- Annual Operational Labor: Includes annual labor costs for operating the treatment plant.

- Annual Power (Extraction and Treatment): Includes annual power usage for the extraction pumps, any booster pumps, air stripper blower(s), transfer pumps, duct heater, AOP unit(s), and operating the treatment plant building.
- Annual Material/Chemicals Usage: Includes annual costs for replacing/regenerating spent GAC, filter bags, pre-treatment agent, and chemicals for the AOP.
- Annual System Maintenance: Includes annual material and labor costs for system maintenance.
- Treatment Plant Monitoring: Includes annual material and labor costs for the collection of monthly process samples to verify the system is operating within the permissible limits. Water samples would be collected from the influent and effluent of the treatment system and analyzed for VOCs, pH, Total Dissolved Solids (TDS), total iron, total manganese, and total zinc. The effluent limits for these parameters are likely to be approved as a State Pollutant Discharge Elimination System (SPDES) permit equivalent. Air samples would be collected at the influent and effluent of the vapor phase GAC, and between the GAC vessels, or (adsorbent media). Laboratory analysis for air samples would only include VOCs.

7.1.3 Treated Water Management

Depending on the discharge evaluated for each alternative, the treated groundwater would be managed utilizing one or more of the following options:

- Existing Recharge Basins: Treatment plants in an area where existing recharge basins can accommodate additional flow would discharge the treated water to available existing recharge basins. Based on an initial evaluation of the existing recharge basins within the study area, it is anticipated that existing recharge basins can accommodate the bulk of the total volume of treated water for each of the alternatives. Discharge to existing recharge basins would be used, where possible, for decentralized treatment plant alternatives ("A" alternatives) based on the number of extraction wells and the total effluent flow rate. A detailed evaluation using existing recharge basins for treated water discharge would be conducted during the remedial design.

  The recharge basin discharge system(s) would be equipped with a level sensor installed in the basin that would temporarily shut down the extraction wells during major storm events when the basins are needed to collect surface water runoff to prevent local flooding.

- Constructed Recharge Basins: In areas where existing recharge basins cannot fully accommodate the additional flow, the treated water would be returned to the aquifer using constructed recharge basins, as well as existing recharge basins, wherever possible. To that end, costs for the construction of several new recharge basins, or the expansion of existing basins, have been included as a contingency within the estimated costs for each of the decentralized treatment plant alternatives. A single 10-acre constructed recharge basin has also been assumed for each of the centralized treatment plant alternatives (the "B" alternatives). The anticipated location for this 10-acre basin is within Bethpage State Park; however, the location would be finalized during the remedial design.

- Surface Water: A portion of treated water from extraction wells located near the Southern State Parkway ROW would be discharged to Massapequa Creek. The mean and maximum stream flows of Massapequa Creek are approximately 8.4 cfs and 57 cfs, respectively. For the purpose of this FS, it has been assumed that between 3.3 cfs (1,500 gpm) and 5.0 cfs (2,250) gpm would be discharged to Massapequa Creek under Alternatives 2A, 2B, 5A and 5B. Discussions with representatives of NYSDEC Division of Fish and Wildlife have indicated that this discharge volume would not be detrimental to the creek and may be a habitat enhancement.

  The surface water discharge system would be equipped with a level sensor installed in the Creek and tied to a rain gauge that would temporarily shut down the associated extraction wells during major storm events to prevent the flooding of downstream areas. A more detailed evaluation of potential impacts to Massapequa Creek and the Massapequa Creek Preserve would need to be completed during the remedial design. Measurable differences from the increased stream flow may include variations in creek water temperature due to discharge of colder groundwater, reductions in salinity as the creek reaches brackish areas, lowered capacity to convey storm water, and possible alterations to wetland areas and biota associated with the creek. The discharged effluent would be subject to the NYS Class A surface water effluent limitations which would be provided by the NYSDEC.

- Irrigation: Treated water from extraction wells located close to the Bethpage State Park would be collected and discharged for beneficial re-use (i.e., irrigation purposes) at the golf course to the extent possible. Irrigation would allow treated water to be discharged through land application or an irrigation system. Given the high effluent flow rates and the average growing season of approximately eight months per year, this discharge option would be used as needed. For the purpose of this FS, a small portion of flow, approximately 925 gpm or 1.3 MGD, is assumed to be discharged through land application or irrigation of vegetation. This discharge option would be used under all alternatives involving treatment via a central treatment plant ("B" alternatives), as well as "A" alternatives that include extraction wells near Bethpage State Park.

7.1.4 Conveyance System

Extracted groundwater would be conveyed from the extraction wells to the decentralized/centralized treatment plant(s) using High Density Polyethylene (HDPE) pipe and from the treatment plant(s) to one or more of the following: existing recharge basin(s), constructed recharge basin(s), injection wells, an irrigation storage tank, or to Massapequa Creek. The pipe conveyance system is assumed to be installed within the street ROW; however, the specific location and routing of piping would be refined during the remedial design. For the purpose of this FS, costs are estimated for the following tasks associated with the installation of the pipe conveyance system: implementation of soil erosion and sediment control; trenching for pipe installation, vaults, and junctions; road crossings and repairs; road closure permits; police presence/traffic control; and asphalt/concrete disposal. Where possible, directional drilling would be used to install conveyance pipes to minimize disruption of public streets and residential areas. Applicability of directional drilling would be determined during the remedial design phase. Therefore, costs for directional drilling are not included in the cost estimates.

- Under "B" alternatives, based on the extraction well flow rate, location, and combined flow rate from two or more extraction wells, double-walled HDPE pipe is sized to convey groundwater from mass flux extraction wells to the two centralized treatment plants; single-walled HDPE pipe is sized to convey groundwater from hydraulic control extraction wells to the treatment plants, as well as treated water to the new recharge basin, existing recharge basins (Alternative 2B and 5B only), a beneficial reuse storage tank in Bethpage State Park and/or Massapequa Creek. Booster pump stations are added to the conveyance network as necessary, based on the conceptual piping design for each of the "B" alternatives.
- Under "A" alternatives, based on the extraction well flow rate, location, and combined flow rate from two or more extraction wells, double-walled HDPE pipe is sized to convey groundwater from each mass flux extraction well to its decentralized treatment plant; single-walled HDPE pipe is sized to convey groundwater from each hydraulic control

extraction well to its treatment plant, as well as treated water to existing recharge basin(s), new recharge basin(s), storage tank(s), and/or Massapequa Creek. For the “A” alternatives, a booster pump station is included only for discharge piping to Massapequa Creek.

- Alternative 4 includes a series of extraction and injection wells, based on the extraction well flow rate and location, single-walled HDPE pipe is sized to convey the groundwater the short distance to its treatment plant; single-walled HDPE pipe is also sized to convey the treated water from the treatment plant to the injection wells.

7.1.5 Performance Monitoring

A performance monitoring program would be implemented to confirm that the groundwater extraction and treatment system is achieving remedial objectives. For the purpose of this FS, the performance monitoring plan would include:

- Monthly evaluation of influent, treatment, and effluent process parameters, such as temperature, flow rate, pH, temperature;
- Laboratory analysis of influent, mid-treatment, and effluent liquid and vapor samples for compliance with applicable permits (or permit equivalence); and
- Preparation of an annual report.

7.1.6 Long Term Monitoring

A LTM program would be implemented to assess the contaminated area outside the active treatment area for each alternative as well as asses the performance of the remediation progress within the groundwater plume throughout the period of performance. A monitoring frequency of once per every year for LTM is included under each of the alternatives. For the purposes of estimating present worth costs, an LTM period of 30 years is assumed for all of the alternatives. The LTM would include:

- Installation of eight 4-inch diameter Schedule 120 polyvinyl chloride (PVC) monitoring wells (four 400 feet deep & four 700 feet deep);
- Collection of synoptic water level measurements and groundwater samples from these monitoring wells (annually through year 30);
- Analysis of groundwater samples for COCs—the results of these analyses would be used to establish baseline conditions and final attainment of SCGs; and
- Preparation of an annual LTM report.

The final number and location of wells associated with LTM would be determined during the remedial design phase of this project to optimize monitoring locations.

7.1.7 Period of Performance

The period of performance of all alternatives was estimated based on the following hydrogeological assumptions:

- It is assumed that on-site source areas have been hydraulically contained by on-site groundwater extraction and treatment systems installed at NGBF and BCP-Former Grumman Settling Ponds;
- It is assumed that remediation systems installed (GM-38 system) or proposed by the Navy and Northrop Grumman (RE-108 and RW-21 systems respectively) are hydraulically containing and treating groundwater as designed;
- A calculation of the pore volume of the SCG, 50-µg/l, and 100-µg/l TCVOC plumes is estimated based on the volume of each plume as shown on Table 3-6, 0.43 total porosity, the number of pore flushes necessary to reduce the concentration of VOCs to the SCGs (5 µg/l), a soil organic carbon-water partitioning coefficient (K_{oc}) of 60.7 (TCE), organic carbon content of soil (f_{oc}) of 0.0001, bulk density of 1.80, and the extraction rate estimated for each alternatives; and
- Based on the above, it is estimated that the period of performance for Alternative 2A, 2B, 5A, and 5B would be greater than 30 years. It is estimated that the period of performance for Alternatives 3A, 3B, and 4 would be less than 30 years; however, these alternatives would not meet the RAOs. For the purpose of estimating net present worth costs for each alternative, a period of 30 years was used for Alternatives 2A, 2B, 5A and 5B. The period of performance was used for Alternatives 3A (22 years), 3B (25 years) and 4 (17 years); however, LTM was anticipated to continue for 30 years under each of these alternatives.

7.1.8 Alternative Water Supply Proposed by Bethpage Water District

Each remedial alternative assumes that the currently operating water district pumping wells (e.g., BWD Plants 4, 5, and 6; South Farmingdale Water District Plants 1 and 3; and American Water New York – Seamans Neck Road Plant, etc.) would continue to withdraw water during remedy operation. Of these water districts, the three Bethpage water plants have been most impacted by the contaminated groundwater originating from the NGBF and NWIRP sites. Specifically, they are immediately down-gradient of the NWIRP and NGBF sites, are within the central portion of the groundwater plume, were the first to require wellhead treatment, and are the wells from which groundwater has exhibited increases in contaminant concentrations over time. While these three BWD plants are operated to meet customer demands, they indirectly remove significant amounts of site-related contaminants from the aquifer system. Although this removal provides an added remedial benefit, this dual use of public water supply wells is not a preferred option over the long term. Therefore, it is the intent of the NYSDEC and NYSDOH to transition the BWD Plants 4, 5, and 6 pumping wells over time from water supply wells to remedial wells. To allow BWD to continue to meet demands without these wells, a provision for development of an alternate water supply in the future is required and included as a common component of each remedial alternative. Costs for development of an alternative water supply have also been included within each of the alternatives other than the No Further Action alternative.

7.2 Alternative 1 – No Further Action

The No Further Action alternative is included as a basis for comparison with active groundwater remediation technologies in accordance with Section 4.2 of NYSDEC *DER-10* (Figure 7-2). At this particular site, the No Further Action alternative assumes that no additional remedial actions would be taken beyond what has already been implemented or planned in regard to the on-site and off-site groundwater contamination (Figure 7-2). On-going remedial efforts being conducted by the Navy and Northrop Grumman are described in Section 3, but generally include:

- Operation of the ONCT (five extraction wells);
- Operation of the BCP Groundwater Containment System (four extraction wells);
- Operation of the GM-38 Groundwater Extraction and Treatment System (currently one extraction well);
- Future operation of the RW-21 Area Groundwater Extraction and Treatment System (three or more extraction wells);
- Future operation of the RE-108 Groundwater Extraction and Treatment System (three or more extraction wells);
- Implementation of the PWS Contingency Plan and Continued wellhead treatment at six public water supplies.

If no further active remedial action is taken, contaminants already present in the groundwater would persist and RAOs for the site would not be met. Groundwater containing COCs above the SCGs would continue to migrate with the groundwater flow and threaten public water supply wells. The No Further Action alternative is retained for further evaluation, as required under NYSDEC *DER-10*, as a point of comparison to other remedial alternatives.

7.3 Alternatives 2A & 2B

Alternatives 2A and 2B include the extraction of the SCG plume as described in Section 3.6. Under these two alternatives, extraction wells would be installed along the western edge of the SCG plume and along the Southern State Parkway based on the USGS groundwater flow modeling and particle tracking analysis. Extraction from these proposed wells would establish hydraulic control of the SCG plume to prevent further contaminant migration to the south.

Based on groundwater flow modeling, extraction well pumping rates ranging from 150 gpm to 900 gpm are proposed for hydraulic containment wells under Alternatives 2A and 2B to create a capture zone that would provide containment of the SCG plume.

7.3.1 Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Plants with Various Discharge Methods

Alternative 2A includes the following components:

- **Groundwater Extraction:** Alternative 2A includes the installation of 16 extraction wells, which are shown on Figure 7-3. In total, these 16 extraction wells would remove approximately 10,350 gpm (14.9 MGD) from the aquifer to provide capture of the SCG plume. Under Alternative 2A, extraction wells would be installed to depths ranging from approximately 300 feet bgs to 950 feet bgs within the Magothy aquifer, with an estimated screen length of 100 to 200 feet per extraction well. The wells are designed to hydraulically contain contaminant mass in shallow, intermediate, and deep zones in the aquifer. For the purpose of this FS, the proposed number of extraction wells for each of the three depth zones are as follows:
  - 7 Extraction wells in depth Zone 1 (down to 300 feet bgs);
  - 4 Extraction wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs); and
  - 5 Extraction wells in depth Zone 3 (deeper than 600 feet bgs).

- ***Ex-Situ* Treatment:** Under Alternative 2A, the contaminated groundwater from each extraction well would be pumped to decentralized groundwater treatment plants. Where possible, the flow from multiple wells would be combined for treatment in a single plant. In total, this alternative includes the construction of six 500-gpm (0.7 MGD) treatment plants, six 1,000-gpm (1.4 MGD) treatment plants, and one 2,250-gpm (3.2 MGD) treatment plant (along the Southern State Parkway near Massapequa Creek). Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 11,200 gpm) as compared to the total extraction rate (i.e., 10,350 gpm) for flexibility during the remedial design. Treatment plants have been sized to provide uniformity for the purpose of costing in the FS, where appropriate, and to also provide a safety factor for future changes in the total extraction rate, if necessary. The treatment process is described in Section 7.1.2. Each treatment plant would be designed based on the influent flow rate and on the capacities of equalization tank, bag filter unit, air stripper unit, vapor phase GAC unit, liquid phase GAC unit, and an AOP unit.

- **Treated Water Management:** Under Alternative 2A, the treated water from each decentralized treatment plant would be discharged to one of thirteen existing recharge basins around the periphery of the SCG plume as shown on Figure 7-3, for a total discharge of approximately 8,100 gpm (11.7 MGD) to existing recharge basins. Treated water from the three smaller, decentralized treatment plants located beyond the southern edge of the groundwater plume would be discharged to three existing recharge basins at a total flow rate of 2,000 gpm (2.9 MGD) to mitigate potential environmental impacts to surface water, wetland water levels, and subsea discharge caused by groundwater extraction under this alternative. Groundwater extracted from DECHC-4, -8, -10 and -11 would be treated and discharged to surface water in Massapequa Creek as shown on Figure 7-3, for a total discharge of 2,250 gpm (3.2 MGD) to surface water.

- **Conveyance System:** Extracted groundwater would be conveyed to the decentralized treatment plants and the treated water would be conveyed to the above-listed discharge locations. The conceptual design assumes the use of single-walled HDPE piping to convey water from the extraction wells to the treatment plants, as well as to convey treated water to the recharge basins or surface water discharge. Based on the conceptual piping design for Alternative 2A, eight booster pumps stations are included. Based on the location of each extraction well and the proposed discharge locations, approximately 82,046 feet (15.5 miles) of underground piping would be installed as part of this remedial alternative.

- **Performance and Long-Term Monitoring:** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.3.2 Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin

Alternative 2B includes the following components:

- **<u>Groundwater Extraction:</u>** Alternative 2B includes the installation of 16 extraction wells, which are shown on Figure 7-4. In total, these 16 extraction wells would remove approximately 9,150 gpm (13.2 MGD) from the aquifer to provide capture of the SCG plume. Extraction wells would be installed to depths ranging from approximately 300 feet bgs to 950 feet bgs within the Magothy aquifer, with an estimated screen length of 100 to 200 feet per extraction well. The wells are designed to hydraulically contain contaminant mass in shallow, intermediate, and deep zones. For the purpose of this FS, the proposed number of extraction wells for each of the three depth zones are as follows:
    - 7 Extraction wells in depth Zone 1 (down to 300 feet bgs);
    - 4 Extraction wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs); and
    - 5 Extraction wells in depth Zone 3 (deeper than 600 feet bgs).

- ***<u>Ex-situ</u>* <u>Treatment:</u>** Under Alternative 2B, contaminated groundwater from each extraction well would be pumped, in general, to two centralized treatment plants as described within Section 7.1.2. The north centralized treatment plant is proposed for placement near the NGBF and NWIRP, and the south centralized treatment plant is proposed for placement within state-owned property within the vicinity of Massapequa Creek. Since the proposed location of the north treatment plant is in an area where land would likely have to be acquired, an approximate cost for acquiring land for the north treatment plant is included in the estimated costs for this alternative. Since the south centralized treatment plant would be constructed within state-owned property under this alternative, land acquisition for this plant is not included in the estimated cost.

  Under this alternative, three decentralized treatment plants have also been proposed within the southern-most reaches of the groundwater plume to facilitate return of water to the aquifer system with existing recharge basins beyond the down-gradient edge of the groundwater plume. Land for the construction of these treatment plants would likely have to be acquired, and the cost for land acquisition of these treatment plants has been included within the cost for this alternative. The approximate locations for the proposed groundwater treatment plants are shown on Figure 7-4.

Under Alternative 2B, the north centralized treatment plant would be capable of treating approximately 5,150 gpm (7.4 MGD), the south centralized treatment plant would be capable of treating 2,000 gpm (2.9 MGD), two decentralized treatment plants located south of the Southern State Parkway would be capable of treating 1,000 gpm (1.4 MGD) and one decentralized treatment plant located south of the Southern State Parkway would be capable of treating 500 gpm (0.72 MGD). Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 9,700 gpm) as compared to the total extraction rate (i.e., 9,150 gpm) for flexibility during the remedial design. The treatment process is described in Section 7.1.2.

- **<u>Treated Water Management:</u>** Under Alternative 2B, the treated water from the north centralized treatment plant would be discharged (i.e., 4,225 gpm) to a constructed recharge basin to be located within Bethpage State Park, as shown on Figure 7-4. Land acquisition for the recharge basin is not included in the cost estimate since it would be located within a state-owned parcel. The constructed recharge basin would be approximately 10 acres in size. Treated water from the south centralized treatment plant would be discharged (i.e., 2,000 gpm) to Massapequa Creek. Treated water from three decentralized treatment plants located south of the Southern State Parkway would be discharged (i.e., 2,000 gpm) to three existing recharge basins to mitigate potential negative environmental impacts to surface water, wetland water levels, and subsea discharge caused by groundwater extraction under this alternative.

  Approximately 925 gpm (1.3 MGD) of the treated water from the north plant is also estimated to be managed as re-use (i.e., irrigation purposes) at the Bethpage State Park for eight months of the year. For the purpose of this FS, the cost estimate includes a storage tank and/or associated pumps/piping needed to convey water to the Bethpage State Park and to Massapequa Creek.

- **<u>Conveyance System:</u>** The contaminated groundwater from each extraction well would be pumped generally to constructed centralized treatment plants, and treated water would be transferred to the constructed recharge basin located near the Bethpage State Park, existing recharge basins located to the south of the Southern State Parkway, or to surface water discharge in Massapequa Creek. The conceptual design assumes the use of single-walled HDPE pipes to convey extracted groundwater to the treatment plants, as well as to convey treated water from the treatment plants to their ultimate discharge locations.

Based on the conceptual piping design for Alternative 2B, approximately 15 booster pumps in 11 total pump stations are included in the conveyance system. Based on the extraction well locations and the constructed recharge basin/point of surface water discharge, approximately 107,638 feet (approximately 20.4 miles) of new underground piping would be installed as part of this remedial alternative.

- **<u>Performance and Long-Term Monitoring:</u>** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.4 Alternatives 3A & 3B

Alternatives 3A and 3B consist of contaminated groundwater extraction from the 50 µg/l TCVOC plume as described in Section 3.6. Under these alternatives, extraction wells would be installed within the 50-µg/l TCVOC plume based on the results of the USGS groundwater flow modeling.

7.4.1 Alternative 3A – Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Alternative 3A differs from Alternative 3B in the options used to achieve each of these components, including the following:

- **<u>Groundwater Extraction:</u>** Alternative 3A includes the installation of 17 extraction wells as shown on Figure 7-5. In total, these 17 extraction wells would remove approximately 9,090 gpm (13.1 MGD) from the aquifer to remove high concentrations of TCVOCs from the aquifer and to provide hydraulic capture of groundwater containing greater than 50 µg/l TCVOC. Extraction wells would be installed to depths ranging from approximately 300 feet bgs to 800 feet bgs within the Magothy aquifer, with an estimated screen length of approximately 100 to 200 feet to address removal of groundwater within the shallow, intermediate, and deeper zones. The proposed extraction wells for Alternative 3A are divided into three depth zones as follows:
  - 3 Extraction Well in depth Zone 1 (down to 300 feet bgs);
  - 10 Extraction wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and,
  - 4 Extraction wells in depth Zone 3 (deeper than 600 feet bgs).

- **<u>*Ex-Situ* Treatment:</u>** Under Alternative 3A, contaminated groundwater from each extraction well would be pumped to a groundwater treatment plant proposed near each well. Where possible, contaminated groundwater from multiple extraction wells would be combined to minimize the number of decentralized treatment plants. In total, this alternative includes the construction of 12 new decentralized treatment plants, including four 500-gpm (0.7 MGD) treatment plants, seven 1,000-gpm (1.4 MGD) treatment plants, and one 2,250-gpm (3.2 MGD) treatment plant. Treatment plants have been sized to provide uniformity for the purpose of costing in the FS, where appropriate, and to also provide a safety factor for future changes in the total extraction rate, if necessary. Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 11,250 gpm) as compared to extraction rate (i.e., 9,090 gpm) for flexibility during the remedial design. The treatment process is described in Section 7.1.2.

- **<u>Treated Water Management:</u>** Under Alternative 3A, the treated water from each decentralized treatment plant would be discharged to 12 existing recharge basins as shown on Figure 7-5 to reach a total discharge of approximately 9,090 gpm (13.1 MGD). Approximately 925 gpm (1.3 MGD) of the treated water would also be discharged to Bethpage State Park and used for irrigation purposes at the park for eight months of the year. For the purpose of this FS, the cost estimate includes a storage tank and/or associated pumps/piping needed to convey treated water to the Bethpage State Park.

- **<u>Conveyance System:</u>** Extracted groundwater would be conveyed via underground piping to the decentralized treatment plants and from the treatment plants to the above listed discharge locations. The conceptual design assumes the use of double-walled HDPE piping to convey extracted groundwater from the mass flux extraction wells to the treatment plants and single-walled HDPE piping to convey treated water from the treatment plants to the recharge basins. Based on the conceptual piping design for Alternative 3A, approximately 15 booster pumps in 12 total pump stations are included only for the pipe conveyance system discharging for beneficial re-use at Bethpage State Park. Based on the location of the extraction wells and proposed discharge locations, approximately 118,293 feet (22.4 miles) of new piping would be installed as part of this remedial alternative.

- **<u>Performance and Long-Term Monitoring:</u>** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.4.2 Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

Alternative 3B, differs from Alternative 3A in the options used to achieve each of these components, including the following:

- **Groundwater Extraction:** Alternative 3B includes the installation of 16 extraction wells as shown on Figure 7-6. In total, these 16 extraction wells would remove approximately 7,140 gpm (10.3 MGD) from the aquifer to remove high concentrations of TCVOCs from the aquifer and to provide hydraulic capture of groundwater containing greater than 50 µg/l TCVOCs. Extraction wells would be installed to depths ranging from approximately 300 feet bgs to 800 feet bgs within the Magothy aquifer, with an estimated screen length of 100 to 200 feet. The proposed extraction wells for Alternative 3B are divided into three depth zones as follows:
    - 1 Extraction wells in depth Zone 1 (down to 300 feet bgs);
    - 11 Extraction wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and,
    - 4 Extraction wells in depth Zone 3 (deeper than 600 feet bgs).

- ***Ex-situ* Treatment:** Under Alternative 3B, the contaminated groundwater from each extraction well would be pumped north to a centralized treatment plant with a capacity of 7,140 gpm (10.3 MGD) proposed within the vicinity of the NGBF and NWIRP. This treatment plant is proposed for placement in an area where land would likely have to be acquired. An approximate cost for acquiring land for the treatment plant is included in the estimated costs for this alternative. The location of the proposed centralized treatment plant under Alternative 3B is shown on Figure 7-6. The treatment process is described in Section 7.1.2.

- **Treated Water Management:** Under Alternative 3B, treated water from the centralized treatment plant would be discharged (i.e., 6,215 gpm) to a constructed recharge basin to be located within Bethpage State Park, as shown on Figure 7-6. Land acquisition for the constructed recharge basin is not included in the cost estimate since it would be located on state-owned property. The constructed recharge basin would be approximately 10 acres in size.

  Approximately 925 gpm of the treated water is also assumed to be discharged for re-use (i.e., irrigation purposes) at Bethpage State Park for eight months of the year. For the purpose of this FS, the cost estimate includes a storage tank and the associated pumps/piping needed to provide treated water to the Bethpage State Park.

- **Conveyance System:** The contaminated groundwater from each extraction well would be pumped to a centralized treatment plant, and treated water would be pumped to the constructed recharge basin located within Bethpage State Park. The conceptual design assumes the use of double-walled HDPE piping to convey groundwater from the mass flux extraction well to the centralized treatment plant and single-walled HDPE piping to convey treated water from treatment plant to the recharge basin. Based on the conceptual piping design for Alternative 3B, approximately 13 booster pumps in 10 pump stations are included in the conveyance system. Based on the proposed location of the extraction wells and new recharge basin, approximately 82,457 feet (15.6 miles) of new piping would be installed under this remedial alternative.

- **Performance and Long-Term Monitoring:** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.5 Alternative 4 – Aquifer Flushing

Alternative 4, identified as Aquifer Flushing, involves the extraction of contaminated groundwater from the 100 µg/l TCVOC plume as described in Section 3.6, *ex-situ* treatment using multiple decentralized treatment plants, conveyance via piping, injection of treated water into the subsurface, and performance monitoring. Under this alternative, extraction wells would be installed within the 100-µg/l plume at locations based on the results of the groundwater flow modeling. Once treated, the water would be injected into the aquifer to increase the movement of groundwater toward the extraction wells, enhance hydraulic control of the aquifer, and prevent further contaminant migration. This aquifer flushing approach is included to expedite remediation of impacted groundwater. The timeframe for remediation of the 100 µg/l plume under this alternative has been estimated to be 17 years; however, this alternative would not achieve the RAOs since this alternative only addresses portions of the plume with COCs greater than 100 µg/l.

Major components of Alternative 4 include the following:

- **Groundwater Extraction:** Alternative 4 includes the installation of 23 extraction wells, with an estimated extraction rate ranging from 50 gpm to 1,000 gpm per well totaling 8,670 gpm (12.5 MGD). The extraction well locations are shown on Figure 7-7. Extraction wells would be installed to depths ranging from approximately 300 feet bgs to 1,000 feet bgs within the Magothy aquifer, with an estimated screen length of 100 to 300 feet for removal of contaminated groundwater within the shallow, intermediate, and deep zones. The proposed extraction wells for Alternative 4 are divided into three depth zones as follows:

- 5 Extraction wells in depth Zone 1 (down to 300 feet bgs);
- 11 Extraction wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and,
- 7 Extraction wells in depth Zone 3 (deeper than 600 feet bgs).

- ***Ex-Situ* Treatment:** Under Alternative 4, the contaminated groundwater from each extraction well would be pumped to a decentralized groundwater treatment plant constructed within the vicinity of each extraction well. In total, this alternative includes construction and operation of three 100-gpm (0.1 MGD) treatment plants, five 200-gpm (0.3 MGD) treatment plants, five 300-gpm (0.4 MGD) treatment plants, seven 500-gpm (0.7 MGD), and three 1,000-gpm (1.4 MGD) treatment plants. Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 9,300 gpm) as compared to the total extraction rate (i.e., 8,670 gpm) for flexibility during the remedial design.

  The treatment process is described in Section 7.1.2 in detail.

- **Treated Water Management:** Under Alternative 4, the treated water from each decentralized treatment plant would be returned to the Magothy aquifer via 43 injection wells (Figure 7-7). Groundwater recharge (i.e., 8,670 gpm) by injection is used under this alternative to enhance hydraulic control and flushing of contamination zones. The injection rate for each of the injection wells ranges from 25 gpm (0.04 MGD) to 700 gpm (1 MGD). Well locations are based on the USGS groundwater flow modeling and particle tracking analysis.

  Injection wells would be installed to depths ranging from approximately 160 feet bgs to 900 bgs. The proposed injection wells for Alternative 4 are divided into three depth zones as follows:

  - 8 Injection wells in depth Zone 1 (depth to 300 feet bgs);
  - 20 Injection wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and,
  - 15 Injection wells in depth Zone 3 (deeper than 600 feet bgs).

- **Conveyance System:** Under this alternative, underground piping would be used to convey extracted groundwater to the decentralized treatment plant and then from the treatment plant to the injection wells. The conceptual design assumes the use of single-walled HDPE piping to convey extracted groundwater the short distance from the extraction well to the treatment plant, single-walled HDPE piping is also used to convey treated water to the injection wells. Based on the anticipated requirement of 23 extraction wells and 43 injection wells, two booster pumps in one pump station and approximately 93,282 feet (17.7 miles) of underground piping would be installed under this alternative.

- **Performance and Long-Term Monitoring:** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.6 Alternatives 5A & 5B

Alternatives 5A and 5B represent, in general, a combination of Alternative 2 (Hydraulic Containment of Site Contaminants above SCGs) and Alternative 3 (Plume Mass Flux Remediation). Under these alternatives, extraction wells would be installed within the 50-µg/l plume as described in Section 3.6, as well as along the western edge and southern edge of the SCG plume. The extraction well locations are based on USGS groundwater flow modeling and particle tracking analysis. The extraction wells installed within the 50-µg/l plume are designed to expedite cleanup of areas where high concentrations of site contaminants exist while extraction wells installed along the margins of the SCG plume are designed to prevent continued expansion of the groundwater plume. The pumping rates for the extraction wells under these alternatives are estimated to range from 150 gpm to 1,000 gpm depending upon their location within the groundwater plume.

7.6.1 Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Alternative 5A differs from Alternative 5B in the options used to achieve each of these components as described below:

- **Groundwater Extraction:** Alternative 5A includes the installation of 8 extraction wells for the purpose of mass flux remediation within the 50-µg/l plume and 16 wells for hydraulic containment of the SCG plume as shown on Figure 7-8. The total rate of groundwater extraction under this alternative is estimated to be 13,340 gpm (19.2 MGD). The location and estimated extraction rate for each of the extraction wells were determined based on the groundwater modeling performed by the USGS. Extraction wells would be installed to depths ranging from approximately 300 feet bgs to 950 feet bgs, with an average screen length of 100 to 200 feet to remove contaminant mass from shallow, intermediate, and deep zones in the Magothy aquifer. Specifically, the proposed extraction wells for Alternative 5A are divided into three depth zones as follows:

  - 8 Extraction Wells in depth Zone 1 (down to 300 feet bgs);
  - 10 Extraction Wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and;
  - 6 Extraction Wells in depth Zone 3 (deeper than 600 feet bgs).

- ***Ex-Situ* Treatment:** Under Alternative 5A, contaminated groundwater from each extraction well would be pumped to decentralized groundwater treatment plants to be constructed within the vicinity of each of the wells. Where possible, the flow from multiple wells would be combined for treatment in a single plant. In total, this alternative includes the construction of 17 decentralized treatment plants. One treatment plant is designed for an influent flow rate of approximately 1,250 gpm (1.8 MGD), four treatment plants are designed for an influent flow rate of approximately 500 gpm (0.72 MGD), 11 treatment plants are designed for an influent flow rate of approximately 1,000 gpm (1.4 MGD), and one plant (along the Southern State Parkway near Massapequa Creek) is designed for a treatment rate of approximately 1,500 gpm (2.2 MGD). Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 15,750 gpm) as compared to extraction rate (i.e., 13,340 gpm) for flexibility during the remedial design. The treatment process is described in more detail within Section 7.1.2.

- **Treated Water Management:** Under Alternative 5A, the treated water from each decentralized treatment plant would be discharged to one of sixteen existing recharge basins around the periphery of the plume as shown on Figure 7-8, for a total discharge of approximately 10,915 gpm (15.7 MGD) to existing recharge basins. Approximately 2,000 gpm would be discharged to three recharge basins south of the Southern State Parkway to mitigate potential environmental impacts to surface water, wetland water levels, and subsea discharge caused by groundwater extraction under this alternative. Groundwater extracted from DECHC -8, -10 and -11 would be treated and discharged to surface water in Massapequa Creek as shown on Figure 7-8, for a total discharge of 1,500 gpm (2.2 MGD) to surface water.

Approximately 925 gpm of the treated water is also assumed to be discharged for re-use (i.e., irrigation purposes) at Bethpage State Park for eight months of the year. For the purpose of this FS, the cost estimate includes a storage tank and the associated pumps/piping needed to provide treated water to the Bethpage State Park.

- **Conveyance System:** Extracted groundwater would be conveyed via underground pipe to the decentralized treatment plant, and from the treatment plant to the above-listed discharge locations. The conceptual design assumes the use of double-walled HDPE piping to convey groundwater from each mass flux extraction well to the treatment plant; single-walled HDPE piping is used to convey groundwater from hydraulic control extraction wells to the treatment plant, as well as treated water from the treatment plant to the recharge basins, surface water, and/or irrigation system. Based on the conceptual piping design for Alternative 5A, 13 booster pumps in 12 pump stations are necessary for conveying water to Bethpage State Park and to Massapequa Creek. Based on the extraction well and discharge locations, approximately 131,063 feet (24.8 miles) of underground conveyance piping would be installed as part of Alternative 5A.

- **Performance and Long-Term Monitoring:** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

7.6.2 Alternative 5B – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

Alternative 5B, differs from Alternative 5A in the options used to achieve each of these components, as described below:

- **Groundwater Extraction:** Alternative 5B also includes the installation of 8 extraction wells for the purpose of mass flux remediation within the 50-µg/l plume, and the installation of 16 wells for hydraulic containment of the SCG plume as shown on Figure 7-9. The total rate of groundwater extraction under this alternative is estimated to be 12,140 gpm (17.5 MGD). The location and estimated extraction rate for each of the extraction wells were determined based on USGS groundwater modeling. Extraction wells would be installed to depths ranging from 300 feet bgs to 950 feet bgs within the Magothy aquifer, with an estimated screen length of 100 to 200 feet to address removal of contaminant mass in shallow, intermediate, and deep zones and to capture COCs above SCGs. The proposed extraction wells for Alternative 5B are divided into three depth zones as follows:

- 8 Extraction Wells in depth Zone 1 (down to 300 feet bgs);
- 10 Extraction Wells in depth Zone 2 (from 300 feet bgs to 600 feet bgs) and;
- 6 Extraction Wells in depth Zone 3 (deeper than 600 feet bgs).

- **_Ex-situ_ Treatment:** Under Alternative 5B, contaminated groundwater from each extraction well would be pumped to one of two centralized treatment plants as described within Section 7.1.2. The north centralized treatment plant is proposed for placement in the vicinity of the former Northrop Grumman property, and the south centralized treatment plant is proposed for placement within state-owned property near Massapequa Creek. The north treatment plant is proposed for placement in an area where land would likely have to be acquired. An approximate cost for acquiring land for the north treatment plant is therefore included in the estimated costs for this alternative. Since the south centralized treatment plant is assumed to be constructed within state owned property, land acquisition for this plant is not included in the estimated cost.

  Under this alternative, three decentralized treatment plants have been proposed within the southern-most reaches of the groundwater plume to facilitate the return of water to the aquifer system with existing recharge basins beyond the down-gradient edge of the groundwater plume. Land for the construction of these treatment plants would likely have to be acquired, and the cost for land acquisition of these treatment plants has been included within the cost for this alternative. The approximate locations for the proposed groundwater treatment plants are shown on Figure 7-9.

  Under Alternative 5B, the north centralized treatment plant would be capable of treating approximately 8,140 gpm (11.7 MGD), the south treatment plant for discharge to Massapequa Creek would be capable of treating 2,000 gpm (2.8 MGD), two decentralized treatment plants located south of the Southern State Parkway would be capable of treating 1,000 gpm (1.4 MGD) each and one decentralized treatment plant located south of the Southern State Parkway would be capable of treating 500 gpm (0.72 MGD). Additional treatment capacity has been included in the size of the treatment plants (i.e., total treatment capacity of 12,640 gpm) as compared to extraction rate (i.e., 12,140 gpm) for flexibility during the remedial design. The treatment process is described in Section 7.1.2.

- **Treated Water Management:** Under Alternative 5B, the treated water from the north centralized treatment plant would be discharged to a constructed recharge basin located within Bethpage State Park (Figure 7-9). Land acquisition costs for the constructed recharge basin are not included in the cost estimate since it would be located within state-owned property. The footprint of the constructed recharge basin would be approximately 10 acres based on an anticipated flow rate of 7,215 gpm (10.4 MGD). Approximately 10% (925 MGD) of the treated water is also assumed to be discharged for re-use (i.e., irrigation purposes) at Bethpage State Park for eight months a year. For the purpose of this FS, a storage tank and required pumps/piping needed to convey water to Bethpage State Park is included in cost estimates.

Treated water from the south centralized treatment plant would be discharged to Massapequa Creek at a flow rate of approximately 2,000 gpm (2.9 MGD). Treated water from the three smaller, decentralized treatment plants located beyond the southern edge of the groundwater plume would be discharged to three existing recharge basins at a total flow rate of 2,000 gpm (2.9 MGD) to mitigate potential environmental impacts to surface water, wetland water levels, and subsea discharge caused by groundwater extraction under this alternative.

- **Conveyance System:** Impacted groundwater from each extraction well would be pumped via underground piping to one of several constructed treatment plants, and treated water would be pumped to a constructed recharge basin located within Bethpage State Park, an irrigation storage tank for the park, to surface water within Massapequa Creek, or three existing recharge basins located to the south of the groundwater plume. The conceptual design assumes the use of double-walled HDPE underground piping to convey groundwater from each mass flux extraction well to the treatment plants; single-walled HDPE piping is used to convey groundwater from hydraulic control extraction wells to the treatment plants, as well as treated water from the treatment plants to the recharge basins and Massapequa Creek. Based on the conceptual piping design for Alternative 5B, approximately 17 booster pumps in 13 stations are included in the conveyance system based on a pump station for every 5,000 linear feet of piping. Based on the location of the extraction wells and discharge locations, approximately 124,411 feet (23.6 miles) of new piping would be constructed as part of this remedial alternative.

- **Performance and Long-Term Monitoring:** Performance and LTM programs would be implemented under this alternative as outlined within Sections 7.1.5 and 7.1.6.

8 DETAILED EVALUATION OF ALTERNATIVES

This section presents a detailed evaluation of the remedial alternatives described in Section 7.2 relative to the eight evaluation criteria summarized below. The purpose of the evaluation is to identify the advantages and disadvantages of each alternative.

8.1 Evaluation Criteria

The evaluation was based on criteria established under NYSDEC *DER-10: Technical Guidance for Site Investigation and Remediation*, Section 4.2. The evaluation criteria are as follows:

- **Overall protection of human health and the environment:** This criterion is an evaluation of the alternative's ability to protect public health and the environment, assessing how risks posed through each existing or potential pathway of exposure are eliminated, reduced, or controlled through removal, treatment, engineering controls, or ICs. The alternative's ability to achieve each of the RAOs is evaluated.
- **Compliance with Standards, Criteria, and Guidance:** This criterion evaluates the compliance of the alternative with all identified SCGs and evaluates whether or not the remedy will achieve compliance.
- **Long-term effectiveness and permanence**: Each alternative is evaluated for its long-term effectiveness after implementation. If wastes or treated residuals remain after the selected remedy has been implemented, the following items are evaluated:
  - The magnitude of the remaining risks (i.e., whether there will be any significant threats, exposure pathways, or risks to the community and environment from the remaining wastes or treated residuals);
  - The adequacy of the engineering and ICs intended to limit the risk;
  - The reliability of these controls; and
  - The ability of the remedy to continue to meet RAOs in the future.
- **Reduction of toxicity, mobility, or volume of contamination through treatment:** Each alternative's ability to reduce the toxicity, mobility, or volume of COCs is evaluated. Preference is given to remedies that permanently and significantly reduce the toxicity, mobility, or volume of the wastes at the site.
- **Short-term impacts and effectiveness:** The potential short-term adverse impacts and risks of the remedy upon the community, the workers, and the environment during construction, and/or implementation are evaluated. A discussion is presented as to how

the identified potential adverse impacts to the community or workers at the site will be controlled, as well as the effectiveness of those controls. A discussion of engineering controls that will be used to mitigate short-term impacts (e.g., dust control measures) is provided. The length of time needed to achieve the remedial objectives is also estimated.

- **Implementability:** The technical and administrative feasibility of implementing each alternative is evaluated for this criterion. Technical feasibility includes the difficulties associated with construction and the ability to monitor the effectiveness of the remedy. For administrative feasibility, the availability of the necessary personnel and material is evaluated along with potential difficulties in obtaining specific operating approvals, access for construction, etc.
- **Cost Effectiveness:** This criterion is an evaluation of the overall cost effectiveness of an alternative or remedy. This criterion evaluates the estimated capital, operations, maintenance, and monitoring costs. Costs are estimated and presented on a present-worth basis. The present worth costs were estimated with expected accuracies of -30 to +50 percent in accordance with NYSDEC and USEPA guidance. Because detailed remedial design activities have not been performed, a contingency has been included within the cost for each alternative to account for potential changes in scope (and costs) that may be identified during the design and implementation activities. In accordance with USEPA and NYSDEC guidance, a 3 percent discount rate (before taxes and after inflation) was used to calculate present worth.
- **Land Use:** This criterion evaluates the current, intended, and reasonably anticipated future use of the site and its surroundings, as it relates to an alternative or remedy when unrestricted levels are not achieved.

The eight groundwater alternatives that were identified and pre-screened for detailed evaluation include:

- Alternative 1 – No Further Action (existing & planned remedial systems);
- Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods;
- Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin;
- Alternative 3A – Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods;

- Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin;
- Alternative 4 – Aquifer Flushing;
- Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods; and
- Alternative 5B – Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin.

An individual analysis of the groundwater alternatives against the criteria was conducted and is presented below. A summary of the evaluation is provided in Table 8-1. Cost breakdowns for each alternative are presented within Appendix A and summarized in Table 8-2.

8.2 Alternative 1 – No Further Action

The No Further Action option is included as a basis for comparison with active groundwater remediation technologies in accordance with Section 4.2 of *DER-10*. At this site, the no further action alternative assumes that no additional remedial actions would be taken beyond what has already been implemented or planned in regard to the on-site and off-site groundwater contamination. On-going remedial efforts being conducted by the Navy and Northrop Grumman are described in Section 3, but generally include:

- Operation of the On-Site Groundwater Containment System (5 remediation wells);
- Operation of the Bethpage Community Park Groundwater Containment System (4 remediation wells);
- Operation of the GM-38 Groundwater Extraction and Treatment System (1-2 remediation wells;
- Future operation of the RW-21 Area Groundwater Extraction and Treatment System (3 or more remediation wells);
- Future operation of the RE-108 Groundwater Extraction and Treatment System (3 or more remediation wells);
- Implementation of the PWS Contingency Plan and continued wellhead treatment at six public water supplies.

If no further active remedial action is taken, contaminants already present in the groundwater would persist and RAOs for the site would not be met. While there would be reductions in contaminant concentrations near the future groundwater extraction and treatment systems (RW-21 Area and RE-108 Area), there would not be a significant reduction in contaminant concentrations outside of the influence of these two systems. This would allow contaminants to continue to move in a southward direction towards public water supply wells and environmental receptors.

8.2.1 Overall protection of human health and the environment

Alternative 1 provides no further control of exposure to contaminated groundwater and no further reduction in risk to the environment posed by contaminated groundwater. The No Further Action alternative does not attain the groundwater RAOs (e.g., restoration of the resource) and does not enhance the protection of human health. The alternative allows for the continued, uncontrolled migration of the groundwater contamination that has already impacted public water supplies. This alternative could result in impacts to wetlands, stream flow, and subsea discharge and to additional public water supply wells.

8.2.2 Compliance with SCGs

Alternative 1 does not comply with SCGs. Contaminated groundwater would continue to exhibit concentrations above the SCGs and it would continue to migrate in the down-gradient direction towards receptors. This continued migration would result in a larger volume of the aquifer containing groundwater with COCs present at concentrations exceeding SCGs.

8.2.3 Long-term effectiveness and permanence

Alternative 1 does not provide long-term effectiveness or permanence. Groundwater containing COCs from a concentration less than approximately 1,000 µg/l to the SCGs would continue to migrate. If no further active remedial action is taken, contaminants in the groundwater would continue to migrate towards receptors and RAOs for the site would not be met in the long term.

8.2.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 1 would not provide a reduction in toxicity, mobility, or volume for COCs that occur at a concentration less than approximately 1,000 µg/l to the SCGs and these COCs would continue to migrate toward public water supplies, wetlands, stream flow, and subsea discharge.

8.2.5 Short-term impacts and effectiveness

This alternative does not result in disruption of properties overlying the plume, and therefore no additional short-term risks are posed to the community, workers, or the environment, as no additional remedial action would occur (beyond those activities associated with the existing and proposed groundwater extraction and treatment systems).

8.2.6 Implementability

There are no implementability concerns posed by this remedy, as no additional remedial actions are being implemented.

8.2.7 Cost Effectiveness

Because this is a No Further Action alternative, the capital, O&M, and net present worth costs are estimated to be $0.

8.2.8 Land Use

The No Further Action alternative would result in groundwater contaminants in excess of SCGs remaining in the aquifer beneath the off-site properties. No environmental easements would be put in place. This alternative would not affect the current, intended, or reasonably anticipated future use of the area, which is a mix of residential, commercial/industrial, and recreational use.

8.3 Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Plants with Various Discharge Methods

Alternative 2A includes extraction of contaminated groundwater from the aquifer within the area where COC concentrations exceed the SCGs through the installation of 16 groundwater extraction wells installed to depths ranging from 300 to 950 feet within the Magothy aquifer, *ex-situ* treatment using multiple decentralized treatment plants, conveyance via underground piping, treated water management, and performance monitoring. This alternative also includes LTM for protection of human health and the environment. Under this alternative, it is assumed that a Pre-Design Investigation (PDI), treatability/bench studies, and an engineering evaluation would be completed.

The period of performance of this alternative could be as long as 130 years based on the assumptions listed in Section 7.1.7 and the extraction rate of 14.9 MGD. For the purpose of calculating the present worth cost for this FS, it is assumed that this alternative would be active for 30 years.

8.3.1 Overall protection of human health and the environment

Alternative 2A would protect human health and the environment by hydraulically containing groundwater with COCs above the SCGs with a series of wells along the western and southern edges of the SCG plume. The groundwater would be treated in 13 decentralized treatment plants to the NYS groundwater effluent limitations before it is returned to the aquifer through 13 recharge basins. It is expected that the hydraulic containment of groundwater containing COCs exceeding the SCGs and the treatment and recharge of groundwater meeting NYS groundwater effluent limitations would allow unrestricted use of the groundwater resources. With the withdrawal of contaminated groundwater from 16 extraction wells, it is expected that Alternative 2A would reduce impacts to public water supply wells that currently contain site contaminants in raw groundwater and this alternative would prevent impacts to currently un-impacted water supply wells. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 2A. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and the locations of recharge basins were adjusted to achieve hydraulic capture of the SCG plume while at the same time minimizing the potential effects to the environment. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 2A would not have an effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 2A are summarized in Table 8-3.

The groundwater flow model predicts (Table 8-3) that in nine of 13 public water supply wells, the water level will decrease from 0.3 to 2.0 feet; and in the remaining four public water supply wells, groundwater levels will decrease from 4.0 to 4.6 feet. These potential changes to the water level are not expected to affect the yield of the wells, given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 2A predicts the stream flow in Massapequa Creek will increase 3.4 cfs. This increase in stream flow is likely to be a benefit to the local aquatic habitat. The stream flow in Seaford Creek, Seamans Creek, and Bellmore Creek will decrease from zero to 0.4 cfs. This small decrease in stream flow is not expected to adversely affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will increase from zero to 1.6 feet, while others will decrease from zero to 0.5 feet during implementation of Alternative 2A. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below the ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council 1995). Therefore, no adverse impacts to the wetland environments are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will not change, while the groundwater flow through the GHB out of the Magothy aquifer will increase by 0.4% (2 gpm). Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 5.6% (6 gpm), while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater interface under Alternative 2A.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 2A since a large fraction of the groundwater extracted from the aquifer would be returned to the aquifer through recharge basins.

8.3.2 Compliance with SCGs

Alternative 2A will reduce the concentration of COCs in groundwater to below the SCGs since groundwater with COCs above SCGs will be hydraulically contained and treated. Treated water would meet the New York State groundwater effluent limitations prior to being discharged to existing recharge basins and/or to surface water at Massapequa Creek. Alternative 2A would continue until COCs are below the SCGs.

8.3.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 2A would provide long-term effectiveness by hydraulically containing (extracting) groundwater containing COCs at concentrations above the SCGs. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system and to assess the remedy's ability to protect human health and the environment.

Alternative 2A would allow unrestricted use of groundwater resources outside of the SCG plume. The concentration of site-related COCs in groundwater extracted by public water supply wells is expected to decrease during operation of the remedy. With hydraulic control of the SCG plume, Alternative 2A is expected to prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.3.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 2A would reduce the toxicity, mobility, and volume of COCs in the aquifer through groundwater extraction and treatment at the down-gradient edge of the SCG plume. Alternative 2A would reduce the toxicity and mobility of COCs by hydraulically containing groundwater with COCs at concentrations exceeding the SCGs. Once the contaminated groundwater is withdrawn from the aquifer, the water is treated at the surface via an air stripping and carbon treatment process to address VOCs, as well as AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of contaminated groundwater within the SCG plume used in Alternative 2A has been estimated to be approximately 150 billion gallons. The volume of the SCG plume would be reduced in Alternative 2A by extracting 14.9 MGD over an estimated 130 years.

8.3.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing COCs above the SCGs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient, capturing COCs within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 16 extraction wells for hydraulic containment;
- 13 treatment plants;
- 13 existing recharge basins to be reworked; and
- 82,046 feet (15.5 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 82,046 feet (15.5 miles) of conveyance piping under Alternative 2A. Pipe crossings at the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected; however, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.3.6 Implementability

Groundwater extraction and treatment is implementable as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increased flow rates, if required.

Acquiring the land and the construction of the extraction wells, treatment facilities, and recharge basins, as listed in Section 8.3.5, would present a challenge to the implementation of Alternative 2A. Land acquisition would likely be required for the construction of decentralized treatment plants. Multiple locations would be required to install the extraction wells and pump stations; however, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 82,046 feet of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to surface water/groundwater.

8.3.7 Cost Effectiveness

The total cost for Alternative 2A is approximately $553M. This alternative includes capital costs associated with constructing extraction wells, decentralized treatment plants, an outfall structure for surface water discharge, irrigation services to Bethpage State Park, and conveyance piping; rehabilitation of existing recharge basins; O&M costs for the operation of the extraction and treatment system; and costs to implement a LTM program. The estimated cost for Alternative 2A is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. For the purpose of developing a cost estimate for comparison purposes, the following assumptions were made:

- Major components include construction of 16 new extraction wells, 13 decentralized treatment plants, pipe conveyance system, and surface water outfall, as well as the rehabilitation of 13 existing recharge basins;
- Present worth calculations are based on 30 years; and
- LTM would be conducted annually through year 30.

8.3.8 Land Use

Alternative 2A would achieve compliance with SCGs, which is sufficient for the current, intended, and reasonably anticipated future use of the impacted area (i.e., residential, commercial, industrial).

8.4 Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plant with a Centralized Recharge Basin

Alternative 2B includes extraction of contaminated groundwater from the aquifer where COCs exceed SCGs through the installation of 16 extraction wells to depths of approximately 300 to 950 feet bgs within the Magothy aquifer, *ex-situ* treatment utilizing north and south centralized treatment plants, three decentralized treatment plants, conveyance via underground piping, construction of a centrally located recharge basin, use of three existing recharge basins, and LTM for protection of human health and the environment. The period of performance of this alternative could be as long as 140 years based on the assumptions listed in Section 7.1.7 and the extraction rate of 13.2 MGD. For the purpose of calculating the present worth cost for this FS, it is assumed that this alternative would be active for 30 years.

8.4.1 Overall protection of human health and the environment

Alternative 2B would protect human health and the environment by hydraulically containing groundwater with COCs above the SCGs with a series of wells along the western and southern edges of the SCG plume. The groundwater would be treated in two centralized and three decentralized treatment plants to the NYS groundwater effluent limitations before it is returned to the aquifer using four recharge basins, discharged to Massapequa Creek, or beneficially re-used for irrigation purposes. It is expected that the hydraulic containment of COCs exceeding the SCGs and the treatment and recharge of groundwater meeting NYS groundwater effluent limitations would allow unrestricted use of the groundwater resources. With the withdrawal of contaminated groundwater from 16 extraction wells, it is expected that Alternative 2B would reduce impacts to public water supply wells that currently contain site contaminants in raw groundwater and this alternative would prevent impacts to currently un-impacted water supply wells. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 2B. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and the locations of recharge basins were adjusted to achieve hydraulic capture of the SCG plume while at the same time minimizing the potential effects to the environment. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 2B would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 2B are summarized in Table 8-3.

The groundwater flow model predicts (Table 8-3) that in eight of the 13 public water supply wells the groundwater level will decrease from 1.2 to 3.0 feet, while groundwater levels will decrease by from 6.3 to 6.8 feet in five public water supply wells. These potential changes to the groundwater levels are not expected to affect the yield of the wells given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 2B predicts the stream flow in Massapequa Creek will increase 0.9 cfs. The increase in stream flow is likely to be a benefit to the local aquatic habitat. The stream flow in Seaford Creek and Seamans Creek will decrease 0.2. The stream flow will decrease 1.0 cfs in Bellmore Creek. These small decreases in stream flow are very low compared to the range of stream flow in these creeks and are not expected to adversely affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will decrease from 0.2 to 2.0 feet during implementation of Alternative 2B. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff during periods of high water. The depth to the water table typically lies well below ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council, 1995). Therefore, no adverse impact to the wetland environments are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 2.8% (4 gpm) while groundwater flow through the GHB out of the Magothy aquifer will decrease by 3.7% (19 gpm). Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 13.9% (15 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface under Alternative 2B.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 2B, since a large fraction of the groundwater extracted from the aquifer would be returned to the aquifer through recharge basins.

8.4.2 Compliance with SCGs

Alternative 2B would reduce the concentration of COCs in groundwater to below the SCGs since groundwater with COCs above SCGs would be hydraulically contained and treated. Treated water would meet the New York State groundwater effluent limitations prior to being discharged to existing recharge basins, the newly constructed recharge basin, surface water at Massapequa Creek, and beneficial re-use by Bethpage State Park.

8.4.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 2B would provide long-term effectiveness by extracting (hydraulic containment) groundwater containing COCs exceeding the SCGs. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system and to assess the remedy's ability to protect human health and the environment.

Alternative 2B would allow unrestricted use of groundwater resources. The concentration of site-related COCs in groundwater extracted by public water supply wells is expected to decrease during operation of the remedy. With hydraulic control of the SCG plume, Alternative 2B is expected to prevent currently un-impacted public water supply wells from requiring treatment to address COCs.

8.4.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 2B would reduce the toxicity, mobility, and volume of COCs in the aquifer through groundwater extraction and treatment at the down-gradient edge of SCG plume. Alternative 2B would reduce the toxicity and mobility of COCs by hydraulically containing groundwater with COCs exceeding the SCGs. Once the contaminated groundwater is withdrawn from the aquifer, the water would be treated at the surface via an air stripping and carbon treatment process to address VOCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of contaminated groundwater within the SCG plume used in Alternative 2B has been estimated to be approximately 150 billion gallons. The volume of the SCG plume would be reduced in Alternative 2B by extracting 13.2 MGD over an estimated 140 years.

8.4.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing COCs above the SCGs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient, capturing groundwater containing COCs within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 16 extraction wells for hydraulic containment;
- 5 treatment plants;
- 1 new recharge basin;
- 3 existing basins to be reworked; and

- 107,638 feet (20.4 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 107,638 feet (20.4 miles) of conveyance piping under Alternative 2B. Pipe crossings at Hempstead Turnpike, the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected; however, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this Alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.4.6 Implementability

Groundwater extraction and treatment is implementable, as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increased flow rates, if required.

Acquiring the land and constructing the extraction wells, treatment facilities, and recharge basins as listed in Section 8.4.5 would present a challenge to the implementation of Alternative 2B. Land acquisition would likely be required for the construction of a north centralized treatment plant and several small decentralized treatment plants under this alternative. Land acquisition is not anticipated for the construction of a centralized recharge basin in the vicinity of Bethpage State Park. Multiple locations would be required to install the extraction wells and pump stations; however, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 107,638 feet of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at Hempstead Turnpike, the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to surface water/groundwater.

8.4.7 Cost Effectiveness

The total cost for Alternative 2B is approximately $485M. This alternative includes capital costs associated with constructing extraction wells, north and south centralized treatment plants, three small decentralized treatment plants, the new recharge basin in the vicinity of Bethpage State Park, irrigation services to Bethpage State Park, an outfall structure for surface water discharge, and conveyance piping; rehabilitation of existing recharge basins; O&M costs for operation of the extraction and treatment systems; and costs to implement the LTM program. The estimated cost for Alternative 2B is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. The following costing assumptions have been made for the purpose of this FS:

- Major components include construction of 16 new extraction wells, two centralized treatment plants, three decentralized treatment plants, one new recharge basin, services for irrigation water, and a pipe conveyance system, as well as rehabilitation of 3 existing recharge basins;
- Present worth calculations are based on 30 years; and
- LTM would be conducted annually through year 30.

8.4.8 Land Use

Alternative 2B would achieve compliance with SCGs, which is sufficient for the current, intended, and reasonably anticipated future use of the impacted area (i.e., residential, commercial, and industrial).

8.5 Alternative 3A - Plume Mass Flux Remediation - Decentralized Plants with Various Discharge Methods

The remedial approach under Alternative 3A includes extraction of contaminated groundwater from the aquifer within the area where TCVOC concentrations exceed 50 µg/l through the installation of 17 extraction wells installed to depths of approximately 300 to 800 feet bgs within the Magothy aquifer, *ex-situ* treatment utilizing multiple decentralized treatment plants, conveyance via underground piping, treated water management, and performance monitoring. This alternative also includes LTM to monitor remediation progress throughout the operational years of the extraction and treatment system. Under this alternative, it is assumed that a PDI, treatability/bench studies, and engineering evaluation would be completed.

The period of performance of this alternative is expected to be approximately 22 years for active remediation, based on the assumptions listed in Section 7.1.7 and the extraction rate of 13.1 MGD; however, this alternative would not achieve the RAOs. For the purpose of calculating the present worth cost for this FS, it is assumed that this alternative would be active for 22 years, while LTM would be conducted for 30 years.

8.5.1 Overall protection of human health and the environment

Alternative 3A would remove groundwater with TCVOCs above the 50 µg/l with a series of extraction wells. The groundwater would be treated in 12 decentralized treatment plants to the NYS groundwater effluent limitations before it is discharged into the aquifer through 12 existing recharge basins. This alternative would remove contaminant mass from the center of the groundwater plume and establish hydraulic control of the most impacted portions of the aquifer; however, it would not be successful at achieving the RAO and it would not provide hydraulic control of impacted groundwater with concentrations between SCGs and 50 µg/l. Groundwater containing TCVOCs less than 50 µg/l and greater than the SCGs would continue to migrate, potentially impacting receptors. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system. This alternative would rely on the existing public water supply contingency plan for the design, construction, operation, and maintenance of wellhead treatment systems, if necessary, for areas outside of the 50 µg/l TCVOC plume.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 3A. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and the locations of recharge basins were adjusted to achieve hydraulic capture of the 50 µg/l plume, while at the same time minimizing the potential effects to the environment. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 3A would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 3A are summarized in Table 8-3.

The groundwater flow model predicts (Table 8-3) that in 10 of the 13 public water supply wells, the groundwater levels will decrease from zero to 2.1 feet; and in the remaining three public water supply well, groundwater levels will decrease from 2.9 to 4.7 feet. These potential changes to the groundwater levels are not expected to affect the yield of the wells given the depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 3A predicts the stream flow in Massapequa Creek will increase 0.2 cfs. The increase in stream flow is likely to be a benefit to the local aquatic habitat. The stream flow will decrease from zero to 0.1 cfs in Seamons Creek, Seaford Creek, and Bellmore Creek. These small decreases in stream flow are very low compared to the range of stream flow in these creeks and is not expected to negatively affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will decrease from zero to 0.2 feet during implementation of Alternative 3A. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council 1995). Therefore, no adverse impacts to wetlands are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 0.7% (1 gpm), while groundwater flow through the GHB out of the Magothy aquifer will decrease by 0.4% (2 gpm). Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 0.9% (1 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface under Alternative 3A.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 3A since a large fraction of the groundwater extracted from the aquifer would be returned to the aquifer through recharge basins.

8.5.2 Compliance with SCGs

Alternative 3A would reduce the concentration of TCVOCs to less than 50 µg/l. Active remedial activities for Alternative 3A would be continued until 50 µg/l has been achieved. There would be no immediate reductions in contaminant concentrations in areas of the plume where contaminant concentrations are less than 50 µg/l other than from natural processes. As such, groundwater containing TCVOCs less than 50 µg/l would continue to migrate, potentially impacting downgradient receptors. Treated water from the decentralized groundwater treatment systems would meet the New York State groundwater effluent limitations prior to being discharged to recharge basins or beneficially re-used for irrigation purposes at Bethpage State Park.

8.5.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 3A would provide long-term effectiveness and permanence at extracting groundwater containing TCVOCs greater than 50 µg/l. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system.

Alternative 3A would not achieve the RAOs. Alternative 3A would not be effective in managing areas of the plume where TCVOC concentrations are less than 50 µg/l, as these areas of the plume are outside the area of active remediation and are not hydraulically contained by the groundwater extraction system. Groundwater containing TCVOCs less than 50 µg/l would continue to migrate, potentially impacting downgradient receptors. Alternative 3A would not allow unrestricted use of the area's groundwater resources. The concentration of COCs in groundwater withdrawn by public water supply wells may increase during the operation of the remedy. Alternative 3A would not prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.5.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 3A would reduce the toxicity, mobility, and volume of COCs in the portion of the aquifer containing groundwater with concentrations of TCVOCs greater than 50 µg/l. The toxicity, mobility, and volume of contamination would not be reduced in the portion of groundwater containing less than 50 µg/l TCVOCs. Alternative 3A would reduce the toxicity and mobility of COCS by hydraulically containing groundwater containing greater than 50 µg/l TCVOCs. Once the contaminated groundwater is withdrawn from the aquifer, the water would be treated at the surface via an air stripping and carbon treatment process to address VOCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of groundwater within the 50 µg/l TCVOC plume used in Alternative 3A has been estimated to be roughly 42 billion gallons of groundwater. The volume of the 50 µg/l TCVOC plume would be reduced under Alternative 3A by extracting 13.1 MGD over an estimated 22 years.

8.5.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing TCVOCs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient capturing TCVOC contaminated groundwater within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, double-walled underground piping and alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 17 extraction wells for mass flux;
- 12 treatment plants;
- 12 existing recharge basins to be reworked; and
- 118,293 feet (22.4 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 118,293 feet (22.4 miles) of conveyance piping under Alternative 3A. Pipe crossings at Hempstead Turnpike, the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected; however, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operation, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.5.6 Implementability

Groundwater extraction and treatment is implementable as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increased flow rates, if required.

Acquiring the land and constructing the extraction wells and treatment facilities, as listed in Section 8.5.5, would present a challenge to the implementation of Alternative 3A. Land acquisition would likely be required for the construction of decentralized treatment plants. Multiple locations would be required to install the extraction wells and pump stations. However, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 118,293 feet of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at Hempstead Turnpike, Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to groundwater.

8.5.7 Cost Effectiveness

The total cost for Alternative 3A is approximately $522M. This alternative includes the capital costs associated with constructing extraction wells, decentralized treatment plants, and conveyance piping; rehabilitation of existing recharge basins; O&M costs for the operation of the extraction and treatment system; and costs to implement the LTM program. The estimated cost for Alternative 3A is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. For the purpose of developing a cost estimate for comparison purposes, the following assumptions were made:

- Major components include construction of 17 new extraction wells, 12 decentralized treatment plants, services for irrigation water, a pipe conveyance system, as well as rehabilitation of 12 existing recharge basins;

- Present worth calculations are based on 22 years; and
- LTM would be conducted annually through year 30.

8.5.8 Land Use

Alternative 3A focuses on remediating groundwater containing TCVOC greater than 50 µg/l and thus allows contaminants outside of these areas to continue to migrate, potentially to downgradient receptors. Therefore, it is not anticipated that this alternative would achieve the SCGs in the foreseeable future. However, this alternative would not affect the current, intended, or reasonably anticipated future use of the area, which is a mix of residential, commercial/industrial, and recreational use.

8.6 Alternative 3B - Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

The remedial approach under Alternative 3B includes extraction of contaminated groundwater from the aquifer within the area where TCVOC concentrations exceed 50 µg/l through the installation of 16 extraction wells installed to depths of 300 to 800 feet bgs, *ex-situ* treatment using a centrally-located treatment plant, conveyance via underground piping, and construction of a centrally-located recharge basin. This alternative also includes LTM to evaluate remediation progress throughout the operational years of the extraction and treatment system. Groundwater containing TCVOCs less than 50 µg/l and greater than the SCGs would continue to migrate, potentially impacting downgradient receptors. Under this alternative, it is assumed that a PDI, treatability/bench studies, and engineering evaluation would be completed. The period of performance of this alternative is expected to be 25 years, based on the assumptions listed in Section 7.1.7 and the extraction rate of 10.3 MGD. However, Alternative 3B would not achieve the RAOs. For the purpose of calculating the present worth cost, it is assumed that this alternative would be active for 25 years, while LTM would be conducted for 30 years.

8.6.1 Overall protection of human health and the environment

Alternative 3B would remove groundwater with TCVOCs at concentrations greater than 50 µg/l with a series of extraction wells. The groundwater would be treated in one centralized treatment plant to the NYS groundwater effluent limitations before it is discharged into the aquifer through a single recharge basin or beneficially re-used for irrigation purposes at Bethpage State Park. This alternative would remove contaminant mass from the center of the groundwater plume and establish hydraulic control of the most impacted portions of the aquifer; however, it would not be successful at achieving the RAOs and it would not provide hydraulic control of impacted groundwater with concentrations between the SCGs and 50 µg/l. Groundwater containing TCVOCs less than 50 µg/l would continue to migrate, potentially impacting downgradient receptors. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system. This alternative would rely on the existing public water supply contingency plan for the design, construction, operation, and maintenance of wellhead treatment systems, if necessary, for areas outside of the 50 µg/l plume.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 3B. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells were adjusted to achieve hydraulic capture of the 50 µg/l plume while at the same time minimizing the potential effects to the environment. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 3B would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 3B are summarized in Table 8-3.

The groundwater flow model predicts (Table 8-3) that in seven of the 13 public water supply wells, the groundwater levels will decrease from 1.3 to 2.8 feet; and in the remaining six public water supply wells, groundwater levels will decrease from 3.4 to 4.8 feet. These potential changes to the groundwater levels are not expected to affect the yield of the wells given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 3B predicts the stream flow in Massapequa Creek and Bellmore Creek will decrease 0.9 and 0.8 cfs, respectively. The stream flow in Seaford Creek and Seamans Creek will decrease 0.2 cfs. These small decrease in stream flow are very low compared to the range of stream flow in these creeks and are not expected to negatively affect the aquatic habitat.

Groundwater flow modeling predicts the water table elevation in wetlands south of the site will decrease from 0.3 to 1.5 feet. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below the ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council 1995). Therefore, no adverse impact to wetlands are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 2.8% (4 gpm), while groundwater flow through the GHB out of the Magothy aquifer will decrease by 3.1% (6 gpm). Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 11.1% (12 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface under Alternative 3B.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 3B since a large fraction of the groundwater extracted from the aquifer would be returned to the aquifer through a central recharge basin.

8.6.2 Compliance with SCGs

Similar to Alternative 3A, Alternative 3B is expected to reduce the concentration of TCVOCs to less than 50 µg/l in the area where TCVOCs are presently greater than 50 µg/l. Remedial activities under Alternative 3B would be continued until 50 µg/l have been achieved within the active remediation area. This would prevent or minimize contaminant migration from the areas where contaminant concentrations are the highest. There would be no immediate reductions in contaminant concentrations in areas of the plume where contaminant concentrations are less than 50 µg/l other than from natural processes. As such, groundwater containing TCVOCs less than 50 µg/l would continue to migrate potentially impacting downgradient receptors. A LTM program would be implemented to evaluate remediation progress throughout the operational years of the extraction and treatment system. Treated water from the centralized groundwater treatment system would meet the New York State groundwater effluent limitations prior to being provided to Bethpage State Park for beneficial re-use as irrigation water or discharged to the aquifer system via a central recharge basin.

8.6.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 3B would provide long-term effectiveness and permanence at extracting groundwater containing TCVOCs greater than 50 µg/l. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system.

Alternative 3B would not achieve the RAOs. Alternative 3B would not be effective in managing areas of the plume where TCVOC concentrations are less than 50 µg/l, as these areas of the plume are outside the area of active remediation and are not hydraulically contained by the groundwater extraction system. Groundwater containing TCVOCs less than 50 µg/l would continue to migrate, potentially impacting downgradient receptors. Alternative 3B would not allow unrestricted use of the region's groundwater resources. The concentration of COCs in groundwater extracted by public water supply wells may increase during the operation of the remedy. Alternative 3B would not prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.6.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 3B would reduce the toxicity, mobility, and volume of COCs in the portion of the aquifer containing greater than 50 µg/l of TCVOCs. The toxicity, mobility, and volume of contamination would not be reduced in the portion of groundwater containing less than 50 µg/l TCVOCs. Alternative 3B would reduce the toxicity and mobility of COCS by hydraulically containing groundwater containing greater than 50 µg/l of TCVOCs. Once the contaminated groundwater is withdrawn from the aquifer, the water is treated at the surface via an air stripping and carbon treatment process to address VOCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of groundwater within the 50 µg/l TCVOC plume used in Alternative 3B has been estimated to be approximately 42 billion gallons. The volume of the 50 µg/l TCVOC plume would be reduced under Alternative 3B by extracting 10.3 MGD over an estimated 25 years.

8.6.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing TCVOCs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient, capturing TCVOC contaminated groundwater within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, double-walled underground piping and alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 16 extraction wells for mass flux;
- 1 treatment plant;
- 1 new recharge basin; and
- 82,457 feet (15.6 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 82,457 feet (15.6 miles) of conveyance piping under Alternative 3B. Pipe crossings at Hempstead Turnpike and the Seaford-Oyster Bay Expressway may also represent difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected. However, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.6.6 Implementability

Groundwater extraction and treatment is implementable as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or increased flow rate, if required.

Acquiring the land and constructing the extraction wells, treatment facility, and recharge basin as listed in Section 8.6.5 would present a challenge to the implementation of Alternative 3B. Land acquisition would likely be required for the construction of a north centralized treatment plant in the vicinity of the former NGBF and NWIRP property. Land acquisition is not anticipated for the construction of a centralized recharge basin in the vicinity of Bethpage State Park. Multiple locations would be required to install the extraction wells and pump stations. However, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 82,457 feet of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at Hempstead Turnpike and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to groundwater.

8.6.7 Cost Effectiveness

The total cost for Alternative 3B is approximately $332M. This alternative includes the capital costs associated with constructing 16 extraction wells, a centralized treatment plant, a centralized recharge basin, and conveyance piping; O&M costs associated with the operation of the extraction and treatment system; and costs to implement the LTM program. The estimated cost for Alternative 3B is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. The following assumptions have been made for the purpose of developing a cost estimate for comparison purposes within this FS:

- Major components include construction of 16 new extraction wells, one centralized treatment plant, one 10-acre recharge basin, services for irrigation water, and a pipe conveyance system;
- Present worth calculations are based on 25 years; and
- LTM would be conducted annually through year 30.

8.6.8 Land Use

Alternative 3B focuses on remediating groundwater containing TCVOC greater than 50 µg/l and thus allows contaminants outside of these areas to continue to migrate, potentially toward downgradient receptors. Therefore, it is not anticipated that this alternative would achieve the SCGs in the foreseeable future. However, this alternative would not affect the current, intended, or reasonably anticipated future use of the area, which is a mix of residential, commercial/industrial, and recreational use.

8.7 Alternative 4 - Aquifer Flushing

The remedial approach under Alternative 4 includes extraction of contaminated groundwater from the aquifer through the installation of 23 extraction wells installed to depths of 300 to 1,000 feet bgs within the area where TCVOC groundwater concentrations are greater than 100 µg/l for, *ex-situ* treatment using 23 decentralized treatment plants, conveyance of water via underground piping, and return of the treated water to the aquifer via the installation of 43 injection wells. This alternative also includes LTM to evaluate remediation progress throughout the operational years of the extraction and treatment system. Assumptions used in evaluating this alternative include a PDI, treatability/bench studies, and engineering evaluation. The period of performance for this alternative is expected to be 17 years for active remediation, which is less than that for the other alternatives, based on the assumptions listed in Section 7.1.7 and the extraction rate of 12.5 MGD. However, Alternative 4 would not achieve the RAOs. For the purpose of calculating the present worth cost, it is assumed that this alternative would be active for 17 years, while long-term monitoring would be conducted for 30 years.

8.7.1 Overall protection of human health and the environment

Alternative 4 would remove groundwater with TCVOCs above 100 µg/l with a series of extraction wells. The groundwater would be treated in 23 decentralized treatment plants to the NYS groundwater effluent limitations before it is returned to the aquifer through a network of 43 injection wells. This alternative would remove contaminant mass from the center of the groundwater plume and establish hydraulic control of the most impacted portions of the aquifer. However, Alternative 4 would not be successful at achieving the RAOs and it would not provide hydraulic control of impacted groundwater with concentrations less than 100 µg/l TCVOCs. Groundwater containing TCVOCs less than 100 µg/l would continue to migrate, potentially impacting downgradient receptors. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system. This alternative would rely on the existing public water supply contingency plan for the design, construction, operation, and maintenance of wellhead treatment systems, if necessary, for areas outside of the 100 µg/l plume.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 4. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and injection wells were adjusted to achieve hydraulic capture of the 100 µg/l plume while at the same time minimizing the potential effects to the environment. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 4 would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 4 are summarized in Table 8-3.

The groundwater flow modeling predicts (Table 8-3) the groundwater level in five of the 13 public water supply wells will increase from zero to 2.8 feet, while groundwater levels in eight nearby public water supply wells will decrease from 0.4 to 1.0 feet. These potential changes to the groundwater levels are not expected to affect the yield of the wells given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 4 predicts the stream flow in Massapequa Creek and Bellmore Creek will decrease 0.6 and 0.2 cfs respectively. The stream flow in Seaford Creek and Seamans Creek will also decrease 0.1 cfs. These small decreases in stream flow are very low compared to the range of stream flow in these creeks and are not expected to adversely affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will decrease as much as 0.4 feet during implementation of Alternative 4. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below the ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council 1995). Therefore, no adverse impacts to wetlands are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. The groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 5.0% (7 gpm), while groundwater flow through the GHB out of the Magothy aquifer will decrease by 2.9% (15 gpm). These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface under Alternative 4. Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 32.4% (35 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 4 since all of the groundwater extracted from the aquifer would be directly returned to the aquifer through a network of injection wells.

8.7.2 Compliance with SCGs

Alternative 4 is expected to reduce the concentration of TCVOCs to 100 µg/l. The remedial activities under Alternative 4 would be continued until the TCVOCs concentration reaches 100 µg/l within the active remediation area. While this would prevent or minimize contaminant migration to the south from areas where contaminant concentrations are the highest, there would be no immediate reductions in contaminant concentrations in areas of the plume where contaminant concentrations are less than 100 µg/l, other than from natural processes. Treated water from the decentralized groundwater treatment systems would meet New York State groundwater effluent limitations prior to being discharged to the injection wells.

8.7.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 4 would provide long-term effectiveness and permanence at extracting groundwater containing TCVOCs greater than 100 µg/l. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system.

Alternative 4 would not achieve the RAOs. Alternative 4 would not be effective in managing areas of the plume where TCVOC concentrations are less than 100 µg/l as these areas of the plume are outside the area of active remediation and are not hydraulically contained by the groundwater extraction system. Groundwater containing TCVOCs less than 100 µg/l and greater than the SCGs would continue to migrate, potentially impacting downgradient receptors. Alternative 4 would not allow unrestricted use of groundwater resources. The concentration of COCs in groundwater extracted by public water supply wells may increase during the operation of the remedy. Alternative 4 would not prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.7.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 4 would reduce the toxicity, mobility, and volume of COCs in the portion of the aquifer containing greater than 100 µg/l of TCVOCs. The toxicity, mobility, and volume of contamination would not be reduced in the portion of groundwater containing less than 100 µg/l TCVOCs. Alternative 4 would reduce the toxicity and mobility of COCs by hydraulically containing groundwater containing greater than 100 µg/l TCVOCs. Once the contaminated groundwater is withdrawn from the aquifer, the water is treated at the surface via an air stripping and carbon treatment process to address VOCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of groundwater within the 100 µg/l TCVOC plume used in Alternative 4 has been estimated to be approximately 24 billion gallons. The volume of 100 µg/l TCVOC plume would be reduced under Alternative 4 by extracting 12.5 MGD over an estimated 17 years.

8.7.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing TCVOCs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient capturing TCVOC contaminated groundwater within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 23 extraction wells;
- 43 injection wells;
- 23 treatment plants; and
- 93,282 (17.7 miles) feet of conveyance piping.

The most significant disruption to traffic would occur during construction of 93,282 feet (17.7 miles) of conveyance piping under Alternative 4. Pipe crossings at Hempstead Turnpike and the Seaford-Oyster Bay Expressway may also represent difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected. However, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.7.6 Implementability

Groundwater extraction and treatment is implementable, as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increased flow rates, if required.

The use of injection wells as a means of managing treated water is also a well-established technology. However, natural processes are expected to diminish the effectiveness of the wells over time due to fouling and sedimentation. This would require significant ongoing maintenance due to the number of injection wells (43) required for this alternative.

Acquiring the land and constructing the extraction wells, treatment facilities, and injection wells as listed in Section 8.7.5 would present a challenge to the implementation of Alternative 4. Land acquisition would likely be required for the construction of decentralized treatment plants. Multiple locations would be required to install the extraction wells, injection wells, and pump stations. However, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 93,282 feet (17.7 miles) of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at Hempstead Turnpike and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to groundwater.

8.7.7 Cost Effectiveness

The total cost for Alternative 4 is approximately $608M. This alternative includes the capital costs associated with constructing extraction and injection wells, conveyance piping, and decentralized treatment plants; O&M costs for the operation of the extraction and treatment system; and costs to implement the LTM program. The estimated cost for Alternative 4 is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. The following assumptions were made for the purpose of developing a cost estimate for comparison purposes:

- Major components include construction of 23 new extraction wells, 23 decentralized treatment plants, 43 injection wells, and a pipe conveyance system;
- Present worth calculations are based on 17 years; and
- LTM would be conducted annually through year 30.

8.7.8 Land Use

Alternative 4 focuses on remediating groundwater containing TCVOCs greater than 100 µg/l and thus allows contaminants outside of these areas to continue to migrate, potentially to downgradient receptors. Therefore, it is not anticipated that this alternative would achieve the SCGs in the foreseeable future. However, this alternative would not affect the current, intended, or reasonably anticipated future use of the area, which is a mix of residential, commercial/industrial, and recreational use.

8.8 Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Plants with Various Discharge Methods

The remedial approach under Alternative 5A includes removal of contaminated groundwater from the aquifer through the installation of 24 extraction wells to depths of 300 to 950 feet bgs within the area where COC concentrations exceed SCGs, as well as the area where TCVOCs exceed 50 µg/l; *ex-situ* treatment utilizing multiple decentralized treatment plants; conveyance via underground piping; treated water management, and long-term groundwater monitoring. This alternative includes LTM to evaluate the effectiveness of the remedy and evaluate protection to human health and the environment. Under this alternative, it is assumed that a PDI, treatability/bench studies, and engineering evaluation would be completed. The period of performance of this alternative is anticipated to be 110 years based on the assumptions listed in Section 7.1.7 and the extraction rate of 19.2 MGD. For the purpose of calculating the present worth costs in this FS, it is assumed that this alternative would be active for 30 years.

8.8.1 Overall protection of human health and the environment

Alternative 5A would protect human health and the environment by hydraulically containing groundwater with COCs above the SCGs with a series of wells along the western and southern edges of the SCG plume. The groundwater would be treated in 17 decentralized treatment plants to the NYS groundwater effluent limitations before it is returned to the aquifer through 16 recharge basins, discharged to Massapequa Creek, or beneficially re-used for irrigation purposes. It is expected that the hydraulic containment of COCs to the SCGs and the treatment and recharge of groundwater meeting NYS groundwater effluent limitations would allow unrestricted use of the groundwater resources. With the withdrawal of contaminated groundwater from 24 extraction wells, it is expected that Alternative 5A would reduce impacts to public water supply wells that currently contain site contaminants in raw groundwater and this alternative would prevent impacts to currently un-impacted public water supply wells. LTM would be used to monitor remediation progress throughout the operational years of the extraction and treatment system.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 5A. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and the locations of recharge basins were adjusted to achieve hydraulic capture of both the 50 µg/l plume and the SCG plume while at the same time minimizing the potential effects to the environment. Specifically, the return of water to the aquifer beyond the southern extent of the groundwater plume was included to mitigate potential negative environmental impacts to surface water and wetland water levels resulting from groundwater extraction under this alternative. Based on this evaluation and compared to the No Further Action Alternative, it is expected that

Alternative 5A would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 5A are summarized in Table 8-3.

The groundwater flow modeling predicts (Table 8-3) that in seven of the 13 public water supply wells, the groundwater level will decrease from 0.8 to 3.9 feet; and in the remaining six public water supply wells, groundwater levels will decrease from 4.8 to 5.3 feet. These potential changes to the water levels are not expected to affect the yield of the wells given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow modeling for Alternative 5A predicts the stream flow in Massapequa Creek will increase as much as 1.3 cfs. The increase in stream flow is likely to be a benefit to the local aquatic habitat. The stream flow in Seaford Creek and Seamans Creek will decrease up to 0.1 cfs. The stream flow will decrease up to 0.6 cfs in Bellmore Creek. These small decreases in stream flow are very low compared to the range of stream flow in these creeks and are not expected to adversely affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will increase 0.1 to 0.8 feet at two of the locations but decrease from 0.3 to 1.1 feet at the other 5 locations during implementation of Alternative 5A. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council 1995). Therefore, no adverse impacts to wetlands are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 7.1% (10 gpm), while groundwater flow through the GHB out of the Magothy aquifer will decrease by 4.1% (11 gpm). Groundwater flow modeling also shows groundwater flow through the GHB into the Lloyd will increase by 37.0% (30 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface under Alternative 5A.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 5A since most of the groundwater extracted from the aquifer would be returned to the aquifer through recharge basins.

8.8.2 Compliance with SCGs

Alternative 5A would reduce the concentration of COCs in groundwater below the SCGs, since groundwater with COCs above SCGs would be hydraulically contained and treated. Treated water would meet the New York State groundwater effluent limitations prior to being discharged to existing recharge basins, surface water at Massapequa Creek, or reuse as irrigation in Bethpage State Park. Alternative 5A would continue until COCs in the SCG plume are below the SCGs.

8.8.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 5A would provide long-term effectiveness by extracting (hydraulic containment) groundwater containing COCs to the SCGs. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system and to assess the remedy’s ability to protect human health and the environment.

The long-term effectiveness of Alternative 5A would be enhanced with the inclusion of eight mass flux extraction wells extracting groundwater containing TCVOCs greater than 50 µg/l. With these eight mass flux wells, it is expected that Alternative 5A would enhance the long-term effectiveness of hydraulic containment and provide added protection to the down-gradient public water supply wells from the areas of the plume where the highest concentrations of TCVOCs occur.

Alternative 5A would allow unrestricted use of groundwater resources. The concentration of site-related COCs in groundwater extracted by public water supply wells is expected to decrease during operation of the remedy. With hydraulic control of the SCG plume, Alternative 5A is expected to prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.8.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 5A would reduce the toxicity, mobility, and volume of COCs in the aquifer through groundwater extraction and treatment at the down-gradient edge of SCG plume, as well as from the central portion of the plume where TCVOC concentrations exceed 50 µg/l. The toxicity and mobility of COCs would be reduced under Alternative 5A by hydraulically containing groundwater with COCs that exceed the SCGs. Alternative 5A would also reduce the contaminant mass in areas containing high (greater than 50 µg/l) concentrations of TCVOCs. Once the contaminated groundwater is withdrawn from the aquifer, the water would be treated at the surface via an air stripping and carbon treatment process to address COCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of groundwater within the SCG plume used in Alternative 5A has been estimated to be roughly 150 billion gallons. The volume of the SCG plume would be reduced in Alternative 5A by extracting 19.2 MGD over an estimated 110 years.

8.8.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing COCs above the SCGs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient, capturing COCs within days or weeks of system startup. The inclusion of eight mass flux wells would allow Alternative 5A to extract groundwater containing high concentrations of TCVOCs within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be implemented during construction. In addition, double-walled underground piping and alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 24 extraction wells (16 for hydraulic containment and 8 for mass flux);

- 17 treatment plants;
- 16 reworks of existing recharge basins; and
- 131,063 feet (24.8 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 131,063 feet (24.8 miles) of conveyance piping under Alternative 5A. Pipe crossings at the Southern State Parkway and the Seaford-Oyster Bay Expressway may also present difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected. However, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.8.6 Implementability

Groundwater extraction and treatment is implementable as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increase flow rate, if required.

Acquiring the land and constructing the extraction wells and treatment facilities, as listed in Section 8.8.5 would present a challenge to the implementation of Alternative 5A. Land acquisition would likely be required for the construction of decentralized treatment plants. Multiple locations would be required to install the extraction wells and pump stations. However, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 131,063 feet (24.8 miles) of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to surface water/groundwater.

8.8.7 Cost Effectiveness

The estimated cost for Alternative 5A is approximately $748M. This alternative includes the capital costs associated with constructing extraction wells, decentralized treatment plants, an outfall structure for surface water discharge, irrigation services to Bethpage State Park, conveyance piping, and rehabilitation of existing recharge basins; O&M costs for operation of the extraction and treatment system; and costs to implement the LTM program. The estimated cost for Alternative 5A is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. The following assumptions were made to develop a cost estimate for comparison purposes:

- Major components include construction of 24 new extraction wells, 17 decentralized treatment plants, services for irrigation water, a pipe conveyance system, a surface water outfall system, as well as rehabilitation of 16 existing recharge basins;
- Present worth calculations are based on 30 years; and
- LTM would be conducted annually through year 30.

8.8.8 Land Use

Alternative 5A would achieve compliance with SCGs which is sufficient for the current, intended, and reasonably anticipated future use of the impacted area (i.e., residential, commercial, and industrial).

8.9 Alternative 5B – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

The remedial approach under Alternative 5B includes extraction of contaminated groundwater from the aquifer within the area where COC concentrations exceed the SCGs and from the area where TCVOCs exceed 50 µg/l through the installation of 24 wells to depths of 300 to 950 feet bgs, *ex-situ* treatment using a north centralized treatment plant, south centralized treatment plant and three smaller decentralized treatment plants, conveyance piping, a 10-acre constructed recharge basin, discharge to Massapequa Creek and three existing recharge basins, beneficial reuse as irrigation at Bethpage State Park, and LTM. This alternative includes LTM to monitor the effectiveness of the remedy and to evaluate protection of human health and the environment. Under this alternative, it is assumed that a PDI, treatability/bench studies, and engineering evaluation would be completed. The period of performance of active remediation for this alternative is anticipated to be 110 years based on the assumptions listed in Section 7.1.7 and the extraction rate of 17.5 MGD. For the purpose of calculating the present worth costs in this FS, it is assumed that this alternative would last 30 years.

8.9.1 Overall protection of human health and the environment

Alternative 5B would protect human health and the environment by hydraulically containing groundwater with COCs above the SCGs with a series of wells along the western and southern edges of the SCG plume. The groundwater would be treated in two centralized treatment plants and three decentralized treatment plants to the NYS groundwater effluent limitations before it is returned to the aquifer through four recharge basins, discharged to Massapequa Creek, or re-used for irrigation purposes at Bethpage State Park. It is expected that the hydraulic containment of COCs to the SCGs and the treatment and recharge of groundwater meeting NYS groundwater effluent limitations would allow unrestricted use of the groundwater resources. With the withdrawal of contaminated groundwater from 24 extraction wells, it is expected that Alternative 5B would reduce impacts to public water supply wells that currently contain site contaminants in raw groundwater and this alternative would prevent impacts to currently un-impacted water supply wells. A LTM program would be used to monitor remediation progress throughout the operational years of the extraction and treatment system.

The groundwater flow model constructed by the USGS was used to evaluate the potential environmental effects (e.g., on surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge) associated with the implementation of Alternative 5B. Through an iterative modeling process, the numbers, locations, and pumping rates of extraction wells and the locations of recharge basins were adjusted to achieve hydraulic capture of both the 50 µg/l plume and the SCG plume while at the same time minimizing the potential effects to the environment. Specifically, the return of water to the aquifer beyond the southern extent of the groundwater plume was included to mitigate potential negative environmental impacts to surface water and wetland water levels resulting from groundwater extraction under this alternative. Based on this evaluation and compared to the No Further Action Alternative, it is expected that Alternative 5B would have little effect on the environment. The specific potential changes to surface water flow, water levels in wetlands, water levels in public water supply wells, and subsea discharge for Alternative 5B are summarized in Table 8-3.

The groundwater model predicts (Table 8-3) that in six of the 13 public water supply wells, the water level will decrease from 1.8 to 4.0 feet; in the remaining seven public water supply wells, groundwater levels will decrease from 5.2 to 7.3 feet. These potential changes to the water levels are not expected to affect the yield of the wells given the well depths, specific capacity, and well efficiency of these public water supply wells.

The groundwater flow mode for Alternative 5B predicts that the stream flow in Massapequa Creek will increase 1.2 cfs. This increase in stream flow is likely to be a benefit to the local aquatic habitat. The stream flow in Seaford Creek and Seamans Creek will decrease 0.2 and 0.3 cfs, respectively. The stream flow will decrease 1.2 cfs in Bellmore Creek. These small decreases in stream flow are very low compared to the range of stream flow in these creeks and are not expected to adversely affect the aquatic habitat.

The groundwater flow modeling predicts the water table elevation in wetlands south of the site will decrease from 0.1 to 2.2 feet during implementation of Alternative 5B. According to the National Wetlands Inventory, the wetlands have been classified as Freshwater Forested/Shrub Wetlands. These wetlands are flooded or ponded for 14 or more consecutive days during the growing season from precipitation runoff. The depth to the water table typically lies well below ground surface for most of the year. The saturated conditions during the growing season is from heavy precipitation/runoff and not controlled by the depth to the water table (National Research Council, 1995). Therefore, no adverse impacts to wetlands are anticipated as a result of a small change in the water table.

The potential effect to the position of the saltwater-freshwater interface was evaluated by modeling the potential changes in subsea discharge. Groundwater flow modeling predicts groundwater flow through the GHB into the Magothy aquifer will increase by 2.1% (3 gpm), while groundwater flow through the GHB out of the Magothy aquifer will decrease by 3.7% (19 gpm). Groundwater flow modeling also predicts groundwater flow through the GHB into the Lloyd will increase by 14.8% (16 gpm) while the groundwater flow through the GHB out of the Lloyd will remain at zero. These small changes in boundary conditions are not expected to affect the position of the saltwater-freshwater interface.

It is not expected that the overall safe yield of the aquifer would be affected by implementation of Alternative 5B, since most of the groundwater extracted from the aquifer would be returned to the aquifer through recharge basins.

8.9.2 Compliance with SCGs

Alternative 5B would reduce the concentration of COCs in groundwater to below the SCGs, since groundwater with COCs above SCGs would be hydraulically contained and treated. Treated water would meet the New York State water effluent limitations prior to being discharged to the constructed recharge basin, the existing recharge basins, Massapequa Creek, and prior to beneficial re-use for irrigation purposes by Bethpage State Park.

8.9.3 Long-term effectiveness and permanence

Groundwater extraction and treatment systems have been demonstrated to be effective and reliable at numerous sites for groundwater treatment for VOCs. Alternative 5B would provide long-term effectiveness by extracting (hydraulic containment) groundwater containing COCs to the SCGs. VOCs would be permanently removed from groundwater with air stripping and GAC processes. 1,4-Dioxane would be permanently removed from groundwater with AOP. A LTM program would be implemented to verify the long-term effectiveness of the extraction and treatment system and to assess the remedy's ability to protect human health and the environment.

The long-term effectiveness of Alternative 5B would be enhanced with the inclusion of eight mass flux extraction wells extracting groundwater containing TCVOCs greater than 50 µg/l. With these eight mass flux wells, it is expected that Alternative 5B would enhance the long-term effectiveness of hydraulic containment and provide added protection to the down-gradient public water supply wells from the areas of the plume where the highest concentrations of TCVOCs occur.

Alternative 5B would allow unrestricted use of groundwater resources. The concentration of site-related COCs in groundwater extracted by public water supply wells is expected to decrease during operation of the remedy. With hydraulic control of the SCG plume, Alternative 5B is expected to prevent currently un-impacted public water supply wells from requiring treatment to address the COCs.

8.9.4 Reduction of toxicity, mobility, or volume of contamination through treatment

Alternative 5B would reduce the toxicity, mobility, and volume of COCs in the aquifer through groundwater extraction and treatment at the down-gradient edge of SCG plume as well as from the central portion of the plume where TCVOC concentrations exceed 50 µg/l. The toxicity and mobility of COCs is reduced under Alternative 5B by hydraulically containing groundwater with COCs that exceed the SCGs. Alternative 5B would also reduce the contaminant mass in areas containing high (greater than 50 µg/l) concentrations of TCVOCs. Once the contaminated groundwater is withdrawn from the aquifer, the water would be treated at the surface via an air stripping and carbon treatment process to address most COCs and AOP to specifically address 1,4-dioxane. Contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed in accordance with applicable waste regulations. AOP provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane. The volume of groundwater within the SCG plume used in Alternative 5B has been estimated to be roughly 150 billion gallons. The volume of the SCG plume would be reduced in Alternative 5B by extracting 17.5 MGD over an estimated 110 years.

8.9.5 Short-term impacts and effectiveness

Groundwater extraction systems are effective at controlling the migration of groundwater containing COCs above the SCGs and removing contaminant mass from an aquifer over the short-term. Groundwater extraction systems would induce a hydraulic gradient capturing COCs within days or weeks of system startup. The inclusion of eight mass flux wells would allow Alternative 5B to extract groundwater containing high concentrations of TCVOCs within days or weeks of system startup. Extraction of contaminated groundwater to the surface for treatment increases the risks of contaminant exposure to workers, the community, and the environment. However, safety techniques, including community air monitoring, traffic control plans, and street closure permits would be needed during construction. In addition, double-walled underground piping and alarmed monitoring equipment would be used to minimize risks from failures of treatment system components. A fence and other potential security measures would be installed around the treatment system facilities to restrict access, discourage trespassers, and limit potential exposure.

Short-term impacts would be incurred during the construction of:

- 24 extraction wells (16 for hydraulic containment and 8 for mass flux);
- 5 treatment plants;
- 1 new recharge basin;
- 3 reworks of existing recharge basins; and
- 124,411 feet (23.6 miles) of conveyance piping.

The most significant disruption to traffic would be caused during construction of 124,411 feet (23.6 miles) of conveyance piping under Alternative 5B. Pipe crossings at Hempstead Turnpike, the

Southern State Parkway and the Seaford-Oyster Bay Expressway may also present difficult challenges. Increased traffic and noise during well installation, underground piping installation, and treatment system construction is expected. However, noise and traffic control plans outlining standard work practices and engineering controls would be implemented to reduce impacts to the community to the extent possible. The construction of this alternative has been estimated to take up to five years. Contaminated water produced during well construction, operations, and LTM would be appropriately managed according to Federal, State, and local regulations.

8.9.6 Implementability

Groundwater extraction and treatment is implementable, as the technique uses well-established technologies and the equipment and services needed to install and operate the treatment systems and to sample groundwater monitoring wells are commercially available. PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment. The treatment components can be expanded to improve treatment effectiveness or handle increase flow rate, if required.

Acquiring the land and constructing the extraction wells, treatment facilities, and recharge basins as listed in Section 8.9.5 would present a challenge to the implementation of Alternative 5B. Land acquisition would likely be required for the construction of a north centralized treatment plant and the four smaller treatment plants under this alternative. Land acquisition is not anticipated for the construction of a centralized recharge basin in the vicinity of Bethpage State Park. Multiple locations would be required to install the extraction wells and pump stations. However, to the maximum extent practicable, public ROWs, and publicly available parcel/properties would be used when evaluating possible locations for the wells and pump stations.

Construction of 124,411 feet (23.6 miles) of conveyance piping would cause disruption to traffic and would be challenging in densely populated areas. Pipe crossings at Hempstead Turnpike, the Southern State Parkway and the Seaford-Oyster Bay Expressway may also represent difficult challenges. A SPDES permit (or equivalent) would be required for the discharge to surface water/groundwater.

8.9.7 Cost Effectiveness

The total cost for Alternative 5B is approximately $585M. This alternative includes capital costs associated with constructing extraction wells, two central treatment plants and three smaller decentralized treatment plants, a central recharge basin, irrigation services to Bethpage State

Park, an outfall structure for surface water discharge, conveyance piping, and rehabilitation of existing recharge basins; O&M costs for operation of the extraction and treatment system; and costs to implement the LTM program. The estimated cost for Alternative 5B is summarized in Table 8-2, and a breakdown of costs for this alternative is provided within Appendix A. The following assumptions were made to develop a cost estimate for comparison purposes:

- Major components include the construction of 24 new extraction wells, two centralized treatment plants, three decentralized treatment plants, one centralized recharge basin, services for irrigation water, a pipe conveyance system, as well as rehabilitation of three existing recharge basins;
- Present worth calculations are based on 30 years; and
- LTM would be conducted annually through year 30.

8.9.8 Land Use

Alternative 5B would achieve compliance with SCGs, which is sufficient for the current, intended, and reasonably anticipated future use of the impacted area (i.e., residential, commercial, and industrial).

9 COMPARATIVE ANALYSIS OF ALTERNATIVES

In Section 8, each of the remedial alternatives for groundwater was individually evaluated with respect to the eight evaluation criteria. In this section, a comparative analysis was completed between the alternatives for each of the evaluation criteria. The purpose of this analysis is to identify the relative advantages and disadvantages of each alternative.

These eight groundwater alternatives that were individually evaluated in Section 8 include:

- Alternative 1 – No Further Action
- Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods
- Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin
- Alternative 3A – Plume Mass Flux Remediation - Decentralized Plants with Various Discharge Methods
- Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin
- Alternative 4 – Aquifer Flushing
- Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods
- Alternative 5B – Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

Each of the remedial alternatives summarized above consists of groundwater extraction, *ex-situ* groundwater treatment, and various approaches for managing and/or reusing the treated water. The overall effectiveness of the selected remedy would be evaluated through implementation of an LTM program.

The primary differences between the groundwater remedial alternatives are:

- Remediation Area:
    a. SCG plume = 150 billion gallons of groundwater;
    b. 50 µg/l TCVOC plume = 42 billion gallons of groundwater; and
    c. 100 µg/l TCVOC plume = 24 billion gallons of groundwater.
- Centralized and Decentralized Treatment Plants:

a. The number of treatment plants ranges from one to 23.

- Centralized or Decentralized Recharge Basins or Injection Wells:
  a. Number of constructed centralized recharge basins is one for all “B” Alternatives;
  b. Number of existing recharge basins to be rehabilitated ranges from 0 to 16; and
  c. Number of injection wells is 43 for Alternative 4 only.
- Conveyance Piping:
  a. Conveyance piping ranges from 82,046 feet (15.5 miles) to 131,063 feet (24.8 miles).
- Beneficial Reuse:
  a. Discharge to Massapequa Creek; and
  b. Discharge as irrigation at Bethpage Golf Course.

Alternatives vary in the portion of the plume targeted for groundwater remediation. Alternatives 2A, 2B, 5A, and 5B target hydraulic containment of the SCG plume. Alternatives 3A and 3B target the high mass flux portions of the aquifer defined by the 50 µg/l TCVOC plume. Alternative 4 targets higher concentration mass flux portions of the SCG plume defined by the 100 µg/l TCVOC plume. Alternative 5A and 5B combine the goals of Alternative 2A and 2B (hydraulic containment of the SCG plume) and Alternative 3A and 3B (the high mass flux portions of the SCG plume defined by the TCVOCs in groundwater that exceed 50 µg/l).

Each of the remedial alternatives relies on the same *ex-situ* treatment technologies to achieve the NYSDEC discharge effluent limitations. Alternatives vary significantly on whether they use decentralized treatment and recharge (“A” alternatives) or centralized treatment and discharge (“B” Alternatives). The number of treatment plants vary from one to 23. The number of recharge basins vary from one to 16. The number of injection wells used in one of the alternatives (Alternative 4) is 43.

The locations of *ex-situ* treatment plants and treated water discharge locations vary between the “A” and “B” alternatives. The locations have a significant impact on the length of water conveyance piping necessary to extract, treat, and discharge the water. The length of conveyance piping ranges from 82,046 to 131,063 feet. Finally, some alternatives use beneficial reuse approaches for treated water management, including discharge to Massapequa Creek and/or irrigation at Bethpage Golf Course.

The alternatives vary in their ability to satisfy the eight evaluation criteria, and the following sections provide a comparative analysis completed between the alternatives for each of the evaluation criteria. A summary of the results of this evaluation is provided within Table 8.1.

9.1 Overall Protectiveness of Public Health and the Environment

Alternatives 5A and 5B are considered to be the most protective of human health and the environment, as each of these alternatives provides hydraulic containment of the SCG plume to minimize continued migration of the groundwater plume, while aggressively removing significant contaminant mass from the groundwater using mass flux wells. These alternatives are anticipated to achieve RAOs for the SCG plume within the shortest timeframe (as much as 110 years). Discharge of a portion of the treated water beyond the southern extent of the groundwater plume would mitigate potential environmental impacts to surface water, wetlands, and subsea discharge.

Alternatives 2A and 2B are the next most protective as both of these alternatives provide hydraulic containment the aquifer to minimize continued migration of the SCG plume. These alternatives (2A and 2B) are anticipated to achieve RAOs in a longer timeframe than Alternatives 5A and 5B (as much as 30 years longer), because they do not target the removal of contaminant mass from the most impacted portions of the SCG plume. Similar to Alternatives 5A and 5B the discharge of a portion of the treated water beyond the southern extent of the groundwater plume would also mitigate potential environmental impacts to surface water, wetlands, and subsea discharge under Alternatives 2A and 2B.

Alternatives 3A, 3B, and 4 are mass flux alternatives that remove contaminant mass from the most heavily impacted portions of the SCG plume; but they do not provide hydraulic control of the entire SCG plume. These alternatives are not protective of human health and the environment, as they rely upon existing wellhead treatment and natural processes to remove COCs to the SCGs. They are considered less protective than the other alternatives (2A, 2B, 5A, and 5B) because they do not achieve hydraulic control of the SCG plume. Furthermore, these alternatives are expected to require the longest timeframes to achieve the RAOs.

The potential for additional human exposure would occur as a result of implementing Alternatives 1, 3A, 3B, and 4 because additional water supplies may become impacted as contaminated groundwater with COCs above the SCGs continues to migrate in the down-gradient direction. The implementation of the existing Public Water Supply Contingency Plan by the Navy and Northrop Grumman involves routine groundwater sampling at early detection monitoring wells.

These wells have been located and designed to allow necessary time for treatment to be provided at down-gradient public water supplies if needed. The potential for human exposure to contaminants resulting from remedy implementation also exists to a lesser extent for all alternatives, because contaminated groundwater is extracted from the aquifer and aboveground treatment is required. Also, direct contact with contaminants could occur during the short periods of time when GAC change-out is occurring. However, these exposures would be mitigated through standard work practices.

Alternatives 2A, 2B, 3A, 3B, 4, 5A, and 5B have been developed with numerous iterations using the USGS groundwater flow model to achieve their individual objectives, while causing very minor impacts to the environment. These potential impacts include changes in stream flow, water levels in wetlands, yield of public water supply wells, and saltwater intrusion (i.e., subsea discharge).

Each of the alternatives would transfer VOC concentrations from groundwater to vapor, which is mitigated with the use of GAC adsorption. The VOCs are then destroyed when the GAC is recycled and regenerated. The AOP technology included in each of the alternatives provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane.

9.2 Compliance with SCGs

Alternatives 2A, 2B, 5A, and 5B, which involve groundwater extraction and treatment of the entire area where groundwater COC concentrations exceed the SCGs, would be the most effective alternatives in achieving compliance with SCGs. By preventing the continued migration of the SCG plume, these alternatives would eliminate the need for additional public water supplies to require wellhead treatment for the COCs and allow unrestricted use of the area's groundwater resources. Of these alternatives, Alternatives 5A and 5B include a mass flux approach to address areas of the plume with high contaminant concentrations, while also capturing remaining portions of impacted groundwater with contaminant concentrations above the SCGs. Alternatives 5A and 5B would therefore be the most effective at achieving SCGs in the least amount of time, followed by Alternatives 2A and 2B.

Alternatives 3A, 3B, and 4 are anticipated to effectively achieve SCGs through the extraction of COCs from only the most highly impacted areas (concentrations greater than 50 µg/l TCVOCs [Alternatives 3A and 3B] and 100 µg/l TCVOCs [Alternatives 4]) and rely on natural processes and wellhead treatment of public water supplies to achieve SCGs for the remainder of the SCG plume. With large portions of the SCG plume not being addressed under Alternatives 3A, 3B, and 4, these alternatives are anticipated to require a much longer timeframe to achieve the SCGs than Alternatives 2A, 2B, 5A, and 5B.

The No Further Action Alternative (Alternative 1) is also expected to achieve SCGs through the extraction of COCs from only the most highly impacted areas (concentrations greater than 1,000 µg/l). However, similar to Alternatives 3A, 3B, and 4, this alternative relies on natural processes and ongoing wellhead treatment of public water supplies to achieve SCGs within the remainder of the plume. This alternative is therefore the least effective at achieving SCGs.

Under each of the alternatives (including Alternative 1), extracted water would be treated to meet NYSDEC discharge effluent limitations prior to groundwater recharge, discharge to surface water, or beneficial reuse. Each of the alternatives therefore meets SCGs for treated water.

9.3 Long-Term Effectiveness and Permanence

Groundwater extraction and ex-situ treatment under each of the alternatives are considered effective technologies for addressing groundwater contaminated with COCs. Alternatives 5A and 5B are anticipated to achieve RAOs in the shortest remedial timeframe by removing a significant contaminant mass from within the most impacted portions of the plume, combined with capture of groundwater with contaminant concentrations above SCGs along the margins of the plume and the discharge of treated water outside the margins of the plume. These alternatives provide the greatest long-term effectiveness at achieving the RAOs.

Alternatives 2A and 2B provide hydraulic containment of groundwater containing COCs at concentrations exceeding the SCGs. While these alternatives would be effective in the long-term in preventing further plume migration, these alternatives (2A and 2B) would require a greater timeframe to achieve RAOs than Alternative 5A and 5B. Furthermore, these alternatives would allow the movement of groundwater with high concentrations of COCs in the down-gradient direction to the south. These alternatives are less effective in the long-term than Alternatives 5A and 5B at achieving the RAOs.

Alternatives 3A, 3B, and 4 would provide significant mass removal of contaminants within the portions of the plume containing TCVOC concentrations above 50 µg/l and 100 µg/l, respectively. However, these alternatives rely on wellhead treatment and natural processes to reduce COCs to achieve SCGs. These alternatives (3A, 3B, and 4) are therefore less effective long-term than Alternatives 2A and 2B at achieving the RAOs. These alternatives also do not address large portions of the SCG plume and allow for the continued, uncontrolled migration of contaminants to the south toward currently un-impacted public water supplies.

While the No Further Action (Alternative 1) controls the sources at NGBF, NWIRP and the BCP-Former Grumman Settling Ponds with the existing or planned remediation systems and addresses areas of the plume with the highest CVOC groundwater concentrations, it relies on natural processes and wellhead treatment to prevent exposure to contaminants at concentrations above SCGs in all other areas of the plume. As Alternative 1 does not address large portions of the SCG plume, it allows for the continued, uncontrolled migration of contaminants to the south toward currently un-impacted public water supplies. Alternative 1 is therefore the least effective in the long-term at achieving the RAOs.

9.4 Reduction of Toxicity, Mobility, or Volume with Treatment

Alternatives 2A, 2B, 3A, 3B, 4, 5A, and 5B would reduce the toxicity, mobility, and volume of contaminants in the aquifer by using extraction wells to remove contaminated groundwater and by providing surface treatment through air stripping, granulated active carbon, and AOP technologies. With extraction wells placed in areas of the plume with high TCVOC concentrations, along with extraction wells placed along the plume margins, Alternatives 5A and 5B would be the most effective in reducing the toxicity, mobility, and volume of contaminants in the shortest amount of time.

Alternatives 2A and 2B would be effective in reducing toxicity, mobility, and volume of site contaminants by operating wells along the margins of the plume. However, it would take a longer timeframe for high TCVOC concentrations to reach the wells along the perimeter of the plume. Withdrawing contaminated groundwater from only the margins of the plume may allow more contaminant mass to diffuse into fine-grained silts and clays. Therefore, Alternatives 2A and 2B would provide less reduction of toxicity and mobility of the COCs in groundwater than Alternatives 5A and 5B.

Alternatives 3A, 3B, and 4 would be effective in reducing the toxicity, mobility, and volume of contaminants in areas of the TCVOC plume above 50 µg/l and 100 µg/l, respectively. However, these alternatives would not actively reduce the toxicity, mobility, and volume in portions of the TCVOC plume less than 50 µg/l and 100 µg/l, respectively. These alternatives would rely on wellhead treatment and natural processes to reduce COCs to the SCGs within these areas of the plume. Therefore, these alternatives would provide less reduction of toxicity, mobility, and volume of the COCs in groundwater than Alternatives 2A, 2B, 5A, or 5B.

The No Further Action Alternative (Alternative 1) would reduce toxicity, mobility, and the volume of groundwater contamination from only the most highly impacted areas (i.e., concentrations greater than 1,000 µg/l with existing or planned treatment systems) of the TCVOC plume. However, similar to Alternatives 3A, 3B, and 4, this alternative relies on natural processes and ongoing wellhead treatment of public water supplies to achieve SCGs within the remainder of the plume. This alternative is therefore the least effective at reducing the toxicity, mobility, and volume of COCs.

Each of the alternatives relies on commonly used treatment technologies to permanently destroy the contaminants once withdrawn from the aquifer. Following air stripping, any remaining contaminants trapped on the GAC adsorption media would be destroyed during regeneration or disposed of in accordance with applicable waste regulations. The AOP technology provides complete destruction and mineralization of many chlorinated solvents, including 1,4-dioxane.

9.5 Short-Term Impacts and Effectiveness

Each of the alternatives would be effective in the short-term at controlling the migration of groundwater containing COCs above the SCGs and removing contaminant mass from the aquifer. Groundwater extraction systems would induce a hydraulic gradient capturing COCs within days or weeks of system startup. With the drilling of extraction wells, installation of underground conveyance piping, construction of treatment plants, and development of discharge locations, each of the alternatives would have short-term impacts on the community. While each of the alternative would have short-term impacts on the local communities, these disruptions would be minimized through noise and traffic control plans, as well as community air monitoring programs during construction to minimize and address any potential impacts to the community, remediation workers, and the environment.

Since Alternative 1 includes remedial actions that are already under various stages of completion, this alternative would result in the least amount of short-term impacts compared to the other alternatives. Specifically, the two on-site containment systems and the GM-38 groundwater extraction and treatment system are already fully constructed and operating. Additionally, three of the extraction wells (RW-21 wells) have already been installed and there are approximately three to five additional extraction wells requiring installation under Alternative 1. Furthermore, these remedial systems are addressing contaminant concentrations that are greater than 1,000 μg/l and therefore disrupt a smaller geographic area than Alternatives 2 through 5. Outside of these existing or planned remedial systems, Alternative 1 does not include additional extraction wells, treatment plants, or underground piping. Therefore, this alternative would cause the least amount of short-term impacts associated with the construction of wells, treatment plants, recharge basins, and conveyance piping.

Alternatives 2A, 3A, and 5A would have large short-term impacts to workers, the public, and the environment during construction of the 12 to 17 decentralized treatment plants and 82,046 to 131,063 feet of piping and the rehabilitation of 12 to 16 existing recharge basins. Alternative 5A with the construction of 24 extraction wells and 17 treatment plants, the reworking of 16 existing recharge basins, and the installation of approximately 131,063 feet of underground piping, would have the most short-term impacts to the local communities relative to Alternatives 2A, 2B, 3A, 3B, and 5B.

Alternatives involving the use of centralized treatment plants and central recharge basins (Alternatives 2B, 3B, and 5B) would also have short-term impacts to the community. Alternatives 2B, 3B, and 5B would have large short-term impacts to workers, the public, and the environment during construction of a single centralized treatment plant, up to four decentralized treatment plants, 82,457 to 124,411 feet of underground piping, and the rehabilitation of up to three existing recharge basins. Alternative 3B, with the installation of 16 extraction wells, construction of a single treatment plant, and a ten-acre recharge basin, and the installation of approximately 82,457 feet of underground piping, would have the least amount of short-term impacts to the local communities. However, this alternative would not achieve the RAOs without natural processes and wellhead treatment. Alternative 5B would have the highest short-term effectiveness (due to mass flux and hydraulic containment extraction wells) and less short-term impacts to the local communities compared to Alternative 5A while achieving the RAOs, with the construction of 24 extraction wells, five treatment plants, and one constructed recharge basin, the rehabilitation of three existing recharge basins, and the installation of approximately 124,411 feet of underground piping.

Alternative 4 (Aquifer Flushing) includes the largest amount of subsurface drilling (23 extraction wells and 43 injection wells), the largest number of treatment plants (23), and 93,282 feet of underground piping and would produce the greatest amount of short-term impacts to the local communities.

9.6 Implementability

While each of the remedial alternatives are technically feasible and implementable, the degree of difficulty is determined by specific construction activities that will need to occur in heavily developed areas. Each alternative involves drilling of extraction wells, installation of underground piping, and construction of treatment plants and would therefore be difficult to implement in the heavily developed areas near the site.

Alternative 1 (No Further Action), would be the easiest alternative to implement as it requires the least potential land acquisition, least amount of construction, and would be the least disruptive to traffic.

Alternatives 2B, 3B, and 5B would be the next easiest to implement. They require the potential acquisition of land in the vicinity of the existing Northrop Grumman and Navy property and, with the exception of Alternative 3B, within the Massapequa Preserve for the construction of centralized treatment plants. These alternatives also require potential land acquisition for the installation of extraction wells and would cause significant disruption to traffic along several major roadways to install underground conveyance piping. The construction of a centralized recharge basin within Bethpage State Park is anticipated to reduce disruptions associated with the possible construction of additional recharge basins to manage treated water. The acquisition of land and permits are not expected to be necessary for construction of the centralized recharge basin.

Alternatives 2A, 3A, and 5A with decentralized treatment plants and various disposal/discharge options would be more difficult to implement as the acquisition of land and permits to build each decentralized treatment plant in highly developed areas would be necessary. These alternatives would also cause disruptions to traffic within several areas to install underground conveyance piping between the extraction wells and the decentralized treatment plants, and from the treatment plants to the individual recharge basins or surface water discharge location.

Alternative 4 would be the most difficult to implement due to the number of extraction/injection wells (23/43), number of treatment plants (23) and 93,282 feet of underground conveyance needed to transfer groundwater to the treatment plants and injection wells.

While each of the alternatives would be difficult to implement in the heavily developed areas, the extraction/injection wells proposed under each alternative are constructed with well-established technologies, equipment, and services. The equipment and services needed to sample groundwater monitoring wells are also commercially available. The ex-situ treatment technologies proposed under all the alternatives are commercially available technologies and are typically easy to install and operate. Additional PDI, pilot testing, and property evaluation would be necessary to determine optimal well placement, flow rates, and any required pre-treatment.

9.7 Cost

The evaluation of costs for each alternative includes an estimation of construction/capital costs, O&M costs and periodic costs. Table 8-2 provides a summary of estimated costs for all groundwater alternatives, while Tables A-1, A-2A, A-2B, A-3A, A-3B, A-4, A-5A, and A-5B within Appendix A include conceptual cost analyses (and assumptions) for these alternatives. The costing was based on conceptual remedy assumptions and the information developed for this FS (e.g., site geology; contaminant concentrations, etc.). The costs are presented in present worth basis for comparison purposes. The cost for each alternative, presented in order of increasing cost is:

- Alternative 1 – No Further Action (**$0**)
- Alternative 3B – Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin **($332 M)**
- Alternative 2B – Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin **($485 M)**
- Alternative 3A – Plume Mass Flux Remediation - Decentralized Plants with Various Discharge Methods **($522 M)**
- Alternative 2A – Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods **($553 M)**
- Alternative 5B – Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatments Plant with a Centralized Recharge Basin **($585 M)**
- Alternative 4 – Aquifer Flushing **($608 M)**
- Alternative 5A – Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods **($748 M)**

9.8 Land Use

Alternatives 5A/5B are anticipated to achieve compliance with SCGs more quickly than the other alternatives, which is sufficient for the current, intended and reasonably anticipated future use of the areas south of the site (i.e., residential, commercial, and industrial). Alternatives 3A, 3B, and 4 would achieve COC concentrations less than 50 and 100 µg/l, respectively, within the area of active remediation in a shorter timeframe; however, reducing contaminant concentrations outside the area of active remediation would require a longer timeframe to achieve compliance with SCGs. Alternatives 2A and 2B are anticipated to achieve compliance with SCGs within a longer timeframe than the other alternatives.

10 CERTIFICATION

I Erich Zimmerman certify that I am currently a NYS registered professional engineer and that this Feasibility Study Report was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10) and that all activities were performed in full accordance with the DER-approved work plan and any DER-approved modifications.

Erich Zimmerman, P.E.

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TABLES

Table 2-1: Contaminants of Concern and Chemical Specific SCGs
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Contaminant of Concern (COC)	CAS RN	OU2 ROD	OU3 ROD	PWSCP	GW Plume FS	NYSDEC Part 703.5 Class GA (μg/l)	NYSDEC TOGS 1.1.1 Class GA (μg/l)	NYSDOH Part 5, Subpart 5-1 (μg/l)	Federal MCLs (μg/l)	Federal MCLG (μg/l)	Lowest SCG (μg/l)
1,1,2,2-Tetrachloroethane	79-34-5			X	X	5	5	5	NS	NG	5
1,1,1-Trichloroethane	71-55-6	X	X	X	X	5	5	5	200	200	5
1,1,2-Trichloroethane	79-00-5		X	X	X	1	1	5	5	3	1
1,1-Dichloroethane	75-34-3	X	X	X	X	5	5	5	NS	NG	5
1,1-Dichloroethene	75-35-4	X	X	X	X	5	5	5	7	7	5
1,2-Dichloroethane	107-06-2	X	X	X	X	0.6	0.6	5	5	0	0.6
1,2-Dichloropropane	78-87-5		X		X	1	1	5	5	0	1
Chloroform	67-66-3		X	X	X	7	7	NS	NS	70	7
cis-1,2-Dichloroethene	156-59-2		X	X	X	5	5	5	70	70	5
Chlorodifluoromethane	75-45-6		X		X	5	5	NS	NS	NG	5
Dichlorodifluoromethane	75-71-8		X		X	5	5	5	NS	NG	5
Tetrachloroethene	127-18-4	X	X	X	X	5	5	5	NS	0	5
Toluene	108-88-3		X		X	5	5	5	1000	1000	5
trans-1,2-Dichloroethene	156-60-5		X	X	X	5	5	5	70	100	5
Trichloroethene	79-01-6	X	X	X	X	5	5	5	5	0	5
Trichlorotrifluoroethane	76-13-1		X	X	X	5	5	NS	NS	NG	5
Vinyl chloride	75-01-4	X	X		X	2	2	2	2	0	2
Carbon disulfide	75-15-0			X	X	60	NS	NS	NS	NG	60
Carbon tetrachloride	56-23-5			X	X	5	5	5	5	0	5
Chlorobenzene	108-90-7			X	X	5	5	5	100	100	5
1-4 Dioxane	123-91-1				X	NS	NS	50 (see notes)	NS	NG	0.35 (see notes)
Chromium	7440-47-3		X		X	50	50	100	100	100	50
Iron	7439-89-6		X		X	300	300	300	NS	NG	300
Nickel	7440-02-0		X		X	100	100	state MCL	NS	NG	100

Notes:
FS - Feasibility Study
ROD - Record of Decision
GW - Groundwater
NS- No published or promulgated standard.
NG- No designated goal
OU - Operable Unit
MCL / MCLG - Maximum Contaminant Level / Maximum Contaminant Level Goal
SCG - Standards, Criteria, and Guidance
μg/l - Micrograms per liter
NYSDOH Part 5, Subpart 5-1 designates a maximum concentration of 50 ug/l for 1-4 Dioxane as a unspecified organic compound.
Federal MCLs - United States Environmental Protection Agency National Primary Drinking Water Regulations (40 CFR Part 141.10).
Criteria based on a 10^-6 lifetime excess cancer risk in drinking water, (EPA IRIS, 2013)
Chlorodifluoromethane (also known as Freon 22) replaced dichlorflouromethane (Freon 21) on this list as the ROD tables inadvently switched the two based on the common name.

Note: Public Water Suplly Contingency Plan lists 1,2-DCE three times (1,2-DCE and cis-/trans- isomers). Only cis and trans- isomers shown here.

Table 2-2A Chemical Specific SCGs
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Title	Citation	Description	Comments
Federal			
Safe Drinking Water Act	40 CFR Part 141	Drinking water standards, expressed as maximum containment levels (MCLs), which apply to specific contaminants that have been determined to have an adverse impact on human health.	Contaminant concentrations exceeding MCL in drinking water may warrant corrective actions.
State of New York			
New York State Department of Environmental Conservation Criteria Governing Thermal Discharges	6 NYCRR Part 704	Water quality standards and criteria for thermal discharges to a water body	May be applicable to the discharge of treated water to surface water sources.
New York State Department of Environmental Conservation Water Quality Standards	6 NYCRR Part 703	Water Quality Standards are the basis for programs to protect the state waters. Standards set forth are the MCL of chemical pollutants and are used as the regulatory targets for permitting, compliance, enforcement, and monitoring and assessing the quality of the state's waters.	Contaminant concentrations exceeding standard and guidance values in drinking water may warrant corrective actions.
New York State Department of Environmental Conservation Derivation and Use of Standards and Guidance Values	6 NYCRR Part 702	Regulations detailing the basis for derivation of water quality standards, and for where no standards exist in Part 703.5, the derivation of guidance values (6 NYCRR 702.15(a), (b), (c), (d), (e), & (f)).	Corrective actions of certain contaminants may be based on guidance values where no applicable health standard exists.
New York State Department of Environmental Conservation Classifications - Surface Waters and Groundwaters	6 NYCRR Part 701	Provides definitions and classifications for various water sources, and defines allowable discharges into those sources.	May be applicable to the discharge of treated water to surface water sources.
New York State Department of Enviromental Conservation Definitions, Samples and Tests (700), References (705), and Appendices for Parts 700 - 705 (706).	6 NYCRR Parts 700, 705, & 706	Regulatory documentation supporting and referred to in 6 NYCRR Part 701 through 704	May be applicable in support of 6 NYCRR Part 701 through 704 SCGs.
New York State Department of Environmental Conservation Water and Technical and Opertional Guidance Series	NYSDEC TOGS 1.1.1	Compilation of ambient water quality standards and guidance values and groundwater effluent limitations for use where there are no standards or regulatory effluent limitations.	Contaminant concentrations exceeding standard and guidance values in drinking water may warrant corrective actions.
New York State Department of Health	NYSDOH Part 5, Subpart 5-1	Rules that are promulgated to protect present or future source of water supply.	Contaminant concentrations exceeding MCL, or in the case of 1,4-Dioxane an unspecific organic contaminant, in drinking water may warrant corrective actions.

Table 2-2B: Location Specific SCGs
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Title	Citation	Description	Comments
Federal			
Executive Order 11988 - Floodplain Management	40 CFR Part 6, Subpart A; 40 CFR 6.302	Activities taking place within floodplains must be performed to avoid adverse impacts and preserve beneficial values	Pertinent to activities that may occur within the floodplain.
Clean Water Act	33 USC 466 Section 404	Activities performed within wetlands areas must be done to avoid adverse impacts	Would be applicable to remediation activities impaction jurisdictional wetlands.
Executive Order 11990 - Protection of Wetlands	40 CFR Part 6, Subpart A	Activities performed within wetlands areas must be done to avoid adverse impacts	Would be applicable to remediation activities impaction jurisdictional wetlands.
Policy on Floodplains and Wetlands Assessments for CERCLA Actions	OSWER 9280.0-02	Guidance for implementing executive orders 11988 and 11990	Executive order implementation guidance.
Wetlands Protection at CERCLA sites	OSWER 9280.0-03	Guidance document to be used to evaluate impacts to wetlands at Superfund sites	Requirements should be considered when evaluating impacts to jurisdictional wetlands.
National Historic Preservation Act	16 CFR Part 470	Established Requirements for the identification and preservation of historic and cultural resources	Would be applicable to the management of historic or achaeological artificats identified on the Site.
Endangered Species Act and Fish and Wildlife Coordination Act	16 CFR Part 661 and 16 U.S.C. 1531	Actions must be taken to conserve critical habitat in areas where they are endangered or threatened species	Requires would be applicable if endagered or threatened species are identified on or adjacent to the Site.
Resource Conservation and Recovery Act (RCRA) Regulations - Location Standards	40 CFR Part 264.18	Regulates the design, construction, operation, and maintenance of hazardous waste management facilities within the 100-year floodplain.	Applicable for on-site treatment, storage or disposal of hazardous waste
State of New York			
New York State Department of Environmental Conservation Protection of Waters Program	6 NYCRR Part 608	Implements regulations that preserve and protect NYS lakes, rivers, streams, and ponds.	Would applicable if Site activities required discharge directly to a NYS water body.
Freshwater Wetlands Permit Requirements	6 NYCRR Part 663	Defines the procedural requirements for any activities taking place within or adjacent to wetlands	May be applicable if Site activities occurred adjacent to, or directly involved, a wetland.

Table 2-2C: Action Specific SCGs

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report

Town of Oyster Bay, Nassau County, New York

Title	Citation	Description	Comments
Federal			
Identification and Listing of Hazardous Wastes	40 CFR Part 261	Outlines criteria for determining if a solid waste is a hazardous waste and is subject to regulation under 40 CFR Parts 260 to 266	These regulations could apply for off-site disposal of contaminated groundwater or by-products of treatment
Hazardous Waste Determination	40 CFR Part 262.11	Generators must characterize their wastes to determine if the waste is hazardous by listing (40 CFR 261, Subpart D) by characteristic (40 CFR 261, Subpart C) or excluded from regulation (40 CFR 261.4)	These regulations could apply for off-site disposal of contaminated groundwater or by-products of treatment
Manifesting	40 CFR Part 262, Subpart B	Generators must prepare a Hazardous waste Manifest (EPA FORM 8700-22) for all off-site shipments of hazardous waste to disposal and/or treatment facilities.	Would apply to all off-site shipments of hazardous waste .
Recordkeeping	40 CFR Part 262.40	Generators must retain copies of an hazardous waste manifests used for off-site disposal	Generator must retain copies of waste manifests for a minimum period of three years after shipment date.
Labeling and Marking	40 CFR Part 262 Subpart C	Specifies EPA naming, labeling and container requirements for off-site disposal of hazardous waste.	Pre-transportation requirements for off-site shipments of hazardous wastes.
Accumulation limitations	40 CFR Part 262.34	Allows generators of hazardous waste to store and treat hazardous wasteat the generation site for up to 90 days in tanks,containers, and containment buildings without having to obtain a RCRA hazardous waste permit.	Hazardous waste may be stored for up to 90 days on-site without the need to meet storage permit substantive requirements.
RCRA - Treatment, Storage and Disposal of Hazardous Waste	40 CFR Parts 264/265	Specifies requirements forthe operation of hazardous waste treatment, storage, and disposal facilities.	Applicablefor on-site hazardous waste treatment,storage, and disposal activities.
National Ambient Air Quality Standards	40 CFR Part 50	Establishes ambient air quality standards for protection of public health.	May be applicable in evaluating air impacts during remedial activities.
USDOT Hazardous Materials Transportation Regulations	49 CFR Parts 171-180	Established classification, packaging, and labeling requirements for shipments of hazardous materials.	Applicable for the preparation of hazardous materials generated on-site for off-site shipment.
New Source Review and Prevention of Significant Deterioration Requirements	40 CFR Part 52	New sources or modifications whcich emit greater than defined thresholds for listed pollutants must perform ambient impact analyses and install controls w ich meet best availabe control technology (BACT)	Potentially applicable for certain remediation technologies and would require a comparison of potential emissions to the emission thresholds.
National Emissions Standards for Hazardous Air Pollutants (NESHAP)	40 CFR Part 61; 40 CFR Part 63	Source-specific regulations which establIsh emissions standards for hazardous air pollutants	NSPS could be relevant and appropriate if regulated new sources of air emissIons were to be established on site.
RCRA Subtitle C land Disposal Restrictions	40 CFR Section 6901; 40 CFR Part 268	Restricts land disposal of hazardous wastes that exceed specific criteria. Establishes Universal Treatment Standards to which hazardous waste must be treated prior to disposal.	Potentially applicable if hazardous residuals are generated from groundwater treatment.
Clean Water Act Effluent Guidelines and Standards; National Pollutant Discharge Elimination System (NPDES) Program	40 CFR Part 401; 40 CFR Parts 122-125	Both on- and off-site dishcarges from CERCLA sites to surface waters are required to meet the substantive Clean Water Act limitations, monitorIng requirements, and best management practices. NPDES permits are required to discharge treated water to a surface water.	Applicable for discharges of groundwater to surface water bodies.

Table 2-2C: Action Specific SCGs
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Title	Citation	Description	Comments
State of New York			
Technical Guidance for Site Investigation and Remediation	DER-10	Guidance for the New York State Department of Environmental Conservation (DEC) Division of Environmental Remediation (DER) and regulates entities on how to conduct acceptable investigation and remediation.	Applicable to all site activities
Environmental Remediation Programs	6 NYCRR Part 375	Provides regulatory framework for the development and implementation of the remedial program and sets forth general and specific requirements for the remediation of inactive hazardous waste disposal sites, brownfield sites, and enviromnetal restoration sites.	Applicable to all site activities
Waste Transportation	6 NYCRR Part 364	Regulates the collection, transport, and delivery of regulated waste, originating or terminating at a location within this State.	Would apply to all off-site shipments of hazardous waste .
Identification and Listing of Hazardous Wastes	6 NYCRR Part 371	Outlines criteria for determining if a solid waste is a hazardous waste and is subject to regulation under 6 NYCRR Part 370 to 373, and 376.	These regulations could apply for off-site disposal of contaminated groundwater or by-products of treatment
Hazardous Waste Manifest System and Related Standards for Generators, Transporters and Facilities	6 NYCRR Part 372	Standards for generators and transporters of hazardous waste and standards for generators, transporters, and treatment, storage or disposal facilities relating to the use of the manifest system and its recordkeeping requirements.	Would apply to all off-site shipments of hazardous waste .
Air Quality Standards	6 NYCRR Part 257	Standards promulgated to provide protection from the adverse health effects of air contamination; and are intended to protect and conserve the natural resources and environment and to promote maximum comfort and enjoyment and use of property consistent with the economic and social well-being of the community.	Applicable to the generation and emission of air pollutants
State Pollutant Discharge Elimination System (SPDES)	6 NYCRR Part 750	Regulations on the implementation of the NPDES program in NYS.	Applicable for discharges of groundwater to surface water bodies, and the point source discharge to groundwaters

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Location	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1
	Sample Date	7/27/2017	7/27/2017	7/27/2017	7/28/2017	7/31/2017	7/31/2017	7/31/2017	7/31/2017	8/1/2017	8/1/2017	8/1/2017	8/2/2017	8/2/2017	8/3/2017	8/3/2017	8/3/2017	8/4/2017
	Top Depth (ft bgs)	58	105	148	208	218	238	258	278	298	318	338	358	398	418	438	458	483
	Bottom Depth (ft bgs)	60	107	150	210	220	240	260	280	300	320	340	360	400	420	440	460	485
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**																	
1,1,1-Trichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U	1.0 U	1.0 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,3-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 U	1.0 U
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dibromo-3-chloropropane	0.04	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 UJ***	***1.0 UJ***
1,2-Dibromoethane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
1,2-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloroethane	0.6	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 UT***	***1.0 UT***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dichloropropane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dioxane	0.35 *	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***
2-Butanone (MEK)	50 (GV)	5.0 U	2.2 J	5.0 U	2.4 J	5.0 U	3.3 J	5.0 U	3.4 J	5.0 U	3.5 J	5.0 U	4.0 J	3.7 J	5.0 U	2.8 J	5.0 U	2.6 J
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	1.1 J	5.0 U	1.4 J	5.0 U	0.98 J	5.0 U	2.5 J	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-pentanone (MIBK)	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	50 (GV)	10 U	15 U	9.3 U	13 U	12 U	13 U	8.8 U	16 U	15 U	13 U	6.2 U	19 U	16 U	11 U	14 U	5.0 U	27 U
Benzene	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.17 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromochloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	50 (GV)	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
Bromomethane	5	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Disulfide	60 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.30 J	0.27 J	1.0 U	1.0 U	1.0 U	0.96 J	1.0 U
Carbon Tetrachloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 U	1.0 U
Chloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U	1.0 U	1.0 U
cis-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 UJ***	***1.0 UJ***
Cyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dibromochloromethane	50 (GV)	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Ethylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Isopropylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
m&p-Xylenes	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Acetate	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	0.21 J	0.41 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylcyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylene Chloride	5	1.0 U	1.7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Styrene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Toluene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 UJ***	***1.0 UJ***
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U	1.0 U	1.0 U
Vinyl Chloride	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tentatively Identified Compounds (TICs) - ug/L																		
Isopropanol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Eicosane	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene Glycol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS,TRANS-1,6-DIMETHYLSPIRO[4.5]DECANE	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UNKNOWN VOLATILE ORGANIC WITH HIGHEST CONC.	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Location	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1
	Sample Date	8/7/2017	8/7/2017	8/7/2017	8/8/2017	8/8/2017	8/8/2017	8/9/2017	8/10/2017	8/11/2017	8/11/2017	8/14/2017	8/14/2017	8/15/2017	8/15/2017	8/16/2017	8/16/2017	8/17/2017
	Top Depth (ft bgs)	503	518	538	558	578	598	638	663	683	698	718	738	763	783	803	818	838
	Bottom Depth (ft bgs)	505	520	540	560	580	600	640	665	685	700	720	740	765	785	805	820	840
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**																	
1,1,1-Trichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,3-Trichlorobenzene	5	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dibromo-3-chloropropane	0.04	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dibromoethane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloroethane	0.6	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dichloropropane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dioxane	0.35 *	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***
2-Butanone (MEK)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	3.4 J	6.0	7.5	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	0.87 J	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-pentanone (MIBK)	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	1.6 J	5.0 U	5.0 U	1.3 J	5.0 U	5.0 U	0.63 J	5.0 U	5.0 U
Acetone	50 (GV)	7.1 U	11 U	4.4 U	8.8 U	3.6 U	6.1 U	20 U	31 U	38 U	9.6 U	16 U	17 U	4.8 U	11 U	11 U	7.3 U	9.6 U
Benzene	1	0.17 J	0.13 J	1.0 U	1.0 U	1.0 U	0.14 J	1.0 U	0.10 J	0.12 J	1.0 U	0.09 J	0.15 J	1.0 U	1.0 U	1.0 U	1.0 U	0.13 J
Bromochloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	50 (GV)	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U
Bromomethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ
Carbon Disulfide	60 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.3	1.0 U	0.43 J	1.0 U	1.0 U	1.0 U	0.37 J	1.0 U	0.37 J	1.0 U	1.0 U	1.2
Carbon Tetrachloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroethane	5	1.0 UT	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 U	1.0 U
Chloroform	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Cyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dibromochloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Ethylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Isopropylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
m&p-Xylenes	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Acetate	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	23	5.3	7.9
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylcyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylene Chloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Styrene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Toluene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	**14**	1.5	**5.4**	2.4	**5.5**	1.0 U	1.0 U	1.0 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Vinyl Chloride	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tentatively Identified Compounds (TICs) - ug/L																		
Isopropanol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Eicosane	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene Glycol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS,TRANS-1,6-DIMETHYLSPIRO[4.5]DECANE	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UNKNOWN VOLATILE ORGANIC WITH HIGHEST CONC.	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Location		DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB1	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2
Sample Date		8/17/2017	8/18/2017	8/21/2017	8/21/2017	8/21/2017	10/19/2017	10/19/2017	10/20/2017	10/20/2017	10/23/2017	10/23/2017	10/23/2017	10/24/2017	10/24/2017	10/24/2017	10/25/2017	10/25/2017
Top Depth (ft bgs)		863	883	903	918	943	58	103	148	198	218	238	258	278	298	318	338	358
Bottom Depth (ft bgs)		865	885	905	920	945	60	105	150	200	220	240	260	280	300	320	340	360
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**																	
1,1,1-Trichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,3-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 U
1,2-Dibromo-3-chloropropane	0.04	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dibromoethane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloroethane	0.6	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloropropane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dioxane	0.35 *	50 U	50 UT	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
2-Butanone (MEK)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-pentanone (MIBK)	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	50 (GV)	5.1 U	5.0 U	8.8 U	12 U	13 U	31 U	24 U	28 U	8.9 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Benzene	1	1.0 U	1.0 U	1.0 U	1.0 U	0.11 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromochloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	50 (GV)	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U
Bromomethane	5	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ
Carbon Disulfide	60 (GV)	1.0 U	1.0 U	0.44 J	0.41 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.1	0.64 J	0.57 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.37 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.94 J	0.75 J	0.76 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,3-Dichloropropene	0.4 **	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Cyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dibromochloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Ethylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Isopropylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
m&p-Xylenes	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Acetate	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.23 J	0.73 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylcyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylene Chloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Styrene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Toluene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,3-Dichloropropene	0.4 **	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.27 J	1.4	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Vinyl Chloride	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tentatively Identified Compounds (TICs) - ug/L																		
Isopropanol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Eicosane	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene Glycol	NS	ND	ND	ND	ND	ND	500 JN	33 JN	9.0 JN	250 JN	ND	ND	ND	ND	ND	ND	ND	ND
TRANS,TRANS-1,6-DIMETHYLSPIRO[4.5]DECANE	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UNKNOWN VOLATILE ORGANIC WITH HIGHEST CONC.	NS	ND	ND	ND	ND	ND	ND	ND	10 J	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Location	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2
	Sample Date	10/25/2017	10/26/2017	10/26/2017	10/26/2017	10/27/2017	10/27/2017	10/30/2017	10/30/2017	10/31/2017	10/31/2017	10/31/2017	11/1/2017	11/1/2017	11/1/2017	11/2/2017	11/3/2017	11/3/2017
	Top Depth (ft bgs)	378	403	418	438	458	478	503	518	538	558	578	598	618	638	658	678	703
	Bottom Depth (ft bgs)	380	405	420	440	460	480	505	520	540	560	580	600	620	640	660	680	705
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**																	
1,1,1-Trichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,3-Trichlorobenzene	5	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dibromo-3-chloropropane	0.04	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dibromoethane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloroethane	0.6	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dichloropropane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dioxane	0.35 *	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***
2-Butanone (MEK)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-pentanone (MIBK)	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	50 (GV)	7.4 U	5.0 U	5.0 U	5.0 U	5.0 U	5.3 U	5.0 U	5.0 U	9.6 U	5.0 U	12 U	12 U	13 U	5.0 U	5.0 U	5.0 U	8.6 U
Benzene	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.096 J	1.0 U	1.0 U	1.0 U	0.11 J
Bromochloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromomethane	5	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 UT	1.0 UT	1.0 U	1.0 UT
Carbon Disulfide	60 (GV)	0.39 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.23 J	1.0 U
Carbon Tetrachloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloromethane	5	0.55 J	1.0 U	1.0 U	1.0 U	1.0 U	0.33 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Cyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dibromochloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Ethylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Isopropylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
m&p-Xylenes	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Acetate	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	0.58 J	5.0 U	5.0 U	5.0 U	5.0 U
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylcyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylene Chloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Styrene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Toluene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Vinyl Chloride	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tentatively Identified Compounds (TICs) - ug/L																		
Isopropanol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	61	ND	ND	ND
N-Eicosane	NS	5.2 JN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene Glycol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS,TRANS-1,6-DIMETHYLSPIRO[4.5]DECANE	NS	6.1 JN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UNKNOWN VOLATILE ORGANIC WITH HIGHEST CONC.	NS	5.4 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Location	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2	DEC-VPB2
	Sample Date	11/6/2017	11/7/2017	11/7/2017	11/7/2017	11/8/2017	11/8/2017	11/9/2017	11/9/2017	11/9/2017	11/10/2017	11/13/2017	11/13/2017	11/13/2017	11/21/2017
	Top Depth (ft bgs)	718	743	758	778	803	818	843	858	878	903	918	938	958	983
	Bottom Depth (ft bgs)	720	745	760	780	805	820	845	860	880	905	920	940	960	985
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**														
1,1,1-Trichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,3-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dibromo-3-chloropropane	0.04	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dibromoethane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,2-Dichloroethane	0.6	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
1,2-Dichloropropane	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 U	1.0 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	3	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
1,4-Dioxane	0.35 *	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***	***50 U***
2-Butanone (MEK)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-pentanone (MIBK)	NS	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	50 (GV)	6.5 U	5.0 U	9.4 U	5.1 U	5.0 U	5.0 U	8.0 U	7.5 U	5.0 U	10 U	9.2 U	5.3 U	5.0 U	12 U
Benzene	1	1.0 U	1.0 U	0.1 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.1 J	1.0 U	1.0 U	1.0 U	1.0 U
Bromochloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	50 (GV)	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Bromomethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 UT	1.0 UT	1.0 UJ	1.0 U
Carbon Disulfide	60 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.46 J
Carbon Tetrachloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chlorobenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U	1.0 UT	1.0 UT	1.0 UT	1.0 U
Chloroform	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloromethane	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Cyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Dibromochloromethane	50 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U
Ethylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Isopropylbenzene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
m&p-Xylenes	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Acetate	NS	5.0 U	5.0 U	1.6 J	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylcyclohexane	NS	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Methylene Chloride	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Styrene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Toluene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
trans-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***	***1.0 U***
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UT	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Vinyl Chloride	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tentatively Identified Compounds (TICs) - ug/L															
Isopropanol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Eicosane	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propylene	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.2 JN	ND	ND	ND	ND
Propylene Glycol	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS,TRANS-1,6-DIMETHYLSPIRO[4.5]DECANE	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UNKNOWN VOLATILE ORGANIC WITH HIGHEST CONC.	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1 J	ND	ND	ND	ND

Table 3-1 Analytical Data Summary - Vertical Profile Borings
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Comparison Criteria
NYSDEC GWQS - New York State Department of Environmental Conservation (NYSDEC) Groundwater Quality Standards. Source: NYSDEC Division of Water Technical & Operation Guidance Series (TOGS) 1.1.1 Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations (June 1998 and subsequent addendums) Class GA Standards (6 NYCRR Part 703.5) and Guidance Values.
(GV) indicates guidance value.
* 1,4-dioxane does not have a promulgated standard or guidance value. United States Environmental Protection Agency risk assessments indicate that the drinking water concentration representing a 1x10-6 cancer risk level for 1,4-dioxane is 0.35 ug/L (EPA IRIS 2013).

** Applies to sum of cis- and trans- isomers for 1,3-dichloropropene.
Bold/Italic indicates reporting limit exceeds applicable criterion.
Bold with shading indicates detected concentration exceeds applicable criterion.
NS indicates no standard applicable.

Abbreviations

ft bgs	Feet below ground surface
ug/L	Micrograms per liter
ND	Indicates TIC (tentatively identified compound) is not detected.

Qualifier Explanations

U	Analyte analyzed for but not detected.
J	Result is less than the RL but greater than or equal to the MDL; Concentration estimated.
T	RPD of the LCS and LCSD exceeds control limits.
B	Compound was found in the blank and sample.
JN	Indicates the presumptive evidence of a compound with concentration estimated (TICs only)

Table 3-2 Analytical Data Summary - Monitoring Well Sampling
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Location	MW-DEC1D1	MW-DEC1D2	MW-DEC2D1
	Sample Date	2/28/2018	2/28/2018	2/1/2018
	Top Depth (ft bgs)	695	760	180
	Bottom Depth (ft bgs)	715	780	200
Volatile Organic Compounds (VOCs) - ug/L	**NYSDEC GWQS**			
1,1,1-Trichloroethane	5	1.0 U	1.0 U	0.28 U
1,1,2,2-Tetrachloroethane	5	1.0 U	1.0 U	0.19 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5	1.0 U	1.0 U	0.34 U
1,1,2-Trichloroethane	1	1.0 U	1.0 U	0.08 U
1,1-Dichloroethane	5	1.0 U	1.0 U	0.24 U
1,1-Dichloroethene	5	1.0 U	1.0 U	0.34 U
1,2,3-Trichlorobenzene	5	1.0 U	1.0 U	0.35 U
1,2,4-Trichlorobenzene	5	1.0 U	1.0 U	0.27 U
1,2-Dibromo-3-chloropropane	0.04	***1.0 U***	***1.0 U***	***0.23 U***
1,2-Dibromoethane	NS	***1.0 U***	***1.0 U***	***0.19 U***
1,2-Dichlorobenzene	3	1.0 U	1.0 U	0.22 U
1,2-Dichloroethane	0.6	***1.0 U***	***1.0 U***	0.25 U
1,2-Dichloropropane	1	1.0 U	1.0 U	0.18 U
1,3-Dichlorobenzene	3	1.0 U	1.0 U	0.33 UT
1,4-Dichlorobenzene	3	1.0 U	1.0 U	0.33 U
1,4-Dioxane	0.35 *	***0.40 U***	***0.40 U***	0.046 J
2-Butanone (MEK)	50 (GV)	5.0 U	5.0 U	2.2 U
2-Hexanone (Methyl n-butyl ketone)	50 (GV)	5.0 U	5.0 U	0.72 U
4-Methyl-2-pentanone (MIBK)	NS	***5.0 U***	***5.0 U***	***0.63 U***
Acetone	50 (GV)	5.0 U	5.0 U	1.1 U
Benzene	1	1.0 U	1.0 U	0.09 UT
Bromochloromethane	5	1.0 U	1.0 U	0.30 U
Bromodichloromethane	50 (GV)	1.0 U	1.0 U	0.22 U
Bromoform	50 (GV)	1.0 UJ	1.0 U	0.18 U
Bromomethane	5	1.0 U	1.0 U	0.18 U
Carbon Disulfide	60 (GV)	1.0 U	1.0 U	0.22 U
Carbon Tetrachloride	5	1.0 U	1.0 U	0.33 U
Chlorobenzene	5	1.0 U	1.0 U	0.24 U
Chloroethane	5	1.0 U	1.0 U	0.37 UT
Chloroform	7	1.0 U	1.0 U	0.34 J
Chloromethane	5	1.0 U	1.0 U	0.22 U
cis-1,2-Dichloroethene	5	1.0 U	1.0 U	0.26 U
cis-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	0.16 U
Cyclohexane	NS	***1.0 U***	***1.0 U***	***0.26 U***
Dibromochloromethane	50 (GV)	1.0 U	1.0 U	0.15 U
Dichlorodifluoromethane (Freon 12)	5	1.0 U	1.0 U	0.14 U
Ethylbenzene	5	1.0 U	1.0 U	0.30 U
Isopropylbenzene	5	1.0 U	1.0 U	0.32 U
m&p-Xylenes	5	1.0 U	1.0 U	0.28 U
Methyl Acetate	NS	***5.0 U***	***5.0 U***	***0.58 UT***
Methyl Tert Butyl Ether (MTBE)	10 (GV)	1.0 U	1.0 U	0.40 J
Methylcyclohexane	NS	***1.0 U***	***1.0 U***	***0.22 U***
Methylene Chloride	5	1.0 U	1.0 U	0.21 U
o-Xylene	5	1.0 U	1.0 U	0.32 U
Styrene	5	1.0 U	1.0 U	0.17 U
Tetrachloroethene (PCE)	5	1.0 U	1.0 U	0.12 U
Toluene	5	2.2 U	1.0 U	0.25 U
trans-1,2-Dichloroethene	5	1.0 U	1.0 U	0.18 U
trans-1,3-Dichloropropene	0.4 **	***1.0 U***	***1.0 U***	0.19 U
Trichloroethene (TCE)	5	1.0 U	1.0 U	1.2
Trichlorofluoromethane (CFC-11)	5	1.0 U	1.0 U	0.15 U
Vinyl Chloride	2	1.0 U	1.0 U	0.06 U

Table 3-2 Analytical Data Summary - Monitoring Well Sampling
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Comparison Criteria

NYSDEC GWQS - New York State Department of Environmental Conservation (NYSDEC) Groundwater Quality Standards. Source: NYSDEC Division of Water Technical & Operation Guidance Series (TOGS) 1.1.1 Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations (June 1998 and subsequent addendums) Class GA Standards (6 NYCRR Part 703.5) and Guidance Values.

(GV) indicates guidance value.

* 1,4-dioxane does not have a promulgated standard or guidance value. United States Environmental Protection Agency risk assessments indicate that the drinking water concentration representing a 1x10-6 cancer risk level for 1,4-dioxane is 0.35 ug/L (EPA IRIS 2013).

** Applies to sum of cis- and trans- isomers for 1,3-dichloropropene.

Bold/Italic indicates reporting limit exceeds applicable criterion.

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Abbreviations

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Qualifier Explanations

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J	Result is less than the RL but greater than or equal to the MDL; Concentration estimated.
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B	Compound was found in the blank and sample.
JN	Indicates the presumptive evidence of a compound with concentration estimated (TICs only)

Table 3-3: Data Sources for Analytical Concentrations Used in Plume Modeling

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report

Town of Oyster Bay, Nassau County, New York

Analytical Data Source	Date Range	Note
Navy in electronic format	April 2009 to December 2017	
Northrop Grumman via EQuIS™[a] database export	July 2004 to March 2017	
NYSDEC via EQuIS™ database export	September 2006	[b]
Manually/electronically transcribed data	June 2000 to December 2017	[c]
NYSDEC in PDF format	August 2017 to September 2017	[d]
Nassau County (municipal supply well data)	June 2014 to June 2017	[e]
NYSDEC/HDR	July 2017 to February 2018	[f]

Notes:

[a] EQuIS is a trademarked environmental data management software developed and published by EarthSoft, Inc.

[b] VP-100 data extracted from DEC dataset to supplement data from Navy and Northrop Grumman. Much of the data provided by NYSDEC was also contained within Navy and Northrop Grumman datasets.

[c] Data from 2000 and 2001 is limited to VPBs numbering 38, 40, 43, 44, 45, 46, 47, 48, 50, 51, 76, and 77.

[d] VPB166

[e] A large quantity of municipal supply well data was received by HDR. The most recent round of data for the wells contained within in the dataset were incorporated into the database. Dates reflect range for latest samples used to supplement plume modeling.

[f] HDR, under contract with NYSDEC, installed two additional vertical profile borings (VPBs) (DEC-VPB-1 and DEC-VPB-2) and three monitoring wells (DEC1D1, DEC1D2, and DEC2D1) along the distal edge of the contaminant plume and collected discrete interval groundwater samples.

Table 3-4: Database Statistics

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report

Town of Oyster Bay, Nassau County, New York

General Database Statistics[a]	
Locations	540 +
Samples	5,600 +
Records	205,000 +

[a] Includes most recent samples from Nassau County municipal supply well dataset used for modeling. See Table 3-3 footnote [e] for additional information.

Table 3-5: Analytes Incorporated in Total Chlorinated Volatile Organic Compounds

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report

Town of Oyster Bay, Nassau County, New York

Analyte	Contaminant Of Concern (COC)
1,1,1,2-Tetrachloroethane	No
1,1,1-Trichloroethane	Yes
1,1,2,2-Tetrachloroethane	Yes
1,1,2-Trichloroethane	Yes
1,1-Dichloroethane	Yes
1,1-Dichloroethene	Yes
1,2-Dichloroethane	Yes
1,2-Dichloroethene	Yes
Chloroethane	No
cis-1,2-Dichloroethene	Yes
Dichlorofluoromethane	Yes
Tetrachloroethene (PCE)	Yes
trans-1,2-Dichloroethene	Yes
Trichloroethene (TCE)	Yes
Vinyl Chloride	Yes

Table 3-6: Estimated Volume of Contaminated Groundwater

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

TOTAL CHLORINATED VOLATILE ORGANIC COMPOUNDS

Water	Layer Volumes			Cumulative Volumes			
	Solid	Liquid					
(μg/l)	(cubic feet)	(gallons)	(liters)	(liters)	(gallons)	(billion gallons)	(percent)
0 - 5	65,080,016,769	209,337,900,000	792,429,800,000	1,385,876,000,000	366,109,900,000	366.11	100%
5 - 10	14,412,268,960	46,358,800,000	175,487,100,000	593,446,200,000	156,772,000,000	156.77	43%
10 - 25	13,924,071,569	44,788,500,000	169,542,800,000	417,959,100,000	110,413,200,000	110.41	30%
25 - 50	7,362,923,864	23,683,800,000	89,652,900,000	248,416,300,000	65,624,700,000	65.62	18%
50 - 100	5,669,501,456	18,236,700,000	69,033,400,000	158,763,400,000	41,940,900,000	41.94	11%
100 - 200	3,262,919,123	10,495,600,000	39,730,100,000	89,730,000,000	23,704,200,000	23.70	6%
200 - 500	1,996,367,070	6,421,600,000	24,308,400,000	49,999,900,000	13,208,600,000	13.21	4%
500 - 1000	1,227,916,601	3,949,700,000	14,951,200,000	25,691,500,000	6,787,000,000	6.79	2%
1000 - 10000	882,066,951	2,837,300,000	10,740,300,000	10,740,300,000	2,837,300,000	2.84	1%
10000 - 12238	1,797	-	-	-	-	-	0%

Notes:

1. A total porosity of 43% is assumed (Todd, 1980)

μg/l - Micrograms per liter

Table 3-7: Estimated Mass of Contaminants in Groundwater

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report

Town of Oyster Bay, Nassau County, New York

TCVOCs	Groundwater Concentration	Mass			Cumulative Mass
		Shell		Cumulative	
(µg/l)	(µg/l)	(µg)	(g)	(g)	(percent)
0 - 5	2.5	1,981,074,500,000	1,980,000	99,560,000	100%
5 - 10	7.5	1,316,153,250,000	1,320,000	97,580,000	98%
10 - 25	17.5	2,966,999,000,000	2,970,000	96,260,000	97%
25 - 50	37.5	3,361,983,750,000	3,360,000	93,290,000	94%
50 - 100	75	5,177,505,000,000	5,180,000	89,930,000	90%
100 - 200	150	5,959,515,000,000	5,960,000	84,750,000	85%
200 - 500	350	8,507,940,000,000	8,510,000	78,790,000	79%
500 - 1000	750	11,213,400,000,000	11,210,000	70,280,000	71%
1000 - 10000	5500	59,071,650,000,000	59,070,000	59,070,000	59%
10000 - 12238	15000	-	-	-	0%

Notes:

g - Gram

µg - Microgram

µg/l - Micrograms per liter

Table 3-8: Summary of Existing Analytical Data - SCG Plume
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Constituent	CAS RN	SCG Value (ug/L)	Count of Samples	Count of Detections	Count of SCG Exceedances	Range of Detected Concentrations (µg/L)
1,1,1-Trichloroethane	71-55-6	5	2953	284	12	0.1 - 110
1,1,2,2-Tetrachloroethane	79-34-5	5	2951	0	0	-
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	76-13-1	5	2704	319	143	0.22 - 170
1,1,2-Trichloroethane	79-00-5	1	2952	105	29	0.24 - 4
1,1-Dichloroethane	75-34-3	5	2953	506	99	0.2 - 64
1,1-Dichloroethene	75-35-4	5	2953	461	80	0.2 - 110
1,2-Dichloroethane	107-06-2	0.6	2953	107	83	0.14 - 39.9
1,2-Dichloroethene	540-59-0	5	1165	203	11	0.21 - 9.1
1,2-Dichloropropane	78-87-5	1	2790	40	21	0.28 - 32.7
1,4-Dioxane	123-91-1	0.35	393	159	145	0.046 - 190
Carbon Disulfide	75-15-0	60	2734	174	0	0.2 - 18
Carbon Tetrachloride	56-23-5	5	2952	85	2	0.18 - 6.2
Chlorobenzene	108-90-7	5	2952	8	0	0.3 - 2
Chlorodifluoromethane (Freon 22)	75-45-6	5	989	55	9	0.21 - 110
Chloroform	67-66-3	7	2909	484	36	0.19 - 45
Chromium, Total	7440-47-3	50	70	38	11	0.4 - 701
cis-1,2-Dichloroethylene	156-59-2	5	2953	593	181	0.19 - 3400
Dichlorodifluoromethane (Freon 12)	75-71-8	5	2746	108	3	0.2 - 32
Iron	7439-89-6	300	15	15	11	120 - 1700
Nickel	7440-02-2	100	15	1	0	30.6 - 30.6
Tetrachloroethylene (PCE)	127-18-4	5	2963	558	186	0.2 - 620
Toluene	108-88-3	5	2790	291	30	0.12 - 160
trans-1,2-Dichloroethene	156-60-5	5	2952	52	10	0.23 - 22
Trichloroethylene (TCE)	79-01-6	5	2967	1239	735	0.23 - 11200
Vinyl Chloride	75-01-4	2	2836	66	52	0.22 - 2400

Notes:
SCG - Standards, Criteria,and Guidance values. See FS text for derivation of SCGs.
µg/L - Micrograms per liter

1. This data presented above represents the subset of database used to develop the plume shells.

2. Count of Samples - total number of samples containing the associated analyte. Data sources / samples reported varying lists of analytes.

3. 1,2-Dichloroethane (1,2-DCE) Note: some raw sources provided total 1,2-DCE instead of the cis/trans isomers. Though not specifically considered a COC, it is included here as reference.

Table 3-9: Summary of Existing Analytical Data - Database
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Constituent	CAS RN	SCG Value (ug/L)	Count of Samples	Count of Detections	Count of SCG Exceedances	Range of Detected Concentrations (ug/L)
1,1,1-Trichloroethane	71-55-6	5	4618	617	31	0.1 - 110
1,1,2,2-Tetrachloroethane	79-34-5	5	4596	4	0	0.2 - 0.25
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	76-13-1	5	4107	665	335	0.22 - 250
1,1,2-Trichloroethane	79-00-5	1	4604	281	83	0.21 - 5
1,1-Dichloroethane	75-34-3	5	4615	1048	205	0.16 - 110
1,1-Dichloroethene	75-35-4	5	4618	1060	195	0.19 - 110
1,2-Dichloroethane	107-06-2	0.6	4616	177	133	0.14 - 39.9
1,2-Dichloroethene	540-59-0	5	1843	459	43	0.21 - 1100
1,2-Dichloropropane	78-87-5	1	4433	63	38	0.28 - 32.7
1,4-Dioxane	123-91-1	0.35	634	332	306	0.046 - 190
Carbon Disulfide	75-15-0	60	4231	182	0	0.089 - 18
Carbon Tetrachloride	56-23-5	5	4605	222	3	0.09 - 8
Chlorobenzene	108-90-7	5	4605	15	2	0.3 - 7
Chlorodifluoromethane (Freon 22)	75-45-6	5	1276	101	22	0.21 - 400
Chloroform	67-66-3	7	4550	1031	100	0.11 - 110
Chromium, Total	7440-47-3	50	113	63	22	0.4 - 804
cis-1,2-Dichloroethylene	156-59-2	5	4243	1402	494	0.19 - 210000
Dichlorodifluoromethane (Freon 12)	75-71-8	5	3767	208	5	0.2 - 32
Iron	7439-89-6	300	15	15	11	120 - 1700
Nickel	7440-02-2	100	15	1	0	30.6 - 30.6
Tetrachloroethylene (PCE)	127-18-4	5	5447	1851	890	0.2 - 940
Toluene	108-88-3	5	4441	465	59	0.06 - 84000
trans-1,2-Dichloroethene	156-60-5	5	4238	178	23	0.23 - 95
Trichloroethylene (TCE)	79-01-6	5	5545	3172	2257	0.23 - 11200
Vinyl Chloride	75-01-4	2	5403	685	568	0.12 - 6300

Notes:
SCG - Standards, Criteria,and Guidance values. See FS text for derivation of SCGs.
µg/L - Micrograms per liter

1. This table represents data made available to, and compiled by, HDR from various providers (see Table 3-3 for details) for the development of this FS and associated plume shells. The plume shells were developed using subsets of this database.

2. Count of Samples - total number of samples containing the associated analyte. Data sources / samples reported varying lists of analytes.

3. 1,2-Dichloroethane (1,2-DCE) Note: some raw sources provided total 1,2-DCE instead of the cis/trans isomers. Though not specifically considered a COC, it is included here as reference.

Table 5-1: General Response Actions
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

General Response Actions	Media	Area /Volume	Identified Use of Area	Presumptive Remedy
No Further Action – The no further action option is included as a basis for comparison with the active groundwater remediation technologies.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	No
Institutional Controls with Long-Term Monitoring – Effective in reducing access and exposure to Site contaminants through restrictions or limitations of site use. Will be used in conjunction with Long-Term Monitoring and as enhancements to a remedial technology.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	No
Monitored Natural Attenuation with Long-Term Monitoring – Relies on natural destructive (biodegradation and chemical reactions) and nondestructive mechanisms (dilution, volatilization, adsorption) to reduce contaminant concentrations within a reasonable timeframe. Can be implemented with other active remedial technologies.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	No
Containment – Groundwater containment is typically achieved using physical vertical barriers or hydraulic controls. As contaminated groundwater at the site is deeper than 100 feet bgs and there are no known continuous low-permeability layers in the area to enhance containment, a physical barrier is not suitable. Hydraulic control, however, can be paired with ex-situ treatment at the site.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	**Yes**
In-situ Treatment – Several types of technologies may be applicable for the in-situ treatment of groundwater, and include biological, physical and chemical treatment.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	No
Ex-situ Treatment – Involves the pumping of impacted groundwater and implementing physical/chemical treatment ex-situ. Pump and treat is an effective technology for hydraulic control and/or removal of groundwater contamination. Various technologies are available for treating organic contaminants in collected groundwater. On-site and off-site treatment/disposal options are available for the collected groundwater.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	**Yes**

Table 5-1: General Response Actions
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

General Response Actions	Media	Area /Volume	Identified Use of Area	Presumptive Remedy
Discharge – Collection is an effective technology for hydraulic control and/or removal of groundwater contamination. Various technologies are available for treating organic contaminants in collected groundwater. On-site and off-site treatment/disposal options are available for the collected groundwater.	Ground water	~4,000 acres / 30 x 10^9 gallons	Residential/ Industrial/ Commercial/ Recreational	**Yes**

Table 6-1: Identification and Screening of Technologies – Groundwater
Northrop Grumman Bethpage Facility / NWIRPFeasibility Study Report
Town of Oyster Bay, Nassau County, New York

Remedial Technology	Presumptive Remedy	Established Technology	Complexity	Overall Cost and Performance					Availability	Treatment Effectiveness				Implementable at Site	Retained for Alternative Evaluation	Reason(s)
				O&M	Capital	Reliability/ Maintain-ability	Present-Worth Cost	Time		VOCs	CVOCs	SVOCs	Inorganics			
No Further Action	No	Yes	Low	Low	Low	Low	Low	Low	High	Not Effective	Not Effective	Not Effective	Not Effective	Yes	**Yes**	Retained as a basis for comparison
Institutional Controls (ICs) and Long-Term Monitoring (LTM)	No	Yes	Low	Low	Medium	Medium	Low	Medium-High	High	Effective	Effective	Limited	Not Effective	Yes	**Yes**	Will be considered and developed in conjunction with active remedial alternatives as contingency/alternative remedy.
Monitored Natural Attenuation (MNA)/LTM	No	Yes	Low	Low	Medium	Medium	Low	Medium-High	High	Effective	Effective	Limited	Not Effective	Yes	**Yes**	Will be considered and developed in conjunction with active remedial alternatives as contingency/alternative remedy.
Containment																
Hydraulic Control																
• Extraction Wells	Yes	Yes	Medium	High	High	High	High	High	High	Effective	Effective	Effective	Effective	Yes	**Yes**	Practicable, with longer remedial timeframe than other alternatives, hydraulic control of contaminated area necessary for implementation.
• Interceptor Trenches	Yes	Yes	High	High	High	High	High	High	High	Effective	Effective	Effective	Effective	No	No	Groundwater contamination is too deep, beyond the practical limit of trenching.
Vertical Barriers																
• Slurry Wall	No	Yes	High	Medium	High	High	Medium-High	Medium-High	High	Effective	Effective	Effective	Effective	No	No	Groundwater contamination is too deep for the use of slurry wall and impractical to install in a highly developed area to recover the contamination.
• Grout Curtain	No	Yes	High	Medium	High	High	Medium-High	Medium-High	High	Effective	Effective	Effective	Effective	No	No	Groundwater contamination is too deep for the use of grout curtain and impractical to install in a highly developed area to recover the contamination.
• Sheet Piling	No	Yes	High	Medium	High	High	Medium-High	Medium-High	High	Effective	Effective	Effective	Effective	No	No	Groundwater contamination is too deep for the use of sheet piling and impractical to install in a highly developed area to recover the contamination..

Table 6-1: Identification and Screening of Technologies – Groundwater
Northrop Grumman Bethpage Facility / NWIRPFeasibility Study Report
Town of Oyster Bay, Nassau County, New York

Remedial Technology	Presumptive Remedy	Established Technology	Complexity	Overall Cost and Performance					Availability	Treatment Effectiveness				Implementable at Site	Retained for Alternative Evaluation	Reason(s)
				O&M	Capital	Reliability/ Maintain-ability	Present-Worth Cost	Time		VOCs	CVOCs	SVOCs	Inorganics			
Surface Capping																
• Multimedia Cap	No	Yes	Low	Low	Medium	Low	Low	Low	High	Limited	Limited	Limited	Limited	No	No	Will not meet RAOs and Not implementable over a 5 square mile area
• Asphalt or Concrete Cap	No	Yes	Low	Low	Medium	Low	Low	Low	High	Limited	Limited	Limited	Limited	No	No	Will not meet RAOs and Not implementable over a 5 square mile area
In-Situ Treatment																
In-Situ Thermal Treatment																
• Steam-Enhanced Extraction	No	Yes	High	High	High	Medium	Medium-High	Low-Medium	Medium	Effective	Effective	Effective	Not Effective	No	No	Steam-enhanced extraction is not suitable for the site given the large area (greater than 5 square miles) and depth (greater than 800 feet) where both closely spaced injection and extraction points would be necessary in a highly developed area to recover the contamination.
• Electrical Resistance Heating	No	Yes	High	High	High	Medium	Medium-High	Low-Medium	Medium	Effective	Effective	Effective	Not Effective	No	No	Electrical Resistance Heating is not suitable for the site given the large area (greater than 5 square miles) and depth (greater than 800 feet) where both closely spaced injection and extraction points would be necessary in a highly developed area to recover the contamination.
• Thermal Conduction Heating	No	Yes	High	High	High	Medium	Medium-High	Low-Medium	Medium	Effective	Effective	Effective	Not Effective	No	No	Thermal conduction heating is not suitable for the site given the large area (greater than 5 square miles) and depth (greater than 800 feet) where both closely spaced injection and extraction points would be necessary in a highly developed area to recover the contamination.

Table 6-1: Identification and Screening of Technologies – Groundwater
Northrop Grumman Bethpage Facility / NWIRPFeasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Remedial Technology	Presumptive Remedy	Established Technology	Complexity	Overall Cost and Performance					Availability	Treatment Effectiveness				Implementable at Site	Retained for Alternative Evaluation	Reason(s)
					O&M	Capital	Reliability/ Maintain-ability	Present-Worth Cost	Time		VOCs	CVOCs	SVOCs	Inorganics			
	In-Situ Biological Treatment	*Yes	Yes	Medium	Medium-High	Medium	Medium	Medium	Medium-High	High	Effective	Effective	Effective	Not Effective	No	No	In-situ bioremediation including biostimulation, bioaugmentation, and in-situ adsorption and biodegradation would involve creating the proper conditions by injecting a carbon substrate into groundwater to create anaerobic conditions, which is necessary for reductive dechlorination of CVOCs. It is potentially effective; however, the large area and depth (greater than 800 feet) of contamination would require a highly concentrated grid of multi-depth injection points within the plume footprint. The highly-developed commercial/ residential nature of the Site would make it difficult to achieve the necessary injection density.
	In-Situ Chemical Oxidation (ISCO)	Yes	Yes	Medium-High	Low	Medium-High	Medium	Medium-High	Low	High	Effective	Effective	Limited	Not Effective	No	No	ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration endpoints. ISCO with is potentially effective; however, the large area (greater than 5 square miles) and depth (greater than 800 feet) of contamination would require a highly concentrated grid of multi-depth injection points within the plume footprint. The highly-developed commercial/residential nature of the area would make it difficult to achieve the necessary injection density.
	Permeable Reactive Barriers	No	Yes	Medium	Medium	High	Medium-High	Medium-High	Medium-High	Medium	Effective	Effective	Effective	Limited	No	No	Groundwater contamination is too deep for the use of passive or reactive treatment barriers.
	In-situ Air Sparging with Soil Vapor Extraction	Yes	Yes	Low	Low	Low-Medium	High	Low	Low-Medium	High	Effective	Effective	Limited	Not Effective	No	No	Air sparging is both presumptive remedies that are very effective for the treatment of cVOCs in groundwater; however, it has a depth limitation since at great depths below the groundwater surface very large pressures would be required to force the air into the aquifer. This technology is not feasible at site because the groundwater contamination is more than 800 feet deep, well below the practical limit of sparging.

Table 6-1: Identification and Screening of Technologies – Groundwater
Northrop Grumman Bethpage Facility / NWIRPFeasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Remedial Technology	Presumptive Remedy	Established Technology	Complexity	Overall Cost and Performance					Availability	Treatment Effectiveness				Implementable at Site	Retained for Alternative Evaluation	Reason(s)
					O&M	Capital	Reliability/ Maintain-ability	Present-Worth Cost	Time		VOCs	CVOCs	SVOCs	Inorganics			
Ex-Situ Treatment																	
	Air Stripping	Yes	Yes	Medium	Medium-High	Medium	High	Medium	High	High	Effective	Effective	Not Effective	Not Effective	Yes	**Yes**	Air stripping is used in conjunction with extraction and treatment systems to enhance performance; it separates VOCs from groundwater by increasing the surface area of the contaminated water exposed to air.
	Adsorption/Granular Activated Carbon (GAC)	Yes	Yes	Low	Medium-High	Medium	High	Medium	Medium-High	High	Effective	Effective	Effective	Not Effective	Yes	**Yes**	GAC is used in conjunction with extraction and treatment systems to enhance performance. Contaminants are adsorbed onto the media, reducing their concentration in the bulk liquid phase.
	Advanced Oxidation Processes (AOPs)	No	Yes	Medium	High	High	Medium	High	Medium-High	High	Effective	Effective	Effective	Not Effective	Yes	**Yes**	AOPs including the use of UV radiation, catalytic oxidation, ozone, and/or hydrogen peroxide can destroy organic contaminants in groundwater. Advanced oxidation processes, is a viable technology for 1,4-dioxane in water.
Groundwater Discharge																	
	Discharge of Water to Publicly Owned Treatment Works	NA	Yes	Low	Low	Low	High	Low	NA	High	Effective	Effective	Effective	Effective	Yes	No	The nearest POTW does not have the future infrastructure capacity to receive the volume of water likely to be extracted. Therefore, discharge to POTW is not feasible due to the volume of discharge anticipated.
	Discharge Untreated Water to RCRA Treatment/Storage/ Disposal Facility	NA	Yes	Low	Low	Low	High	Low	NA	High	Effective	Effective	Effective	Effective	Yes	No	A suitable facility for this option is not present in the vicinity of the site. Therefore, discharge to RCRA Treatment/Storage/Disposal Facility is not feasible.
	Discharge to Surface Water	NA	Yes	Low	Low	Low	High	Low	NA	High	Effective	Effective	Effective	Effective	Yes	**Yes**	The discharge of treated groundwater to a Massapequa Creek is retained In conjunction with other disposal/discharge options.

HDR

Table 6-1: Identification and Screening of Technologies – Groundwater
Northrop Grumman Bethpage Facility / NWIRPFeasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Remedial Technology	Presumptive Remedy	Established Technology	Complexity	Overall Cost and Performance					Availability	Treatment Effectiveness				Implementable at Site	Retained for Alternative Evaluation	Reason(s)
					O&M	Capital	Reliability/ Maintain-ability	Present-Worth Cost	Time		VOCs	CVOCs	SVOCs	Inorganics			
	Discharge to Recharge Basin/Infiltration Galleries	NA	Yes	Low	Low	Low	High	Low	NA	High	Effective	Effective	Effective	Effective	Yes	**Yes**	In conjunction with other disposal/discharge options, discharge to existing or new recharge basins and infiltration galleries have been retained for further evaluation.
	Well Injection	NA	Yes	Low	High	High	High	High	NA	High	Effective	Effective	Effective	Effective	Yes	**Yes**	The use of injection wells will be able to receive the treated water discharge as component of the overall discharge design. The use of injection wells will therefore be retained for further evaluation.
	Irrigation	NA	Yes	Low	Low	Low	High	Low	NA	High	Effective	Effective	Effective	Effective	Yes	**Yes**	Irrigation allows treated water to be discharged through land application or irrigation of vegetation. The use of irrigation could seasonally receive a portion of the discharge flow; therefore, irrigation is retained In conjunction with other disposal/discharge options.

Notes: O&M – relative overall cost and performance of operation and maintenance. Capital – relative overall cost and performance of capital investment. Table adapted from Federal Remediation Technologies Roundtable Technology Screening Matrix, 2007. www.frtr.gov.

Table 7-1: Alternatives Summary
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alternative ID		2A	2B	3A	3B	4	5A	5B
Description		**Hydraulic Containment of Site Contaminants above SCGs** Decentralized Treatment Plants with Various Discharge Methods	**Hydraulic Containment of Site Contaminants above SCGs** Centralized Treatment Plants with a Centralized Recharge Basin	**Plume Mass Flux Remediation** Decentralized Treatment Plants with Various Discharge Methods	**Plume Mass Flux Remediation** Centralized Treatment Plant with a Centralized Recharge Basin	**Aquifer Flushing**	**Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation** Decentralized Treatment Plants with Various Discharge Methods	**Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation** Centralized Treatment Plants with a Centralized Recharge Basin
Groundwater Extraction	Number of Groundwater Extraction Wells	• 16 wells for hydraulic containment	• 16 wells for hydraulic containment	• 17 wells for mass flux	• 16 wells for mass flux	• 23 wells	• 16 wells for hydraulic containment • 8 wells for mass flux	• 16 wells for hydraulic containment • 8 wells for mass flux
	Estimated Groundwater Extraction Rate	10,350 GPM (14.9 MGD)	9,150 GPM (13.2 MGD)	9,090 GPM (13.1 MGD)	7,140 GPM (10.3 MGD)	8,670 GPM (12.5 MGD)	13,340 GPM (19.2 MGD)	12,140 GPM (17.5 MGD)
Ex-Situ Treatment	Treatment System Location(s)	Decentralized Treatment	Centralized Treatment	Decentralized Treatment	Centralized Treatment	Decentralized Treatment	Decentralized Treatment	Centralized Treatment
	Treatment Plant(s)	13 plants total: • 6 plants at 500 GPM • 6 plants at 1,000 GPM • 1 plant at 2,250 GPM	5 plants total: • 1 plant at 500 GPM • 2 plants at 1,000 GPM • 1 plant at 2,000 GPM • 1 plant at 5,150 GPM	12 plants total: • 4 plants at 500 GPM • 7 plants at 1,000 GPM • 1 plant at 2,250 GPM	1 plant total: • 1 plant at 7,140 GPM	23 plants total: • 3 plants at 100 GPM • 5 plants at 200 GPM • 5 plants at 300 GPM • 7 plants at 500 GPM • 3 plants at 1,000 GPM	17 plants total: • 4 plants at 500 GPM • 11 plants at 1,000 GPM • 1 plant at 1,500 GPM • 1 plant at 1,250 GPM	5 plants total: • 1 plant at 500 GPM • 2 plants at 1,000 GPM • 1 plant at 2,000 GPM • 1 plant at 8,140 GPM
Disposal/ Discharge	Existing Recharge Basin(s) Used	13 basins 8,100 GPM total	3 basins 2,000 GPM total	12 basins 8,165 GPM total	-	-	16 basins 10,915 GPM total	3 basins 2,000 GPM total
	New Centralized Recharge Basin	-	1 basin 4,225 GPM	-	1 basin 6,215 GPM	-	-	1 basin 7,215 GPM
	Beneficial Reuse (Irrigation)	-	925 GPM	925 GPM	925 GPM	-	925 GPM	925 GPM
	Surface Water	2,250 GPM	2,000 GPM	-	-	-	1,500 GPM	2,000 GPM
	Injection Wells	-	-	-	-	43 injection wells 8,670 GPM total	-	-
Conveyance System	Total Piping	82,046 feet	107,638 feet	118,293 feet	82,457 feet	93,282 feet	131,063 feet	124,411 feet
	Number of Pumps	8	15	15	13	2	13	17
	Number of Pump Stations	8	11	12	10	1	12	13

Notes:
GPM - Gallons per minute
MGD - Million gallons per day

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
1	**No Further Action**	- Will not meet the RAOs for the site. - Will not protect the environment.	- Will not meet SCGs. - Groundwater that contains COCs greater than the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Contaminants remain in the environment. - Magnitude of remaining risks down gradient will be unchanged. - Groundwater that contains COCs greater than the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Does not reduce toxicity, mobility or volume of contamination present at the site. - Groundwater that contains COCs greater than the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Does not result in disruption of properties or pose a short-term threat to public health or the environment.	- No technical or administrative difficulties or constraints.	Capital Cost: **$0** O&M Present Worth Cost: **$0** Periodic Present Worth Cost: **$0** Total Present Worth Cost: **$0**	- Will not restore groundwater quality and does not provide any restrictions to prevent use of groundwater at the impacted areas.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
2A	**Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods**	- Will remove contaminant mass from the area where any COC concentration exceeds its SCG and establish hydraulic control to minimize migration of the SCG plume. - Protective of public health as it will remove COCs in groundwater above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will result in a reduction of COC concentrations, achieving the groundwater SCGs at down gradient edge of the active treatment area. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to existing recharge basins and to surface water at Massapequa Creek.	- Permanent reduction of groundwater contaminants from active groundwater extraction and treatment system. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - Allow unrestricted use of groundwater resource. - Water Treatment on currently impacted water supply wells may be removed over time after the implementation of this alternative. -Prevent down-gradient water supply wells from being impacted with COCs above the SCGs.	- Will reduce the volume of COCs in groundwater at down gradient edge of the SCG plume. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the SCG plume.	- Construction of extraction wells, multiple treatment systems, and conveyance systems will cause localized noise and disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other potential security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for extraction wells and treatment facilities (decentralized treatment plants). - A SPDES permit is required for the discharge to surface water option.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 130 years. Capital Cost: **$ 210,206,000** O&M Present Worth Cost: **$ 326,442,000** Periodic Present Worth Cost: **$ 16,601,000** Total Present Worth Cost: **$ 553,249,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permenence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
2B	**Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin**	- Will remove contaminant mass from the area where any COC concentration exceeds its SCG and establish hydraulic control to minimize migration of the SCG plume. - Protective of public health as it will remove COCs in groundwater above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will result in a reduction of COC concentrations, achieving the groundwater SCGs at down-gradient edge of the active treatment area. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to existing/new recharge basins, storage for beneficial reuse, and discharge to surface water at Massapequa Creek.	- Permanent reduction of groundwater contaminants from active groundwater extraction and treatment system. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - Allow unrestricted use of groundwater resource. - Water Treatment on currently impacted water supply wells may be removed over time after the implementation of this alternative. -Prevent down-gradient water supply wells from being impacted with COCs above the SCGs.	- Will reduce the volume of COCs in groundwater at down gradient edge of the SCG plume. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the SCG plume.	- Construction of extraction wells, and five treatment systems will cause noise and disruption to traffic. Construction of the conveyance systems will cause disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other potential security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for extraction wells and treatment plants (in the southern portion of the site). - The centralized treatment plant will be located in the vicinity of the Navy/Grumman parcel, and the new recharge basin in the vicinity of the Bethpage State Park. - Construction of conveyance piping will cause disruption to traffic and will be challenging in the densely developed area. - A SPDES permit is required for the discharge to surface water option.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 140 years. Capital Cost: **$ 194,894,000** O&M Present Worth Cost: **$ 272,890,000** Periodic Present Worth Cost: **$ 17,111,000** Total Present Worth Cost: **$ 484,895,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
3A	**Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods**	- Will remove contaminant mass from the area where TCVOC concentrations exceed 50 ug/l and establish hydraulic control to minimize off-site migration of the 50 ug/l plume. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will reduce TCVOC concentrations to less than 50 ug/l within the treatment area. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to existing recharge basins and storage for beneficial reuse.	- Permanent reduction of groundwater contaminants from active groundwater remediation. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion).	- Will reduce the volume of TCVOCs in groundwater within the area where TCVOC concentrations exceed 50 ug/l. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the 50 ug/l plume. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Construction of extraction wells, multiple treatment systems and conveyance systems will cause localized noise and disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for treatment facilities (decentralized treatment plants and extraction wells).	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 22 years; however, this will not achieve RAOs. Capital Cost: **$ 233,987,000** O&M Present Worth Cost: **$ 274,424,000** Periodic Present Worth Cost: **$ 13,990,000** Total Present Worth Cost: **$ 522,410,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
3B	**Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin**	- Will remove contaminant mass from the area where TCVOC concentrations exceed 50 ug/l and establish hydraulic control to minimize migration of the 50 ug/l plume. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will reduce TCVOC concentrations to less than 50 ug/l within the treatment area. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to new recharge basin and storage for beneficial reuse.	- Permanent reduction of groundwater contaminants from active groundwater remediation. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion).	- Will reduce the volume of TCVOCs in groundwater within the area where TCVOC concentrations exceed 50 ug/l. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the 50 ug/l plume. - The portion of groundwater that contains TCVOCs from 50 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Construction of extraction wells, and one centralized treatment system will cause noise and disruption to traffic. The conveyance systems will cause disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for extraction wells. - The centralized treatment plant will be located within the Navy/Grumman parcel, and the new recharge basin in the vicinity of the Bethpage State Park. - Construction of conveyance piping will cause disruption to traffic and will be challenging in the densely developed area.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 25 years; however, this will not achieve RAOs. Capital Cost: **$ 168,475,000** O&M Present Worth Cost: **$ 151,022,000** Periodic Present Worth Cost: **$ 12,215,000** Total Present Worth Cost: **$ 331,712,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the site: residential/ commercial/industrial.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
4	**Aquifer Flushing**	- Will remove contaminant mass from the area where TCVOC concentrations exceed 100 ug/l and establish hydraulic control to minimize migration of the 100 ug/l plume. - The portion of groundwater that contains TCVOCs from 100 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will reduce TCVOC concentrations to less than 100 ug/l within the treatment area. - The portion of groundwater that contains TCVOCs from 100 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge via injection wells.	- Permanent reduction of groundwater contaminants from active groundwater remediation. - The portion of groundwater that contains TCVOCs from 100 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion).	- Will reduce the volume of TCVOCs in groundwater within the area where TCVOC concentrations exceed 100 ug/l. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the 100 ug/l plume. - The portion of groundwater that contains TCVOCs from 100 ug/l to the SCGs will continue to migrate with regional groundwater and potentially impact receptors.	- Construction of extraction wells, multiple treatment systems and conveyance systems will cause localized noise and disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for treatment facilities (decentralized treatment plants, extraction wells, and injection wells). - Construction of conveyance piping from extraction wells to injection wells will cause disruption to traffic and will be challenging in the densely developed area.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 17 years; however, this will not achieve RAOs. Capital Cost: **$ 313,879,000** O&M Present Worth Cost: **$ 277,374,000** Periodic Present Worth Cost: **$ 17,135,000** Total Present Worth Cost: **$ 608,390,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Table 8-1: Detailed Evaluation of Groundwater Alternatives
Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
5A	**Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods**	- Will remove contaminant mass from the area where any COC concentration exceeds its SCG and establish hydraulic control to minimize migration of the SCG plume. Will remove contaminant mass from the area containing high TCVOC concentrations. - Protective of public health as it will remove COCs in groundwater above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will result in a reduction of COC concentrations, achieving the groundwater SCGs within the treatment area. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to existing recharge basins, storage for beneficial reuse, and discharge to surface water at Massapequa Creek.	- Permanent reduction of groundwater contaminants from active groundwater remediation. - Extraction of high TCVOC concentrations could shorten the period of performance of the remedy; reduce the risk to the natural resource; reduce the risk to municipal water supply wells. - Allow unrestricted use of groundwater resource. - Water Treatment on currently impacted water supply wells may be removed over time after the implementation of this alternative. -Prevent down-gradient water supply wells from being impacted with COCs above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion).	- Will reduce the volume of CVOCs in groundwater within the area where any COC concentration exceeds its SCG. - Will reduce contaminant mass from the area containing high TCVOC concentration. - Extraction of high TCVOC concentrations could shorten the period of performance of the remedy; reduce the risk to the natural resource; reduce the risk to public water supply wells. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the MCL plume.	- Construction of extraction wells, multiple treatment systems and conveyance systems will cause localized noise and disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing and other security measures will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The impacted area is densely developed, posing a challenge in selecting suitable locations for extraction wells and treatment facilities (decentralized treatment plants). - A SPDES permit is required for the discharge to surface water option.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 110 years. Capital Cost: **$ 282,959,000** O&M Present Worth Cost: **$ 440,803,000** Periodic Present Worth Cost: **$ 24,173,000** Total Present Worth Cost: **$ 747,935,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Alt. No.	Alternative Name	Overall Protectiveness of Public Health and the Environment	Compliance with SCGs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume of Contamination Through Treatment	Short-Term Impact and Effectiveness	Implementability	Cost Effectiveness	Land Use Criteria
5B	**Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin**	- Will remove contaminant mass from both the area where any COC concentration exceeds its MCL and establish hydraulic control to minimize off-site migration of the SCG plume. - Protective of public health as it will remove COCs in groundwater above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion). - LTM will be implemented to monitor contaminant concentrations over time.	- Will result in a reduction of COC concentrations, achieving the groundwater SCGs within the treatment area. - Treated effluent from treatment system will meet NY State groundwater effluent limitations prior to discharge to existing/new recharge basins, storage for beneficial reuse, and discharge to surface water at Massapequa Creek.	- Permanent reduction of groundwater contaminants from active groundwater remediation. - Extraction of high TCVOC concentrations could shorten the period of performance of the remedy; reduce the risk to the natural resource; reduce the risk to public water supply wells. - Allow unrestricted use of groundwater resource. - Water Treatment on currently impacted water supply wells may be removed over time after the implementation of this alternative. -Prevent down-gradient water supply wells from being impacted with COCs above the SCGs. - Can be implemented in a manner than protects the environment (surface water, wetlands, and saltwater intrusion).	- Will reduce the volume of COCs in groundwater within the area where any COC concentration exceeds its SCG. - Will reduce the volume of contaminated groundwater. - Will establish hydraulic control of the aquifer to minimize migration of the SCG plume.	- Construction of extraction wells, and one centralized pump and treat system will cause noise and disruption to traffic; the conveyance systems will cause disruption to traffic on major and minor roadways. - A health and safety plan, including community air monitoring, traffic control plan and street closure permits will be needed during construction. - Fencing will be installed around the treatment facilities to restrict access, discourage trespassers, and limit potential exposure.	- Extraction and treatment is a well-established technology. - Pre-design investigation and pilot testing are needed. - The site is densely developed, posing a challenge in selecting suitable locations for extraction wells and treatment plants (in the southern portion of the site). - The treatment plant will be located in the vicinity of Navy/Grumman parcel, and the new recharge basin in the vicinity of the Bethpage State Park. - Construction of conveyance piping will cause disruption to traffic and will be challenging in the densely developed area. - A SPDES permit is required for the discharge to surface water option.	- Present worth calculations are based on 30 years. - The duration of the remedy has been estimated to be approximately 110 years. Capital Cost: **$ 240,448,000** O&M Present Worth Cost: **$ 320,297,000** Periodic Present Worth Cost: **$ 23,905,000** Total Present Worth Cost: **$ 584,650,000**	- Sufficient for the current, intended, and reasonably anticipated future use of the impacted area: residential/ commercial/industrial.

Table 8-2: Summary of Cost Estimates

Northrop Grumman Bethpage Facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

Site:	Grumman Aerospace-Bethpage Facility	**Base Year:**	2019
Location:	Nassau County, New York	**Date:**	January 2019
Phase:	Feasibility (-30% - +50%)		

	Alternative 1	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B	Alternative 4	Alternative 5A	Alternative 5B
Description	No Further Action (With Existing & Planned Remedial Systems)	Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods	Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin	Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods	Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin	Aquifer Flushing	Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods	Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin
Treatment System Location(s)	-	Decentralized	Centralized	Decentralized	Centralized	Decentralized	Decentralized	Centralized
Discharge Options	-	Recharge Basins Surface Water	Recharge Basins Beneficial Reuse Surface Water	Recharge Basins Beneficial Reuse	Recharge Basins Beneficial Reuse	Injection Wells	Recharge Basins Beneficial Reuse Surface Water	Recharge Basins Beneficial Reuse Surface Water
Number of Groundwater Extraction Wells	0	16	16	17	16	23	24	24
Estimated Groundwater Extraction Rate (MGD)	0	14.9	13.2	13.1	10.3	12.5	19.2	17.5
Estimated Active Remediation Duration (Years)	-	130	140	22	25	17	110	110
Estimated Project Duration with LTM for FS (Years)	-	30	30	30	30	30	30	30
Capital Cost	$ -	$ 210,206,000	$ 194,894,000	$ 233,987,000	$ 168,475,000	$ 313,879,000	$ 282,959,000	$ 240,448,000
Total O&M Cost (NPV)	$ -	$ 326,442,000	$ 272,890,000	$ 274,424,000	$ 151,022,000	$ 277,374,000	$ 440,803,000	$ 320,297,000
Total Periodic Cost (NPV)	$ -	$ 16,601,000	$ 17,111,000	$ 13,990,000	$ 12,215,000	$ 17,135,000	$ 24,173,000	$ 23,905,000
Total Present Value of Options	$ -	**$ 553,249,000**	**$ 484,895,000**	**$ 522,410,000**	**$ 331,712,000**	**$ 608,390,000**	**$ 747,935,000**	**$ 584,650,000**

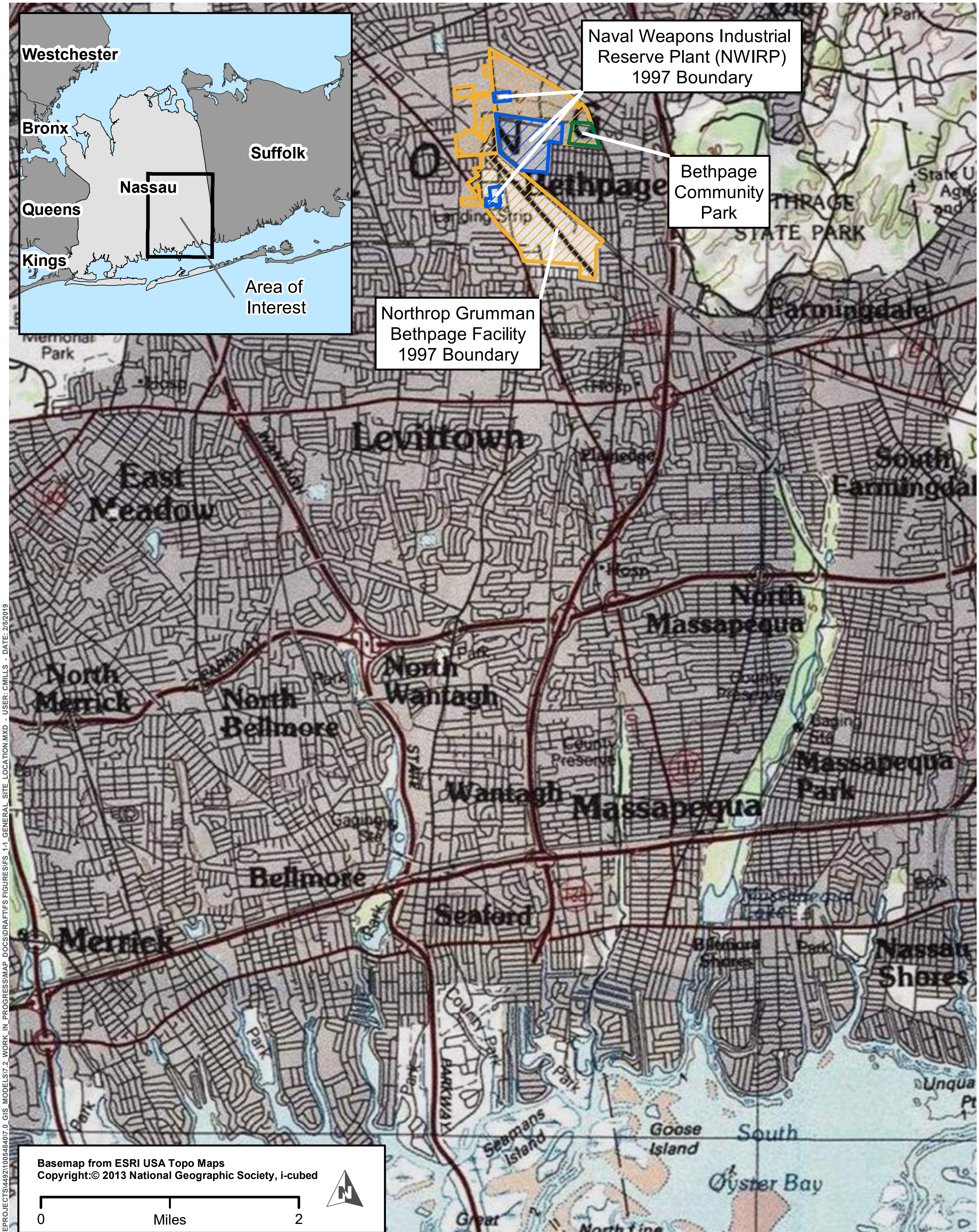
Note:
NPV – Net Present Value

Table 8-3
Potential Environmental Impacts
Northrop Grumman Bethpage facility / NWIRP Feasibility Study Report
Town of Oyster Bay, Nassau County, New York

	Alternative 1	Alternative 2A		Alternative 2B		Alternative 3A		Alternative 3B		Alternative 4		Alternative 5A		Alternative 5B	
	Value	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change
Public Water Supply															
Metric: Water Level (feet mean sea level)															
BWD 4-1 (N6915)	39.7	38.2	-1.5	38.6	-1.2	38.2	-1.5	37.6	-2.1	39.88	0.2	37.8	-2.0	37.5	-2.2
BWD 4-2 (N6916)	36.2	34.6	-1.6	34.8	-1.4	34.4	-1.8	33.9	-2.3	36.15	0.0	34.0	-2.2	33.8	-2.4
BWD 5-1 (N8004)	42.5	40.5	-2.0	39.9	-2.6	39.6	-2.9	39.1	-3.4	43.69	1.2	39.1	-3.4	38.5	-4.0
BWD 6-1 (N3876)	51.3	49.6	-1.7	48.8	-2.5	48.0	-3.3	46.6	-4.7	51.95	0.7	47.4	-3.9	46.1	-5.2
BWD 6-2 (N8941)	48.1	46.3	-1.7	45.8	-2.3	43.4	-4.7	43.2	-4.8	50.88	2.8	43.3	-4.8	42.5	-5.6
ANY SNR-3S (N8480)	7.3	3.0	-4.2	0.8	-6.4	5.5	-1.7	3.8	-3.5	6.36	-0.9	2.3	-5.0	0.0	-7.2
ANY SNR-4S (N9338)	2.3	1.9	-0.4	-4.1	-6.3	0.5	-1.7	-1.2	-3.5	1.37	-0.9	-2.6	-4.8	-4.9	-7.2
SFWD 1-3 (N5148)	38.5	36.8	-1.7	35.6	-3.0	38.3	-0.2	36.9	-1.6	38.01	-0.5	36.2	-2.3	36.0	-2.5
SFWD 3-1 (N6150)	26.7	22.7	-4.0	20.5	-6.3	24.6	-2.1	23.0	-3.7	25.69	-1.0	21.7	-5.0	19.7	-7.1
SFWD 6-1 (N8664)	11.9	7.3	-4.6	5.1	-6.8	10.8	-1.1	9.1	-2.8	11.09	-0.8	6.5	-5.3	4.6	-7.3
SFWD 6-2 (N8665)	10.4	6.0	-4.4	3.8	-6.7	9.4	-1.0	7.7	-2.8	9.66	-0.8	5.2	-5.2	3.3	-7.1
MWD 4 (N6442)	15.3	14.6	-0.7	13.3	-2.0	15.2	-0.1	14.1	-1.3	14.91	-0.4	14.1	-1.3	13.1	-2.2
MWD 5 (N6443)	16.9	16.6	-0.3	15.3	-1.6	16.9	0.0	15.6	-1.3	16.51	-0.4	16.1	-0.8	15.1	-1.8
Wetlands															
Metric: Water Level (feet mean sea level)															
Massapequa Creek - North	41.4	41.3	-0.1	40.7	-0.7	41.4	0.0	41.1	-0.3	41.11	-0.3	40.8	-0.6	41.0	-0.4
Massapequa Creek - Mid	34.7	36.3	1.6	34.2	-0.4	34.9	0.2	34.1	-0.5	34.43	-0.3	35.4	0.8	34.4	-0.3
Massapequa Creek - South	23.9	24.5	0.6	23.7	-0.2	23.9	0.0	23.5	-0.4	23.71	-0.2	24.0	0.1	23.7	-0.1
Seaford Creek - North	24.4	23.9	-0.5	22.4	-2.0	24.3	-0.1	22.9	-1.5	23.95	-0.4	23.3	-1.1	22.2	-2.2
Seaford Creek - South	16.7	16.6	0.0	15.9	-0.7	16.7	0.0	16.0	-0.6	16.45	-0.2	16.3	-0.3	15.8	-0.8
Bellmore Creek - North	24.7	24.4	-0.3	23.5	-1.2	24.7	-0.1	23.9	-0.8	24.54	-0.2	24.2	-0.6	23.3	-1.5
Bellmore Creek - South	19.5	19.3	-0.1	18.9	-0.6	19.4	0.0	19.0	-0.4	19.35	-0.1	19.2	-0.3	18.7	-0.7
Stream Flow															
Metric: Flow Rate (cfs)															
Massapequa	-5.5	-8.9	-3.4	-6.4	-0.9	-5.8	-0.2	-4.7	0.9	-4.96	0.6	-6.9	-1.3	-6.7	-1.2
Seaford	-1.2	-1.2	0.0	-1.1	0.2	-1.2	0.0	-1.1	0.2	-1.17	0.1	-1.1	0.1	-1.0	0.2
Seaman	-1.8	-1.7	0.0	-1.5	0.2	-1.8	0.0	-1.6	0.2	-1.69	0.1	-1.7	0.1	-1.5	0.3
Bellmore	-2.4	-2.1	0.4	-1.4	1.0	-2.3	0.1	-1.6	0.8	-2.21	0.2	-1.8	0.6	-1.3	1.2
Subsea Discharge															
Metric: Flow Rate (gpm)															
Coastal Aquifer															
GHB In	946	946	0.0%	949	0.3%	946	0.0%	949	0.3%	949	0.3%	950	0.4%	949	0.3%
GHB Out	21633	21667	0.2%	21382	-1.2%	21652	0.1%	21431	-0.9%	21,528	-0.5%	21472	-0.7%	21377	-1.2%
Magothy															
GHB In	141	141	0.0%	145	2.8%	142	0.7%	145	2.8%	148	5.0%	151	7.1%	144	2.1%
GHB Out	510	512	0.4%	491	-3.7%	512	0.4%	494	-3.1%	495	-2.9%	489	-4.1%	491	-3.7%
Lloyd															
GHB In	108	114	5.6%	123	13.9%	109	0.9%	120	11.1%	143	32.4%	148	37.0%	124	14.8%
GHB Out	0.0	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0	0.0%	0	0.0%	0	0.0%

Notes:
cfs=cubic feet per second
gpm=gallons per minute
GHB=General Head Boundary

FIGURES



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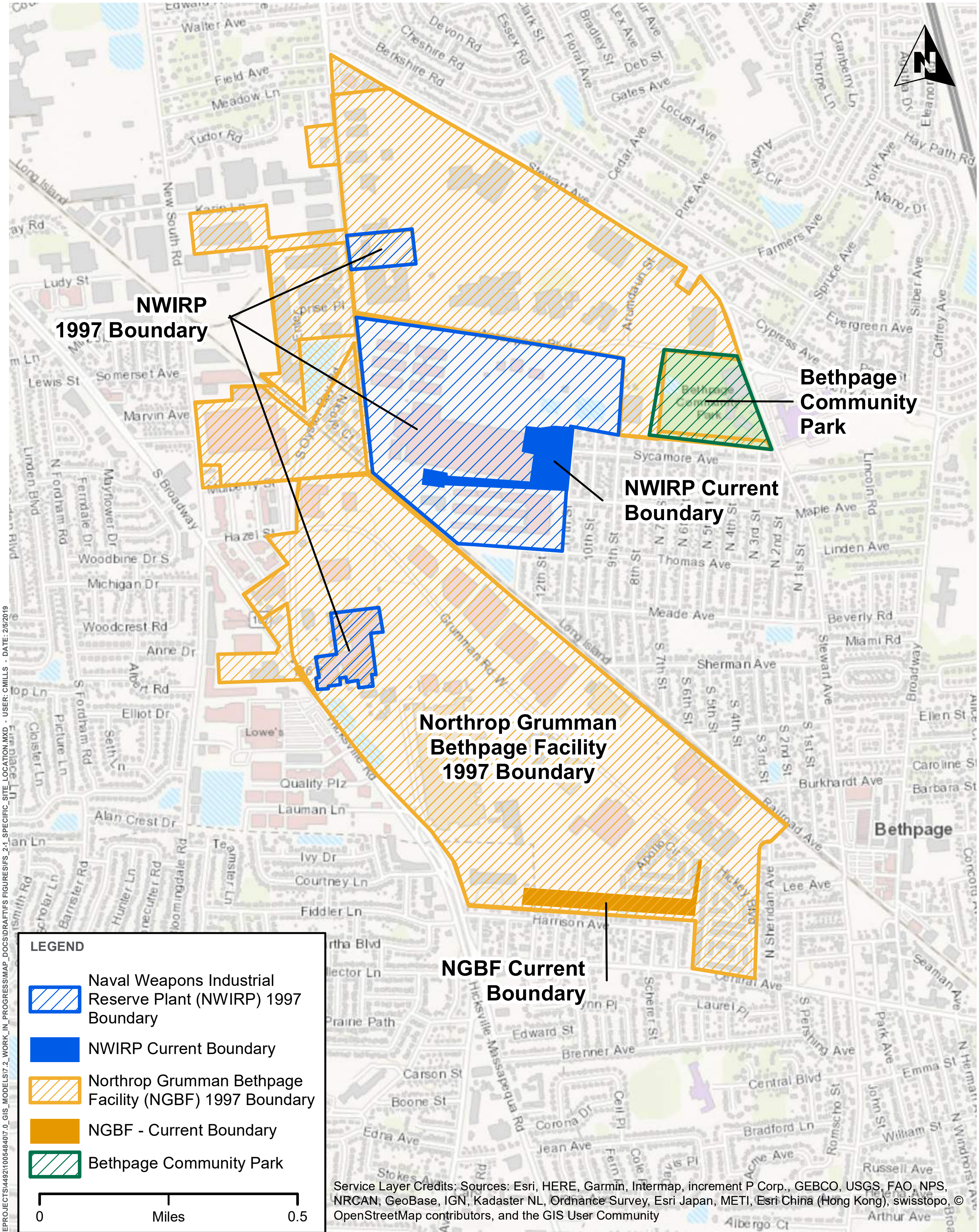
GENERAL SITE LOCATION

NYSDEC SITE # 130003

FIGURE 1-1



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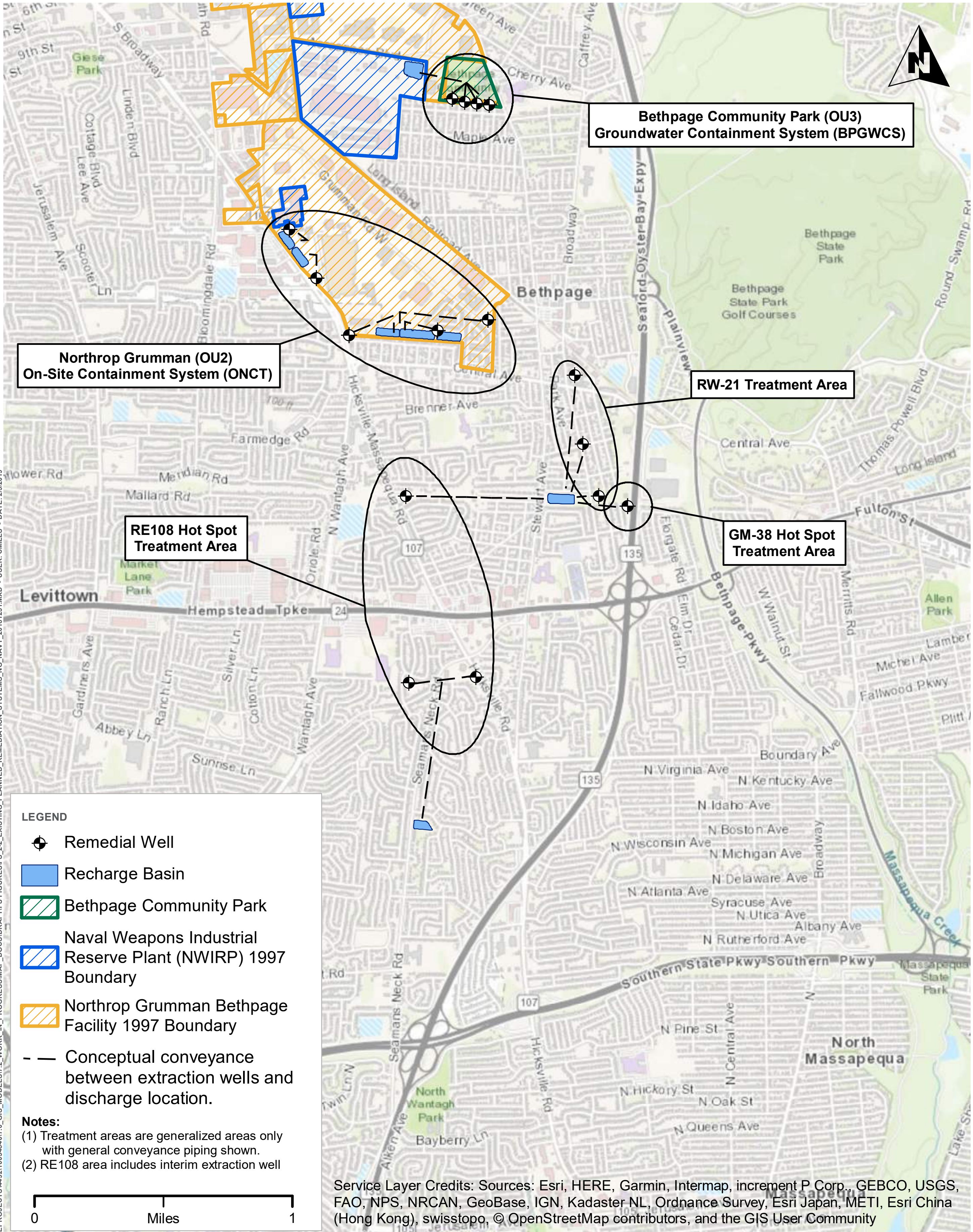
NORTHROP GRUMMAN BETHPAGE FACILITY / NWIRP

NYSDEC SITE # 130003

FIGURE 2-1



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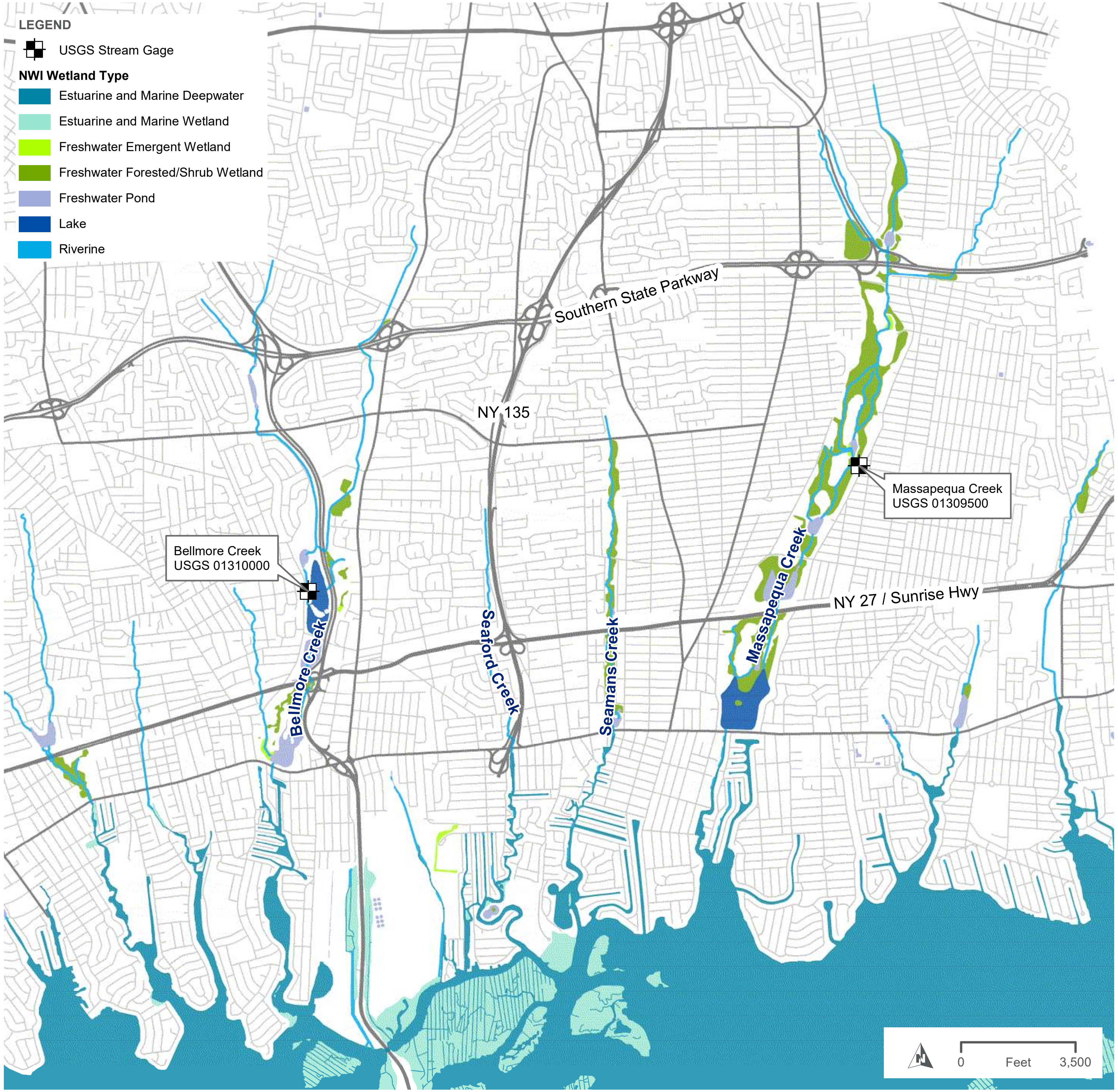
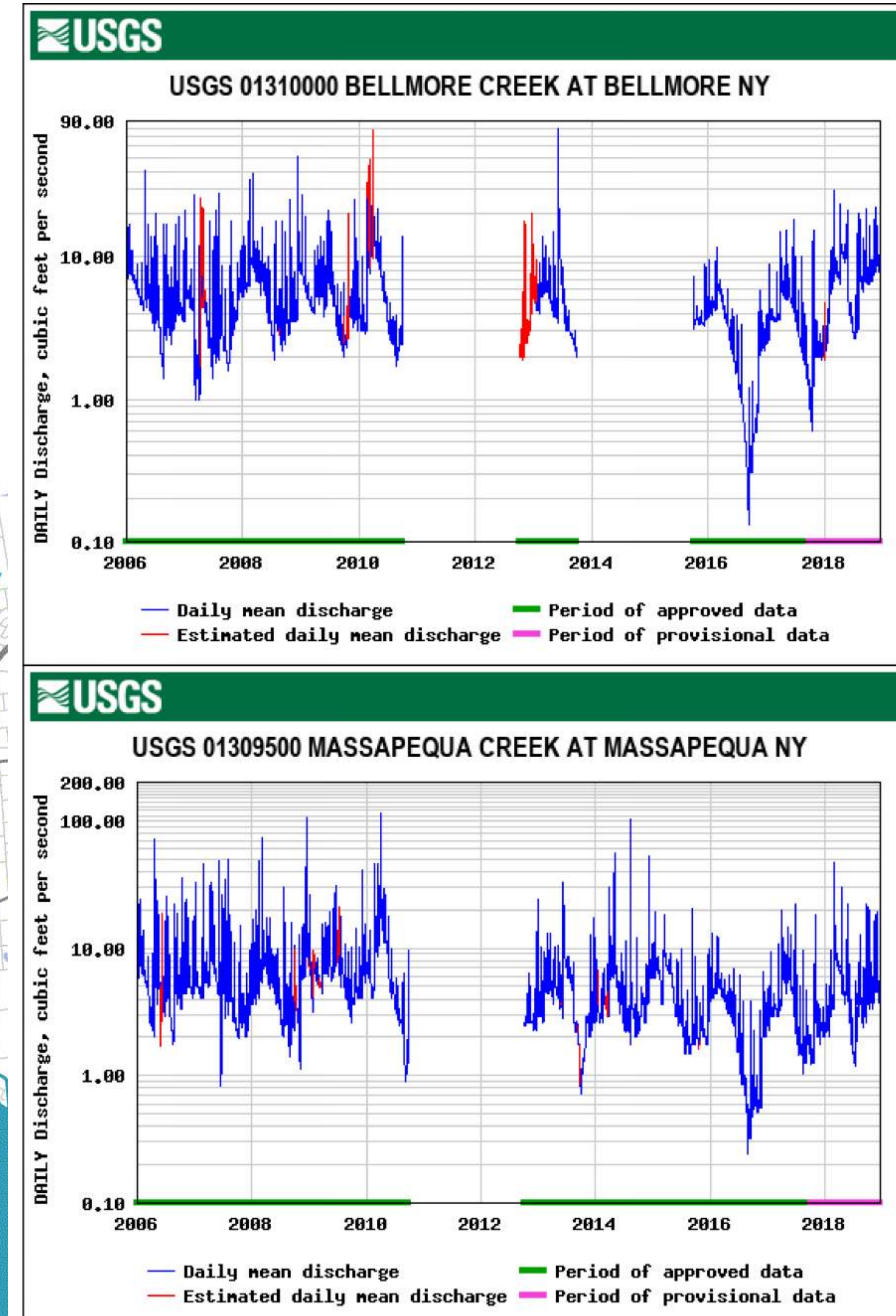
REMEDIATION TREATMENT SYSTEMS - OPERATING & PENDING

NYSDEC SITE# 130003

FIGURE 2-2





Data Sources:
USGS Stream Gage Data: https://waterdata.usgs.gov/nwis
National Wetlands Inventory (NWI) Layer: https://www.fws.gov/wetlands/data/Mapper.html
Roads: Nassau County GIS

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STREAM FLOW IN MASSAPEQUA AND BELLMORE CREEKS

NYSDEC SITE # 130003

FIGURE 2-3

System	Series	Geologic Units		Hydrogeologic Unit	Range of Thickness (feet)	Range of Altitude of Upper Surface, in feet above or below sea level
Quaternary	Holocene	Shore, beach Salt-Marsh deposits, and alluvium				
Quaternary	Pleistocene	Wisconsin Glaciation (Harbor Hill, Interstadial Marine, and Ronkonkoma Drift)	Till (ground terminal moraine) Outwash 20-foot Clay (marine)	Upper Glacial aquifer	0 to 450	Land Surface
Quaternary	Pleistocene	Sangamon Interglaciation	Gardiners Clay (marine)	Gardiners Clay	0 to 320	-40 to -250
Quaternary	Pleistocene	Pre-Wisconsin Glaciation (Illinoian)	Jameco Gravel	Jameco aquifer	0 to 185	-90 to -450
Tertiary	Pliocene	Mannetto Gravel		Unsaturated	0-220	0 to -120
Cretaceous	Upper Cretaceous	Matawan Group - Magothy Formation (undifferentiated)		Magothy aquifer	0 to 800	200 to -350
Cretaceous	Upper Cretaceous	Raritan Formation	Clay member	Raritan Clay confining unit	0 to 300	-100 to -1,000
Cretaceous	Upper Cretaceous	Raritan Formation	Lloyd sand member	Lloyd aquifer	0 to 300	-200 to -1,200
Precambrian		Crystaline Bedrock		Bedrock	--	-400 to -1,500

Source: Malcom Pirnie, 2010, GTE Operations Support Incoporated, Former Sylvania Electric Products Incorporated Facility, Hicksville, New York.

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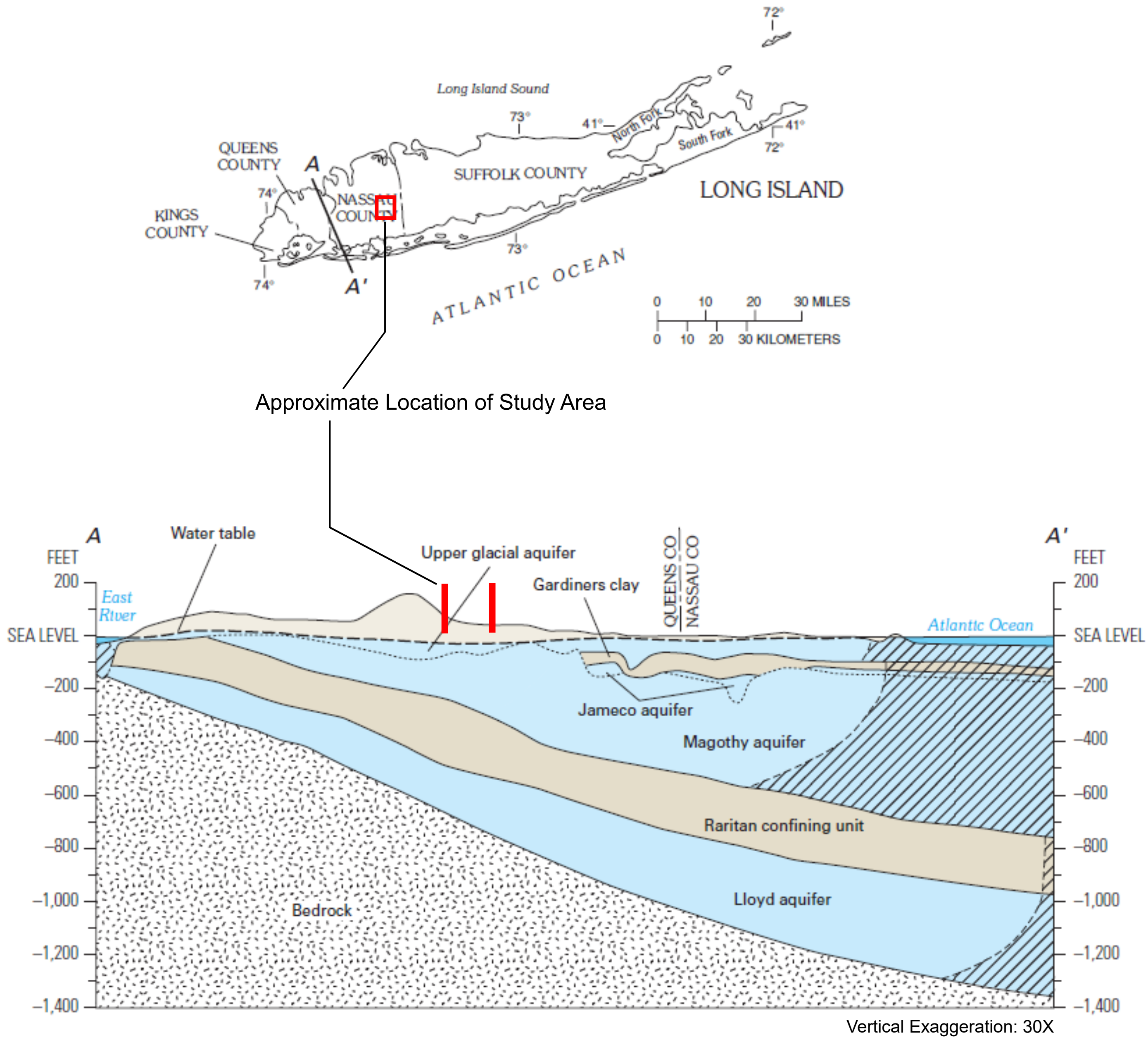
STRATIGRAPHIC COLUMN OF GEOLOGIC AND HYDROGEOLOGIC UNITS OF LONG ISLAND, NY

NYSDEC SITE #130003

FIGURE 2-4



LEGEND

Area of salty ground water

Confining unit

Sea level refers to the National Geodetic Vertical Datum of 1929

Notes:

Figure modified from:

(1) Barlow, P. M., 2003, Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast, U.S. Geological Survey Circular 1262, 121 p.

(2) Buxton, Herbert T.; Smolensky, Douglas A., 1999, Simulation of the effects of development of the ground-water flow system of Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 98-4069, 57 p.

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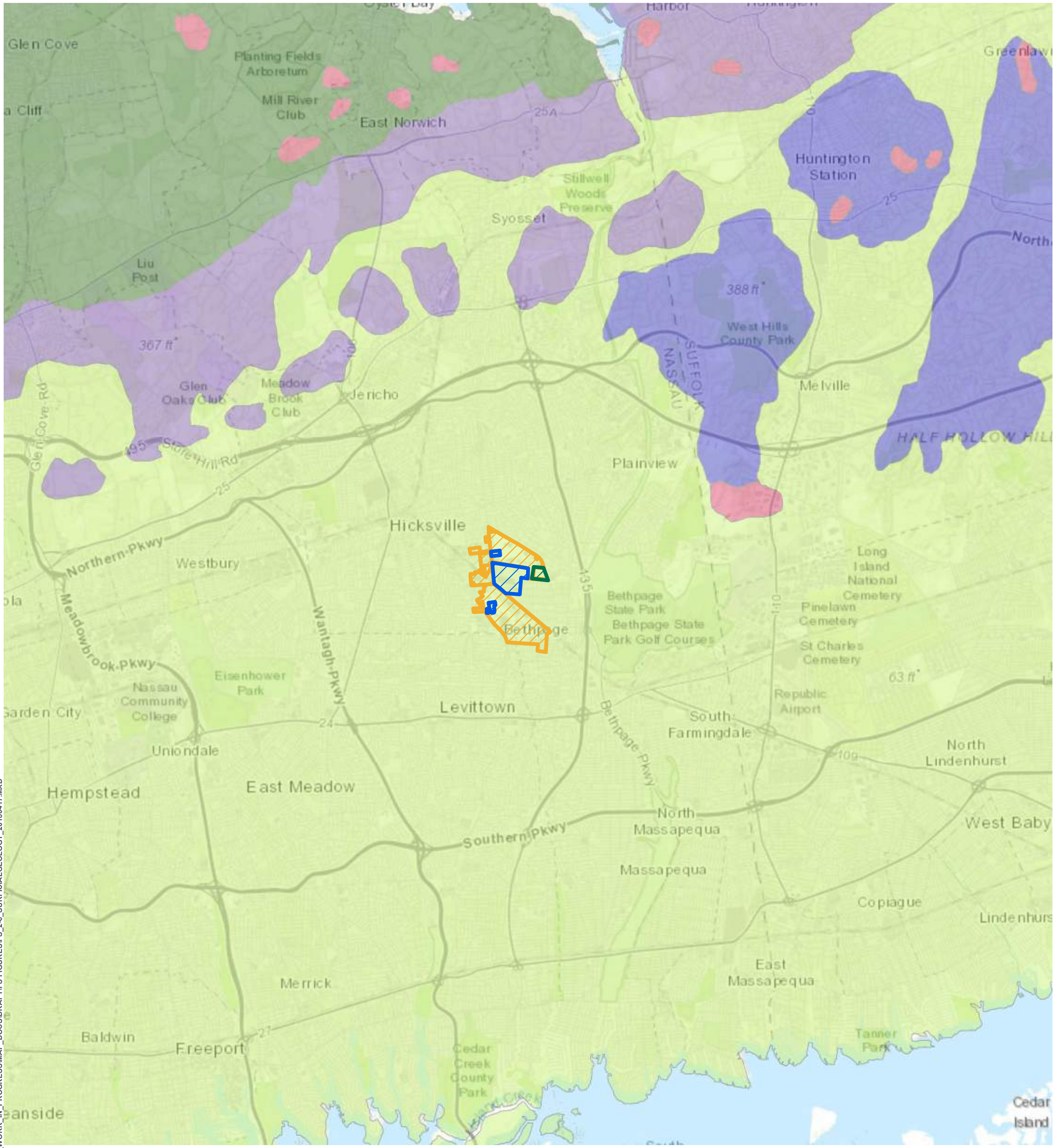
GENERALIZED HYDROGEOLOGIC CROSS SECTION

NYSDEC SITE #130003

FIGURE 2-5



LEGEND

- Northrop Grumman Bethpage Facility 1997 Boundary
- Naval Weapons Industrial Reserve Plant (NWIRP) 1997 Boundary
- Bethpage Community Park
- Kame Moraine
- Kame and Ice Contact
- Morainic
- Outwash Sand and Gravel
- Till

Geologic Data Source: United States Geological Survey, NYS GIS Clearinghouse
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_2-6_SURFICIALGEOLOGY_20180417.MXD

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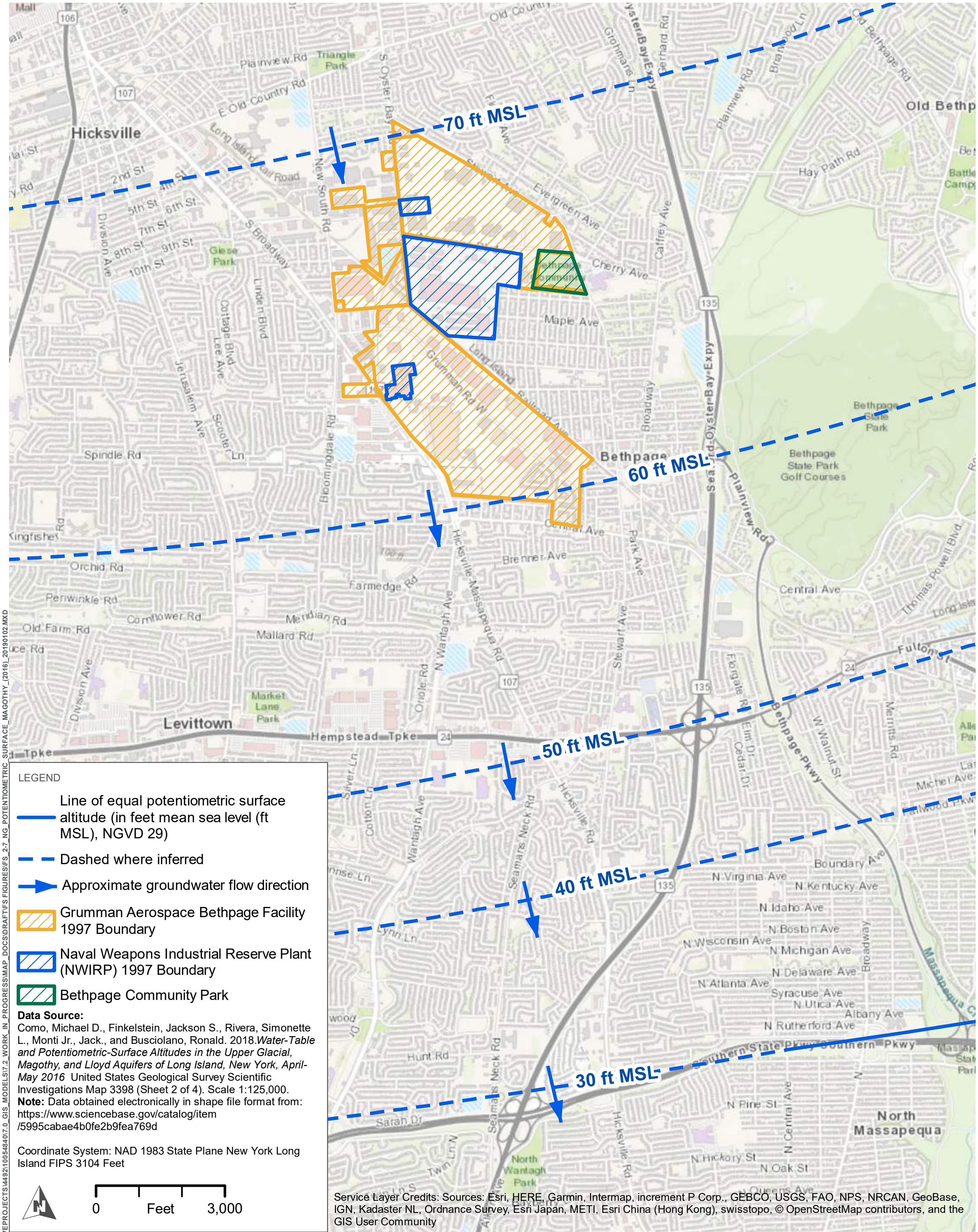
SURFICIAL GEOLOGY

NYSDEC SITE# 130003

FIGURE 2-6



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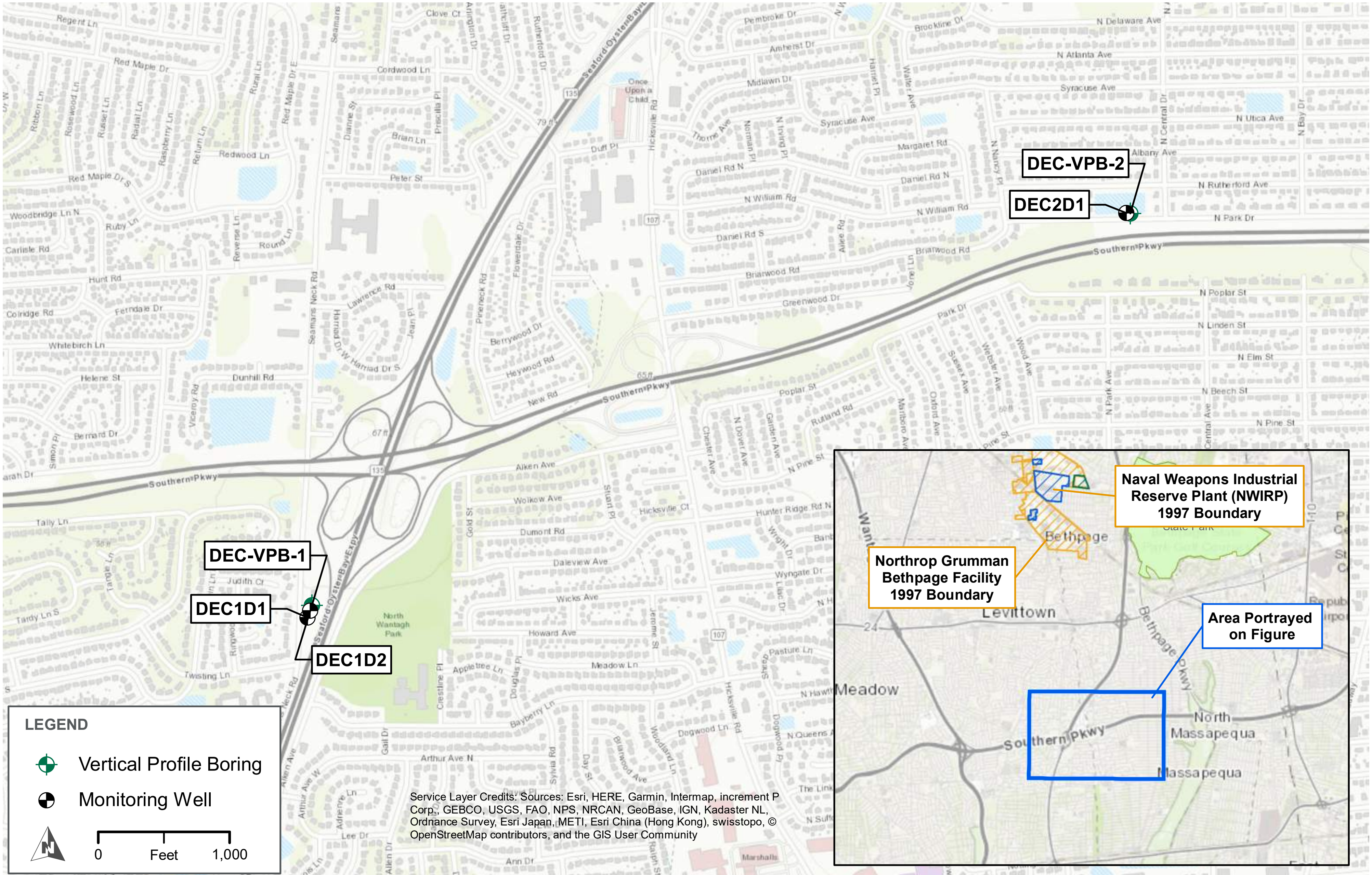
POTENTIOMETRIC SURFACE OF THE MAGOTHY AQUIFER

NYSDEC SITE# 130003

FIGURE 2-7



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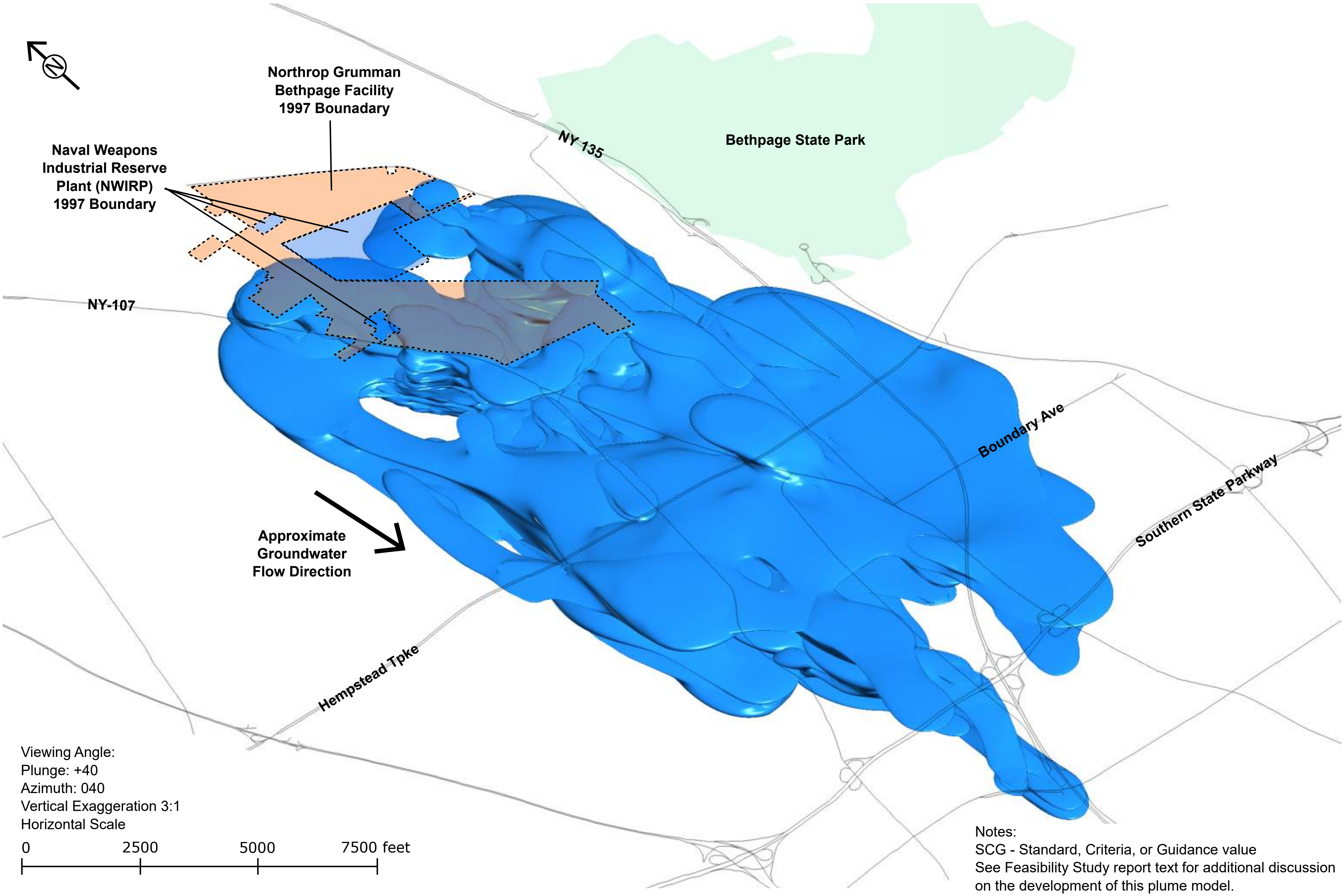
NYSDEC VPB AND MONITORING WELL LOCATIONS

NYSDEC SITE # 130003

FIGURE 3-1

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_3-1_MW AND VPB LOCATIONS.MXD - USER: CMILLS - DATE: 2/5/2019



Notes:
SCG - Standard, Criteria, or Guidance value
See Feasibility Study report text for additional discussion on the development of this plume model.

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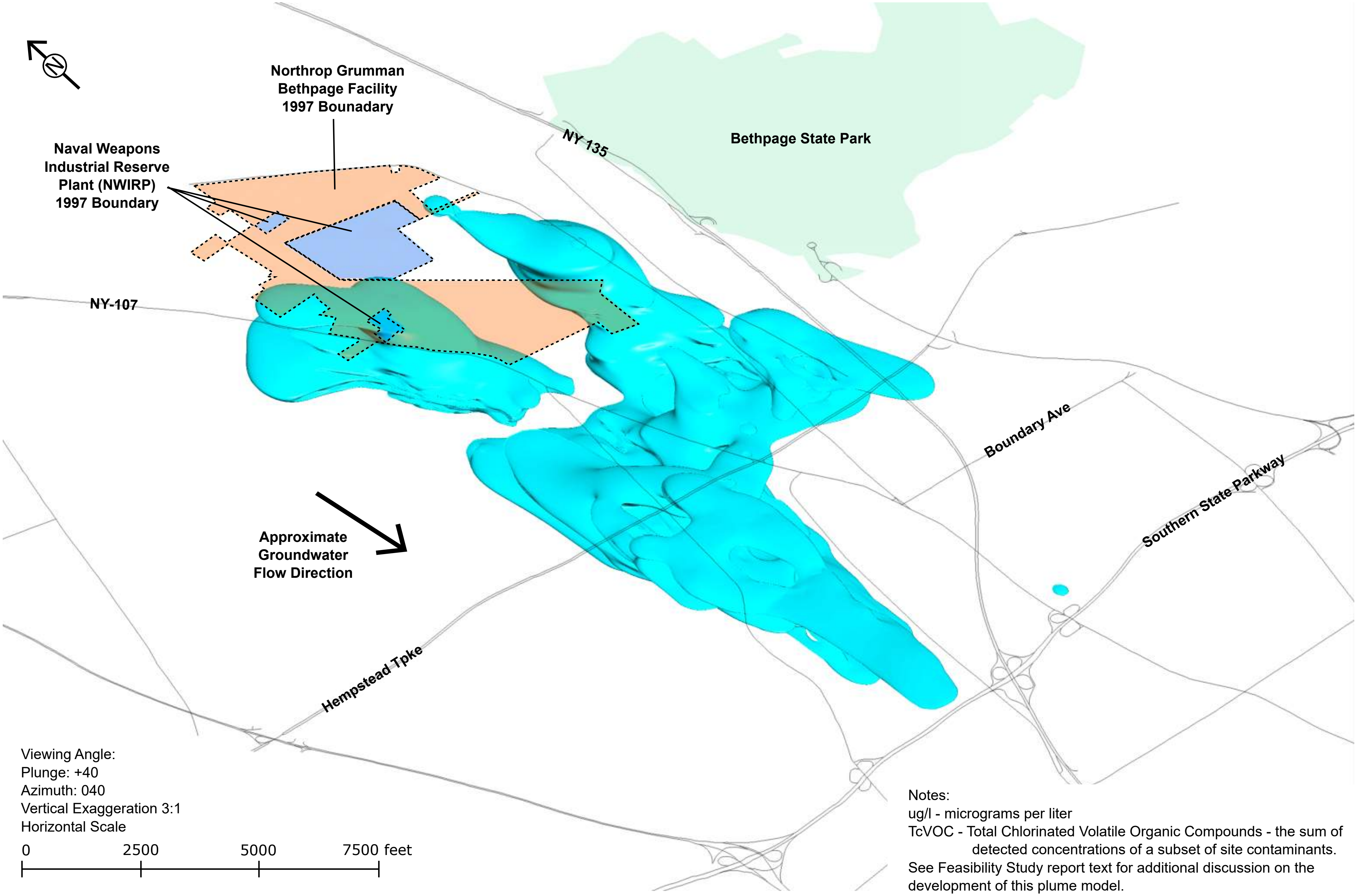
GROUNDWATER EXCEEDING SCGs - OBLIQUE 3D VIEW

NYSDEC SITE # 130003

FIGURE 3-2

USER: CMILLS DATE: 07/30/2018



Viewing Angle:
Plunge: +40
Azimuth: 040
Vertical Exaggeration 3:1
Horizontal Scale

0 2500 5000 7500 feet

Notes:
ug/l - micrograms per liter
TcVOC - Total Chlorinated Volatile Organic Compounds - the sum of detected concentrations of a subset of site contaminants.
See Feasibility Study report text for additional discussion on the development of this plume model.

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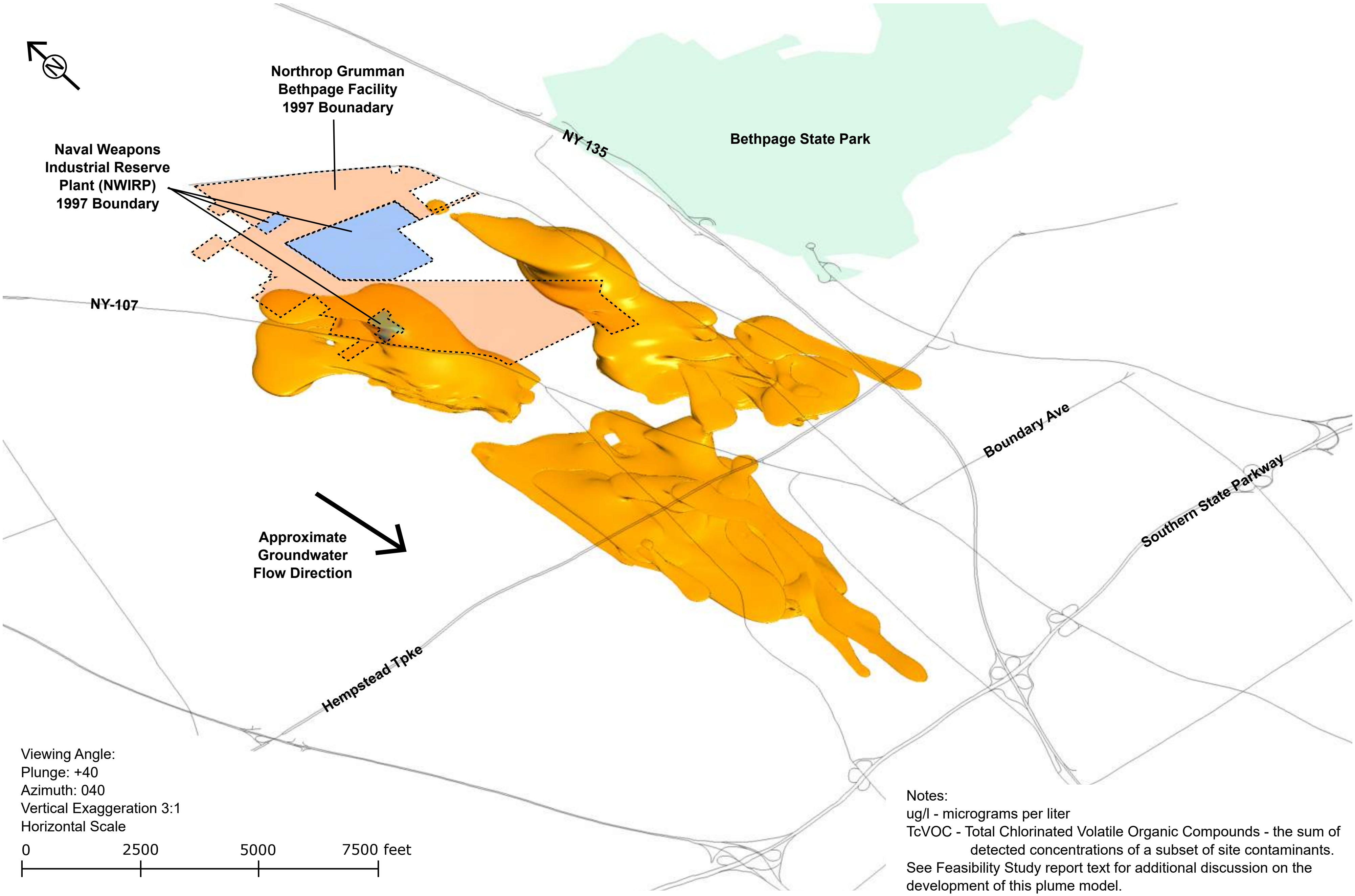
50 ug/l TcVOC PLUME - OBLIQUE 3D VIEW

NYSDEC SITE # 130003

FIGURE 3-3

USER: CMILLS DATE: 07/30/2018



Viewing Angle:
Plunge: +40
Azimuth: 040
Vertical Exaggeration 3:1
Horizontal Scale

0 2500 5000 7500 feet

Notes:
ug/l - micrograms per liter
TcVOC - Total Chlorinated Volatile Organic Compounds - the sum of detected concentrations of a subset of site contaminants.
See Feasibility Study report text for additional discussion on the development of this plume model.

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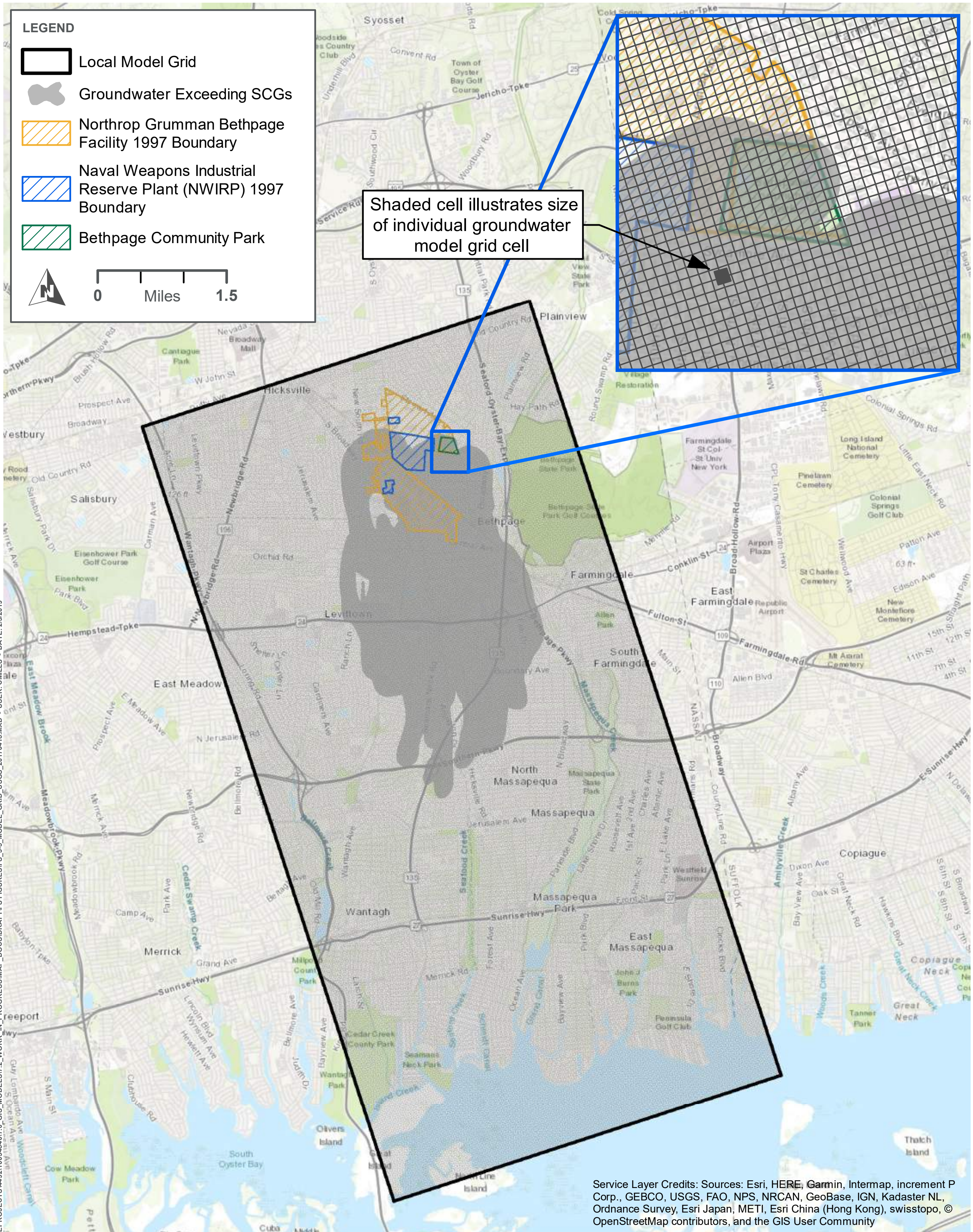
100 ug/l TcVOC PLUME - OBLIQUE 3D VIEW

NYSDEC SITE # 130003

FIGURE 3-4

USER: CMILLS DATE: 07/30/2018



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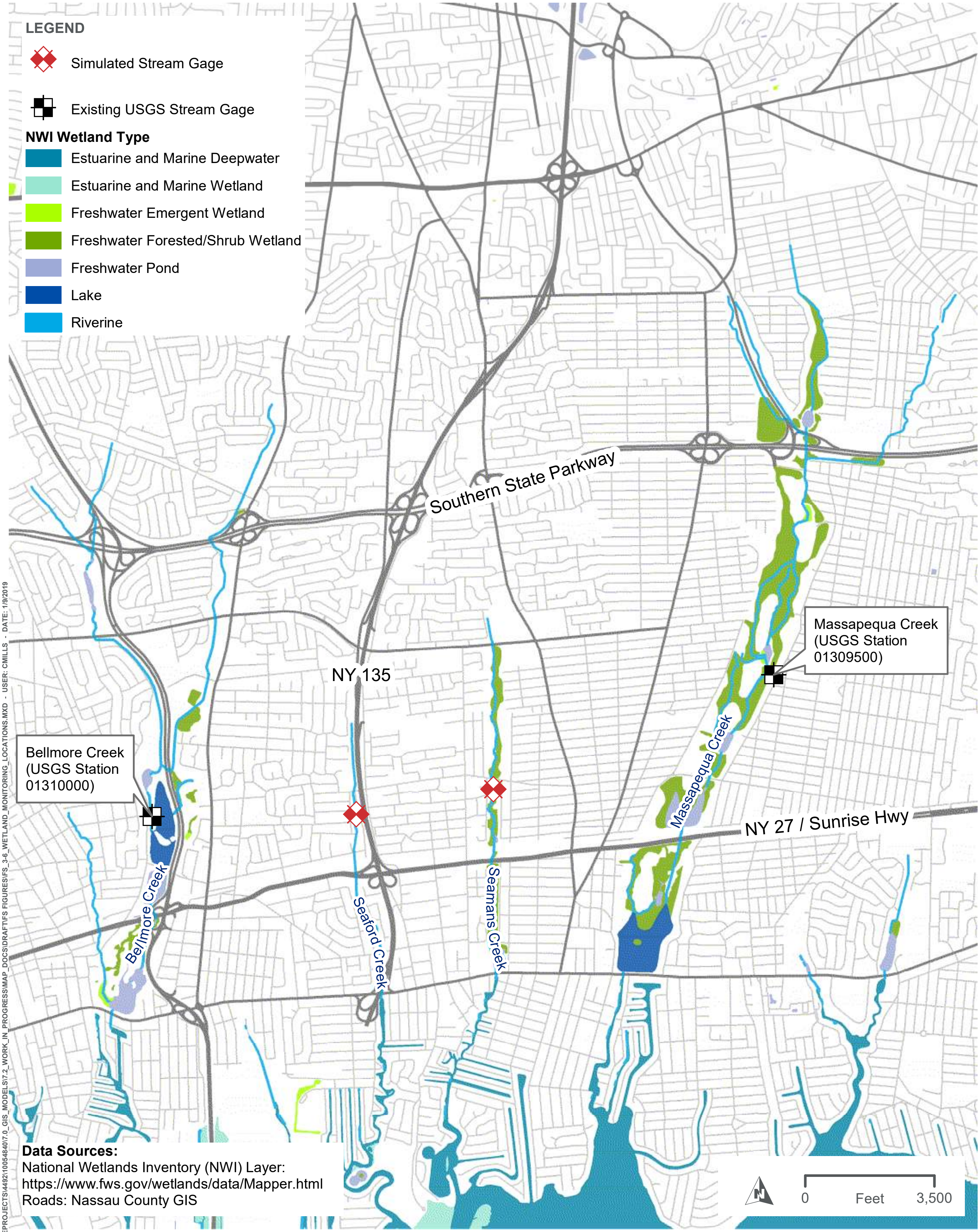
USGS GROUNDWATER MODEL GRID

NYSDEC SITE # 130003

FIGURE 3-5



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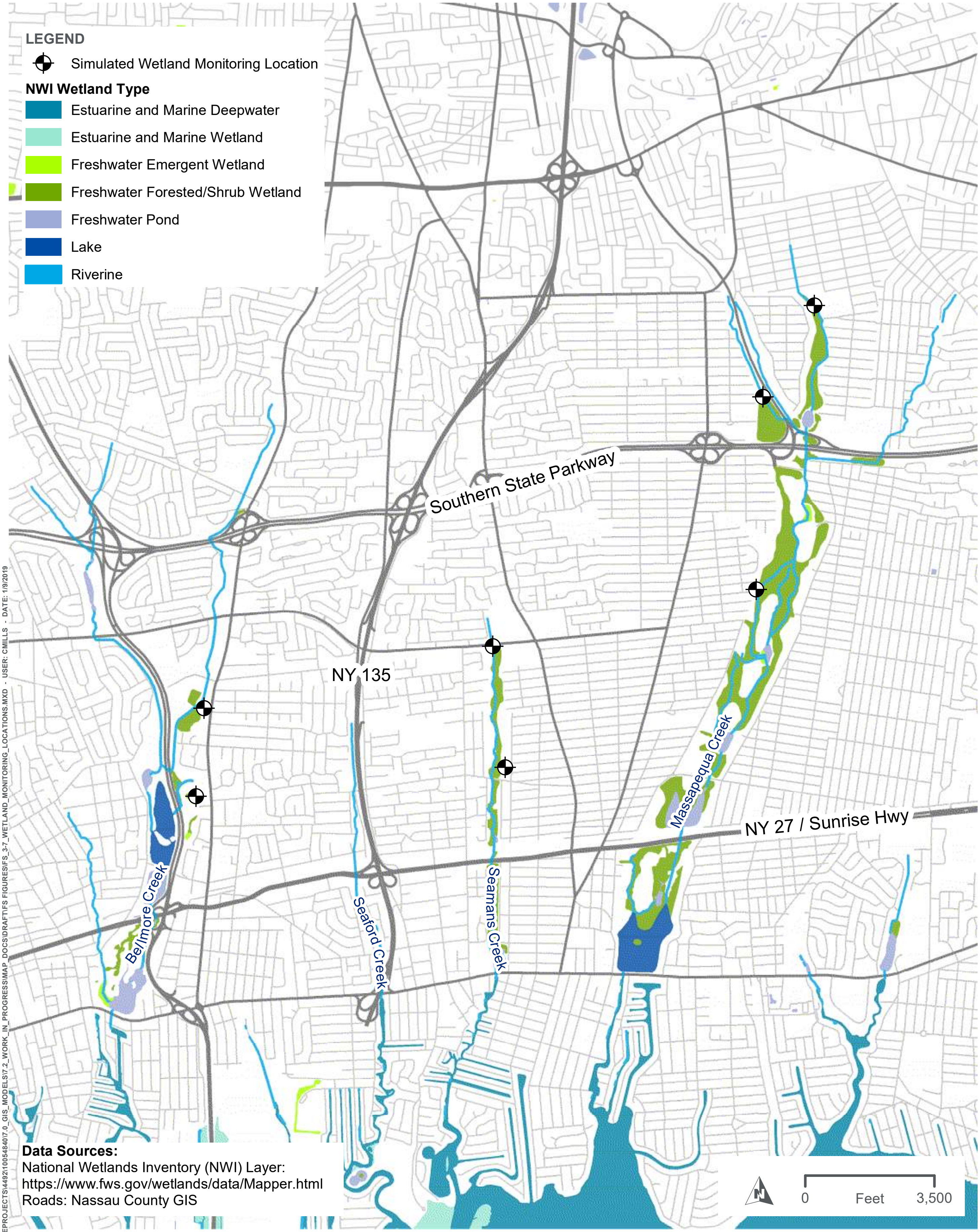
SIMULATED STREAM GAGE LOCATIONS

NYSDEC SITE # 130003

FIGURE 3-6



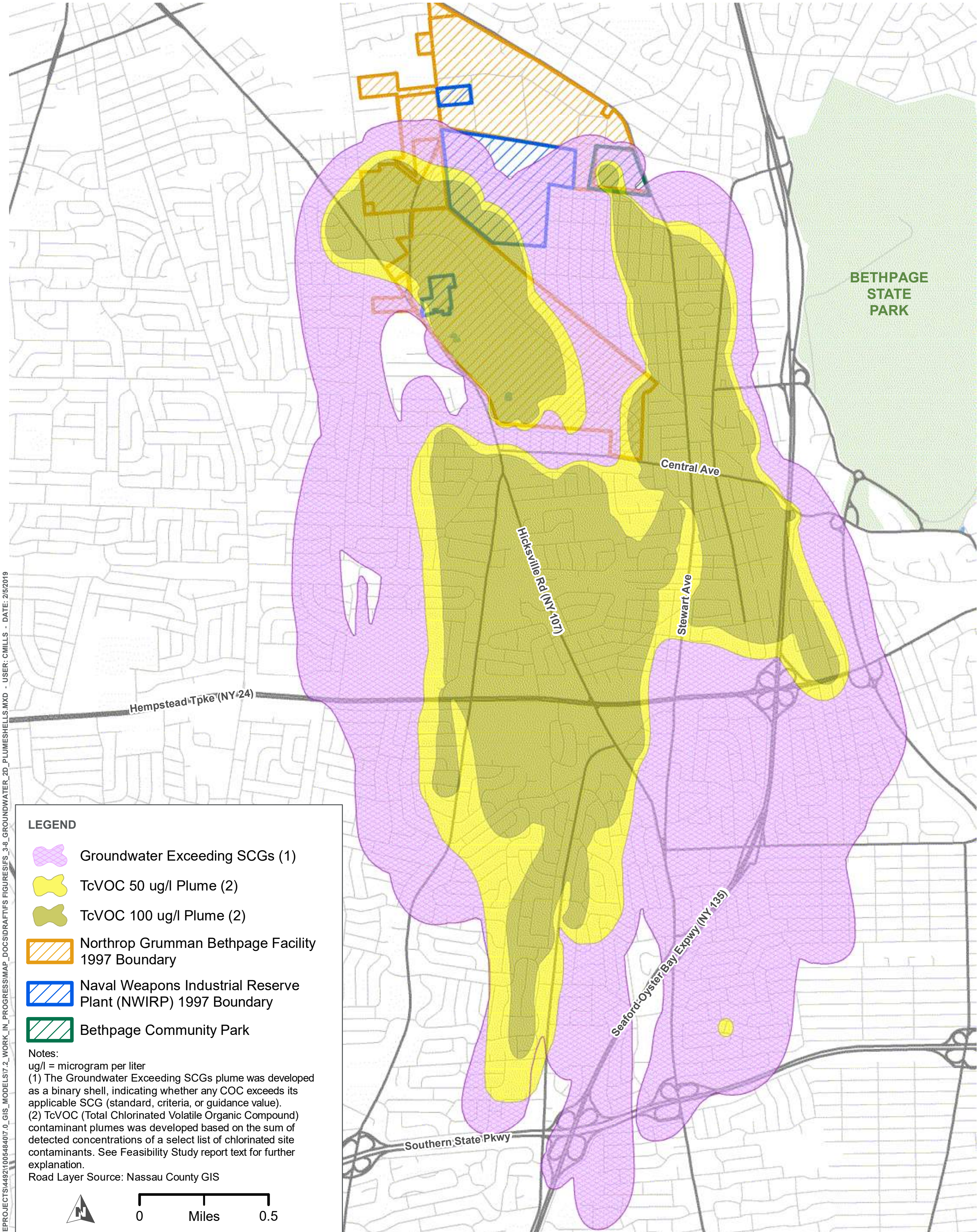
SIMULATED WETLAND MONITORING LOCATIONS

NYSDEC SITE # 130003

FIGURE 3-7

NORTHROP GRUMMAN BETHPAGE FACILITY / NWIRP FEASIBILITY STUDY REPORT

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_3-7_WETLAND_MONITORING_LOCATIONS.MXD - USER: CMILLS - DATE: 1/9/2019



PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\44921\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_3-8_GROUNDWATER_2D_PLUMESHELLS.MXD - USER: CMILLS - DATE: 2/5/2019

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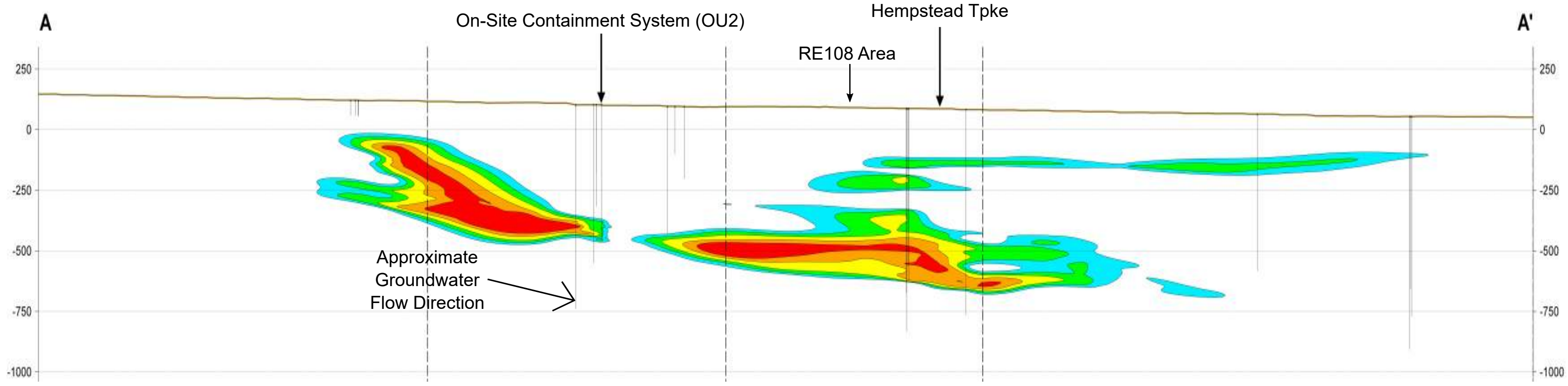
GROUNDWATER PLUMES

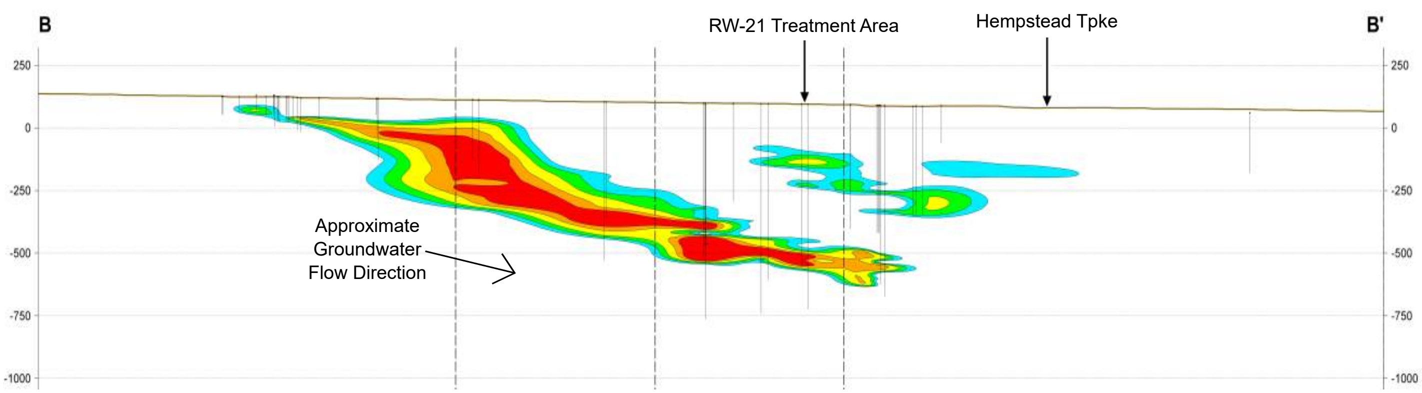
NYSDEC SITE # 130003

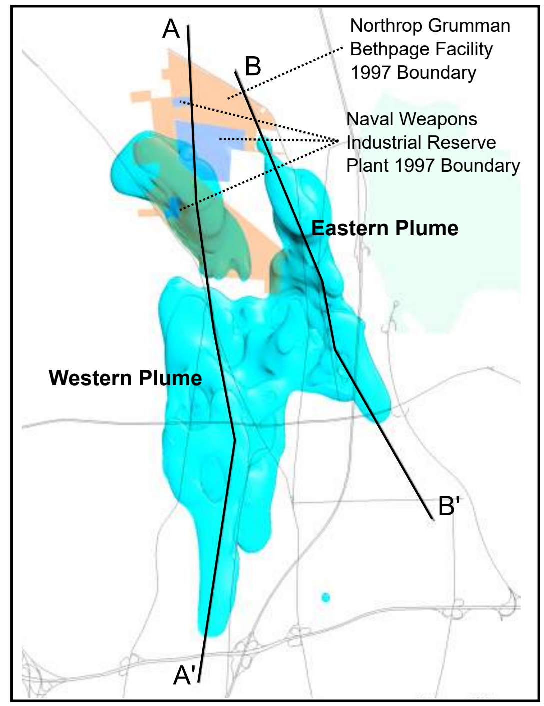
FIGURE 3-8

Western Plume



Eastern Plume





- 50 to 100 ug/l
- 100 - 200 ug/l
- 200 - 500 ug/l
- 500 - 1000 ug/l
- >1000 ug/l

Dashed lines are section breaks; Vertical Exaggeration: 3:1

0 2500 5000 feet

Notes:
ug/l - micrograms per liter
TcVOC - Total Chlorinated Volatile Organic Compounds - the sum of detected concentrations of a subset of site contaminants.
See Feasibility Study report text for additional discussion on the development of this plume model.

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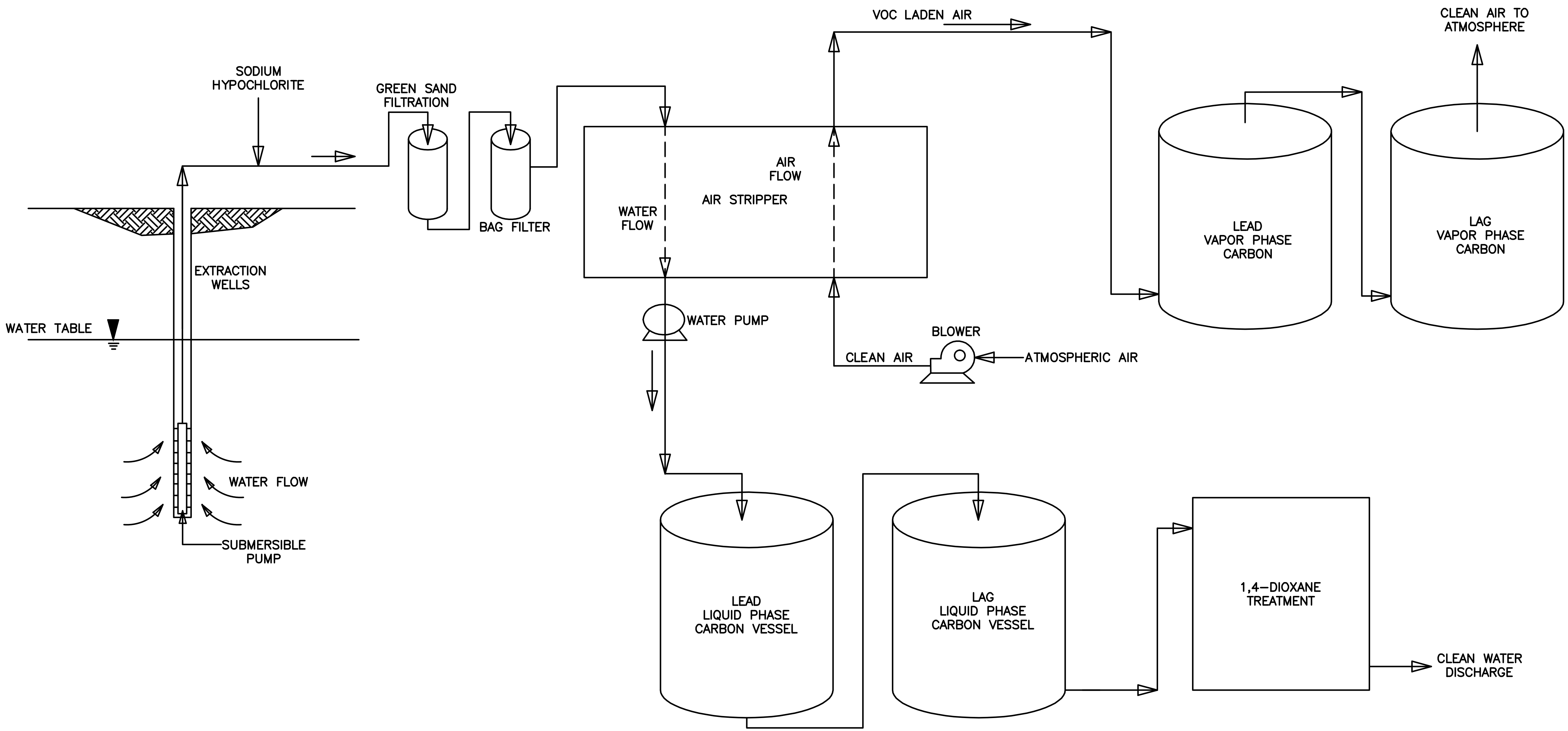
TcVOC GROUNDWATER PLUME CROSS-SECTIONS

NYSDEC SITE # 130003

FIGURE 3-9

USER: CMILLS DATE: 07/30/2018

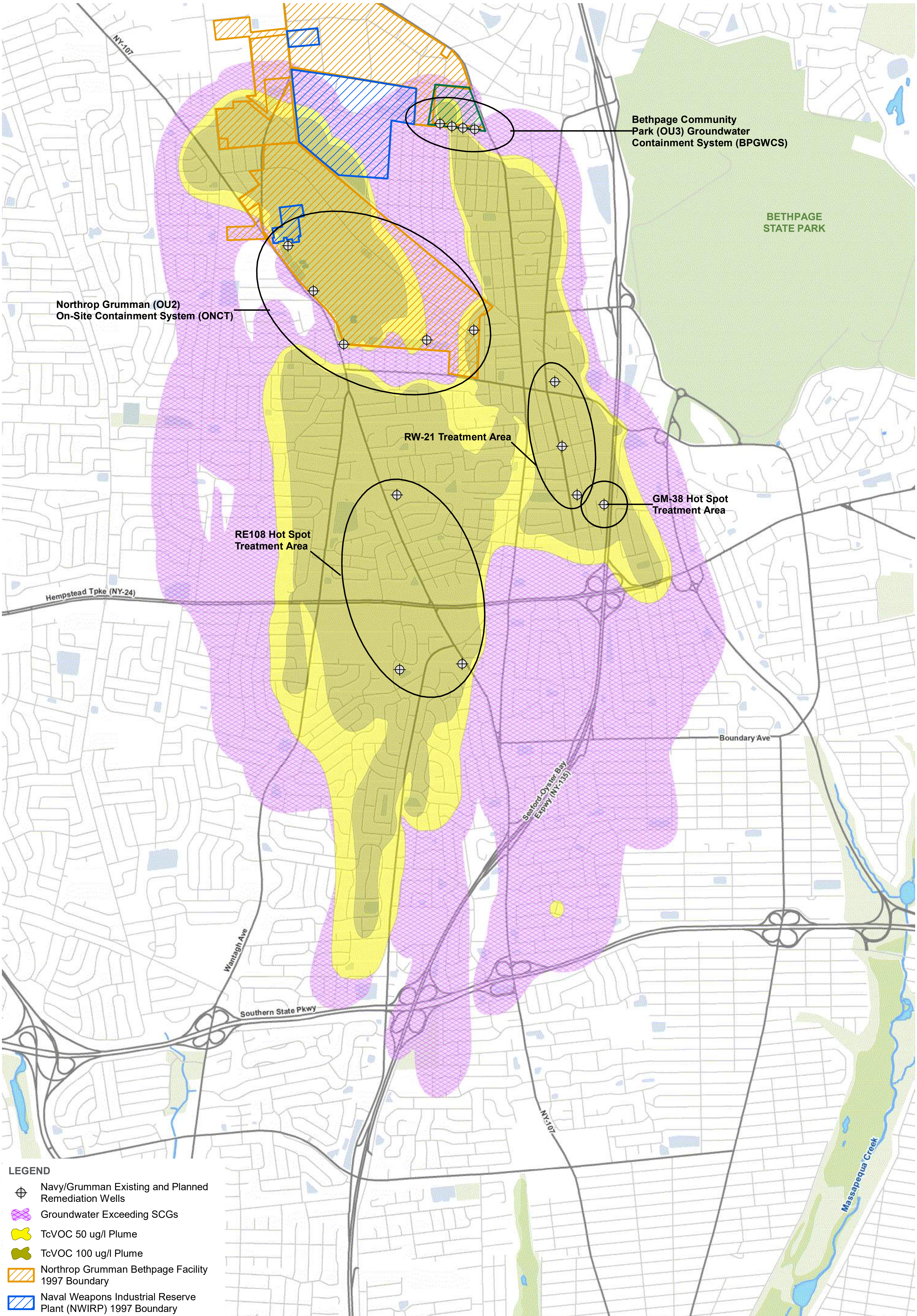


SCALE: NOT TO SCALE

TYPICAL TREATMENT SYSTEM PROCESS SCHEMATIC

NYSDEC SITE #130003

FIGURE 7-1



LEGEND

- Navy/Grumman Existing and Planned Remediation Wells
- Groundwater Exceeding SCGs
- TcVOC 50 ug/l Plume
- TcVOC 100 ug/l Plume
- Northrop Grumman Bethpage Facility 1997 Boundary
- Naval Weapons Industrial Reserve Plant (NWIRP) 1997 Boundary
- Bethpage Community Park
- Recharge Basin

See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
SCG - Standards, Criteria, and Guidance Values
Basemap information provided by Nassau County GIS.

0 Feet 2,000

ALTERNATIVE 1

NO FURTHER ACTION (EXISTING & PLANNED REMEDIAL SYSTEMS)

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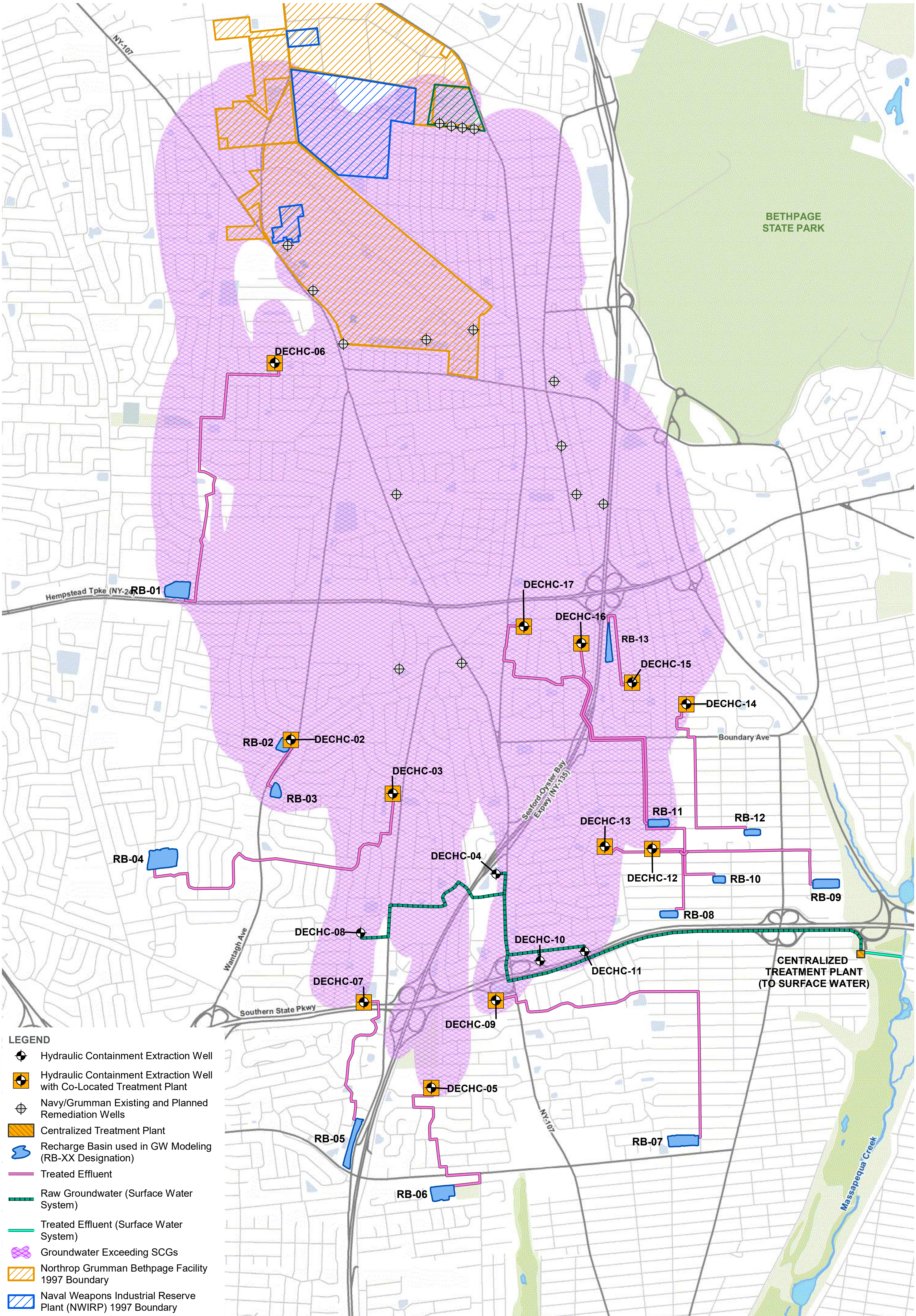
NYSDEC SITE # 130003

FIGURE 7-2

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
SCG - Standards, Criteria, and Guidance Values
Basemap information provided by Nassau County GIS.

ALTERNATIVE 2A

HYDRAULIC CONTAINMENT OF SITE CONTAMINANTS ABOVE SCGs – DECENTRALIZED TREATMENT PLANTS WITH VARIOUS DISCHARGE METHODS

NYSDEC SITE # 130003

FIGURE 7-3

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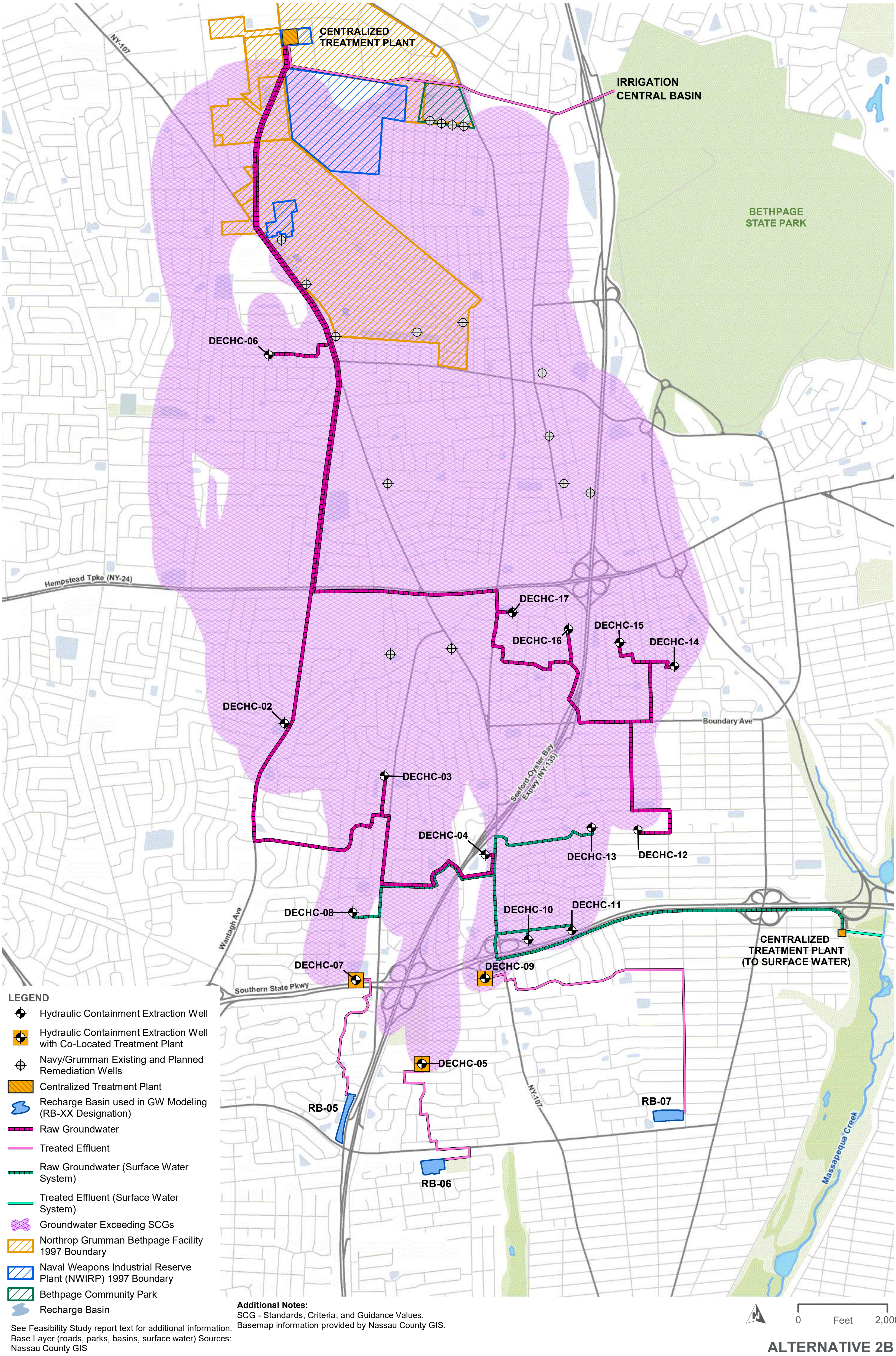
PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
SCG - Standards, Criteria, and Guidance Values.
Basemap information provided by Nassau County GIS.

ALTERNATIVE 2B

HYDRAULIC CONTAINMENT OF SITE CONTAMINANTS ABOVE SCGs – CENTRALIZED TREATMENT PLANTS WITH A CENTRALIZED RECHARGE BASIN

NYSDEC SITE # 130003

FIGURE 7-4

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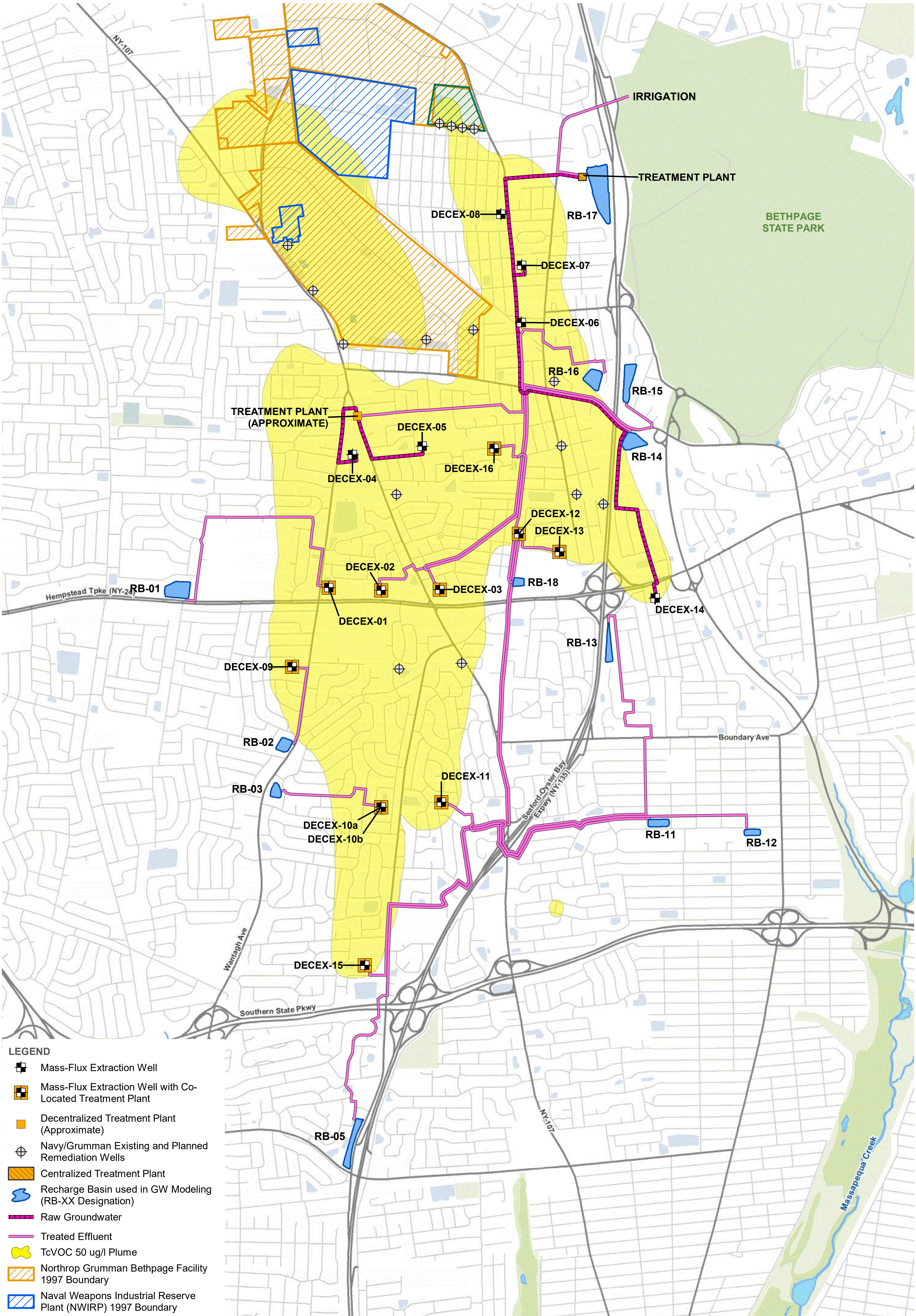

See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
Basemap information provided by Nassau County GIS.

ALTERNATIVE 3A
PLUME MASS FLUX REMEDIATION – DECENTRALIZED TREATMENT PLANTS WITH VARIOUS DISCHARGE METHODS
NYSDEC SITE # 130003

FDR
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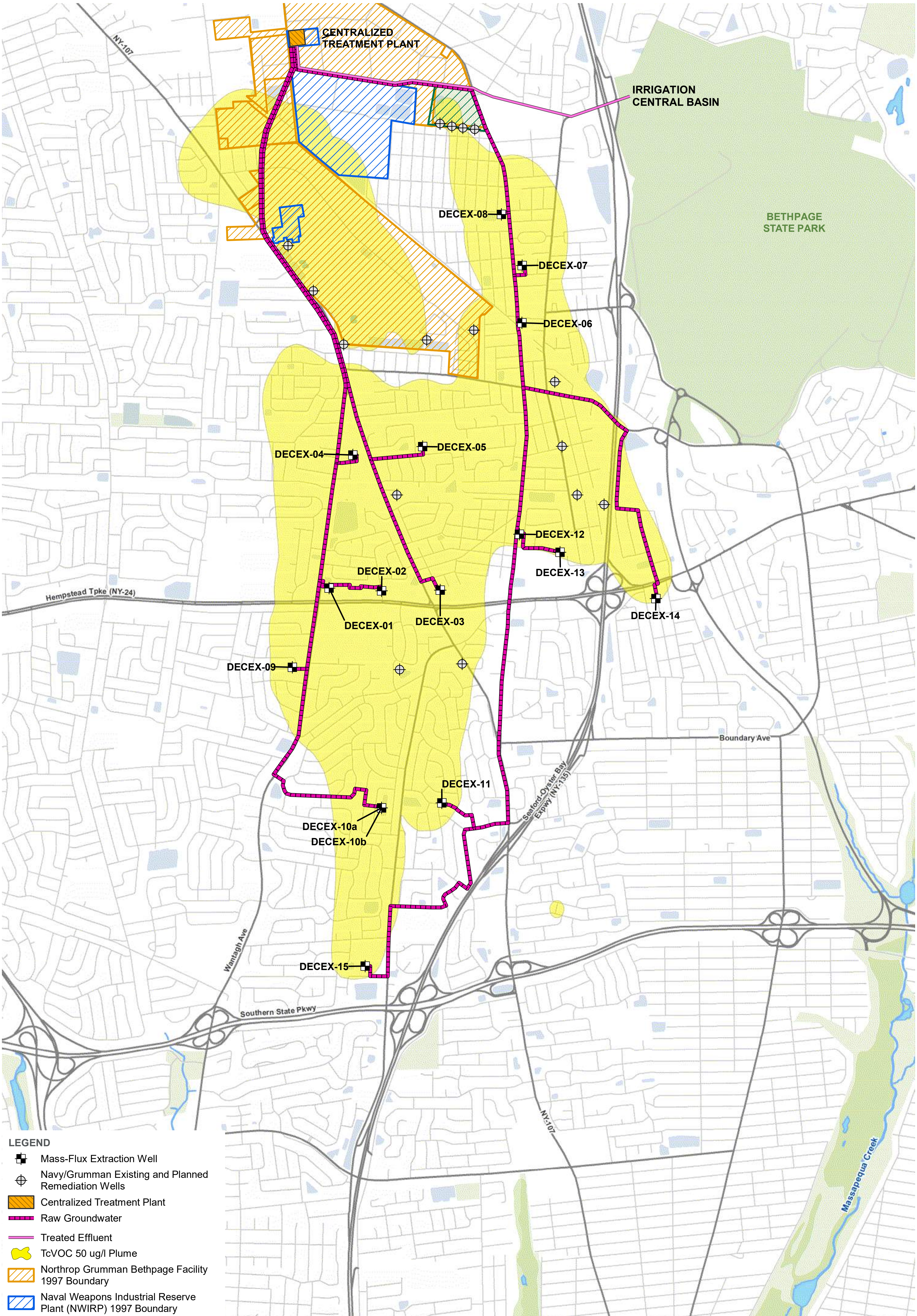
FIGURE 7-5



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
Basemap information provided by Nassau County GIS.

ALTERNATIVE 3B
PLUME MASS FLUX REMEDIATION –
CENTRALIZED TREATMENT PLANTS WITH A CENTRALIZED RECHARGE BASIN
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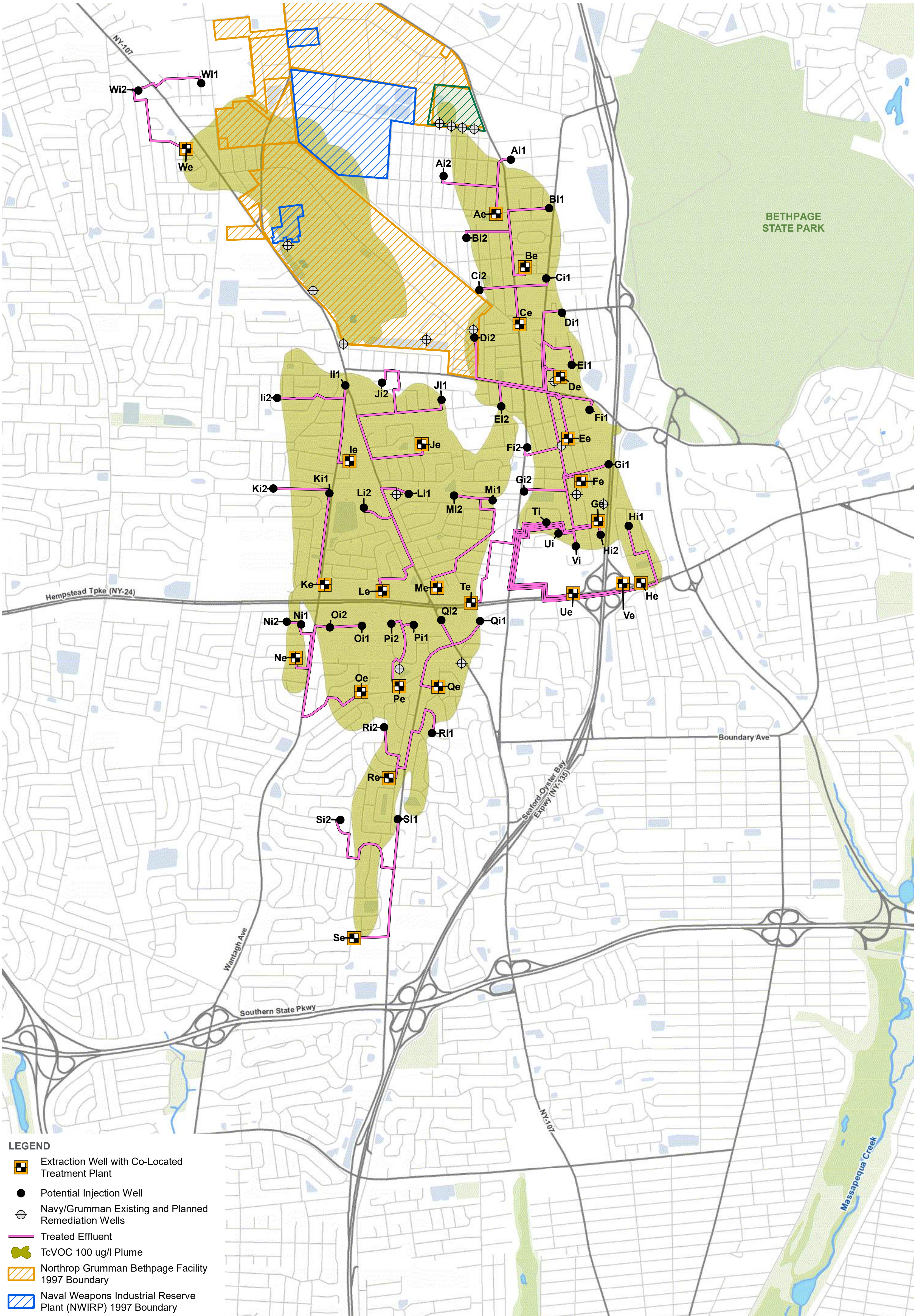
FIGURE 7-6

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
Basemap information provided by Nassau County GIS.

ALTERNATIVE 4
AQUIFER FLUSHING

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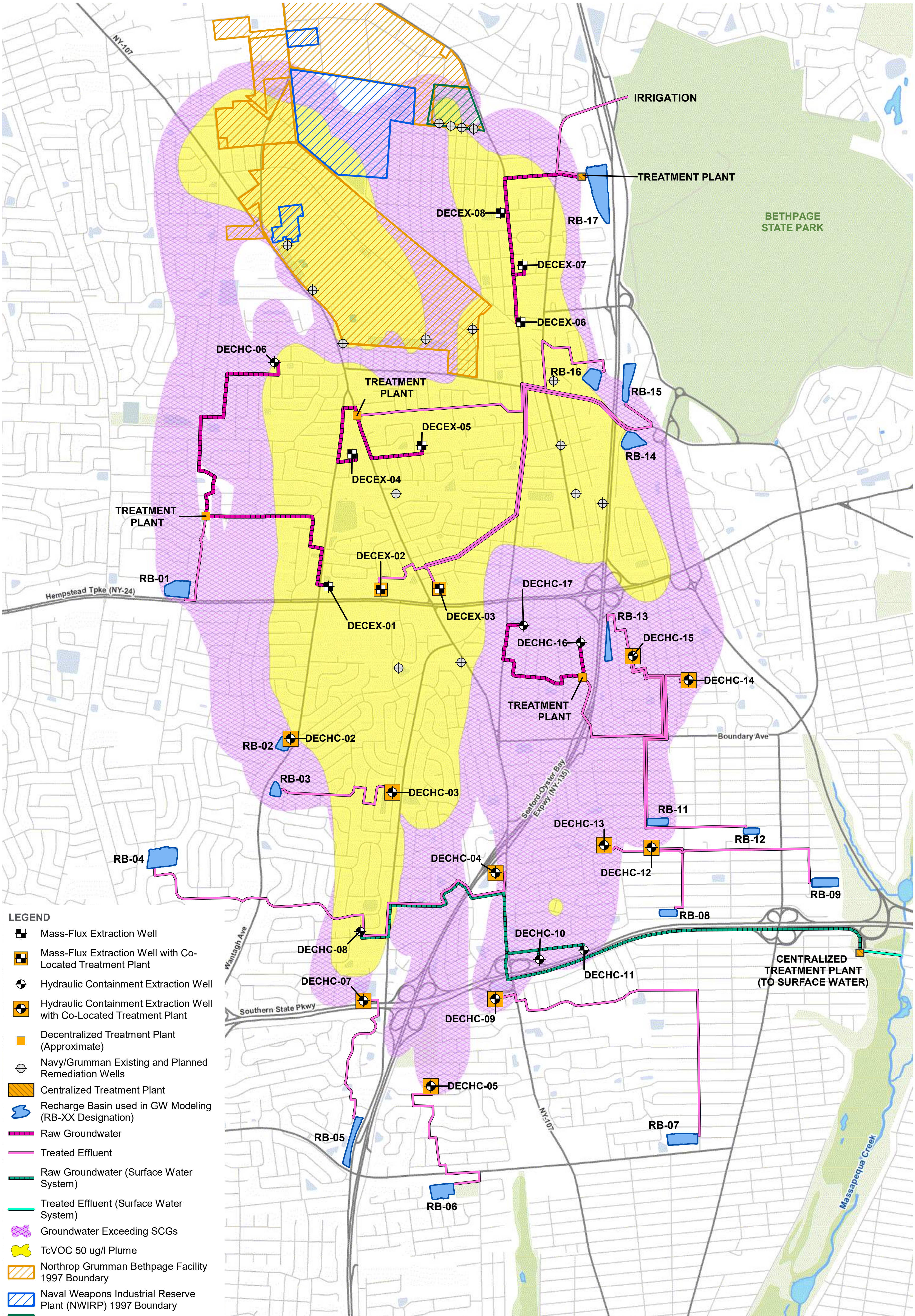
FIGURE 7-7

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
SCG - Standards, Criteria, and Guidance Values
Basemap information provided by Nassau County GIS.

ALTERNATIVE 5A
HYDRAULIC CONTAINMENT OF SITE CONTAMINANTS ABOVE SCGs COMBINED WITH MASS FLUX REMEDIATION – DECENTRALIZED TREATMENT PLANTS WITH VARIOUS DISCHARGE METHODS
NYSDEC SITE # 130003

FIGURE 7-8

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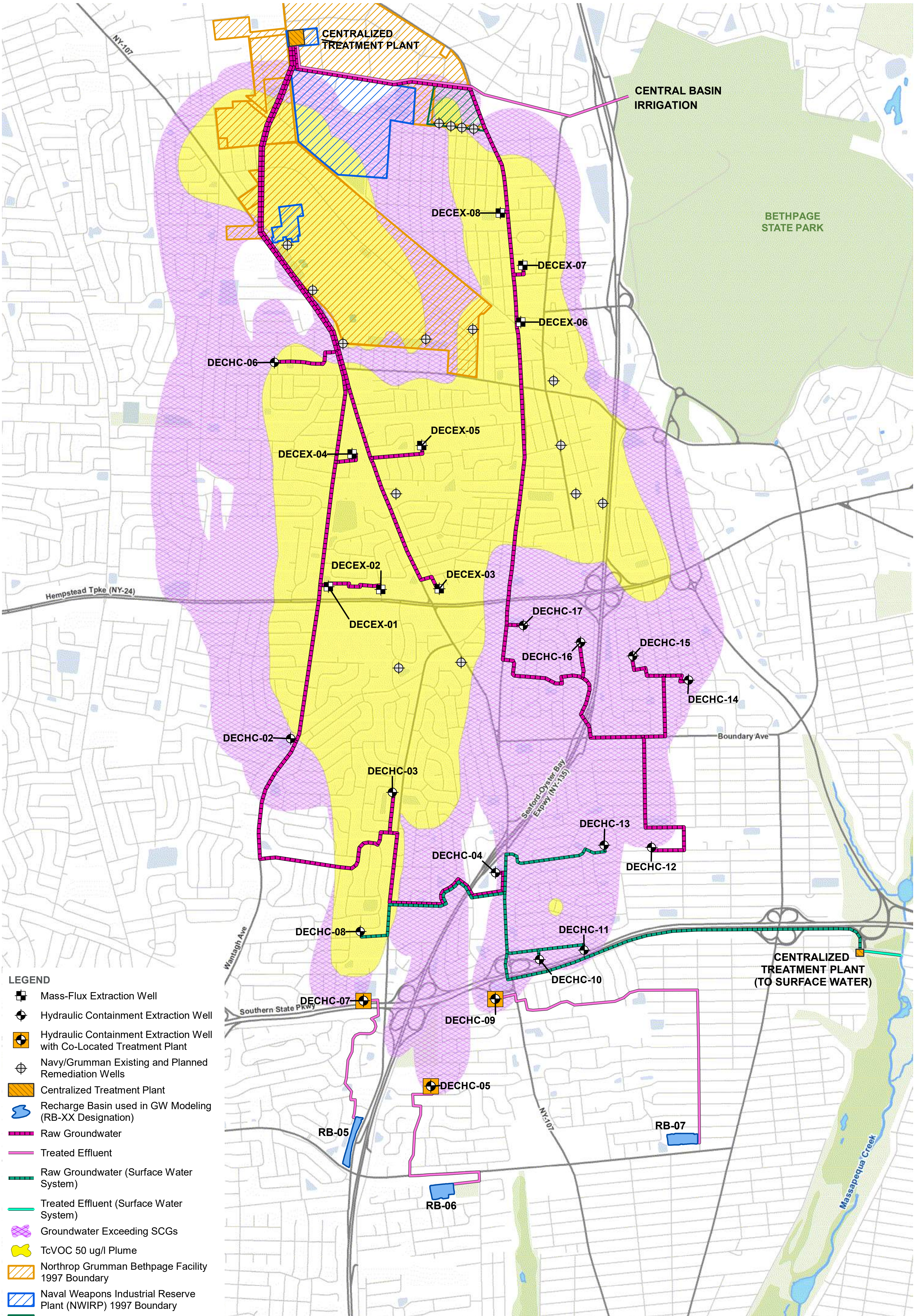
PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019



See Feasibility Study report text for additional information.
Base Layer (roads, parks, basins, surface water) Sources: Nassau County GIS

Additional Notes:
ug/l - micrograms per liter
TCVOC - Total Chlorinated Volatile Organic Compounds (subset list of site contaminants of concern)
SCG - Standards, Criteria, and Guidance Values
Basemap information provided by Nassau County GIS.

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ALTERNATIVE 5B

HYDRAULIC CONTAINMENT OF SITE CONTAMINANTS ABOVE SCGs COMBINED WITH MASS FLUX REMEDIATION – CENTRALIZED TREATMENT PLANTS WITH A CENTRALIZED RECHARGE BASIN

NYSDEC SITE # 130003

FIGURE 7-9

PATH: \\MAHPI-FILE01\ACTIVEPROJECTS\4492\10054840\7.0_GIS_MODELS\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FS FIGURES\FS_7-2_TO_7-9_DESIGNALTERNATIVES 11X17.MXD - USER: CMILLS - DATE: 2/5/2019

APPENDIX A

Breakdown of Costs for Groundwater Remedial Alternatives

Table A-1 - Alternative 1 Cost Breakdown

No Further Action (With Existing & Planned Remedial Systems)

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: No Further Action (With Existing & Planned Remedial Systems)

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
1	**TOTAL CAPITAL COST**				**$ -**	

O&M COST:

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2	**Long-Term Monitoring and Reporting**					
2.1	Site-Wide Long-Term Monitoring	0	LS	$ 121,700	$ -	
	Sub-Total				**$ -**	
	Project Management	5%			$ -	
	Contingency	10%			$ -	5% scope + 5% bid.
	Sub-Total				**$ -**	

PERIODIC COSTS:

Item No.	Description	Year	Quantity	Unit	Unit Cost	Total	Notes
3	**ICs**						
3.1	Institutional Controls	5	0	LS	$ 25,000	$ -	
	Sub-Total					**$ -**	
	Project Management		5%			$ -	
	Contingency		10%			$ -	5% scope + 5% bid.
	Sub-Total					**$ -**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
1	**Capital Cost**	0	$ -	**$ -**	
2	**O & M**				
2.1	Long-Term Monitoring and Reporting		$ -	$ -	Annual cost for the life of the system
	Sub-Total			**$ -**	**NPV Assuming 3% Discount Rate**
3	**Periodic Costs**				
3.1	ICs	5	$ -	$ -	Every 5 years
	Sub-Total			**$ -**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ -**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-2A - Alternative 2A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2A includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 13 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 13 existing recharge basins (with a contingency for the construction of 3 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**16**				
	Number of ~ 300 ft deep extraction wells	7				
	Number of ~ 600 ft deep extraction wells	4				
	Number of ~ 800 ft deep extraction wells	5				
	Total Number of 500 GPM (0.7 MGD) Treatment Plants	**6**				
	Total Number of 1000 GPM (1.4 MGD) Treatment Plants	**6**				
	Total Number of 2,250 (3.2 MGD) GPM Treatment Plants	**1**				
	Total Number of Recharge Basins	**16**				
	Number of Contingent New Recharge Basins	3				
	Number of Existing Recharge Basins	13				
1. CAPITAL COSTS:						
1.0	**Pre-Design Investigation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Groundwater Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	7	EA	$ 638,000	$4,466,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	4	EA	$ 879,700	$3,518,800	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	5	EA	$ 973,900	$4,869,500	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	16	EA	$ 346,500	$5,544,000	
	Sub-Total				**$ 18,660,800**	
1.2A	**Treatment - 500 GPM (0.7 MGD)**					
1.2A.1	Land Acquisition for Treatment Plant	6	EA	$ 500,000	$3,000,000	
1.2A.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	6	EA	$ 267,200	$1,603,200	
1.2A.3	Site Work	6	EA	$ 19,200	$115,200	
1.2A.4	Electrical & Instrumentation	6	EA	$ 1,025,000	$6,150,000	
1.2A.5	Process Equipment	6	EA	$ 1,171,400	$7,028,400	
1.2A.6	Start-Up and Reporting	6	EA	$ 78,000	$468,000	
	Sub-Total				**$ 18,364,800**	
1.2B	**Treatment - 1,000 GPM (1.4 MGD)**					
1.2B.1	Land Acquisition for Treatment Plant	6	EA	$ 1,000,000	$6,000,000	
1.2B.2	1000 GPM Decentralized Plant Building Construction	6	EA	$ 306,100	$1,836,600	
1.2B.3	Site Work	6	EA	$ 31,600	$189,600	
1.2B.4	Electrical & Instrumentation	6	EA	$ 1,025,000	$6,150,000	
1.2B.5	Process Equipment	6	EA	$ 1,620,500	$9,723,000	
1.2B.6	Start-Up and Reporting	6	EA	$ 96,000	$576,000	
	Sub-Total				**$ 24,475,200**	
1.2C	**Treatment - 2,250 GPM (3.2 MGD)**					
1.2C.1	Land Acquisition for Treatment Plant	1	EA	$ -	$0	
1.2C.2	~ 2250 GPM (3.2 MGD) Plant Building Construction	1	EA	$ 485,900	$485,900	
1.2C.3	Site Work	1	EA	$ 21,100	$21,100	
1.2C.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2C.5	Process Equipment	1	EA	$ 3,812,500	$3,812,500	
1.2C.6	Start-Up and Reporting	1	EA	$ 321,000	$321,000	
	Sub-Total				**$ 5,665,500**	
1.3A	**Discharge - Contingent New Recharge Basin**					
1.3A.1	Land Cost	3	EA	$ 3,000,000	$9,000,000	
1.3A.2	Site Preparation	3	EA	$ 50,000	$150,000	
1.3A.3	Recharge Basin Construction	3	EA	$ 215,200	$645,600	
1.3A.4	Miscellaneous Cost	3	EA	$ 43,100	$129,300	
	Sub-Total				**$ 9,924,900**	
1.3B	**Discharge - Existing Recharge Basin**					
1.3B.1	Recharge Basin Re-Work Costs	13	EA	$ 42,000	$546,000	
	Sub-Total				**$ 546,000**	
1.3C	**Discharge - Surface Water**					
1.3C.1	Surface Water Discharge Infrastructure	1	LS	$ 100,000	$100,000	
	Sub-Total				**$ 100,000**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 36,400,000	$36,400,000	
1.4.2	Pumps and Booster Stations	1	LS	$ 4,000,000	$4,000,000	
	Sub-Total				**$ 40,400,000**	
	Sub-Total				**$ 140,137,200**	Sub-Total All Construction Costs.
	Sub-Total					
	Contingency	25%			$ 35,034,000	10% scope + 15% bid.
	Sub-Total				**$ 175,171,200**	
	Project Management	5%			$ 8,759,000	
	Remedial Design	6%			$ 10,510,000	
	Construction Management	6%			$ 10,510,000	
	Construction Oversight	3%			$ 5,255,000	
	TOTAL CAPITAL COST				**$ 210,206,000**	

Table A-2A - Alternative 2A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2A includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 13 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 13 existing recharge basins (with a contingency for the construction of 3 new recharge basins) for groundwater discharge.

Item No.	Description	Frequency	Quantity	Unit	Unit Cost	Total	Notes
2. OPERATIONAL AND MAINTENANCE COSTs:							
2.0	**Annual O & M (Extraction)**						
2.0.1	Annual Power (Extraction)		16	EA	$ 47,100	$753,600	
2.0.2	Annual Power (Pump Stations)		1	LS	$ 1,003,400	$1,003,400	
	Sub-Total					**$ 1,757,000**	
2.1A	**Annual O & M - ~ 500 GPM (0.7 MGD)**						
2.1A.1	Annual Operational Labor		6	EA	$ 101,600	$609,600	
2.1A.2	Annual Power (Treatment)		6	EA	$ 187,800	$1,126,800	
2.1A.3	Annual Material/Chemicals Usage		6	EA	$ 236,700	$1,420,200	
2.1A.4	Annual System Maintenance		6	EA	$ 51,400	$308,400	
2.1A.5	Treatment Plant Monitoring		6	EA	$ 116,600	$699,600	
	Sub-Total					**$ 4,164,600**	
2.1B	**Annual O & M - 1,000 GPM (1.4 MGD)**						
2.1B.1	Annual Operational Labor		6	EA	$ 136,700	$820,200	
2.1B.2	Annual Power (Treatment)		6	EA	$ 210,300	$1,261,800	
2.1B.3	Annual Material/Chemicals Usage		6	EA	$ 466,200	$2,797,200	
2.1B.4	Annual System Maintenance		6	EA	$ 51,400	$308,400	
2.1B.5	Treatment Plant Monitoring		6	EA	$ 116,600	$699,600	
	Sub-Total					**$ 5,887,200**	
2.1C	**Annual O & M - 2,250 GPM (3.2 MGD)**						
2.1C.1	Annual Operational Labor		1	EA	$ 136,700	$136,700	
2.1C.2	Annual Power (Treatment)		1	EA	$ 563,700	$563,700	
2.1C.3	Annual Material/Chemicals Usage		1	EA	$ 1,158,500	$1,158,500	
2.1C.4	Annual System Maintenance		1	EA	$ 51,400	$51,400	
2.1C.5	Treatment Plant Monitoring		1	EA	$ 116,600	$116,600	
	Sub-Total					**$ 2,026,900**	
2.2	**Site-Wide Long-Term Monitoring**						
2.2.1	Site-Wide Long-Term Monitoring		1	EA	$ 121,700	$121,700	
	Sub-Total					**$ 121,700**	
2.3	**Recharge Basin Maintenance**						
2.3.1	Recharge Basin Maintenance (~ 1,000 GPM)		16	EA	$ 28,900	$462,400	
	Sub-Total					**$ 462,400**	
	Sub-Total					**$ 14,419,800**	Sub-Total All Annual O & M Costs.
	Sub-Total						
	Contingency		10%			$ 1,442,000	5% scope + 5% bid.
	Sub-Total					**$ 15,861,800**	
	Project Management		5%			$ 793,000	
	TOTAL ANNUAL O & M COST					**$ 16,654,800**	
3. PERIODIC COSTS:		**Frequency**					
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	16	EA	$ 15,000	$240,000	
	Contingency		15%			$ 36,000	10% scope + 5% bid.
	Sub-Total					**$ 276,000**	
	Project Management		5%			$ 14,000	
	Technical Support		3%			$ 8,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 298,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	16	EA	$ 80,000	$1,280,000	
3.2.2	Bag Filter Pump Replacement	5	15	EA	$ 25,000	$375,000	
3.2.3	Air Stripper Cleaning	5	15	EA	$ 24,400	$366,000	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 112,000	$112,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 2,158,000**	
	Contingency		10%			$ 216,000	5% scope + 5% bid.
	Sub-Total					**$ 2,374,000**	
	Project Management		5%			$ 119,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 2,493,000**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	16	EA	$ 85,000	$1,360,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 800,000	$800,000	
3.3.3	Recharge Basin Rehabilitation	10	16	EA	$ 8,000	$128,000	
	Sub-Total					**$ 2,288,000**	
	Contingency		10%			$ 229,000	5% scope + 5% bid.
	Sub-Total					**$ 2,517,000**	
	Project Management		5%			$ 126,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 2,643,000**	

Table A-2A - Alternative 2A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2A includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 13 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 13 existing recharge basins (with a contingency for the construction of 3 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.		Cost Type	Year	Total Cost	Present Value	Notes
A		**1. CAPITAL COSTS:**	0	$ 210,206,000	**$ 210,206,000**	
B		**2. OPERATIONAL AND MAINTENANCE COSTs:**				
		TOTAL ANNUAL O & M COST		$ 16,654,800	$326,442,000	Annual cost for the life of the system
		Sub-Total			**$ 326,442,000**	**NPV Assuming 3% Discount Rate**
C		**Periodic Costs**				
	3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 298,000	$ 2,878,000	Every 2 years
	3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 2,493,000	$ 9,204,000	Every 5 years
	3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 2,643,000	$ 4,519,000	Every 10 years
		Sub-Total			**$ 16,601,000**	**NPV Assuming 3% Discount Rate**
		TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 553,249,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-2B - Alternative 2B Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**16**				
	Number of ~300 ft deep extraction wells	7				
	Number of ~600 ft deep extraction wells	4				
	Number of ~800 ft deep extraction wells	5				
	Total Number of 500 GPM (0.7 MGD) Treatment Plants	**1**				
	Total Number of 1,000 GPM (1.4 MGD) Treatment Plants	**2**				
	Total Number of 2,000 GPM (2.9 MGD) Treatment Plants	**1**				
	Total Number of 5,150 GPM (7.4 MGD) Treatment Plants	**1**				
	Total Number of Recharge Basins	**4**				
	Number of New Recharge Basins	1				
	Number of Existing Recharge Basins	3				
1. CAPITAL COSTS:						
1.0	**Pre-Design Investigation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	7	EA	$ 638,000	$4,466,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	4	EA	$ 879,700	$3,518,800	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	5	EA	$ 973,900	$4,869,500	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	16	EA	$ 346,500	$5,544,000	
	Sub-Total				**$ 18,660,800**	
1.2A	**Treatment - 500 GPM (0.7 MGD)**					
1.2A.1	Land Acquisition for Treatment Plant	1	EA	$ 500,000	$500,000	
1.2A.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	1	EA	$ 267,200	$267,200	
1.2A.3	Site Work	1	EA	$ 19,200	$19,200	
1.2A.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2A.5	Process Equipment	1	EA	$ 1,171,400	$1,171,400	
1.2A.6	Start-Up and Reporting	1	EA	$ 78,000	$78,000	
	Sub-Total				**$ 3,060,800**	
1.2B	**Treatment - 1,000 GPM (1.4 MGD)**					
1.2B.1	Land Acquisition for Treatment Plant	2	EA	$ 1,000,000	$2,000,000	
1.2B.2	1000 GPM Decentralized Plant Building Construction	2	EA	$ 306,100	$612,200	
1.2B.3	Site Work	2	EA	$ 31,600	$63,200	
1.2B.4	Electrical & Instrumentation	2	EA	$ 1,025,000	$2,050,000	
1.2B.5	Process Equipment	2	EA	$ 1,620,500	$3,241,000	
1.2B.6	Start-Up and Reporting	2	EA	$ 96,000	$192,000	
	Sub-Total				**$ 8,158,400**	
1.2C	**Treatment - 2,000 GPM (2.9 MGD)**					
1.2C.1	Land Acquisition for Treatment Plant	1	EA	$ -	$0	
1.2C.2	~ 2250 GPM (3.2 MGD) Plant Building Construction	1	EA	$ 485,900	$485,900	
1.2C.3	Site Work	1	EA	$ 21,100	$21,100	
1.2C.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2C.5	Process Equipment	1	EA	$ 3,812,500	$3,812,500	
1.2C.6	Start-Up and Reporting	1	EA	$ 321,000	$321,000	
	Sub-Total				**$ 5,665,500**	
1.2D	**Treatment - 5,150 GPM (7.4 MGD)**					
1.2D.1	Land Acquisition for Treatment Plant	1	EA	$ 2,500,000	$2,500,000	
1.2D.2	5150 GPM (7.4 MGD) Plant Building Construction	1	EA	$ 826,100	$826,100	
1.2D.3	Site Work	1	EA	$ 31,200	$31,200	
1.2D.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2D.5	Process Equipment	1	EA	$ 6,820,700	$6,820,700	
1.2D.6	Start-Up and Reporting	1	EA	$ 960,000	$960,000	
	Sub-Total				**$ 12,163,000**	
1.3A	**DO A - Recharge Basin - 5,150 GPM (7.4 MGD)**					
1.3A.1	Land Cost	1	EA	$ -	$0	Assumes no costs as state owned property will be used to construct recharge basin
1.3A.2	Site Preparation	1	EA	$ 500,000	$500,000	
1.3A.3	Recharge Basin Construction	1	EA	$ 2,497,000	$2,497,000	
1.3A.4	Miscellaneous Cost	1	EA	$ 499,400	$499,400	
	Sub-Total				**$ 3,496,400**	
1.3B	**Discharge - Existing Recharge Basin**					
1.3B.1	Recharge Basin Re-Work Costs	3	EA	$ 42,000	$126,000	
	Sub-Total				**$ 126,000**	
1.3C	**Discharge - Surface Water**					
1.3C.1	Surface Water Discharge Infrastructure	1	LS	$ 100,000	$100,000	
	Sub-Total				**$ 100,000**	
1.3D	**Discharge - Beneficial Reuse (Irrigation)**					
1.3D.1	Beneficial Reuse Infrastructure	1	LS	$ 1,700,000	$1,700,000	
	Sub-Total				**$ 1,700,000**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 48,897,200	$48,897,200	
1.4.2	Pumps and Booster Stations	1	LS	$ 5,900,000	$5,900,000	
	Sub-Total				**$ 54,797,200**	
	Sub-Total				**$ 129,928,100**	Sub-Total All Construction Costs.

Table A-2B - Alternative 2B Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Sub-Total					
	Contingency	25%			$ 32,482,000	10% scope + 15% bid.
	Sub-Total				**$ 162,410,100**	
	Project Management	5%			$ 8,121,000	
	Remedial Design	6%			$ 9,745,000	
	Construction Management	6%			$ 9,745,000	
	Construction Oversight	3%			$ 4,872,000	
	TOTAL CAPITAL COST				**$ 194,894,000**	

2. OPERATIONAL AND MAINTENANCE COSTS:

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2.0	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	16	EA	$ 47,100	$753,600	
2.0.2	Annual Power (Pump Stations)	1	LS	$ 1,881,400	$1,881,400	
	Sub-Total				**$ 2,635,000**	
2.1A	**Annual O & M - ~ 500 GPM (0.7 MGD)**					
2.1A.1	Annual Operational Labor	1	EA	$ 101,600	$101,600	
2.1A.2	Annual Power (Treatment)	1	EA	$ 187,800	$187,800	
2.1A.3	Annual Material/Chemicals Usage	1	EA	$ 236,700	$236,700	
2.1A.4	Annual System Maintenance	1	EA	$ 51,400	$51,400	
2.1A.5	Treatment Plant Monitoring	1	EA	$ 116,600	$116,600	
	Sub-Total				**$ 694,100**	
2.1B	**Annual O & M - 1,000 GPM (1.4 MGD)**					
2.1B.1	Annual Operational Labor	2	EA	$ 136,700	$273,400	
2.1B.2	Annual Power (Treatment)	2	EA	$ 210,300	$420,600	
2.1B.3	Annual Material/Chemicals Usage	2	EA	$ 466,200	$932,400	
2.1B.4	Annual System Maintenance	2	EA	$ 51,400	$102,800	
2.1B.5	Treatment Plant Monitoring	2	LS	$ 116,600	$233,200	
	Sub-Total				**$ 1,962,400**	
2.1C	**Annual O & M - 2,250 GPM (3.2 MGD)**					
2.1C.1	Annual Operational Labor	1	EA	$ 136,700	$136,700	
2.1C.2	Annual Power (Treatment)	1	EA	$ 563,700	$563,700	
2.1C.3	Annual Material/Chemicals Usage	1	EA	$ 1,158,500	$1,158,500	
2.1C.4	Annual System Maintenance	1	EA	$ 51,400	$51,400	
2.1C.5	Treatment Plant Monitoring	1	LS	$ 116,600	$116,600	
	Sub-Total				**$ 2,026,900**	
2.1D	**Annual O & M - 5,150 GPM (7.4 MGD)**					
2.1D.1	Annual Operational Labor	1	EA	$ 677,100	$677,100	
2.1D.2	Annual Power (Treatment)	1	EA	$ 1,348,400	$1,348,400	
2.1D.3	Annual Material/Chemicals Usage	1	EA	$ 1,537,000	$1,537,000	
2.1D.4	Annual System Maintenance	1	EA	$ 513,600	$513,600	
2.1D.5	Treatment Plant Monitoring	1	EA	$ 116,600	$116,600	
	Sub-Total				**$ 4,192,700**	
2.2	**Site-Wide Long-Term Monitoring**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
2.3	**Recharge Basin Maintenance (~ 5,150 GPM)**					
2.3.1	Recharge Basin Maintenance (~ 5,150 GPM)	1	EA	$ 335,100	$335,100	
2.3.2	Recharge Basin Maintenance (~ 1,000 GPM)	3	EA	$ 28,900	$86,700	
	Sub-Total				**$ 421,800**	
	Sub-Total				**$ 12,054,600**	Sub-Total All Annual O & M Costs.
	Sub-Total					
	Contingency	10%			$ 1,205,000	5% scope + 5% bid.
	Sub-Total				**$ 13,259,600**	
	Project Management	5%			$ 663,000	
	TOTAL ANNUAL O & M COST				**$ 13,922,600**	

Table A-2B - Alternative 2B Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 2B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Frequency	Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:		**Frequency**					
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	16	EA	$ 15,000	$240,000	
	Contingency		10%			$ 24,000	5% scope + 5% bid.
	Sub-Total					**$ 264,000**	
	Project Management		5%			$ 13,000	
	Technical Support		3%			$ 8,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 285,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	16	EA	$ 80,000	$1,280,000	
3.2.2	Bag Filter Pump Replacement	5	12	EA	$ 25,000	$300,000	
3.2.3	Air Stripper Cleaning	5	12	EA	$ 24,400	$292,800	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 97,000	$97,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 1,994,800**	
	Contingency		10%			$ 199,000	5% scope + 5% bid.
	Sub-Total					**$ 2,193,800**	
	Project Management		5%			$ 110,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 2,303,800**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	16	EA	$ 85,000	$1,360,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 1,500,000	$1,500,000	
3.3.3	Recharge Basin Rehabilitation	10	1	LS	$ 104,000	$104,000	
	Sub-Total					**$ 2,964,000**	
	Contingency		10%			$ 296,000	5% scope + 5% bid.
	Sub-Total					**$ 3,260,000**	
	Project Management		5%			$ 163,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 3,423,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 194,894,000	**$ 194,894,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTS:**				
	TOTAL ANNUAL O & M COST		$ 13,922,600	$272,890,000	Annual cost for the life of the system
	Sub-Total			**$ 272,890,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 285,000	$ 2,752,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 2,303,800	$ 8,506,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 3,423,000	$ 5,853,000	Every 10 years
	Sub-Total			**$ 17,111,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 484,895,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-3A - Alternative 3A Cost Breakdown

Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3A includes the installation of 17 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 12 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 12 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**17**				
	Number of ~300 ft deep extraction wells	3				
	Number of ~600 ft deep extraction wells	10				
	Number of ~800 ft deep extraction wells	4				
	Total Number of 500 GPM (0.7 MGD) Treatment Plants	**4**				
	Total Number of 1000 GPM (1.4 MGD) Treatment Plants	**7**				
	Total Number of 2,250 GPM (3.2 MGD) Treatment Plants	**1**				
	Total Number of Recharge Basins	**14**				
	Number of Contingent New Recharge Basins	2				
	Number of Existing Recharge Basins	12				
1. CAPITAL COSTS:						
1.0	**Site Preparation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	3	EA	$ 638,000	$1,914,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	10	EA	$ 879,700	$8,797,000	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	4	EA	$ 973,900	$3,895,600	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	17	EA	$ 346,500	$5,890,500	
	Sub-Total				**$ 20,759,600**	
1.2A	**Treatment - 500 GPM (0.7 MGD)**					
1.2A.1	Land Acquisition for Treatment Plant	4	EA	$ 500,000	$2,000,000	
1.2A.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	4	EA	$ 267,200	$1,068,800	
1.2A.3	Site Work	4	EA	$ 19,200	$76,800	
1.2A.4	Electrical & Instrumentation	4	EA	$ 1,025,000	$4,100,000	
1.2A.5	Process Equipment	4	EA	$ 1,171,400	$4,685,600	
1.2A.6	Start-Up and Reporting	4	EA	$ 78,000	$312,000	
	Sub-Total				**$ 12,243,200**	
1.2B	**Treatment - 1,000 GPM (1.4 MGD)**					
1.2B.1	Land Acquisition for Treatment Plant	7	EA	$ 1,000,000	$7,000,000	
1.2B.2	1000 GPM Decentralized Plant Building Construction	7	EA	$ 306,100	$2,142,700	
1.2B.3	Site Work	7	EA	$ 31,600	$221,200	
1.2B.4	Electrical & Instrumentation	7	EA	$ 1,025,000	$7,175,000	
1.2B.5	Process Equipment	7	EA	$ 1,620,500	$11,343,500	
1.2B.6	Start-Up and Reporting	7	EA	$ 96,000	$672,000	
	Sub-Total				**$ 28,554,400**	
1.2C	**Treatment - 2,250 GPM (3.2 MGD)**					
1.2C.1	Land Acquisition for Treatment Plant	1	EA	$ -	$0	
1.2C.2	~ 2250 GPM (3.2 MGD) Plant Building Construction	1	EA	$ 485,900	$485,900	
1.2C.3	Site Work	1	EA	$ 21,100	$21,100	
1.2C.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2C.5	Process Equipment	1	EA	$ 3,812,500	$3,812,500	
1.2C.6	Start-Up and Reporting	1	EA	$ 321,000	$321,000	
	Sub-Total				**$ 5,665,500**	
1.3A	**Discharge - Contingent New Recharge Basin**					
1.3A.1	Land Cost	2	EA	$ 3,000,000	$6,000,000	
1.3A.2	Site Preparation	2	EA	$ 50,000	$100,000	
1.3A.3	Recharge Basin Construction	2	EA	$ 215,200	$430,400	
1.3A.4	Miscellaneous Cost	2	EA	$ 43,100	$86,200	
	Sub-Total				**$ 6,616,600**	
1.3B	**Discharge - Existing Recharge Basin**					
1.3B.1	Recharge Basin Re-Work Costs	12	EA	$ 42,000	$504,000	
	Sub-Total				**$ 504,000**	
1.3D	**Discharge - Beneficial Reuse**					
1.3D.1	Beneficial Reuse Infrastructure	1	LS	$ 1,700,000	$1,700,000	
	Sub-Total				**$ 1,700,000**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 51,647,903	$51,647,903	
1.4.2	Pumps and Booster Stations	1	LS	$ 6,300,000	$6,300,000	
	Sub-Total				**$ 57,947,903**	
	Sub-Total				**$ 155,991,203**	Sub-Total All Construction Costs.
	Sub-Total					
	Contingency	25%			$ 38,998,000	10% scope + 15% bid.
	Sub-Total				**$ 194,989,203**	
	Project Management	5%			$ 9,749,000	
	Remedial Design	6%			$ 11,699,000	
	Construction Management	6%			$ 11,699,000	
	Construction Oversight	3%			$ 5,850,000	
	TOTAL CAPITAL COST				**$ 233,986,203**	

Table A-3A - Alternative 3A Cost Breakdown

Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3A includes the installation of 17 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 12 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 12 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2. OPERATIONAL AND MAINTENANCE COSTs:						
Item No.	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**	**Notes**
2.1 ACTIVE REMEDIATION O&M COSTS (22 YEARS DURATION)						
2.1A	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	17	EA	$ 47,100	$800,700	
2.0.2	Annual Power (Pump Stations)	1	LS	$ 1,881,400	$1,881,400	
	Sub-Total				**$ 2,682,100**	
2.1B	**Annual O & M - ~ 500 GPM (0.7 MGD)**					
2.1A.1	Annual Operational Labor	4	EA	$ 101,600	$406,400	
2.1A.2	Annual Power (Treatment)	4	EA	$ 187,800	$751,200	
2.1A.3	Annual Material/Chemicals Usage	4	EA	$ 236,700	$946,800	
2.1A.4	Annual System Maintenance	4	EA	$ 51,400	$205,600	
2.1A.5	Treatment Plant Monitoring	4	EA	$ 116,600	$466,400	
	Sub-Total				**$ 2,776,400**	
2.1C	**Annual O & M - 1,000 GPM (1.4 MGD)**					
2.1B.1	Annual Operational Labor	7	EA	$ 136,700	$956,900	
2.1B.2	Annual Power (Treatment)	7	EA	$ 210,300	$1,472,100	
2.1B.3	Annual Material/Chemicals Usage	7	EA	$ 466,200	$3,263,400	
2.1B.4	Annual System Maintenance	7	EA	$ 51,400	$359,800	
2.1B.5	Treatment Plant Monitoring	7	LS	$ 116,600	$816,200	
	Sub-Total				**$ 6,868,400**	
2.1D	**Annual O & M - 2,250 GPM (3.2 MGD)**					
2.1C.1	Annual Operational Labor	1	EA	$ 136,700	$136,700	
2.1C.2	Annual Power (Treatment)	1	EA	$ 563,700	$563,700	
2.1C.3	Annual Material/Chemicals Usage	1	EA	$ 1,158,500	$1,158,500	
2.1C.4	Annual System Maintenance	1	EA	$ 51,400	$51,400	
2.1C.5	Treatment Plant Monitoring	1	LS	$ 116,600	$116,600	
	Sub-Total				**$ 2,026,900**	
2.1E	**Recharge Basin Maintenance**					
2.1E.1	Recharge Basin Maintenance (~ 1,000 GPM)	14	EA	$ 28,900	$404,600	
	Sub-Total				**$ 404,600**	
	Sub-Total				**$ 14,758,400**	Sub-Total 2.1: All Annual O & M Costs.
	Contingency	10%			$ 1,476,000	5% scope + 5% bid.
	Sub-Total				**$ 16,234,400**	
	Project Management	5%			$ 812,000	
	TOTAL ANNUAL O & M COST (Years 1 through 22)				**$ 17,046,400**	
2.2	**SITE-WIDE LTM COSTS (30 YEARS DURATION)**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
	Contingency	10%			**$ 12,170**	5% scope + 5% bid.
	Sub-Total				**$ 133,870**	
	Project Management	5%			$ 6,693.50	
	TOTAL ANNUAL LTM COSTS (Years 1 through 30)				**$ 140,564**	
	TOTAL ANNUAL O&M COST				**$ 17,186,964**	

Table A-3A - Alternative 3A Cost Breakdown

Plume Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3A includes the installation of 17 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 12 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 12 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description	Frequency	Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:		**Frequency**					
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	17	EA	$ 15,000	$255,000	
	Contingency		15%			$ 38,000	10% scope + 5% bid.
	Sub-Total					**$ 293,000**	
	Project Management		5%			$ 15,000	
	Technical Support		3%			$ 9,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 317,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	17	EA	$ 80,000	$1,360,000	
3.2.2	Bag Filter Pump Replacement	5	14	EA	$ 25,000	$350,000	
3.2.3	Air Stripper Cleaning	5	14	EA	$ 24,400	$341,600	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 112,000	$112,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 2,188,600**	
	Contingency		10%			$ 219,000	5% scope + 5% bid.
	Sub-Total					**$ 2,407,600**	
	Project Management		5%			$ 120,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 2,527,600**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	17	EA	$ 85,000	$1,445,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 1,500,000	$1,500,000	
3.3.3	Recharge Basin Rehabilitation	10	14	EA	$ 8,000	$112,000	
	Sub-Total					**$ 3,057,000**	
	Contingency		10%			$ 306,000	5% scope + 5% bid.
	Sub-Total					**$ 3,363,000**	
	Project Management		5%			$ 168,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 3,531,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 233,986,203	**$ 233,987,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTs:**				
2.1	TOTAL ANNUAL O & M COST (Years 1 through 22)		$ 17,046,400	$271,668,000	Annual o&m cost for the duration of active remediation
2.2	TOTAL LTM COSTS (Years 1 through 30)		$ 140,564	$2,756,000	Annual o&m cost for 30 years of LTM
	Sub-Total			**$ 274,424,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 317,000	$ 2,324,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 2,527,600	$ 7,083,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 3,531,000	$ 4,583,000	Every 10 years
	Sub-Total			**$ 13,990,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 522,410,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-3B - Alternative 3B Cost Breakdown

Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 1 treatment facility with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**16**				
	Number of ~300 ft deep extraction wells	3				
	Number of ~600 ft deep extraction wells	10				
	Number of ~800 ft deep extraction wells	3				
	Total Number of 7,140 (10.3 MGD) Treatment Plants	**1**				
	Total Number of New Recharge Basins	**1**				
1. CAPITAL COSTS:						
1.0	**Site Preparation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	3	EA	$ 638,000	$1,914,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	10	EA	$ 879,700	$8,797,000	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	3	EA	$ 973,900	$2,921,700	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	16	EA	$ 346,500	$5,544,000	
	Sub-Total				**$ 19,439,200**	
1.2	**Treatment - 7,140 GPM (10.3 MGD)**					
1.2.1	Land Acquisition for Treatment Plant	1	EA	$ 2,500,000	$2,500,000	
1.2.2	7,140 GPM (10.3 MGD) Plant Building Construction	1	EA	$ 937,900	$937,900	
1.2.3	Site Work	1	EA	$ 47,400	$47,400	
1.2.4	Electrical & Instrumentation	1	EA	$ 1,920,000	$1,920,000	
1.2.5	Process Equipment	1	EA	$ 8,208,700	$8,208,700	
1.2.6	Start-Up and Reporting	1	EA	$ 960,000	$960,000	
	Sub-Total				**$ 14,574,000**	
1.3A	**DO A - New Recharge Basin - 7,140 GPM (10.3 MGD)**					
1.3A.1	Land Cost	1	EA	$ -	$0	Assumes no costs as state owned property will be used to construct recharge basin
1.3A.2	Site Preparation	1	EA	$ 500,000	$500,000	
1.3A.3	Recharge Basin Construction	1	EA	$ 1,669,000	$1,669,000	
1.3A.4	Miscellaneous Cost	1	EA	$ 333,800	$333,800	
	Sub-Total				**$ 2,502,800**	
1.3B	**Discharge - Beneficial Reuse**					
1.3B.1	Beneficial Reuse Infrastructure	1	LS	$ 1,700,000	$1,700,000	
	Sub-Total				**$ 1,700,000**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 46,800,000	$46,800,000	
1.4.2	Pumps and Booster Stations	1	LS	$ 5,300,000	$5,300,000	
	Sub-Total				**$ 52,100,000**	
	Sub-Total				**$ 112,316,000**	Sub-Total All Construction Costs.
	Sub-Total					
	Contingency	25%			$ 28,079,000	10% scope + 15% bid.
	Sub-Total				**$ 140,395,000**	
	Project Management	5%			$ 7,020,000	
	Remedial Design	6%			$ 8,424,000	
	Construction Management	6%			$ 8,424,000	
	Construction Oversight	3%			$ 4,212,000	
	TOTAL CAPITAL COST				**$ 168,475,000**	

Table A-3B - Alternative 3B Cost Breakdown

Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 1 treatment facility with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2. OPERATIONAL AND MAINTENANCE COSTs:						
Item No.	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**	**Notes**
2.1	**ACTIVE REMEDIATION O&M COSTS (25 YEARS DURATION)**					
2.1A	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	16	EA	$ 47,100	$753,600	
2.0.2	Annual Power (Pump Stations)	1	LS	$ 1,630,500	$1,630,500	
	Sub-Total				**$ 2,384,100**	
2.1B	**Annual O & M - 7,140 GPM (10.3 MGD)**					
2.1.1	Annual Operational Labor	1	EA	$ 677,100	$677,100	
2.1.2	Annual Power (Treatment)	1	EA	$ 1,677,900	$1,677,900	
2.1.3	Annual Material/Chemicals Usage	1	EA	$ 1,779,300	$1,779,300	
2.1.4	Annual System Maintenance	1	EA	$ 513,600	$513,600	
2.1.5	Treatment Plant Monitoring	1	EA	$ 116,600	$116,600	
	Sub-Total				**$ 4,764,500**	
2.1C	**Recharge Basin Maintenance**					
2.3.1	Recharge Basin Maintenance (~ 7,140 GPM)	1	EA	$ 224,000	$224,000	
	Sub-Total				**$ 224,000**	
	Sub-Total				**$ 7,372,600**	Sub-Total All Annual O & M Costs.
	Contingency	10%			$ 737,000	5% scope + 5% bid.
	Sub-Total				**$ 8,109,600**	
	Project Management	5%			$ 405,000	
	TOTAL ANNUAL O&M COST (Years 1 through 25)				**$ 8,514,600**	
2.2	**SITE-WIDE LTM COSTS (30 YEARS DURATION)**					
2.2	**Site-Wide Long-Term Monitoring**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
	Contingency	10%			$ 12,170	
	Sub-Total				**$ 133,870**	
	Project Management	5%			$ 6,693.50	
	TOTAL SITE-WIDE LTM COST (Years 1 through 30)				**$ 140,564**	
	TOTAL ANNUAL O & M COST				**$ 8,655,164**	

Table A-3B - Alternative 3B Cost Breakdown

Plume Mass Flux Remediation - Centralized Treatment Plant with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 3B includes the installation of 16 groundwater extraction wells to a maximum depth of approximately 800 feet bgs; the construction of a total of 1 treatment facility with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the construction of 1 new recharge basin located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Frequency	Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:		**Frequency**					
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	16	EA	$ 15,000	$240,000	
	Contingency		10%			$ 24,000	5% scope + 5% bid.
	Sub-Total					**$ 264,000**	
	Project Management		5%			$ 13,000	
	Technical Support		3%			$ 8,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 285,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	16	EA	$ 80,000	$1,280,000	
3.2.2	Bag Filter Pump Replacement	5	8	EA	$ 25,000	$200,000	
3.2.3	Air Stripper Cleaning	5	8	EA	$ 24,400	$195,200	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 70,000	$70,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 1,770,200**	
	Contingency		10%			$ 177,000	5% scope + 5% bid.
	Sub-Total					**$ 1,947,200**	
	Project Management		5%			$ 97,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 2,044,200**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	16	EA	$ 85,000	$1,360,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 1,300,000	$1,300,000	
3.3.3	Recharge Basin Rehabilitation	10	1	LS	$ 80,000	$80,000	
	Sub-Total					**$ 2,740,000**	
	Contingency		10%			$ 274,000	5% scope + 5% bid.
	Sub-Total					**$ 3,014,000**	
	Project Management		5%			$ 151,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 3,165,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 168,475,000	**$ 168,475,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTs:**				
2.1	TOTAL ANNUAL O&M COST (Years 1 through 25)		$ 8,514,600	$148,266,000	Annual o&m cost for the duration of active remediation
2.2	TOTAL SITE-WIDE LTM COST (Years 1 through 30)		$ 140,564	$2,756,000	Annual o&m cost for 30 years of LTM
	Sub-Total			**$ 151,022,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 285,000	$ 2,378,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 2,044,200	$ 5,729,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 3,165,000	$ 4,108,000	Every 10 years
	Sub-Total			**$ 12,215,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 331,712,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-4 - Alternative 4 Cost Breakdown

Aquifer Flushing

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 4 includes the installation of 23 groundwater extraction wells to a maximum depth of approximately 1000 feet bgs; the construction of a total of 23 groundwater treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the installation of 43 injection wells for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**23**				
	Number of ~300 ft deep extraction wells	5				
	Number of ~600 ft deep extraction wells	11				
	Number of ~800 ft deep extraction wells	7				
	Total Number of ~500 GPM Treatment Plants	**23**				
	Total Number of Injection Wells	**43**				
	Number of ~300 ft deep Injection wells	8				
	Number of ~600 ft deep Injection wells	20				
	Number of ~800 ft deep injection wells	15				
1. CAPITAL COSTS:						
1.0	**Site Preparation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	5	EA	$ 638,000	$3,190,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	11	EA	$ 879,700	$9,676,700	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	7	EA	$ 973,900	$6,817,300	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	23	EA	$ 346,500	$7,969,500	
	Sub-Total				**$ 27,916,000**	
1.2	**Treatment - 500 GPM (0.7 MGD)**					
1.2.1	Land Acquisition for Treatment Plant	23	EA	$ 500,000	$11,500,000	
1.2.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	23	EA	$ 267,200	$6,145,600	
1.2.3	Site Work	23	EA	$ 19,200	$441,600	
1.2.4	Electrical & Instrumentation	23	EA	$ 1,025,000	$23,575,000	
1.2.5	Process Equipment	23	EA	$ 1,171,400	$26,942,200	
1.2.6	Start-Up and Reporting	23	EA	$ 78,000	$1,794,000	
	Sub-Total				**$ 70,398,400**	
1.3	**Discharge - Injection**					
1.3.1	Site Preparation (Well Installation)	1	EA	$ 137,500	$137,500	
1.3.2	Mobilization (Well Installation)	1	EA	$ 125,000	$125,000	
1.3.3	Injection Well Installation (~ 300 feet bgs)	8	EA	$ 638,000	$5,104,000	
1.3.4	Injection Well Installation (~ 600 feet bgs)	20	EA	$ 879,700	$17,594,000	
1.3.5	Injection Well Installation (> 600; < 800 feet bgs)	15	EA	$ 973,900	$14,608,500	
1.3.6	Injection Well Electrical, Instrumentation and Permitting	43	EA	$ 236,500	$10,169,500	
	Sub-Total				**$ 47,738,500**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 40,600,000	$40,600,000	
1.4.2	Pumps and Booster Stations	1	LS	$ 600,000	$600,000	
	Sub-Total				**$ 41,200,000**	
	Sub-Total				**$ 209,252,900**	Sub-Total All Construction Costs.
	Sub-Total					
	Contingency	25%			$ 52,313,000	10% scope + 15% bid.
	Sub-Total				**$ 261,565,900**	
	Project Management	5%			$ 13,078,000	
	Remedial Design	6%			$ 15,694,000	
	Construction Management	6%			$ 15,694,000	
	Construction Oversight	3%			$ 7,847,000	
	TOTAL CAPITAL COST				**$ 313,879,000**	

Table A-4 - Alternative 4 Cost Breakdown

Aquifer Flushing

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 4 includes the installation of 23 groundwater extraction wells to a maximum depth of approximately 1000 feet bgs; the construction of a total of 23 groundwater treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the installation of 43 injection wells for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2. OPERATIONAL AND MAINTENANCE COSTs:						
Item No.	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**	**Notes**
2.1	**ACTIVE REMEDIATION O&M COSTS (17 YEARS DURATION)**					
2.1A	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	23	EA	$ 47,100	$1,083,300	
	Sub-Total				**$ 1,083,300**	
2.1B	**Annual O & M - ~ 500 GPM (0.7 MGD) (From Year 1 to 20)**					
2.1A.1	Annual Operational Labor	23	EA	$ 101,600	$2,336,800	
2.1A.2	Annual Power (Treatment)	23	EA	$ 187,800	$4,319,400	
2.1A.3	Annual Power (Injection)	43	EA	$ 23,516	$1,011,205	
2.1A.4	Annual Material/Chemicals Usage	23	EA	$ 236,700	$5,444,100	
2.1A.5	Annual System Maintenance	23	EA	$ 51,400	$1,182,200	
2.1A.6	Treatment Plant Monitoring	23	EA	$ 116,600	$2,681,800	
	Sub-Total				**$ 16,975,505**	
	Sub-Total				**$ 18,058,805**	
	Contingency	10%			$ 1,805,880	5% scope + 5% bid.
	Sub-Total				**$ 19,864,685**	
	Project Management	5%			$ 993,234	
	TOTAL ANNUAL O & M COST (17 YEARS DURATION)				**$ 20,857,920**	
2.2	**Site-Wide Long-Term Monitoring (From Year 1 to 30)**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
	Contingency	10%			$ 12,170	5% scope + 5% bid.
	Sub-Total				**$ 133,870**	
	Project Management	5%			$ 6,694	
	TOTAL SITE-WIDE LTM COST (30 YEARS DURATION)				**$ 140,564**	
	TOTAL ANNUAL O & M COST				**$ 20,998,483**	

Table A-4 - Alternative 4 Cost Breakdown

Aquifer Flushing

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 4 includes the installation of 23 groundwater extraction wells to a maximum depth of approximately 1000 feet bgs; the construction of a total of 23 groundwater treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the installation of 43 injection wells for groundwater discharge.

Item No.	Description	Frequency	Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:		**Frequency**					
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	23	EA	$ 15,000	$345,000	
3.1.2	Injection Well Back-flush	2	43	EA	$ 12,000	$516,000	
	Sub-Total					**$ 861,000**	
	Contingency		15%			$ 129,000	10% scope + 5% bid.
	Sub-Total					**$ 990,000**	
	Project Management		5%			$ 50,000	
	Technical Support		3%			$ 30,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 1,070,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	23	EA	$ 80,000	$1,840,000	
3.2.2	Bag Filter Pump Replacement	5	23	EA	$ 25,000	$575,000	
3.2.3	Air Stripper Cleaning	5	23	EA	$ 24,400	$561,200	
3.2.4	Replace Interconnection Piping and Valves	5	23	EA	$ 5,000	$115,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 3,116,200**	
	Contingency		10%			$ 312,000	5% scope + 5% bid.
	Sub-Total					**$ 3,428,200**	
	Project Management		5%			$ 171,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, and 20					**$ 3,599,200**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	23	EA	$ 85,000	$1,955,000	
3.3.2	Injection Well Pump Replacement	10	43	EA	$ 20,000	$860,000	
	Sub-Total					**$ 2,815,000**	
	Contingency		10%			$ 282,000	5% scope + 5% bid.
	Sub-Total					**$ 3,097,000**	
	Project Management		5%			$ 155,000	
	TOTAL PERIODIC COSTS @ YEAR 10 and 20					**$ 3,252,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 313,879,000	**$ 313,879,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTs:**				
2.1	TOTAL ANNUAL O & M COST (17 YEARS DURATION)		$ 20,857,920	$274,618,000	Annual cost for monitoring
2.2	TOTAL SITE-WIDE LTM COST (30 YEARS DURATION)		$ 140,564	$2,756,000	
	Sub-Total			**$ 277,374,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 1,070,000	$ 6,621,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, and 20		$ 3,599,200	$ 8,094,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10 and 20		$ 3,252,000	$ 2,420,000	Every 10 years
	Sub-Total			**$ 17,135,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 608,390,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-5A - Alternative 5A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5A includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 17 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 16 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**24**				
	Number of ~300 ft deep extraction wells	8				
	Number of ~600 ft deep extraction wells	10				
	Number of ~800 ft deep extraction wells	6				
	Total Number of 500 GPM (0.7 MGD) Treatment Plants	**4**				
	Total Number of 1000 GPM (1.4 MGD) Treatment Plants	**11**				
	Total Number of ~1,500 GPM (2.2 MGD) Plants	**2**				
	Total Number of Recharge Basins	**18**				
	Number of Contingent New Recharge Basins	2				
	Number of Existing Recharge Basins	16				
1. CAPITAL COSTS:						
1.0	**Site Preparation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	8	EA	$ 638,000	$5,104,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	10	EA	$ 879,700	$8,797,000	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	6	EA	$ 973,900	$5,843,400	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	24	EA	$ 346,500	$8,316,000	
	Sub-Total				**$ 28,322,900**	
1.2A	**Treatment - 500 GPM (0.7 MGD)**					
1.2A.1	Land Acquisition for Treatment Plant	4	EA	$ 500,000	$2,000,000	
1.2A.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	4	EA	$ 267,200	$1,068,800	
1.2A.3	Site Work	4	EA	$ 19,200	$76,800	
1.2A.4	Electrical & Instrumentation	4	EA	$ 1,025,000	$4,100,000	
1.2A.5	Process Equipment	4	EA	$ 1,171,400	$4,685,600	
1.2A.6	Start-Up and Reporting	4	EA	$ 78,000	$312,000	
	Sub-Total				**$ 12,243,200**	
1.2B	**Treatment - 1,000 GPM (1.4 MGD)**					
1.2B.1	Land Acquisition for Treatment Plant	11	EA	$ 1,000,000	$11,000,000	
1.2B.2	1000 GPM Decentralized Plant Building Construction	11	EA	$ 306,100	$3,367,100	
1.2B.3	Site Work	11	EA	$ 31,600	$347,600	
1.2B.4	Electrical & Instrumentation	11	EA	$ 1,025,000	$11,275,000	
1.2B.5	Process Equipment	11	EA	$ 1,620,500	$17,825,500	
1.2B.6	Start-Up and Reporting	11	EA	$ 96,000	$1,056,000	
	Sub-Total				**$ 44,871,200**	
1.2C	**Treatment - 1,500 GPM (2.2 MGD)**					
1.2C.1	Land Acquisition for Treatment Plant	2	EA	$ -	$0	
1.2C.2	~ 1500 GPM Decentralized Plant Building Construction	2	EA	$ 379,000	$758,000	
1.2C.3	Site Work	2	EA	$ 18,500	$37,000	
1.2C.4	Electrical & Instrumentation	2	EA	$ 1,025,000	$2,050,000	
1.2C.5	Process Equipment	2	EA	$ 2,237,600	$4,475,200	
1.2C.6	Start-Up and Reporting	2	EA	$ 96,000	$192,000	
	Sub-Total				**$ 7,512,200**	
1.3A	**Discharge - Contingent New Recharge Basin**					
1.3A.1	Land Cost	2	EA	$ 3,000,000	$6,000,000	
1.3A.2	Site Preparation	2	EA	$ 50,000	$100,000	
1.3A.3	Recharge Basin Construction	2	EA	$ 215,200	$430,400	
1.3A.4	Miscellaneous Cost	2	EA	$ 43,100	$86,200	
	Sub-Total				**$ 6,616,600**	
1.3B	**Discharge - Existing Recharge Basin**					
1.3B.1	Recharge Basin Re-Work Costs	16	EA	$ 42,000	$672,000	
	Sub-Total				**$ 672,000**	
1.3C	**Discharge - Surface Water**					
1.3C.1	Surface Water Discharge Infrastructure	1	LS	$ 100,000	$100,000	
	Sub-Total				**$ 100,000**	
1.3D	**Discharge - Beneficial Reuse**					
1.3D.1	Beneficial Reuse Infrastructure	1	LS	$ 1,700,000	$1,700,000	
	Sub-Total				**$ 1,700,000**	

Table A-5A - Alternative 5A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5A includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 17 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 16 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 58,500,000	$58,500,000	
1.4.2	Pumps and Booster Stations	1	LS	$ 6,100,000	$6,100,000	
	Sub-Total				**$ 64,600,000**	
	Sub-Total				**$ 188,638,100**	Sub-Total All Construction Costs.
	Sub-Total					
	Contingency	25%			$ 47,160,000	10% scope + 15% bid.
	Sub-Total				**$ 235,798,100**	
	Project Management	5%			$ 11,790,000	
	Remedial Design	6%			$ 14,148,000	
	Construction Management	6%			$ 14,148,000	
	Construction Oversight	3%			$ 7,074,000	
	TOTAL CAPITAL COST				**$ 282,959,000**	

2. OPERATIONAL AND MAINTENANCE COSTs:

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2.0	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	24	EA	$ 47,100	$1,130,400	
2.0.2	Annual Power (Pump Stations)	1	LS	$ 1,630,500	$1,630,500	
	Sub-Total				**$ 2,760,900**	
2.1A	**Annual O & M - ~ 500 GPM (0.7 MGD)**					
2.1A.1	Annual Operational Labor	4	EA	$ 101,600	$406,400	
2.1A.2	Annual Power (Treatment)	4	EA	$ 187,800	$751,200	
2.1A.3	Annual Material/Chemicals Usage	4	EA	$ 236,700	$946,800	
2.1A.4	Annual System Maintenance	4	EA	$ 51,400	$205,600	
2.1A.5	Treatment Plant Monitoring	4	EA	$ 116,600	$466,400	
	Sub-Total				**$ 2,776,400**	
2.1B	**Annual O & M - 1,000 GPM (1.4 MGD)**					
2.1B.1	Annual Operational Labor	11	EA	$ 136,700	$1,503,700	
2.1B.2	Annual Power (Treatment)	11	EA	$ 210,300	$2,313,300	
2.1B.3	Annual Material/Chemicals Usage	11	EA	$ 466,200	$5,128,200	
2.1B.4	Annual System Maintenance	11	EA	$ 51,400	$565,400	
2.1B.5	Treatment Plant Monitoring	11	LS	$ 116,600	$1,282,600	
	Sub-Total				**$ 10,793,200**	
2.1C	**Annual O & M - ~1,500 GPM (2.2 MGD)**					
2.1C.1	Annual Operational Labor	2	EA	$ 136,700	$273,400	
2.1C.2	Annual Power (Treatment)	2	EA	$ 386,300	$772,600	
2.1C.3	Annual Material/Chemicals Usage	2	EA	$ 558,500	$1,117,000	
2.1C.4	Annual System Maintenance	2	EA	$ 51,400	$102,800	
2.1C.5	Treatment Plant Monitoring	2	EA	$ 116,600	$233,200	
	Sub-Total				**$ 2,499,000**	
2.2	**Site-Wide Long-Term Monitoring**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
2.3	**Recharge Basin Maintenance**					
2.3.1	Recharge Basin Maintenance (~ 1,000 GPM)	18	EA	$ 28,900	$520,200	
	Sub-Total				**$ 520,200**	
	Sub-Total				**$ 19,471,400**	Sub-Total All Annual O & M Costs.
	Sub-Total					
	Contingency	10%			$ 1,947,000	5% scope + 5% bid.
	Sub-Total				**$ 21,418,400**	
	Project Management	5%			$ 1,071,000	
	TOTAL ANNUAL O & M COST				**$ 22,489,400**	

Table A-5A - Alternative 5A Cost Breakdown

Hydraulic Containment of Site Contaminants above SCGs Combined with Mass Flux Remediation - Decentralized Treatment Plants with Various Discharge Methods

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5A includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 17 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 16 existing recharge basins (with a contingency for construction of 2 new recharge basins) for groundwater discharge.

Item No.	Description		Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:							
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	24	EA	$ 15,000	$360,000	
	Contingency		15%			$ 54,000	10% scope + 5% bid.
	Sub-Total					**$ 414,000**	
	Project Management		5%			$ 21,000	
	Technical Support		3%			$ 12,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 447,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	24	EA	$ 80,000	$1,920,000	
3.2.2	Bag Filter Pump Replacement	5	19	EA	$ 25,000	$475,000	
3.2.3	Air Stripper Cleaning	5	19	EA	$ 24,400	$463,600	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 160,000	$160,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 3,043,600**	
	Contingency		10%			$ 304,000	5% scope + 5% bid.
	Sub-Total					**$ 3,347,600**	
	Project Management		5%			$ 167,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 3,514,600**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	24	EA	$ 85,000	$2,040,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 1,300,000	$1,300,000	
3.3.3	Recharge Basin Rehabilitation	10	18	EA	$ 8,000	$144,000	
	Sub-Total					**$ 3,484,000**	
	Contingency		10%			$ 348,000	5% scope + 5% bid.
	Sub-Total					**$ 3,832,000**	
	Project Management		5%			$ 192,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 4,024,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 282,959,000	**$ 282,959,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTs:**				
	TOTAL ANNUAL O & M COST		$ 22,489,400	$ 440,803,000	Annual cost for the life of the system
	Sub-Total			**$ 440,803,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 447,000	$ 4,316,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 3,514,600	$ 12,976,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 4,024,000	$ 6,881,000	Every 10 years
	Sub-Total			**$ 24,173,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 747,935,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.

Table A-5B - Alternative 5B Cost Breakdown

Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5B includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and the construction of 1 new recharge basins located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Total Number of Extraction Wells	**24**				
	Number of ~300 ft deep extraction wells	8				
	Number of ~600 ft deep extraction wells	10				
	Number of ~800 ft deep extraction wells	6				
	Total Number of 500 GPM (0.7 MGD) Treatment Plants	**1**				
	Total Number of 1,000 GPM (1.4 MGD) Treatment Plants	**2**				
	Total Number of 2,000 GPM (2.9 MGD) Treatment Plants	**1**				
	Total Number of 8,140 GPM (11.7 MGD) Treatment Plants	**1**				
	Total Number of Recharge Basins	**4**				
	Number of New Recharge Basins	1				
	Number of Existing Recharge Basins	3				
1. CAPITAL COSTS:						
1.0	**Site Preparation**					
1.0.1	Pre-Design Investigation	1	LS	$ 5,000,000	$ 5,000,000	
1.0.2	Alternate Water Supply	1	LS	$ 17,000,000	$ 17,000,000	By Bethpage Water District
	Sub-Total				**$ 22,000,000**	
1.1	**Extraction**					
1.1.1	Site Preparation (Well Installation)	1	LS	$ 137,500	$137,500	
1.1.2	Mobilization (Well Installation)	1	LS	$ 125,000	$125,000	
1.1.3	Extraction Well Installation (~ 300 feet bgs)	8	EA	$ 638,000	$5,104,000	
1.1.4	Extraction Well Installation (~ 600 feet bgs)	10	EA	$ 879,700	$8,797,000	
1.1.5	Extraction Well Installation (~ 800 feet bgs)	6	EA	$ 973,900	$5,843,400	
1.1.6	Extraction Well Electrical, Instrumentation and Permitting	24	EA	$ 346,500	$8,316,000	
	Sub-Total				**$ 28,322,900**	
1.2A	**Treatment - 500 GPM (0.7 MGD)**					
1.2A.1	Land Acquisition for Treatment Plant	1	EA	$ 500,000	$500,000	
1.2A.2	~500 GPM (0.7 MGD) Decentralized Plant Building Construction	1	EA	$ 267,200	$267,200	
1.2A.3	Site Work	1	EA	$ 19,200	$19,200	
1.2A.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2A.5	Process Equipment	1	EA	$ 1,171,400	$1,171,400	
1.2A.6	Start-Up and Reporting	1	EA	$ 78,000	$78,000	
	Sub-Total				**$ 3,060,800**	
1.2B	**Treatment - 1,000 GPM (1.4 MGD)**					
1.2B.1	Land Acquisition for Treatment Plant	2	EA	$ 1,000,000	$2,000,000	
1.2B.2	1000 GPM Decentralized Plant Building Construction	2	EA	$ 306,100	$612,200	
1.2B.3	Site Work	2	EA	$ 31,600	$63,200	
1.2B.4	Electrical & Instrumentation	2	EA	$ 1,025,000	$2,050,000	
1.2B.5	Process Equipment	2	EA	$ 1,620,500	$3,241,000	
1.2B.6	Start-Up and Reporting	2	EA	$ 96,000	$192,000	
	Sub-Total				**$ 8,158,400**	
1.2C	**Treatment - 2,000 GPM (2.9 MGD)**					
1.2C.1	Land Acquisition for Treatment Plant	1	EA	$ -	$0	
1.2C.2	~ 2250 GPM (3.2 MGD) Plant Building Construction	1	EA	$ 485,900	$485,900	
1.2C.3	Site Work	1	EA	$ 21,100	$21,100	
1.2C.4	Electrical & Instrumentation	1	EA	$ 1,025,000	$1,025,000	
1.2C.5	Process Equipment	1	EA	$ 3,812,500	$3,812,500	
1.2C.6	Start-Up and Reporting	1	EA	$ 321,000	$321,000	
	Sub-Total				**$ 5,665,500**	
1.2D	**Treatment - 8,140 GPM (11.7 MGD)**					
1.2D.1	Land Acquisition for Treatment Plant	1	EA	$ 2,500,000	$2,500,000	
1.2D.2	8,140 GPM (11.7 MGD) Plant Building Construction	1	EA	$ 1,326,700	$1,326,700	
1.2D.3	Site Work	1	EA	$ 51,700	$51,700	
1.2D.4	Electrical & Instrumentation	1	EA	$ 2,070,000	$2,070,000	
1.2D.5	Process Equipment	1	EA	$ 11,354,200	$11,354,200	
1.2D.6	Start-Up and Reporting	1	EA	$ 960,000	$960,000	
	Sub-Total				**$ 18,262,600**	
1.3A	**DO A - New Recharge Basin - 8,140 GPM (11.7 MGD)**					
1.3A.1	Land Cost	1	EA	$ -	$0	Assumes no costs as state owned property will be used to construct recharge basin
1.3A.2	Site Preparation	1	EA	$ 500,000	$500,000	
1.3A.3	Recharge Basin Construction	1	EA	$ 1,669,000	$1,669,000	
1.3A.4	Miscellaneous Cost	1	EA	$ 333,800	$333,800	
	Sub-Total				**$ 2,502,800**	
1.3B	**Discharge - Existing Recharge Basin**					
1.3B.1	Recharge Basin Re-Work Costs	3	EA	$ 42,000	$126,000	
	Sub-Total				**$ 126,000**	
1.3C	**Discharge - Surface Water**					
1.3C.1	Surface Water Discharge Infrastructure	1	LS	$ 100,000	$100,000	
	Sub-Total				**$ 100,000**	
1.3D	**Discharge - Beneficial Reuse**					
1.3D.1	Beneficial Reuse Infrastructure	1	LS	$ 1,700,000	$1,700,000	
	Sub-Total				**$ 1,700,000**	
1.4	**Conveyance System**					
1.4.1	Pipe Conveyance	1	LS	$ 63,500,000	$63,500,000	
1.4.2	Pumps and Booster Stations	1	LS	$ 6,900,000	$6,900,000	
	Sub-Total				**$ 70,400,000**	
	Sub-Total				**$ 160,299,000**	Sub-Total All Construction Costs.

Table A-5B - Alternative 5B Cost Breakdown

Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5B includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and the construction of 1 new recharge basins located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
	Sub-Total					
	Contingency	25%			$ 40,075,000	10% scope + 15% bid.
	Sub-Total				**$ 200,374,000**	
	Project Management	5%			$ 10,019,000	
	Remedial Design	6%			$ 12,022,000	
	Construction Management	6%			$ 12,022,000	
	Construction Oversight	3%			$ 6,011,000	
	TOTAL CAPITAL COST				**$ 240,448,000**	

2. OPERATIONAL AND MAINTENANCE COSTs:

Item No.	Description	Quantity	Unit	Unit Cost	Total	Notes
2.0	**Annual O & M (Extraction)**					
2.0.1	Annual Power (Extraction)	24	EA	$ 47,100	$1,130,400	
2.0.2	Annual Power (Pump Stations)	1	LS	$ 2,132,200	$2,132,200	
	Sub-Total				**$ 3,262,600**	
2.1A	**Annual O & M - ~ 500 GPM (0.7 MGD)**					
2.1A.1	Annual Operational Labor	1	EA	$ 101,600	$101,600	
2.1A.2	Annual Power (Treatment)	1	EA	$ 187,800	$187,800	
2.1A.3	Annual Material/Chemicals Usage	1	EA	$ 236,700	$236,700	
2.1A.4	Annual System Maintenance	1	EA	$ 51,400	$51,400	
2.1A.5	Treatment Plant Monitoring	1	EA	$ 116,600	$116,600	
	Sub-Total				**$ 694,100**	
2.1B	**Annual O & M - 1,000 GPM (1.4 MGD)**					
2.1B.1	Annual Operational Labor	2	EA	$ 136,700	$273,400	
2.1B.2	Annual Power (Treatment)	2	EA	$ 210,300	$420,600	
2.1B.3	Annual Material/Chemicals Usage	2	EA	$ 466,200	$932,400	
2.1B.4	Annual System Maintenance	2	EA	$ 51,400	$102,800	
2.1B.5	Treatment Plant Monitoring	2	LS	$ 116,600	$233,200	
	Sub-Total				**$ 1,962,400**	
2.1C	**Annual O & M - 2,250 GPM (3.2 MGD)**					
2.1C.1	Annual Operational Labor	1	EA	$ 136,700	$136,700	
2.1C.2	Annual Power (Treatment)	1	EA	$ 563,700	$563,700	
2.1C.3	Annual Material/Chemicals Usage	1	EA	$ 1,158,500	$1,158,500	
2.1C.4	Annual System Maintenance	1	EA	$ 51,400	$51,400	
2.1C.5	Treatment Plant Monitoring	1	LS	$ 116,600	$116,600	
	Sub-Total				**$ 2,026,900**	
2.1D	**Annual O & M - 8,140 GPM (11.7 MGD)**					
2.1D.1	Annual Operational Labor	1	EA	$ 1,051,500	$1,051,500	
2.1D.2	Annual Power (Treatment)	1	EA	$ 2,067,800	$2,067,800	
2.1D.3	Annual Material/Chemicals Usage	1	EA	$ 2,020,400	$2,020,400	
2.1D.4	Annual System Maintenance	1	EA	$ 513,600	$513,600	
2.1D.5	Treatment Plant Monitoring	1	EA	$ 116,600	$116,600	
	Sub-Total				**$ 5,769,900**	
2.2	**Site-Wide Long-Term Monitoring**					
2.2.1	Site-Wide Long-Term Monitoring	1	EA	$ 121,700	$121,700	
	Sub-Total				**$ 121,700**	
2.3	**Recharge Basin Maintenance**					
2.3.1	Recharge Basin Maintenance (~ 7,090 GPM)	1	EA	$ 224,000	$224,000	
2.3.2	Recharge Basin Maintenance (~ 1,000 GPM)	3	EA	$ 28,900	$86,700	
	Sub-Total				**$ 310,700**	
	Sub-Total				**$ 14,148,300**	Sub-Total All Annual O & M Costs.
	Sub-Total					
	Contingency	10%			$ 1,415,000	5% scope + 5% bid.
	Sub-Total				**$ 15,563,300**	
	Project Management	5%			$ 778,000	
	TOTAL ANNUAL O & M COST				**$ 16,341,300**	

Table A-5B - Alternative 5B Cost Breakdown

Hydraulic Containment of Site Contaminants Above SCGs Combined with Mass Flux Remediation - Centralized Treatment Plants with a Centralized Recharge Basin

Site: Grumman Aerospace-Bethpage Facility
Location: Nassau County, New York
Phase: Feasibility Study (-30% - +50%)
Base Year: 2019
Date: January 11, 2019

Description: Alternative 5B includes the installation of 24 groundwater extraction wells to a maximum depth of approximately 950 feet bgs; the construction of a total of 5 treatment facilities with filtration, air stripping, GAC adsorption, and advanced oxidation processes; and the use of 3 existing recharge basins and the construction of 1 new recharge basins located in the vicinity of the Bethpage State Park (north of the golf course) for groundwater discharge.

Item No.	Description		Quantity	Unit	Unit Cost	Total	Notes
3. PERIODIC COSTS:							
3.1	**Once in Every 2 Years**						
3.1.1	Extraction Well Pump Rehabilitation	2	24	EA	$ 15,000	$360,000	
	Contingency		15%			$ 54,000	10% scope + 5% bid.
	Sub-Total					**$ 414,000**	
	Project Management		5%			$ 21,000	
	Technical Support		3%			$ 12,000	
	TOTAL PERIODIC COSTS @ EVERY 2 YEARS					**$ 447,000**	
3.2	**Once in Every 5 Years**						
3.2.1	Extraction Well Maintenance	5	24	EA	$ 80,000	$1,920,000	
3.2.2	Bag Filter Pump Replacement	5	15	EA	$ 25,000	$375,000	
3.2.3	Air Stripper Cleaning	5	15	EA	$ 24,400	$366,000	
3.2.4	Replace Interconnection Piping and Valves	5	1	LS	$ 128,000	$128,000	
3.2.5	Institutional Controls	5	1	LS	$ 25,000	$25,000	
	Sub-Total					**$ 2,814,000**	
	Contingency		10%			$ 281,000	5% scope + 5% bid.
	Sub-Total					**$ 3,095,000**	
	Project Management		5%			$ 155,000	
	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30					**$ 3,250,000**	
3.3	**Once in Every 10 Years**						
3.3.1	Extraction Well Pump Replacement	10	24	EA	$ 85,000	$2,040,000	
3.3.2	Pump Stations - Pump Replacement	10	1	LS	$ 1,700,000	$1,700,000	
3.3.3	Recharge Basin Rehabilitation	10	1	LS	$ 104,000	$104,000	
	Sub-Total					**$ 3,844,000**	
	Contingency		10%			$ 384,000	5% scope + 5% bid.
	Sub-Total					**$ 4,228,000**	
	Project Management		5%			$ 211,000	
	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30					**$ 4,439,000**	

PRESENT VALUE ANALYSIS: Discount Rate 3%

Item No.	Cost Type	Year	Total Cost	Present Value	Notes
A	**1. CAPITAL COSTS:**	0	$ 240,448,000	**$ 240,448,000**	
B	**2. OPERATIONAL AND MAINTENANCE COSTs:**				
	TOTAL ANNUAL O & M COST		$ 16,341,300	$ 320,297,000	Annual cost for the life of the system
	Sub-Total			**$ 320,297,000**	**NPV Assuming 3% Discount Rate**
C	**Periodic Costs**				
3.1	TOTAL PERIODIC COSTS @ EVERY 2 YEARS		$ 447,000	$ 4,316,000	Every 2 years
3.2	TOTAL PERIODIC COSTS @ YEAR 5, 10, 15, 20, 25 and 30		$ 3,250,000	$ 11,999,000	Every 5 years
3.3	TOTAL PERIODIC COSTS @ YEAR 10, 20 and 30		$ 4,439,000	$ 7,590,000	Every 10 years
	Sub-Total			**$ 23,905,000**	**NPV Assuming 3% Discount Rate**
	TOTAL PRESENT VALUE OF ALTERNATIVE			**$ 584,650,000**	

* The annual and periodic costs over the life of the system changes on an annual basis as noted. For simplicity, the total O&M and periodic costs over the 30 years are presented.