Health Consultation

PUBLIC COMMENT RELEASE

NORTHROP GRUMMAN/NAVAL WEAPONS INDUSTRIAL RESERVE PLANT FACILITIES GROUNDWATER IMPACTS

BETHPAGE, NASSAU COUNTY AND CALVERTON, SUFFOLK COUNTY, NEW YORK

EPA FACILITIES ID: NYD002047967/NY1570024249

Prepared by:
New York State Department of Health

MAY 23, 2019

COMMENT PERIOD ENDS: JULY 22, 2019

Prepared Under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This document is being released for a 60-day public comment period. Subsequent to the public comment period, ATSDR or ATSDR's Cooperative Agreement Partner will address all public comment and revise or append the document as appropriate. The health consultation will then be reissued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or

Visit our Home Page at: https://www.atsdr.cdc.gov

HEALTH CONSULTATION

Public Comment Release

NORTHROP GRUMMAN/NAVAL WEAPONS INDUSTRIAL RESERVE PLANT FACILITIES GROUNDWATER IMPACTS

BETHPAGE, NASSAU COUNTY AND CALVERTON,
SUFFOLK COUNTY, NEW YORK
EPA FACILITIES ID: NYD002047967/NY1570024249

Prepared by:

New York State Department of Health
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations

For copies of this document, or with other questions, you may contact the

New York State Department of Health
Center for Environmental Health
Empire State Plaza, Corning Tower, Room 1787
Albany, New York 12237
518-402-7860
E-mail: documentcomments@health.ny.gov

TABLE OF CONTENTS

SUMMARY

INTRODUCTION

This health consultation was prepared in response to a June 30, 2012 petition letter sent to the Agency for Toxic Substances and Disease Registry (ATSDR) by a Patchogue, Long Island resident. The petitioner expressed concerns that local residents could be exposed to contaminants (primarily volatile organic compounds [VOCs]) in groundwater originating from Northrop Grumman/National Weapons Industrial Reserve Plant (NWIRP) facilities located in Bethpage, Great River, and Calverton, Long Island, New York. The top priority of this health consultation is to ensure that the community has the best information possible about how contaminants in groundwater from the facilities might affect their health.

Findings from environmental investigations that began in the 1980's led the New York State Department of Environmental Conservation (NYSDEC), in consultation with the New York State Department of Health (NYSDOH), to list the Northrop Grumman/NWIRP facilities in Bethpage and Calverton on the New York State Registry of Inactive Hazardous Waste Disposal Sites (also known as State Superfund list). Sites on the State Superfund list require further environmental investigation to confirm the presence of hazardous waste and determine the threat posed by the site to public health or the environment. See Appendix C of this document for additional site history and investigation details of the Northrop Grumman/Naval Weapons Industrial Reserve Plant facilities in Bethpage and Calverton.

The Northrop Grumman facility located in the hamlet of Great River, in the Town of Islip, Suffolk County was wholly owned by Northrop Grumman and never included on the New York State Superfund list or the United States Environmental Protection Agency's (EPA) National Priorities List (federal Superfund list). When in operation, the Northrop Grumman Great River facility was regulated by the EPA's Resource Conservation and Recovery Act. EPA's Detailed Facility Report indicates the Great River facility had no violations [EPA 2013]. The available data for the Great River facility provide no indication that groundwater has been impacted by contamination originating from the Northrop Grumman's former Great River facility, and therefore, this facility is not discussed further in this health consultation.

This health consultation provides information about historic and recent analytical data and related information on public water supply wells and area monitoring and irrigation wells and describes how this information was evaluated to determine if ingestion (drinking) and inhalation exposures to contaminants in groundwater could have occurred in the past or could currently be occurring. An in-depth review of available information about potential exposures forms the basis for drawing conclusions about the public health implications. The evaluation of data for the Bethpage and Calverton facilities is the basis for the conclusions and recommendations presented in this health consultation.

CONCLUSION 1

The evaluation of VOCs included in this health consultation indicates that currently, drinking or other uses of water from public water supplies affected by the Northrop Grumman/NWIRP facility in Bethpage, Nassau County are not expected to harm people's health.

BASIS FOR CONCLUSION

The public water supplies are monitored for chemical contaminants on a regular basis and based on current drinking water standards, treatment to remove VOC contaminants from the public water supplies is being implemented when necessary prior to distribution to consumers.

CONCLUSION 2

Past use of drinking water contaminated with trichloroethene (TCE) from Bethpage Water District Well 6-1 (prior to 1976) could have harmed people's health. Past long-term ingestion and inhalation exposure to tetrachloroethene (PCE) and 1,1,1-trichloroethane (1,1,1-TCA) in Bethpage Well 6-1 is not expected to have harmed people's health.

BASIS FOR CONCLUSION

The estimated ingestion and inhalation exposures to TCE (the primary contaminant in the water) in Well 6-1, occurring before 1976, approached exposures that could have resulted in immune or developmental toxicity. Past research has shown TCE exposure is associated with immune system effects and developmental effects such as congenital heart defects. While studies have suggested TCE exposures can cause changes in the body's immune system, it is difficult to identify the specific health problems that might result. Studies that focused on relatively high-level exposures among occupational groups associated TCE exposures with kidney cancer, liver cancer, and lymphoma. Exposures to TCE from Well 6-1 ended in 1976, and it is not possible to know whether any specific individual has already experienced health effects or to predict whether an individual will experience health effects resulting from this particular past exposure. Preventive health recommendations for people who had drinking water and/or inhalation exposures to TCE from Well 6-1 prior to 1976 are similar to general recommendations for others: maintain a healthy lifestyle, have regular medical checkups, and discuss specific concerns with healthcare providers.

PCE was found in Well 6-1 at levels estimated to pose a very low[1] increased risk for cancer, and 1,1,1-TCA and PCE were at levels that posed a minimal[2] risk for noncancer health effects.

CONCLUSION 3

Past long-term ingestion and inhalation exposure to TCE in the other public water supplies (i.e., other than Bethpage Water District Well 6-1) affected by Northrop Grumman/NWIRP facility in Bethpage is not expected to harm people's health.

[1]The estimated exposure poses a cancer risk of less than one in one million.

[2]The estimated exposures are less than the contaminant's reference dose. The reference dose is defined by the EPA as an estimate (with uncertainty spanning perhaps an order of magnitude) of a chronic (up to a lifetime) contaminant exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

TCE was found at levels in drinking water estimated to pose a very low[1] to low[3] increased risk for cancer and a minimal[2] risk for noncancer health effects. In one well (Bethpage Water District Well 6-2), taken out of service in 1988, the estimated past exposure to infants is slightly higher than the TCE reference dose but is still well below EPA's estimate of the human exposure that corresponds to a dose that causes immune toxicity in mice. This difference, or margin of exposure is sufficient to conclude that the risk for immune toxicity from past exposure to TCE in Bethpage Water District Well 6-2 is low. Since then, water from both wells has been treated and routine monitoring is conducted to verify that the water meets NYS drinking water standards prior to distribution.

CONCLUSION 4

While exposures to facility-related contaminants through the use of unpermitted private wells may have occurred, such exposures are unlikely.

BASIS FOR CONCLUSION

Nassau County has not permitted the installation of private wells for drinking purposes in areas where public water is available since 1987. Since there is very limited historical and/or current data for private wells in the area of the Northrop Grumman/NWIRP facility in Bethpage, we do not know if or for how long people may have been exposed to contaminated water. Any private wells that might exist are unlikely to have been installed at depths that would intersect contaminated groundwater associated with the Northrop Grumman/NWIRP facility. Since the area is serviced by public water, any private wells that may exist in the area would likely only be used for irrigation purposes. Exposure to VOCs in irrigation wells does not constitute an exposure concern. Any VOCs in groundwater would volatilize into the air when the water was released during irrigation.

CONCLUSION 5

Currently, drinking or other uses of water from public water supplies in Calverton, Suffolk County, are not expected to harm people's health.

BASIS FOR CONCLUSION

No public water supplies have been impacted by the Northrop Grumman/NWIRP facility in Calverton, Suffolk County.

CONCLUSION 6

Past use of drinking water from the Peconic River Sportsman Club private well (Suffolk County) is not expected to harm people's health.

BASIS FOR CONCLUSION

The levels of VOCs detected in one Peconic River Sportsman's Club well did not exceed standards or available comparison values. The Club is currently connected to the Riverhead Water District public water supply and wells on the property were abandoned, grouted, cut and capped and no longer available for use.

[3]The estimated exposures pose a cancer risk between one in one million and one in ten thousand.

NEXT STEPS

Recent data for one compound, 1,4-dioxane, indicate it is present in public drinking water supplies, including those within the Northrup Grumman/NWIRP facility plume, and community concern has been voiced regarding this compound. (See page 8 for additional information.) The public health implications of the 1,4-dioxane data are not evaluated in this health consultation. NYSDOH and NYSDEC are committed to the evaluation and future regulation of this compound in drinking water. Recently enacted statute requires public water systems in New York to test for 1,4-dioxane and other emerging contaminants in the future (Chapter 57 of the laws of 2017). In December 2018, the New York State Drinking Water Quality Council recommended that the NYSDOH adopt a maximum contaminant level of 1 part per billion for 1,4-dioxane. The next steps involve consideration of the recommendation by the Commissioner of Health, formal publication of proposed regulations, and an official public comment period. During the interim period before contaminant levels are adopted, the NYSDOH will continue to work with NYSDEC and County Health agencies, as well as with the NYS Drinking Water Quality Council to evaluate 1,4-dioxane data collected by public water supply systems to determine whether further public health actions are needed to reduce drinking water exposures to 1,4-dioxane.

The requirements of Operable Units 2 and 3 (OU2 and OU3) Records of Decision (ROD) for the Northrop Grumman/NWIRP facility in Bethpage will continue to be enforced. Both RODs include a *Public Water Supply Protection* component that is designed to ensure that public water supply wells impacted or threatened by the Northrop Grumman/NWIRP facility groundwater contamination are able to deliver water to their customers that meet state and federal drinking water requirements [DEC 2001 and DEC 2013]. The NYSDOH will work with the NYSDEC and with the Nassau County Health Department (NCDOH) to ensure that the stipulations set forth in the OU2 and OU3 RODs are met and that all impacted and threatened public water supply systems continue to comply with the New York State Part 5 Drinking Water Regulations (Part 5) and federal public drinking water standards.

In addition, the NYSDEC has completed a study on the feasibility of implementing remedial actions to fully contain the groundwater contamination originating at the Northrup Grumman/NWIRP facility. The findings of this feasibility study, and the specific remedial actions that have been identified as being capable of achieving full plume containment, will be incorporated by the NYSDEC into a distinct Proposed Remedial Action Plan for full plume containment.

The NYSDOH will continue to work with the NYSDEC, County Health agencies, the EPA, and ATSDR to review information as it becomes available, evaluate the public health implications of any sampling results, and recommend public health actions as needed.

FOR MORE INFORMATION

If you have questions about the environmental investigation of the Northrop Grumman/NWIRP facilities on Long Island please contact Jason Pelton of the NYSDEC at 518-402-9676. If you have questions about this public health consultation or other health concerns related to the facilities, please contact Steve Karpinski of the NYSDOH at 518-402-7860.

BACKGROUND AND STATEMENT OF ISSUES

This health consultation was prepared in response to a June 30, 2012 petition by a resident of Patchogue, Long Island, New York to the Agency for Toxic Substances and Disease Registry (ATSDR). The petition described concerns about contaminated groundwater originating from Northrop Grumman/Naval Weapons Industrial Reserve Plant (NWIRP) facilities in Bethpage and Calverton, and the Northrop Grumman facility in Great River, Long Island, New York. The petitioner expressed concern that local residents could be exposed to facility-related contaminants (primarily volatile organic compounds [VOCs]) if they relied on groundwater for household use or for irrigation.

This health consultation describes the evaluation of relevant information to find out whether the public is currently being exposed to groundwater impacted by contaminants originating from the Northrop Grumman/NWIRP facilities that exceed maximum contaminant levels established by the United States Environmental Protection Agency (EPA) and by New York State as well as to find out whether the public could have been exposed to these contaminants in the past.

This evaluation includes:

- Review of results of raw, untreated water samples from public water supply wells and monitoring wells in areas that were impacted by facility-related groundwater contamination;
- Assessment of whether private and/or non-community water supply wells were, or are currently, in use in areas where facility-related groundwater contamination exists;
- Evaluation of whether there could have been past exposures to contaminants in drinking water; and
- Characterizing the risk for adverse health effects associated with past or current exposures to contaminated groundwater.

BACKGROUND

The New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), United States Environmental Protection Agency, Nassau County Department of Health (NCDOH), and Suffolk County Department of Health Services (SCDHS) have been involved in the evaluation of environmental contamination associated with Northrop Grumman/NWIRP Bethpage facility and the NWIRP Calverton facility since the 1980s. The Northrop Grumman/NWIRP Bethpage facility is located in the hamlet of Bethpage, in the Town of Oyster Bay, Nassau County, and the NWIRP Calverton facility is located in the hamlet of Calverton in the Town of Riverhead, Suffolk County (Appendix A, Figure 1). Part of the Northrop Grumman/NWIRP facility, and all of the NWIRP Calverton facility were Naval Weapons Industrial Reserve Plants that were owned by the Navy and operated by Northrop Grumman (see Appendix B for more details on these sites). The NYSDEC and NYSDOH have no information indicating that groundwater has been impacted by contamination originating from the Northrop Grumman's former Great River facility, and therefore, this facility is not discussed further in this health consultation.

The three principal groundwater aquifers on Long Island are the Upper Glacial Aquifer, the Magothy Aquifer, and the Lloyd Aquifer (see Appendix A, Figure 2). The Upper Glacial Aquifer is an unconfined aquifer generally found around 30 to 50 feet below ground surface in the Bethpage area. The Magothy Aquifer attains a maximum thickness of approximately 1,100 feet and is the source of water for most of Nassau County and about half of Suffolk County. The

Raritan Formation underlies the Magothy and consists of an upper clay member and a lower sand member (Lloyd Sand). The Lloyd Aquifer is the deepest and oldest of Long Island's aquifers. It is a sand and gravel formation ranging in thickness from zero to five hundred feet. [DEC 2014]. Long Island obtains its drinking water supply primarily from the Magothy and Lloyd aquifers. EPA has designated the Long Island aquifer system as a sole source aquifer, which means that the aquifer is the sole or principal drinking water source for an area and, if contaminated, would create a significant hazard to public health [EPA 2014].

In the early 1970s, standard waste handling practices used by industry, including Northrop Grumman, were found to be contaminating groundwater throughout the United States. These practices included disposal of wastes directly to on-site surface impoundments or to sub-surface liquid waste handling systems, such as cesspools and septic tanks. These practices were common on Long Island and have resulted in extensive groundwater contamination in both Nassau and Suffolk Counties.

Due to an expanding understanding and concern about groundwater contamination and its impact on drinking water supplies, particularly on Long Island, the NYSDOH established interim drinking water guidelines in 1977. These interim guidelines required drinking water suppliers to sample their public water supply wells and restricted the concentration of any one organic chemical allowed in drinking water to no more than 50 micrograms per liter (mcg/L). The interim guidelines were in place until 1989, when New York State established regulations and allowable maximum contaminant levels (MCLs) for public drinking water systems under 10 NYCRR Part 5, Subpart 5-1 (also known as Part 5) [DOH 2013a]. The 1989 regulations lowered the MCLs for many VOCs, including Northrop Grumman facility-related contaminants, to 5 mcg/L. The Part 5 regulations require public water suppliers in New York State to conduct scheduled sampling of the untreated water supply (i.e., raw water) and the water that is distributed to customers. If a water supplier discovers that an MCL is being exceeded, or that one is about to be exceeded, subsection 1.12 of Part 5 requires that the supplier notify the State and take specific actions which include identifying the cause of the MCL exceedance, making modifications to or installation of treatment to meet Part 5 requirements, and submittal of a written report to the State within 30 days that documents these actions. Since suppliers must meet Part 5 requirements, it is unlikely exposures to contaminant levels above MCLs have occurred from public water supplies since implementation of Part 5 regulations in 1989.

NORTHROP GRUMMAN/NWIRP FACILITY

Northrop Grumman has occupied the facility in Bethpage since the early 1930s, and the Naval Weapons Industrial Reserve Plant in Bethpage since 1942. Activities conducted at these facilities included research, prototyping, testing, design engineering, fabrication, and primary assembly of military aircraft and spacecraft. Northrop Grumman/NWIRP ceased most manufacturing-related operations at the Bethpage facility in 1998.

The NYSDEC, in consultation with the NYSDOH, listed the Northrop Grumman Bethpage facility on the New York State Registry of Inactive Hazardous Waste Disposal Sites (also known as State Superfund) in 1983 and has segregated remedial activities into three distinct operable units. An operable unit (OU) is a portion of a remedial site that for technical or administrative reasons can be more effectively addressed separately. OU1 addresses on-site soil contamination, OU2 includes off-site groundwater contamination, and OU3 includes disposal areas referred to as the former Grumman settling ponds that are now occupied by the Town of Oyster Bay Community Park. OU3 also includes off-site groundwater contamination that originated from the settling ponds. The Naval Weapons Industrial Reserve Plant was listed by

the NYSDEC and NYSDOH in 1993. See Appendix B for more information about the history of the Bethpage facility and enforcement actions undertaken by the NYSDEC.

The primary groundwater contaminants of concern for the Northrop Grumman/NWIRP facility are the chlorinated volatile organic compounds (VOCs) tetrachloroethene (PCE), trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), and associated degradation products. Vinyl chloride is also present in the groundwater, but originates from an upgradient property not related to the Northrop Grumman/NWIRP facility. These contaminants have been found at concentrations greater than Part 5 MCLs in public water supply wells. This health consultation evaluates the public health implications of exposures to Northrop Grumman/NWIRP facility contaminants seen in public water supply wells at concentrations exceeding New York State Part 5 and federal drinking water standards.

Public water systems serving more than 10,000 people are required by the Safe Drinking Water Act to also monitor their water supply for select unregulated contaminants. Once every five years, EPA is required to issue a list of unregulated contaminants to be monitored by public water systems. The third Unregulated Contaminant Monitoring Rule (UCMR 3) was published on May 2, 2012. UCMR 3 required monitoring for 30 contaminants (28 chemicals and two viruses) between 2013 and 2015. The UCMR provides a basis for future regulatory actions to protect public health. While not specifically indicated in the petitioner's request for evaluation, one compound, 1,4-dioxane, is included in the UCMR 3 list and data indicate it is present in public drinking water supplies, including those within the Northrup Grumman/NWIRP facility plume, and community concern has been voiced regarding this compound. Summary information about 1,4-dioxane levels in public water supply wells within the Northrup Grumman/NWIRP facility plume is provided in Appendix C. This summary information indicates some Bethpage Water District supply wells are showing increasing levels of 1,4-dioxane over time. In response, the Bethpage Water District began installation of an advanced oxidation process (AOP) treatment system in 2017.

The public health implications of the 1,4-dioxane data are not evaluated in this health consultation. However, the NYSDOH and NYSDEC have committed to the evaluation and regulation of this compound in drinking water. Recently enacted statute requires public water systems in New York to test for 1,4-dioxane and other emerging contaminants in the future (Chapter 57 of the laws of 2017). In December 2018, the New York State Drinking Water Quality Council recommended that the NYSDOH adopt a maximum contaminant level of 1 part per billion for 1,4-dioxane. This recommendation is currently under consideration by the Health Commissioner.

VOC contaminated groundwater originating at the Northrop Grumman/NWIRP facility moves rapidly down through the Upper Glacial Aquifer before coming in contact with the Magothy Aquifer. Impacted groundwater flows to the south, away from the Northrop Grumman/NWIRP facility, as three distinct plumes: a shallow plume, a deep western plume, and a deep eastern plume. The shallow plume is approximately 9,700 feet wide and at least 17,000 feet long (covering approximately 3,800 acres of area). The eastern and western deep plumes appear to be relatively narrow (2,000 feet or less in width) and relatively continuous. The shallow plume generally occurs at depths between 100 and 300 feet below ground surface, and contains TCE, PCE, 1,1,1-TCA, and associated degradation products at concentrations typically less than 50 mcg/L. The deep western plume generally occurs between 300 and 750 feet below ground surface, and contains primarily TCE at concentrations typically greater than 50 mcg/L. The downgradient extent of this plume is approximately 12,000 feet south of what has been identified as the OU2 source areas (see Appendix B for additional information on OUs). The deep eastern plume is believed to have originated from the Bethpage Community Park (former Grumman settling ponds area) which is being administered as OU3. This plume is understood

to be 300 to 650 feet below ground surface, and contains TCE, PCE, 1,1,1-TCA, and degradation products at concentrations typically greater than 50 mcg/L [NFEC 2012]. At least eight public water supply well fields are located within the path of the contaminated groundwater plumes and are either impacted or threatened (likely to become impacted) by the Northrop Grumman/NWIRP facility-related contamination. (See the following section for information on specific well fields). Both the Navy and Grumman are currently designing and constructing groundwater extraction and treatment systems to address groundwater contamination hot-spots in both the western and eastern plumes. Grumman and the Navy are also conducting additional OU2 and OU3 investigations to continue to refine the nature and extent of the off-site groundwater contamination.

The March 2001 and March 2013 NYSDEC RODs for OU2 and OU3 respectively address the bulk of off-site groundwater contamination associated with the Northrop Grumman/NWIRP facility. A ROD presents the remedial action plan for an inactive hazardous waste disposal site and documents the information and rationale used to arrive at the decision. Both RODs call for the implementation of a Public Water Supply Protection Program. This program includes procedures to ensure that appropriate wellhead treatment is put in place that will enable the public water suppliers to deliver water to customers that meet drinking water standards in accordance with New York State Part 5 Drinking Water Regulations and federal drinking water standards [DEC 2001]. Both RODs require Northrop Grumman and/or the Navy to fund the installation of appropriate wellhead treatment systems at impacted public water supply wells. The Public Water Supply Protection Program also includes long-term monitoring of the groundwater upgradient of public water supply well fields to ensure that wellhead treatment facilities can be constructed and be made operational prior to wells being impacted.

In 2017, the NYSDEC reassessed the remedies set forth in the OU2 and OU3 RODs and completed a study on the feasibility of implementing remedial actions to fully contain the groundwater contamination originating at the Northrup Grumman/NWIRP facility. The findings of this feasibility study, and the specific remedial actions that have been identified as being capable of achieving full plume containment, will be incorporated by the NYSDEC into a Proposed Remedial Action Plan (PRAP). A PRAP is a document that the NYSDEC uses to present alternatives to the public and interested parties on how inactive hazardous waste sites can be remediated. The public and interested parties then have an opportunity to comment on the proposed remedial actions presented in the PRAP. Once comments are considered, the final remedy will be documented by the NYSDEC in a ROD. If implemented, full containment would ensure that additional public supply wells south of the identified groundwater contamination area can avoid the need for treatment for facility-related contaminants. Full containment would not only provide significant future protections for public health, it also would avoid long term-costs associated with treatment of additional public supply wells. As stated above, no matter which remedies are ultimately implemented, the appropriate wellhead treatment systems will be installed at any impacted public water supply wells.

Public Water Supplies Impacted or Threatened by the Northrop Grumman/NWIRP Facility

Data from sampling conducted by public water suppliers (as required by Part 5 regulations) and groundwater monitoring data collected (as required by the OU2 and OU3 RODs) show that six public water supply well fields are impacted by the Northrop Grumman/NWIRP facility groundwater contamination (Appendix A, Figure 3). One purpose of the OU2 and OU3 RODs groundwater monitoring requirements is to ensure that appropriate treatment systems are installed at currently impacted public water supply wells, and at those that might become impacted in the future. The OU2 and OU3 RODs also stipulate that Northrop Grumman and the

Navy will fund construction and operating costs associated with the treatment systems. A description of the impacted or threatened public water supplies follows.

1) South Farmingdale Water District

South Farmingdale Water District wells at the Langdon Road and Hicksville-Massapequa Road well fields contain Northrop Grumman/NWIRP facility-related VOCs but at levels below the drinking water standard. Prior to the detection of VOCs, treatment systems were installed at the Langdon Road well field in 2011 and at the Hicksville-Massapequa Road well field in August of 2013 [Dennis Kelleher, H2M Architects and Engineers, personal communication, June 25, 2013], as precautionary measures. The treatment systems were approved by the NCDOH and have operated since 2011 and 2013, respectively. A condition of that approval is that both systems must treat the raw water for both wells even if contamination is not detected in the water. No other South Farmingdale Water District public water supply wells are threatened or impacted by contamination from the Bethpage Facility.

2) New York American Water Company – Merrick Operations

Two New York American Water Company - Merrick Operations supply wells (Well Number 3 and Well Number 4) at the Seaman's Neck Road well field have been contaminated by Northrop Grumman/NWIRP facility-related VOCs, but measured concentrations in raw, untreated water are all below Part 5 MCLs. The Part 5 MCL for TCE is 5 mcg/L. In 2006, TCE was detected at a concentration of 0.6 mcg/L in Well Number 3 (Appendix D, Table 1). Subsequently, TCE concentrations slowly increased to a maximum of 3.3 mcg/L on October 18, 2011. TCE was detected at low levels (0.5 mcg/L) in the New York American Water Company's Well Number 4 in early 2008. The highest TCE level of 0.9 mcg/L was detected in Well Number 4 in February of 2011 (Appendix D, Table 1).

In response to the contamination, the Navy installed an interim (i.e., temporary) VOC treatment system at the Seaman's Neck Road Water Plant in July 2012. A permanent, full scale VOC wellhead treatment system for the Seaman's Neck Road wells went on line in February of 2015. No other New York American Water Company public water supply wells have been threatened or impacted by contamination from the Bethpage facility.

3) Bethpage Water District

Three Bethpage Water District well fields are located within the boundary of the plumes of contaminated groundwater that originate at the Bethpage facility. The Bethpage Water District provides treatment at all of its wells prior to distribution of water to customers.

Bethpage Water District Plant 6

The wells at Bethpage Water District Plant 6 were sampled three times between November and December of 1976 by the NCDOH. TCE was detected in the raw, untreated water samples collected from Well 6-1 at concentrations of 28, 26 and 60 mcg/L during these three sampling events. In December 1976, PCE and 1,1,1-TCA were detected at concentrations of 17 mcg/L and 15 mcg/L, respectively (Appendix D, Table 2). These detections predated the establishment of the NYSDOH interim drinking water guideline for individual VOCs of 50 mcg/L and the current drinking water standards. The District took Well 6-1 out of service in December 1976 when 60 mcg/L of TCE was detected in the well water.

In February 1985, sampling first detected TCE in raw, untreated water from Well Number 6-2 at a concentration of 1 mcg/L. In February 1987, the TCE concentration reached as high as 5 mcg/L in the raw, untreated water (Appendix D, Table 3). Well 6-2 was taken out of service in November 1988.

A VOC treatment system was installed at the Bethpage Water District Plant 6 in 1990. The District returned Well 6-1 into service in June of 1990, and returned Well 6-2 into service in December 1990. Since then, water from both wells has been treated and routine monitoring is conducted to verify that the water meets NYS drinking water standards prior to distribution.

Bethpage Water District Plant 4

TCE was detected in raw, untreated water from Bethpage Water District Plant 4 Well 4-1 between September 7, 1988 and July 30, 1990 (range 0.5 to 2.6 mcg/L). Contamination from the Northrop Grumman/NWIRP facility was not detected in routine monitoring samples again until October of 1992 (1.2 mcg/L) (Appendix D, Table 4). After October 1992, TCE was detected in Well 4-1 at or above the reporting limit during four sampling events between 1993 and 1995.TCE was detected occasionally at low levels in Well 4-2 between January 7, 1993 and October 3, 1994 (Appendix D, Table 5). VOC treatment equipment (air stripper) was installed on wells at the Bethpage Water District Plant 4 (Wells 4-1 and 4-2) in 1995 to treat the raw water prior to its distribution to customers. Routine monitoring is conducted to verify that the water meets NYS drinking water standards prior to distribution. Bethpage Water District removed Well 4-1 from service in February 2013.

Bethpage Water District Plant 5

A VOC treatment system was installed at the Bethpage Water District Plant 5 (Well 5-1) in October of 1995. The first VOC detection in the raw, untreated water at this well did not occur until 2007, when TCE was detected at 0.6 mcg/L. This water was never distributed to customers.

No other Bethpage Water District public water supply wells have been threatened or impacted by contamination from the Northrop Grumman/NWIRP facility. Blending of raw water within the Bethpage Water District occurs depending on seasonal need, however, all District plant sites treat raw water prior to distribution to customers. The Bethpage Water District routinely monitors the drinking water in accordance with Part 5 regulations to assess if the water quality meets state and federal drinking water standards.

Private Wells in the Bethpage Area

The NYSDOH reviewed NYSDEC Region 1 well completion reports[4] for permitted private irrigation and cooling wells in the area downgradient of the Northrop Grumman/NWIRP facility dating back to the 1940s to evaluate whether wells other than the wells associated with public water suppliers could have been impacted by groundwater contamination from the Northrop Grumman/NWIRP facility. Overall, the limited well completion reports indicated that past or current exposure to Northrop Grumman/NWIRP facility site contaminants through the use of permitted non-public water supply wells is unlikely.

[4] The NYS Environmental Conservation Law requires that a well completion report be completed by the well driller and filed with the NYSDEC for each well drilled within the State of New York that has the ability to pump greater than 45 gallons per minute.

The available well completion reports show that an irrigation well was located at a farm near the Northrop Grumman/NWIRP facility. However, current satellite imagery for the address on the well completion report shows that the area is heavily developed, and that there is no farm currently at this location. The NYSDOH has no documentation showing that the well was abandoned. However, due to the availability of public water in the area, continued use of a farm well is unlikely.

The well completion reports also show two irrigation wells installed at the Island Trees public school campus on Owl Place in Levittown, a location that is downgradient (in terms of groundwater flow direction) of the Northrop Grumman/NWIRP facility. The reports indicate that the wells were installed to depths of 61 feet and 108 feet. One irrigation well has been decommissioned. A groundwater sample collected in 2007 from the remaining irrigation well, as part of an environmental investigation of a nearby drycleaner, did not detect contaminants in the well. Data from vertical profile boring sampling conducted in this general area show that facility-related groundwater contamination is greater than 140 feet below ground surface, therefore these wells will not likely be impacted [NFEC 2012].

Two additional wells were identified near the Northrop Grumman/NWIRP facility. Well completion reports indicate that the wells were installed to the same depth as contaminated groundwater associated with the Northrop Grumman/NWIRP facility. The NYSDEC reports that one of these wells, installed at 100 Lauman Lane (immediately west of the Northrop Grumman/NWIRP facility across Hicksville Road) for the Lauman Company in 1967 has been abandoned [Bill Spitz, NYSDEC Region 1, personal communication, July 3, 2012], although the date of abandonment is unknown. The well completion report only noted that this well was a replacement for a previously installed well. The report did not specify the use of this well. There are no known exposures resulting from the use of this well. The second nearby well was installed in 1953. The completion report for this well noted that it was used to cool a restaurant located near the Northrop Grumman/NWIRP facility. The type of cooling system used in conjunction with this well is not known. However, cooling systems in this part of Long Island are typically closed (i.e., the water is circulated through the system and not exposed to the air). The well is no longer in use, but the date of abandonment is unknown. If the water from this well was used in a closed system for cooling, it is unlikely that past exposures occurred.

Nassau County has not permitted the installation of private wells for potable purposes in areas that are served by public water supplies since 1987. However, there are no prohibitions on the installation of irrigation wells having a pumping capacity no greater than 45 gallons per minute. Any new well installed with a pumping capacity greater than 45 gallons per minute requires permitting by the NYSDEC. There is no program in place to identify whether private wells are in use in Nassau County [John Lovejoy, NCDOH, personal communication, March 11, 2014]. Consequently, the NYSDOH cannot determine whether anyone is being exposed to site-related contaminants through the use of private wells. However, data from vertical profile borings and monitoring well sampling show that groundwater contamination associated with the Northrop Grumman/NWIRP facility is generally located at depths greater than 140 feet below ground [NFEC 2012]. Any private wells are unlikely to have been installed at depths that would intersect contaminated groundwater associated with the Northrop Grumman/NWIRP facility. Since the area is served by public water, these wells are probably used only for irrigation and are unlikely to be used for drinking purposes. Exposure to VOCs in irrigation wells does not constitute an exposure concern. Any VOCs in groundwater would volatilize into the air when the water was released during irrigation.

NWIRP FACILITY

The Naval Weapons Industrial Reserve Plant in Calverton (Appendix A, Figure 4) was operated by Northrop Grumman from the early 1950s until 1996. More detailed information about the Northrop Grumman facility in Calverton can be found in Appendix B.

The NWIRP facility is a New York State Superfund site. Contaminants of concern in groundwater include the chlorinated solvent 1,1,1-TCA and its associated breakdown products 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), and chloroethane. Contaminated groundwater has migrated off-site in a southerly direction and has impacted an area of approximately 93 acres [NWIRP 2012a].

Private wells, Brookhaven National Laboratory federal government owned wells, and three municipal water supply systems (Riverhead Water District, Shorewood Water Company, and Suffolk Water Company) are used to meet the drinking water needs of the area. These wells are located far outside the area of groundwater contamination associated with the NWIRP Calverton site, and are not impacted [NFEC 2006].

Two former Northrop Grumman production wells are located on the NWIRP site. These wells are located on land that is now owned by the Town of Riverhead and are controlled by the Riverhead Water District. These wells are not currently permitted by the NYSDEC and cannot be used by the Riverhead Water District as part of its public water supply system or for any other purpose without Suffolk County Department of Health Services – Office of Water Resources approval.

Water Supplies Impacted or Threatened by the NWIRP Facility

The only wells impacted by contamination originating at the NWIRP site that were used for drinking water are on the privately owned Peconic River Sportsman's Club property (Appendix A, Figure 4).

1) Peconic River Sportsman's Club

The Peconic River Sportsman's Club (Club) is situated on 400 acres south of the NWIRP site (see Appendix A, Figure 4). The Main Lodge, an activity center, a private residence, and a shooting range on the Club's property were supplied drinking water from on-site wells until 2012, prior to the property being connected to a public water supply.

Beginning in 1983, the SCDHS regulated the well at the Main Lodge (Well Number 1) as a non-community public water supply. A non-community water system is a public water system, such as a private well serving a restaurant, that serves the public, but does not generally serve the same people year-round [DOH 2007]. Routine sampling of Well Number 1 by the SCDHS between 1988 and 2007 detected the site-related volatile organic compounds 1,1-DCA at 0.7 mcg/L and in 1996 detected 1,1-DCE at 0.5 mcg/L [SCDHS 2007]. Both detections were below the New York State drinking water standard of 5 mcg/L.

Wells installed at the activity center (Well Number 2) in 2001 and at the shooting range (Well Number 3) in 2007 were also considered non-community public water supply wells. A water sample from the activity center well (Well Number 2) on October 24, 2001 (collected immediately after the well was installed) showed 1,1-DCA at a concentration of 11 mcg/L. Since this level exceeded the New York State MCL of 5 mcg/L for 1,1-DCA, the SCDHS advised the

Club that the water supplied by this well should not be used for drinking or cooking until a permanent solution to the contamination could be found [SCDHS 2002]. The Club did not use the activity center well for potable purposes until 2007, when a point-of-entry granular activated carbon treatment system was installed.

In January of 2008, the Navy began quarterly sampling of all four wells on the Club property (lodge, activity center, private residence and shooting range), including pre- and post-treatment samples of the activity center well. During this time, the lodge well was not used for drinking purposes due to VOC detections, and the well supplying the activity center was treated with a liquid-phase granular activated carbon system prior to use. Data do not indicate that the supply well at the shooting range (Well Number 3) and the private well at the residence on the property have ever been impacted by site-related contamination. Analysis of the post-treatment samples for the activity center system did not detect site-related contaminants [NWIRP 2012b].

In June of 2012, the Navy completed installation of a water line that connected the Club to the Riverhead Water District public water supply. All Club wells were then abandoned, grouted, cut and capped [NWIRP 2012c], and quarterly sampling of the wells ended.

DISCUSSION

Exposure Pathways

An exposure pathway is the process by which a person can come into contact with a hazardous substance. People were exposed in the past to Northrop Grumman/NWIRP facility groundwater contamination in public drinking water supplies. Homeowners with contaminated water were exposed in several ways to the chemicals in their water. These include:

- ingestion - consuming the water by drinking it and cooking with it,
- inhalation - chemicals evaporating into the air may be breathed in during bathing, showering, or using water in household chores; and,
- direct contact with the skin.

Because historical sampling data for the public supply wells is limited, we do not know for exactly how long consumers of the public water supply had been using contaminated drinking water. The duration of contaminant exposure was generally assumed to be the length of time between when the contaminant was first detected in a given well to the time of the last detection and people were known to still be drinking water from that well. The exception to this was the assumed exposure duration in Bethpage Water District Well 6-1. This well was shown to be contaminated at the first sampling event in 1976, and was assumed to be contaminated for 24 years, from the time the well was put into service in 1952. No other well showed contamination at the first sampling event. This indicates the contamination in the other wells began at later dates.

Nassau County has not permitted the installation of private wells for drinking purposes in areas where public water is available since 1987. Since no historical or current data for private wells in the area of the Northrop Grumman/NWIRP facility are available, we do not know if and for how long people may have been exposed to contaminated water. Due to data limitations, this pathway was not evaluated.

A summary of the exposure pathways related to the Northrop Grumman/NWIRP facility in Bethpage and NWIRP facility in Calverton is presented in Table 1 below.

Table 1: Exposure Pathway Evaluation for Drinking Water Supply Wells Impacted by Northrop Grumman Facilities.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Pathway Classification
Northrop Grumman/NWIRP facility Release	Groundwater	Private wells	Ingestion Inhalation Dermal	Residents (adults and children)	Past, Current, Future - Potential
		South Farmingdale Water District	Ingestion Inhalation Dermal	Residents (adults and children)	Past, Current, Future - Eliminated
		NYAWC Well 3 & Well 4	Ingestion Inhalation Dermal	Residents (adults and children)	Past –Complete Current and Future– Eliminated
		BWD Plant 6 Well 6-1	Ingestion Inhalation Dermal	Residents (adults and children)	Past – Complete Current and Future- Eliminated
		BWD Plant 6 Well 6-2	Ingestion Inhalation Dermal	Residents (adults and children)	Past – Complete Current and Future- Eliminated
		BWD Plant 4 Well 4-1	Ingestion Inhalation Dermal	Residents (adults and children)	Past – Complete Current and Future - Eliminated
		BWD Plant 4 Well 4-2	Ingestion Inhalation Dermal	Residents (adults and children)	Past – Complete Current and Future - Eliminated
NWIRP facility Release	Groundwater	PRSC	Ingestion Inhalation Dermal	Residents (adults and children)	Past – Complete Current and Future - Eliminated

NYAWC: New York American Water Company – Merrick Operations; BWD: Bethpage Water District;
PRSC: Peconic River Sportsman's Club

Selection of Contaminants for Further Evaluation

Contaminants were selected for further evaluation by comparing the highest contaminant level (concentration) for each well to its New York State public drinking water standard [DOH 2013a] and the ATSDR's drinking water comparison value [ATSDR 2017]. Both the standards and the comparison values are water concentrations at which adverse health effects are not expected to occur. Exceeding a drinking water standard or comparison value does not mean that an adverse health effect will occur, but that further evaluation of the contaminant is needed. The comparison values are based solely on health-based criteria, while the water standards are enforceable regulatory values that consider other factors in addition to health (e.g., the cost of compliance and the ability to reliably detect the chemical). Contaminants exceeding either of these values (Table 1) included PCE (Bethpage Water District Well 6-1), 1,1,1-TCA (Bethpage Water District Well 6-1), and TCE (New York American Water Company Wells 3 and 4, and Bethpage Water District Wells 4-1, 4-2, 6-1 and 6-2). The risks for cancer and noncancer health effects for exposures to these chemicals in these wells were further evaluated and are presented in this document. Potential health effects of site-related chemicals selected for further evaluation are discussed in Appendix E.

The levels of 1,1-DCA and 1,1-DCE in the Peconic River Sportsman's Club well do not exceed the New York State drinking water standards or available ATSDR comparison values (Table 2), and are therefore not evaluated further.

Table 2. Comparison of Highest Contaminant Concentrations in Public Water Supply Wells Impacted by Northrop Grumman Facilities to NYS Drinking Water Standards and ATSDR Drinking Water Comparison Values.
(all values in micrograms per liter)

Chemical	Well	Highest Detected Level	Contaminant Selected for Further Evaluation	New York State Drinking Water Standard	ATSDR Drinking Water Comparison Value
1,1-DCA	PRSC 1	0.7	No	5	not available
1,1-DCE	PRSC 1	0.5	No	5	63(EMEG)
PCE	BWD 6-1	17	Yes	5	12 (CREG)
1,1,1-TCA	BWD 6-1	15	Yes	5	14,000 (RMEG)
TCE	NYAWC 3	3.3	Yes	5	0.43 (CREG)
	NYAWC 4	0.9	Yes		
	BWD 4-1	2.6	Yes		
	BWD 4-2	1	Yes		
	BWD 6-1	60	Yes		
	BWD 6-2	5	Yes		

1,1-DCA = 1,1-dichloroethane; 1,1-DCE = 1,1-dichloroethene; PCE = tetrachloroethene; 1,1,1-TCA = 1,1,1-trichloroethane; TCE = trichloroethene; PRSC = Peconic River Sportsman's Club; BWD = Bethpage Water District; NYAWD = New York American Water Company – Merrick Operations; CREG = Cancer Risk Evaluation Guide; EMEG = chronic Environmental Media Evaluation Guide; RMEG = intermediate Reference Dose Media Evaluation Guide for a child.

Public Health Implications of Completed Pathways

The increased risk for developing cancer (above the background lifetime cancer rate for humans) for people who drank and used water containing TCE and PCE is evaluated by estimating exposure for each drinking water contaminant and then applying the chemical's cancer potency factor (1,1,1-TCA has not been classified as a carcinogen). The cancer potency factor is a numerical estimate of the carcinogenic strength (potency) of a chemical. Noncancer health risks are evaluated by comparing the exposure estimates for each chemical to the corresponding chemical reference dose, which represents a lifetime exposure at which noncancer health effects are unlikely to occur. The cancer and noncancer health risks from drinking water are evaluated using ATSDR guidance [ATSDR 2014a]. In cases when exposure to contaminated water was for periods less than lifetime, the cancer risks were calculated from birth to the when the exposure was assumed to end, which included the early stages of life when contaminant exposure and vulnerability are higher compared to adults.

Since exposure to VOCs such as TCE, PCE, and 1,1,1-TCA in drinking water is possible not only by ingestion, but also by dermal contact and inhalation from water uses such as showering and bathing, exposure through the inhalation and dermal routes together is assumed to be equal to that of the ingestion route. Thus, we doubled the water concentration used in our calculation to estimate the dose of the chemical in drinking water.[5]

[5] The basis for the assumption is that numerous investigations establish inhalation and dermal exposure pathways, and several investigations that looked at the contribution of the inhalation/dermal pathway to the total exposure showed that under certain conditions exposures by the inhalation or dermal routes could approach the same level as exposure by ingestion (e.g., Bogen and McKone, 1988; McKone, 1989; McKone and Knezovich, 1991; Maxwell et. al., 1991; Chinery and Gleason, 1993; Weisel and Jo, 1996).

Bethpage Water District Well 6-1

Well 6-1 in the Bethpage Water District had the highest contaminant levels of the wells influenced by Northrup Grumman facilities. In 1976, Well 6-1 contained TCE as high as 60 mcg/L, and also had elevated levels of PCE (maximum = 17 mcg/L) and 1,1,1-TCA (maximum = 15 mcg/L) (see Appendix D, Table 2). The District installed the well in 1952 [DEC 1952], and the first sampling in 1976 showed contamination. The District took the well out of service shortly thereafter.

The average water concentrations during November and December 1976, when the well was known to be contaminated and in service, are used to estimate the cancer risk. It is also assumed that people drank water at the average concentration for 24 years (the estimated number of years the well was in operation and used for drinking water). Based on the available sampling information, our exposure estimates, and the cancer potency factor, past long-term exposure (i.e., 24 years) to drinking water containing TCE at the average concentration[6] found in Well 6-1 (38 mcg/L) while it was in service posed an increased lifetime risk for cancer between 3 in one hundred thousand and 8 in one hundred thousand.[7] This increase in cancer risk is characterized as low. The estimated increased cancer risk for exposure to the average level[2] of PCE (5.8 mcg/L) in Well 6-1 was between 1 in ten million and 4 in ten million, which is considered to be very low. See Appendix F for additional detail on the cancer risk calculations for TCE and PCE.

To evaluate noncancer risks, children and adult exposure estimates for PCE, 1,1,1-TCA, and TCE are compared to each chemical's EPA reference dose [EPA 2007b; 2011b; 2012b]. For PCE and 1,1,1-TCA, children and adult exposure estimates based on the contaminant levels in Well 6-1 were below the reference dose. Therefore, the risk for noncancer health effects from these exposures is minimal (see Appendix F for additional details on the noncancer risk calculations).

The EPA reference dose for TCE[8] is based on studies reporting immune toxicity in mice [Keil *et al*. 2009; Peden-Adams *et al*. 2006] and developmental toxicity (fetal heart defects) in rats [Johnson *et al*. 2003]. The average TCE concentration in the drinking water from Well 6-1 (38 mcg/L), which was assumed to represent long-term past daily exposure, was used to evaluate risks to the immune system. The estimated exposures of children are up to 22 times higher than the reference dose, and the estimated exposures of adults are up to 6 times higher than the reference dose. The evaluation indicates that past exposures posed a risk for effects on the immune system based on a comparison of the exposures of children and adults to estimated effect levels. The TCE exposures in drinking water for children and adults were 4 and 16 times lower, respectively, than the EPA's estimate of the human exposure that corresponds to a dose that causes immune toxicity in mice [EPA 2011b]. This difference, or margin of exposure, is considered to be too small to be adequately protective of public health. Stated another way, the

[6] The average values for TCE and PCE were calculated using the sampling results from November 29, December 2, and December 6, 1976, which represent the only sampling dates during the time the well was in service (see Table 2, Appendix C). A value of one-half the detection limit (0.25 mcg/L) was used for non-detects.

[7] The calculation of estimated cancer risks for TCE uses age-dependent adjustment factors to account for the potential increased vulnerability in early life stages for those exposed to chemicals such as TCE that cause cancer by a mutagenic mode of action [EPA 2011a,b].

[8] For TCE, ATSDR has adopted the EPA reference dose of 0.0005 mg/kg/day as its chronic oral minimal risk level [ATSDR 2014b]. The chronic minimal risk level is virtually identical to a reference dose and is defined as an estimate of a daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects for exposures up to a lifetime.

estimated TCE exposure from using water from Bethpage Water District Well 6-1 approaches exposures that might cause immune system effects in humans.

The highest TCE water concentration was used to evaluate the risk for developmental effects because these effects may occur after relatively short periods of exposure (e.g., early pregnancy). Using the highest TCE water concentration (60 mcg/L), a pregnant woman (used to evaluate the risk to the fetus) is estimated to receive an exposure that is about 8 times higher than the reference dose. The evaluation determined that the highest TCE water concentration posed a risk for fetal heart malformations because the estimated TCE exposure at 60 mcg/L is only 1.2 times lower than the EPA's estimated human TCE exposure that corresponds to a dose associated with fetal heart malformations in rats [EPA 2011b]. This difference, or margin of exposure, is considered to be too small to be adequately protective of public health. Stated another way, the estimated TCE exposure from using water from Bethpage Water District Well 6-1 approaches exposures that could result in fetal heart defects in humans. Additional details on our calculation of noncancer hazard quotients and margins of exposure are found in Appendix F.

Bethpage Water District Wells 4-1, 4-2, 6-2 and New York American Water Company Wells 3 and 4

Exposures and cancer and noncancer health risks for TCE in the other wells influenced by the Northrop Grumman facilities (New York American Water Company Wells 3 and 4, and Bethpage Water District Wells 4-1, 4-2, and 6-2) were estimated using the same general methods as for Bethpage Water District Well 6-1. For each well, the cancer risk estimates reflected the period of time that persons might have been using TCE-contaminated water from that well. In each case, the exposure duration was assumed to be the length of time between when TCE was first detected in a given well, to the time of the last detection when people were known to still be drinking water from that well. All the estimated TCE exposures in these wells are estimated to have posed a very low to low increased lifetime cancer risk (ranging from about 9 in 100 million to 2 in one million). The exposures are also estimated to have posed a minimal risk for noncancer health effects, since they do not exceed each chemical's reference dose, with the exception of exposure to the average level of 2 mcg/L TCE in Bethpage Water District Well 6-2. The estimated TCE infant exposure at this water level is slightly higher than the TCE reference dose, but is 84 times lower than the EPA's estimate of the human exposure that corresponds to a dose that causes immune toxicity in mice [EPA 2011b]. This difference, or margin of exposure, is considered to be sufficient to conclude that the risk for immune toxicity from past exposure to the average TCE level in Bethpage Water District Well 6-2 (2 mcg/L) is low. A summary of the evaluation of cancer and noncancer risks is provided in Table 3. See Appendix F for additional details on our risk calculations for these wells.

Table 3: Water Concentrations, Exposure Durations, Cancer Risks and Hazard Quotients for TCE in Public Water Supply Wells Impacted by Northrop Grumman Facilities

Chemical	Well	Maximum Water Concentration (mcg/L)	Average Water Concentration[1] (mcg/L)	Exposure Duration (years)[2]	Cancer Risk[3]	Noncancer Hazard Quotient[4]
TCE	BWD 6-2	5	2.0	4	2 in 1,000,000	1.1
	BWD 4-1	2.6	0.49	7	6 in 1,000,000	0.36
	BWD 4-2	1	0.48	3	4 in 10,000,000	0.27
	NYAWC 3	3.3	1.12	6	1 in 1,000,000	0.64
	NYAWC 4	1	0.37	4	3 in 10,000,000	0.21

TCE= trichloroethene; mcg/L = micrograms per liter; BWD = Bethpage Water District; NYAWC = New York American Water Company.

[1]The water concentrations were average over the time between when the contaminant was first detected to the time of the last detection when people were known to still be drinking water from that well, using one-half the detection limit for any non-detects over the exposure duration. Average water concentrations were used to evaluate cancer and non-cancer risks except for TCE developmental toxicity, for which the highest detected water concentration was used. See Appendix F for additional detail and calculations.

[2]The duration of contaminant exposure was assumed to be the length of time between when the contaminant was first detected in a given well to the time of the last detection and people were known to still be drinking water from that well.

[3]Highest cancer risk is shown of those calculated for several age groups. See Appendix F for additional detail and calculations.

[4]Highest hazard quotient is shown of those calculated for several age groups. The hazard quotient is calculated by dividing the estimated contaminant exposure by the chemical's reference dose. Hazard quotients less than 1 indicate that the exposure is less than the reference dose and there is minimal risk for noncancer health effects. See Appendix F for additional detail and calculations.

LIMITATIONS

The conclusions described in this report are based on available data. Since there is limited historic private well data or a program in place to identify whether private wells are still in use in Nassau County, it is not possible to determine past, current or future public health implications of exposures to contaminants in private water supplies in the area of the Northrop Grumman/NWIRP facility. Since the area is served by public water, any such private wells are probably used only for irrigation and are unlikely to be used for drinking. Exposure to VOCs in irrigation wells does not constitute an exposure concern. Any VOCs in groundwater would volatilize into the air when the water was released during irrigation. In addition, private wells are unlikely to have been installed at depths that would intersect contaminated groundwater associated with the Northrop Grumman/NWIRP facility. Any uncertainties related to the use of private wells would not be expected to change any of the conclusions of this health consultation.

CONCLUSIONS

The evaluation of VOCs included in this health consultation indicates that currently, drinking or other uses of water from public water supplies affected by the Northrop Grumman/NWIRP facility in Bethpage, Nassau County is not expected to harm people's health. This is because the public water supplies are monitored for chemical contaminants on a regular basis based on current drinking water standards, treatment to remove VOC contaminants from the public water

supplies is being implemented when necessary prior to distribution. Furthermore, 30 sentinel/outpost monitoring wells located upgradient of water district supply wells are monitored on a quarterly basis by Northrop Grumman. These sentinel/outpost monitoring wells were designed to provide 5-year early detection to downgradient water supply wells.

Past use of drinking water contaminated with TCE from Bethpage Water District Well 6-1 in the past (before 1976) could have harmed people's health. Some people were likely exposed to VOCs, including TCE, in drinking water prior to the time when water treatment systems were installed on certain supply wells. The estimated ingestion and inhalation exposures to TCE (the primary contaminant in the water) in Well 6-1, occurring before 1976, approached exposures that could have resulted in immune or developmental toxicity. Past research has shown TCE exposure is associated with immune system effects and developmental effects such as congenital heart defects. While studies have suggested TCE exposures can cause changes in the body's immune system, it is difficult to identify the specific health problems that might result. Studies that focused on relatively high-level exposures among occupational groups associated TCE exposures with kidney cancer, liver cancer, and lymphoma. Exposures to TCE from Well 6-1 ended in 1976, and it is not possible to know whether any specific individual has already experienced health effects or to predict whether an individual will experience health effects resulting from this particular past exposure. Preventive health recommendations for people who had drinking water and/or inhalation exposures to TCE from Well 6-1 prior to 1976 are similar to general recommendations for others: maintain a healthy lifestyle, have regular medical checkups, and discuss specific concerns with healthcare providers.

Past long-term ingestion and inhalation exposure to PCE and 1,1,1-TCA in Bethpage Well-6-1 is not expected to harm people's health because PCE was found in Well 6-1 at levels estimated to pose a very low increased risk for cancer, and 1,1,1-TCA and PCE were at levels that posed a minimal risk for noncancer health effects.

Past long-term ingestion and inhalation exposure to TCE in the other public water supplies (i.e., other than Bethpage Water District Well 6-1) affected by Northrop Grumman/NWIRP facility in Bethpage is not expected to harm people's health. This is because these TCE was found at levels in drinking water estimated to pose a very low to low increased risk for cancer and a minimal risk for noncancer health effects. In one well (Bethpage Water District Well 6-2), taken out of service in 1988, the estimated past exposure to infants is slightly higher than the TCE reference dose but is still well below EPA's estimate of the human exposure that corresponds to a dose that causes immune toxicity in mice. This difference, or margin of exposure is sufficient to conclude that the risk for immune toxicity from past exposure to TCE in Bethpage Water District Well 6-2 is low. Since then, water from both wells has been treated and routine monitoring is conducted to verify that the water meets NYS drinking water standards prior to distribution.

While exposures to facility-related contaminants through the use of unpermitted private wells may have occurred, such exposures are unlikely. Nassau County has not permitted the installation of private wells for drinking purposes in areas where public water is available since 1987. Since there is very limited historical and/or current data for private wells in the area of the Northrop Grumman/NWIRP facility in Bethpage, we do not know if and for how long people may have been exposed to contaminated water. Data from vertical profile borings and monitoring well sampling show that groundwater contamination associated with the Northrop Grumman/NWIRP facility is generally located at depths greater than 140 feet below ground [NFEC 2012]. Any private wells that might exist are unlikely to have been installed at depths that would intersect contaminated groundwater associated with the Northrop Grumman/NWIRP facility. Since the area is served by public water, any such private wells are probably used only

for irrigation and are unlikely to be used for drinking. Exposure to VOCs in irrigation wells does not constitute an exposure concern. Any VOCs in groundwater would volatilize into the air when the water was released during irrigation.

Currently, drinking or other uses of water from public water supplies in Calverton, Suffolk County, are not expected to harm people's health. This is because no public water supplies have been impacted by the Northrop Grumman/NWIRP facility in Calverton, Suffolk County.

Past use of drinking water from the Peconic River Sportsman Club private well (Suffolk County) is not expected to harm people's health. This is because the levels of VOCs detected in one Peconic River Sportsman's Club well did not exceed standards or available comparison values. The Club is currently connected to the Riverhead Water District public water supply. The Club's private wells were abandoned, grouted, cut and capped and no longer available for use.

RECOMMENDATIONS

The NYSDOH and NYSDEC will ensure that the requirements of the OU2 and OU3 RODs for the Northrop Grumman/NWIRP facility in Bethpage continue to be enforced. Both RODs include a Public Water Supply Protection component that is designed to ensure that public water supply wells impacted or threatened by the Northrop Grumman/NWIRP facility groundwater contamination are able to deliver water to their customers that meet state and federal drinking water requirements [DEC 2001].

The conclusions drawn regarding the protectiveness of the existing Records of Decision are based on hydrological information and chemical analysis available at the time of their execution – and the remedies selected and in place rely heavily on continued treatment of existing public water supply wells. The NYSDEC has completed a study on the feasibility of implementing additional remedial actions to fully contain the groundwater contamination originating at the Northrup Grumman/NWIRP facility. The findings of this feasibility study, and the specific remedial actions that have been identified as being capable of achieving full plume containment, will be incorporated by the NYSDEC into a Proposed Remedial Action Plan (PRAP). Any additional remedial actions identified by the NYSDEC will continue to similarly ensure that any public water supply wells impacted or threatened would be treated to deliver water to customers that meets all applicable standards.

Exposures to TCE from Well 6-1 ended in 1976, and it is not possible to know whether any specific individual has already experienced health effects or to predict whether an individual will experience health effects resulting from this past exposure. Preventive health recommendations for people who had drinking water and/or inhalation exposures to TCE from Well 6-1 prior to 1976 are similar to general recommendations for others: maintain a healthy lifestyle, have regular medical checkups, and discuss specific concerns with healthcare providers.

The State has committed to the evaluation and regulation of 1,4-dioxane in drinking water, and the NYSDOH will work with ATSDR, NYSDEC, EPA and County Health agencies to evaluate 1,4-dioxane data collected by public water supply systems to determine whether further public health actions are needed.

PUBLIC HEALTH ACTION PLAN

The NYSDOH will work with the NYSDEC and with the Nassau County Department of Health to ensure that the stipulations set forth in the OU2 and OU3 RODs for the Northrop Grumman/NWIRP are met and that all impacted and threatened public water supply systems continue to comply with the New York State Drinking Water Regulations and federal public drinking water standards. The program is designed to ensure that appropriate wellhead treatment is put in place that will enable the public water suppliers to meet drinking water standards.

The NYSDOH will continue to work with NYSDEC and County Health agencies to evaluate 1,4-dioxane data collected by public water supply systems to determine whether further public health actions are needed to reduce drinking water exposures to 1,4-dioxane. In support of this activity, NYSDOH and NYSDEC will continue to work with the NYS Drinking Water Quality Council established by NYS Public Health Law 1113 in 2017 to provide science-based recommendations about emerging contaminants in drinking water to protect public health. In December 2018, the New York State Drinking Water Quality Council recommended that the NYSDOH adopt a maximum contaminant level of 1 part per billion for 1,4-dioxane. This recommendation is currently under consideration by the Commissioner of Health. Next steps include formal publication of newly proposed regulations and an official public comment period.

The NYSDOH will also continue to work with the NYSDEC, County Health agencies, the EPA, and the ATSDR to review information as it becomes available, evaluate the public health implications of any sampling results, and recommend public health actions as needed.

REFERENCES

[ATSDR] Agency for Toxic Substances and Disease Registry. 2006. Toxicological Profile for 1,1,1-Trichloroethane. US Department of Health and Human Services. Public Health Service. [updated 2006 July; accessed 2014 February 18]. Available from: http://www.atsdr.cdc.gov/ToxProfiles/tp70.pdf.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2014a. Exposure Dose Guidance for Water Ingestion. Division of Community Health Investigations.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2014b. Toxicological Profile for Trichloroethylene. US Department of Health and Human Services. Public Health Service. [updated 2015 January 21; accessed 2018 October 18]. Available from: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=173&tid=30

[ATSDR] Agency for Toxic Substances and Disease Registry. 2017. Drinking Water Comparison Values. Atlanta, GA. [updated February 2017; accessed 2017 December 20].

[BWD] Bethpage Water District. 1987. Air Stripping Report. December 1987.

[DEC] New York State Department of Environmental Conservation. 1952. Completion Report: Long Island Well. Well No. N-3876-T. Division of Water Power and Control.

[DEC] New York State Department of Environmental Conservation. 2001. Record of Decision, Operable Unit 2 Groundwater, Northrop Grumman and Naval Weapons Industrial Reserve Plant Sites, Nassau County, Site Numbers 1-30-003A & B.

[DEC] New York State Department of Environmental Conservation. 2013. Record of Decision, Northrop Grumman – Bethpage Facility, Operable Unit Number: 03, State Superfund Project, Bethpage, Nassau County, Site Number 1-30-003A, March 2013.

[DEC] New York State Department of Environmental Conservation. 2014. Long Island Aquifers. [updated 2014; accessed 2018 October 18]. Available from: http://www.dec.ny.gov/lands/36183.html.

[DOH] New York State Department of Health. 1977. New Release. January 13, 1977. Robert P. Whalen, MD, Commissioner.

[DOH] New York State Department of Health. 2006. Trichloroethene (TCE) [updated 2015 September; accessed 2018 October 18]. Available from: http://www.health.ny.gov/environmental/chemicals/trichloroethene/docs/cd_tce.pdf.

[DOH] New York State Department of Health. 2007. Drinking Water Program: Frequently Asked Questions [updated 2007 August; accessed 2018 October 18]. Available from: https://www.health.ny.gov/environmental/water/drinking/faq_def.htm.

[DOH] New York State Department of Health. 2013a. 10 NYCRR (New York State Codes, Rules and Regulations). Part 5, Drinking Water. Subpart 5-1, Public Water Systems [updated 2014 June; accessed 2018 October 18]. Available from: http://www.health.ny.gov/environmental/water/drinking/regulations/.

[DOH] New York State Department of Health. 2013b. Tetrachloroethene (Perc) in Indoor and Outdoor Air. September 2013 Fact Sheet [updated 2013; accessed 2018 October 18]. Available from: http://www.health.ny.gov/environmental/chemicals/tetrachloroethene/docs/perc.pdf.

[EPA] United States Environmental Protection Agency. 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. Risk Assessment Forum. EPA/630/R-03/003F [accessed 2018 October 18]. Available from: http://www.epa.gov/ttn/atw/childrens_supplement_final.pdf.

[EPA] United States Environmental Protection Agency. 2006. Implementation of the Cancer Guidelines and Accompanying Supplemental Guidance - Science Policy Council Cancer Guidelines Implementation Workgroup Communication II: Performing Risk Assessments that Include Carcinogens Described in the Supplemental Guidance as Having a Mutagenic Mode of Action. Memo from William H. Farland to Science Policy Council.

[EPA] United States Environmental Protection Agency. 2007a. Toxicological Review of 1,1,1-Trichloroethane. EPA/635/R-03/013 [updated 2007 September 28; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2007b. Integrated Risk Information System. 1,1,1-Trichloroethane (CASRN 71-55-6). National Center for Environmental Assessment, Office of Research and Development [updated 2007 September 28; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2011a. Toxicological Review of Trichloroethylene. EPA/635/R-09/011F [updated 2011 September 28; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2011b. Integrated Risk Information System. Trichloroethylene (CASRN 79-01-6). National Center for Environmental Assessment, Office of Research and Development [updated 2011 September 28; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2011c. Exposure Factors Handbook: 2011 Edition. EPA/600/R-090/052F [updated 2016 April 6; accessed 2018 October 18]. Available from: http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

[EPA] United States Environmental Protection Agency. 2012a. Toxicological Review of Tetrachloroethylene (Perchloroethylene). EPA/635/R-08/011F [updated 2012 February 10; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2012b. Integrated Risk Information System. Tetrachloroethylene (CASRN 127-18-4). National Center for Environmental Assessment, Office of Research and Development [updated 2012 February 10; accessed 2018 October 18]. Available from: https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2013. Enforcement and Compliance History On-line. Detailed Facility Report [updated 2014 September 12; accessed 2018 October 18]. Available from: https://echo.epa.gov/detailed-facility-report?fid=110033146138.

[EPA] United States Environmental Protection Agency. 2014. Sole Source Aquifers. Region 2 Water [updated 2015 October 22; accessed 2016 February 18]. Available from: https://www.epa.gov/dwssa.

Forand SP, Lewis-Michl EL, Gomez MI. 2012. Maternal exposure to tetrachloroethylene and trichloroethylene through soil vapor intrusion and adverse birth outcomes in New York State. Environ Health Perspect 120: 616-621.

Goldberg SJ, Lebowitz MD, Graver EJ, Hicks S. 1990. An association of human congenital cardiac malformations and drinking water contaminants. J Am Coll Cardiol 16: 155-164.

Johnson PD, Goldberg SJ, Mays MZ, *et al*. 2003. Threshold of trichloroethylene contamination in maternal drinking waters affecting fetal heart development in the rat. Environ Health Perspect 111: 289-292.

Keil DE, Peden-Adams MM, Wallace S, *et al*. 2009. Assessment of trichloroethylene (TCE) exposure in murine strains genetically-prone and non-prone to develop autoimmune disease. J Environ Sci Health A Tox Hazard Subst Environ Eng 44:443-453.

[NFEC] Naval Facilities Engineering Command. 2006. Feasibility Study/Corrective Measures Study for Off-Site Southern Area Plume. US Navy. January 2006.

[NFEC] Naval Facilities Engineering Command. 2012. Study of Alternatives for Management of Impacted Groundwater at Bethpage. Prepared by Tetra Tech for Naval Facilities Engineering Command Mid-Atlantic. January 2012.

[NWIRP] Naval Weapons Industrial Reserve Plant, Calverton. 2012a. Data Summary Report for 2011 Groundwater Investigation Activities at Site 2. Fire Training Area Site 6A. Fuel Calibration Area Site 10B. Engine Test House and Southern Area Naval Weapons Industrial Reserve Plant, Calverton, New York. April 2012.

[NWIRP] Naval Weapons Industrial Reserve Plant, Calverton. 2012b. Draft Final Work Plan for Installation of Water Service to Peconic River Sportsman's Club Naval Weapons Industrial Reserve Plant Calverton, New York. Issued: January 2012.

[NWIRP] Naval Weapons Industrial Reserve Plant, Calverton. 2012c. Final Construction Completion Report for Installation of Water Service to Peconic River Sportsman's Club Naval Weapons Industrial Reserve Plant Calverton, New York. August 2012.

Peden-Adams MM, Eudaly JG, Heesemann LM, *et al*. 2006. Developmental immunotoxicity of trichloroethylene (TCE): Studies in B6C3F1 mice. J Environ Sci Health A Tox Hazard Subst Environ Eng 41: 249-271.

[SCDHS] Suffolk County Department of Health Services. 2002. Letter from Daniel L. Morris to Rudy Gibiser, Peconic River Sportsmen Club. March 13, 2002.

[SCDHS] Suffolk County Department of Health Services. 2007. Letter from Andrew Rapiejko to Jacqueline Nealon, New York State Department of Health. June 29, 2007.

State of New York Executive Chamber. 2017. Letter from Andrew M. Cuomo to Catherine McCabe, United States Environmental Protection Agency. February 11, 2017.

REPORT PREPARATION

The New York State Department of Health (NYSDOH) prepared this Health Consultation for the Northrop Grumman/Naval Weapons Industrial Reserve Plant Facilities, located in the towns of Bethpage, Nassau County and Calverton, Suffolk County, New York. This publication was made possible by Grant Number 1NU61TS000274-01-00 under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). The NYSDOH evaluated data of known quality using approved methods, policies, and procedures existing at the date of publication. ATSDR reviewed this document and concurs with its findings based on the information presented by the NYSDOH.

New York State Department of Health

Steven Karpinski, Don Miles and Fay S. Navratil
Public Health Specialists
Bureau of Environmental Exposure Investigation

Thomas Johnson, PhD and Alyssa Woodworth, MPH
Research Scientists
Bureau of Toxic Substance Assessment

ATSDR Technical Project Officer

Eva D. McLanahan, PhD, REHS/RS
Commander, US Public Health Service
Division of Community Health Investigation

ATSDR Regional Representatives

Leah Graziano, RS
Regional Director - Region 2
Division of Community Health Investigation

Elena Vaouli, MPH, REHS/RS
Commander, U.S. Public Health Service
Regional Representative, Region 2

Appendix A: Figures

Figure 1. Overview Map of Northrop Grumman Facility Locations

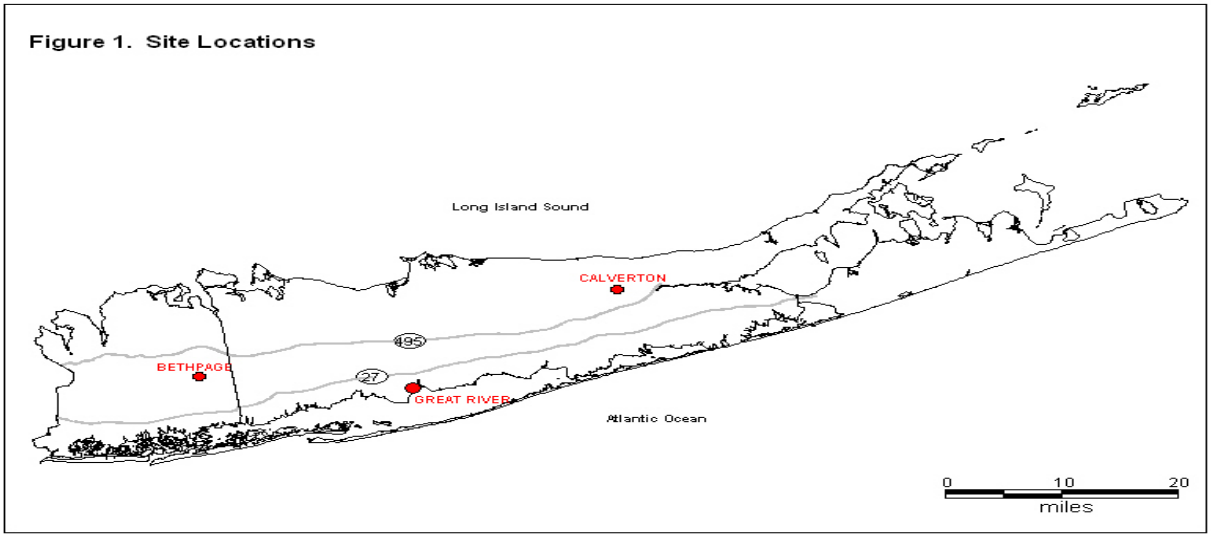


Figure 2. Units of the Long Island Aquifer

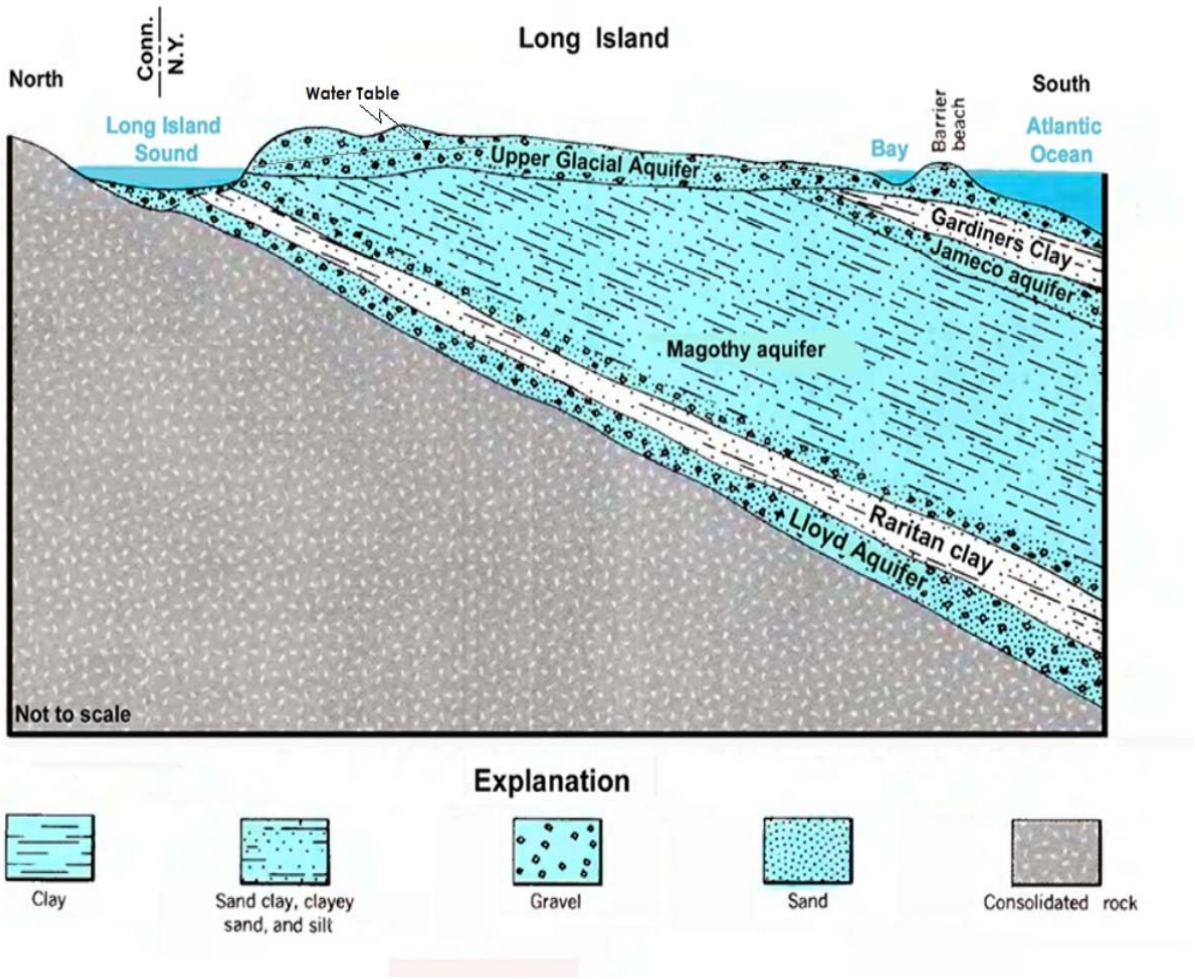


Figure 3. Northrop Grumman/NWIRP facility and Public Water Supply Wells

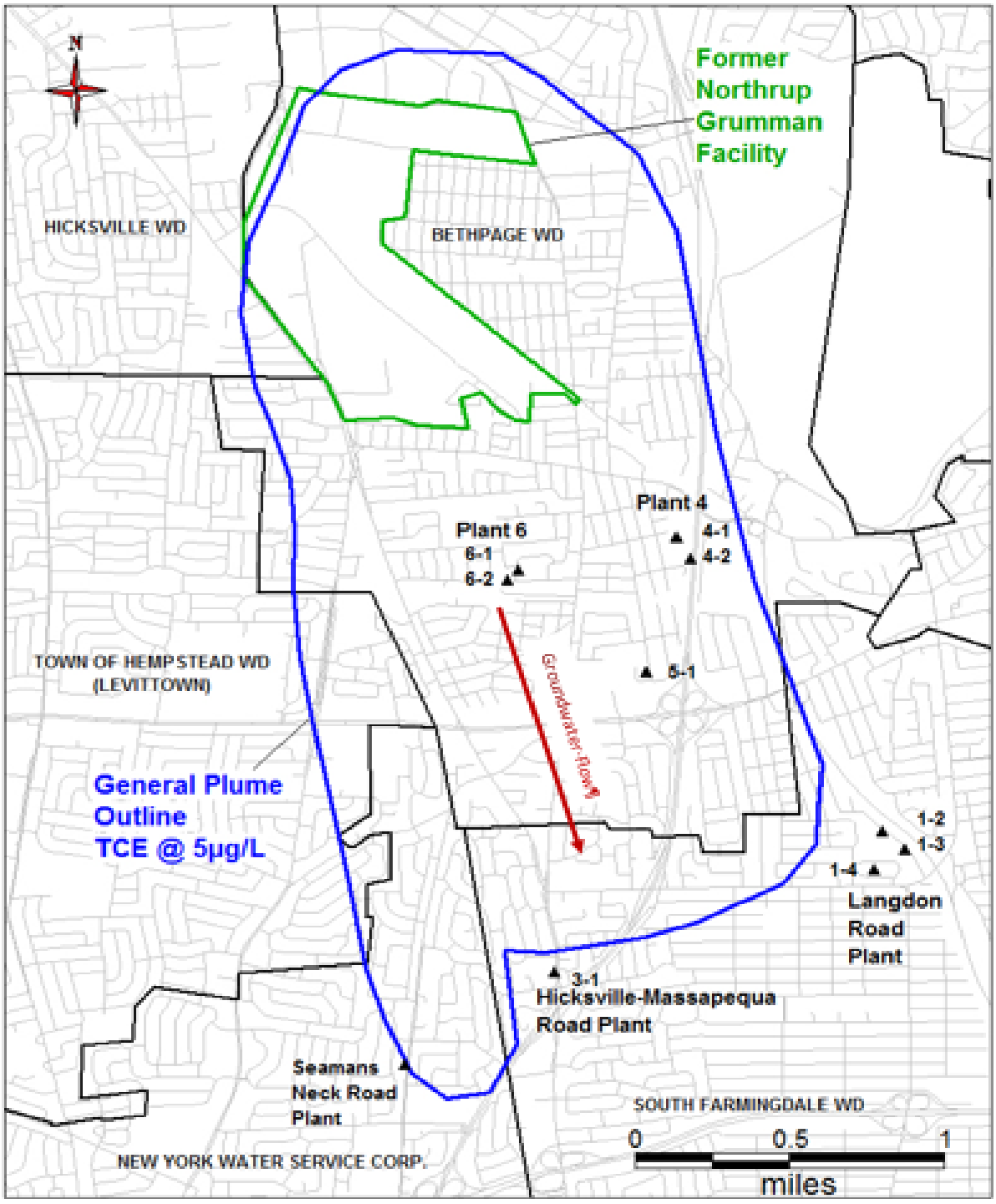
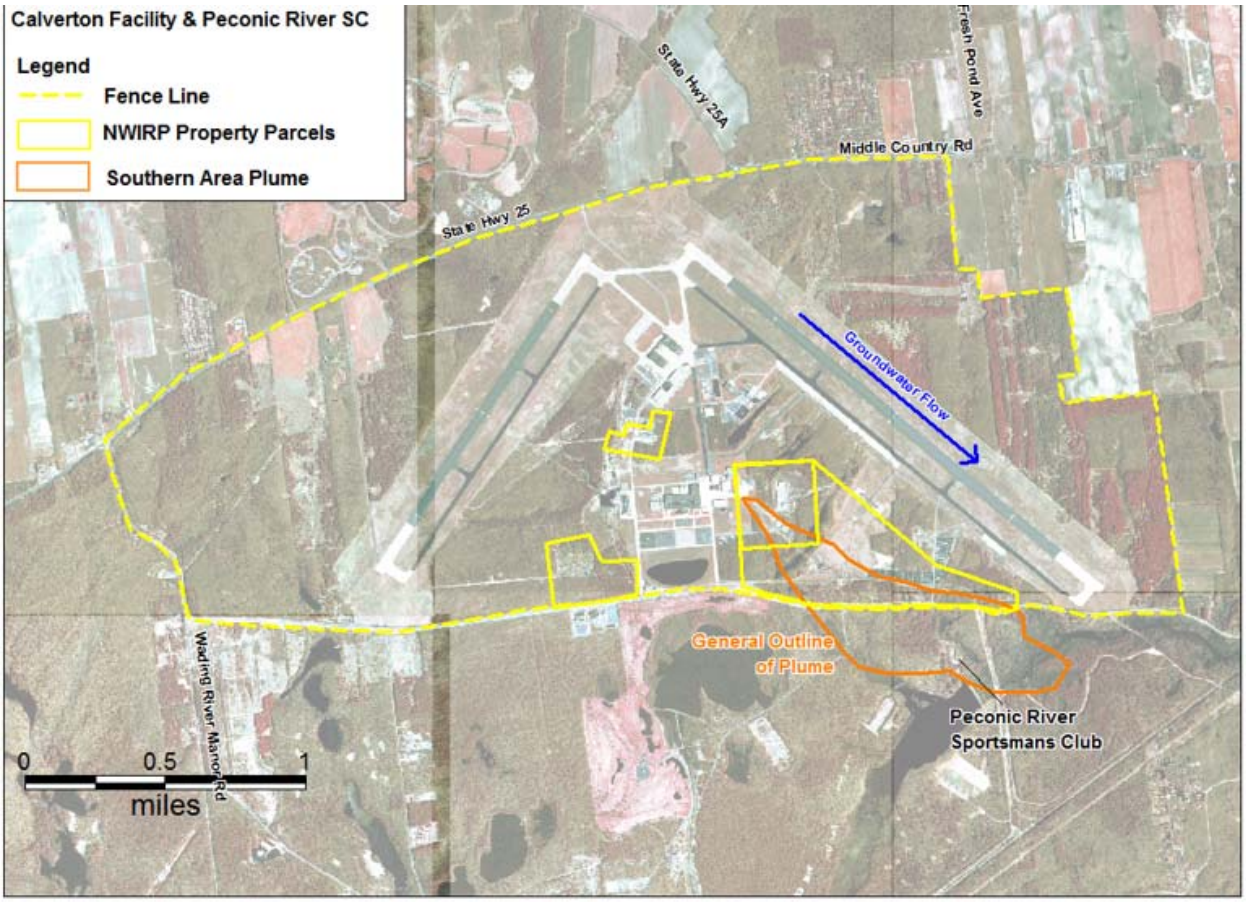


Figure 4. Calverton Facility



Appendix B: Site Details

Northrop Grumman/Naval Weapons Industrial Reserve Plant (NWIRP)

Northrop Grumman/NWIRP facility

Northrop Grumman (formerly Grumman Aircraft Engineering Corporation, later Grumman Aerospace Corporation) first occupied the Northrop Grumman facility in Bethpage in the early 1930s and by the 1990s the property covered approximately 500 acres. Activities conducted at the facility included research, prototyping, testing, design engineering, fabrication and primary assembly of various military aircraft and spacecraft. The United States Navy established the Naval Weapons Industrial Reserve Plant in Bethpage in 1942, which occupied approximately 109 acres within the Northrop Grumman facility. The Naval Weapons Industrial Reserve Plant was a Government-Owned Contractor Operated facility that was run by Northrop Grumman. Northrop Grumman ceased most manufacturing related operations at the Northrop Grumman/NWIRP facility in 1998.

The activities that took place at the Northrop Grumman Northrop Grumman/NWIRP facility generated significant amounts of inorganic and volatile organic wastes. During the first 40 or so years that the Northrop Grumman/NWIRP facility was in operation, the accepted waste handling procedures typically called for disposal directly to on-site surface impoundments or to on-site sub-surface liquid waste handling systems such as cesspools and septic tanks. These disposal practices were eventually discontinued as the impacts to drinking water supplies became apparent.

Taste and odor issues associated with Northrop Grumman's on-site water supply wells used for drinking led to investigations by the NCDOH, the EPA, and the NYSDOH in the mid-1970s. These investigations found vinyl chloride, trichloroethene (TCE) and tetrachloroethene (PCE) in the Northrop Grumman water supply wells. In 1976, Northrop Grumman connected its Northrop Grumman/NWIRP facility to the Bethpage Water District for supply of potable water. Thereafter, Northrop Grumman used the on-site supply wells only for industrial and cooling purposes. While Northrop Grumman used TCE and PCE on site, it was determined that the source of vinyl chloride was from another industrial site located northeast of the Bethpage Complex.

The NYSDEC, in consultation with the NYSDOH, listed the Northrop Grumman Northrop Grumman/NWIRP facility on the New York State Registry of Inactive Hazardous Waste Sites (also known as State Superfund) in 1983. Findings from investigations conducted between 1989 and 1994 led the NYSDEC to divide the remedial programs for the Northrop Grumman/NWIRP facility into distinct operable units. An operable unit is a portion of a remedial site that for technical or administrative reasons can be more effectively addressed separately. NYSDEC created operable units (OU) to address on-site soil contamination (OU1), groundwater contamination that was migrating off the site (OU2), and disposal areas now occupied by the Town of Oyster Bay Community Park (OU3).

The NYSDEC issued a Record of Decision for OU1 in 1995. The company remediated OU1 soil contamination at Plant 2 and a small area of PCE contamination at Plant 15 using a soil vapor extraction method. Northrop Grumman addressed other areas of contamination at their Northrop Grumman facility by separate removal actions and by deed restrictions that require maintenance of a cap or cover system.

Investigations conducted between 1991 and 1995 identified soil contamination at three areas within the Naval Weapons Industrial Reserve Plant portion of the Northrop Grumman Bethpage Complex. In 1993 the NYSDEC, in consultation with the NYSDOH, listed the Naval Weapons Industrial Reserve Plant separately. In 1995, the NYSDEC issued the OU1 Record of Decision for the Naval Weapons Industrial Reserve Plant that called for excavation of polychlorinated biphenyls (PCBs) and VOC contaminated soil, and implementation of a system to remediate shallow on-site groundwater contamination.

Northrop Grumman and the Navy continued to investigate the nature and extent of groundwater contamination associated with the Northrop Grumman/NWIRP facility throughout the 1990s. The information from these investigations showed that actions were needed to prevent further migration of contaminants off the site. In 1997, Northrop Grumman implemented an interim remedial measure in the form of groundwater containment known as the On-Site Containment System, which consists of five wells that extract groundwater at the southern site boundary, and treats the extracted water to remove VOC contaminants. The treated water is then discharged to on-site recharge basins or used by a nearby power plant. The On-Site Containment System continues to operate.

In March 2001, the NYSDEC issued a Record of Decision (ROD) for Northrop Grumman OU2 to address the regional groundwater contamination plume. At that time NYSDEC and NYSDOH estimated the groundwater plume to have extended over an area of more than 2,000 acres and to a depth of approximately 700 feet below ground surface. The agencies identified the primary groundwater contaminants to be the chlorinated VOCs PCE, TCE, 1,1-dichloroethene (1,1-DCE), vinyl chloride, and 1,1,1-trichloroethane (1,1,1-TCA). As previously noted, the vinyl chloride groundwater contamination is not associated with the Northrup Grumman Northrop Grumman/NWIRP facility, but resulted from improper waste disposal at an upgradient site northeast of the property.

The Groundwater Remedial Program, as specified in the OU2 ROD included 1) continued operation of the On-Site Containment groundwater extraction and treatment system, 2) evaluation of the On-Site Containment system to confirm that it is performing effectively, 3) implementation of an off-site groundwater extraction and treatment system in an area known as GM 38 monitoring well cluster, 4) long-term operation and maintenance of the On-Site Containment and GM 38 area remedy, 5) continued investigation to better define the extent of groundwater contamination and to determine whether additional groundwater remediation systems are required, 6) long-term monitoring of the groundwater including a comprehensive monitoring of plume attenuation, 7) the formation of a technical advisory committee as deemed necessary by the NYSDEC, to be comprised at a minimum, of the involved Agencies, participating local water districts, Northrop Grumman and the Department of the Navy, and 7) establishment of a Public Water Supply Protection Program.

The Public Water Supply Protection Program is the primary mechanism that ensures public water suppliers do not deliver water to customers that contains site-related contamination at concentrations greater than state or federal drinking water standards. The standards are established by the NYSDOH and included in New York State's Part 5, Subpart 5-1 Public Water Systems Regulations [DOH 2013a] and by the EPA as federal drinking water standards. The Public Water Supply Protection Program implements procedures to ensure that appropriate wellhead treatment is put in place that will enable the public water suppliers to meet drinking water standards, with costs of the treatment systems funded by Northrop Grumman and/or the Navy. The Public Water Supply Protection Program also includes long-term monitoring of the groundwater upgradient of public water supply well fields to ensure that wellhead treatment facilities can be constructed and be made operational prior to wells being impacted.

In 2014 the State of New York passed Assembly Bill 9492 calling for the NYSDEC to create and deliver to the state legislature a report detailing the options for intercepting and remediating the groundwater plume of contaminants emanating from the Northrop Grumman and NWIRP facilities in Bethpage. In response, the NYSDEC worked with a State Engineering Contractor (HDR Inc.) and prepared and released a Remedial Options Report in August 2016. This report provided a big picture view of the remedial options and identified three potential hydraulic containment remedies. This Remedial Options Report was not designed to support development of a Proposed Remedial Action Plan (PRAP). In February 2017, the Executive Branch directed NYSDEC to undertake an investigation and engineering analysis to further evaluate options for managing of the groundwater plume. A NYSDEC standby contractor was tasked to complete this detailed analysis of remedial alternatives as part of a Feasibility Study. The findings of this Feasibility Study, and the specific remedial actions that have been identified as being capable of achieving full plume containment, will be incorporated by the NYSDEC into a Proposed Remedial Action Plan and will be presented to the public for review and comment.

As of December 2017, Northrop Grumman and the Navy continue to address groundwater contamination that has migrated from the facility through implementation of two additional systems to extract contaminated groundwater from specific areas identified as hot spots. These hot spots have been targeted as a result of the on-going investigations that the Navy and Northrop Grumman have been conducting. The extracted groundwater will be treated to remove contaminants and the treated water returned to the aquifer.

Calverton Facility

The Naval Weapons Industrial Reserve Plant in Calverton was a Government-Owned Contractor Operated facility that originally occupied 6,000 acres (Appendix A, Figure 4). Northrop Grumman operated the facility from its construction in the early 1950s until 1996, when operations ceased and the land was returned to Navy control. The company transferred most of the land within the site to the Town of Riverhead for economic redevelopment, to NYSDEC for conservation and public recreation, or to the Veterans Administration.

The Navy retained three non-contiguous parcels of land totaling approximately 209 acres to continue Environmental Restoration Program activities. One of these areas was the source of groundwater contamination that migrated off-site, creating what is referred to as the Southern Area Plume (see Appendix A, Figure 4). The Navy's Environmental Restoration Program is responsible for ensuring that appropriate remedial actions are developed and implemented as necessary to protect public health and the environment.

The Calverton facility is a NYSDEC State Superfund site, and chlorinated VOC groundwater contamination has migrated off the southern boundary of the site. The contaminated groundwater encompasses an area of approximately 118 acres, with 25 acres on Naval Weapons Industrial Reserve Plant Calverton property and 93 acres off the property [NWIRP 2012a].

Appendix C: Summary Information about 1,4-Dioxane Concentrations in Water Supply Wells, Data Reported by Water Districts within the Northrop Grumman/NWIRP Facility Plume

Water District	Date	Range of 1,4-dioxane concentrations, in micrograms per liter
South Farmingdale Water District		
	03-02-2014	ND – 1.0
	12-18-2017	ND – 1.4
New York American Water Company, Merrick Operations		
	2014	ND – 1.35
	2017	ND – 1.35
Bethpage Water District		
	12-11-2013	0.3 - 8.6
	04-15-2016	2.1 - 12.0
	11-30-2017	0.37 – 15.4

Data provided here are from Water Quality Reports:
http://sfwater.com/news/water-quality-reports/
http://www.amwater.com/ccr/merrick.pdf
http://bethpagewater.com/Water-Quality

Appendix D: Health Consultation Tables

Table 1. Trichloroethene Concentrations in Raw, Untreated Water Samples from the New York American Water Company Seaman's Neck Well Field.

(all values in micrograms per liter)

Sampling Date	Concentration	
	Well 3 (N-8480)	Well 4 (N-9338)
2003	ND	NS
2004	ND	NS
2005	ND	NS
September 11, 2006	0.6	NS
September 26, 2006	NS	ND
October 2, 2006	0.5	NS
February 2, 2007	NS	ND
March 27, 2007	NS	ND
April 10, 2007	0.4	NS
April 25, 2007	0.5	ND
May 14, 2007	0.6	ND
June 5, 2007	0.6	ND
July 19, 2007	0.8	ND
August 7, 2007	0.6	ND
September 7, 2007	0.8	ND
October 4, 2007	0.8	ND
November 2, 2007	0.6	ND
December 5, 2007	NS	ND
December 10, 2007	0.5	NS
January 7, 2008	NS	ND
January 9, 2008	0.7	NS
February 4, 2008	0.5	ND
March 6, 2008	0.6	0.5
March 14, 2008	NS	0.5
March 19, 2008	NS	0.5
March 24, 2008	NS	< 0.5
April 2, 2008	< 0.5	< 0.5
May 1, 2008	0.6	NS
May 15, 2008	NS	< 0.5
June 5, 2008	NS	< 0.5
June 16, 2008	1.0	NS
July 15, 2008	1.2	< 0.5
August 15, 2008	1.1	< 0.5
September 3, 2008	1.4	< 0.5
October 6, 2008	0.9	NS
October 7, 2008	NS	< 0.5
November 7, 2008	0.7	NS
November 10, 2008	NS	< 0.5
December 2, 2008	0.8	< 0.5
January 6, 2009	NS	0.5
January 7, 2009	0.8	NS
February 13, 2009	0.8	< 0.5
March 4, 2009	0.9	< 0.5

Sampling Date	Concentration	
	Well 3 (N-8480)	Well 4 (N-9338)
April 6, 2009	NS	< 0.5
April 20, 2009	0.9	NS
May 13, 2009	0.9	0.5
July 14, 2009	NS	< 0.5
July 16, 2009	1.2	NS
August 11, 2009	1.2	< 0.5
September 11, 2009	1.6	< 0.5
October 8, 2009	0.9	< 0.5
December 8, 2009	NS	0.6
January 28, 2010	1.1	NS
March 8, 2010	NS	0.7
March 9, 2010	1.4	NS
June 2, 2010	1.9	NS
June 8, 2010	NS	< 0.5
July 28, 2010	2	< 0.5
October 5, 2010	2.1	< 0.5
February 12, 2011	2.4	NS
February 17, 2011	NS	0.9
June 17, 2011	2.3	ND
July 19, 2011	1.4	NS
July 20, 2011	NS	ND
July 22, 2011	NS	ND
October 13, 2011	NS	0.8
October 18, 2011	3.3	NS
October 28, 2011	2.6	NS
February 7, 2012	NS	1
April 10, 2012*	2.4	NS

*Temporary treatment operational.

NS = Well not sampled

ND = not detected, detection limit not available. Results beginning with "<" indicate that the chemical was not detected, followed by the analytical detection limit.

Table 2. Trichloroethene (TCE), Tetrachloroethene (PCE), and 1,1,1-Trichloroethane (1,1,1-TCA) Concentrations for Raw, Untreated Water Samples from Bethpage Water District Well 6-1.

(all values in micrograms per liter)

Date of Sampling	Source	Trichloroethene (TCE) Concentration	Tetrachloroethene (PCE) Concentration	1,1,1-Trichloroethane (1,1,1-TCA) Concentration
November 29, 1976	raw water	28	ND	2
December 2, 1976	raw water	26	ND	3
December 6, 1976*	raw water	60	17	15

*Well taken out of service after collection of this sample.
ND = not detected, detection limit not available.

Table 3. Trichloroethene (TCE), Tetrachloroethene (PCE), and 1,1,1-Trichloroethane (1,1,1-TCA) Concentrations for Raw, Untreated Water Samples from Bethpage Water District Well 6-2.

(all values in micrograms per liter)

Date of Sampling	Source	Trichloroethene (TCE) Concentration	Tetrachloroethene (PCE) Concentration	1,1,1-Trichloroethane (1,1,1-TCA) Concentration
February 1, 1985	raw water	1	ND	ND
July 24, 1985	raw water	1	ND	ND
October 8, 1985	raw water	ND	ND	ND
May 14, 1986	raw water	2	ND	ND
July 24, 1986	raw water	2	ND	ND
July 29, 1986	raw water	3	ND	ND
November 21, 1986	raw water	4	ND	ND
February 6, 1987	raw water	5	ND	ND
May 12, 1987	raw water	4	ND	ND
September 28,1987	raw water	4	ND	ND
March 29, 1988	raw water	0.8	ND	ND
April 26,1988	raw water	ND	ND	ND
September 22,1988	raw water	0.8	ND	ND
October 19, 1988	raw water	ND	ND	ND

ND = not detected, detection limit not available.

Table 4. Trichloroethene (TCE) Concentrations for Raw, Untreated Water Samples from Bethpage Water District Well 4-1.

(all values in micrograms per liter)

Date of Sampling	Trichloroethene (TCE) Concentration
September 7, 1988	1.1
August 22, 1989	0.5
November 7, 1989	0.7
February 20, 1990	0.5
May 15, 1990	0.6
July 27, 1990	1
July 30, 1990	2.6
October 5, 1992	1.2
June 3, 1993	0.5
August 3, 1993	0.5
October 4, 1993	0.5
March 13, 1995	2.2

In accordance with New York State Part 5 drinking water regulations, routine monitoring of supply well water has been conducted. TCE was not detected (except as noted above) in 52 samples from 1976 to 1995.

Table 5. Trichloroethene Concentrations for Raw, Untreated Water Samples from Bethpage Water District Well 4-2.

(all values in micrograms per liter)

Date of Sampling	Trichloroethene (TCE) Concentration
January 7, 1993	0.8
January 12, 1993	0.6
January 13, 1993	<0.5
February 8, 1993	0.5
March 2, 1993	0.5
April 6, 1993	<0.5
May 6, 1993	0.5
June 3, 1993	0.6
July 7, 1993	0.6
August 3, 1993	<0.5
September 2, 1993	<0.5
October 4, 1993	0.7
June 14, 1994	<0.5
July 13, 1994	0.5
August 2, 1994	0.5
October 3, 1994	1
March 13, 1995	<0.5
May 2, 1995	<0.5

Results beginning with "<" indicate that the chemical was not detected, followed by the analytical detection limit.

In accordance with New York State Part 5 drinking water regulations, routine monitoring of supply well water has been conducted. TCE was not detected except as noted above from 1993 to 1995.

Appendix E: Health Effects of Site-Related Chemicals

Health Effects of Trichloroethene (TCE), Tetrachloroethene (PCE) and 1,1,1-Trichloroethane (1,1,1-TCA)

All chemicals can cause health effects. The risk for adverse health effects from any chemical depends on the chemical's toxicity, the amount of the chemical to which a person is exposed, and how long and how often the exposure occurs. Below is some general information about the kinds of health effects that are associated with exposure to chemicals associated with the Northrop Grumman/Naval Weapons Industrial Reserve Plant Facilities.

The EPA classifies TCE as carcinogenic to humans by all routes of exposure [EPA 2011a,b]. The types of cancer most strongly associated with human TCE exposure are non-Hodgkin's lymphoma and cancer of the liver and kidney. The EPA identifies TCE as a chemical that causes kidney cancer by a mutagenic mode of action, and recommends the use of age-dependent adjustment factors to account for the greater vulnerability of cancer in early life stages when evaluating cancer risks from TCE exposure [EPA 2005, 2006, 2011a]. PCE is classified by EPA as likely to be carcinogenic to humans by all routes of exposure [EPA 2012a,b]. There is inadequate information to assess the carcinogenic potential of 1,1,1-TCA [EPA 2007a,b].

Exposure to TCE, PCE and 1,1,1-TCA at levels higher than typical environmental exposures can cause noncancer health effects, primarily on the nervous system and liver [ATSDR 2006; DOH 2006; EPA 2011a; 2012a]. Exposure to 1,1,1-TCA causes body weight changes and can damage the cardiovascular system in laboratory animals [ATSDR 2006]. Exposure to TCE affects the immune system of laboratory animals and can cause fetal heart malformations in their offspring [EPA 2011a]. Some studies report an increased risk for adverse effects on human fetal heart development in the offspring of women who lived in areas with elevated levels of TCE in air or drinking water [Goldberg et al. 1990; Forand et al. 2012], but it is not known if the effects are due to TCE or some other factor. Studies of people exposed to mixtures of chlorinated solvents (including PCE) in drinking water during pregnancy suggest an increased risk for birth defects, but there are uncertainties about how much contaminated water the women drank during pregnancy and about how much PCE was in that water [EPA 2012a]. Some studies show a slightly increased risk for some types of reproductive effects among workers (including dry-cleaning workers) exposed to PCE and other chemicals [DOH 2013b]. In each of these PCE studies, the role of other factors in causing these effects is not fully known, and they therefore suggest, but do not prove, that PCE can cause reproductive toxicity and effects on the developing fetus.

Appendix F: Sample Calculations

ATSDR-Recommended Exposure Parameters for Drinking Water

Age Group	Reasonable Maximum Exposure			Central Tendency Exposure		
	Drinking Water Daily Intake (mL/day)	Body Weight (kg)	Drinking Water Daily Dose (L/kg/day)	Drinking Water Daily Intake (mL/day)	Body Weight (kg)	Drinking Water Daily Dose (L/kg/day)
Birth to < 1 year	1113	7.8	0.1427	504	7.8	0.0646
1 to < 2 years	893	11.4	0.0783	308	11.4	0.0270
2 to < 6 years	977	17.4	0.0561	376	17.4	0.0216
6 to < 11 years	1404	31.8	0.0442	511	31.8	0.0161
11 to < 16 years	1976	56.8	0.0348	637	56.8	0.0112
16 to < 21 years	2444	71.6	0.0341	770	71.6	0.0108
≥ 21 years	3092	80	0.0387	1227	80	0.0153
Pregnant women	2589	73	0.0355	872	73	0.0119

mL/day = milliliters per day; kg = kilograms; L/kg/day = liters per kilogram per day
ATSDR 2016; EPA 2011c

All sample calculations are done using the maximum drinking water concentration of trichloroethene or tetrachloroethene in the 6-1 well. All calculations are done using ATSDR's Exposure Dose Guidance for Drinking Water Ingestion [ATSDR 2016].

1. **Calculation of Noncancer Exposure Estimates and Hazard Quotients:**

   A. Noncancer Ingestion Exposure Dose:

$$\mathrm{D} = 2(C) \times IR$$

D = exposure dose (mg/kg/day)
C = Contaminant concentration in drinking water, doubled to account for exposure via non-ingestion pathways (mg/L)
IR = Age-specific water ingestion rate (L/kg/day)

   B. Hazard Quotient:

$$\mathrm{HQ} = \frac{D}{Rfd}$$

D = exposure dose (mg/kg/day)
RfD = reference dose (mg/kg/day)

Northrup Grumman Groundwater Contamination Area
Noncancer Exposure Estimates and Hazard Quotients

Trichloroethene - Bethpage Water District Well 6-1 (average concentration = 38 mcg/L; maximum concentration = 60 mcg/L)

Group	Water Concentration (mg/L)	Double Water Concentration (mg/L)	Drinking Water Consumption Rate[1] (L/kg/day)		Exposure Dose (mg/kg/day)		Reference Dose[2] (mg/kg/day)	Hazard Quotient[3]	
			RME	CTE	RME	CTE		RME	CTE
0 to < 1	0.038	0.076	0.143	0.065	1.08E-02	4.91E-03	5.0E-04	21.7	9.8
1 to < 2	0.038	0.076	0.078	0.027	5.95E-03	2.05E-03	5.0E-04	11.9	4.1
2 to < 6	0.038	0.076	0.056	0.022	4.27E-03	1.64E-03	5.0E-04	8.5	3.3
6 to < 11	0.038	0.076	0.044	0.016	3.36E-03	1.22E-03	5.0E-04	6.7	2.4
11 to < 16	0.038	0.076	0.035	0.011	2.64E-03	8.52E-04	5.0E-04	5.3	1.7
16 to < 21	0.038	0.076	0.034	0.011	2.59E-03	8.17E-04	5.0E-04	5.2	1.6
≥ 21	0.038	0.076	0.039	0.015	2.94E-03	1.17E-03	5.0E-04	5.9	2.3
Pregnant Women	0.060	0.120	0.035	0.012	4.20E-03	1.44E-03	5.0E-04	8.4	2.9

[1]Drinking water consumption rates are from the Exposure Factors Handbook (EPA 2011c) and applied as recommended by ATSDR (ATSDR 2016).

[2]Reference dose derived by the United States Environmental Protection Agency (EPA 2011b).

[3]Hazard quotient = contaminant dose/reference dose.

mcg/L: micrograms per liter; mg/L: milligrams per liter; L/kg-day: liters per kilogram per day; mg/kg/day: milligrams per kilogram per day; RME = reasonable maximum exposure; CTE= central tendency exposure

C. Calculation of Margins of Exposure:

$$\text{MOE} = \frac{Effect\ Level}{Estimated\ Exposure\ Dose}$$

Effect level: For TCE, a lowest observe effect level (LOEL) for decreased thymus weights in mice for immune toxicity of 0.048 mg/kg/day or a 1% increased risk for fetal malformations in rats ($BMDL_{01}$, see EPA 2011b) of 0.0051 mg/kg/day

Trichloroethene - Bethpage Water District Well 6-1

Calculation of Margins of Exposure for Immune and Developmental Toxicity

Contaminant	Water District	Well	Contaminant Concentration[1] (mcg/L)	Reference Dose[2] (mg/kg/day)	Adult			Child		
					Dose (mg/kg/day)	Hazard Quotient[3]	Margin of Exposure[4]	Dose (mg/kg/day)	Hazard Quotient[3]	Margin of Exposure[4]
TCE	Bethpage	6-1	38.0	5E-04	2.94E-03	5.87	16	1.08E-02	21.7	4.4
	Bethpage	6-1	60.0	5E-04	4.20E-03	8.40	1.2	-	-	-

[1]The average TCE concentration is used to evaluate immunotoxicity for children and adults, the maximum TCE concentration and the maternal dose are used to evaluate developmental toxicity.

[2]Reference dose derived by the United States Environmental Protection Agency (EPA 2011b).

[3]Hazard quotient = contaminant dose/reference dose.

[4]The margin of exposure for immune toxicity is the dose that corresponds to a lowest observe effect level (LOEL) for decreased thymus weights in mice (see EPA 2011b) divided by the estimated adult or child contaminant exposure at the average TCE water concentration. The dose at the LOEL for decreased thymus weights is 0.048 mg/kg/day. Margin of exposure for immune toxicity = (0.048 mg/kg/day)/dose. The margin of exposure for developmental toxicity is the dose that corresponds to a 1% increased risk for fetal malformations in rats (BMDL01, see EPA 2011b) divided by the estimated contaminant exposure for a pregnant woman at the highest TCE water concentration. The $BMDL_{01}$ for fetal heart malformations is 0.0051 mg/kg/day. Margin of exposure for developmental toxicity = (0.0051 mg/kg/day)/dose.

TCE = trichloroethene; mcg/L: micrograms per liter; mg/kg/day: milligrams per kilogram per day

2. Calculation of Cancer Risk:

A. Cancer Ingestion Exposure Dose

$$\text{D} = 2(C)\ \text{x}\ \left(\frac{ED}{AT}\right)\ \text{x}\ IR$$

D = Exposure dose (mg/kg/day)
C = Contaminant concentration in drinking water, doubled to account for exposure via non-ingestion pathways (mg/L)
ED = Exposure duration, specific to how long each well was in use (years)
AT = Averaging time (78 years)
IR = Age-specific water ingestion rate (L/kg/day)

B. Cancer risk:

Cancer risk = exposure dose x cancer slope factor

C. Lifetime RME cancer risk:

Lifetime cancer risk = sum of cancer risk for each age group

Bethpage Water District Well 6-1
Calculation of Tetrachloroethene Cancer Risk in Drinking Water
(Average Drinking Water Concentration = 5.8 mcg/L; Exposure Duration = 24 years)

Age Group	Exposure Duration (years)	Fraction of Lifetime	Drinking Water Concentration (mg/L)	Drinking Water Concentration Doubled (mg/L)	Drinking Water Consumption Rate (L/kg/day)		Exposure Dose (mg/kg/day)		Cancer Risk	
					RME	CTE	RME	CTE	RME	CTE
0 to < 1	1	0.0128	0.0058	0.0116	0.143	0.065	0.002	0.001	4.5E-08	2.0E-08
1 to < 2	1	0.0128	0.0058	0.0116	0.078	0.027	0.001	0.000	2.4E-08	8.4E-09
2 to < 6	4	0.0513	0.0058	0.0116	0.056	0.022	0.001	0.000	7.0E-08	2.7E-08
6 to < 11	5	0.0641	0.0058	0.0116	0.044	0.016	0.001	0.000	6.9E-08	2.5E-08
11 to < 16	5	0.0641	0.0058	0.0116	0.035	0.011	0.000	0.000	5.4E-08	1.8E-08
16 to < 21	5	0.0641	0.0058	0.0116	0.034	0.011	0.000	0.000	5.3E-08	1.7E-08
21 to < 24	3	0.0385	0.0058	0.0116	0.039	0.015	0.000	0.000	3.6E-08	1.4E-08
					Total Cancer Risk for 24 Year Exposure:				3.5E-07	1.3E-07

mcg/L = micrograms per liter; mg/L = milligrams per liter, RME = reasonable maximum exposure; CTE = central tendency exposure
Cancer risk calculated according to ATSDR guidance (ATSDR 2016). Cancer potency factor = 0.0021 $(mg/kg/day)^{-1}$ (EPA 2012b).
Drinking water consumption rates are from the Exposure Factors Handbook (US EPA, 2011c) and applied as recommended by ATSDR (ATSDR 2016).

3. Calculation of Trichloroethene Cancer Risk using Age Dependent Adjustment Factors:

A. Kidney cancer risk adjusted with ADAFs for mutagenic mode of action:

$$\text{Kidney cancer risk} = 2(C) \text{ x } \left(\frac{ED}{AT}\right) x\ IR_x\ \ ADAF\ x\ CPF$$

C = Contaminant concentration in drinking water, doubled to account for exposure via non-ingestion pathways (mg/L)
ED = Exposure duration, specific to how long each well was in use (years)
AT = Averaging time (78 years)
IR = Age-specific water ingestion rate (L/kg/day)
ADAF = Age-dependent adjustment factor
CPF = Unadjusted lifetime kidney cancer potency factor $(mg/kg/day)^{-1}$

B. Non-Hodgkin's Lymphoma and liver cancer risk:

$$\text{NHL and liver cancer risk} = 2(C) \text{ x } \left(\frac{ED}{AT}\right) x\ IR_x\ \ CPF$$

C = Contaminant concentration in drinking water, doubled to account for exposure via non-ingestion pathways (mg/L)
ED = Exposure duration, specific to how long each well was in use (years)
AT = Averaging time (78 years)
IR = Age-specific water ingestion rate (L/kg/day)
CPF = Unadjusted lifetime Non-Hodgkin's Lymphoma and liver cancer potency factor $(mg/kg/day)^{-1}$

C. TCE cancer risk:

$$\text{TCE cancer risk} = \text{Kidney cancer risk} + [\text{Non Hodgkin's Lymphoma and liver cancer risk}]$$

D. Total TCE lifetime cancer risk:

$$\text{Lifetime TCE cancer risk} = \text{sum of TCE cancer risk for each age group}$$

Bethpage Water District Well 6-1

Calculation of Trichloroethene Cancer Risk in Drinking Water Using Age Dependent Adjustment Factors

(Average Drinking Water Concentration = 38 mcg/L; Exposure Duration = 24 years)

ATSDR Recommended 95th Percentile Ingestion Rates (RME)

EXPOSURE PARAMETERS						DOSE RESPONSE ASSESSMENT CALCULATIONS						
Age Group	Drinking Water Consumption Rate (L/kg/day)	Drinking Water Concentration (mg/L)	Drinking Water Concentration Doubled (mg/L)	Years	Fraction of Lifetime	Kidney Unadjusted Lifetime Potency Factor $(mg/kg/day)^{-1}$	ADAFs	Kidney ADAF Adjusted Partial Risk	Kidney + NHL + Liver Unadjusted Lifetime Potency Factor $(mg/kg/day)^{-1}$	NHL + Liver Unadjusted Lifetime Potency Factor $(mg/kg/day)^{-1}$	NHL and Liver Partial Risk	Total Risk
0 to < 1	0.1427	0.038	0.076	1	0.0128	9.30E-03	10	1.29E-05	4.60E-02	3.67E-02	5.10E-06	1.80E-05
1 to < 2	0.0783	0.038	0.076	1	0.0128	9.30E-03	10	7.10E-06	4.60E-02	3.67E-02	2.80E-06	9.90E-06
2 to < 6	0.0561	0.038	0.076	4	0.0513	9.30E-03	3	6.11E-06	4.60E-02	3.67E-02	8.03E-06	1.41E-05
6 to < 11	0.0442	0.038	0.076	5	0.0641	9.30E-03	3	6.00E-06	4.60E-02	3.67E-02	7.89E-06	1.39E-05
11 to < 16	0.0348	0.038	0.076	5	0.0641	9.30E-03	3	4.73E-06	4.60E-02	3.67E-02	6.22E-06	1.09E-05
16 to < 21	0.0341	0.038	0.076	5	0.0641	9.30E-03	1	1.55E-06	4.60E-02	3.67E-02	6.10E-06	7.65E-06
21 to < 24	0.0387	0.038	0.076	3	0.0385	9.30E-03	1	1.05E-06	4.60E-02	3.67E-02	4.15E-06	5.20E-06
										Total Risk for 24 Year Exposure:		**7.98E-05**

RME = reasonable maximum exposure; CTE = central tendency exposure; mcg/L: micrograms per liter; mg/L: milligrams per liter; L/kg-day: liters per kilogram per day; mg/kg/day: milligrams per kilogram per day;

NHL: non-Hodgkin's lymphoma; ADAF = age-dependent adjustment factor.

Drinking water consumption rates are from the Exposure Factors Handbook (US EPA, 2011c) and applied as recommended by ATSDR (ATSDR 2016). Age-Dependent Adjustment Factors (ADAFs) are recommended by US EPA (2005, 2006) for chemicals such as TCE that cause cancer by a mutagenic mode of action and are applied as recommended by ATSDR (ATSDR 2016).

References for Appendix F

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016. Exposure Dose Guidance for Water Ingestion. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, October 26.

[USEPA] United States Environmental Protection Agency. 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. Risk Assessment Forum. EPA/630/R-03/003F [accessed 2018 October 22]. Available from http://www.epa.gov/ttn/atw/childrens_supplement_final.pdf.

[USEPA] United States Environmental Protection Agency. 2006. Implementation of the Cancer Guidelines and Accompanying Supplemental Guidance - Science Policy Council Cancer Guidelines Implementation Workgroup Communication II: Performing Risk Assessments that Include Carcinogens Described in the Supplemental Guidance as Having a Mutagenic Mode of Action. Memo from William H. Farland to Science Policy Council.

[EPA] United States Environmental Protection Agency. 2011b. Integrated Risk Information System. Trichloroethylene (CASRN 79-01-6). National Center for Environmental Assessment, Office of Research and Development [updated 2011 September 28; accessed 2018 October 22]. Available from:
https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=

[EPA] United States Environmental Protection Agency. 2011c. Exposure Factors Handbook: 2011 Edition. EPA/600/R-090/052F [updated 2016 April 6; accessed 2018 October 22]. Available from: http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

[EPA] United States Environmental Protection Agency. 2012b. Integrated Risk Information System. Tetrachloroethylene (CASRN 127-18-4). National Center for Environmental Assessment, Office of Research and Development [updated 2012 February 10; accessed 2018 October 22]. Available from:
https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=