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ATSDR
AGENCY FOR TOXIC SUBSTANCES
AND DISEASE REGISTRY

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# Public Health Assessment for

FORMER NANSEMOND ORDNANCE DEPOT
SUFFOLK, VIRGINIA
EPA FACILITY ID: VAD123933426
FEBRUARY 19, 2004

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES**
**PUBLIC HEALTH SERVICE**
Agency for Toxic Substances and Disease Registry

# THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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# PUBLIC HEALTH ASSESSMENT

FORMER NANSEMOND ORDNANCE DEPOT

SUFFOLK, VIRGINIA

EPA FACILITY ID: VAD123933426

Prepared by:

Superfund Site Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

# FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. (The legal definition of a health assessment is included on the inside front cover.) If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

**Exposure:** As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

**Health Effects:** If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

**Conclusions:** The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

**Interactive Process:** The health assessment is an interactive process. ATSDR solicits and evaluates information from numerous city, state and federal agencies, the companies responsible for cleaning up the site, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report to make sure that the data they have provided is accurate and current. When informed of ATSDR's conclusions and recommendations, sometimes the agencies will begin to act on them before the final release of the report.

**Community:** ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

**Comments:** If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E60), Atlanta, GA 30333.

## Table of Contents

Table of Contents ........ ii
List of Acronyms ........ iv
Summary ........ 1
I. Purpose and Health Issues ........ 3
II. Background ........ 3
  A. Site Description and Scope of Assessment ........ 3
  B. Site History ........ 5
  C. Recent Site Activities ........ 6
  D. Previous ATSDR Reports ........ 6
  E. Demographics ........ 7
  F. Land and Natural Resource Use ........ 7
III. Discussion ........ 9
  A. Types of Data Used ........ 9
  B. Scope of Public Health Evaluation ........ 9
  C. Chemical Contamination: Summary of Areas Evaluated at FNOD ........ 10
    1. Dominion Lands ........ 10
    2. GE Lands ........ 12
    3. TCC Property ........ 12
    4. Offsite Area Evaluated—Respass Beach Potable Water Wells ........ 14
  D. Evaluation Process ........ 14
  E. Contaminant Screening, Exposure Analysis, and Toxicological Evaluation ........ 15
    1. Dominion Lands ........ 15
    2. GE Lands ........ 22
    3. TCC Property ........ 24
    4. Offsite Area Evaluated ........ 37
  F. Nonordnance Physical Hazards Evaluation ........ 38
  G. Ordnance Physical Hazards Evaluation ........ 39
    Investigations and Removals ........ 39
    Evaluation of Hazard ........ 41
  H. Health Outcome Data Evaluation ........ 42
  I. Child Health Considerations ........ 42
  J. Community Health Concerns Evaluation ........ 42
IV. Hazard Category ........ 45
V. Conclusions ........ 45
VI. Recommendations ........ 45
VII. Public Health Action Plan ........ 46
VIII. Public Comments ........ 47
VIII. ATSDR Site Team ........ 48
IX. References ........ 49
Appendix A. Explanation of Evaluation Process ........ 57
  Screening Process ........ 57
  Determination of Exposure Pathways ........ 58

- Evaluation of Public Health Implications ........ 58
  - Soil Ingestion ........ 59
  - Groundwater Ingestion ........ 59
  - Surface Water Ingestion ........ 59
  - Sediment Ingestion ........ 60
- Noncancer Health Effects ........ 60
  - Minimal Risk Level (MRLs)—Developed by ATSDR ........ 60
  - Reference Dose (RfD) - Developed by EPA ........ 60
- Calculation of Risk of Carcinogenic Effects ........ 60

Appendix B. Public Comments Received ........ 62

Appendix C. ATSDR Glossary of Environmental Health Terms ........ 64

## List of Acronyms

| | |
|---|---|
| AL | Action Level |
| AOC | Area of Concern |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CPW | College Production Well |
| CREG | Cancer Risk Evaluation Guide |
| DDD | 1,1-dichloro-2,2-*bis*(p-chlorophenyl)ethane |
| DDE | 1,1-dichloro-2,2-*bis*(p-chlorophenyl)ethylene |
| DDT | 1,1,1-trichloro-2,2-*bis*(p-chlorophenyl)ethane |
| EE/CA | Engineering Evaluation/Cost Analysis |
| EMEG | Environmental Media Evaluation Guide |
| EPA | Environmental Protection Agency |
| FNOD | Former Nansemond Ordnance Depot |
| FUD site | Formerly Used Defense site |
| GE | General Electric |
| HRSD | Hampton Roads Sanitation District |
| kg | kilogram |
| MCL | Maximum Contaminant Level |
| mg | milligram |
| mm | millimeter |
| NPL | National Priorities List |
| ppm | part per million |
| ppb | part per billion |
| PAHs | Polycyclic Aromatic Hydrocarbons |
| PCB | Polychlorinated Biphenyls |
| PHA | Public Health Assessment |
| PHAP | Public Health Action Plan |
| RAB | Restoration Advisory Board |
| RI/FS | Remedial Investigation/ Feasibility Study |
| RBC | Risk-based Concentrations |
| SVOC | Semi-volatile Organic Compound |

## List of Acronyms (continued)

| | |
|---|---|
| TCC | Tidewater Community College |
| TNT | 2,4,6-Trinitrotoluene |
| µg/L | microgram per liter |
| ACE | United States Army Corps of Engineers |
| UXO | Unexploded Ordnance |
| VDEQ | Virginia Department of Environmental Quality |
| VDOT | Virginia Department of Transportation |
| VOC | Volatile Organic Compound |

## Summary

The Former Nansemond Ordnance Depot (FNOD) site consists of 975 acres located at the confluence of the James and Nansemond Rivers in Suffolk County, Virginia. The site is a former US military facility where handling, processing, shipping, receiving, and decommissioning of ordnance items occurred from 1917 to 1960. Many site areas once contained, or may still contain, ordnance chemical residues, other chemicals, ordnance items, or explosives. A large quantity of trinitrotoluene (TNT) was discovered at the site area known as the TNT Burial Site.

Portions of the site are occupied by a local community college, Tidewater Community College (TCC). Other landowners and former landowners of portions of the site include the General Electric Company (GE) and Dominion Lands, a development company. The Respass Beach Community is a residential development several hundred feet east of the site.

The Agency for Toxic Substances and Disease Registry (ATSDR) reviewed available information to assess the public health implications of the site, as required by virtue of the site's proposal for inclusion on the National Priorities List (NPL). On the basis of this information, ATSDR has made the following conclusions about the FNOD site:

1. Past exposure to contaminants in soil at most areas was too small to result in adverse health effects. The levels of TNT and lead at the TNT Burial Site and lead at the James River Beachfront Area could theoretically have increased the risk of adverse health effects, but regular contact with the highest detected levels would have been necessary.
2. Although contaminant levels have been decreased through site cleanup activities, some remaining elevated levels of TNT and lead could pose a risk in the future if small children have more regular contact with soil, as could happen if the area is developed for residential use.
3. Past exposures to contaminants in TCC drinking water were too low to result in adverse health effects. No evidence that other site groundwater was or is currently used for drinking was found. Untreated groundwater is unsuitable for future drinking water purposes because of elevated levels of metals in groundwater at the Dominion Lands area and elevated metals and TNT in groundwater at the TNT Burial Site on TCC Property.
4. No adverse health effects are expected from past, present, or future exposure to surface water or sediments, from eating fish caught at TCC Lake or J-Lake, or from drinking private well water in the Respass Beach Community.
5. Physical hazards are posed by the remaining open brick vaults, the World War II pier, and debris surfacing at beachfront areas.
6. If appropriate clearance procedures are followed and enforceable land use controls are put in place, the risk of accidents involving ordnance will be minimized. However, a small chance of encountering ordnance continues to exist.

ATSDR has made the following recommendations about the site:

1. Continue cleanup activities to address contaminants in soil at the TNT Burial Site.
2. If areas are developed for residential use, test soils for lead and clean up if necessary.

3. Do not use groundwater at the site for drinking water, unless the water is fully characterized and treated to ensure that drinking water standards are met.
4. Address physical hazards by filling in open brick vaults, removing or restricting access to the World War II pier, and cleaning up debris or keeping access restrictions in place at the beachfront areas.
5. Follow ordnance and explosives clearance procedures for expected future land use and set up appropriate, enforceable land use controls. Educate potential future landowners and occupants about hazards posed by ordnance materials and procedures to follow if ordnance is encountered.

# I. Purpose and Health Issues

The US Environmental Protection Agency (EPA) proposed the Former Nansemond Ordnance Depot (FNOD) in Suffolk, Virginia for the National Priorities List (NPL) in January 1999 and listed it as final in July 1999. The Agency for Toxic Substances and Disease Registry (ATSDR) is required by Congress to conduct public health assessments on all sites proposed for the NPL. In this public health assessment, ATSDR evaluates the public health significance of chemical contamination and ordnance at the site. ATSDR reviewed the available environmental contamination and ordnance data, likely exposure pathways, toxicological information, and community health concerns to determine whether adverse health effects are possible. ATSDR also evaluated whether actions are needed to reduce or prevent the potential for substantive site-related exposure and associated adverse health effects.

# II. Background

## A. Site Description and Scope of Assessment

The FNOD site occupies about 975 acres in Suffolk, Virginia, at the confluence of the James and Nansemond Rivers, as shown in Figure 1 [1]. The site is a former US military facility where handling, processing, shipping, receiving, and decommissioning of ordnance items once occurred. The site is bordered to the west by the Nansemond River, to the north by the James River, to the east by Streeter Creek, and to the south and southwest by developing areas of Suffolk, Virginia. The Respass Beach community is off the site just east of Streeter Creek. A portion of the FNOD property is currently used by the Portsmouth Campus of Tidewater Community College (TCC), a two-year college. Some businesses occupy parts of a large building formerly used by the General Electric Company (GE) for manufacturing, and an industrial park is also located in the southern part of the site on what is referred to as the former Dominion Lands [1].

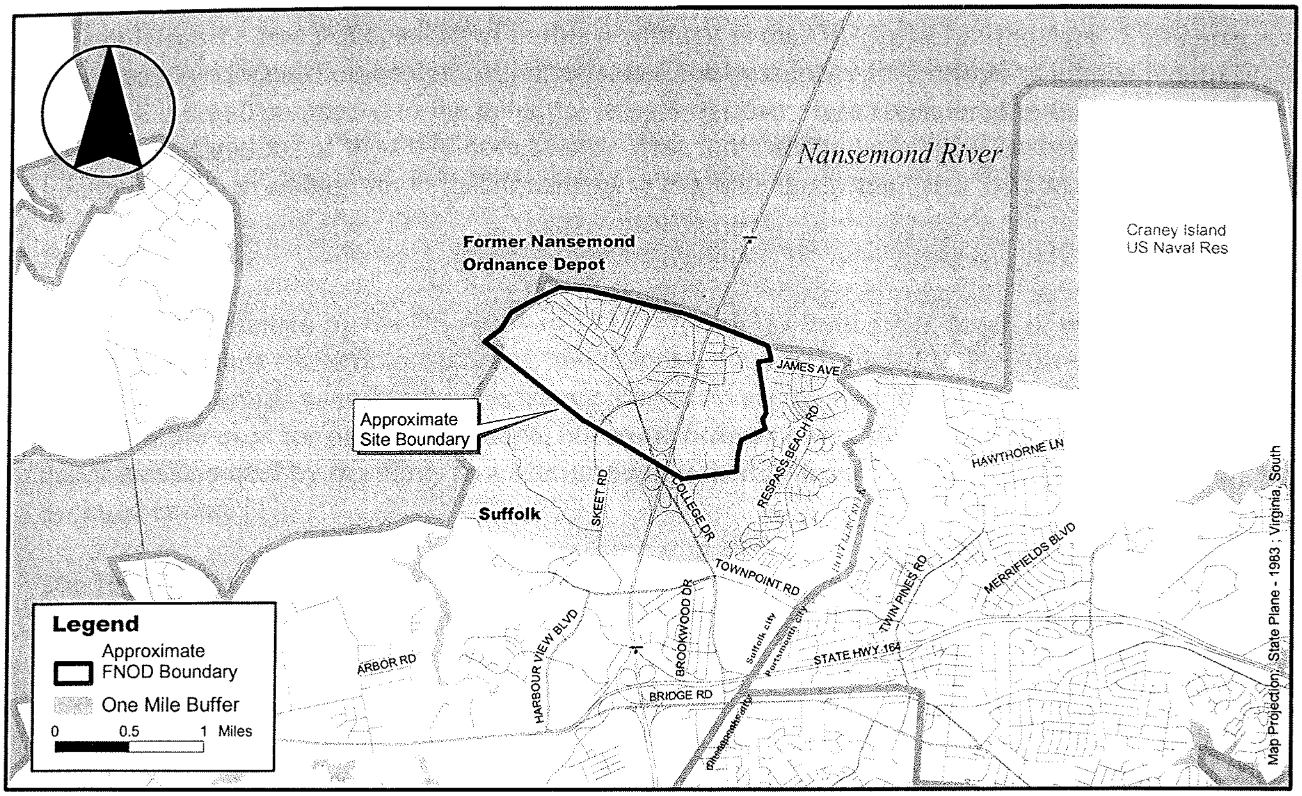
Many site areas once contained, or may still contain, ordnance chemical residues, other chemicals, ordnance items, or explosives. Seven areas were identified as source areas in the proposal of the site to the NPL [1]. These include the James River Beachfront Landfill, the Main Burning Ground/ Steam-out Pond, the Horseshoe Pond Disposal Area, the Track K Dump/ Tire Pile, the TNT Burial Site, the Off-shore Marine Area, and the XXCC3 Landfill, also known as the Impregnite Kit area. (Soils in the Impregnite Kit Area were deleted from the NPL listing in March 2003 after successful completion of soil cleanup activities.) In addition to the source areas, many other areas of concern (AOC) have been identified for investigation and/or cleanup. Boundaries of these locations are not all well defined. A number of investigations and removal and/or remedial actions have occurred, but additional investigation and cleanup of various site locations is still ongoing or planned.

This document has been prepared by use of data through June 2003 provided by EPA, the US Army Corps of Engineers (ACE), and the Virginia Department of Environmental Quality (VDEQ). ATSDR evaluated data available on most of the source areas listed above and for several additional areas, including the Dominion Lands outside the defined source areas, the

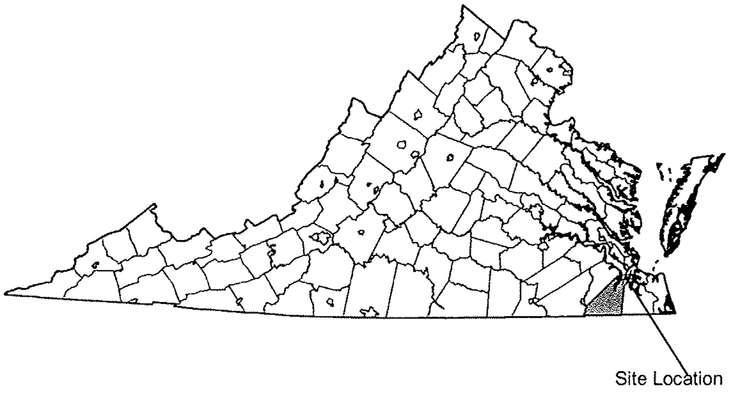
# Former Nansemond Ordnance Depot INTRO MAP

## Suffolk, Virginia

## EPA Facility ID VAD123933426



Base Map Source: 1995 TIGER/Line Files



**Suffolk City, Virginia**

| Demographic Statistics<br>Within One-Mile Radius of Site* | |
|---|---|
| Total Population | 3075 |
| White alone | 1561 |
| Black alone | 1327 |
| Am. Indian and Alaska Native alone | 10 |
| Asian alone | 77 |
| Native Hawaiian and Other Pacific Islander alone | 1 |
| Some other race alone | 25 |
| Two or More races | 74 |
| Hispanic or Latino | 77 |
| Children Aged 6 and Younger | 474 |
| Adults Aged 65 and Older | 99 |
| Females Aged 15 - 44 | 842 |
| Total Housing Units | 1028 |

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique

Figure 1. Site Location and Demographics

Nansemond River Beachfront, TCC lake, J-Area lake, Streeter Creek, TCC's former water supply wells, and the Respass Beach community potable water wells. In addition, ATSDR considered physical hazards and hazards posed by ordnance and explosives (OE) throughout the site.

The only source area not considered in this document is the Off-Shore Marine Area. Studies in this area have focused on ecological impacts, and the possibility for impacts to human health in this area is small compared to the potential impact of other areas considered in this document. If future investigations of the Off-Shore Marine Area indicate the possibility for appreciable human health impact, an addendum to this document to evaluate this source area will be produced.

## B. Site History

The site was obtained by the US Army in 1917. From 1917 until 1950, much of the property was used for ordnance reclamation, storage, and disposal activities related to the Army's mission. Ordnance is defined as military material, such as weapons, ammunition, and equipment. Many bunkers were used for ordnance storage, but some ordnance was stored outside of bunkers. The depot was operated by the Navy as a Marine supply facility from 1950 to 1960, when it was declared excess [1].

The Beazley Foundation acquired the property in 1960, with the Virginia Department Of Highways receiving an easement of several acres. The Foundation operated a four-year institution, Frederick College, at the site from the fall of 1961 until the college closed in spring of 1968 [2]. Soon after, portions of the property were conveyed to the Virginia Electric Power Company, GE, and Suffolk County. The Foundation donated the rest of the property to the State Board of Community Colleges, and TCC opened on the former Frederick College campus in fall of 1968. In 1977, a portion of TCC's property was conveyed to Hampton Roads Sanitation District (HRSD). The remaining 590 acres, currently owned by the State Board of Community Colleges, contains the TCC campus [3].

On the basis of conversations with former Frederick College students and faculty, students lived in concrete block buildings by the school in the 1960s. Some of the school's employees and their families lived in about 30 renovated former bunkers near TCC Lake and further east. TCC also currently uses some buildings that had been part of depot operations.

GE acquired a large building in 1965, expanded it, and used it for manufacturing television sets until the late 1980s. Now, other companies use the building for warehousing. The Virginia Department of Transportation (VDOT) constructed Interstate 664 and a vehicle inspection station on the FNOD site in the early 1990s. The HRSD operates a wastewater treatment plant on its own property. Dominion Lands Company acquired property on-site and off-site at the southwest part of the site. This property has since been sold to Continental Properties and various other businesses, but it will be referred to herein as "Dominion Lands". Bridgeway Commerce Park, an office and commercial development, has been built in the south-central part of the Dominion Lands, near the interstate, and it is currently being occupied by several light industrial companies.

TCC is planning to relocate its campus and sell its FNOD site property [4–6]. Potential future uses of that property include light industrial, commercial, recreational, and residential development.

Some fires, explosions, and other accidents occurred while the depot operated, and some ordnance items and residues remain at random locations on the site. After the depot was declared excess, the first documented concern occurred in April 1987, when a youth found some crystals at a location on College Drive and took them home to show that they burned when lit [7]. The crystals were found to be trinitrotoluene (TNT), and the location has thereafter been called the TNT Burial Site. The ACE has conducted a number of unexploded ordnance (UXO) and hazardous substances investigations at the 2- to 3-acre area, identifying bulk explosives, ordnance items, crystalline TNT, and cigar-shaped burlap bags filled with TNT and used as fuses. Many of these items have been removed, and cleanup is ongoing. Other investigations have been initiated since the late 1980s at many locations on FNOD. Some investigations found ordnance items and potentially hazardous substances, including metals, nitroaromatics (explosives), volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and pesticides. Near-shore river locations might also contain ordnance and related hazardous substances. Investigations continue, and others are planned [1].

## C. Recent Site Activities

FNOD is a formerly used defense (FUD) site. The ACE has been assigned the responsibility for environmental investigation and remediation of FUD sites, and the Norfolk District ACE is responsible for oversight of FNOD through the FUD program. EPA placed the site on the NPL and is responsible for seeing that site investigations and restorations meet Superfund requirements. The environmental condition of FNOD is being evaluated through ACE, EPA, and current site property owners. The source areas identified in the NPL listing and other AOCs are being investigated and remediated via the Superfund process. Other areas may be added or deleted as work proceeds. Some areas may be "carved out" and eliminated from further consideration—for example, areas where evaluations indicate that substantive depot-related activities did not occur or areas that have already been remediated [8].

ACE organized a Restoration Advisory Board (RAB) in June 1997. During bimonthly RAB meetings, ACE, EPA, VDEQ, other governmental entities, property owners, and citizens review progress and discuss environmental restoration activities. The restoration activities will occur over a period of years. ACE developed a Site Management Plan that will be used to disseminate environmental cleanup information [3]. The plan identifies source areas, AOCs, cleanup actions and schedules, and deadlines for submitting primary documents. It will be updated periodically. AOCs are identified on the basis of several types of background information and are evaluated by use of a Site Screening Process [8,9]. The process is expected to expedite investigations and determine the appropriate follow-up actions, which could range from no action—and deletion as an AOC—to a remedial investigation/feasibility study (RI/FS) [10].

## D. Previous ATSDR Reports

In 1995, ATSDR received a request by petition to conduct a public health assessment on the drinking water at TCC. In response, ATSDR reviewed groundwater and soil data, conducted site visits, and met with other agencies involved. It was determined that a public health assessment was not warranted at that time. However, ATSDR did make several recommendations unrelated to the petitioner's concerns to the college and ACE. These recommendations included conducting an ordnance survey, undertaking additional monitoring, conducting more site investigation, and addressing physical hazards identified on site[11,12]. The ordnance and site characterization concerns have been and are being addressed through ongoing remedial investigation activities.

When additional groundwater data became available, ATSDR prepared a public health consultation concerning the TCC water supply wells. This June 1996 consultation concluded that contaminant levels detected in the water supply were not at levels that would represent a public health hazard [13]. Later that year, at EPA's request, ATSDR also reviewed additional beachfront soil data and concluded that for a probable scenario of infrequent exposure, significant adverse health effects were not likely [14].

### E. Demographics

In the early days of activity, military personnel lived in the core building area. FNOD workers entered the site each day. In the years during which Frederick College was open, students and some faculty lived on site. GE employees worked, but did not live, on the site.

Today, the site population is transient and includes commuter students, college staff, fishermen, and workers at the former GE building, VDOT, and HRSD. No one currently lives on the property. The nearest residents are in the Respass Beach community located several hundred feet from the property, on the east side of Streeter Creek. A residential area developed within the past two years is also located southwest of the site. In addition, on-site areas of the southwest side of the site are being developed for residential as well as commercial/ light industrial use.] Considerable residential development is continuing both east of Streeter Creek and south of the Dominion Lands property.

According to the 2000 census, there are 3,075 people, including 474 children age 6 or younger, living within one mile of the site [15]. The ethnic makeup of the surrounding population is mostly Caucasian (51%) and African-American (43%). The population in 2000 was about ten times the population in 1990 [15]. Because of continuing development within the past few years, the number of people close to the site may be appreciably higher today.

### F. Land and Natural Resource Use

The military converted what was, before 1917, mostly agricultural land into a munitions storage, shipping, and decommissioning facility. Aerial photos show that by the time military activities ceased in 1960, essentially the entire property had been used in some manner to support this mission. The core buildings were located in the north-central portion of the site. Bunkers and connecting railroad and road systems were constructed at intervals on essentially all of the rest of the property. The Main Burning Ground/Steamout Area was used to extract and dispose of explosives. Physical evidence of disposal of "solid waste" and ordnance has been noted at some locations. However, information that fully describes the extent of such disposals on the property is not available.

Since 1960, a portion of the property has been used for education and some field athletic activities. On the western side of the property, the former GE manufacturing building is now used for warehousing. The Dominion Lands are being developed bit by bit for light industrial and possibly residential use. Other site areas will likely be developed for various uses in the future. The eastern part of the property contains Interstate 664 and VDOT vehicle inspection and road maintenance facilities. East of the interstate, HRSD operates a wastewater treatment plant. Elsewhere, the FNOD property is heavily overgrown and experiences little use besides limited recreational activities by trespassers. After relocation of the TCC campus, potential future uses of the TCC property include light industrial, commercial, recreational, and residential development.

The FNOD site is bounded on the west, north, and east by waters that are used for fishing and other recreation. TCC Lake is likely to have been used extensively by faculty families and students when they lived on the site in the 1960s. Access to lakes on site now is limited because of undergrowth and fences. Anecdotal information indicates that recreational fishing presently occurs at TCC Lake, at the World War II pier, and possibly at the J-Area Lake. Some camping on the site has also been reported.

During operations, the military obtained potable water from wells located in the core building area. More recently, the college and the GE building received potable water from several TCC wells until 1997, when the distribution system was connected to the Suffolk City water system. The city draws its water from surface supplies located miles from the site. The past and present water delivery system has segments of lead pipe leading from water mains to buildings.

VDOT staff indicated that the vehicle inspection facility has wells that until recently were used for the workers' potable water supply. Now, workers drink bottled water and use well water only for maintenance purposes. Residents of the Respass Beach community use private wells as a source of potable water.

Groundwater is known to be contaminated at three principal locations on the site: The TNT Burial Site, the GE building, and the James River Beachfront Landfill. The former depot and TCC potable water supply wells are near the TNT Burial Site; these wells may have been impacted by the disposed materials while the wells were in use. No water supply wells are known to have been in the vicinity of the GE building or the James River Beachfront Landfill.

Several areas on site have had removal or remedial actions to date. These include the TNT Burial Site, where several thousand pounds of crystalline TNT and associated contaminated soil have been removed; the XXCC3 Landfill (a.k.a. Impregnite Kit Area), where soil was removed; the James River Beachfront Landfill, where debris was removed and beach stabilization (a revetment wall) was constructed; the Track K/Tire Pile area, where tires and waste were removed; and the Nansemond Beach Beachfront, where debris was removed. Other site areas have been the focus of ordnance and explosives surveys and removals, and most site areas are in the process of being characterized and/or cleaned up.

## III. Discussion

### A. Types of Data Used

The preparation of this report involved the review of site historical documents, correspondence, and numerous reports on previous investigations at the site. Reviewed investigations included ordnance surveys as well as sampling of site soils, groundwater, surface water, sediments, and fish at locations in and around the site. ATSDR also reviewed reports of the removal and remedial activities that have taken place on the site to date.

In addition to site environmental data, ATSDR considered health outcome data available for the population near the site. ATSDR assessed current site conditions during two visits to the site on June 22 and 23, 1999 and on June 26, 2003. During the June 1999 site visit, ATSDR also met with the community to learn what health concerns nearby residents had about the site.

The conclusions reached in this document are based on the data available at this time and are subject to modification, depending on what additional information becomes available as EPA/ACE activities continue at the site.

### B. Scope of Public Health Evaluation

In this public health assessment, ATSDR attempts to draw conclusions about public health implications for the site as a whole from the findings for areas that have been investigated to date. Because of the large size of this site, the investigations for both ordnance and chemical contamination have focused on specific areas, such as known disposal areas, where contamination is considered likely. Characterizing the boundaries and cleaning up these areas will address the vast majority of chemical and ordnance hazards. However, it is possible that previously undocumented areas of chemical contamination and/or ordnance items will be discovered in the future. Such a discovery could alter the general conclusions made in this document.

ATSDR's evaluation of past exposures includes the time frame after 1960, when the facility was converted to private use. Assessing historical exposures to former military personnel, who may have had direct occupational exposures as well as indirect environmental exposures, would involve too many uncertainties to allow meaningful conclusions to be drawn.

Several geographical areas on the FNOD site will not be evaluated in this document. The offshore marine area has limited information on which to base an assessment of potential human exposures, and human exposures in this area are expected to be small compared to those in other areas. In addition, the VDOT and HRSD properties have limited access, and the limited information available of these properties does not indicate significantly elevated contaminant levels [16,17]. ATSDR assumes that exposures to workers at these controlled sites are small compared to exposures to people in other areas. Finally, GE is performing cleanup activities at the GE building area. Because the current building occupants are mainly warehouse employees and therefore not extensively exposed to outdoor contaminants, ATSDR assumes that their exposures are small compared to exposures of people in other areas. If data or other information become available indicating that any of these assumptions are invalid, ATSDR will evaluate these areas in an addendum to this document.

### C. Chemical Contamination: Summary of Areas Evaluated at FNOD

To organize the vast amount of data available on areas of FNOD, ATSDR broke the site up into four tracts of land on the basis of the ownership of the land, as shown in Figure 2. These are the Dominion Lands, the GE Lands, the TCC Property, and the VDOT/HRSD Property. As discussed previously, the VDOT/HRSD property will not be evaluated in this PHA because exposures of workers on these limited-access sites are not as great as exposures of people elsewhere on the site. These properties will be evaluated at a later date if new information indicates such an evaluation is warranted.

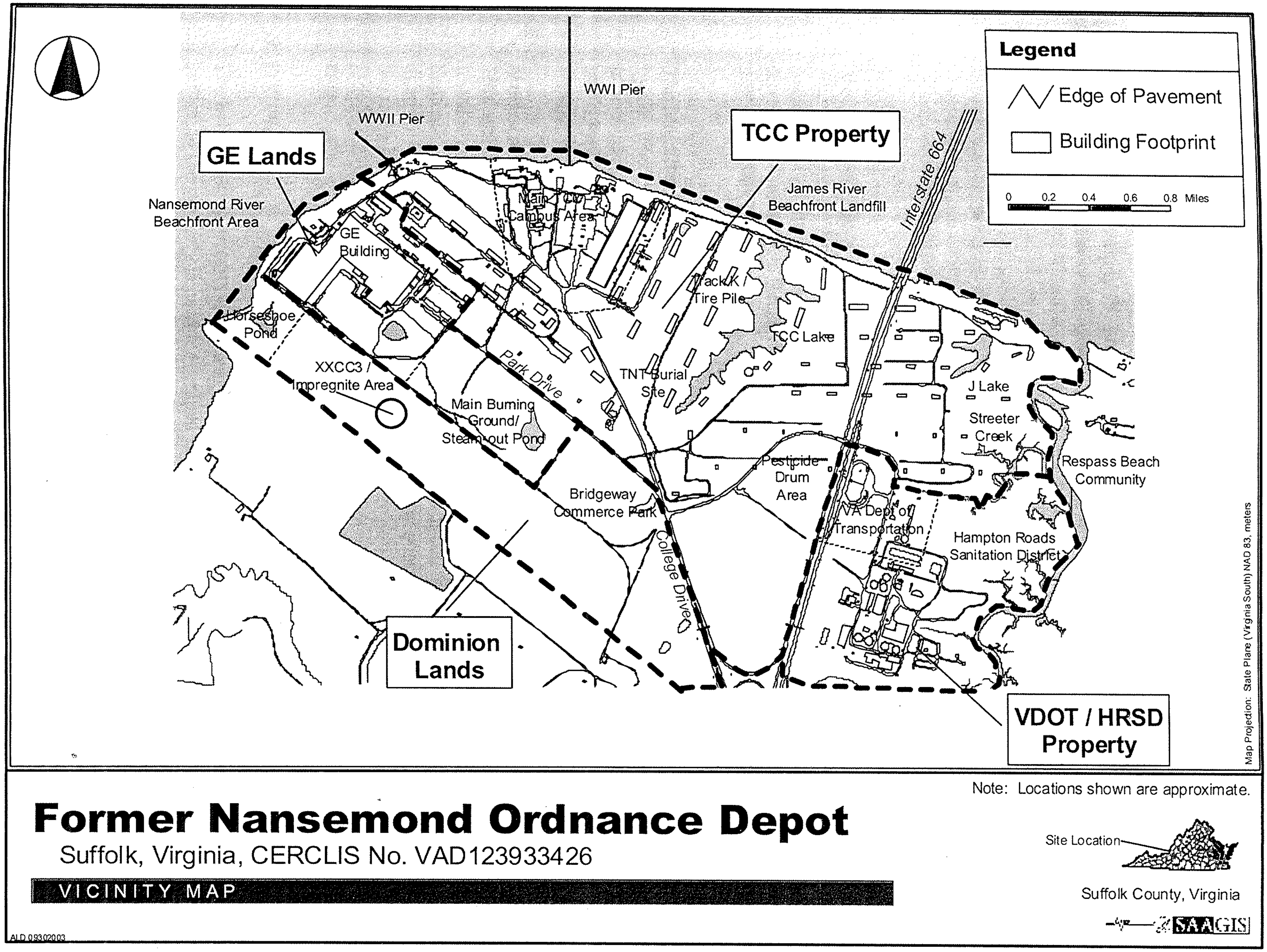
#### *1. Dominion Lands*

The Dominion Lands run along the southwest border of the FNOD site. Substantial parts of the onsite area have been the subject of chemical and ordnance investigation and cleanup activities [1,18–28]. The southeast part of the Dominion Lands contains a number of deep brick vaults of unknown function that may pose physical hazards. About 135 acres of the land on the site and additional adjacent property have been developed by Dominion Lands into an industrial/ commercial park called Bridgeway Commerce Park [29]. Other parcels of the land might be developed in the future. A summary of the main areas on Dominion Lands for which chemical contaminant data are available follows.

*Horseshoe Pond Disposal Area*
The Horseshoe Pond Disposal Area is located on the northwest end of the Dominion Lands property. The area is bordered on the northwest by the Nansemond River, on the southwest by a tidal marsh, on the southeast by a heavily wooded area, and on the northeast by the GE plant building and parking area [30]. Metal debris and other solid waste have been observed along the pond, and it appears that land around the pond has been excavated, possibly to cover debris in the area. The pond itself is approximately 1–2 acres in size and has no inlets or discharge points. Groundwater discharge is the major source of water for the pond. A remedial investigation was performed on this area, and supplemental investigations are occurring [30,31].

*Impregnite Kit Area (a.k.a. XXCC3 Landfill)*
This source area was a former disposal area for impregnite kits located on the Dominion Lands property about 1,000 feet from the Nansemond River. Impregnite kits, used during World War II to increase the chemical resistance of military issue chemical suits, contained XXCC3, a fine, white, powder, and a black waxy material or honey-like syrup. These materials and several other hazardous substances were found at the site prior to cleanup. Removal of the kits and the surrounding contaminated soil was conducted in December 1998 and January 1999. Geophysical investigations were conducted in June 1999 and August 2002 to confirm that no other disposal areas were present [32]. Results of confirmation soil sampling collected starting in July 1999 were used to show that no threat to human health remained from soils, and the soils in the area were deleted from the NPL in March 2003

Figure 2. Land Tracts at FNOD



Note: Locations shown are approximate.

**Former Nansemond Ordnance Depot**

Suffolk, Virginia, CERCLIS No. VAD123933426

VICINITY MAP

Suffolk County, Virginia

[33,34]. Groundwater underneath the XXCC3 area is still being characterized as part of the remedial investigation.

### 2. *GE Lands*

The GE Lands run along the northeast border of the Dominion Lands, and includes a large building that is a former television manufacturing facility, the shoreline along the Nansemond River, the GE pond, which drains through a culvert to the Nansemond River, and the Main Burning Ground and Steam-out Pond, two areas associated with former military decommissioning activities. The building itself will not be included in this evaluation; however, other areas on the GE lands have been the subject of chemical and ordnance investigations and cleanup activities. A summary of the main areas on GE Lands for which chemical contaminant data were evaluated follows.

#### *GE Pond*

The GE pond is located next to the GE building. A drainage ditch formerly ran from the Main Burning Ground / Steam-out Pond to the GE Pond, suggesting that contaminants might have been deposited there. The GE Pond drains through an underground culvert to the Nansemond River Beachfront Area. Sediments in the GE Pond and at the culvert's outfall were sampled in 1997 and 2001 [35].

#### *Main Burning Ground/ Steam-out Pond*

The Main Burning Ground/ Steam-out Pond is located south of Park Drive on property owned by GE. The area is a likely location of inspection, decommissioning, and disposal of unserviceable ammunition by defusing or burning during World Wars I and II. TNT from shells handled at the site was recovered at the Steam-out Pond [30]. A remedial investigation was performed on this area, and supplemental investigations are occurring [30,31].

#### *Nansemond River Beachfront*

This area is a 353-foot stretch of beach located behind the GE plant on TCC property. ACE found non-hazardous metal slag on the beach, and visible large debris was removed in September 2001. Small pieces of slag material continued to surface under rocks and concrete debris on the beach as a result of wave action. Consequently, one foot of soil from underneath the rocks was removed and disposed of offsite. Erosion control measures are being evaluated [36–38]. Slag material and unexploded ordnance have continued to surface on the beachfront area.

### 3. *TCC Property*

The balance of the FNOD site, about 520 acres, is currently owned by TCC. A relatively small portion of the property is used for campus activities, and lands lying mostly to the east side of the property are overgrown and unused, although several buildings and other structures from former military operations are still present. Many areas on the TCC Property have been the subject of chemical and ordnance investigations and cleanup activities. A summary of the main areas on TCC Property for which chemical contaminant data were evaluated follows.

### *TNT Burial Site*

The TNT Burial Site consists of a 2- to 3-acre plot on College Drive where disposed ordnance and a large quantity of bulk crystalline TNT were discovered in 1987. The plot is bordered on the north by a college athletic field and on the west by College Drive, with unused land to the south and east. The area has been the subject of numerous soil and groundwater sampling events, surface ordnance sweeps, and soil and ordnance removals. Clean fill soils have been placed in excavated areas [3,7,39–41]. The latest round of soil and groundwater sampling at this area was completed in spring 2003 [42]. Ordnance removals continue at this area; TNT, both crystalline and in small burlap fuse bags, continues to be encountered.

### *James River Beachfront Landfill*

The James River Beachfront Landfill was apparently used as a general disposal site during the World War II era. The waste buried at the area has been shown to include scrap metal, construction and building debris, and some World War I and World War II ordnance material (including projectiles, metal boxes, caisson parts, and fuses). The area is undeveloped and subject to continued erosion by the James River, which washed away some cover soils and disposed materials in the past. Environmental sampling and ordnance surveys have been conducted at the disposal area [18,19,43–47]. ATSDR previously reviewed pre-1996 soil sample data and concluded that for infrequent exposure, significant adverse health effects were not likely [14]. A removal of debris and inert ordnance was conducted in the summer of 2001, and a stone wall was installed to protect the shoreline from further erosion. In this document, ATSDR will review post-removal confirmation soil samples, considering potential future development scenarios [36,37].

### *Track K Dump/Tire Pile*

The Track K Dump/Tire Pile is located west of South Road on the TCC campus. This source area is a 7 to 10-acre unused wooded area containing a 250×100 foot area of discarded tires and a 12×12 foot area of discarded paint cans. ACE removed the tires and paint cans in June 2001. Confirmation soil sampling showed no elevated levels of tire- or paint can-related contaminants in soils at the site. No further remedial action is anticipated for this site [37,48].

### *TCC Lake*

TCC Lake has been used for recreational activities, including fishing. Students and faculty of Frederick College lived next to the lake in the 1960s. Several former bunker locations nearby have been subjected to sampling activities. Non-intrusive ordnance inspections and surveys have been initiated on the lake and along its shoreline [18–20,44,49]. Fish and sediment from TCC Lake were sampled in August 2000 [50,51].

### *J-Area Lake*

J-Area Lake has been used for recreational activities, including fishing. Several former bunkers were located nearby, and adjacent ground may have been used for burning ordnance materials [19,20]. Fish and sediment from J-Area Lake were sampled in August 2000 [52].

### *TCC Former Water Supply Wells*

Until early 1997, TCC had used several wells for potable water for students, faculty, and staff. Water samples from these wells have been taken on several occasions. In about 1993, in response to concerns about the potential for contamination, TCC made bottled water available. The wells were abandoned when the college connected to the City of Suffolk municipal water system [1,7,18,39,53,54].

In 1995, in response to a citizen's petition that raised concerns about the site, ATSDR evaluated a set of 1992 water quality data for the TCC supply wells. ATSDR concluded that contaminant levels detected in a number of samples were not at levels that would represent a public health hazard [13].

#### *Streeter Creek*

Streeter Creek lies at the east end of the site and discharges northward into the James River. Several magazines and possible disposal areas lie close to the creek or its tributaries. Several water and sediment samples have been taken, in and around the main creek channel [18,55].

### *4. Offsite Area Evaluated—Respass Beach Potable Water Wells*

In addition to the land tracts described above, some offsite areas have the potential to be affected by former uses of the site, in particular the Respass Beach community. This community consists of a group of about 80 homes located east of the mouth of Streeter Creek. The community relies on groundwater wells for its potable water supply. Several wells have been tested [56,57], and results are evaluated in this document.

As additional information becomes available through ongoing and future investigations, ATSDR will address health issues in other locations, as appropriate. Also, conclusions for areas addressed herein will be reevaluated, if warranted by new information.

## D. Evaluation Process

The process by which ATSDR evaluates the possible health impact of contaminants is summarized here and described in more detail in Appendix A. The first step involves screening the available data for contaminants of concern (COCs). ATSDR uses comparison values (CVs) to determine which chemicals to examine more closely. CVs are concentrations of chemicals in the environment (water, soil, or sediment) below which no adverse human health effects are expected to occur. Exceeding a CV does not mean that health effects will occur; rather, it indicates that more evaluation is needed. ATSDR also considers sampling location and data quality; exposure probability, frequency, and duration; and community health concerns in determining which chemicals to evaluate further.

If a chemical contaminant is selected for further evaluation, the next step is to identify which chemicals and exposure situations could be a health hazard. Child and adult exposure doses are calculated for COCs in site media (e.g., soil, groundwater, surface water, sediment, or fish), using exposure assumptions as described in Appendix B. Exposure doses are the estimated amounts of a contaminant that people come in contact with under specified exposure situations. These exposure doses are compared to appropriate health guidelines for that chemical. Health guideline values are considered safe doses—that is, health effects are unlikely below this level. If the exposure dose for a chemical is greater than the health guideline, then the exposure dose is compared to known health effect levels identified in ATSDR's toxicological profiles. If the COC is a carcinogen, the cancer risk is also estimated. These comparisons are the basis for stating whether the exposure is a health hazard.

## E. Contaminant Screening, Exposure Analysis, and Toxicological Evaluation

The following sections describe the various ways people could come into contact with contaminants at the site. Each of these ways is called an exposure pathway. ATSDR sorted the large amount of contaminant data available by media (soil, sediment, surface water, groundwater, or fish) and by the land tract in which the sampling was performed. Next, each media in each land tract was screened for COCs. COCs were further evaluated by estimating exposure doses based on assumed uses of the different land tracts detailed below in Table 1. For past exposures, ATSDR used data from before any cleanup activities took place. Present exposure and future evaluations considered post-removal confirmatory sampling.

**Table 1. Assumed Land Uses at FNOD**

| Land Tract | Distant Past Use (1960–1967) | Present and Recent Past Use (1967–2003) | Potential Future Use | Potential Exposure Media |
|---|---|---|---|---|
| Dominion Lands | Light industrial use, trespassing, occasional recreation | Light industrial use, occasional recreation | Residential use, recreation, fishing, light industrial use | Soil, sediments, surface water |
| GE Lands | Light industrial use, trespassing, occasional recreation | Light industrial use, trespassing, occasional recreation | Light industrial use, trespassing, occasional recreation | Soil, sediments, surface water |
| TCC Property | Residential use near TCC Lake, more frequent recreation, fishing, swimming | Day students & faculty, occasional recreation, fishing | Residential use, recreation, fishing, light industrial | Soil, sediments, surface water, groundwater (pre-1997), fish |
| VDOT/HRSD Properties | Unknown (Not Evaluated) | Limited access (Not Evaluated) | Limited access (Not Evaluated) | Not Evaluated |

### *1. Dominion Lands*

#### *a) Soil and Sediment*

Tables 2 and 3 list the chemicals in the Dominion Lands area that were detected in soil and sediment at least once above substance-specific soil or sediment CVs.

**Table 2. Surface Soil Contaminants Present Above Comparison Values—Dominion Lands**

| Contaminant | Maximum concentration in soil, parts per million (ppm) | Comparison Value (CV) in ppm | CV Source (defined in Appendix A) |
|---|---|---|---|
| **Impregnite Kit Area (Before Removal):** | | | |
| Carbon tetrachloride | 21* | 5 | CREG |
| Dieldrin | 1.0†† | 3 / 0.04 | cEMEG / CREG |
| Phosphorus | 239** | 1 | RMEG |
| **Impregnite Kit Area (Post-Removal):** | | | |
| Arsenic | 5† | 20 / 0.5 | cEMEG / CREG |
| **Horseshoe Pond Area:** | | | |
| Antimony | 62‡ | 20 | RMEG |
| Arsenic | 40‡ | 20 / 0.5 | cEMEG / CREG |
| Iron | 340,000‡ | 23,000 | R9 PRG |
| Lead | 599‡ | 400 | SSL |
| Thallium | 16‡ | 5.2 | R9 PRG |
| Polycyclic Aromatic Hydrocarbon Toxicity Equivalence Quotient | 0.8‡ | 0.1 | CREG |
| **Bridgeway Commerce Park and Other Dominion Lands Areas:** | | | |
| Arsenic | 15** | 20 / 0.5 | cEMEG / CREG |
| Dieldrin | 0.08‡‡ | 3 / 0.04 | cEMEG / CREG |
| Phosphorus | 1240** | 1 | RMEG |
| Sources: *[1]; ††[20]; †[34]; ‡[31]; **[22]; ‡‡[21]. | | | |

**Table 3. Sediment Contaminants Present Above Comparison Values—Dominion Lands**

| Contaminant | Maximum concentration in sediment, parts per million (ppm) | Comparison Value (CV) in ppm§ | CV Source (defined in Appendix A) |
|---|---|---|---|
| **Horseshoe Pond Area:** | | | |
| Arsenic | 40* | 200 / 5 | cEMEG / CREG |
| Polycyclic Aromatic Hydrocarbon Toxicity Equivalence Quotient | 1.3† | 1 | CREG |
| § Sediment CVs calculated as ten times the soil CV.<br>Sources: *[31]; †[24] | | | |

These chemicals were then evaluated using assumptions of how people could have been or could be exposed at this site. For past exposures, ATSDR assumed that adults or older children might be on Dominion Lands four times a week throughout the year. ATSDR assumed that each day they were on site, adults accidentally ingested 100 milligrams (mg) of soil or 10 mg of sediment, and children accidentally ingested 200 mg of soil or 20 mg of sediment (see Appendix A for further exposure assumption details). Initial screening was performed with the maximum soil or sediment value. The resulting estimated exposure doses for all compounds except iron, lead, and phosphorus in soil were lower than health guideline values, indicating that no health effects are expected. Past and present exposures to iron, lead, and phosphorus in soil were retained for further consideration and are evaluated below.

ATSDR was requested to evaluate potential future uses of the Dominion Lands, including residential use. For future exposures, the same calculation was performed using the maximum soil value detected and assuming potential future residential use (i.e., small children could access the soil throughout the year). The only estimated exposure doses higher than health guideline values were those for antimony, arsenic, iron, lead, phosphorus, and thallium. Evaluation of these potential future exposures follows.

### Further Evaluation of Soil and Sediment—Dominion Lands

#### Iron

The estimated past exposure of older children to the maximum concentration of iron found in soil is 1 mg/kg/day, higher than the health guideline of 0.3 mg/kg/day. However, no health effects are expected from this exposure. The Institute of Medicine has established tolerable upper intake levels for iron ranging from 40 mg/day for infants and children to 45 mg/day for teenagers and adults [59]. The estimated exposure dose would correspond to a daily intake of about 36 mg/day, within the recommended intake. In addition, the estimated dose conservatively overestimated actual exposure to iron, because the maximum concentration was used instead of the average, iron may be less available in soil than in toxicological studies, and exposure to soil will probably be less frequent than assumed due to climate and weather factors. Therefore, no health effects due to past and present exposure to iron in soil at the Dominion Lands are expected. If the exposure were to increase as a result of conversion of the Dominion Lands to residential use, the estimated maximum iron dose would rise to 7 mg/kg/day, or about 70 mg/day for small children. This dose would be unlikely to result in severe toxic effects for an acute exposure, and long-term exposure at this dose is unlikely because exposure would be to an average rather than the maximum concentration. No health effects would be expected from residential exposures to iron in soil at the Dominion Lands.

#### Lead

Exposure to lead can cause a wide range of effects [60]. However, the lack of a clear threshold for health effects and the need to consider multi-media routes of exposure have made determining toxicological effect levels for lead difficult. The level of lead in blood is a good measure of recent exposure to lead and also correlates well with health effects. Children are especially sensitive to lead, and many of its effects are observed at lower concentrations in children than in adults. Levels of 10 micrograms per deciliter ($\mu$g/dL) and less in children's blood have been associated with small decreases in IQ and slightly impaired hearing and growth. The maximum concentration of lead detected in the Dominion Lands was 599 mg/kg (or part per million (ppm)). For the past exposure of older children and adults assumed above, this level of lead in soil would not be expected to raise blood levels enough to result in adverse health effects.

If the Dominion Lands are developed for residential use in the future, small children might be exposed to lead in soil. Epidemiological studies have determined soil slope factors that predict blood lead levels to increase from between 0.0007 and 0.0068 $\mu$g/dL for each ppm increase in soil lead level [60]. This wide range resulted from the presence of different sources of lead, exposure conditions, and exposed populations. The highest slope factor of 0.0068 $\mu$g/dL/ppm indicates that the maximum lead concentration measured in soil (599 ppm) would be expected to increase blood lead levels by 4.1 $\mu$g/dL. The health effects associated with such an increase would depend partly on the existing body burden of lead.

The actual blood lead level would be much lower, because children would be exposed to an average rather than the maximum lead concentration and because weather and grass cover would decrease the percentage of time children would be able to contact the soil.

Phosphorus

Phosphorus is a component of several compounds commonly found in the environment, but it does not occur by itself (as an element) naturally. In the soil sampling at Dominion Lands, the phosphorus is listed as *total phosphorus*, which includes phosphorus compounds and 3 forms of elemental phosphorus (red, black, and white phosphorus). White phosphorus is the form usually associated with munitions and is the most toxic. White phosphorus at high concentrations poses a fire and/or explosive hazard, but because it is so reactive, it does not remain in soil unless it is coated with a protective oxide layer or it is in deep soils where no oxygen is present. Even assuming that the level measured in the soil was mostly white phosphorus, the exposure doses estimated for past exposures of adults and older children would be a fraction of the dose that caused no toxic effects in animal studies, called the no-observed-adverse-effect level (NOAEL) [61]. No adverse health effects would be expected from this exposure. If future development results in children accessing the maximum concentration in a residential setting, the estimated dose would be similar to the NOAEL. However, the actual dose that a child would receive would be significantly lower because exposure would be to an average rather than to the maximum concentration, the percentage of phosphorus present in the most toxic form (white) would be a small percentage of the total, and weather conditions would likely preclude daily contact with soil. No adverse health effects would be expected from this exposure.

Antimony

No health effects are expected from exposure to antimony in soil at the Dominion Lands. Exposure to the maximum concentration of antimony was only slightly above the health guideline value for potential future residential exposures to small children. The actual dose a child might get would be lower because exposure would be to an average concentration rather than to the maximum. Moreover, antimony would not be as easily absorbed from soil as from the aqueous solutions used in toxicological studies [62].

Arsenic

No health effects are expected from exposure to arsenic in soil at the Dominion Lands. Exposure to the maximum concentration of arsenic would be only slightly above the health guideline value for potential future residential exposures to small children. The child residential dose is equal to the dose observed in human epidemiological studies that did not cause any health effects [63]. The actual dose a child might get would be even lower because exposure would be to an average rather than to a maximum concentration. Moreover, arsenic would not be as easily absorbed from soil as from the aqueous solutions that toxicological effect levels are based on. Arsenic is known to cause cancer. However, the estimated increase in the risk of cancer from a lifetime of exposure to arsenic in soil at the Dominion Lands is so low as to be negligible.

Thallium

No health effects are expected from exposure to thallium in soil at the Dominion Lands. Exposure even to the maximum concentration of thallium is only slightly above the health guideline value for potential future residential exposures to small children. The actual dose a child might get would be lower because exposure would be to an average rather than to the maximum concentration and because thallium would not be as easily absorbed from soil as from the aqueous solutions used in toxicological studies [64].

*b) Groundwater*

Table 4 lists the chemicals that were detected at least once above substance-specific drinking water CVs in shallow groundwater in the Dominion Lands area. The monitoring wells were placed in the unconfined Columbia aquifer. (No chemicals were detected in surface water above drinking water CVs.) Groundwater at the Dominion Lands has never been used for drinking water, so that the past groundwater exposure pathway for this area is incomplete and therefore will not be evaluated further.

**Table 4. Groundwater Contaminants Present Above Drinking Water Comparison Values – Dominion Lands**

| **Contaminant** | **Maximum concentration in groundwater, micrograms per liter (µg/L)** | | | **Drinking Water Comparison Value (CV) in µg/L** | **CV Source (defined in Appendix A)** |
|---|---|---|---|---|---|
| | Horseshoe Pond Area | Impregnite Kit Area | Other Dominion Lands | | |
| Aluminum | 97,100* | 113,000* | 77,200* | 20,000 | iEMEG |
| Arsenic | 194* | 214* | 141* | 3 / 0.2 | cEMEG / CREG |
| Diethylhexyl phthalate (DEHP) | 6† | Not analyzed | Not analyzed | 3 | CREG |
| Beryllium | 23.9* | Less than CV | Less than CV | 20 | cEMEG |
| Cadmium | 8.5* | Less than CV | Less than CV | 2 | cEMEG |
| Chromium | 420* | 193* | 365* | 30 | RMEG (hexavalent) |
| Cobalt | 261* | Less than CV | Less than CV | 100 | iEMEG |
| Iron | 284,000* | 165,000* | 103,000* | 11,000 | R9 PRG |
| Lead | 79.3* | 73.3* | 54.7* | 15 | AL |
| Manganese | 8,910* | 939* | Less than CV | 500 | RMEG |
| Nickel | 281* | Less than CV | Less than CV | 200 | RMEG |
| Vanadium | 477* | 317* | 370* | 30 | iEMEG |

Sources: *[24]; †[31].

ATSDR was requested to evaluate the Dominion Lands groundwater for potential future drinking water use. Using exposure assumptions described in Appendix A, ATSDR estimated exposure doses for the COCs listed in Table 4. The estimates assumed that adults would drink 2 liters of water per day (L/day) and that children would drink 1 L/day. The estimated exposure dose for diethylhexyl phthalate was lower than the health guideline values and not expected to significantly increase the risk of cancer, so that no health effects are expected from exposure to this contaminant in groundwater. An evaluation of potential future exposure to the other COCs in groundwater at the Dominion Lands follows.

## Further Evaluation of Groundwater—Dominion Lands

### Aluminum

Both child and adult doses (10 mg/kg/day and 3 mg/kg/day, respectively) from drinking the maximum level of aluminum in drinking water would be higher than the intermediate MRL of 2 mg/kg/day. The child dose is about one-sixth the intermediate-duration NOAEL for neurotoxicity found in a mouse study, 62 mg/kg/day [65]. Exposure to aluminum would be unlikely to result in health effects.

### Arsenic

The child dose from drinking the maximum level of arsenic in drinking water (0.02 mg/kg/day) would be higher than the LOAEL shown to cause skin changes in human epidemiologic studies, 0.014 mg/kg/day [63]. The adult dose of 0.006 mg/kg/day would be about half the LOAEL. A lifetime of drinking this level of arsenic in water would result in a moderate to high increased risk of developing cancer.

### Beryllium

Drinking water containing the maximum level of beryllium in Dominion Lands groundwater would be unlikely to lead to health effects. Estimated adult and child exposure doses were only slightly above the minimal risk level and were still hundreds of times lower than the dose estimated to result in an increase in the incidence of small intestine lesions in a dog study [66].

### Cadmium

Drinking water containing the maximum level of cadmium in Dominion Lands groundwater would be unlikely to lead to health effects. Estimated child and adult exposure doses (0.0009 mg/kg/day and 0.00024 mg/kg/day, respectively) were lower than the NOAEL of 0.0021 mg/kg/day from human studies. Animal data indicate that cadmium is a probable human carcinogen [67]. However, there is no oral cancer slope factor for cadmium, so that it is not possible to evaluate carcinogenic risk.

### Chromium

Most of the available data did not specify the type of chromium detected; when the type was not specified, ATSDR conservatively assumed the reported concentrations to be chromium (VI), which is more toxic than chromium (III). If adults or children were to drink water containing the highest concentration of chromium measured in the Dominion Lands groundwater, they would receive doses of chromium estimated at 0.01 mg/kg/day for adults and 0.04 mg/kg/day for children. While these doses are less than the chronic LOAEL for humans of 0.57 mg/kg/day, some sensitive individuals might still experience gastrointestinal effects. In addition, less serious effects, such as enhancement of dermatitis, have been reported after acute exposure to doses as low as 0.036 mg/kg/day [68].

### Cobalt

The estimated cobalt dose for a child drinking water containing the maximum amount of cobalt was 0.03 mg/kg/day, several times lower than the lowest observed adverse effect level (LOAEL) of 1 mg/kg/day, which caused a reversible increase in the number of red blood cells in adult male volunteers [69]. The estimated adult dose is lower than the MRL. No health effects would be expected to result from exposure to cobalt at this level in drinking water.

### Iron

The calculated child dose from drinking water with the highest iron concentration is 30 mg/kg/day, high enough to result in acute toxic effects, including nausea and vomiting [58]. The adult dose (8 mg/kg/day) would probably not result in acute effects. However, the daily intake resulting from this exposure is ten times the tolerable upper limit, and long-term exposure to this level could cause clinical effects such as accumulation of iron in the liver [59,58]. Water containing such a high iron concentration would have an unpleasant taste, reducing the likelihood that it would be used for drinking.

### Lead

As described previously, levels of lead in children's blood of 10 micrograms per deciliter ($\mu$g/dL), and perhaps lower, have been associated with small decreases in IQ and slightly impaired hearing and growth. A slope factor for the increase in blood lead concentration per increase in water lead concentration for infants has been calculated as 0.04 $\mu$g/dL blood per part per billion (ppb) lead for water lead levels above 15 ppb [60]. The corresponding slope factor for school children was found to be 0.03 $\mu$g/dL per ppb. At the maximum concentration of 79 ppb lead measured in the Dominion Lands groundwater, increases in blood lead concentrations of 3.2 $\mu$g/dL and 2.4 $\mu$g/dL are predicted for infants and school children, respectively. The health effects associated with such increases would depend partly on the existing body burden of lead.

### Manganese

Epidemiologic studies suggest an association between ingesting water containing elevated concentrations of manganese and the development of neurological symptoms. However, each of the studies had uncertainty regarding the exposure level or whether the effects were solely attributable to manganese, so that no NOAEL, LOAEL, or minimal risk level could be identified [70]. Studies with rats have shown a LOAEL for neurological changes of 14 mg/kg/day, an order of magnitude higher than the estimated child dose of 0.9 mg/kg/day and also much higher than the adult dose of 0.3 mg/kg/day. However, humans appear to be more sensitive to manganese than animals [70]. Therefore, the estimated future child and adult manganese dose for this pathway could cause health effects.

### Nickel

The estimated dose for a child drinking water containing the maximum concentration of nickel is 0.03 mg/kg/day, only slightly more than EPA's reference dose (RfD) of 0.02 mg/kg/day. Oral exposure to nickel has caused skin reactions in sensitive people at doses as low as 0.009 mg/kg/day, but in general, reactions are considered unlikely for doses less than the RfD [71].

Vanadium
The maximum concentration of vanadium in Dominion Lands groundwater would not be expected to result in health effects if the water were used for drinking. The estimated child and adult doses (0.05 mg/kg/day and 0.01 mg/kg/day, respectively) are several times lower than the NOAEL for renal effects found in an intermediate duration study in rats. Another study in which adult humans were given doses of vanadium 50 times higher than the doses estimated here showed no changes in liver or renal enzymes nor hematological abnormalities over 45 to 68 days [72].

Summary—Potential Future Use of Dominion Lands Groundwater for Drinking

The available data indicate that without treatment, the shallow groundwater in the Dominion Lands area is not suitable for drinking purposes. The levels of several contaminants, especially arsenic, chromium, iron, lead, and manganese, are high enough to cause adverse health effects in children and/or adults. Because the sampled groundwater was from the shallow, unconfined aquifer, it is unlikely to be used for drinking water. Deeper groundwater in this area was not sampled and therefore is not evaluated in this report.

### *2. GE Lands*

#### *a) Soil and Sediment*

Tables 5 and 6 list the chemicals in the GE Lands that were detected in soil and sediment at least once above substance-specific soil or sediment CVs. For past exposures, ATSDR assumed that adults or older children might be on GE Lands 4 times a week throughout the year. ATSDR also assumed that each day they were on site, adults accidentally ingested 100 milligrams (mg) of soil or 10 mg of sediment, and children accidentally ingested 200 mg of soil or 20 mg of sediment (see Appendix A for further exposure assumption details). Initial screening was performed with the maximum soil or sediment value. The resulting estimated exposure doses for all soil and sediment COCs were lower than health guideline values, indicating that no health effects are expected.

**Table 5. Surface Soil Contaminants Present Above Comparison Values—GE Lands**

| Contaminant | Maximum concentration in soil, parts per million (ppm) | Comparison Value in ppm | CV Source (defined in Appendix A) |
|---|---|---|---|
| Arsenic | 6.5* | 20 / 0.5 | cEMEG / CREG |
| Dieldrin | 0.17* | 3 / 0.04 | cEMEG / CREG |
| Polycyclic Aromatic Hydrocarbon Toxicity Equivalence Quotient | 1.0* | 0.1 | CREG |

* Source: [31]

**Table 6. Sediment Contaminants Present Above Comparison Values—GE Lands**

| Contaminant | Maximum concentration in sediment, parts per million (ppm) | Comparison Value (CV) in ppm[§] | CV Source (defined in Appendix A) |
|---|---|---|---|
| Arsenic | 39.5* | 200 / 5 | cEMEG / CREG |

[§] Sediment CV calculated as ten times the soil CV.
* Source: [31]

ATSDR was requested to evaluate future uses of the property. For the GE Lands, potential future uses are likely to be similar to present uses; therefore, the conclusions reached for past and present use will apply in the future as long as the use remains light industrial with only occasional trespassing or recreational use. No health effects from soil or sediment exposure are expected for such future uses.

*b) Groundwater*

Table 7 lists the chemicals detected in groundwater at least once above substance-specific drinking water CVs in the GE Lands area. (No chemicals were detected in surface water above drinking water CVs.) Specifically, the groundwater data in Table 7 come from the main burning ground area. In the past, workers in the GE building obtained drinking water from a nearby groundwater well. The data in Table 7 are not representative of this drinking water source, and therefore an evaluation of the past drinking water usage at the GE building cannot be performed in this PHA.

**Table 7. Groundwater Contaminants Present Above Drinking Water Comparison Values—GE Lands**

| Contaminant | Maximum concentration in groundwater, micrograms per liter (µg/L) | Drinking Water Comparison Value (CV) in µg/L | CV Source (defined in Appendix A) |
|---|---|---|---|
| Arsenic | 13* | 3 / 0.2 | cEMEG / CREG |
| Diethylhexyl phthalate | 6[†] | 3 | CREG |
| Dieldrin | 0.0078* | 0.002 | CREG |

[†] Source: [31]

ATSDR was requested to evaluate the GE Lands groundwater for potential future drinking water use. Using residential exposure assumptions described in Appendix A, ATSDR estimated exposure doses for the COCs listed in Table 7. Estimated exposure doses of diethylhexyl phthalate and dieldrin were lower than health guideline values, so that no health effects are expected from exposure to these contaminants in groundwater. An evaluation of potential future exposure to arsenic in groundwater at the GE Lands follows.

### Further Evaluation of Groundwater—GE Lands

#### Arsenic

The exposure doses for children and adults derived from the assuming residential consumption of the maximum concentration of arsenic in GE Lands groundwater were higher than the MRL of 0.0003 mg/kg/day. However, according to EPA, the GE Lands will not be developed for residential use in the future. Therefore, ATSDR modified the exposure assumption to that of adult workers who drank water with the maximum concentration of arsenic for 250 days a year for up to 20 years. ATSDR also assumed that only 75% of a worker's daily water intake, or 1.5 liters per day, would be from groundwater at the site. On the basis of these assumptions, the estimated dose was lower than the MRL, so that chronic noncancer health effects are unlikely. Arsenic is a carcinogen, but the estimated increase in the risk of cancer from drinking the water as assumed is within EPA's acceptable range [63].

### *3. TCC Property*

#### *a) Soil—TNT Burial Site*

Table 8 lists the chemicals that were detected in soil in the TCC Property area at least once above substance-specific soil CVs. For past exposures at the TNT Burial Site, ATSDR assumed that adults or teenagers might be at this area 5 times a week for 48 weeks of the year, or that 10-year-old soccer players might be at the area 3 times a week for half the year. ATSDR also assumed that each day they were on site, adults or teens accidentally ingested 100 milligrams (mg) of soil, and children accidentally ingested 200 mg of soil (see Appendix A for further exposure assumption details). Initial screening was performed by use of the maximum soil value detected before 1992. The resulting estimated exposure doses for arsenic and trinitrobenzene were lower than cancer and noncancer health guideline values, indicating that no health effects are expected. Evaluation of exposure to lead, TNT, and 2-amino-4,6-nitrotoluene follows below.

For present and future exposures, the same calculation was performed using the maximum soil value detected in post-removal sampling and assuming potential future residential use (i.e., small children could access the soil throughout the year). Estimated exposure doses of dieldrin, trinitrobenzene, and PAHs were lower than health guideline values. Evaluation of current and potential future exposures to arsenic, lead, and TNT follows.

**Table 8A. TCC Property Surface Soil Contaminants Present Above Comparison Values—TNT Burial Site**

| **Contaminant** | **Maximum concentration in soil, parts per million (ppm)** | | | | | | **Comparison Value (CV) in ppm** | **CV Source (defined in Appendix A)** |
|---|---|---|---|---|---|---|---|---|
| | **1987*** | **1989†** | **1991 (Pre-removal) †** | **1992 (Post-removal) †** | **1998†** | **2003††** | | |
| Arsenic | 164 | 30 | 25 | Not Detected | 19 | 41 | 20 / 0.5 | cEMEG / CREG |
| Lead | 785 | 3,400 | 6,990 | 873 | 1,930 | 515 | 400 | SSL |
| Dieldrin | Not Analyzed | Not Analyzed | Not Analyzed | Not Analyzed | 0.24 | Not Detected | 3 / 0.04 | cEMEG / CREG |
| 2-Amino-4,6-Dinitrotoluene | 47,000 | 1,500 | Not Analyzed | Not Analyzed | Not Detected | 1,470 | 16 | R3 RBC |
| Trinitrobenzene | Not Analyzed | Not Detected | 25.1 | 4.4 | Not Detected | Not Detected | 3 | cRMEG |
| Trinitrotoluene (TNT) | 140,000‡ | Not Detected | 28,600 | 650 | Less than CV | Not Detected§ | 20 | CREG |
| TEQ, PAHs | Not Analyzed | Not Analyzed | Not Analyzed | Not Analyzed | 0.8 | 1.2 | 0.1 | CREG |

Sources: *[73];† [39]; †† [42].

‡ Sample was of obvious crystalline TNT present in soil. Source: [41].

§ Although TNT was not detected in the 2003 soil sampling, crystalline TNT in bags and in slab form is still encountered at this site.

## Further Evaluation of Soil—TCC Property/TNT Burial Site

### Arsenic

No health effects are expected from exposure to arsenic in soil at the TNT Burial Site. Exposure to the maximum concentration of arsenic was only slightly above the health guideline value for potential future residential exposures to small children. This dose was equal to the NOAEL observed in toxicological studies [63]. The actual dose a child might get would be even lower because exposure would be to an average rather than the maximum concentration. Moreover, arsenic would not be as easily absorbed from soil as from the aqueous solutions used in toxicological studies. Arsenic is known to cause cancer. However, the estimated increase in the risk of cancer from a lifetime of exposure to arsenic in soil at the TNT Burial Site is so low as to be negligible.

### Lead

As previously discussed, levels of 10 $\mu$g/dL and less in children's blood have been associated with small decreases in IQ and slightly impaired hearing and growth. The maximum concentration of lead detected in the TNT Burial Site soil before the removal action was 6,990 mg/kg (ppm). Epidemiological studies have determined soil slope factors that predict blood lead levels to increase from between 0.0007 and 0.0068 $\mu$g/dL per ppm increase in soil lead level for children 1–18 years old, and from 0.001 to 0.003 $\mu$g/dL per ppm for adults 18–65 years old [60]. These wide ranges resulted from the presence of different sources of lead, different exposure conditions, and different exposed populations. The highest appropriate soil slope factor, corrected by the amount of time spent on site, indicates that adults and older teenagers would have a maximum increase in blood lead level of 14 $\mu$g/dL, and child soccer players could have an increase as high as 10 $\mu$g/dL. The actual blood lead level would be lower, however, because exposure is to an average, rather than to the maximum, lead concentration. The predicted blood lead increases are not expected to lead to any adverse health effects in adults or teenagers, who are more resistant than children to lead's effects. However, a child's increase could possibly result in some health effects, depending on the existing body burden of lead.

According to the limited post-removal sampling data, the lead concentration decreased, so that the current maximum level is 1,930 ppm. Use of a soil slope factor of 0.0068 $\mu$g/dL/ppm for children 1–18 years at this maximum lead concentration results in a child's blood lead level increase of 13.1 $\mu$g/dL. The health effects associated with such an increase would depend partly on the existing body burden of lead. The actual blood lead level would be much lower because children would be exposed to an average rather than the maximum lead concentration and because weather would decrease the percentage of time during which children would be able to contact the soil. However, the lead in soil at the TNT Burial Site could present a risk for small children who access the soil in residential conditions.

### TNT

Exposure to TNT (trinitrotoluene) in high doses can result in liver problems and blood disorders. The estimated exposure doses for teens and adults who occasionally, in the past, contacted the maximum concentration of TNT were 0.2 and 0.1 mg/kg/day, respectively. Children playing soccer three times weekly would have received a dose similar to the teens. Toxicological studies have shown that a dose of 0.5 mg/kg/day over 6 months resulted in mild adverse liver effects in dogs [74]. Therefore, and in light of the uncertainty associated with the differences between animals and humans, the estimated past exposures to TNT may have resulted in health effects. TNT has been classified as a possible human carcinogen. Exposure as described to the maximum concentration of TNT over a ten-year period would result in a low to moderate increased risk of cancer [74]. It should be noted, however, that the actual exposure to TNT would be to an average concentration rather than to the maximum, and other exposure factors such as weather or soil cover could decrease the amount of soil ingested over a period of time [74].

The populations unusually susceptible to the toxic effects of TNT are very young children, individuals with impaired kidney or liver function, and individuals deficient in G6PD enzyme. Also at increased risk are individuals with sickle cell trait, genetically induced unstable hemoglobin forms, or congenital hypercholesterolemia [74].

Dermal exposure to the TNT in the soil may have irritated some people's skin. Some people develop an allergic reaction to TNT, especially after repeated exposure, a reaction that may cause itching and irritation. The concentration of TNT or duration of exposure necessary to cause this effect is unknown. TNT also presents a physical hazard, because in high concentrations it can explode or ignite.

A large quantity of TNT has been removed from the site. However, crystalline TNT in soil and in small bags used as fuses have been encountered at the site during recent investigations, suggesting that more sampling is needed to determine the extent of contamination.

To estimate potential future exposures, the maximum TNT concentration in soil after the removal was used. The estimated doses for small children and adults are 0.01 mg/kg/day and 0.002 mg/kg/day, respectively. Toxicological studies have shown that a dose of 0.5 mg/kg/day over 6 months resulted in mild adverse liver effects in dogs [74]. Adverse human health effects from TNT exposure at the TCC Property/TNT Burial Site are unlikely. However, in light of the uncertainty associated with the differences between animals and humans, exposure to TNT by regular contact with the highest remaining concentration of TNT in soil might contribute to liver problems in sensitive individuals. The estimated doses likely overestimate actual potential exposure, because chronic exposure would be to an average rather than to the maximum concentration, and because TNT levels appear to be decreasing (the latest soil sampling did not detect TNT). Nevertheless, for the purpose of eliminating physical hazards, further sampling to identify and remove remaining concentrated TNT in the area is recommended.

2-Amino-4,6-dinitrotoluene

Under reducing conditions, TNT can be degraded by the stepwise conversion of the nitro ($NO_2$-) groups to amino ($NH_2$-) groups. Before the removal, the first degradation product in this series, 2-amino-4,6-dinitrotoluene (ADNT), was detected in the surface soil at lower levels (maximum 47,000 mg/kg) than the levels of TNT. The estimated exposure doses for teens and adults who occasionally, in the past, contacted the maximum concentration of ADNT were 0.04 and 0.06 mg/kg/day, respectively. Children playing soccer three times weekly would have received a dose similar to the teens. Experiments on soil test organisms showed that the toxicity of TNT in soil decreased with aging and with conversion to its degradation products [75]. Despite the uncertainties, it can be assumed that past exposure to the maximum concentration of ADNT may have led to health effects similar to those possible from exposure to TNT, as described above.

In the post-removal sampling, ADNT was detected at a maximum level of 1,470 mg/kg. To estimate potential future exposures, this maximum ADNT concentration was used to estimate doses for small children, teens, and adults of 0.04, 0.004, and 0.003 mg/kg/day, respectively. The estimated doses likely overestimate actual potential exposure, because chronic exposure would be to an average rather than to the maximum concentration. It is assumed that this exposure might contribute to liver problems in sensitive individuals, as with exposure to TNT.

### *b) Soil—James River Beachfront Landfill*

For past soil exposures at the James River Beachfront Landfill, ATSDR assumed that adults or older children might be at this area four times a week throughout the year. ATSDR also assumed that each day adults were on site, they accidentally ingested 100 milligrams (mg) of soil and children accidentally ingested 200 mg each day on site (see Appendix A for further exposure assumption details). Initial screening was performed, using the maximum soil value detected before the removal. It should be noted that significant erosion of the beachfront area was and is occurring, so that waste and contaminants previously buried were being uncovered. It is possible that the maximum levels existing shortly before removal are not representative of actual concentrations people might have been exposed to in the more distant past. These maximum values were used, however, as a conservatively high estimate. The resulting estimated exposure doses for antimony, cadmium, and PAHs were lower than cancer and noncancer health guideline values, indicating that no health effects are expected from exposure to these contaminants. Evaluation of past exposure to arsenic, copper, iron, lead, phosphorus, and thallium follows below.

For present and future exposures, the same calculation was performed with use of the maximum soil value detected in post-removal sampling, assuming potential future residential use (i.e., small children could access the soil). The estimated exposure dose to arsenic was lower than health guideline values. Evaluation of current and potential future exposures to iron, lead, and PAHs follows. Table 8B presents a summary of all TCC Property surface soil contaminants found to be above comparison values.

**Table 8B. TCC Property Surface Soil Contaminants Present Above Comparison Values—James River Beachfront Landfill**

| **Contaminant** | **Maximum concentration in soil, parts per million (ppm)** * | | **Comparison Value (CV) in ppm** | **CV Source (defined in Appendix A)** |
|---|---|---|---|---|
| | Before Removal | After Removal | | |
| Antimony | 61 | Less than CV | 20 | cRMEG |
| Arsenic | 700 | 11.6 | 20 / 0.5 | cEMEG / CREG |
| Cadmium | 26 | Less than CV | 10 | cEMEG |
| Copper | 20,000 | Less than CV | 2,000 | iEMEG |
| Iron | 390,000 | 44,600 | 23,000 | R9 PRG |
| Lead | 4,300 | 603 | 400 | SSL |
| Phosphorus | 1,100 | Less than CV | 1 | cRMEG |
| Thallium | 310 | Less than CV | 5.2 | R9 PRG |
| TEQ, Polycyclic Aromatic Hydrocarbons (PAHs) | 104 | 18.5 | 0.1 | CREG |

* Source: [36].

### Further Evaluation of Soil—TCC Property/James River Beachfront Landfill

#### Arsenic

No health effects are expected from past exposure to arsenic in soil at the James River Beachfront Landfill. Occasional exposure of older children to the maximum concentration of arsenic was only slightly higher than the level shown to cause no adverse effects in toxicological studies [63]. The actual dose that would have been received would be much lower because exposure would be to an average rather than to the maximum concentration, and arsenic would not be as easily absorbed from soil as from the aqueous solutions that toxicological effect levels are based on. Arsenic is known to cause cancer. If children or adults were exposed to the maximum level of arsenic in soil for 10 years, it would result in a low to moderate increase in the risk of cancer. However, the actual risk of cancer is considered unlikely to have been elevated because of the protective assumptions used in calculating risk.

If the property were developed for residential use, exposure to the post-removal maximum concentration of arsenic (12 ppm) results in a dose to small children lower than the health guideline, and the estimated increase in risk of cancer is so low as to be negligible. Therefore, no health effects would be expected from potential future exposures.

Copper

No health effects are expected from exposure to copper in soil at the James River Beachfront Landfill. Exposure to the maximum concentration of copper was above the health guideline value only for potential future residential exposures of small children. This dose, 0.06 mg/kg/day, corresponds to an intake of 0.6 mg/day. No health effects are expected because the intake is lower than the tolerable upper intake level of 1 mg/day [76,77]. The actual dose a child might get would be lower because exposure would be to an average rather than to the maximum concentration, and copper would not be as easily absorbed from soil as from the aqueous solutions used in toxicological studies.

Iron

The estimated past exposure dose of older children who occasionally contacted the maximum iron concentration in soil at the James River Beachfront Landfill is 0.6 mg/kg/day, higher than the health guideline of 0.3 mg/kg/day. However, no health effects are expected for this exposure. Long-term exposure to elevated iron can cause clinical effects such as accumulation of iron in the liver, but severe toxic effects are unlikely with exposures under 30 mg/kg of body weight [58]. The estimated exposure dose conservatively overestimated actual exposure to iron, because the maximum concentration was used instead of the average and because iron may be less available in soil than in the media used in toxicological studies. Therefore, no health effects from past exposure to iron in soil at the James River Beachfront Landfill are expected. For estimating future exposures, ATSDR assumed that small children would be exposed throughout the year to the maximum iron concentration after removal. The dose thereby estimated for future exposure to iron in soil is 0.4 mg/kg/day. For the reasons described above, no health effects would be expected from future residential exposures to iron in soil at the James River Beachfront Landfill.

Lead

Lead was detected at a maximum concentration of 4,300 ppm in soil on the beachfront. Use of the highest appropriate soil slope factor, corrected by the amount of time spent on site, yields a prediction of increases in blood lead levels as high as 7 $\mu$g/dL and 17 $\mu$g/dL, respectively, for adults and older children. The actual blood lead levels would have been lower, because the exposure is to an average, rather than to the maximum lead concentration. The predicted blood lead increases are not expected to have led to any adverse health effects in adults, who are more resistant to lead's effects. However, the child increase could possibly have resulted in some health effects, depending on the existing body burden of lead [60].

In the future, if the Beachfront is developed for residential use, small children could contact lead in soil at levels up to the post-removal maximum, 600 ppm. Use of the highest blood lead soil slope factor of 0.0068 $\mu$g/dL/ppm (described previously) indicates that the maximum lead concentration measured in soil would be expected to increase blood lead levels by 4.1 $\mu$g/dL. The health effects associated with such an increase would depend partly on the existing body burden of lead. The actual blood lead level would be much lower, because children would be exposed to an average rather than to the maximum lead concentration and because weather and climate factors would decrease the percentage of time children would be able to contact the soil.

### Phosphorus

Phosphorus is a common component of larger compounds in the environment. It does not occur as an element naturally. The analysis of the soil sample did not distinguish the form of the elemental phosphorus (white, red, or black). Therefore, it is conservatively assumed in this evaluation that it was all white phosphorus, the most reactive and toxic form. White phosphorus is very reactive and may pose a fire and/or explosive hazard, but because of its reactivity will change to a less toxic compound when oxygen is present. For white phosphorus to be present in soil, it must either have a protective coating or it must be located below the surface where oxygen is not available [61].

At the maximum concentration of elemental phosphorus detected in soil before the removal (1100 ppm), the past chronic and intermediate exposure doses for older children and adults are approximately 200 times lower than the animal study dose at which no adverse health effect was noted [61]. It is unlikely that past exposure to the phosphorus present in the soil was high enough to result in health effects [61]. After the removal, phosphorus was not detected above the comparison value, so that potential future exposures are also not expected to result in any health effects.

### Thallium

Before the removal, the maximum concentration of thallium detected in soil was estimated to result in exposure doses to older children and adults of 0.0005 mg/kg/day and 0.0001 mg/kg/day, respectively, on the basis of occasional use. These doses are about 200 times lower than the lowest value that resulted in learning impairment in offspring of exposed rats [64]. It is unlikely that past exposure to thallium in James River Beachfront Landfill soils would result in human health effects.

After the removal, thallium was not detected above the comparison value, and therefore potential future exposures are not expected to result in any health effects.

### Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a group of chemicals that are formed during the incomplete burning of organic substances; they can also be found in crude oil and creosote. Low levels of PAHs are found throughout the environment. Table 8B and other tables in this document show a TEQ, or toxicity equivalency quotient, which is the sum of all PAHs, weighted by their relative toxicity compared to benzo(a)pyrene, the most studied PAH compound. In the past, exposure to PAHs was too low to result in any health effects, mainly because of infrequent use of the site. To estimate risk from potential future residential exposure, exposure doses were calculated from the maximum post-removal TEQ listed in Table 8B. The resulting dose was thousands of times smaller than effect levels for noncancer effects seen in animal experiments. Some PAHs cause cancer. ATSDR's estimate of the increased risk of cancer, using the maximum post-removal TEQ and assuming daily contact over a 70-year lifetime, is a low increased risk. However, because of the conservative assumptions used, the actual risk is likely to be much smaller. Based on the post-removal concentrations, ATSDR does not consider the level of PAHs at the James River Beachfront Area to present an undue risk, even for residential scenarios.

### *c) Soil—Other TCC Property Areas*

For past and present exposures at other areas on the TCC Property, ATSDR assumed that adults and older children would access the area similarly to other recreational visitors (4 days a week throughout the year, 100 mg and 200 mg of soil ingested per day by adults and children, respectively). Estimated exposure doses for all COCs listed in Table 8C were lower than corresponding cancer and noncancer health guidelines. For potential future exposures, ATSDR estimated exposure of a small child to the maximum concentration every day throughout the year; the estimated doses were again lower than the health guideline values. Therefore, no health effects are expected from exposure to contaminants in soil at other areas on the TCC Property.

**Table 8C. TCC Property Surface Soil Contaminants Present Above Comparison Values—Other TCC Property Areas**

| Contaminant | Maximum concentration in soil, parts per million (ppm) | | Comparison Value (CV) in ppm | CV Source (defined in Appendix A) |
|---|---|---|---|---|
| | Track K / Tire Pile (after tire removal)* | Pesticide Drum Area (after drum removal)† | | |
| Arsenic | 5.5 | Not analyzed | 20 / 0.5 | cEMEG / CREG |
| Dieldrin | 0.5 | 0.4 | 3 / 0.04 | cEMEG / CREG |
| TEQ, PAHs | Less than CV | 0.11 | 0.1 | CREG |
| Sources: *[48]; †[79] | | | | |

### *d) Sediment*

Table 9 lists the chemicals in the TCC Property area that were detected in sediment (either from TCC Lake, J-Lake, or Streeter Creek) at least once above substance-specific CVs. For past exposures, ATSDR assumed that adults or older children might be on the property four times a week throughout the year. ATSDR also assumed that each day they were on site, adults accidentally ingested 10 mg of sediment and children accidentally ingested 20 mg of sediment (see Appendix A for further exposure assumption details). Initial screening was performed with use of the maximum sediment value. The resulting estimated exposure doses for all sediment COCs were lower than health guideline values, indicating that no health effects are expected. ATSDR was requested to evaluate potential future uses of the property, including residential use. For this evaluation, the dose calculation was repeated under the assumption that a smaller child is exposed throughout the year. These exposure doses were also lower than health guideline values, so that no health effects from sediment exposure are expected for potential future uses.

As part of EPA's general screening protocols, gross alpha and beta radiation were measured in sediments in TCC Lake and J Lake. The levels were similar to typical soil values. EPA does not consider these levels of radiation to indicate unusual radiation sources (personal communication, Harry Wheeler, TechLaw, Inc., August 2003).

**Table 9. Sediment Contaminants Present Above Comparison Values—TCC Property**

| Contaminant | Maximum concentration in sediment, parts per million (ppm) | Comparison Value (CV) in ppm[§] | CV Source (defined in Appendix A) |
|---|---|---|---|
| **TCC and J-Lakes:**[*] | | | |
| Arsenic | 17.9 | 200 / 5 | cEMEG / CREG |
| TEQ, PAHs | 2.6 | 1 | CREG |
| **Streeter Creek:**[†] | | | |
| Arsenic | 11.6 | 200 / 5 | cEMEG / CREG |
| TEQ, PAHs | 23 | 1 | CREG |
| **James River Beachfront Landfill (Before Removal):**[‡] | | | |
| Arsenic | Less than CV | 200 / 5 | cEMEG / CREG |

[§] Sediment CV calculated as ten times the soil CV.

Sources: [*][20]; [†][18]; [‡][36]

*e) Surface Water and Groundwater*

Tables 10 and 11 list the contaminants detected in surface water and groundwater, respectively, in the TCC Property area at least once above substance-specific drinking water CVs. For past exposures to surface water, ATSDR assumed that adults and older children contacted surface water 4 days a week for 6 months a year and that they accidentally swallowed some surface water. (See Appendix A for further details on the exposure assumptions used.) Estimated exposure doses of arsenic and lead resulting from this exposure are lower than health guideline values and therefore are not expected to result in health effects.

**Table 10. Surface Water Contaminants Present Above Drinking Water Comparison Values—TCC Property**

| Contaminant | Maximum concentration in surface water, micrograms per liter (µg/L) | Drinking Water Comparison Value in µg/L | CV Source (defined in Appendix A) |
|---|---|---|---|
| **TCC and J-Lakes:**[*] | | | |
| Arsenic | 9[*] | 3 / 0.2 | cEMEG / CREG |
| Lead | 159[†] | 15 | AL |
| **Streeter Creek:**[†] | | | |
| Arsenic | 23[*] | 3 / 0.2 | cEMEG / CREG |

Sources: [*][20]; [†][18]

Groundwater data, shown in Table 11, are from two sources sampled on the TCC property: 1) TCC community wells, from which students and faculty could have drunk from 1960 until 1998, when the college was connected to the municipal system; and 2) groundwater in the TNT Burial Site, which has never been used for drinking purposes. For past exposures, ATSDR assumed that adults or teenagers drank 75% of their daily water from the community well and that they drank water containing the maximum concentration of each COC. See Appendix A for further details on the exposure assumptions used. The estimated exposure doses for arsenic, manganese, and diethylhexyl phthalate were lower than health guideline values and are not expected to significantly increase the risk of cancer, so that no health effects are expected from exposure to these contaminants in the drinking water. An evaluation of past TCC exposure to lead from community wells follows.

**Table 11. Groundwater Contaminants Present Above Drinking Water Comparison Values—TCC Property**

| Contaminant | Maximum concentration in groundwater, micrograms per liter (µg/L) | Drinking Water Comparison Value (CV) in µg/L | CV Source (defined in Appendix A) |
|---|---|---|---|
| **TCC Former Drinking Water Wells (1989-1997):*** | | | |
| Arsenic | 7 | 3 / 0.2 | cEMEG / CREG |
| Lead | 24.1 | 15 | AL |
| Manganese | 77.4 | 50 | cRMEG |
| Diethylhexyl phthalate | 8 | 3 | CREG |
| Trinitrotoluene‡ | 0.09 | 1 | CREG |
| **TNT Area (1992-2003 sampling):†** | | | |
| Arsenic | 37 | 3 / 0.2 | cEMEG / CREG |
| Copper | 305 | 300 | iEMEG |
| Iron | 26,000 | 11,000 | R9 PRG |
| Lead | 65 | 15 | AL |
| Manganese | 1,300 | 50 | cRMEG |
| RDX | 12.9 | 0.3 | CREG |
| Dinitrobenzene | 4.5 | 1 | cRMEG |
| Trinitrotoluene | 173 | 1 | CREG |

Sources: *[7,18,39,53,54]; †[39,42]

‡ This contaminant is included even though EPA questions its single detection and even though the level is below the CV, because the detection suggests that contaminants from the TNT Burial Site may be reaching this former water source.

## Further Evaluation of Groundwater—TCC Property (Past)

### Lead

In the 1960s, students and faculty of Frederick College (and their families) lived on the site. No water supply data are available from that time period. Without such data, ATSDR is unable to determine conclusively whether substantive exposures occurred during that time. However, if contaminant levels were similar to the maximum levels detected from 1989–1997, no adverse health effects would be expected. This conclusion could be changed if more information about contaminant levels in the TCC drinking water from earlier time periods becomes available.

## Groundwater—TCC Property (Potential Future)

ATSDR was requested to evaluate the TCC Property groundwater for potential drinking water use in the future. Using exposure assumptions described in Appendix A, ATSDR estimated exposure doses for all the COCs listed in Table 11, assuming that adults and small children might drink the TCC Property groundwater exclusively. The estimated exposure doses for RDX and diethylhexyl phthalate were lower than health guideline values, and those doses are not expected to increase the risk of cancer significantly. Therefore, no health effects are expected from exposure to these contaminants in groundwater. An evaluation of potential future exposure to arsenic, copper, iron, lead, manganese, dinitrobenzene, and trinitrotoluene in groundwater follows.

Further Evaluation of Groundwater—TCC Property (Potential Future)

Arsenic

The child dose from drinking the maximum level of arsenic in groundwater from the TCC Property is predicted to be about 0.004 mg/kg/day. This estimated dose is higher than the no observed adverse effect level of 0.0008 mg/kg/day but only about a third of the lowest level shown to cause skin changes in human epidemiologic studies, 0.014 mg/kg/day [63]. The adult dose of 0.001 mg/kg/day would be less than a tenth of this lowest observed adverse effect level. A lifetime of drinking this level of arsenic in water would result in a moderately increased risk of developing cancer.

Copper

The estimated dose from using drinking water containing the maximum level of copper detected would be 0.031 mg/kg/day for a small child, only marginally higher than the health guideline value of 0.03 mg/kg/day. Drinking well water containing the maximum amount of copper is not likely to result in health effects [77].

Iron

The estimated potential future child dose from drinking TCC Property groundwater with the highest iron concentration is 2 mg/kg/day, higher than the health guideline of 0.3 mg/kg/day. The adult dose of 0.7 mg/kg/day is also higher than the health guideline. However, no acute health effects are expected from these exposures because severe toxic effects are not likely from exposure doses less than 30 mg/kg of body weight [58]. However, long-term exposure to the maximum iron level could cause such clinical effects as accumulation of iron in the liver [58,59].

Lead

As discussed previously, lead levels in children's blood of 10 micrograms per deciliter ($\mu$g/dL), and perhaps lower, have been associated with small decreases in IQ and slightly impaired hearing and growth. A slope factor for the increase in blood lead concentration per increase in water lead concentration for infants has been calculated as 0.04 $\mu$g/dL blood per part per billion (ppb) lead at water lead levels above 15 ppb [60]. The corresponding slope factor for school children is 0.03 $\mu$g/dL per ppb. Use of the maximum concentration of 65 ppb lead measured in the TCC Property groundwater indicates increases in blood lead concentrations of 2.6 $\mu$g/dL and 2.0 $\mu$g/dL for infants and school children, respectively. The health effects associated with such increases would depend partly on the existing body burden of lead.

Manganese

Epidemiologic studies suggest an association between ingesting water containing elevated concentrations of manganese and the development of neurological symptoms. However, each of the studies had uncertainty regarding the exposure level or whether the effects were solely attributable to manganese, so that no effect levels based on human studies could be identified [70]. Studies with rats have shown a lowest observed adverse effect level for neurological changes of 14 mg/kg/day, more than an order of magnitude higher than the estimated child dose of 0.1 mg/kg/day and also higher than the adult dose of 0.04

mg/kg/day. However, humans appear to be more sensitive to manganese than animals [70]. Therefore, the estimated future child and adult manganese dose for this pathway could lead to adverse health effects.

### Dinitrobenzene

The estimated potential future exposure doses from drinking TCC Property groundwater with the highest dinitrobenzene concentration for children and adults are 0.0004 mg/kg/day and 0.0001 mg/kg/day, respectively. These doses are thousands of times smaller than the lowest dose shown to cause symptoms consistent with hemolytic anemia in rats (0.75 mg/kg/day) [78]. It is unlikely that this exposure would lead to health effects.

### Trinitrotoluene (TNT)

The estimated potential future exposure doses for children and adults from drinking TCC Property groundwater with the highest TNT concentration are 0.02 mg/kg/day and 0.005 mg/kg/day, respectively. Toxicological studies have shown that a dose of 0.5 mg/kg/day over six months resulted in mild adverse liver effects in dogs [74]. Although adverse human health effects are unlikely, in light of the uncertainty in differences between animals and humans, the exposure to TNT by drinking this groundwater might contribute to liver problems in sensitive individuals.

### Summary—Potential Future Use of TCC Property Groundwater for Drinking

The available data indicate that without treatment, the groundwater at the TCC Property area is not suitable for drinking purposes. The levels of several contaminants, especially arsenic, iron, lead, manganese, and TNT, are high enough to cause adverse health effects in children and/or adults.

## *f) Fish—TCC Lake and J-area Lake*

Whole fish were sampled from TCC and J- Lakes in 1997, and fish filet samples were collected in 2000 [20, 50–52]. A summary of the contaminants detected in fish tissue composites is presented in Table 12. Although the whole fish measurements may overestimate or underestimate the concentration consumed if people eat only the filet, ATSDR used the whole fish data as well as the filet data to screen for chemicals that might be a health concern. ATSDR assumed that the concentration in the whole fish is similar to the concentration in the filet.

Although fishing activity at the lakes appears infrequent today, it may have been more common in the past, when people lived on the site and the land surrounding the lakes was not as overgrown. ATSDR assumed the 95th percentile fish ingestion rate for freshwater recreational anglers of 25 grams per day for adults [80]. Small children weighing 10 kg were estimated to consume 12.5 grams of fish per day, on average. These assumptions are considered conservative for consumption of fish from TCC and J Lakes. It is possible that consumption of fish takes place at higher levels, especially from the Nansemond and James Rivers near the site, but no data are available for fish from these locations. ATSDR will, upon request, evaluate data on fish from these or other locations if they become available in the future.

Fish Filet Results [51]
Whole Fish Results [20]

**Table 12. Fish Sampling Results—TCC Lake and J-Lake**

| | Contaminant | Highest Tissue Concentration, milligram per kilogram (mg/kg) | | Estimated Highest Dose for Child, mg/kg/day | Health Guideline, mg/kg/day | HG Source (defined in Appendix A) | Excess Cancer Risk, if applicable | Exceeds Health Guideline? |
|---|---|---|---|---|---|---|---|---|
| | | TCC Lake | J-Lake | | | | | |
| **Fish Filet Results [51]** | Mercury | 0.032 | 0.032 | 0.00001 | 0.0001 | Oral RfD for methylmercury | NA | No |
| | Total PAHs | 0.0104 | 0.0132 | 0.00005 | none | Not applicable (NA) | 3 in 100,000 | No |
| | Total Chlordane | 0.00035 | Not measured | 0.0000001 | 0.0005 | Oral RfD | Less than 1 in 1,000,000 | No |
| | Total DDT | 0.011 | 0.0013 | 0.000004 | 0.0005 | Oral RfD | 1 in 1,000,000 | No |
| | Total PCB | 0.00224 | 0.00144 | 0.0000008 | none | NA | 2 in 1,000,000 | No |
| **Whole Fish Results [20]** | Lead | 0.68 | 0.53 | 0.0009 | none | NA | NA | No |
| | Manganese | 23.1 | Below DL | 0.03 | 0.05 | Oral RfD | NA | No |
| | Mercury | 0.05 | 0.04 | 0.00006 | 0.0001 | Oral RfD for methylmercury | NA | No |
| | Selenium | Below Detection Limit (DL) | 0.83 | 0.001 | 0.005 | Oral MRL | NA | No |
| | Aldrin | 0.00066 | 0.001 | 0.000001 | 0.00003 | Oral MRL | 6 in 1,000,000 | No |
| | Alpha-BHC | 0.00051 | 0.00087 | 0.000001 | 0.008 | Oral MRL | 2 in 1,000,000 | No |
| | Alpha Chlordane | Below DL | 0.0011 | 0.000001 | 0.0005 | Oral RfD | Less than 1 in 1,000,000 | No |
| | DDD | 0.037 | 0.0062 | 0.00005 | none | NA | 3 in 1,000,000 | No |
| | DDE | 0.02 | 0.02 | 0.00003 | none | NA | 2 in 1,000,000 | No |
| | DDT | 0.0016 | 0.0015 | 0.000002 | 0.0005 | Oral RfD | Less than 1 in 1,000,000 | No |
| | Dieldrin | 0.0034 | 0.0029 | 0.000004 | 0.0005 | Oral MRL | 2 in 100,000 | No |
| | Endosulfan II | 0.00043 | 0.00053 | 0.0000007 | 0.006 | Oral MRL | NA. | No |
| | Lindane | Below DL | 0.00053 | 0.0000007 | 0.0003 | Oral RfD | NA | No |
| | Heptachlor Epoxide | 0.00043 | 0.0005 | 0.0000006 | 0.00001 | Oral RfD | 2 in 1,000,000 | No |
| | Endrin Aldehyde | 0.0018 | 0.00072 | 0.000002 | 0.0003 | Oral MRL for endrin | NA | No |

All the estimated exposure doses were below health guideline values for adult and child doses. In addition, excess cancer risk calculated for the carcinogenic substances detected (both individually and cumulative) are within the range generally accepted as safe by EPA, typically less than 1 in 10,000. Lead, which has no established "safe" level, was detected only in the whole fish sampling event, and only at levels that would not be expected to cause elevated blood lead levels [60].

## *4. Offsite Area Evaluated*

### *Drinking Water—Respass Beach Well Water*

Five wells in the Respass Beach community were tested prior to 2000. In this historical testing, arsenic, sodium, and diethylhexyl phthalate were detected at least once above the corresponding CV. Uncertainty existed about whether the pre-2000 samples were collected before or after filtration (personal communication, Rob Thomson, EPA, February 2000). In 2002, eight wells in the Respass Beach community were sampled and analyzed for metals, PAHs, fluoride, nitrates, dinitrotoluene, explosives, pesticides and PCBs, and volatile and semi-volatile organic compounds. In this testing, several compounds, including sodium, methyl tert-butyl ether, nitrates, and various metals were detected; however, only two compounds (copper and sodium) were detected at concentrations above the corresponding ATSDR drinking water CV. The contaminants detected at least once at a level above the CV (in either sampling event) are evaluated further below.

**Table 13. Groundwater Contaminants Present Above Drinking Water Comparison Values—Respass Beach**

| Contaminant | Maximum concentration in groundwater, micrograms per liter (µg/L) | Drinking Water Comparison Value (CV) in µg/L | CV Source (defined in Appendix A) |
|---|---|---|---|
| Arsenic | 4.8* | 3 / 0.2 | cEMEG / CREG |
| Copper | 510† | 300 | iEMEG |
| Diethylhexyl phthalate | 23* | 3 | CREG |
| Sodium | 306,000* | 200,000 | WHO |
| Sources: *[56]; †[57] | | | |

### Further Evaluation of Groundwater—Respass Beach

#### Arsenic

The maximum concentration of arsenic detected in the few Respass Beach wells tested was 4.8 µg/L, less than EPA's Maximum Contaminant Level (MCL) for drinking water of 10 µg/L. Drinking water with the highest arsenic level would be unlikely to result in noncancer adverse health effects. The estimated increased risk of cancer from drinking water with the highest level of arsenic every day for a lifetime (70 years) would be 2 in 10,000. ATSDR classifies this as a low increased risk of cancer, but it should be noted that a number of uncertainties are inherent in estimating cancer risk. The estimated increased cancer risk therefore should be considered a worst-case estimate. See Appendix A for details [63]. The arsenic in the Respass Beach wells may be naturally occurring, because the levels are similar to site background levels and no trend of increasing arsenic concentrations from before 2000 to 2002 was observed.

#### Copper

The estimated dose from using drinking water containing the maximum level of copper detected would be 0.05 mg/kg/day for a small child, higher than the health guideline value of 0.03 mg/kg/day. Animal studies have shown that copper can affect the liver when ingested in high doses. However, no effects were found in a study of human infants exposed to 0.315 mg/kg/day of copper [77]. Therefore, drinking well water containing the maximum amount of copper is not likely to result in health effects.

Sodium

Sodium is an element that occurs naturally in soil and groundwater and is also found in food products, such as table salt. It is not generally considered toxic, but some individuals need to restrict their sodium intake for medical reasons. The maximum concentration of sodium detected was 306,000 ppb. Individuals on sodium-restricted diets in this community should review their well test results (or have their wells tested) and then consult their physicians.

Diethylhexyl phthalate (DEHP)

DEHP is a man-made chemical commonly found in plastics. Sometimes, DEHP is a laboratory contaminant. In initial sampling, DEHP was not detected in duplicate samples, and re-sampling in 2002 did not show any detections of the compound. The highest DEHP concentration detected in the well water, 23 µg/L, corresponds to an exposure dose for children of 0.002 mg/kg/day. Drinking water with this concentration of DEHP would not be expected to cause noncancer adverse health effects, because the estimated dose is an order of magnitude smaller than EPA's reference dose of 0.02 mg/kg/day. DEHP is classified as a probable human carcinogen, but the estimated increase in cancer risk from drinking water with the highest level of DEHP over a 70-year lifetime is less than 1 in 100,000 [81].

Summary—Use of Respass Beach Well Water for Drinking

On the basis of the available well water sampling results, no health effects are expected from normal drinking of the Respass Beach well water. Periodic monitoring of this water is recommended, however, to ensure that the water remains unaffected by site contaminants and that it meets water quality standards.

### F. Nonordnance Physical Hazards Evaluation

The brick vaults present on the Dominion Lands may pose a physical hazard. At one time, as many as 30 uncovered vaults (both square and coffin-shaped) extending as far as 35 feet into the ground existed. Many vaults have been filled with soil, and it is expected that remaining vaults will be filled in or removed as development proceeds [21]. However, heavy undergrowth in the area may allow undiscovered vaults to remain. These could pose a hazard in the future.

The World War II pier does not have curbs or railings. Parts of the deck planking are missing, and the far end of the pier appears to be very unstable. The pier is posted with signs warning "Use Pier at Own Risk". However, the pier is reportedly used often for fishing by both adults and children.

Debris continues to surface near the Nansemond and James River beachfront areas. These items could pose physical hazards to people using the areas.

## G. Ordnance Physical Hazards Evaluation

FNOD was extensively used for transshipment, storage, and re-working of ordnance. During early operations, unserviceable ammunition was routinely dumped at sea or disposed of by defusing or burning. Since the facility was converted to private use in 1960, occasional discoveries of ordnance and explosive (OE)-related items have occurred. No detonations or injuries have resulted from the discoveries to date. To minimize the risk of such accidents, a concerted effort to recover OE items began in 1987 [19].

Of the hundreds of OE items discovered since 1960, many have been inert (not likely to detonate) [19]. Types of OE recovered include crystallized explosives residue (resulting from steam-out and washout runoff), empty or demilitarized projectiles, fragments, and small arms ammunition. Live items, including grenades and artillery projectiles, have also been discovered. Most discoveries have been made within or in the immediate vicinity of known disposal areas or steam-out/burnout areas.

On the basis of surveys conducted within the past 15 years, OE disposal does not appear to have been evenly distributed throughout FNOD. However, any area where OE items have been found in the past has the potential for future encounters. The U.S. Army Corps of Engineers (ACE) has outlined a protocol for survey and clearance to maximize protection of the public. The protocol is based on varying types of future uses.

The following sections summarize the OE investigations and removals that have occurred since 1987. Following is a discussion of the possible extent of remaining OE items and ACE's suggested protocol for future use.

### *Investigations and Removals*

*1987 TNT Burial Site Investigation*
This investigation focused on a 3-acre area of the TNT Burial Site. The ACE investigation included a geophysical (magnetometer) survey to identify metal anomalies and an excavation of test pits. ACE also installed groundwater monitoring wells and collected soil samples. The locations for the test pits were based on available historical information and the results of the geophysical survey. Items recovered during the survey and associated removal included live small arms ammunition, projectiles and boosters, detonating and time fuses, and a several-ton slab of crystalline TNT. In addition, several hundred tons of scrap metal and 15 tons of contaminated soil were removed [19].

*1992 Removal at James River Beach*
ACE investigated 12 World War II-aged 155-millimeter (mm) projectiles found on the James River beach. The projectiles were examined by explosives removal experts and confirmed to be empty; one was removed, and eleven were left in place [19].

*1993 Additional Removal at James River Beach*
Recreational users of the James River Beach reported several additional OE items. Five empty 155-mm projectiles and 6 empty 170-mm projectiles were removed and disposed of. Two 55-

gallon drums and two 1-ton containers were tested to ensure that they were free of chemical residues; they were also removed [19].

### *1995 Dominion Lands Survey*

Dominion Lands Management conducted a survey in 1995 at 200 statistically selected locations on the Dominion Lands property. A total of 450 pieces of scrap and two unexploded ordnance items were removed. A further study located numerous inert items, including projectiles, small arms ammunition, and fragments [19].

### *1996 Construction Soil Pile Sifting for OE*

In 1996, ACE sifted soil for the purpose of discovering OE. TCC had excavated the soil during construction of a storm water retention pond. From the sifting, 31,450 pounds of inert OE-related items were removed, including fuse adapters, booster cups, 20-mm and 37-mm artillery projectiles, and 60-mm mortar rounds [19].

### *1997 Survey of Areas of Concern*

Areas of concern were identified from historical information including where ordnance disposals were known to have occurred, where OE items had previously been found, and aerial photos showing ground scars or other evidence of ordnance burials [19]. Geophysical studies conducted in statistically chosen ¼-acre grids within the areas of concern identified several OE items, including live and inert projectiles, a live rocket, and two live smoke grenades. Test pits were dug at locations that had numerous anomalies in the geophysical study. The only ordnance-related items found were at the GE Main Burning Ground/ Steamout Pond. This study identified as a potential OE concern only 133 of the 975 total acres at FNOD [82,83]

### *1999 Survey of Derelict Pier Areas*

The 1997 survey suggested that the underwater areas of the derelict piers might be sites of OE disposal. A study conducted in 1999 did not report any OE items [98].

### *OE Removal Activities Since 1999*

EPA and ACE agreed to remove OE in designated areas of FNOD, including the James River and Nansemond River Beachfront Areas, the Dominion Lands, and the GE Main Burning Ground kick-out areas and burial/burn trenches [83].

### *Other OE Investigations Since 1999*

Surface clearances and geophysical investigations have been initiated in several others areas of concern. OE has been found at the TNT Burial Site (where ordnance items, crystalline TNT, and TNT-filled fuses continue to be discovered). Clearance activities have also recently been held at the GE Main Burning Ground and Dominion Lands.

While clearance and removal activities are continuing, as of March 2002 over two-thirds of the land identified as a potential OE concern in 1997 had been investigated and found to be free of OE or cleared [83]. However, it remains necessary to consider future land use due to the possibility that ordnance items may be discovered or encountered in the future.

### *Evaluation of Hazard*

The U.S. Army Corps of Engineers (ACE) has conducted surveys, sweeps, and clearances at the FNOD site on the basis of the best available information on potential locations for OE-related items. Numerous items, live and inert, have been recovered and disposed of. Still, it cannot be declared with certainty that all potential areas have been discovered and all items recovered.

Although live ordnance should always be considered dangerous and should be avoided when possible, injury is much more likely to occur only when the ordnance is tampered with [84,85]. Ordnance remaining in such areas of frequent use as residential areas poses a particularly high risk, especially for children and adolescents who are more likely to play or tamper with strange objects. This behavior makes it more likely for children than for adults to be injured by unexploded ordnance [86].

The ACE has developed a protocol of institutional controls, surveys, and removals for former military facilities opened to non-military use [19]. The protocol, outlined below, is based on the types of uses intended. Included in the protective measures is a Memorandum of Agreement (MOA) to be enacted between the ACE, local governments, and the entities gaining control of the property. The purpose of the MOA is to ensure that the protocol is followed and that all future owners and users are aware of the potential for encounters with OE items and understand the potential for harm from any such encounters. Currently, all such land use controls as those listed below are voluntary. It is expected, however, that land use controls will be formalized upon signing of a Record of Decision (ROD) for the site (personal communication, Rob Thomson, EPA, June 26, 2003).

ATSDR supports formalization of land use controls to protect public health in the future. Without enforceable controls, any ordnance remaining on site will pose a public health hazard to future site users or residents.

**ACE Standards for UXO/OE Clearance Based on Intended Future Use**

Limited public access (e.g., park, livestock grazing, no construction or excavation anticipated)
- Fencing and warning signs
- Periodic visual sweeps
- Education of owners and utilities regarding risk of encountering UXO/OE and what to do if it is.
- Periodic review of tax plats by local authorities to ensure proper owner notification.
- Deed notices, covenants and restrictions.
- Local ordinances for development control and defining appropriate government agency for clearance, permits, etc.
- Memorandum of Agreement with ACE and state/local governments.

Public Access Areas (e.g., farming, surface storage, general recreation, and vehicle parking)
- Above items, plus:
- Surface clearance with a magnetometer
- UXO/OE clearance by excavation to at least 4 feet below ground surface.

Commercial or Residential Development (i.e., construction)
- Above items, plus:
- Additional clearance to 10-foot depth for high-risk areas where construction requires excavation.

## H. Health Outcome Data Evaluation

Health outcome databases can sometimes be evaluated in a public health assessment to identify whether a group of people who are exposed to site contamination have a higher rate of a specific disease or condition than unexposed people. This evaluation may occur when the following conditions are encountered: contamination is present, people are exposed to enough of the contamination that it may affect their health, and a suitable health outcome database is available for review. A few examples of health outcome databases are cancer registries, blood lead data from clinics, and birth defect registries.

Health outcome data were not reviewed for this public health assessment. While a possible public health hazard existed in the past (because of exposure to TNT and lead), the exposed population is not well defined, and the health effects, if any, would not have been recorded in a database. ATSDR may reconsider evaluating health outcome data if a historical database is discovered or if new data become available.

## I. Child Health Considerations

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contamination of their water, soil, air, or food. Children are at a greater risk than adults from certain kinds of exposures to hazardous substances emitted from waste sites and emergency events. They are more likely to be exposed because they play outdoors and they have more hand-to-mouth behaviors. They are more likely to come in contact with dust, soil, and heavy vapors close to the ground. Also, they receive higher doses of chemical exposure because of their lower body weights. In addition, the developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

The possibility of health effects in children due to toxic exposures was evaluated in this public health assessment. In the past, it was assumed that small children did not have regular access to contaminated areas on the site. Because older children were only intermittently on the site, most past exposures were too small to result in health effects. The exceptions are exposure to soils: TNT exposure in soils at the TNT Burial Site could have increased the risk of liver problems or dermal reactions, and lead exposure in soils at the TNT Burial Site or the James River Beachfront Landfill might have increased the risk of slight neurological problems.

With future residential development possible, younger children could have frequent access to site areas that may still have elevated contaminant levels. Current information suggests that children may have an increased risk of developing health effects from residential exposure to lead in soil at the Dominion Lands, to lead and TNT in soil at the TNT Burial Site on TCC Property, and to lead in soil at the James River Beachfront Landfill on TCC Property. If children were to drink groundwater from the Dominion Lands or TCC Property areas, they could be at risk of severe adverse reactions to iron and other health effects from heavy metals and/or TNT.

## J. Community Health Concerns Evaluation

ATSDR advertised and conducted a meeting on June 23, 1999, at the TCC campus so that citizens could meet with ATSDR staff and raise any health-related concerns about the site. In addition, a newspaper article in the *Virginian-Pilot* on June 24, 1999, described ATSDR's participation in the FNOD site and listed a toll-free number at which concerned citizens could reach ATSDR staff. A few local residents attended the meeting, and other citizens formerly associated with the site called ATSDR to report their concerns and questions. The health concerns expressed are listed below.

*One person who spent some years on the site reported experiencing dizziness, internal pains, tumors, memory problems, thyroid disease, skin disorders, and liver and lung problems since leaving the site.*

Response: From the chemical information reviewed in this public health assessment, ATSDR did not find levels of contaminants that would pose a health hazard to adults. TNT can cause abnormal liver function, but it is unlikely that an adult would have ingested sufficient TNT from the soil in the TNT Burial Site area to result in adverse health effects (see discussion on page 13). As investigations continue at the FNOD site, ATSDR will evaluate the public health implications of site contamination, as appropriate.

*Another area resident reported E. coli bacteria violations in the TCC water supply in 1993 and said that many students experienced stomach distress and headaches.*

Response: ATSDR did not find any bacteria violations in the well water data reviewed. If E. coli bacteria were present in the TCC drinking water, they could cause the symptoms reported. The college is currently connected to the municipal water system. Any bacterial contamination in the past would not be related to handling or processing of ordnance materials.

*A resident of Respass Beach wondered whether their home well water might be the cause of adult and youth acne.*

Response: The evaluation of the well water at Respass Beach is discussed on page 19. At the levels of contamination detected in the five wells, adverse health effects are not expected. Many types and causes of acne exist. A personal physician should be consulted to get a diagnosis of the type of acne and a recommendation for appropriate treatment.

*A former faculty member, who resided on the site in the 1960s, reported lung and breast cancer in their family.*

Response: The environmental data reviewed in this public health assessment indicated that past exposure to contaminants at the site would not cause an increased risk of the types of cancer mentioned. However, most of the sampling data are from the 1980s or 1990s and may not be applicable to the situation in the 1960s. For example, the source or quality of the water supply for the former students and faculty members of Frederick College is not known. The extent of exposure to disposal areas is not known. In addition, the amount of ordnance residue remaining in the converted bunkers/homes, if any, is not known. Therefore, ATSDR is unable to evaluate the excess cancer risk from that time.

*An alumnus of Frederick College reported having a skin disorder called vitiligo, which affects the pigmentation, and wondered if other students had similar problems.*

Response: ATSDR has not received any other reports of former students or faculty members developing vitiligo, although only a handful of health concerns have been received so far. Vitiligo is the appearance of non-pigmented white patches on otherwise normal skin. No cause of vitiligo is known, but the disorder may be associated with autoimmune or endocrine abnormalities. The disorder affects about 1% of the general population [87].

Vitiligo is indistinguishable from chemically-induced hypopigmentation (lack of pigmentation), which may result from contact with alkylphenol compounds [87]. Based on our review of the site to date, these compounds were not detected in any significant quantity.

*A former worker on the site was diagnosed with Parkinson's disease soon after leaving her job. She wanted to know if there was a connection to the site.*

Response: The cause of Parkinson's disease is not known. Four mechanisms have been suggested as a cause: oxidative damage, environmental toxins, genetic predispositions, and accelerated aging. So far, no research has provided conclusive proof that an environmental toxin is the cause of the disease [88]. The types of environmental chemicals being considered as possible causes include pesticides, metals, and industrial solvents [89]. ATSDR is unable to evaluate any connection of Parkinson's disease to the site, because the connection to environmental contaminants has not been made.

*A couple who both worked at the GE facility on-site in the 1970s did not report any health problems, but they were concerned about their possible exposure to site contaminants, especially in their drinking water.*

Response: The GE facility received its water from the TCC wells up until 1997, when both GE and TCC were connected to the municipal water system. The available TCC well water data from 1989–1997 were reviewed in this document, starting on page 27. The level of contamination during that period was found not to have posed a health hazard. ATSDR did not locate any TCC well water data from the 1970s.

*A former worker at the GE facility reported seeing a reddish-colored cloud on site.*

Response: No record of an air release that might be consistent with this observation was found. Potential health issues associated with possible exposure to this cloud could not be evaluated because the chemical makeup of any air releases and their frequency and duration are unknown and cannot be estimated.

On December 4, 2003, ATSDR attended the FNOD RAB meeting to present the public comment release of the FNOD Public Health Assessment. Jill Dyken of ATSDR reviewed the public health assessment process then discussed the results of the FNOD PHA. Questions raised and information provided by the public attending the meeting were:

## IV. Hazard Category

ATSDR has made the following classifications of the FNOD site based on exposure to chemical contaminants present at the site. Because past exposures to TNT and lead in soil were high enough to result in adverse health effects, ATSDR classifies FNOD as a *past public health hazard*. In the present, people are not in contact with contaminants at high enough levels to result in health effects; therefore, ATSDR classifies the site currently as *no apparent public health hazard*. Future residential development is likely at the site. Without proper cleanup or land use controls to prevent exposure to contaminants in soil or groundwater, the site could pose a *future public health hazard*.

Physical hazards currently at the site have the potential to cause injury and are therefore considered a public health hazard in the past, the present, and, if not addressed, the future. For the issue of ordnance and explosives on site, ATSDR acknowledges that significant improvements in safety have been made through removal and cleanup actions to date. However, because it is impossible to be certain every ordnance item has been removed, ATSDR considers ordnance and explosives at the site to pose a public health hazard.

## V. Conclusions

1. Past exposure to contaminants in soil at most areas was too small to result in adverse health effects. The levels of TNT and lead at the TNT Burial Site and lead at the James River Beachfront Area could theoretically have increased the risk of adverse health effects, but regular contact with the highest detected levels would have been necessary.
2. Although contaminant levels have been decreased through site cleanup activities, some remaining elevated levels of TNT and lead could pose a risk in the future if small children have more regular contact with soil, as could happen if the area is developed for residential use.
3. Past exposures to contaminants in TCC drinking water were too low to result in adverse health effects. No evidence that other site groundwater was or is currently used for drinking was found. Untreated groundwater is unsuitable for future drinking water purposes because of elevated levels of metals in groundwater at the Dominion Lands area and elevated metals and TNT in groundwater at the TNT Burial Site on TCC Property.
4. No adverse health effects are expected from past, present, or future exposure to surface water or sediments, from eating fish caught at TCC Lake or J-Lake, or from drinking private well water in the Respass Beach Community.
5. Physical hazards are posed by the remaining open brick vaults, the World War II pier, and debris surfacing at beachfront areas.
6. If appropriate clearance procedures are followed and enforceable land use controls are put in place, the risk of accidents involving ordnance will be minimized. However, a small chance of encountering ordnance continues to exist.

## VI. Recommendations

1. Continue cleanup activities to address contaminants in soil at the TNT Burial Site.
2. If areas are developed for residential use, test soils for lead and clean up if necessary.

3. Do not use groundwater at the site for drinking water, unless the water is fully characterized and treated to ensure that drinking water standards are met.
4. Address physical hazards by filling in open brick vaults, removing or restricting access to the World War II pier, and cleaning up debris or keeping access restrictions in place at the beachfront areas.
5. Follow ordnance and explosives clearance procedures for expected future land use and set up appropriate, enforceable land use controls. Educate potential future landowners and occupants about hazards posed by ordnance materials and procedures to follow if ordnance is encountered.

## VII. Public Health Action Plan

The Public Health Action Plan for the site contains a description of actions that have been or will be taken by ATSDR and/or other government agencies at the site. The purpose of the Public Health Action Plan is to ensure that this public health assessment not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of ATSDR to follow up on this plan to ensure its implementation. The public health actions that have been completed are as follows:

- Before the site was proposed to the NPL, ATSDR published two health consultations evaluating public health implications of possible exposure to TCC's well water and the James River Beachfront Landfill soil.
- ATSDR conducted two site visits to verify site conditions and gather pertinent information and data for the site.
- ATSDR held a public availability session to gather health concerns from the surrounding community.

The public health actions to be implemented follow:

- EPA and ACE will continue investigating and cleaning up the site, as necessary.
- ATSDR will continue to work with the federal and state environmental agencies and review the results of future investigations, as necessary.

Planned Public Health Actions:

ATSDR will reevaluate and expand this plan when necessary. New environmental, toxicological, or health outcome data or the results of implementing the above proposed actions could result in the need for additional actions at this site.

# VIII. Public Comments

This public health assessment (PHA) was available for public review and comment at the Portsmouth Campus Library of Tidewater Community College in Portsmouth, Virginia and at the offices of the Norfolk Corps of Engineers on Front Street in Norfolk, Virginia from December 1, 2003 to January 20, 2004. The document was also available for viewing or downloading from the ATSDR web site.

The public comment period was announced in local newspapers. The public health assessment was sent to members of the FNOD RAB; private citizens; and staff in Virginia DEQ, ACE, and EPA.

Comments were received from a member of the RAB. They can be found in Appendix B, along with ATSDR's responses to them.

## VIII. ATSDR Site Team

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# Appendix A. Explanation of Evaluation Process

## Screening Process

In evaluating these data, ATSDR used comparison values (CVs) to determine which chemicals to examine more closely. CVs are the health-based thresholds for contaminant concentrations found in a specific media (air, soil, or water). They are used in the selection of contaminants for further evaluation. A CV incorporates assumptions about daily exposure to a chemical and the standard amount of air, water, and soil that someone might inhale or ingest each day.

A CV represents a concentration below which no known or anticipated adverse human health effects are expected to occur. Different CVs are developed for cancer and noncancer health effects. Noncancer levels are based on valid toxicologic studies for a chemical, with appropriate safety factors included, and the assumption that small children (22 pounds or less) and adults are exposed every day. Cancer levels are based on a one-in-one-million excess cancer risk for an adult eating contaminated soil or drinking contaminated water every day for 70 years. For chemicals for which both cancer and noncancer levels exist, ATSDR uses the lower of the levels to be protective of human health. However, exceeding a CV does not mean that health effects will occur; it merely means that more evaluation is needed.

The CVs used in the evaluation in this document are listed below:

*Environmental Media Evaluation Guides (EMEGs)* are estimated contaminant concentrations in a media at which noncarcinogenic health effects are unlikely. EMEGs are derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL).

*Cancer Risk Evaluation Guides (CREGs)* are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in one million persons exposed over a lifetime. CREGs are calculated from the U.S. Environmental Protection Agency's (EPA) cancer slope factors (CSFs).

*Reference Media Evaluation Guides (RMEGs)* are estimated contaminant concentrations in a media at levels at which noncarcinogenic health effects are unlikely. RMEGs are derived from EPA's reference dose (RfD).

*Region 9 Preliminary Remediation Goals (R9 PRGs)* are the estimated contaminant concentrations in a media at which carcinogenic or noncarcinogenic health effects are unlikely. The PRGs used in this PHA were derived by use of provisional reference doses or CSFs calculated by EPA's Region 9 toxicologists and were last updated in October 2002.

*Region 3 Risk-based Concentrations (R3 RBCs)* are the estimated contaminant concentrations in a media at which carcinogenic or noncarcinogenic health effects are unlikely. The RBCs used in this PHA were derived by use of provisional reference doses or CSFs calculated by EPA's Region 3 toxicologists and were last updated in October 2003.

*EPA Action Levels (ALs)* are the estimated contaminant concentrations in water at which additional evaluation is needed to determine whether action is required to eliminate or reduce exposure. Action levels can be based on mathematical models.

*EPA Soil Screening Levels (SSLs)* are estimated contaminant concentrations in soil at which additional evaluation is needed to determine if action is required to eliminate or reduce exposure.

*World Health Organization guidelines (WHO)* are guidelines published by the World Health Organization for drinking water quality.

Some CVs may be based on different durations of exposure. Acute duration is defined as exposure lasting 14 days or less. Intermediate duration exposure lasts between 15 and 364 days, and chronic exposures last one year or more. Comparison values based on chronic exposure studies are used whenever available. If an intermediate or acute comparison value is used, it is denoted with a small *i* or *a* before the CV (e.g., iEMEG refers to the intermediate duration EMEG).

**Determination of Exposure Pathways**

ATSDR identifies human exposure pathways by examining environmental and human components that might lead to contact with COCs. A pathway analysis considers five principal elements: a source of contamination, transport through an environmental medium, a point of exposure, a route of human exposure, and an exposed population. Completed exposure pathways are those for which the five elements are evident; such pathways indicate that exposure to a contaminant has occurred in the past, is now occurring, or will occur in the future. Potential exposure pathways are those for which exposure seems possible, but one or more of the elements is not clearly defined. Potential pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring now, or could occur in the future. It should be noted that the identification of an exposure pathway does not imply that health effects will occur. Exposures might or might not be substantive. Therefore, even if exposure has occurred, is now occurring, or is likely to occur in the future, human health effects might not result.

ATSDR reviewed site history, information on site activities, and the available sampling data. On the basis of this review, ATSDR identified numerous exposure pathways that warranted consideration.

**Evaluation of Public Health Implications**

The next step is to consider those contaminants present at levels above the CVs and further identify which chemicals and exposure situations are likely to be a health hazard. Child and adult exposure doses are calculated for the site-specific exposure scenario, using ATSDR's assumptions about who goes on the site and how often they contact the site contaminants. The exposure dose is the amount of a contaminant that gets into a person's body. Following is a brief explanation of how ATSDR calculated the estimated exposure doses for the site.

### *Soil Ingestion*

Exposure doses for ingestion of contaminants present in soil were calculated by use of the maximum concentration measured in soil, in milligrams per kilogram (mg/kg), or parts per million (ppm). This maximum concentration is then multiplied by the soil ingestion rate for adults or teenagers (100 mg/day) or children (200 mg/day). For occasional recreational exposure, the multiplication product was divided by the average weight for an adult, 70 kg (154 pounds), or for a 10-year-old child, 36 kg (80 pounds). The resulting dose was then multiplied by a factor of 208/365, because the exposure was assumed to occur on average four times a week throughout the year. For exposure of college students and faculty, the body weights used were 70 kg (154 pounds) for adults and 50 kg (110 pounds) for older teenagers, and the exposure factor was 240/365 (5 days a week for 48 weeks out of the year). For child soccer players, the assumed weight was 36 kg and the exposure factor was 78/365 (3 days a week for 26 weeks out of the year). For the purpose of estimating residential exposures, the child weight was 10 kg (22 pounds) for a 1-year-old child and the exposure factor was 1 to account for exposure throughout the year.

### *Groundwater Ingestion*

For past exposure to contaminants in the TCC drinking water wells, the maximum detected groundwater concentration was multiplied by an ingestion rate of 1.5 liters per day (L/day) for adults or 0.75 L/day for teenagers (75% of the daily dose was assumed to occur on campus). The result was divided by the average weight of an adult, 70 kg (154 pounds) or of an older teenager, 50 kg (110 pounds). The result was multiplied by an exposure factor of 350/365, because exposure was assumed to occur 350 days out of the year. For past, present, and potential future residential exposure to contaminants in groundwater, the drinking water ingestion rate used was 2 L/day for adults and 1 L/day for children. The average body weight was 70 kg (154 pounds) for adults and 10 kg (22 pounds) for children, and the exposure factor was 1 to account for year-round exposure. For the purpose of estimating future exposures to groundwater contaminants by workers, only adults were considered to be exposed, the ingestion rate was 1.5 L/day, and the exposure factor was 250/365, because exposure was assumed to occur 5 days a week for 50 weeks out of the year.

### *Surface Water Ingestion*

Exposure doses for surface water ingestion were calculated by use of the maximum concentration for a surface water contaminant, in milligrams per liter (mg/L). This maximum concentration was then multiplied by an incidental surface water ingestion rate of 0.2 liter/day for adults or 0.1 liter/day for children. These ingestion rates are 1/10th of the EPA default drinking water rates. The multiplication product was divided by the average weight for an adult (70 kg) or for a 10-year-old child (36 kg). The resulting dose was then multiplied by a factor of 208/365, because the exposure was assumed to occur four times a week throughout the year.

### *Sediment Ingestion*

Exposure doses for ingestion of contaminants from the sediment were calculated by use of the maximum concentration measured in the sediment, in mg/kg or ppm, multiplied by 1/10th of the soil ingestion rate—10 mg/day for adults or 20 mg/day for children. The multiplication product was divided by the average weight for an adult (70 kg) or a 10-year-old child (36.3 kg). The resulting dose was then multiplied by a factor of 208/365, because the exposure was assumed to occur four times a week throughout the year. For the purpose of estimating future residential exposures, a 1-year-old child (10 kg or 22 pounds) was assumed to be exposed throughout the year (i.e., the exposure factor was 1).

## Noncancer Health Effects

The calculated exposure doses are then compared to an appropriate health guideline for that chemical. Health guideline values are considered safe doses—that is, health effects are unlikely below this level. The health guideline value is based on valid toxicological studies for a chemical, with appropriate safety factors built in to account for human variation, animal-to-human differences, and/or the use of the lowest adverse effect level. For noncancer health effects, the following health guideline values are used.

### *Minimal Risk Level (MRLs)—Developed by ATSDR*

An MRL is an estimate of daily human exposure—by a specified route and length of time—to a chemical dose that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects. A list of MRLs can be found at http://www.atsdr.cdc.gov/mrls.html.

### *Reference Dose (RfD) - Developed by EPA*

An RfD is an estimate, with safety factors built in, of the daily lifetime exposure of human populations to a possible hazard that is not likely to cause noncancerous health effects. RfDs can be found at http://www.epa.gov/iris.

If the estimated exposure dose for a chemical is less than the health guideline value, then the exposure is unlikely to cause a noncarcinogenic health effect in that specific situation. If the exposure dose for a chemical is greater than the health guideline, then the exposure dose is compared to known toxicologic values for that chemical and is discussed in more detail in the PHA. These toxicologic values are doses derived from human and animal studies that are summarized in the ATSDR *Toxicological Profiles*. A direct comparison of site-specific exposure and doses to study-derived exposures and doses that cause adverse health effects is the basis for deciding whether health effects are likely.

## Calculation of Risk of Carcinogenic Effects

The estimated risk of developing cancer resulting from exposure to the contaminants was calculated by multiplying the site-specific adult exposure dose by EPA's corresponding CSF (which can be found at http://www.epa.gov/iris ). The results estimate the maximum increase in the risk of developing cancer after 70 years of exposure to the contaminant. If the duration of possible exposure to the contaminant is less than 70 years, the estimate is reduced by the appropriate fraction (for example, for a duration of 10 years, the product of adult exposure dose and CSF would be multiplied by 10/70).

The actual risk of cancer is probably lower than the calculated number, which gives a worst-case excess cancer risk. The method used to calculate EPA's CSF assumes that high-dose animal data can be used to estimate the risk for low-dose exposures in humans. The method also assumes that no safe level exists for exposure. Little experimental evidence exists to confirm or refute those two assumptions. Lastly, the method computes the 95% upper bound for the risk, rather than the average risk, suggesting that the cancer risk is actually lower, perhaps by several orders of magnitude.[2]

Because of uncertainties involved in estimating carcinogenic risk, ATSDR employs a weight-of-evidence approach in evaluating all relevant data.[3] Therefore, the carcinogenic risk is described in words (qualitatively) rather than giving a numerical risk estimate only. The numerical risk estimate must be considered in the context of the variables and assumptions involved in the risk's derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions. The actual parameters of environmental exposures must be given careful consideration in evaluating the assumptions and variables relating to both toxicity and exposure.

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[3] Agency for Toxic Substances and Disease Registry (ATSDR). Cancer policy framework. Atlanta (GA): US Department of Health and Human Services; 1993.

## Appendix B. Public Comments Received

This public health assessment (PHA) was available for public review and comment at the Portsmouth Campus Library of Tidewater Community College in Portsmouth, Virginia and at the offices of the Norfolk Corps of Engineers on Front Street in Norfolk, Virginia from December 1, 2003 to January 20, 2004. The document was also available for viewing or downloading from the ATSDR web site.

The public comment period was announced in local newspapers. The public health assessment was sent to members of the FNOD RAB; private citizens; and staff in Virginia DEQ, ACE, and EPA. Only one comment on the public health assessment was received.

### Comments

From a member of the FNOD Restoration Advisory Board (RAB):

*Has ATSDR evaluated the exposure to a resident if a homeowner had a shallow well put down to use the water for watering the lawn, or filling a child's wading pool?... I realize that any residential subdivision home built in that area, by law, would connnect to the municpal water system. Aside from that, many homeowners in this area will also put down a shallow well for yard use. Oft times children (as well as adults) will drink that water. Would this present a hazardous situation for incidental use of this water? How much would an individual have to consume in a day, week, month, year, etc. to pose a health threatening condition?*

**Response:** Thank you for the question. In response to your concern, we estimated exposures to the shallow groundwater from swimming and wading pool activities; watering the lawn; and occasional ingestion from drinking out of the hose in the yard. We have already recommended that the groundwater at the site not be use for drinking water unless it is fully characterized to ensure its safety (see page 45), so this review is in addition to that recommendation.

We want to point out that making these estimates is full of uncertainties. The shallow groundwater has been sampled in certain locations (source areas) across the FNOD site, generally where chemical contamination was present or suspected. Those areas may not be representative of the whole site. Most likely, the source areas have higher levels of contaminants, but because of this uncertainty, we used the maximum concentrations detected in each area. The shallow groundwater quality will vary across the site, depending on historical use of the land and the depth of the well. In general, surface activities would be expected to impact shallow groundwater to a greater extent than deeper groundwater.

Given the uncertainties of what shallow groundwater at a particular property might contain, we looked at the groundwater data that we do have from the possible source areas and estimated the exposures to the maximum concentrations found. We made the following assumptions:

- Children and adults would drink 100 milliliters of water (~1/2 cup) every day for 4 months of the year (this would include accidental swallowing of pool water and the occasional drink from the garden hose),
- Children and adults would have contact with the water from wading or swimming activities for 2 hours every day for 3 months (dermal exposure), and
- Residents would water their vegetable gardens with the groundwater throughout the growing season.

Based on these assumptions and the chemical concentrations detected, occasional exposure to the site groundwater from dermal contact and from limited ingestion **are not likely to cause adverse human health effects**. The estimated doses are all below levels where one would expect to see health effects. In addition, the chemicals in the groundwater are not likely to accumulate in garden produce so as to harm humans. TNT in the soil and groundwater could be taken up by plants. However, exposure to TNT at the TNT Burial Site area is unlikely in the future because a cleanup is underway and residential development in this area will be restricted [102].

## Appendix C. ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

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| **Absorption** | How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in. |
| **Acute Exposure** | Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days. |
| **Additive Effect** | A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together. |
| **Adverse Health Effect** | A change in body function or the structures of cells that can lead to disease or health problems. |
| **Antagonistic Effect** | A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together. |
| **ATSDR** | The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals. |
| **Background Level** | An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment. |
| **Bioavailability** | See **Relative Bioavailability**. |

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| **Biota** | Used in public health, things that humans would eat – including animals, fish and plants. |
| **Cancer** | A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control |
| **Cancer Slope Factor (CSF)** | The slope of the dose-response curve for cancer. Multiplying the CSF by the dose gives a prediction of excess cancer risk for a contaminant. |
| **Carcinogen** | Any substance shown to cause tumors or cancer in experimental studies. |
| **Chronic Exposure** | A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*. |
| **Completed Exposure Pathway** | See **Exposure Pathway**. |
| **Community Assistance Panel (CAP)** | A group of people from the community and health and environmental agencies who work together on issues and problems at hazardous waste sites. |
| **Comparison Value (CV)** | Concentrations of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated. |
| **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)** | **CERCLA** was put into place in 1980. It is also known as **Superfund.** This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. This act created ATSDR and gave it the responsibility to look into health issues related to hazardous waste sites. |
| **Concentration** | How much or the amount of a substance present in a certain amount of soil, water, air, or food. |
| **Contaminant** | See **Environmental Contaminant.** |
| **Delayed Health Effect** | A disease or injury that happens as a result of exposures that may have occurred far in the past. |

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| **Dermal Contact** | A chemical getting onto your skin (see **Route of Exposure**). |
| **Dose** | The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day". |
| **Dose / Response** | The relationship between the amount of exposure (dose) and the change in body function or health that results. |
| **Duration** | The amount of time (days, months, years) that a person is exposed to a chemical. |
| **Environmental Contaminant** | A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than the **Background Level**, or what would be expected. |
| **Environmental Media** | Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**. |
| **US Environmental Protection Agency (EPA)** | The federal agency that develops and enforces environmental laws to protect the environment and the public's health. |
| **Epidemiology** | The study of the different factors that determine how often, in how many people, and in which people will disease occur. |
| **Exposure** | Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.) |
| **Exposure Assessment** | The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact. |
| **Exposure Pathway** | A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.<br>ATSDR defines an exposure pathway as having 5 parts:<br>1. Source of Contamination,<br>2. Environmental Media and Transport Mechanism,<br>3. Point of Exposure,<br>4. Route of Exposure, and |

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| | 5. Receptor Population.<br>When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary. |
| **Frequency** | How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month. |
| **Hazardous Waste** | Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them. |
| **Health Effect** | ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary). |
| **Indeterminate Public Health Hazard** | The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures. |
| **Ingestion** | Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (see **Route of Exposure**). |
| **Inhalation** | Breathing. It is a way a chemical can enter your body (see **Route of Exposure**). |
| **LOAEL** | Lowest **O**bserved **A**dverse **E**ffect Level. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals. |
| **Malignancy** | See **Cancer**. |
| **MRL** | Minimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects. |
| **NPL** | The **N**ational **P**riorities **L**ist. (Which is part of **Superfund.**) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site. |
| **NOAEL** | No **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a |

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| | study, or group of studies, that did not cause harmful health effects in people or animals. |
| **No Apparent Public Health Hazard** | The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects. |
| **No Public Health Hazard** | The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals. |
| **PHA** | Public **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed. |
| **Plume** | A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds and streams). |
| **Point of Exposure** | The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). Some examples include: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, or the backyard area where someone might breathe contaminated air. |
| **Population** | A group of people living in a certain area; or the number of people in a certain area. |
| **PRP** | **P**otentially **R**esponsible **P**arty. A company, government or person that is responsible for causing the pollution at a hazardous waste site. PRP's are expected to help pay for the clean up of a site. |
| **Public Health Assessment(s)** | See **PHA**. |
| **Public Health Hazard** | The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects. |
| **Public Health Hazard Criteria** | PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the |

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| | Glossary. The categories are:<br>– Urgent Public Health Hazard<br>– Public Health Hazard<br>– Indeterminate Public Health Hazard<br>– No Apparent Public Health Hazard<br>– No Public Health Hazard |
| **Receptor Population** | People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**). |
| **Reference Dose (RfD)** | An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person. |
| **Relative Bioavailability** | The amount of a compound that can be absorbed from a particular medium (such as soil) compared to the amount absorbed from a reference material (such as water). Expressed in percentage form. |
| **Route of Exposure** | The way a chemical can get into a person's body. There are three exposure routes:<br>– breathing (also called inhalation),<br>– eating or drinking (also called ingestion), and<br>– getting something on the skin (also called dermal contact). |
| **Safety Factor** | Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people. |
| **SARA** | The Superfund Amendments and Reauthorization Act in 1986 amended CERCLA (see **CERCLA**) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects resulting from chemical exposures at hazardous waste sites. |
| **Sample Size** | The number of people that are needed for a health study. |
| **Sample** | A small number of people chosen from a larger population (see **Population**). |
| **Source (of Contamination)** | The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**. |

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| **Special Populations** | People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations. |
| **Statistics** | A branch of the math process of collecting, looking at, and summarizing data or information. |
| **Superfund Site** | See **NPL**. |
| **Survey** | A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services. |
| **Synergistic Effect** | A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together are greater than the effects of the chemicals acting by themselves. |
| **Toxic** | Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick. |
| **Toxicology** | The study of the harmful effects of chemicals on humans or animals. |
| **Tumor** | Abnormal growth of tissue or cells that have formed a lump or mass. |
| **Uncertainty Factor** | See **Safety Factor**. |
| **Urgent Public Health Hazard** | This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed. |