ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

NAVAL WEAPONS INDUSTRIAL RESERVE PLANT BEDFORD
BEDFORD, MASSACHUSETTS
EPA FACILITY ID: MA6170023570
AUGUST 19, 2005

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

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AUGUST 19, 2005

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substance 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 cleanup 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. 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. Whatever the form of the public health assessment, the 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 than adults. 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 it touches on cases in which this is so, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually 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.

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 (E-60)
Atlanta, GA 30333

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List of Abbreviations

AFB	Air Force Base
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BMD	benchmark dose modeling
BTEX	benzene, toluene, ethylbenzene, and xylene
BW	body weight
CEL	cancer effect level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	conversion factor
CREG	ATSDR's cancer risk evaluation guide
CRP	community response plan
CSF	EPA's cancer slope factor
CV	comparison value
DCE	dichloroethylene
DOD	Department of Defense
ED	exposure duration
EF	exposure frequency
EMEG	ATSDR's environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
ERH	electrical resistive heating
FDA	Food and Drug Administration
FFA	Federal Facilities Agreement
FR	flow rate
FS	feasibility study
FTF	flight test facility
gpm	gallons per minute
IR	ingestion rate
IRP	Installation Restoration Program
LF	landfill
LOAEL	lowest-observed-adverse-effect level
MCL	EPA's maximum contaminant level
µg/dL	micrograms per deciliter
$\mu g/m^3$	micrograms per cubic meter
mg/kg/day	milligrams per kilogram per day
MADEP	Massachusetts Department of Environmental Protection
MRL	ATSDR's minimum risk level
MT	mass transfer

List of Abbreviations (continued)

Navy	Department of the Navy
NFA	no further action
NOAEL	no-observed-adverse-effect level
NPL	EPA's National Priorities List
NWIRP	Naval Weapons Industrial Reserve Plant
O/W	oil/water
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
PHA	public health assessment
PHAP	Public Health Action Plan
ppb	parts per billion
ppm	parts per million
RAB	restoration advisory board
RBC	EPA's risk-based concentration
RfD	EPA's reference dose
RfC	EPA's reference concentration
RI	remedial investigation
RMEG	ATSDR's reference dose media evaluation guide
ROD	record of decision
SFTA	Southern Flight Test Area
SVOCs	semi-volatile organic compounds
T	time
TCE	trichloroethylene
TWA	time-weighted average
USAF	U.S. Air Force
UST	underground storage tank
V	volume
VOCs	volatile organic compounds

I. Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) prepared this public health assessment (PHA) to evaluate potential health hazards from past, current, and future exposures to contaminants originating from the Naval Weapons Industrial Reserve Plant (NWIRP)–Bedford. Our assessment indicates that people exposed to contaminants from the NWIRP Bedford site are unlikely to have harmful health effects.

NWIRP Bedford is located on 46 acres in Bedford, Middlesex County, Massachusetts, about 14 miles northwest of Boston, Massachusetts. The U.S. Department of the Navy (Navy) owned the NWIRP Bedford property; beginning in 1952, the Raytheon Corporation used the property for missile and radar development. Operations were expanded to design, fabrication, and testing of prototype equipment, such as missile guidance and controls systems. The site consists of two sections divided by Hartwell Road. The northern section is located on Hartwell's Hill; it contains the Components Laboratory and its auxiliary buildings, the compact test range, the facility's Storage Building, the Antenna Range Facility, the Transportation Buildings, a former incinerator, and the Vitro Tower. The southern section, the Southern Flight Test area (SFTA), is immediately south of Hartwell's Hill; it contains the Flight Test Facility (FTF), the Deluge Pump Station, the Guard House, a parking lot, a small storage building, and a concrete apron surrounding ： of the FTF. The entire site is bound on the south by Lawrence G. Hanscom Field and Hanscom Air Force Base; on the west by Raytheon Electronic Systems facility, wetlands, and a U.S. Air Force trailer park; on the north by woods and wetlands; and on the east by woods, wetlands, and private residences. Raytheon ceased operations at the facility in December 2000, and the land is now vacant. Future use is being determined.

ATSDR conducted a public health assessment to evaluate potential hazards at NWIRP Bedford. ATSDR's public health assessment process is designed to identify populations which may have been exposed to hazardous substances and determine the public health implications of the exposure. As part of this process, ATSDR conducted a site visit and met with representatives from the Navy and NWIRP Bedford in July 2003. ATSDR gathered information on the nature and extent of contamination associated with the site and considered past, current, and potential future exposure situations.

On the basis of this evaluation, ATSDR determined that exposures to hazardous substances in soil do not pose a public health hazard because either (1) the area where the contamination is located is not widely used or accessible to the public, (2) contamination was detected only at low levels, or (3) the contamination has been removed from the site. ATSDR did identify several situations in which the public may be coming in contact with site-related contaminants. ATSDR studied possible hazards associated with these exposures and concluded the following:

- **Groundwater contamination and private well use near NWIRP Bedford.** *ATSDR has determined that use of local private wells has not posed a past, current or potential future public health hazard with respect to groundwater contamination from the NWIRP Bedford site.* Although contaminants have leached into the groundwater beneath NWIRP Bedford, levels are being reduced through pump and treat systems and removals of contaminated soil and sources. Some contaminants have migrated with groundwater flow north of the site. There are thirteen residences within half a mile east/northeast of NWIRP Bedford which have private wells. These wells are permitted for irrigation and the residences are connected to Bedford's municipal water supply. Because contaminant levels are being reduced and nearby households are connected to the municipal water supply, we do not anticipate future public health hazards. ATSDR recommends, as a prudent public health action, that residents continue to use municipal water for household uses due to multiple sources of area groundwater contamination.

- **Contaminants in the Hartwell Road well field between 1983 and 1984.** *ATSDR determined that no harmful exposures have occurred in the past from consuming water from the off-site municipal drinking water wells in the Hartwell Road well field. ATSDR recommends water quality testing and treating the affected groundwater to safe levels required by EPA and MADEP before restoring it to public use.* In the fall and winter of 1983, the town of Bedford discovered volatile organic compounds (VOCs) and dissolved iron in their Hartwell Road municipal well field, about ½ mile northwest of the NWIRP Bedford site. After further testing showed unacceptable levels of VOCs and dissolved iron, the town closed the well field in April 1984. ATSDR examined exposures to the detected levels of contaminants in the well field and determined that no health effects would have occurred for people who drank the water or used it for other domestic uses in the past. Since 1984, no exposure has occurred because the wells are no longer used. Because there are multiple sources of contamination in the area and contamination in fractured bedrock, ATSDR recommends that this well field not be reopened until groundwater remediation in the area is complete, potential sources of contamination have been investigated, and groundwater has been verified to be safe for use as drinking water.

- **Contaminants in Elm Brook.** *Contaminants from NWIRP Bedford have entered Elm Brook, but ATSDR determined that the levels are too low to pose harm to people who might visit the brook.* NWIRP Bedford contaminants have reached Elm Brook, a small, shallow stream that runs within 300 to 600 feet of the site's northern boundary. People are not expected to come in contact with contaminants in the brook often or for long periods of time, since Elm Brook is not used for drinking water or widely used for recreation. Any limited past, current, or future exposure to contaminants at the levels detected in surface water or sediment is not expected to result in adverse health effects. The already low contaminant concentrations are expected to further decrease before they reach the downstream Shawsheen River.

- **Possible vapors in on-site buildings located above the groundwater plumes.** *ATSDR determined that people who worked in or visited buildings above on-site groundwater contamination were not likely to encounter harmful levels of indoor air contaminants or suffer adverse health effects.* Some buildings at NWIRP Bedford sit above contaminated groundwater, which could release VOCs into building foundations. Conservative indoor modeling of potentially affected buildings units showed that VOC contaminants could be present in the air inside of certain buildings, but at levels below those associated with known adverse health effects.

II. Background

A. Site Description and Operational History

The Naval Weapons Industrial Reserve Plant (NWIRP)–Bedford is located on 46 acres in Bedford, Middlesex County, Massachusetts, approximately 14 miles northwest of Boston. The NWIRP Bedford property was owned by the Navy and operated by Raytheon Corporation. The site consists of two sections divided by Hartwell Road. The northern section is located on Hartwell's Hill; it contains the Components Laboratory and its auxiliary buildings, the compact test range, the facility's storage building, the antenna range facility, the transportation buildings, a former incinerator, and the Vitro Tower. The southern section abuts Hanscom Field immediately south of Hartwell's Hill and contains the Southern Flight Test Area (SFTA): the Flight Test Facility (FTF), the deluge pump station, the guard house, a parking lot, a small storage building, and a concrete apron surrounding ： of the FTF (NUS Inc. 2001). The entire site is bounded to the south by Lawrence G. Hanscom Field and Hanscom Air Force Base; to the west by Raytheon Electronic Systems Facility, wetlands, and a U.S. Air Force (USAF) trailer park; to the north by woods and wetlands; and to the east by woods, wetlands, and private residences (Figure 1).

NWIRP Bedford was created in October 1952, when the Components Laboratory (then known as the Naval Industrial Research Aircraft Center) was constructed as a missile and radar development facility for Raytheon (see Figure 2). By 1959, the Navy had added flight test areas on the southern portion of the site. The facility expanded between 1959 and 1977, adding an additional 43 acres and the large facility storage and government buildings near the northern property boundary, an Antenna Range Building, air conditioning and incineration facilities, and the Advanced Medium Range Air to Air Missile Development (AMRAD) Building (EPA 2003). About 20 buildings were located on the NWIRP property, most of which supported work at the Components Laboratory and the FTF. Most recently, the facility was used for design, fabrication, and testing of prototype equipment, such as missile guidance and controls systems (ENSR 1992,

EPA 2003). Raytheon operations at the site ceased in December 2000 and the site, with the exception of a few buildings, is now vacant as future use is being determined.

B. Remedial and Regulatory History

Routine activities and waste disposal practices at NWIRP Bedford in the past have resulted in accidental spills or releases of chemicals to the environment. Some examples of these activities include the on-site storage of waste ash from the Old Incinerator (Site 1) and use and storage of fuels. Contaminants released to surrounding soil as a result of these activities include heavy metals in the waste ash (such as silver from classified film and lead, chromium, and zinc from paint wastes) and petroleum hydrocarbons and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds associated with fuels (Roger, Golden, & Halpern 1986). Some of the contamination released to the soil seeped through it and, eventually, reached the underlying groundwater or was carried toward Elm Brook.

Environmental investigations began at NWIRP Bedford under the Department of Defense's Installation Restoration Program (IRP) in 1985. At that time, the Navy initiated a preliminary assessment (then known as an initial assessment study) and records review. The Navy continued environmental investigations at NWIRP Bedford in 1988 with the start of a remedial investigation (RI). The RI was undertaken to determine the nature and extent of contamination at NWIRP Bedford. Through the RI, the Navy found contaminants, including solvents and metals, in groundwater and/or soil at on-site locations (Tetra Tech NUS Inc. 2001). Data collected through this process were then used to evaluate potential risks to human health. In cases where risks exceeded regulatory guidelines (such as those of the U.S. Environmental Protection Agency, or EPA, and the Massachusetts Department of Environmental Protection, or MADEP), a feasibility study was conducted to identify and test alternative remedial actions.

On May 31, 1994, EPA added NWIRP Bedford to the National Priorities List (NPL) of sites to be investigated. (The NPL is part of EPA's Comprehensive Environmental Response,

Compensation, and Liability Act, or CERCLA, which is commonly known as "Superfund.") The Navy then entered into a Federal Facility Agreement (FFA) with EPA's Region I and MADEP to outline a comprehensive strategy for conducting environmental investigations and completing remedial actions on NWIRP property where hazardous materials might have been disposed of, spilled, or stored (EPA 2003).

The Navy continued to evaluate environmental conditions at NWIRP Bedford through a number of environmental investigations. Those investigations included the 1992–1993 Phase II RI and an RI Phase II supplemental study in 1998 that further defined the limits of groundwater plumes and possible source areas on site. Through this work, they investigated four IRP sites identified as having (or potentially having) hazardous contamination (Brown & Root Environmental 1997). The four sites, shown in Figure 2 and described in detail in Table 1, are:

- Site 1: Old Incinerator Ash Disposal Area
- Site 2: Components Laboratory (Fuel Oil Tank release)
- Site 3: Northwest Groundwater Plume of chlorinated VOCs
- Site 4: BTEX Fuel Area

For some on-site locations, the Navy has undertaken the following measures to control the spread of contamination:

- Operation of a row of extraction wells at the base of Hartwell's Hill since 1997. The wells contain contamination associated with the chlorinated plume from Site 3 and prevent it from migrating north toward Elm Brook. Water captured by the wells is pumped to a treatment system that removes the chlorinated VOCs and metals. The Navy continues to monitor the system on a quarterly basis.
- Excavation and removal of the contaminated soil from the Components Laboratory Fuel Oil Tank (Site 2).
- Removal of the 7,600-gallon gasoline underground storage tank (UST) and 75 to 100 cubic yards of gasoline-contaminated soil from Site 4.

Records of decision (RODs) for no further action at Sites 1 and 2 were selected by the Navy and EPA with concurrence of the Massachusetts Department of Environmental Protection. The September 2000 RODs indicate these sites pose no threat to humans or the environment (U.S. EPA. 2000a, 2000b).

Further remedial actions are underway at Sites 3 and 4. Currently, the Navy is conducting a pilot study to test whether they can use electrical resistive heating (ERH) to reduce total chlorinated volatile organic compounds (VOCs) at Site 3 by 95% to 99%. The Navy also plans to supplement the cleanup process at Site 4 with the ERH technology to reduce benzene concentrations in groundwater to 50 parts per billion (ppb) or below in the most contaminated areas (ENSR 2003).

The Navy also investigated the Southern Flight Test Area (SFTA) during RI activities for Site 3 (Tetra Tech NUS Inc. 2001). The investigation showed that the sources of contamination in the SFTA were likely related to the neighboring Hanscom Air Force Base, not NWIRP Bedford operations. Hanscom Air Force Base has operated a groundwater extraction system since 1997 to control the migration of contaminants from the site; as a result, the SFTA has not been addressed under the FFA for NWIRP Bedford. A Memorandum of Understanding regarding the containment and the cleanup of contamination at the SFTA was submitted to the Air Force in May 2001.

C. ATSDR Activities

Through the public health assessment (PHA) process, ATSDR assesses conditions at a site from a public health perspective to determine whether people can be exposed to site-related contaminants through contact with the site's groundwater/drinking water, surface water, soil, biota, or air. As part of the PHA process, ATSDR visited NWIRP Bedford in July 2003. The purpose of the visit was to collect information necessary to examine public health issues related to environmental contamination at the facility and to identify community health concerns.

During the visit, staff met with Navy and NWIRP Bedford personnel and representatives from federal and state agencies. On the basis of discussions, the site visit, and data reviews, ATSDR concluded at the time that little potential existed for immediate threats to human health. ATSDR did, however, identify several exposure pathways that required further evaluation. ATSDR prepared this PHA to further evaluate those pathways.

A draft of the Naval Weapons Industrial Reserve Plant (NWIRP)–Bedford public health assessment was released to the public for comment on April 25, 2005. The public comment period ended May 27, 2005, with no comments having been received.

D. Demographics

ATSDR examines demographic information, or population information, to identify the presence of sensitive populations, such as young children (age 6 and under), the elderly (age 65 and older), and women of childbearing age (age 15 through 44). Demographics also provide details on population mobility and residential history in a particular area. This information helps ATSDR evaluate how long residents might have been exposed to environmental contaminants.

No one has ever lived at the site. The closest residents live in private residences in the Hartwell Acres housing subdivision and at the USAF trailer park. According to U.S. census data, about 3,523 people, including 395 children aged 6 and under and 361 adults aged 65 and older, live within 1 mile of the site (Figure 3). The town of Bedford, overall, accounts for 13,000 residents (MADHCD 2003). Other towns near Bedford include Billerica (population 39,000) to the north, Lexington (population 30,000) to the east, Lincoln (population 8,000) to the south, and Concord (population 17,000) to the west (MADHCD 2003).

E. Land Use

ATSDR examines land use to determine what activities might put people at risk for exposure to contaminants related to NWIRP Bedford. Land at NWIRP Bedford is mostly paved and was used

to house metal-sided or reinforced concrete buildings that supported research and development of radar and missile guidance systems. All testing occurred in enclosed buildings; no testing was conducted outside (Brown and Root Environmental 1997). While the site was in full operation, access was controlled by a partial fence and guard houses. Today, the site is no longer operational and the property is completely enclosed by a 6-foot-high chain-link fence.

Land surrounding NWIRP Bedford is zoned for residential and industrial use, and there are also large tracts of open land. Residential areas are located to the east/northeast (private homes) and west/southwest, including a trailer park for Hanscom staff located between the north and south sides of NWIRP Bedford. The next nearest residence to the site is about 200 yards to the northwest (Roger, Golden, & Halpern 1986). Hanscom Field and Raytheon Missile Systems Division Facilities are south and west of the site, respectively. Undeveloped wetlands, woods, and meadows border the site to the north/northwest (Halliburton NUS 1994).

Groundwater is the primary source of drinking water and irrigation water for Bedford residents (including residents of the Hanscom AFB trailer park adjacent to NWIRP Bedford) (Roger, Golden, & Halpern 1986). In 1983, the town of Bedford began drawing drinking water from the Hartwell Road well field, located less than ½ mile from the northwest corner of the NWIRP Bedford site. The well field was closed in 1984 after elevated levels of VOCs and dissolved iron were detected in the wells (Roger, Golden, & Halpern 1986). Today, about 85 percent of the drinking water for the town of Bedford comes from the Massachusetts Water Resources Authority (MWRA) via the town of Lexington municipal system. This water is augmented with water from the Shawsheen well field, located about 1.5 miles northeast of NWIRP Bedford. Only one of the three wells at the Shawsheen well field is currently operational (Bedford DPW 2003). Some residences connected to the municipal water system in the area of NWIRP Bedford also have private wells. A survey completed by the town of Bedford identified 12 private wells within 1 mile of the NWIRP Bedford site boundaries, the closest being 700 feet north-northeast of the site.

F. Natural Resources

Natural resources used in the vicinity of NWIRP Bedford include groundwater for drinking water and surface-water bodies for recreational uses (Shawsheen River). Some of the key exposure concerns associated with NWIRP Bedford pertain to chemical contamination in the shallow aquifer (groundwater) and releases to the Elm Brook, which is a tributary of the Shawsheen River. For information on how contaminants might migrate to and/or accumulate in these media, ATSDR obtained background information on the local topography, climatology, groundwater hydrogeology, and surface-water hydrology.

Geology and Hydrogeology

The northern section of NWIRP Bedford sits on the 40-acre Hartwell's Hill, which rises about 70 feet above the surrounding ground surface (or 205 feet above sea level). The hill is composed of glacial till overlying a bedrock base (Halliburton NUS 1992, Tetra Tech NUS Inc 2000; Dames & Moore 1992b; Brown and Root 1997)); with additional fill on top of the deposits. Extensive wetlands and flat to gently rolling wooded land dominate the land around the hill. NWIRP Bedford's lowest point occurs at its southern portion in the SFTA, near Hanscom Field (Roger, Golden, & Halpern 1986). In order of descending depth, the key subsurface layers are further described below:

- **Fill.** Manmade fill of sands and gravel, added to the property during its construction, covers a major portion of the hill. This fill ranges in thickness from about 10 to 23 feet on the hill, thins out in all directions from the hill and eventually disappears at the southern end of the site.

- **Glacial Deposits.** The fill is largely underlain by glacial deposits consisting of a sandy and clayey till layer. The till ranges in thickness from about 125 feet on the northwest portion of the hill to about 10 feet in the low-lying areas around the hill, and disappears at the southern end of the SFTA. The till is the only unit of glacial deposits present on the hill. Other glacial deposits surrounding the hill include outwash, located near Elm Brook and in the southern portion of the site, and a few areas of fine-grained lake deposits sandwiched between the till and outwash deposits.

- **Bedrock.** The weathered bedrock beneath the till layer is fractured, and ranges in depths from 135 feet in the northwest portion of the site to 26 feet in the southern end of the site.

Groundwater at NWIRP Bedford is primarily found in the surface layers and in the underlying fractured bedrock (Halliburton NUS 1992, 1993). The depth at which the groundwater is encountered varies, however, with the season and the amount of precipitation. The water table aquifer, or shallow aquifer, is typically encountered 15 to 30 feet below the ground surface, and roughly corresponds to the ground surface topography. From its high of 185 feet above mean sea level near the top of the hill, the shallow aquifer slopes steeply to the north, south, and east, and less steeply to the west. Given the fairly steep gradients on the hill, shallow groundwater would be expected to move vertically, or downward. However, the underlying glacial till is densely packed and acts as a low-permeability confining layer, or aquitard. This aquitard limits flow from the shallow aquifer to the bedrock aquifer (Halliburton NUS 1993). Consequently, groundwater flow in the shallow aquifer appears to move radially from Hartwells Hill and is strongly controlled by ground surface topography until it reaches the more permeable glacial deposits at the base of the hill (Dames & Moore 1992b). (This is important because contaminants in the shallow groundwater would be expected to move laterally in the shallow flow rather than migrate in significant concentrations to the deeper bedrock aquifer.) As the groundwater from the northern and western portions moves from the hill and toward Elm Brook, it is influenced more by the brook's surface hydrology.[1] Groundwater flow in the southern portion of the site near the SFTA is predominantly south and southeast, except when it is influenced and captured by the USAF's groundwater extraction system (Halliburton NUS 1993; Tetra Tech NUS Inc. 2002).

Groundwater flow in the bedrock aquifer is influenced by bedrock topography, but is similar to the direction in the shallow aquifer. Therefore, groundwater in the bedrock from the northern and western portions of the hill flows radially from the top of the hill and, like water in the shallow aquifer, ultimately discharges to Elm Brook (Tetra Tech NUS Inc. 2002a).

[1] Groundwater in the shallow aquifer on the western edge of the site might be drawn into a recovery well operated at the Raytheon Missile Systems Building rather than discharging to Elm Brook.

Surface Water Hydrology

Storm drains on the northern portion of the site collect rain and snow melt from paved areas atop Hartwell's Hill and empty out at several points at the edge of the slope (Halliburton NUS 1992). Other storm drains near the SFTA discharge to a drainage ditch southwest of the SFTA and toward one of the Hanscom Field runways. Runoff not collected by the drainage system likely enters the wetlands bordering Elm Brook (Roger, Golden, & Halpern 1986). Elm Brook, a tributary of the Shawsheen River, is the predominant natural surface water system near NWIRP Bedford. Elm Brook originates in a wetland about 4 miles southwest of the NWIRP Bedford site, and flows past the northern site boundary before joining the Shawsheen River, about 1.2 miles northeast of the NWIRP site (Halliburton NUS 1994). Elm Brook is typically a shallow, low-flow brook, except during the spring when heavy runoff increases its size (Roger, Golden, & Halpern 1986). As its limited size suggests, Elm Brook is not used as a source of potable or irrigation water, nor can it support a permanent fish population. The downstream Shawsheen River, however, has been used for both drinking water and recreation, and the town of Burlington continues to use the river as a source of potable water (Burlington DPW 2004). Surface water was pumped from the river into the Mill Pond Reservoir (about 10 miles downstream of NWIRP Bedford) and treated before use (Roger, Golden, & Halpern 1986). Sport fishing is popular at the Shawsheen River, but the Massachusetts Department of Public Health has posted a fish consumption advisory at the river due to elevated mercury concentrations in its fish (MADPH 2003).

G. Quality Assurance and Quality Control

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. Documents prepared for the CERCLA program must meet standards for quality assurance and control measures for chain of custody, laboratory procedures, and data reporting. The environmental data presented in this PHA come from remedial investigations and other site reports. ATSDR has determined that the data's quality is adequate for making public health decisions.

III. Evaluation of Environmental Contamination and Exposure Pathways

A. Introduction

Identifying Exposure

ATSDR's PHAs are exposure (or contact) driven. People who work or live in an area of environmental release can only be exposed to a contaminant if they come in contact with it. A person might be exposed by breathing, eating, or drinking a substance containing the contaminant, or by skin contact with a substance containing the contaminant. But contact does not always happen when contaminants are released into the environment—*a release does not always result in exposure*.

ATSDR evaluates site conditions to determine if people could have been (a past scenario), are (a current scenario), or could be (a future scenario) exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation. ATSDR also identifies an exposure pathway as *completed* or *potential*, or *eliminates the pathway from further evaluation*. Completed exposure pathways exist if all elements of a human exposure are present. (See "Exposure Pathway" in Appendix A for a description of the elements of a completed exposure pathway.) A potential pathway is one that ATSDR cannot rule out, because one or more of its elements cannot be definitely proved or disproved. A pathway is eliminated if one or more of its elements is definitely absent.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/HAGM/ or by contacting ATSDR at 1-888-42ATSDR. ATSDR also provides community web-based training at http://www.atsdr.cdc.gov/COM.

Exposure and Health Effects

Given sufficient exposure levels, chemical contaminants disposed of or released into the environment can cause adverse health effects. The type and severity of health effects that an individual can suffer after contacting a contaminant depend on the exposure concentration (how much), the frequency and/or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (the combination of contaminants). Once exposure occurs, characteristics such as the exposed person's age, sex, nutritional status, genetics, lifestyle, and health status influence how he or she absorbs, distributes, metabolizes, and excretes the contaminant.

ATSDR selects contaminants for further evaluation by comparing their detected levels to health-based comparison values, or CVs. CVs are developed from the available scientific literature on exposure and health effects. Derived for a particular medium in which a contaminant can be present, a CV reflects the estimated concentration of that contaminant in that medium that is *not expected* to cause adverse health effects, assuming a standard daily contact rate (e.g., amount of water or soil consumed or amount of air breathed) and body weight. In order to be conservative and protective of public health, ATSDR CVs are generally based on contaminant concentrations *many times lower than levels at which no effects were observed* in experimental animals or human epidemiologic studies. They are not used to predict the occurrence of adverse health effects. Rather, they serve as a protective screen and first step in the evaluation of public health implications.

CVs used in this PHA are the environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), and cancer risk evaluation guides (CREGs). EMEGs, RMEGs, and CREGs are non-enforceable, health-based CVs developed by ATSDR for screening environmental contamination for further evaluation. In addition, ATSDR uses EPA's maximum contaminant levels (MCLs). MCLs are enforceable drinking water regulations developed to protect public health. (See Appendix B for a description of the CVs.)

If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (for example, duration and frequency), the toxicology of the contaminant, other epidemiology studies, and the weight of evidence for possible health effects. Figure 4 provides an overview of ATSDR's exposure evaluation process.

Possible Exposure Situations at NWIRP Bedford

ATSDR reviewed data for NWIRP's four IRP sites and the SFTA to determine if they are associated with past, current, or future public health hazards. (Table 1 describes each site and briefly summarizes our evaluation.) When evaluating these areas, ATSDR assesses the level of contamination present or degree of physical hazard, the extent to which individuals come into contact with the contamination or hazard, and whether this contact would result in a public health hazard. The review indicates that contamination from at NWIRP Bedford is not associated with any known public health hazards because the contaminant concentrations detected are too low to pose a health hazard or past and current exposure to the general public has been prevented.

In this review, however, ATSDR identified the following possible exposure situations at NWIRP Bedford that required further evaluation:

- Past, current, or future exposure to groundwater contamination via off-site private wells
- Past exposure to contaminants in the town of Bedford's Hartwell Road Well Field
- Past, current, or future exposure to contaminants in Elm Brook
- Past exposure to indoor air contaminants in on-site buildings above groundwater plumes

Of these possible exposure situations, the only completed exposure pathway is the past exposure to contaminants in the Hartwell Road well field. Exposure situations at NWIRP Bedford are evaluated in detail in the following discussion and summarized in Table 2. To acquaint the reader with terminology and methods used in this PHA, Appendix A provides a glossary of environmental and health terms presented in the discussion, Appendix B describes the CVs

ATSDR used in screening contaminants for further evaluation, and Appendix C describes the methods ATSDR used to evaluate whether health hazards exist.

B. Concern: Potential for Contamination to Reach Private Wells

Groundwater beneath the NWIRP Bedford site has become contaminated with VOCs and metals. Contamination in the northern portion of the site has been linked to former operations and waste disposal practices. Groundwater from the northern portion of the site flows toward and discharges into Elm Brook. VOC contamination in the southern portion of the site, at the SFTA, has not been linked to an on-site source. This contamination flows toward and is captured by the Hanscom Air Force Base groundwater treatment system located at the adjacent Hanscom Field. No wells serving private residents are located near site contamination. Navy investigations show that contaminant concentrations in the groundwater at both the northern and southern portions of the site have decreased substantially.

Discussion

Area Private Wells

The Bedford Board of Health and Department of Public Works undertook surveys to determine whether any private drinking water wells were located near the NWIRP Bedford site (Halliburton NUS 1992, 1994). The survey results indicated that 12 residences within 1 mile east and northeast of the site (in the Hartwell Acres neighborhood) had private wells. The closest of the residences is 700 feet from the northeast property line. All the homes are connected to the town of Bedford's municipal water supply. Some of the private well owners reported using well water for watering lawns (Roger, Golden, & Halpern 1986). Although we have no way of knowing the full extent to which residents use their private wells, information gathered through the survey indicates that the wells are unlikely to have been used for drinking water or other domestic uses. Furthermore, 10 of the 12 residences registered average municipal water use. Although two residences had average-to-low or low municipal water use, they are located more

than 2,000 feet from the northeast corner of NWIRP Bedford and therefore, are unlikely to be impacted by site contamination (Halliburton NUS 1992, 1994).

Groundwater Investigations

The Navy investigated the groundwater beneath the NWIRP Bedford site during several environmental studies: the 1989 Phase I RI, the 1990 Supplemental Investigation, the 1992–1993 Phase II RI, the 1997 Environmental Baseline Study, and the 1998 Supplemental Investigation. Groundwater investigations indicate that groundwater flow from Hartwell's Hill is largely influenced by topography: groundwater in the till flows outward in all directions from the top of the hill into the more permeable glacial outwash sands at the base of the hill (Halliburton NUS 1992). Once in the flat area at the base of the hill in the northern section, groundwater slowly discharges further northward into the Elm Brook (Roger, Golden, & Halpern 1986). Groundwater contamination in the southern section of the site is believed to be coming from the Hanscom Air Force Base site. The results of these groundwater investigations are summarized in Table 3 and in the discussions below.

Northern Section of the NWIRP Bedford Site

Volatile Organic Contamination

The Navy collected 22 shallow and deep groundwater samples as part of the initial phase of its RI at the NWIRP Bedford site. Sixteen of these samples (eight shallow and eight bedrock) were collected from the northern portion of the site, then analyzed for VOCs and metals. This analysis identified VOCs as the primary contaminant of the northern section. Although groundwater contaminants have migrated primarily to the northwest, some northeasterly migration has also occurred.

VOCs were detected in the groundwater of the northern section of the NWIRP Bedford site. Contamination has migrated primarily to the northwest and to a much lesser degree to the northeast. The closest private wells, to the east/northeast of the site, are permitted for irrigation. The Hartwell Road Well Field, to the northwest, was closed in April 1984. There are currently no known exposures to groundwater contaminants.

Most of the VOCs migrated off Hartwell's Hill to the west and then to the northwest towards Elm Brook. VOCs in the northwestern portion of the northern section appeared to be limited to the shallow aquifer (MW1S, MW2S, and MW11S). The highest VOC concentrations were discovered in a shallow well (MW11S) near the former Print Shop within the Factory Storage Building. At this location, the maximum trichloroethylene (TCE) and benzene concentrations were 2,300 ppb and 75 ppb, respectively. A breakdown product of TCE, 1,1-dichloroethylene (1,1-DCE), was also detected in the shallow aquifer at the same location at a maximum concentration of 1,200 ppb. Lower VOC concentrations (up to 210 ppb for TCE and nondetect for benzene) were discovered in the shallow well (MW2) just down-gradient of the Old Incinerator Ash Disposal piles. No VOCs were detected in the bedrock wells at either the Print Shop or the Ash Disposal piles (Dames & Moore Inc. 1992 a, b).

Along the northeast corner of the northern section, near the Component Laboratory (approximately 500 feet from the Facility Storage Building), VOCs were again detected, but at lower concentrations and over much smaller distances than contaminants migrating northwesterly from the Print Shop area. The Print Shop area in the northeastern corner of the Components Laboratory is also the suspected source area for this northeasterly contamination (Dames & Moore Inc. 1992a, b).TCE was found in both shallow and deep groundwater, indicating that contamination at this location, while lower in concentration, had reached the deeper bedrock aquifer. However, the extent of bedrock contamination was limited. TCE was detected at a maximum concentration of 110 ppb in the shallow aquifer. Other VOCs included 1,1-dichloroethane (1,1-DCA) (14 ppb), 1,2-DCA (1,2-dichloroethane) (44 ppb), 1,1-DCE (28 ppb), methylene chloride (10 ppb), and tetrachloroethylene (PCE) (11 ppb), all at levels just above their CVs. The deeper groundwater samples contained similar constituents, but at reduced concentrations (up to 42 ppb for TCE).

As noted, several private wells are located north of the site but are apparently not used for drinking water. It is not known whether contaminated groundwater from NWIRP Bedford has traveled northward far enough to reach these wells.

BTEX Contamination

High concentrations of BTEX (benzene, toluene, ethylbenzene, and xylene) compounds were identified in the unconsolidated deposits along the northern portion of the site and north-northwest into the low-lying area and wetlands. This area is known as Site 4. The BTEX contamination is believed to have originated from the pump of a former gasoline underground storage tank (UST) once located near the Transportation Building. Although the time over which the gasoline release occurred in the past is not known, evidence of the release was not confirmed until the suspect tank and associated pumping equipment were removed between December 1988 and January 1989 (Tetra Tech NUS 2000a).

BTEX is an acronym for benzene, toluene, ethylbenzene, and xylene, a group of volatile organic compounds found in petroleum hydrocarbons such as gasoline. These compounds were found in the groundwater in the northern section of the NWIRP Bedford site likely from gasoline released from a former UST. BTEX can dissolve in and move in groundwater, but because it sticks to soil particles, it moves slower than groundwater.

BTEX compounds contaminate the groundwater beneath the Transportation and Antennae Range Buildings of the site. The highest concentrations of these contaminants were detected during 1993 Phase II sampling in monitoring well (MW) 18, where total BTEX compounds reached 99,800 parts per billion (ppb). Concentrations of the individual constituents (benzene at 3,000 ppb, ethylbenzene at 7,800 ppb, toluene at 49,000 ppb, and total xylenes at 40,000 ppb) exceeded ATSDR's CVs for drinking water. Table 8 presents the maximum concentration of BTEX compounds detected at the site. Polycyclic aromatic hydrocarbons (PAHs) such as napthalene (up to 130 ppb) and 2-methylnapthalene (up to 38 ppb)—also constituents of gasoline—were detected in the overburden samples at concentrations above ATSDR's CV for drinking water. Findings of BTEX and PAHs together provide further evidence that the plume most likely originated from the gasoline release at the former UST. Neither BTEX constituents nor PAHs were measured in samples collected from the bedrock aquifer (Tetra Tech NUS 1999, 2000a).

The BTEX compounds were also detected in down-gradient overburden monitoring wells, so they appear to migrate northward in a narrow groundwater plume (about 50 feet wide by 720 feet long). Concentrations detected in the down-gradient wells are lower than those measured at the source area, suggesting that contaminant concentrations diminish with distance from the former release area. Total BTEX concentrations at the down-gradient wells were 51 to 6,530 ppb for MW15S and 200 to 1,400 ppb for GEI107U during supplement investigations in 1998 (Tetra Tech NUS 1999). Further down-gradient, in an area roughly estimated to be the lateral extent of the plume, benzene was detected in MW35S at 14.4 ppb and in MW36S at 1.6 ppb. Detections of BTEX compounds further down-gradient (near Elm Brook) were reported only during a 1996 sampling. During that event, benzene was estimated at 3 ppb in monitoring well ELM2 adjacent to the brook. Since then, BTEX has not been observed in that well during supplemental investigations and quarterly monitoring for the IRA system. According to all the monitoring data collected during the RI, the supplemental investigation, and quarterly monitoring events, the concentrations of the BTEX compounds in the groundwater within the overburden (shallow aquifer) have decreased over time, even though the plume's size and shape have stayed relatively the same (Tetra Tech NUS 1999, 2000a).

The Navy began evaluating an *in situ* chemical oxidation system in 2000 to address contamination in the source area at the Transportation and Antennae Range Buildings. (To further reduce contaminant source contributions, the Navy had removed an additional 35 cubic yards of contaminated soil from the former UST area and placed a liner over the area before backfilling soil.) The goal of the treatment system was to restore the groundwater beneath the site to drinking water quality; reducing BTEX concentrations in the source areas would also be expected to decrease the contamination in the groundwater plume over time. Chemical oxidation was selected because it has been shown to destroy chemicals such as those found in gasoline. The process works by injecting oxygen-containing compounds, such as hydrogen peroxide, into the ground so as to convert groundwater contaminants into harmless carbon dioxide and water.

The Navy evaluated the process in three treatment phases between November 2000 and January 2001. In total, the Navy injected over 6,000 gallons of 50% hydrogen peroxide (plus a catalyst) using 20 injectors and 9 vent wells over the extent of the source area during three separate 5-day treatment events. After the third round of injections in January 2001, only two wells remained above the interim cleanup objective of 300 ppb for BTEX, with a maximum total BTEX concentration of 1,880 ppb—a greater than 90% reduction in BTEX concentration (Krivansky et al. 2001).

The Navy reported that while the chemical oxidation treatment system had reduced contaminant levels, it had not adequately achieved the cleanup goal of 300 ppb for BTEX. As a next step, the Navy selected an *in situ* thermal treatment system using electrical resistance to further clean up the residual contamination in soil and groundwater. This time they selected a removal action goal for the source areas of 300 ppb for benzene. (Modeling conducted by the Navy indicated that a benzene concentration of 300 ppb at Site 4 would allow them to reach cleanup goals for safe drinking water in the area of the plume. This, as well as benzene's long cleanup time and low drinking water standard, is why the Navy chose benzene concentrations to indicate the thermal system's overall effectiveness.) Groundwater monitoring results indicated that by April 2004 the removal action goal had been achieved (Navy 2004).

After the thermal treatment system was used, the Navy monitored groundwater quality at 10 wells (3 in the source area and 7 down-gradient) in June 2004. This sampling showed that conditions were favorable for natural attenuation (see text box) —and that it was occurring in the area of the groundwater plume. Model analysis of the plume area predicted that, through natural attenuation, cleanup goals (drinking water standards for the individual constituents) in the area of the plume would be achieved in 20 years (Navy 2004).

Natural attenuation is the process by which naturally occurring microorganisms in the soil and groundwater help reduce chemical contaminant concentrations.

Southern Portion of the NWIRP Bedford Site

The southern portion of the site primarily consists of the SFTA. Contamination in the SFTA was identified and investigated during RI activities, in coordination with Site 3. The VOCs TCE, 1,1-DCE, and 1,2-DCE were detected in groundwater, but only TCE exceeded its current ATSDR CV of 5 ppb. The highest TCE concentrations were measured in the bedrock wells, particularly MW24R, in which concentrations reached 250 ppb in 1993. (MW24R and MW25R were not sampled in 1989.) By 1998, TCE concentrations in the bedrock had decreased, though they still exceeded ATSDR's CV. Concentrations of TCE (estimated maximum of 71 ppb in 1989) in the overburden wells, which were lower than concentrations in the bedrock wells, had also decreased by the 1998 sampling.

Groundwater contamination in the **SFTA** bedrock likely comes from sources associated with Hanscom AFB. This contamination is captured and treated by the groundwater treatment system at Hanscom Field. Groundwater contaminants beneath the SFTA are not reaching area groundwater users.

Findings of the Phase II RI in the early 1990s and of the 1990 Supplemental Investigation, show no on-site source for the chlorinated solvents in the SFTA (Tetra Tech NUS Inc. 2002). Groundwater flow in the SFTA is predominantly south and southeast, but no VOCs were detected up-gradient (and north) of well MW24R. Furthermore, lower concentrations of TCE (less than 71 ppb) were detected in the SFTA overburden. Together, these findings suggest that sources other than SFTA may be contributing to the bedrock contamination, including off-site sources associated with neighboring Hanscom Air Force Base (AFB) (Tetra Tech NUS Inc. 2001). The groundwater treatment system at Hanscom AFB has a radius of influence that includes the SFTA of the NWIRP Bedford site. Therefore, groundwater and associated contaminants from SFTA are not expected to travel north toward area production wells, Elm Brook, the Hartwell Road well field, or to private wells north or northeast of the site.

The USAF operates a groundwater extraction system on Hanscom Field that controls the migration of contaminated groundwater in the SFTA. Because the contamination is not from NWIRP Bedford operations and the USAF system is effectively controlling its migration, the

Navy has not listed SFTA as an area of concern in the FFA with the USAF (Tetra Tech NUS Inc. 2001; ATSDR 2004).

Public Health Implications of Contaminants in Off-Site Groundwater

There is no past, current, or potential future exposure to or health hazards from contaminants in groundwater via private wells. ATSDR examined whether private well owners who live near NWIRP Bedford have been or could be exposed to the contaminants in groundwater. Some residents with private wells live north or northeast of known groundwater contamination at the northern portion of NWIRP Bedford. The potential for contaminants to reach private wells from NWIRP Bedford, however, is considered to be low. Few private wells exist in the direct path of typical groundwater flow in the area and none are close enough that they are likely to be contaminated by NWIRP Bedford. The closest private drinking water well in the path of typical groundwater flow direction is approximately 700 feet from the site.

Even if contaminants reached the residential area, local residents should not come in direct contact with contaminants in private well water frequently or for long periods of time. This is because the residences are connected to the municipal water supply and the private well water is permitted for irrigation. Some residents who use these wells for irrigation may contact contaminants in the water through skin contact or incidental ingestion of water. Nonetheless, the potential exposure via this exposure pathway is expected to be limited and not of health consequence. No harmful exposures to groundwater contaminants via private wells are anticipated in the near future if the residents continue to use municipal water for consumption and household use.

C. Concern: Past Contamination of the Hartwell Road Well Field

In April 1983, the town of Bedford began operating three water wells at the Hartwell Road well field to supply the town's drinking water. The well field is less than ½ mile from the northwest corner of the NWIRP Bedford site. Sampling of the well water in October 1983 identified organic

solvents and dissolved iron at levels above current drinking water standards. Following further sampling, the town of Bedford closed the municipal well field in April 1984 and provided Bedford residents with a safe alternate water supply. The town government believed that groundwater pumped at the Hartwell Road well field had become contaminated with VOCs from NWIRP Bedford and other neighboring properties.

Residents who used water from the well field during its operation were possibly exposed to the contaminants when they drank the water or used it for other domestic purposes. ATSDR reviewed the environmental data and possible exposures to the well water for Bedford users. Through this review, ATSDR determined that no ill effects would be expected for people who used the water until the wells were closed in April 1984, a period of about 1 year. Because the town has not used the wells since 1984 and has not developed plans for future use, no exposure is occurring now or expected to occur in the future. Wells that currently supply Bedford residents with drinking water have not been affected by site releases.

Discussion

Because of closure of the Hartwell Road well field in April 1984, no exposures to contaminated groundwater have occurred since then. Past exposures were not sufficient to result in adverse health effects. A groundwater extraction system on NWIRP captures site contamination that heads north/northwestward.

Hartwell Road Well Field History

By the spring of 1983, the town of Bedford completed construction of the Hartwell Road municipal well field and treatment plant. The town intended to use the new well field as its primary water supply source and to partially replace other municipal wells lost in 1978 to industrial contamination (CDM 1984a). The new well field housed three production wells (wells 10, 11, and 12, which were completed in 1981) and was equipped with an iron and manganese treatment system. The well field is located less than ½ mile from the northwest corner of the NWIRP Bedford site (Figure 5). Water quality analyses conducted prior to startup indicated that the finished water from the well field was acceptable for public consumption and was free of VOCs (CDM 1984a, ENSR 1992). Bedford officials began operations of the treatment system in April 1983.

By October 1983—after only 6 months of operation—VOCs were discovered in a tap at the Town Hall during routine sampling, and an investigation was undertaken by the town to determine the source of the contamination. (Table 4 presents the chronological summary of monitoring activities at the Hartwell Road well field.) The investigation indicated that VOCs were present in each of the three new production wells (CDM 1984a, 1984b, 1984c), thus confirming contamination of the new Hartwell Road well field. TCE, an industrial solvent, was detected at concentrations up to 33 ppb and above ATSDR's CV of 5 ppb in one of the wells. Following the discovery of VOCs in the Hartwell Road wells, the town closed Well 11—the most contaminated well—while keeping Wells 10 and 12 online. By mid-December 1983, the town began a formal sampling program to monitor VOC concentrations in the well water (including Well 11). Through that sampling, the town detected benzene at levels up to 30 ppb. Table 5 presents the maximum concentrations of contaminants detected in the production wells.

Also in mid-December 1983, iron levels in the treatment plant's finished water began to rise. Sampling of the water at each well that month showed that most of the iron came from Well 10, which contained iron at 11,000 ppb. Iron levels in Well 10 continued to rise, jumping to a high of 31,000 ppb by early January, and then fluctuated between 25,000 ppb and 31,000 ppb through the end of the month.[2] Iron levels in Well 12 remained stable at less than 5,000 ppb during the same time period.

Iron was detected in the water from the Hartwell Road well field in the past. Iron is a naturally occurring metal that is present in all groundwater in New England to some extent. The iron discovered in the well water was predominantly in the form of ferrous iron—that is, dissolved or reduced iron. Ferrous iron tends to remain in solution until it is oxidized by either chlorine or oxygen (from bacteria), so water containing ferrous iron appears totally clear (CDM 1984a).

Because of the unacceptable iron levels in Well 10's raw water, town officials closed that well and kept only Well 12 in operation. Well 12 continued to produce up to 260 gallons per minute of raw water into the treatment system. Then, in March 1984, elevated benzene concentrations (7

ppb) began to show up in samples of finished water from Well 12 (CDM 1984c, ENSR 1992). Town officials shut down the entire well field on April 3, 1984; they ultimately came to rely on MWRA water via the town of Lexington, and to a lesser extent on the Shawsheen well field, for public drinking water (CDM 1984c).

Groundwater Monitoring

Hartwell Road Well Field

Environmental investigations conducted in 1984 by the town of Bedford found VOCs and iron in the groundwater in the area of the Hartwell Road well field. The well field is located in a complex aquifer made up of five geologic units: the upper aquifer, the middle silt layer, the lower aquifer, the glacial till layer, and the bedrock. The primary water-bearing units are the upper and lower aquifers, which are thickest at the well field and thin out in all directions with distance from the wells. In fact, the lower aquifer is only 800 feet wide within the well field area, disappears to the west, east, and south, and does not appear to extend to Elm Brook (CDM 1984c). Under non-operating conditions, groundwater typically did not flow from the upper aquifer to the lower aquifer beneath the well field (CDM 1984c). In contrast, when the wells were pumping, groundwater leaked through the middle silt layer to the lower aquifer and the groundwater flow in the lower aquifer was diverted to the Hartwell Road well field production wells from its natural flow path toward the Elm Brook (CDM 1984c).

VOCs were discovered in the groundwater within the well field, but only in the lower aquifer. They included benzene, 1,1- DCE, trans1,2-DCE, TCE, 1,1,2,2-tetrachloroethylene, and toluene. Table 6 presents the maximum concentration of contaminants detected above ATSDR's CV. Of the VOCs detected, benzene, TCE, and 1,1-DCE appeared most consistently and in the highest concentrations (CDM 1984c). Apparently, the contamination was drawn into the Hartwell Road well field from an off-site location when the wells were pumping. The contaminants likely

[2] Water quality results from early pump tests in October 1980 showed iron concentrations at only 3 ppm. Iron up to 50 ppb was detected in Well 11, which was closed at the time of detection.

entered the lower aquifer from either solvents that had moved along the glacial sediment from a nearby source or that had traveled within the fractured bedrock zone from an undetermined location. In either case, the sources were believed to be from properties located south-southeast of the well field (CDM 1984c).

In addition to VOCs, elevated concentrations of iron were widespread in both the upper and lower aquifers within the well field (CDM 1984c). The highest detected iron concentrations (up to 310,000 ppb) were more than 40 times higher than background concentrations (430 to 7,200 ppb) typical for the area and higher than the secondary MCL (level based on taste and other nonhealth-based parameters) for iron in drinking water of 300,000 ppb (Table 6). The study indicated that the iron in the groundwater likely originated from minerals in soil, and reached high concentrations because of chemical and biological reactions brought about by low pH conditions and high levels of sulfate (possibly from a sulfuric acid release to the west of Hartwell Road) (CDM 1984c).

NWIRP Bedford

The results gathered from the RI sampling identified that solvents and metals had contaminated the groundwater beneath the site. The principal contaminants were benzene, TCE, PCE, and 1,2-DCE. Information on VOC contamination at the site is discussed in section III.B above.

Iron concentrations at NWIRP Bedford were detected at concentrations up to 2,840 ppb in a shallow groundwater well (MW11) located near the Facility Storage Building and up to 225 ppb in a deep (bedrock) groundwater well (MW2) situated near the Antenna Range Building (Dames & Moore Inc. 1992a, b). The levels still are well below the maximum concentration detected at the off-site Hartwell Road well field of 31,000 ppb and within the range of values typically observed in the groundwater for the Bedford area (430 ppb to 7,200 ppb) (CDM 1984a).

Following the RI, the town of Bedford came to the conclusion that groundwater pumped at the Hartwell Road well field had become contaminated with VOCs that originated from the NWIRP

Bedford site and other neighboring properties (Dames & Moore Inc. 1992a). The town of Bedford then filed a civil action naming the Raytheon Company, Massachusetts Port Authority (operators of the Hanscom Field), the USAF, and the Navy as defendants with regard to contamination of Hartwell Road well field (Dames & Moore Inc. 1992a).

The Navy has conducted many investigations at NWIRP Bedford to characterize the hydrogeology and nature and extent of groundwater contamination at the site: the Phase I RI in 1989, the 1990 Supplemental Investigation, the 1992–1993 Phase II RI, the 1997 Environmental Baseline Survey, the 1998 Former Underground Storage Tank (UST) Assessment, the 1998 Supplemental Investigation for the SFTA, and the September 2000 Final Report for the Phase II RI for NWIRP. These investigations have not tied past Hartwell Road well field contamination with activities at the NWIRP Bedford site.

Public Health Implications of VOCs and Dissolved Iron in the Hartwell Road Well Field

There are no public health hazards from past exposure to contaminants in the Hartwell Road well field. Sampling in 1983 and 1984 found VOCs and iron in the municipal water supply wells at the Hartwell Road well field, which served the town of Bedford in the past. The contaminants benzene, TCE, and dissolved iron exceeded ATSDR comparison values. Surrounding properties including NWIRP Bedford might have contributed to the contamination in the affected wells, even though environmental investigations have not directly linked the contamination to the Navy site. Regardless of the source, ATSDR examined the possibility of harmful effects on people who used water from the well field in the past. Exposure to VOCs could have occurred when residents drank the water or used the water for other domestic purposes (e.g., showering) between the time the well field was opened (April 1983) and when it was closed (April 1984)—approximately 1 year. ***No exposure has occurred since April 1984.*** Bedford residents have since received most of their drinking water from the MWRA via the town of Lexington. ATSDR focused its public health evaluation, therefore, on possible *past* exposures to contaminants in the Hartwell Road well field.

Past Exposure to TCE, Benzene, and Dissolved Iron in Drinking Water

ATSDR estimated the potential exposure dose for adults and children who drank water originating from the Hartwell Road well field to determine if a health hazard existed. ATSDR estimated doses for exposure to the contaminants that exceeded CVs or other screening values: benzene, TCE, and dissolved iron. In deriving human exposure doses, ATSDR incorporated information about the frequency and duration of potential contaminant exposure. For example, because it is not known when VOCs first reached the Hartwell Road wells, ATSDR used an exposure period of 1 year (the full amount of time the well field was operating) for adults and children to calculate a *theoretical* maximum exposure dose. To be protective, ATSDR also assumed that all drinking water pumped to residential taps contained the highest detected concentrations of benzene, TCE, and dissolved iron measured in the affected wells. ATSDR recognizes that, in most exposure situations, a person is unlikely to be continuously exposed to the highest concentration detected over time. ATSDR's approach is a conservative way to evaluate whether a contaminant is likely to pose a health concern. Appendix C describes ATSDR's approach in detail.

ATSDR compared the estimated exposure doses with standard health guidelines, such as ATSDR's oral minimal risk levels (MRLs) and EPA's reference doses (RfDs), if available. The MRLs and RfDs provide a protective estimate of daily exposures to noncancer agents that are not likely to result in adverse health effects, even for the most sensitive members of a community (e.g., pregnant women, children). The estimated exposure doses for ingestion of water from the Hartwell Road well field are provided in Appendix C, Table C-1.

Estimated exposure doses for adults and children are below MRLs/RfDs or several times lower than the levels at which adverse effects were observed in laboratory animal studies. Current toxicological literature suggests that the detected levels of TCE and benzene are also below levels thought to cause cancer via the oral route of exposure (ATSDR 1997a, 1997b). *Considering this information, exposure to detected levels of contaminants from past ingestion of*

drinking water from the Hartwell Road well field are not expected to cause adverse health effects.

Past Exposure From Breathing in VOCs Released From Household Use

Vapors, from water contaminated with detected levels of VOCs, might be released during normal household use, such as washing and bathing. The primary route for VOCs to enter the body is through inhalation of contaminated air. Persons who drank water from the Hartwell Road well field between April 1983 and April 1984 in the past, therefore, might have been additionally exposed to VOCs when they used the municipal water for household purposes. Some information suggests that the highest level of inhalation exposure to VOCs in the home occurs during showering (Lindstrom 1994). Consequently, ATSDR assessed exposures to VOCs moving from the water to air during showering. To be protective, ATSDR used a screening-level model to predict air concentrations based on the maximum detected VOCs in water. ATSDR also assumed that 100% of the VOCs volitalized to air and that no dissipation occurred. ATSDR's assumptions and methods, as well as the estimated doses, are further described in Appendix C. *Using these assumptions, ATSDR found no evidence that VOCs would reach levels in indoor air associated with adverse health effects from breathing in contaminants released during washing and bathing.*

D. Concern: Contamination Reaching Elm Brook

NWIRP Bedford is located in the Shawsheen River surface water drainage basin. While no surface water body flows through the site, Elm Brook runs within 300 to 600 feet north of the site's northern boundary. Relatively low concentrations of contaminants from NWIRP Bedford have reached the surface water and sediment of the brook. Even so, no public health hazards are expected from limited past, current, or future contact with the levels of contaminants measured in this brook. Elm Brook is not known to be used for drinking water or widely used for recreation, and the levels of contaminants in the brook are too low to harm people who might come in contact with the brook infrequently or for brief periods of time. The already low

concentrations of contaminants are expected to further decrease before the water reaches the downstream Shawsheen River.

Discussion

Elm Brook Hydrology

NWIRP Bedford sits in the drainage basin of the Shawsheen River. The site does not contain any natural surface water bodies. The closest water body to the site is Elm Brook, which flows within 300 to 600 feet of the northern boundary of NWIRP Bedford. Elm Brook flows year-round, but is greatly diminished in the warmer months. No surface water runoff from the NWIRP Bedford is believed to reach the brook or the Shawsheen River directly, because the area northwest, north, and east of the site is dominated by wetlands (Roger, Golden, & Halpern 1986). These extensive wetlands likely intercept any surface water runoff from the site before it can reach the brook. Groundwater at NWIRP Bedford migrates radially off the Hartwell Hill toward the surrounding wetland area. In the immediate area of NWIRP Bedford, groundwater in the till layer (shallow aquifer) discharges to Elm Brook, and possibly also to the Shawsheen River (Roger, Golden, & Halpern 1986). Elm Brook eventually flows into the Shawsheen River, about 1.4 miles to the east of the NWIRP Bedford site. The river is used for recreational activities and drinking water for the town of Burlington (e.g., fishing and boating), although not typically for swimming.

Surface Water and Sediment Monitoring Data

Surface Water Data

During the RI activities, the Navy collected four surface samples from Elm Brook and one sample from the drainage ditch in the SFTA that feeds into Elm Brook. All of the samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), and metals using EPA's methodology. One sample was also analyzed for cyanide, pesticides, and PCBs (Tetra Tech NUS Inc. 2000a, 2000b).

Table 7 presents the range of contaminant concentrations in surface water that exceed ATSDR's CVs. Most contaminants were either not detected or detected at levels below health screening values. Only TCE and arsenic were found at concentrations above their CVs. TCE was discovered in two of the five samples at estimated concentrations of 1 ppb and 7 ppb, with the highest concentration reported for the sample taken from the drainage ditch. Arsenic was consistently detected in all five samples at concentrations between 3 and 5.2 ppb—but below the arsenic CV for drinking water of 10 ppb.

Sediment Data

The Navy collected seven sediment samples from the top 5 inches of Elm Brook substrate and one sample from the SFTA drainage ditch during the 1992 RI. All of the samples were analyzed for VOCs, SVOCs, and metals using EPA methodology. One sample was also analyzed for cyanide, pesticides, and PCBs (Tetra Tech NUS Inc. 2000a, 2000b).

Of the contaminants assessed in the sediment, only arsenic and the SVOC benzo(a)pyrene were detected at concentrations above their CVs for soil. As Table 7 shows, the highest arsenic concentration (47.4 ppm, above ATSDR's CV of 20 ppm for arsenic in soil) was measured in the sample collected from the drainage ditch. Arsenic concentrations in other samples collected along the brook were lower (ranging from 3.9 ppm to 35.7 ppm), but some samples were still above ATSDR's CV for arsenic in soil.

Public Health Implications of Contaminants in Elm Brook Surface Water and Sediment

No public health hazards are associated with past, current, or future exposure to contaminants from NWIRP Bedford that have reached Elm Brook. Although VOCs, metals, and SVOCs have been detected at levels above ATSDR's CVs in the surface water or sediment of Elm Brook that flows near NWIRP Bedford, people are not expected to come in contact with harmful levels of these contaminants. Nothing indicates that people use or will use Elm Brook in ways that would result in appreciable skin contact with surface water or sediment. Any skin contact with

contaminants in surface water or sediment is expected to be limited in frequency and duration, and not of health consequence. Furthermore, the Navy has taken and continues to take measures to prevent groundwater contaminants at the NWIRP Bedford site from reaching the brook. Natural processes, such as dilution and mixing, would likely further reduce concentrations of any migrating contaminants before they reach the Shawsheen River, thus precluding the buildup of harmful levels of site-related contaminants in Shawsheen River surface water, sediment, or fish. ATSDR does not expect incidental exposure to contaminants in surface water and sediment to pose a public health hazard.

E. Concern: Vapor Intrusion From Groundwater Plumes Beneath On-Site Buildings

Groundwater beneath certain sections of the NWIRP Bedford site is contaminated with VOCs. Under some conditions, the VOCs can travel up from the groundwater, through the soils, and into the air of buildings. People in affected buildings could then breathe in air containing VOCs. However, no indoor air sampling has been conducted to determine whether contaminants associated with the groundwater plumes have entered the buildings and adversely affected indoor air quality.

Many of the buildings at the NWIRP Bedford site were used for industrial processes or storage. Even so, ATSDR estimated indoor air concentrations for vapor intrusion above or near the highest levels of groundwater contamination. The estimated maximum indoor air level of VOCs is much lower than the level at which we would expect to see adverse health effects. Therefore, contaminants associated with groundwater plumes probably did not seep into and accumulate to harmful levels inside NWIRP Bedford buildings located above groundwater contamination.

Discussion

NWIRP Bedford Groundwater Contamination

As discussed in a previous section, Section III.B., contamination is present in groundwater at discontinuous, isolated locations beneath the NWRIP Bedford site. The groundwater contamination contains mostly VOCs, with the highest concentrations discovered in the shallow groundwater next to the former Print Shop within the Factory Storage Building, where TCE, benzene, and 1,1-DCE concentrations reached 2,300 ppb, 75 ppb, and 1,200 ppb, respectively. Lower VOC concentrations (up to 210 ppb for TCE and nondetect for benzene) were discovered in the shallow groundwater just down-gradient of the Old Incinerators Ash Disposal piles. No VOCs were detected in the bedrock aquifer at either the Print Shop or the Old Incinerators Ash Disposal piles (Dames & Moore Inc. 1992a, b).

More widespread VOC contamination—but with far lower contaminant concentrations—was observed at the northeast and southern corners of the Components Laboratory. At these locations, VOCs were measured in both the shallow and deep groundwater aquifer. The contaminants likely came from the paint shop in the northeastern corner of the Components Laboratory, about 200 feet from MW5.

Public Health Implications of Exposures to Estimated Indoor Air Contaminants

No public health hazards associated with exposure from contaminants seeping into on-site buildings likely existed in the past. The groundwater beneath NWIRP Bedford is contaminated with VOCs, which can move from the groundwater through soil, and eventually seep into basements and affect the indoor air. If this occurred, people could have been exposed to contaminants in the air inside the on-site buildings.

Indoor air sampling data are not available for buildings at the NWIRP Bedford site above the VOC groundwater contamination. ATSDR, therefore, applied EPA's Johnson and Ettinger

(1991) model to estimate indoor air concentration. The model is a *screening-level* model that estimates the transport of contaminated vapors from either subsurface soils or groundwater into the spaces directly above the source of contamination (EPA 2003).

ATSDR estimated indoor air concentrations for benzene, TCE, and 1,1-DCE from vapor intrusion. ATSDR selected these three contaminants for review because they were detected frequently in the groundwater beneath the site in high concentrations. ATSDR then compared the concentrations to health based screening values, such as inhalation MRLs, and to information in the toxicological literature to determine whether indoor air contaminants could be associated with any adverse health effects. An estimated indoor air concentration less than the inhalation MRL is not expected to cause adverse health effects. Table C-5 lists the estimated indoor air concentrations for benzene, TCE, and 1,1-DCE, along with available health-based screening values.

ATSDR estimated benzene, TCE, and 1,1-DCE indoor air concentrations at 11.54 ppb, 8.5 ppb, and 24 ppb, respectively, based on the highest detected groundwater concentrations. The estimated exposure concentrations are lower than their intermediate inhalation MRLs or levels at which health effects have been reported. In fact, the estimated indoor air concentrations are more than 200 to 1,000 times lower than levels shown to elicit adverse health (ATSDR 1996, 1997a; EPA 2003b).

IV. Community Health Concerns

Throughout the PHA process, ATSDR gathers information about community health concerns. At the NWIRP Bedford site, ATSDR inquired about concerns through meetings with state, local, and Navy officials and review of site documents, including the Community Relations Plan (CRP). The CRP provides guidance for involving the community and other interested parties in the remedial decision-making process and for distributing information to these parties (Halliburton NUS 1992). While preparing the CRP, the Navy interviewed community members who are or potentially are affected by contamination at NWIRP Bedford. As part of its community relations activities, the Navy formed a restoration advisory board (RAB). The RAB, which is represented largely by local community members, meets to periodically review site documents and comment on actions and proposed actions taken by NWIRP Bedford.

No specific health concerns have been brought to ATSDR's attention, although general concerns about potential health hazards associated with the site and off-site migration of contaminants are identified in the CRP. ATSDR addresses these concerns in the "Evaluation of Environmental Contamination and Potential Exposure Pathways" section of this PHA.

V. 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 greater risk than adults from certain exposures to hazardous substances emitted from waste sites and emergency events involving hazardous chemicals. In general, children are more likely to be exposed because they play outdoors, have more hand-to-mouth behavior, and often bring food into contaminated areas. They are shorter than adults, which means they breathe dust, soil, and heavy vapors that are close to the ground. Children are also smaller, so they receive higher doses of chemical exposure proportional to their body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care.

ATSDR has attempted to identify populations of children in the vicinity of NWIRP Bedford and any public health hazards associated with NWIRP Bedford that have or could threaten these children. According to U.S. census data, about 395 children aged 6 and under live within 1 mile of the site. ATSDR determined, however, that no harmful exposures to children living in the area have occurred in the past, nor are they expected to occur now or in the future. Although contaminants have been detected at NWIRP Bedford site, children cannot access the site or locations of contamination at NWIRP Bedford and no harmful exposures associated with the site are specific to children in the vicinity of the site. Children could visit Elm Brook, adjacent to and downgradient of the NWIRP Bedford site. Contaminants that have entered the surface water and sediment of the brook are low and below levels that could cause harmful health effects for these children. (Exposure pathways are discussed in the “Evaluation of Contamination and Exposure Pathways” section of this public health assessment.)

VI. Conclusions

Conclusions regarding potential past, current, and future exposure situations on and in the communities near NWIRP Bedford are based on an evaluation of site investigation data and observations made during site visits. Conclusions about exposures are described below. (The public health hazard conclusion categories are described in the glossary.)

- **Contaminated groundwater and private well use.** Contaminants have leached into the groundwater beneath NWIRP Bedford. Some contaminants have migrated with groundwater flow north of the site. There are thirteen residences within half a mile east/northeast of NWIRP Bedford which have private wells. These wells are permitted for irrigation and the residences are connected to Bedford's municipal water supply. Because contaminant levels are being reduced and nearby households are connected to the municipal water supply, we do not anticipate future public health hazards. ATSDR recommends that residents continue to use municipal water for household uses due to multiple sources of area groundwater contamination. ATSDR concludes that there is *no past, current, or future apparent public health hazard* associated with groundwater contamination from NWIRP Bedford and local private well use.

- **Contaminants in drinking water from the Hartwell Road well field in 1983 through 1984.** VOCs and iron were detected in the Hartwell Road well field, which supplied the town of Bedford with drinking water between 1983 and 1984. The amount of contaminants detected in the wells would not be expected to cause illness or health effects for people who drank water from the wells in the past. This past exposure, occurring during the short time period of well operation, posed *no apparent public health hazard.* Information indicates that other, non–NWIRP Bedford sources may be partially or primarily responsible for the contamination. The town of Bedford has supplied the residents with an alternate water supply since 1984. Because no exposures are currently occurring or are likely to occur in the future, there is *no apparent public health hazard.*

- **Contaminants in Elm Brook near NWIRP Bedford**. NWIRP Bedford contaminants have reached Elm Brook, a small, shallow stream that runs within 300 to 600 feet of the site's northern boundary. Elm Brook is not used for drinking water or widely used for recreation. Incidental exposures (via dermal contact) during occasional visits to the brook are the only types of exposures that likely occur. Given this, it is not expected that people would come in contact with contaminants in Elm Brook surface water and sediment often enough or at high enough levels for a health concern to exist. The already relatively low contaminant concentrations are expected to further decrease before the water reaches the downstream Shawsheen River. Thus, past, current, and future exposures pose *no apparent public health hazard.*

- **Possible vapors from on-site groundwater plumes.** Some buildings at NWIRP Bedford sit above groundwater contamination released from former site activities. Conservative indoor modeling showed that VOC contaminants could be present in the air inside of certain buildings, but at levels below those associated with known adverse health effects. Therefore, ATSDR believes that people who worked in or visited buildings above on-site groundwater contamination did not encounter harmful levels of indoor air contaminants. Given these findings, ATSDR concludes that there is *no apparent past public health hazard* associated with vapor intrusion. Since the buildings are now closed, no public health hazard is occurring.

VII. Recommendations

Its assessment of environmental data and potential exposure scenarios leads ATSDR to make the following recommendations:

1. If new information becomes available suggesting exposure at levels of health concern from contamination at NWIRP Bedford, ATSDR will evaluate the data and make appropriate public health recommendations.

2. ATSDR recommends water quality testing and treating the affected groundwater to safe levels required by EPA and MADEP before restoring the Hartwell Well Field to public use. *Note that ATSDR has verified with the Bedford Department of Public Works that the Town of Bedford currently plans to continue its use of water from the Massachusetts Water Resources Authority. However, the town of Bedford, under agreement with the Massachusetts Water Resources Authority, plans to continue considering this aquifer for future use as a public water supply. ATSDR was assured that, before the wells are put back into production, a complete chemical analysis of the water will be conducted to ensure that the water, treated if necessary, will meet all Safe Drinking Water requirements set by EPA and will be safe for human consumption.*

3. Due to multiple sources of groundwater contamination in the area, ATSDR recommends, as a prudent public health action, that private wells not be used for drinking water or other household uses and residents continue to use municipal water.

VIII. Public Health Action Plan

The public health action plan (PHAP) for NWIRP Bedford describes actions taken and to be taken by the Navy, ATSDR, EPA, MADEP, and the town of Bedford at and in the vicinity of the site once this PHA is completed. The purpose of the PHAP is to ensure that this PHA not only identifies potential and ongoing 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. The public health actions that are completed, ongoing/planned, or recommended are as follows.

Completed Actions

1. The town of Bedford closed wells at the Hartwell Road well field, located less than ½ mile northwest of NWIRP Bedford, in 1984 after elevated levels of VOCs and dissolved iron were detected in three of the water supply wells following a few months of operation.

2. A town of Bedford investigation determined that NWIRP Bedford and Hanscom Air Force Base were potential contributors to the groundwater contamination in the area.

3. Partly in response to the contamination in the municipal wells, the Navy began an investigation of the site in 1986 to identify possible contaminant sources. That investigation—and subsequent Navy investigations—did confirm the presence of contamination at NWIRP Bedford. Through the various investigations, the Navy identified and investigated four IRP sites. The Navy also investigated the SFTA under Site 3's RI activities. To date, the Navy has collected no data that confirm that NWIRP Bedford contributed to the Hartwell Road well water contamination.

4. EPA placed NWIRP Bedford on the NPL on February 2, 2000.

5. The town of Bedford has designated the aquifer beneath NWIRP Bedford an aquifer protection district. This is the most protective classification; the aquifer earns this designation because of its high use values as a potential drinking water source area.

6. The Navy has undertaken measures to reduce the sources of contamination at NWIRP Bedford. These measures include implementation of an immediate response action (formerly known as a short term measure investigation) that used a groundwater extraction and treatment system at Site 3 to remove chlorinated volatile organic

contaminants and metals. Additional measures include removal of a 7,600-gallon UST and 75 to 100 cubic yards of contaminated soil at Site 4 as well as removal of a fuel oil tank at Site 2.

7. The Navy has recommended Site 1 and Site 2 for no further action because they pose no risk to human health or they have been remediated to cleanup standards. No further action RODs were signed for these sites in September 2000.

8. ATSDR visited NWIRP Bedford in July 2003 to tour the site, meet with site representatives, and gather environmental and exposure information to complete this public health assessment.

Ongoing and Planned Actions

1. The Navy continues to construct a thermal treatment system as part of a pilot study at Site 3. This study's goal is to reduce the total chlorinated VOCs in the groundwater by 95% to 99% within the pilot test area on site. The Navy will monitor the groundwater during the treatment phase, and then again (possibly at 90 days and 150 days) after treatment.

2. The Navy plans to use the thermal treatment process to accelerate cleanup at Site 4 to reduce benzene concentrations in groundwater to 50 ppb in the area of highest contamination.

3. The Navy has agreed to conduct semi-annual groundwater monitoring of the SFTA.

4. The USAF operates a groundwater extraction system on Hanscom Field, near the SFTA. The system controls the migration of contaminated groundwater in the SFTA. (The suspected source of contamination is located on Hansom Field and is probably associated with HAFB activities, not the NWIRP Bedford site. Because the NWIRP site is not the suspect source of SFTA contamination and the USAF system is controlling the contaminant migration, the SFTA is not listed as an area of concern in the FFA. It is still included in the site's management plan.)

5. The Navy will pursue an agreement with the USAF to ensure the ongoing operation of the groundwater treatment system at Hanscom Field until groundwater contamination at the SFTA is fully addressed.

6. The Navy will continue to operate, maintain, monitor, and if necessary modify, the remedies for Sites 3 and 4 in accordance with the RODs and all other relevant US EPA, MA DEP and Navy decision documents.

7. Institutional controls should be implemented preventing private or public use of groundwater beneath NWIRP until site remediation is complete and the regulatory agencies have deemed the water safe for drinking.

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Tables

Table 1. Evaluation of Public Potential Health Hazards at NWIRP Bedford

Site	Site Description/Waste Disposal History	Investigation Results/Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Site 1 **Old Incinerator Ash Disposal Area**	Site 1 is located at the northern edge of the site, near the Facility Storage Building. The site housed an incinerator that was used for 19 years to destroy paint and film used at the site. Incineration of these materials over time produced about 2 pounds of silver, 320 pounds of zinc, 570 pounds of lead, and 190 pounds of chromium.	**Groundwater:** Metals were detected but at levels below ATSDR comparison values (CVs). **Soil:** Metals were detected, but at levels below ATSDR CVs. **Surface Water:** Concentrations of cadmium, copper, lead, and zinc were found to be higher than Ambient Water Quality Standards.	The site was investigated during a 1989 Phase I remedial investigation (RI) and site investigation and a 199X Phase II RI. The Phase II report concluded that no further characterization was needed and that a feasibility study should be performed to identify clean-up options.	Based on a review of site data and potential exposure scenarios, ATSDR anticipates no potential public health hazards at this site. The public has limited or no access and measures have been taken to reduce contaminant concentrations.

Site	Site Description/Waste Disposal History	Investigation Results/Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Site 2 **Components Laboratory Fuel Tank**	Site 2 is located at the northeast corner of the Components Laboratory. The site housed a 20,000-gallon tank that supplied No. 6 fuel oil to boilers from 1953 to 1982. In 1982, the Navy drained and cleaned the tank and then installed an oil/water (o/w) separator. Oil and water from the separator was allowed to percolate through the soil. In 1989, the tank and about 50-75 cubic yards of contaminated soil were removed.	**Groundwater:** The VOCs TCE (up to 110 ppb), 1,1-dichloroethane (1,1-DCA) (up to 14 ppb), 1,2-DCA (1,2-dichloroethane) (up to 44 ppb), 1,1-DCE (28 ppb), methylene chloride (up to 10 ppb), and tetrachloroethylene (PCE) (up to 11 ppb) were detected in the groundwater in the area of the Components Laboratory. **Soil:** Total petroleum hydrocarbons were detected. **Surface Water:** Metals were detected. **Sediment**: SVOCs and metals (lead, nickel, zinc) were detected.	Actions to remove contaminated material began in early 1989 and included removal of the tank and about 50-75 cubic yards of contaminated soil. The Phase II report concluded that no further characterization was needed and that a feasibility study should be performed to identify clean-up options.	Based on a review of site data and potential exposure scenarios, ATSDR anticipates no potential public health hazards. The public had limited to no access to the contaminated subsurface soil in the past and the contaminated subsurface soil has since been removed. At the time of the ROD in 1997, none of the constituents of the plume were migrating off base at levels above the CVs, nor are they expected to in the future. Groundwater monitoring will be used to ensure that the natural attenuation is reducing the contaminant concentrations and preventing off-site migration.

Site	Site Description/Waste Disposal History	Investigation Results/Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Site 3 **Chlorinated Solvent Area**	Site 3 is a chlorinated VOC groundwater plume located at the northern portion of the activity near the Facility Storage Building and the Components Laboratory. A dissolved-phase plume (known as the northwest plume) migrates from a subsurface dense non-aqueous phase liquids (DNAPLs) source area in a northwesterly direction across the site and into an off-site wetland. Another VOC plume of lower concentrations migrates easterly from the source area toward the eastern and northeastern boundary of the site. This plume is called the eastern plume. A 1979 Raytheon memo documents a spill at the site, releasing 1,1,1 trichloroethane (1,1,1-TCA). This spill may have contributed to the plumes. Potential sources of 1,1,1-TCA included the Components Laboratory, the Facility Storage Building print shop, a storm drain, the Antenna Range, the Transportation Building, AMRAD building, and the Hazardous waste storage area, and the Old Incinerator.	**Groundwater:** VOCs were detected in the groundwater at several locations at this site at levels above ATSDR CVs. **Surface Water:** TCE was detected at a maximum concentration of 7 ppb, and just above ATSDR's CV, in samples collected from Elm Brook.	The site was investigated under the 1990-1991 Phase I and 1992-93 Phase II RI investigations. The Navy initiated an immediate response action (IRA) after 1989 field studies indicated the plumes were migrating from Hartwell's Hill toward Elm Brook. The IRA consisted of an extraction and treatment system designed to remove naturally-occurring metals and chlorinated VOCs via granular activated carbon. The Navy has operated the groundwater treatment system since 1997, and they monitor performance quarterly. The RI Phase II recommended a feasibility study for this site. The Navy conducted a Pilot Study Area Characterization in February 2002. Results of the study indicated that the product was not encountered and that chemical concentrations were highest in the sandy till unit in the central portion of the study area north of the Components Laboratory. The Navy submitted a draft work plan for the Pilot Study in September 2002. The Pilot Study will attempt to achieve 95-99% reduction of total chlorinated VOCs in the pilot test area via electrical resistive heating. (ERH)	Based on a review of site data and potential exposure scenarios, no potential public health hazards are expected at this site. The public has had limited access to the site and the underlying groundwater is not used as a source of drinking water.

Site	Site Description/Waste Disposal History	Investigation Results/Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Site 4 **BTEX Groundwater Plume**	Site 4 is a plume containing benzene, toluene, ethylbenzene, and xylenes (BTEX) associated with a release (prior to 1984) from a 7,600-gallon underground storage tank (UST). The tank was located south of the Transportation Building from 1960 through 1984. The BTEX plume at Site 4 has migrated north, down Hartwell's Hill.	**Groundwater**: BTEX compounds were detected in groundwater at concentrations exceeding ATSDR CVs. **Soil**: BTEX compounds were detected in soil at a maximum concentration of 35 ppm.	Site 4 was identified during the Phase II RI investigations. The UST and associated contaminated soil were removed in 1988 and 1989. The Navv used in-situ chemical oxidation with Fenton's reagent to remediate the contamination. The process was effective at most wells, except one well that failed to meet the cleanup goal of 300 ppb for benzene. To supplement the cleanup process, the Navy will use the ERH thermal treatment process to achieve a reduction of benzene concentrations in groundwater to 50 ppb or below in the maximum contaminated areas.	Based on a review of site data and potential exposure scenarios, ATSDR anticipates no potential public health hazards at Site 4. The public has limited access to in soil, and no drinking water wells are located at this site.

Site	Site Description/Waste Disposal History	Investigation Results/Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Southern Flight Test Area	The Southern Flight Test Area (SFTA) is located on the southern portion of the NWIRP Bedford site, and borders the northern portion of Hanscom Field. The SFTA was primarily used to flight test prototype models at the Flight Test Facility. The SFTA also housed the Old Hanger, the Plating Laboratory, the Lark Building (for the former NWIRP Bedford publications Department), and the Van Duesen Building (for storage of Hawk missile equipment). VOCs were detected in groundwater near the Old Hangar.	**Groundwater**: Monitoring since 1989 has shown VOCs, primarily TCE, at levels up to 250 ppb in the overburden and bedrock groundwater beneath the site. These levels exceed ATSDR CVs. **Soil**: Semi-volatile organic compounds (SVOCs) were detected at concentrations up to 1.8 ppb for di-n-butylphthalate.	The SFTA was investigated through the 1990 Phase I Supplemental Investigation and the RI. Hanscom Air Force Base began operating a groundwater extraction and treatment system near the SFTA since 1991. The system was designed to treat and control contamination in groundwater migrating from three sites at Hanscom Field and Hanscom Air Force Base. The Navy agreed to conduct semi-annual groundwater monitoring groundwater at SFTA.	Based on a review of site data and potential exposure scenarios, ATSDR anticipates no potential public health hazards at the SFTA. The public has limited access to the contaminants in soil and no drinking water wells are located at this part of the activity.

Sources: ENSR 2003; Tetra Tech NUS Inc. 2001, 2002.

Key:

BTEX	benzene, toluene, ethylbenzene, and xylenes	ppm	parts per million
CV	ATSDR's comparison value	RI	remedial investigation
1,2-DCA	1,2-dichloroethane	SFTA	Southern Flight Test Area
1,2-DCE	1,2-dichloroethene	SVOCs	semivolatile organic compounds
IRA	immediate response action	1,1,1-TCA	1,1,1-trichloroethane
o/w	oil water separator	TCE	trichloroethylene
PCE	tetrachloroethylene	VOCs	volatile organic compounds
ppb	parts per billion		

Table 2. Evaluation of Exposure Pathways at NWIRP Bedford

Pathway	Elements of an Exposure Pathway						Comment
	Source	**Media**	**Point of Exposure**	**Route of Exposure**	**Time Frame**	**Exposed Population**	
Completed Exposure Pathways							
Off-Site Groundwater: Municipal Well Water Use Exposure to VOCs and dissolved iron in the former Hartwell Road well field that served the town of Bedford between 1983 and 1984	Former NWIRP Bedford activities	Groundwater	Bedford municipal taps	Ingestion, dermal contact, and inhalation	Past (1983-1984)	Bedford municipal water supply users	*Past:* The former Hartwell Road well field located northwest of the NWIRP site contained VOCs and iron above ATSDR's CV and EPA's MCL during the first few months of operation in 1983-1984. Exposure occurred, but not likely at levels of health concern. The well field was closed in 1984 and Bedford residents have since been provided with an alternate source of water. *Current and Future:* No current or future exposures are expected as the Hartwell Road well field remains closed and Bedford residents continue to rely on other sources of drinking water that routine tests show is safe to drink.
Potential Exposure Pathways							
Off-Site Groundwater Private Well	Former NWIRP Bedford activities	Groundwater	Bedford private well taps	Incidental ingestion and skin contact	Past Current Future	Private well owners located near NWIRP Bedford	*Past, Current, and Future:* Local private wells are not likely used for drinking water because the residences are connected to the municipal water supply. Some private wells may be used for irrigation. The limited exposure associated with this type of use is not expected to cause health effects.

Pathway	Elements of an Exposure Pathway						Comment
	Source	**Media**	**Point of Exposure**	**Route of Exposure**	**Time Frame**	**Exposed Population**	
Surface Water at Elm Brook Exposure of visitors to contaminants in Elm Brook surface water	Former NWIRP Bedford activities	Surface water	Elm Brook	Dermal Contact	Past Current Future	Visitors to Elm Brook	*Past, Current, and Future:* Low levels of contaminants were detected in Elm Brook surface water and sediment. People may have contacted or continue to contact these contaminants. The low levels of contaminants and type of exposure would not be expected to cause harm to visitors to the brook.
Indoor Air Exposure to vapors possibly inside buildings above groundwater plume	Organic compounds in the groundwater plumes that possibly volatilized and seeped into buildings at NWIRP Bedford	Indoor air	NWIRP Buildings	Inhalation	Past	Occupants of NWIRP Bedford buildings	*Past, Current, Future:* Some on-site buildings sit above or near groundwater plumes at NWIRP Bedford. Modeling predicts that the contaminants could enter the buildings, but at levels generally lower than those associated with adverse health effects.

Table 3. Maximum Contaminant Concentration in Groundwater at NWIRP Bedford

Contaminant	Concentration (ppb)*	Comparison Value (ppb)
Benzene	75	0.6 CREG†
Trichloroethylene	2,300	5 MCL‡
Iron	ND	300 Secondary MCL

* parts per billion
† ATSDR's cancer risk evaluation guide
‡ EPA's maximum contaminant level
ND=not detected

Table 4. Chronological Summary of Monitoring Activities at the Hartwell Road Well Field

Date	Activity
Summer and Fall 1981	Construction of three production wells at the Hartwell Road well field is completed. The wells 10, 11, and 12 were constructed as the primary water supply for the town and as a partial replacement for other municipal wells (Wells 3, 7, 8, and 9) lost due to industrial contamination.
	A 24-hour pump test was performed and water samples were collected and analyzed. Only a trace level of trichloroethylene (TCE) was detected in Well 12. The trace detection was not confirmed upon subsequent sampling. The initial concentrations of iron at the well field ranged from 180 to 5,000 parts per billion (ppb).
March 1983	The Hartwell Road Well Field Treatment Plant is completed and placed in service. Wells 10, 11, and 12 were pumped to 225 gallons per minute (gpm), 90 gpm, and 260 gpm, respectively.
October 1983	A routine sampling from a tap at the Bedford town offices showed volatile organic compounds (VOCs) in Wells 10 and 11. Subsequent sampling confirmed that VOCs were present in Wells 10 and 11, and now Well 12. The highest concentrations were measured in Well 11. Well 11 is taken off line.
December 1983	The town of Bedford began a water-testing program to assess the contaminant concentrations in the Hartwell Road well field.
Mid-December 1983	Although no changes had been made to the treatment operation, iron levels in the treatment plant's finished water began to increase and the chlorine residual began to fluctuate.
December 1983 –January 1984	TCE was initially detected at 33 ppb in the well field (date not provided). Through December 1983 and January 1984, TCE concentrations in Well 11fluctuated between 14 ppb and 26 ppb, concentrations above ATSDR's current CV for TCE of 5 ppb.
January 10, 1984	Well 10 is taken off line.
February 1984	In early February, traces of benzene and other VOCs were detected in Well 12. By late February, benzene concentrations had increased to 5 ppb in that well. (Benzene was also detected at a high of 30 ppb in off line Well 10. Subsequent sampling did not confirm the high concentration.)
March 1984	Bv March 1984, only Well 12 was in service at the well field. Benzene was detected in finished water collected form the treatment plant at Hartwell Road at a concentration of 7 ppb.
April 3, 1984	The town of Bedford shuts down the treatment plant and the three production wells at Harwell Road.

Source: CDM 1984 a, b, c.

Table 5. Contaminant Concentrations in the Hartwell Road Well Field, 1983–1984

Well ID	Month Sampled	Contaminant Concentrations (ppb)*		
		Benzene	**TCE†**	**Iron**
Well 10	October 1983		**33‡**	
	November 1983			
	December 1983			11,000
	January 1984	<10 P	**10**	31,000
	February 1984 (off line)	<5P–**30**	**11–13**	
	March 1984 (off line)			
Well 11	October 1983			
	November 1983			
	December 1983 (off line)		**21**	
	January 1984 (off line)		**14–26**	
	February 1984 (off line)	<5P	**13–16**	
	March 1984			
Well 12	October 1983			
	November 1983			
	December 1983			
	January 1984			
	February 1984	<5P–**5**	<1P–2	
	March 1984			
Finished Water	October 1983			
	November 1983			
	December 1983			
	January 1984	<5P	**6–7**	
	February 1984	<5P–**5**	<1P–**9**	
	March 1984	**7**	**5**	

Source: CDM 1984b.
* parts per billion
† A 24-pump test following completion of construction and before start-up showed trace levels of TCE and between 180 and 5,000 ppb of iron.
‡ TCE was initially detected at 33 ppb in the Hartwell Road well field. Site documentation did not provide the date of this detection.
P=the contaminant was detected, but the concentration was not quantifiable.
Bolded numbers are quantifiable and exceed or are equivalent to a comparison value.

Table 6. Maximum Contaminant Concentrations in Groundwater at the Hartwell Road Well Field

Contaminant	Concentration (ppb)*	Comparison Value (ppb)
Benzene	35	0.6 CREG†
Trichloroethylene	8.5 (upper aquifer)	5 MCL‡
Iron	310,000	300,000 Secondary MCL

Source: CDM 1984c.
* parts per billion
† ATSDR's cancer risk evaluation guide
‡ EPA's maximum contaminant level

Table 7. Contaminant Concentration Range in Elm Brook Surface Water and Sediment

Contaminant by Media	Concentration (Frequency Above CV)	CV
Surface Water		
Arsenic	3.4–5.2 J*ppb†	10 ppb MCL‡
Trichloroethylene	1 J–7 J ppb (1/5)	5 ppb MCL
Sediment		
Arsenic	3.9–47.4 ppm§ (2/7)	20 ppm EMEG¶- child**
Benzo(a)pyrene	1.2 ppm	0.1 ppm CREG††

Source: Tetra Tech NUS Inc. 2000a,b.
* J=estimated results based on validation criteria; positive detected value less than the Contract Required Quantitation Limit (CRQL).
† parts per billion
‡ EPA's maximum contaminant level
§ parts per million
¶ environmental media evaluation guide
** ATSDR has a 0.5 ppm CREG for arsenic; however, it is often below soil/sediment background concentrations and was not used as the screening level.
†† ATSDR's cancer risk evaluation guide

Table 8. BTEX Concentrations in the Northern Plume

Contaminant	Shallow Aquifer (Overburden)		Deep Aquifer (Bedrock)	
	Concentration ppb	**Well / Sampling Event ***	**Concentration ppb**	**Well/ Sampling Event ***
Total BTEX	99,800	MW18/Ph II (1993)	13 J	MW15R/ Ph II (1993)
Benzene	3,000	MW18/Ph II (1993)	ND	---
Toluene	49,000	MW18/Ph II (1993)	ND	MW15R/ Ph II (1993)
Ethylbenzene	7,800	MW18/Ph II (1993)	2 J	---
Xylenes	40,000	MW18/Ph II (1993)	11	MW15R/Ph II (1993)

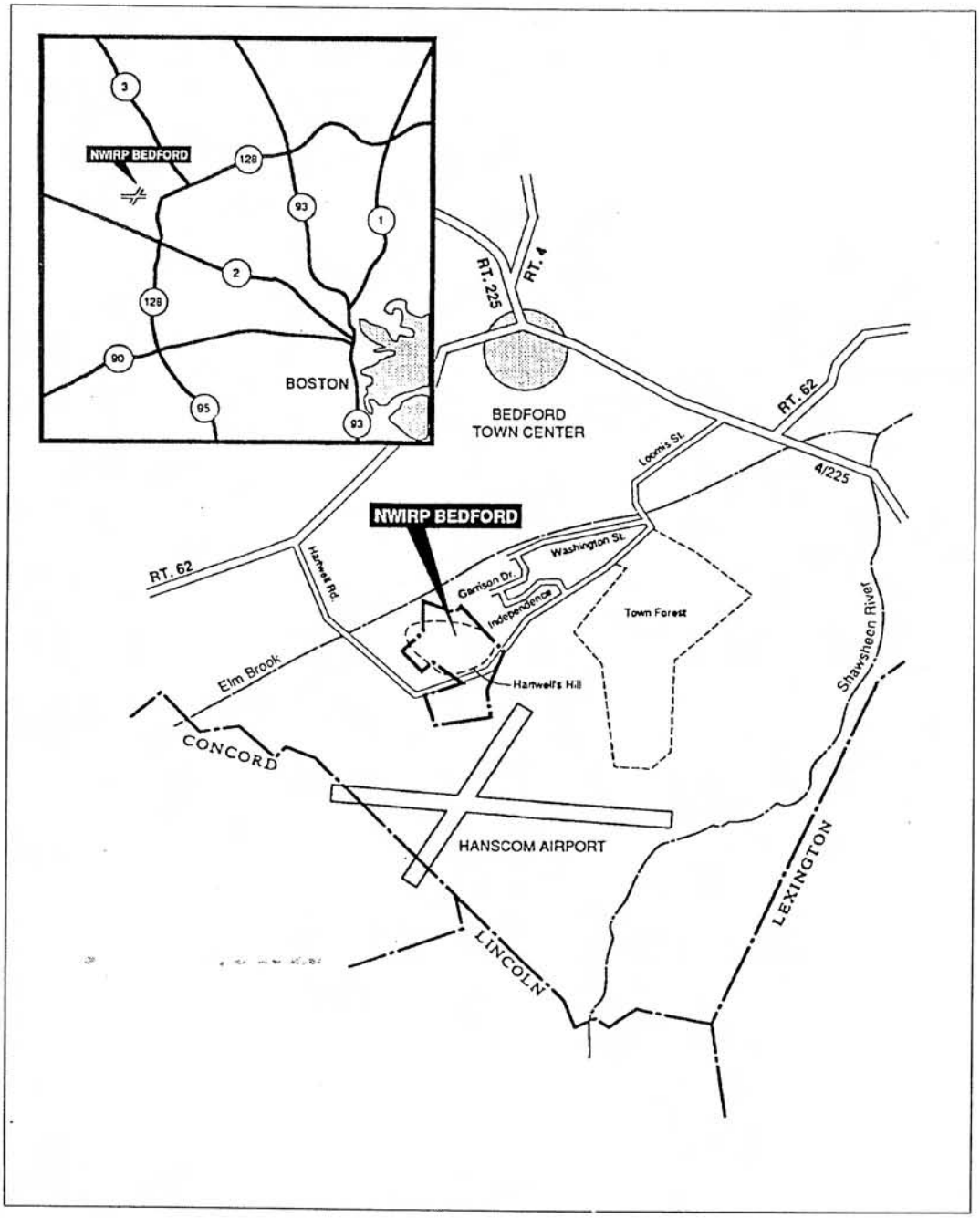
Source: Tetra Tech NUS 2000a.

*****Phase II (Ph II) remedial investigation results were collected in 1993. Samples from six shallow (overburden) wells (MW2S, MW3S, MW15S, MW18, ELM2, GEI107U) and four bedrock wells (MW2B, MW3B, MW15R, GEI107R) were analyzed for BTEX compounds.

J=estimated value; ND=not detected.

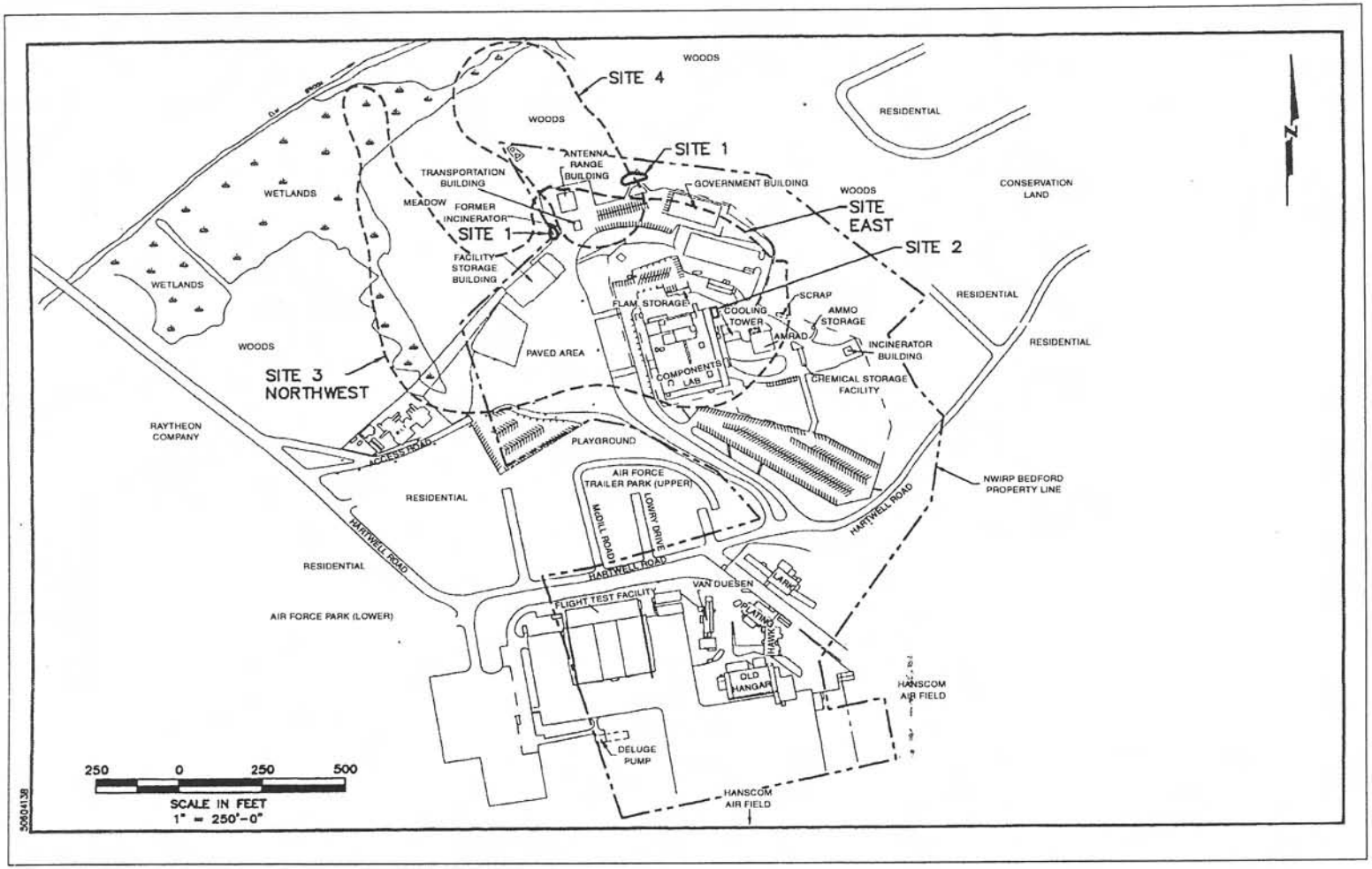
Figures

Figure 1. Area Map



Source: Tetra Tech NUS Inc. 2001.

Figure 2. Site Map



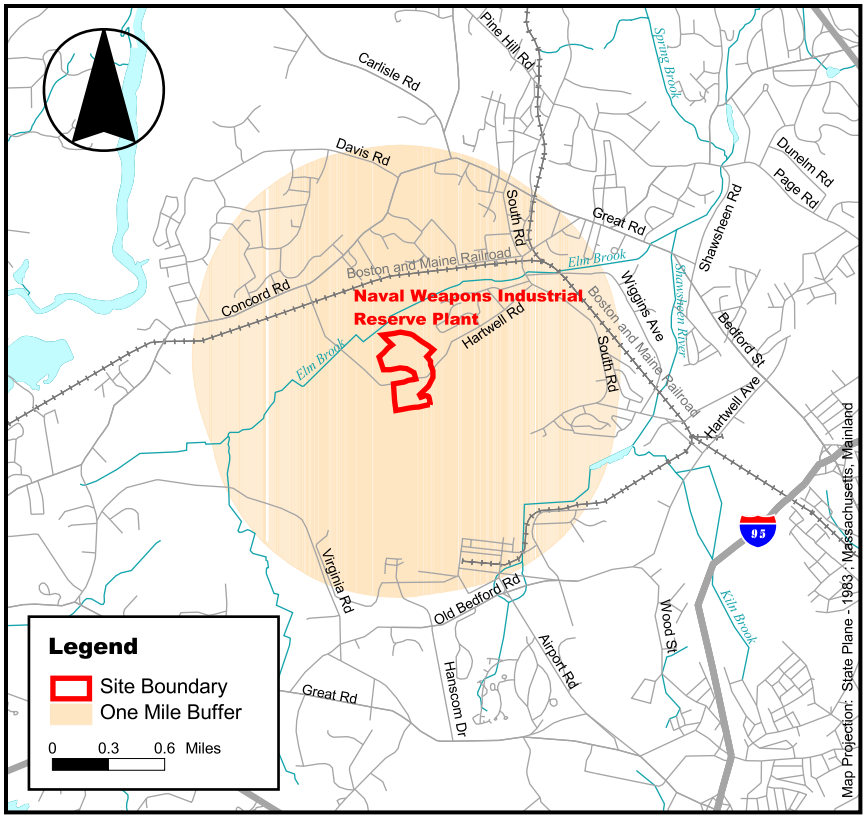
Source: Modified from Tetra Tech NUS Inc. 2001.

Naval Weapons Industrial Reserve Plant

FIGURE 3

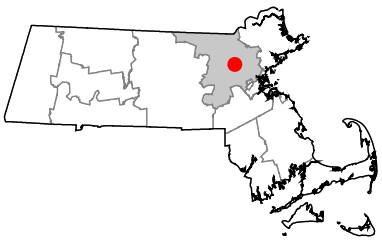
Bedford, Massachusetts

EPA Facility ID MA6170023570



Base Map Source: 1995 TIGER/Line Files

Site Location

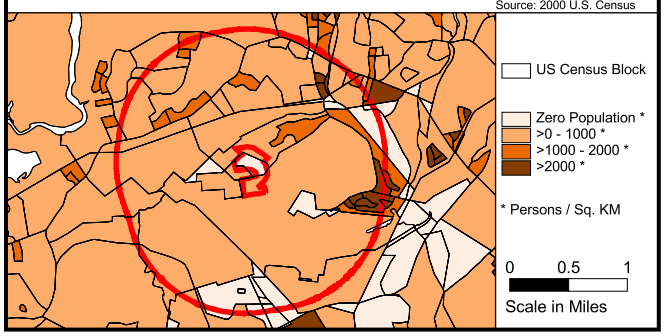


Middlesex County, Massachusetts

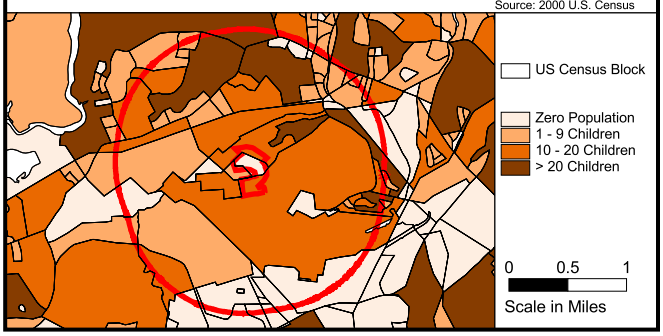
Demographic Statistics Within One Mile of Site*	
Total Population	3523
White alone	3129
Black alone	74
Am. Indian and Alaska Native alone	10
Asian alone	232
Native Hawaiian and Other Pacific Islander alone	0
Some other race alone	24
Two or More races	53
Hispanic or Latino	67
Children Aged 6 and Younger	395
Adults Aged 65 and Older	361
Females Aged 15 - 44	751
Total Housing Units	1301

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

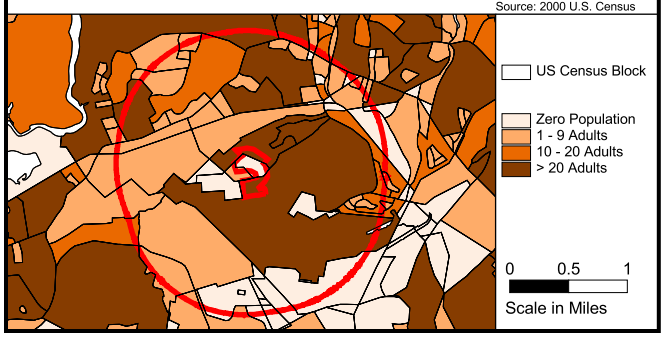
Population Density



Children 6 Years and Younger



Adults 65 Years and Older



Females Aged 15 - 44

JVA121803

Figure 4. Exposure Pathway Figure

REMEMBER: For a public health threat to exist, the following three conditions must all be met:

- Contaminants must exist in the environment
- People must come into contact with areas that have potential contamination
- The amount of contamination must be sufficient to affect people's health

Are the Environmental Media Contaminated?

ATSDR considers:

Soil
Ground water
Surface water and sediment
Air
Food sources

Are People Exposed To Areas With Potentially Contaminated Media?

For exposure to occur, contaminants must be in locations where people can contact them.

People may contact contaminants by any of the following three exposure routes:

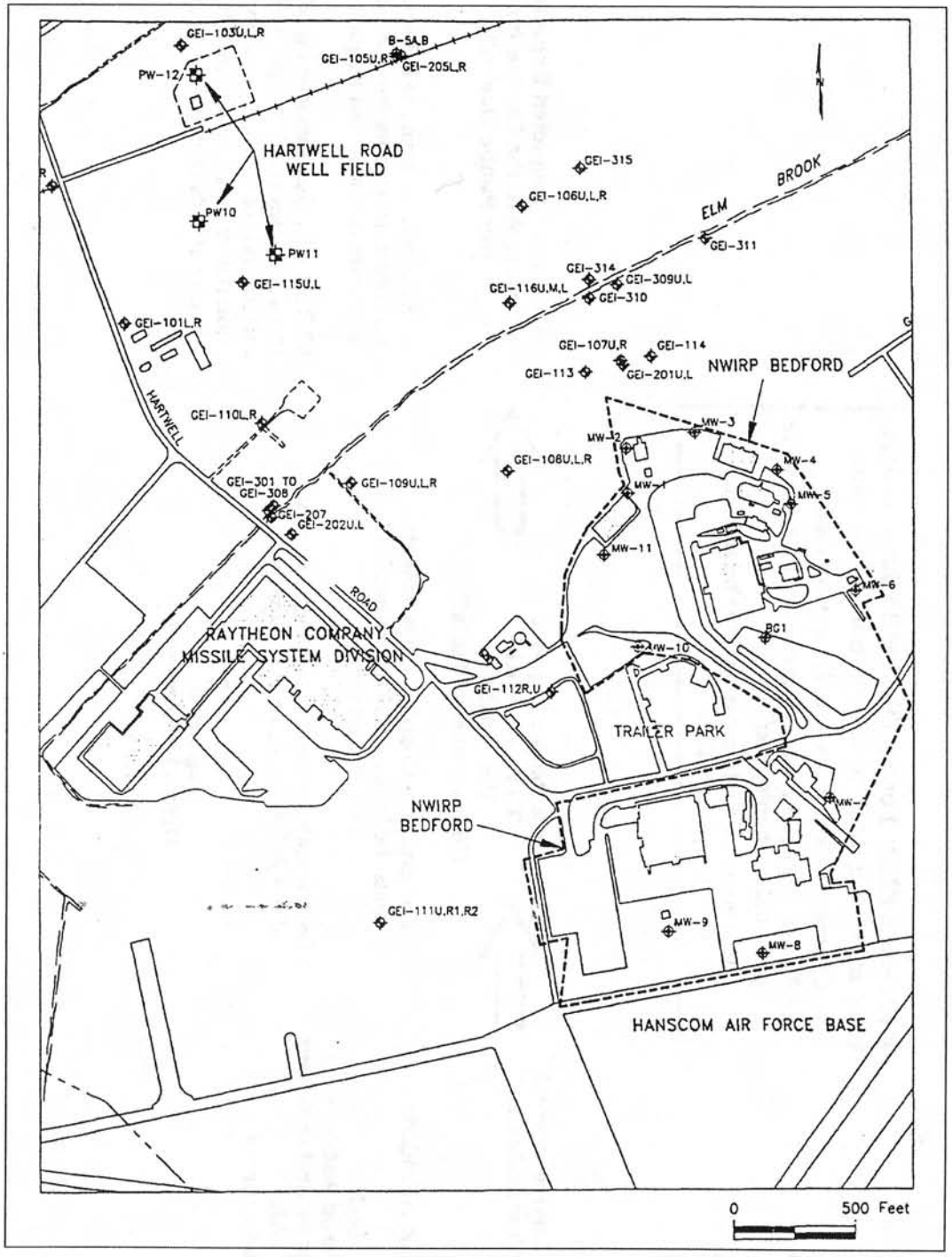
Inhalation
Ingestion
Dermal absorption

For Each Completed Exposure Pathway, Will the Contamination Affect Public Health?

ATSDR will evaluate existing data on contaminant concentration and exposure duration and frequency.

ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

Figure 5. Hartwell Road Well Field



Source: Dames & Moore 1992a.

Appendix A. Glossary

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).

General Terms

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP [see Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention
Measures used to prevent a disease or reduce its severity.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiologic surveillance [see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm2
Milligram per square centimeter (of a surface).

mg/m3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

National Center for Environmental Health (CDC)
(http://www.cdc.gov/nceh/dls/report/glossary.htm)

National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

For more information on the work of ATSDR, please contact:
Office of Policy and External Affairs
Agency for Toxic Substances and Disease Registry
1600 Clifton Road, N.E. (MS E-60)
Atlanta, GA 30333
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Appendix B. Comparison Values

ATSDR health assessors use comparison values (CVs) as screening tools to evaluate environmental data that are relevant to the exposure pathways. CVs represent media-specific contaminant concentrations that are much lower than exposure concentrations observed to cause adverse health effects. This means that CVs are protective of public health in essentially all exposure situations. If the concentrations in the exposure medium are less than the CV, the exposures are not of health concern and no further analysis of the pathway is required. However, while concentrations below the CV are not expected to lead to any observable health effect, it should not be inferred that a concentration greater than the CV will necessarily lead to adverse effects. Depending on site-specific environmental exposure factors (for example, duration of exposure) and activities of people that result in exposure (time spent in area of contamination), exposure to levels above the CV may or may not lead to a health effect. Therefore, ATSDR's CVs are not used to predict the occurrence of adverse health effects. Rather, they are used by ATSDR to select contaminants for further evaluation to determine the possibility of adverse health effects.

CVs used in this PHA include:

Cancer Risk Evaluation Guide (CREG)

Estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over a 70-year life span. ATSDR's CREGs are calculated from EPA's cancer slope factors (CSFs).

Environmental Media Evaluation Guide (EMEG)

EMEGs are based on ATSDR minimal risk levels (MRLs) and factor in body weight and ingestion rates. An EMEG is an estimate of daily human exposure to a chemical (in mg/kg/day) that is likely to be without noncarcinogenic health effects over a specified duration of exposure to include acute, intermediate, and chronic exposures.

Reference Media Evaluation Guide (RMEG)

ATSDR derives RMEGs from EPA's oral reference doses (RfDs). The RMEG represents the concentration in water or soil at which daily human exposure is unlikely to result in adverse noncarcinogenic effects.

EPA's Region III Risk-Based Concentration (RBC)

EPA combines RfDs and CSF with "standard" exposure scenarios to calculate RBCs, which are chemical concentrations corresponding to fixed levels of risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

EPA's Maximum Contaminant Level (MCL)

The MCL is the drinking water standard established by EPA. It is the maximum permissible level of a contaminant in water that is delivered to a free-flowing outlet. MCLs are considered protective of human health over a lifetime (70 years) for individuals consuming 2 liters of water per day.

CVs are derived from available health guidelines, such as ATSDR's MRLs, EPA's RfDs, and EPA's CSFs. These guidelines are based on the no-observed-adverse-effect levels (NOAELs), lowest-observed-adverse-effect levels (LOAELs), or cancer effect levels (CELs) reported for a contaminant in the toxicological literature. A description of these terms is provided:

Minimal Risk Level (MRL)

MRLs are estimates of daily human exposure to a chemical (i.e., doses expressed in mg/kg/day) that are unlikely to be associated with any appreciable risk of deleterious noncancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute ($\leq$ 14 days), intermediate (15 to 364 days), and chronic ($\geq$ 365 days) exposures.

Reference Dose (RfD)

The 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 them harm.

Cancer Slope Factor (CSF)

Usually derived from dose-response models and expressed in milligrams per kilogram per day, CSFs describe the inherent potency of carcinogens and estimate an upper limit on the likelihood that lifetime exposure to a particular chemical could lead to excess cancer deaths.

Lowest-Observed-Adverse-Effect Level (LOAEL)

The lowest dose of a chemical that produced an adverse effect when it was administered to animals in a toxicity study or following human exposure.

No-Observed-Adverse-Effect Level (NOAEL)

The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

Cancer Effect Level (CEL)

The CEL is the lowest dose of a chemical in a study, or group of studies, that was found to produce increased incidences of cancer (or tumors).

Appendix C. ATSDR's Methods for Determining Whether a Health Hazard Exists

I. Overview of ATSDR's Methodology for Evaluating Potential Public Health Hazards

The health hazards that could plausibly result from exposures to contaminants detected in the vicinity of NWIRP Bedford are discussed in further detail in this appendix. It is important to note that public health hazards from environmental contamination happen only when (1) people are exposed to the contaminated media and (2) the exposure is at high enough doses to result in an effect.

Selecting Exposure Situations for Further Evaluation

As an initial screen, ATSDR evaluated available data to determine whether contaminants were accessible to the public or were above ATSDR's comparison values (CVs). The majority of detected contaminants were either not accessible to the public or fell at or below comparison values and were not evaluated further. Exposure situations with contaminants above comparison values or that had insufficient environmental data were deemed worthy of further evaluation. These exposure situations are:

- Past exposure of Bedford residents to VOCs and dissolved iron in municipal water from the Hartwell Road well field between 1983 and 1984.

- Possible past hazards from breathing in vapors that seeped into on-site buildings situated above groundwater plumes. ATSDR evaluated this pathway using the Johnson Ettinger Indoor Air Model (EPA 2003a).

Estimating Exposure Doses

ATSDR derived exposure doses for those contaminants that were detected above ATSDR's CVs or did not have a CV for each of the two exposure situations. Exposure doses are expressed in milligrams per kilogram of body weight per day (mg/kg/day). This represents the amount of contaminant mass that an individual is assumed to inhale, ingest, or touch (in milligrams), divided by the body weight of the individual (in kilograms) each day. When estimating exposure doses, health assessors evaluate chemical concentrations to which people could be exposed, together with the length of time and the frequency of exposure. Variables considered when estimating exposure doses include the contaminant concentration, the exposure amount (how much), the exposure frequency (how often), and the exposure duration (how long). There is often considerable uncertainty about the true level of exposure to environmental contamination, because we do not know exactly how long someone could have been exposed or to what concentration exposure occurred over time. To account for the uncertainty and to be protective of public health, ATSDR scientists typically use worst-case exposure level estimates as the basis for

determining whether adverse health effects are *possible*. These estimated exposure levels usually are much higher than the levels that people are really exposed to.

Using Exposure Doses To Evaluate Potential Health Hazards

ATSDR analyzes the available toxicological, medical, and epidemiologic data to determine whether exposures might be associated with harmful health effects (noncancer and cancer).As a first step in evaluating noncancer effects, ATSDR compares estimated exposure doses to conservative health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's reference doses (RfDs). The MRLs and RfDs are estimates of daily human exposure to a substance that are unlikely to result in noncancer effects over a specified duration. *Estimated exposure doses that are less than these values are not considered to be of health concern.* To maximize human health protection, MRLs and RfDs have built-in uncertainty or safety factors, making them considerably lower than levels at which health effects have been observed. The result is that even if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur.

For carcinogens, ATSDR also calculates a theoretical increase of cancer cases in a population (for example, 1 in 1,000,000 or 10^{-6}) using EPA's cancer slope factors (CSFs), which represent the relative potency of carcinogens. This is accomplished by multiplying the calculated exposure dose by a chemical-specific CSF. Because they are derived using mathematical models which apply a number of uncertainties and conservative assumptions, risk estimates generated by using CSFs tend to be overestimated.

If health guideline values are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies as well as experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). For cancer effects, ATSDR compares an estimated lifetime exposure dose to available cancer effect levels (CELs), which are doses that produce significant increases in the incidence of cancer or tumors, and reviews genotoxicity studies to understand further the extent to which a chemical might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Sources for Health-Based Guidelines

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects from contamination at NWIRP Bedford. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or by contacting the National Technical Information Service at 1-800-553-6847. EPA also develops health effects guidelines; in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines

are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, please call EPA's IRIS hotline at 1-301-345-2870 or e-mail at Hotline.IRIS@epamail.epa.gov.

II. Evaluation of Exposure to Contaminants in the Hartwell Road Well Field in the Past

The contaminants benzene, trichloroethylene (TCE), and dissolved iron were detected in the Hartwell Road well field in 1983 and 1984 at concentrations greater than health guidance levels for drinking water. The wells contained other VOCs, but at lower concentrations. The primary exposure pathway of concern was past exposure through consumption of the well water or inhalation of volatilized VOCs during household use. No exposures are occurring now because the wells are not being used for drinking water or domestic use. Because residents of the town used the water drawn from the wells in the past, ATSDR evaluated the health effects from past ingestion to benzene, TCE, and dissolved iron in drinking water and inhalation exposure to benzene and TCE vapors from household use.

II.A. Exposure to Contaminants via Consumption of Drinking Water

ATSDR used the following equation and default assumptions to estimate the exposure doses from drinking water contaminated with benzene, TCE, and dissolved iron*****.

$$\text{Estimated dose} = \frac{C \times CF \times IR \times EF \times ED}{BW \times AT}$$

where:

C: Maximum concentration in parts per billion (ppb)
CF Conversion factor to convert ppb to milligrams per liter (mg/L)
IR: Ingestion rate: adult = 2 liters per day; child = 1 liters per day (EPA 1997)
EF: Exposure frequency, or number of exposure events per year of exposure: 365 days/year
ED: Exposure duration, or the duration over which exposure occurs: For Bedford water supply: adult and child = 1 year
BW: Body weight: adult = 70 kg (or 154 pounds), child = 10 kg (or 22 pounds)
AT = Averaging time, or period over which cumulative exposure are averaged (6 years or 30 years x 365 days/year for noncancer effects, 70 years x 365 days/year for cancer effects)

* Iron doses were estimated by multiplying the iron concentration in water (ppm or mg/kg) by the ingestion rate (liters/day) to derive doses expressed in mg/day for comparison to the U.S. Food and Drug Administration Daily Values (mg/day).

ATSDR applied this equation to the maximum concentrations of benzene, TCE, and dissolved iron. ATSDR then compared the estimated doses to health guidance levels and information in the toxicological literature to assess whether health effects were likely to occur at the detected concentration. The results are discussed below.

Benzene

Noncancer: Benzene was detected at a maximum concentration of 30 ppb in the Hartwell Road productions wells. Health effects in humans exposed to benzene in drinking water are not known (ATSDR 1997a). EPA recently set an RfD of 0.004 (mg/kg/day) for benzene based on route-to-route extrapolation of the results of benchmark dose modeling (BMD) of the absolute lymphocyte count data from an occupational study conducted by Rothman et al. (1996) (EPA 2003b). In this study, workers were exposed to benzene by inhalation. In comparison, the ATSDR's estimated doses for an adult of 0.0008 mg/kg/day and a child of 0.003 mg/kg/day are below the RfD of 0.004 mg/kg/day (Table C-1). The RfD is based on a benzene dose to workers of 1.2 mg/kg/day, which is 400 to 1,500 times greater the doses estimated for exposure to benzene levels detected in the Hartwell Road wells.

Cancer: Though inhaled benzene is classified as a known human carcinogen, there is little information available about the human cancer effects of ingesting benzene. The EPA determined that ingesting benzene causes cancer in people based on studies of people who inhaled benzene and on studies of laboratory animals that ingested benzene. Cancer studies in animals link benzene to leukemia in rodents and various organ carcinomas in rats. The cancer effect level (CEL) for benzene ranges from 25 to 500 mg/kg/day based on findings of animals studies and are more than a million times greater than the estimated doses from drinking water containing the detected level of benzene in the municipal well field (Table C-2). People drinking water in the past contaminated with a benzene level of 30 ppb face no apparent increase risk of cancer.

TCE

Noncancer: TCE was detected in water collected from the Hartwell Road production wells at levels up to 33 ppb. Using this maximum concentration, ATSDR derived exposure doses to TCE in the well water of 0.0009 mg/kg/day for an adult and 0.003 mg/kg/day for a child (Table C-1). While these doses are slightly greater than the provisional chronic oral RfD for TCE of 0.0003 mg/kg/day, they are well below the levels at which no harmful health effects have been observed in animals orally exposed to TCE for less than 1 year (doses ranging from 18 mg/kg/day to 3,200 mg/kg/day; ATSDR 1997b). Although intermediate doses less than these have been observed to cause developmental health effects (0.18 mg/kg/day caused 5% increased fetal heart abnormalities in rats; Dawson et al. 1993 as cited in ATSDR 1997b), this lowest-observed-adverse-effect level (LOAEL) is still two orders of magnitude higher than the estimated exposure doses that ATSDR derived. Therefore, drinking water containing this level of TCE from the

Hartwell Road well field between 1983 and 1984 is not likely to have resulted in adverse noncancer health effects.

Cancer: EPA is currently reviewing the scientific literature pertaining to the carcinogenicity of TCE to determine its cancer classification (EPA 2003b). The link between TCE and cancer in people's drinking water is controversial. Available studies are inconclusive and the data are inadequate to establish an association. Some studies have shown that individuals drinking TCE-contaminated water with up to 220 ppb—a concentration about 7 times greater than the maximum level detected at Hartwell Road production wells suffered no increased incidence of cancer (ATSDR 1997b). ATSDR compared the estimated dose (0.00001 mg/kg/day; Table C-2) to the cancer effects levels (CELs) for TCE, which are based on animal studies in which carcinomas were observed at 1,000 mg/kg/day (NTP 1990 as cited in ATSDR 1997b). In comparison, the estimated exposure from ingesting water containing TCE at the well field would result in a dose millions of times below the CELs. On the basis of these results, ATSDR concludes that ingestion of TCE at the levels detected in the Hartwell Road production wells between 1983 and 1984 would not have caused an increased likelihood of developing cancer.

Dissolved Iron

Noncancer: Iron was detected at concentrations up to 31,000 ppb in the Hartwell Road production wells. Iron is a mineral that is often found in drinking water supplies. EPA considers this mineral to be a secondary—or aesthetic— contaminant because it can impart an unpleasant metallic taste to the water while still being safe to drink. Water high in iron can also cause reddish-brown staining on bathroom fixtures and laundry. The iron in water from the Hartwell Road well field contained dissolved or soluble iron. This type of iron is most common to water systems and creates the most complaints from water users (NCCES 1996).

The presence of iron in drinking water is, however, generally not considered a health problem. Iron in small amounts is essential to good health because it is used by the body to make hemoglobin, which carries oxygen in the blood from the lungs to other areas of the body. Iron can also help the body's resistance to stress and disease. According to the National Academy of Sciences, the median daily intake of dietary iron is roughly 11–13 mg/day for children 1 to 8 years old, 13–20 mg/day for adolescents 9 to 18 years old, 16–18 mg/day for adult men, and 12 mg/day for adult women (NAS 2001).

Iron is generally not harmful except when swallowed in extremely large doses, such as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children under 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). However, doses of this magnitude are generally the result of children ingesting iron pills. The daily increases in consumption (from drinking water from the Hartwell Road well field) are not likely to cause a person's daily dose to exceed levels known to induce poisoning (e.g., greater than 200 mg/event). Therefore, drinking water containing this level of iron from the

Hartwell Road well field between 1983 and 1984 is not likely to have resulted in adverse noncancer health effects.

Cancer: Iron is not known to be a carcinogen.

Finally, the exposure doses that ATSDR calculated are most likely overestimated by the use of maximum concentrations detected in the production wells. The water from any one production well was diluted with water from the other wells before being distributed to people's houses. Thus, the water people actually drank most likely contained much lower concentrations than the maximum contaminant concentration detected among the three wells. Therefore, ATSDR concluded that no adverse health effects are expected from drinking water from the Hartwell Road well field in the past.

II.B Exposure to VOCs During Showering

II.B.1 Acute Exposures

ATSDR evaluated possible inhalation exposures of Bedford residents to VOCs (benzene, and TCE) in the municipal water while showering. VOC exposure during showering poses a concern because these compounds can easily evaporate from water into the air. The VOC can then enter the body when a person breathes the air contaminated with the chemical. Exposure to the detected levels of VOCs in drinking water, which was evaluated previously in this appendix, was found to be below levels of health concern.

ATSDR used the following screening level model and assumptions to estimate VOC concentrations in air during showering. Although some exposure may occur while in the bathroom, studies suggest that the highest inhalation exposure in the home occurs within the shower stall as a result of actually showering with VOC-contaminated water. Inhalation exposures to some VOCs in the shower were 2.1 to 4.9 times higher than corresponding bathroom exposures (Lindstrom 1994). Therefore, ATSDR used this model to approximate the VOC air concentration in the shower stall from showering with water containing the maximum detected VOCs. Different types of showering conditions, such as water temperature, humidity, and actual duration of the shower, might influence the concentrations of VOC released to the bathroom air. A more detailed analysis would require the use of chemical and physical properties and knowledge of more precise exposure parameters.

Table C-3 presents the estimated air concentrations of benzene and TCE during showering.

$$C_a = \frac{C_w \text{ x MT x FR x T}}{V}$$

where:

C_a	Concentration of the VOC in air (micrograms per cubic meter [$\mu g/m^3$])
C_w	Concentration of the VOC in water: micrograms per liter ($\mu g/L$)
MT	Mass transfer: 1 (represents 100% transfer of the VOC from water to the air)
FR	Flow rate (rate of water flowing from the shower head): 12 liters per minute (L/min). Average flow from a high flow shower head (EPA 1997).
T	Time in shower: 10 minutes. Average shower length (EPA 1997).
V	Volume of bathroom: 10 cubic meters (m^3). Based on a small bathroom with the dimensions of 7 feet by 7 feet by 8 feet.

These assumptions are protective–that is, believed to overestimate possible exposure conditions because:

- ATSDR assumes in the screening model that 100% of the VOCs are volatilized. Information about the chemical properties of VOCs, however, suggests that a portion of the VOCs would actually remain in the water and would not be released to a person breathing the air while showering in the bathroom.

- ATSDR assumes that all the VOCs released from the water to the indoor air and would remain in the bathroom used for showering. Because of bathroom fans or drafts at the door or windows, a portion of the VOCs would escape from the bathroom during the showering, thus lessening the air concentration in the bathroom. A small increase in VOC concentrations in other portions of the house might occur, however, these concentrations would still be well below the concentration estimated in the bathroom.

- ATSDR evaluated exposure to the maximum detected VOC concentrations found in the municipal well water between October 1983 through April 1984. ATSDR does not have sampling data for April 1983 to October 1983. No exposure was expected after the use of the well was discontinued.

Benzene

Showering with water containing 30 ppb of benzene would result in an estimated indoor air concentration during showering of 360 $\mu g/m^3$. The estimated concentration of benzene is above the acute inhalation MRL for benzene of 160 $\mu g/m^3$. The MRL is based on a study in which depressed immune systems were observed in mice

MRLs for exposures to contaminants in air are expressed as concentrations (i.e., $\mu g/m^3$) so that air concentrations can be directly compared to the MRLs, eliminating the need to estimate doses.

administered benzene. The lowest concentration at which this effect was observed in the mice (called the lowest-adverse effect level or LOAEL) was 35,586 μg/m^3 (Rozen 1984 as cited in ATSDR 1997a). In comparison, this value is about 100 times higher than the estimated benzene concentration in air during showering with water containing the maximum detected concentration of benzene found in Hartwell Road wells in the past.[3]

ATSDR further reviewed the scientific literature on inhalation exposure to benzene and human health effects. Benzene is readily absorbed by inhalation and is rapidly distributed throughout the body, particularly in fatty tissues. The half-life of benzene in humans, however, is just 1 to 2 days, and therefore, accumulation is not expected for either benzene or its metabolites. Benzene leaves the body primarily when exhaled through the lungs unchanged or excreted as metabolites in the urine (ATSDR 1997a).

No information was available on the adverse effects of breathing in benzene while showering. Information on other types of inhalation exposures suggest that short-term benzene exposure to human affects the central nervous system, marked by drowsiness, dizziness, headache, nausea, loss of coordination, confusion and unconsciousness. Nose and throat irritations have also been reported following short-term exposure. These effects have been observed at benzene concentrations greater than 79,000 μg/m^3 in occupational settings (CCOHS 2003). In most cases, people felt better when the exposure stopped and they began to breathe fresh air. The levels at which human health effects have been reported following short-term benzene exposure are more than 200 times greater than the estimated benzene air concentration released while showering with water from the well field in the past.

TCE

ATSDR estimated that showering with water containing 33 ppb of TCE would result in air concentration within the shower of 396 μg/m^3. In comparison, the estimated TCE in the bathroom air during showering is well below ATSDR's acute MRL for TCE in air of 10,748 μg/m^3. The acute MRL is based on a study of people exposed to TCE at a concentration of approximately 1,074,000 μg/m^3. At this LOAEL for acute exposures, exposed persons experienced fatigue and other transitory effects (Stewart 1980 as cited in ATSDR 1997b). Considering this information, ATSDR does not expect TCE-related health effects for people who showered with water originating from the well field.

II.B.2 Intermediate or Long-term Exposures

ATSDR evaluated intermediate and chronic exposures by expressing the acute dose as a time-weighted average (TWA). A TWA is the VOC concentration over a 24-hour period that matches the amount a person was exposed to in the 10 minute shower, as assumed in ATSDR's calculations. The TWAs were calculated as follows:

[3] Concentrations can be expressed in parts per billion (ppb). To convert ppb to μg/m^3, multiply the concentrations in ppb by the molecular weight/24.45. The molecular weight for benzene and TCE are 78.11 and 131.4, respectively.

$$\textbf{TWA } \mu g/m^3 = \frac{\text{Acute indoor air concentration } (\mu g/m^3)}{\text{The number of 10 minute intervals in a day, or 144 (unitless)}}$$

As shown in Table C-4, the TWA concentrations of the VOCs in air are below ATSDR's intermediate or chronic MRL or EPA's inhalation reference concentration (RfC), both of which represent the concentration in air below which no appreciable adverse effects are expected. Given that the estimated concentrations are below these health-based screening levels, no long-term health effects are expected for people who showered in the past with water obtained from the well field.

III. Evaluation of Exposure to Indoor Air Contaminants via Vapor Intrusion

Groundwater contamination at NWRIP Bedford involves the shallow aquifer at depths less than 50 feet. The majority of contaminants in the groundwater are volatile organic compounds (VOCs) that can move from the groundwater through soil, and eventually seep into basements and affect the indoor air.

Indoor air sampling data were not available for buildings at the site that are situated above a VOC plume. ATSDR therefore applied the Johnson and Ettinger (1991) model to estimate indoor air in those areas not sampled.

III.A. VOC Indoor Air Modeling

The U.S. Environmental Protection Agency (EPA) developed the Johnson and Ettinger model to estimate indoor air concentrations and associated health hazards from subsurface vapor intrusion into buildings. This model is a *screening-level* model that estimates the transport of contaminated vapors from either subsurface soils or groundwater into the spaces directly above the source of contamination (EPA 2003a).

The Johnson and Ettinger model is a first-tier screening tool that uses data about properties of the soil, chemical properties of the contaminant, and structural properties of the building (EPA 2003a). All but the most sensitive parameters have been set to either an upper bound value or the median value. As a result, the model is very conservative when predicting indoor air concentrations. To predict indoor air concentrations in homes at NWIRP Bedford, ATSDR entered the maximum groundwater for benzene and trichloroethylene (TCE) into the Johnson and Ettinger model. The model generates an infinite source building indoor concentration, which is the estimated indoor air concentration of the VOC contaminant for a building located above the plume.

Although the model is a useful tool that enables ATSDR scientists to conservatively predict indoor air concentration, it has limitations:

- It does not consider the effects of multiple contaminants.
- Its calculations do not account for preferential vapor pathways due to soil fractures, vegetation root pathways, or the effects of a gravel layer beneath the floor slab.
- The groundwater model does not account for the rise and fall of the water table due to aquifer discharge and recharge.
- The model also assumes that all vapor will enter the building, implying that a constant pressure field is generated between the interior spaces and the soil surface.
- It neglects periods of near zero pressure differential.
- Soil properties in the area of contamination are assumed to be identical to those in the area above the contamination.

III.B. VOC Indoor Air Modeling Results

ATSDR compared the modeled indoor air VOC concentrations from vapor intrusion to a reference value for that compound. Based on this strategy, ATSDR found that none of the predicted air concentrations exceeded reference values and thus were not at levels that could cause adverse health effects.

Table C-5 lists the indoor air concentrations that ATSDR estimated for VOCs considered in this analysis. We emphasize that these are *conservative estimates:* our initial modeling application assumed that the maximum concentration of VOCs detected in the plume entered the home. As the table indicates, the estimates of the indoor air concentrations of the VOCs were lower than the associated ATSDR inhalation minimal risk level (MRL) and the levels at which effects have been observed in animal studies or exposed humans (also known as the lowest-observed-adverse-effect levels). The findings suggest that the air concentrations of VOCs inside buildings above the plume do not reach unhealthy levels as a result of the operations at NWIRP Bedford.

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Table C-1. Estimated Exposure Doses—Noncancer Effects From Ingestion of Hartwell Road Drinking Water

Contaminant	Maximum Detected Contaminant Concentration (ppb) *	Estimated Exposure Dose		Health Guideline	Basis for Health Guideline
		Adult	Child		
Benzene	30	0.0008 mg/kg/day‡	0.003mg/kg/day	0.004 mg/kg/day	EPA chronic oral RfD
TCE	33	0.0009 mg/kg/day	0.003 mg/kg/day	0.0003 mg/kg/day	EPA chronic oral RfD
Dissolved Iron	31,000	62 mg/day†	31 mg/day	18 mg/day	FDA daily value

Sources: EPA 2003b; FDA 1993.
* parts per billion
† mg/day = milligram of contaminant per day
‡ mg/kg/day = milligrams of contaminant per kilogram of body weight per day
RfD = EPA's reference dose
FDA = Food and Drug Administration

Table C-2. Estimated Exposure Doses—Cancer Effects From Ingestion of Hartwell Road Drinking Water

Contaminant	Maximum Detected Contaminant Concentration (ppb) *	Estimated Exposure Dose (mg/kg/day) † (Adult)	CSF § $(mg/kg/day)^{-1}$	Theoretical Excess Cancer Risk	CEL for Oral Exposure (mg/kg/day) †
Benzene	30	0.00001	0.055	6×10^{-7}	25; zymbal gland carcinoma NTP 1986
TCE	33	0.00001	0.4	5×10^{-6}	1,000; heptatocellular carcinomas, mice; NTP 1990

Sources: ATSDR 1997a, 1997b.
* parts per billion
† mg/kg/day = milligrams of contaminant per kilogram of body weight per day
† CELs (cancer effect levels) are reported in ATSDR 1997a, 1997b.
§ CSFs (cancer slope factors) are reported in EPA Region 3 risk-based concentration table.

Table C-3: Acute Inhalation Exposure Concentrations and Comparison Values

VOC	EstimatedAcute Indoor Air Concentration During a Showering Event ($\mu g/m^3$) *	Acute MRLs ($\mu g/m^3$)	LOAELs † ($\mu g/m^3$)	
Benzene	360	160	35,586	Rozen et al. 1984. A decreased response of the immune system in mice.
TCE	396	10,748	1,074,000	Stewart et al. 1970. Mild neurological effects in humans.

Sources: ATSDR 1997a, 1997b.
* micrograms per cubic meter
† The LOAELs are the lowest LOAELs reported in the literature and serve as the basis for the acute inhalation MRLs.
VOC= volatile organic compounds
MRL= minimum risk level
LOAEL= lowest-observed-adverse-effect level

Table C-4: Time-Weighted Averages for Intermediate/Long-Term Inhalation Exposures

VOC	Acute Indoor Air Concentration During a Showering Event ($\mu g/m^3$) *	TWA ($\mu g/m^3$)	MRL/RfC ($\mu g/m^3$)	
			Intermediate	
Benzene	360	2.5	13 (MRL)	
TCE	396	2.7	537 (MRL)	

Sources: ATSDR 1997a, 1997b; EPA 2003b.
* micrograms per cubic meter
VOC= volatile organic compounds
TCE= trichloroethylene
TWA= time-weighted average
MRL= ATSDR's minimum risk level
RfC= EPA's reference concentration

Table C-5. Model Incremental Risk and Indoor Air Concentrations

VOC	Maximum Groundwater Concentration (ppb) *	Model Indoor Air Concentration		Inhalation MRL (ppb)	LOAEL (ppb)
		µg/m³ †	ppb		
Benzene	75	0.966	11.54	4 (Intermediate)	780
TCE	2,300	46.1	8.5	100	50,000
1,1-DCE	1,200	81.1	24.0	Not available	10,000 NOAEL in animal studies

Sources: ATSDR 1994, 1997a, 1997b; EPA 2003b.
* parts per billion
† micrograms per cubic meter
VOC= volatile organic compounds
TCE= trichloroethylene
DCE= dichloroethylene
MRL= ATSDR's minimum risk level
LOAEL= lowest-observed-adverse-effect level
NOAEL= no-observed-adverse-effect level