Public Health Assessment for

BOEING MICHIGAN AERONAUTICAL RESEARCH CENTER/
MCGUIRE MISSILE
NEW EGYPT, OCEAN COUNTY, NEW JERSEY
EPA FACILITY ID: NJ2570026268
SEPTEMBER 23, 2002

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

PUBLIC HEALTH ASSESSMENT

BOEING MICHIGAN AERONAUTICAL RESEARCH CENTER/MCGUIRE MISSILE

NEW EGYPT, OCEAN COUNTY, NEW JERSEY

EPA FACILITY ID: NJ2570026268

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
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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FOREWORD

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

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

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

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

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

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

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

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

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

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

Letters should be addressed as follows:

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

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List of Abbreviations

AFB	Air Force Base
AFIERA	Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis
AFRL	Air Force Research Laboratory
Air Force	U.S. Air Force
Am	americium
ATSDR	Agency for Toxic Substances and Disease Registry
BOMARC	Boeing Michigan Aeronautical Research Center
Bq/g	becquerels per gram
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CREG	ATSDR's cancer risk evaluation guide
CV	comparison value
DCE	dichloroethylene
DD	decision document
DOD	U.S. Department of Defense
EIS	Environmental Impact Statement
EMEG	ATSDR's environmental media evaluation guide
EOD	explosive, ordnance, and demolition
EPA	U.S. Environmental Protection Agency
FS	feasibility study
g	gram
ICRP	International Commission on Radiological Protection
IRP	Installation Restoration Program
JP-4	jet fuel
LANL	Los Alamos National Laboratory
µg	microgram
MCL	EPA's maximum contaminant level
MOGAS	automobile gasoline
mrem	millirem
mSv	millisievert
MTBE	methyl tertiary butyl ether
NCRP	National Council on Radiation Protection and Measurements
ND	not detected
NDI	non-destructive inspection
NFRAP	no further response action planned
NJDEP	New Jersey Department of Environmental Protection
OT	other
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls

LIST OF ABBREVIATIONS (continued)

pCi/g	picocuries per gram
PHA	public health assessment
PHAP	Public Health Action Plan
ppb	parts per billion
ppm	parts per million
PRM	Potomac/Raritan/Magothy
PQL	practical quantitation limit
RAB	restoration advisory board
RADCON	Army Radiological Control Team
RCRA	Resource Conservation and Recovery Act
ResRad	residual radioactive
RI	remedial investigation
RMEG	ATSDR's reference dose media evaluation guide
ROD	record of decision
RW	radioactive waste site
ST	storage tank
SVOCs	semivolatile organic compounds
TCE	trichloroethylene
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WP	waste pit

SUMMARY

The Agency for Toxic Substances and Disease Registry (ATSDR) has prepared this public health assessment to evaluate the potential for contamination from the McGuire Air Force Base's (McGuire AFB's) Boeing Michigan Aeronautical Research Center (BOMARC) site to cause harm to people working at or living near the facility. Following a detailed review, ATSDR finds that the BOMARC site poses no threat to public health.

The BOMARC site occupies approximately 218 acres within the Range and Impact Area of the U.S. Army's Fort Dix Installation, in New Egypt, Plumsted Township, Ocean County, New Jersey. Although on U.S. Army property, the site is leased by McGuire AFB, located about 11 miles west of the BOMARC site. In the late 1950s, the Air Force used the land to construct anti-aircraft missile shelters. Some of the primary functions in support of operational nuclear-warhead missiles included missile fueling and defueling, missile maintenance, and power production. As a result of normal operations, hazardous materials were spilled or released to the environment. Principal contaminants associated with past routine operations at the site are hydraulic fluids, nitric acid, and nitrates.

On June 7, 1960, a non-nuclear explosion and fire occurred in BOMARC Missile Shelter 204. The fire burned uncontrolled for about 30 minutes. The force of the explosion destroyed the missile, its plutonium-containing warhead, and portions of the shelter roof; flames rose to about 20 feet and black smoke blanketed the area. Emergency response personnel responding to the accident sprayed the area with water from fire hoses to contain the fire. Monitoring and decontamination activities were initiated to characterize and immobilize the contamination. The missile wreckage and the launcher from Shelter 204 were apparently removed and disposed of off site. A 6-foot chain link fence topped with barbed wire was installed around the site to restrict access. The facility was deactivated in 1972 and all missiles were removed from the shelters. The BOMARC site remains within the domain of the Air Force. The BOMARC property is in the process of being remediated to remove contaminated structures, debris, and soil to an off-site disposal facility, but no definitive plans for future uses of the site have been announced.

Through its public health assessment process, ATSDR conducted site visits and met with representatives from the community, McGuire AFB, the U.S. Army, and local health departments. At the time of these visits, ATSDR did not identify any hazards posing immediate threats to public health. ATSDR determined, however, that additional information was needed for a more complete evaluation of ways in which people could have been exposed, or could be exposed, to radiologically contaminated media and to volatile organic compounds (VOCs) in the groundwater and nearby streams. ATSDR prepared this PHA to further evaluate these possible exposure situations.

After a review of available information, ATSDR drew the following conclusions about potential exposure hazards.

Exposure to Radionuclides Released From the 1960 Explosion: The explosion and fire at the BOMARC site in 1960 released radionuclides to the environment via smoke, dust, and water runoff resulting from fire-fighting efforts. Some workers responding to the accident may have been exposed to alpha radiation as a result of inhaling plutonium released from the accident. There is insufficient, however, detailed information on specific exposure conditions at the time of the accident to allow an accurate assessment of their exposure. Nonetheless, conservatively derived estimates of past potential exposure suggest that workers would not be expected to develop long-term adverse health effects or cancer.

Most radionuclide contamination from the accident at the BOMARC site has been covered with concrete and asphalt. Due to the restricted nature of the BOMARC site and the presence of the concrete and asphalt barrier, on-site contamination is not expected to pose a current or future public health hazard. Some contamination, primarily from plutonium, would have been carried with the wind south of the BOMARC property and onto surrounding military property (i.e., the Range and Impact Area of Fort Dix). Contact, if any, with the low levels of fugitive contamination that possibly settled off site on soil or accumulated in foods has not posed, nor is it expected to pose, a public health hazard.

Exposure to VOCs in Groundwater and Surface Water: A VOC plume is migrating in eastward in groundwater from the BOMARC site toward the downgradient Colliers Mill Wildlife Management area. Of the VOCs in the plume, trichloroethylene (TCE) is detected most frequently and in the highest concentrations. The source of the TCE has not yet been determined. Area residents are not expected to be exposed to VOCs when they drink water, since no public or private drinking water wells draw water from the vicinity of the plume. The plume discharges into the Success Branch at Colliers Mill Wildlife Management area. The stream is not used as a source of drinking water, and people wading, fishing, or hunting in or near the stream are not expected to come in contact with potentially harmful levels of VOCs.

BACKGROUND

Site Description and History

The Boeing Michigan Aeronautical Research Center (BOMARC) site occupies approximately 218 acres within the Range and Impact Area of the U.S. Army's Fort Dix Installation, in New Egypt, Plumsted Township, Ocean County, New Jersey (Figure 1). The site was operated by and continues to fall under the jurisdiction of McGuire Air Force Base (McGuire AFB), which is located 11 miles west of the BOMARC site. McGuire AFB was authorized to use the land for construction of an anti-aircraft missile facility in 1958. Rows of missile shelters were constructed during the late 1950s and early 1960s to house BOMARC's nuclear warhead–equipped missiles. Key operations at BOMARC included missile fueling and defueling, missile maintenance, and power production operations. As a result of these operations and former waste handling practices, hazardous materials, such as hydraulic fluids, nitric acid, and nitrates, were released to the surrounding environment (USAF 1998a). The BOMARC site is a secure site surrounded by locked chain fences, and signs are posted along the perimeter of the site prohibiting trespassing. The site is no longer used and no definitive plans for future use of the site have been announced.

On June 7, 1960, a non-nuclear explosion and fire occurred in BOMARC Missile Shelter 204. The fire burned uncontrolled for about 30 minutes. The force of the explosion destroyed the missile, its plutonium-containing warhead, and portions of the shelter roof; flames rose to 20 feet and black smoke blanketed the area. Fire fighting crews responded to contain the fire from the explosion. Following the accident, monitoring and decontamination activities were initiated. Response teams washed and spray-painted the shelter in an attempt to immobilize the contamination. The missile wreckage and the launcher from Shelter 204 were apparently removed and disposed of off site. The pit inside the shelter was filled with soil excavated from the rear of the shelter and the pit was subsequently sealed with concrete. To further immobilize the radiologic contamination outside the shelter, reinforced concrete was poured over the asphalt apron in front of Shelter 204 and 2 inches of asphalt also were placed along the bottom of the drainage ditch that leads from the shelter. A 6-foot chain link fence topped with barbed wire was installed around the site to restrict access (OHM 1998). The facility was deactivated in 1972 and all missiles were removed from the shelters. The BOMARC site remains within the domain of the Air Force (USAF 1992).

Remedial and Regulatory History

The Air Force (specifically the Air Force Radiological Health Laboratory, now the Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis [AFIERA]) have conducted a series of radiation surveys on and around the site since the 1960s and the Army (specifically the Army Environmental Hygiene Agency, now the U.S. Center for Health Promotion and Preventive Medicine, and the Army Radiological Control Team, or RADCON

Team) have done so since the 1970s (USAF 1992, Army 2001). The Air Force began further investigations in 1986 through the U.S. Department of Defense's (DOD's) installation restoration program (IRP). DOD developed the IRP program to address contamination associated with past waste management practices at DOD sites, including Air Force bases. Six areas at BOMARC investigated under the IRP are: the Missile Accident Area (RW-01), the JP-X Discharge Pit (WP-05), the Transformer Pad T-15 (OT-12), the Former MOGAS underground storage tank (UST) (ST-15), Missile Launchers (OT-16), and the Neutralized Nitric Acid Pit (WP-17). (See Figure 2 for locations and Table 1 for a detailed description of each of these sites.) In January 1989, a remedial investigation/feasibility study (RI/FS) and an Environmental Impact Statement (EIS) were started at RW-01, the missile accident site, in response to the release of radioactive material in this area.

The Air Force, with the U.S. Environmental Protection Agency's (EPA's) approval, signed a record of decision (ROD) in 1992 that outlined the preferred remedial actions for the accident site. The Air Force has also investigated the other five IRP sites for contamination, including other components of the missile system and chemical contamination such as cleaning solvents. The results of these investigations included removal of polychlorinated biphenyls- (PCB-) contaminated soil at OT-12 in 1993, launcher hydraulic fluid from OT-16 in 1996, and petroleum-contaminated soil and underground storage tanks at ST-15 in 1993. Because relatively low contaminant concentrations remain at WP-05, OT-12, ST-15, and WP-17, the Air Force has proposed no further actions at these sites. For each site, the Air Force is now either gathering confirmatory sampling data or addressing the New Jersey Department of Environmental Protection's (NJDEP's) questions to support closure. The Air Force is also continuing to monitor volatile organic compounds (VOCs) in groundwater that are moving as a plume. Trichloroethylene (TCE) is the most common VOC in the plume. Although the origin of the TCE has not been definitively determined, OT-16, the Missile Launcher area, is a suspected source (USAF 1998a).

Demographics and Land Use

The Agency for Toxic Substances and Disease Registry (ATSDR) examines demographic information, or population information, to identify the presence of sensitive populations, such as young children and the elderly in the vicinity of a site. Demographics also provide details on residential history in a particular area—information that helps ATSDR assess time frames of potential human exposure to contaminants. They should not be interpreted, however, as definitive of the populations exposed to site-related contamination. Demographic information for the residential areas surrounding McGuire AFB is presented in this section and in Figure 3. As the U.S. Census demographic information in Figure 3 indicates, four residents lived within a 1-mile buffer of the BOMARC site boundaries in 2000. None of the residents were children under the age of 7 or adults over the age of 64.

There have been no operations at the BOMARC site since the Air Force deactivated the facility in 1972. Most of the land around the BOMARC site is wooded and semi-rural. Land owned by the Fort Dix Military Reservation adjoins the site to the north, west, and south; this land is not used for active military training operations. Land to the east of the site consists of the Colliers Mill Wildlife Management Area, which is overseen by New Jersey's Pinelands Commission and the Naval Air Engineering Station, Lakehurst. The nearest private residences to the BOMARC site lie a little more than 1 mile to the north-northwest and 3 miles in the south-southeast. Communities in the area include New Egypt (6 miles to the northwest), Wrightstown (10 miles to the west), Whiting (5 miles to the south), Lakehurst (5 miles to the east) and Browns Mill (9 miles to the southwest).

The BOMARC site is located along the northern boundary of the outer coastal plain section of the Atlantic Coastal Plan Physiographic Province. The land is generally "low-lying with poor drainage, many swamps, and slow-flowing streams." No surface water is present under normal conditions at the BOMARC site, but runoff from the site flows toward a ditch and culvert along the western boundary of the site. The only natural drainage near the site is the intermittently flowing Elisha Branch of Toms River. Surface water flows with the Elisha Branch easterly along the southeast boundary of the BOMARC site, eventually reaching the Success Branch in the Colliers Mill Wildlife Management Area and then the Ridgeway Branch, before emptying into the southeast-trending Toms River (USAF 1992; OHM 1998). Two lakes, Success Lake and Cassville Lake, are downstream of the site (OHM 1998).

Groundwater in the area exists in two principal aquifer systems: the shallower Cohansey/ Kirkwood formation and the deeper Potomac/Raritan/Magothy (PRM) formation. The 100-foot-thick unconfined shallower aquifer system is made up of hydraulically-connected sediments underlain by silt and clay beds. Depth to the shallower or water table aquifer ranges from 12 to 40 feet below ground surface in the BOMARC site's support area and 18 to 54 feet in the Missile Launcher area of the site. There are indications that the area near BOMARC is an active recharge zone for the Cohansey/Kirkwood aquifer system. Any contamination entering the Cohansey/Kirkwood aquifer could be transported to nearby surface water bodies or shallow aquifer wells. Groundwater flow for this area in the shallow aquifer is generally toward the northeast and east. The PRM system is the major deep (500 to 2,000 feet deep) formation in the area of the BOMARC site and is a major source of potable water. Groundwater flow in the deep aquifer is inferred to be in a down-dipped direction toward the southeast (USAF 1985, 1998a, Army 2001a, URS 1998b).

Groundwater has been and still is used as a drinking water source in the area of BOMARC and by neighboring communities. Table 2 lists the drinking water supply wells identified within 2.5 miles of the BOMARC site. All wells within that radius have serviced or currently service military property and draw from the shallower aquifer. No municipal or regional drinking water service companies are located within a 5-mile radius of BOMARC's boundaries.

As noted in Table 2, five drinking water wells supplied water to the BOMARC facility. Four wells installed in the 1950s were located on site, and a fifth well was installed in 1979 about 0.5 miles northwest of the BOMARC site (URS 1998a). Two of the on-site BOMARC wells were situated in the southwest corner of the BOMARC site, within the fenced-off boundary and downgradient of a rock-filled pit, apparently used for seepage disposal of liquids.[1] During operation, the two BOMARC wells drew water from a depth of 100 feet below ground surface, but have been subsequently sealed according to NJDEP requirements at site closure. Six other drinking water wells identified within the 2.5-mile radius of the site belong to Fort Dix, the Army Corps of Engineers, and the Naval Air Engineering Station, Lakehurst. The closest use of groundwater downgradient of the site is at the Naval Air Engineering Station, Lakehurst. The station operates a total of two deep and five shallow groundwater wells for its potable water supply, and then tests and treats its potable water at one of its three water treatment systems prior to use (OHM 1998, Lakehurst 2001).

Site Visits and Community Concerns

Through the public health assessment (PHA) process, ATSDR assesses site conditions from a public health perspective to determine whether people can be exposed to site-related contaminants through contact with the groundwater/drinking water, surface water, soil, biota, or air. As part of the PHA process, ATSDR visited the BOMARC site in December 1998. ATSDR visited the site again on November 29 through December 2, 1999. The purpose of the visits was to tour the site, meet with site representatives, and gather the necessary information to prepare a PHA. ATSDR also met with local officials and held a public availability meeting in May 2000.

Based on site visits and a preliminary review of the data, ATSDR did not find any health threats at the BOMARC site requiring *immediate* attention. ATSDR did, however, note potential exposure pathways that require further study. ATSDR prepared this public health assessment to further evaluate these pathways.

ATSDR gathered information about health concerns voiced by members of the community. In gathering this information, ATSDR interviewed base public affairs personnel who address community questions and concerns about the BOMARC site, met with other base personnel (including the support group commander, civil engineers, the judge advocate, and the flight commanders of public and occupational health) who also meet with the public, reviewed the results of the base's survey of community concerns (which is listed in the base's community relations plan), and reviewed concerns expressed by the community during the public health

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[1] A 1979 report by the Office of Project for Chemical Demilitarization and Installation Restoration indicated that an injection well was located in the southwest corner of the site. During a 1981 investigation at the site, a rock-filled pit was found at the suspected location of the injection well. See the Community Health Concern section of this document for further discussion about the suspected injection well.

assessment process for the neighboring Fort Dix site. Many of the community concerns focus on health and safety hazards stemming from the BOMARC missile accident in 1960.

Quality Assurance and Quality Control

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. Documents prepared for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA) programs must meet specific standards for adequate quality assurance and control measures for chain-of-custody procedures, laboratory procedures, and data reporting. The environmental data presented in this PHA come from site characterization, remedial investigation, and groundwater monitoring reports prepared by the Air Force under CERCLA and RCRA. ATSDR carefully reviewed the radiological data collected for the BOMARC site in the days following the 1960 accident as well as annual reports prepared in later years. ATSDR has specific concerns about the radiological data, including the varied sampling and laboratory techniques and the sources of error in the estimates of plutonium isotopes. These concerns are described in detail in Appendix A of this PHA. Despite these concerns, ATSDR's evaluation determined that the environmental data available in site-related documents are of high enough quality to be a basis for public health decisions.

EVALUATION OF CONTAMINATION AND POTENTIAL HUMAN EXPOSURE

Introduction

What is meant by exposure?

ATSDR's PHAs are exposure, or contact, driven. Given sufficient exposure levels, chemical contaminants disposed of or released into the environment have the potential to cause adverse health effects. However, *a release does not always result in exposure.* People can only be exposed to a contaminant if they come in contact with that contaminant. People can be exposed by breathing, eating, or drinking a substance containing the contaminant or by skin contact with a substance containing the contaminant.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate 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.

If exposure was, is, or could be possible, ATSDR scientists then consider whether contamination is present at levels that might affect public health. ATSDR scientists select contaminants for further evaluation by comparing them against health-based comparison values (CVs). These CVs are developed by ATSDR from scientific literature available on exposure and health effects. CVs are derived for each of the different media; each CV reflects an estimated contaminant concentration that is *not likely* to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., amount of water or soil consumed or amount of air breathed) and body weight.

CVs are not thresholds for adverse health effects. ATSDR CVs establish contaminant concentrations many times lower than levels at which no effects were observed in experimental animals or human epidemiologic studies. 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 health effects.

Some of the CVs used by ATSDR scientists include ATSDR's environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), and cancer risk evaluation guides (CREGs), as well as EPA's maximum contaminant levels (MCLs). MCLs are enforceable drinking water regulations developed to protect public health. CREGs, EMEGs, and RMEGs are non-enforceable, health-based CVs developed by ATSDR for screening environmental contamination for further evaluation.

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 (1-888-422-8737).

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual from contact with 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 (combination of contaminants). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur as a result of exposure to a contaminant in the environment.

There is considerable uncertainty about the true level of exposure to environmental contamination. To account for the uncertainty and to be protective of public health, ATSDR scientists typically use high-end, 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. If the exposure levels indicate that adverse health effects are possible, then the scientists perform a more detailed review of exposure, referring to scientific information from the toxicologic and epidemiologic literature about the health effects from exposure to hazardous substances. Figure 4 provides an overview of ATSDR's exposure evaluation process.

What exposure situations were evaluated for the BOMARC site?

ATSDR analyzed all six BOMARC IRP sites to determine if they are associated with past, current, or future public health hazards. Table 1 provides a description and a summary of our evaluation for each site. Our review indicated that most areas of the BOMARC site are not associated with any known public health hazards because: (1) contaminant concentrations detected are too low to pose a health hazard or (2) past and current exposure to the general public has been prevented.

ATSDR did, however, identify two situations at the BOMARC site for further evaluation: (1) potential exposures of workers or nearby populations to radionuclides released as a result of the 1960 accident and subsequent fire-fighting activities, and (2) exposure of individuals to VOC-contaminated groundwater and surface water/sediment. Our evaluation is summarized in Table 3 and discussed in greater detail below.

In the section that follows, ATSDR states an exposure concern associated with an environmental pathway, presents a brief summary of our conclusions, and describes in more detail any identified exposure pathways and the basis for our conclusions. To acquaint the reader with terminology and methods used in this PHA, Appendix B provides a glossary of environmental and health terms presented in the discussion, Appendix C describes the CVs used to select environmental contaminants for further evaluation, Appendix D describes radiation and radiological terminology discussed in this document, and Appendix E contains comments received on this document during the public comment period (June 10 to July 25, 2002) and ATSDR's responses to those comments.

Concern: Radionuclides

Have radionuclides associated with the June 1960 explosion and fire contaminated the site or reached areas accessible by the public; if so, has that contamination resulted, or will it result, in adverse human health effects?

Conclusions

After review of the available data, ATSDR has drawn the following conclusions:

- An *non-nuclear* explosion and fire at the BOMARC site in 1960 released plutonium, its decay products, and uranium to the environment via smoke, dust, and water runoff from fire-fighting efforts.

- Workers responding to the accident or downwind of the accident may have been exposed to alpha radiation when they breathed in smoke released during the accident and fire-fighting activities or in resuspended dust. Likewise, workers could have been exposed to external gamma radiation associated with warhead components. The lack of information about the specific exposure conditions at the time of the accident makes it challenging to accurately assess worker intake and doses. Conservative dose estimates prepared by the Air Force and reviewed by ATSDR, however, suggest that workers at the site would not have received radiation doses that would result in the development of long-term harmful effects.

- Some airborne radiological contamination has migrated off the BOMARC site, but not necessarily off military property. Highly conservative estimates suggest that contact with the low levels of fugitive contamination that possibly settled on soil or accumulated in local crops has not posed, nor is it expected to pose, a public health concern.

- Most radiological-contaminated material at the accident site has been covered with concrete and asphalt. Due to the restricted nature of the site and the concrete and asphalt barrier, on-site contamination is not expected to pose a current or future threat to public health.

Discussion

Description of Accident

What radioactive materials were present in the missile at Shelter 204?

Weapons-grade plutonium, enriched uranium (uranium 235), and tritium were contained in the nuclear missiles stored at the BOMARC Missile Shelter 204 site. The amount of these materials in the weapon remains classified. As a result of an accident and explosion in 1960 at the shelter, plutonium and uranium were released from the damaged missile, but tritium was not.

On June 7, 1960, a *non-nuclear* explosion and fire occurred in BOMARC Missile Shelter 204. The fire burned out of control for about 30 minutes. The force of the explosion destroyed the missile in the shelter, its warhead, and portions of the shelter roof; flames rose to about 20 feet and black smoke blanketed the area. Although no nuclear explosion or nuclear criticality took place, the nuclear warhead component of the missile—containing the nuclear material—melted and burned, the missile was destroyed, and the launcher shelter was badly damaged (USAF 1992).

At the time of the fire, a north-northeast wind of 2 to 8 knots (2.3 to 9.2 miles per hour) blew the smoke into surrounding areas. The missile contained weapons-grade plutonium, enriched uranium (uranium processed to contain more uranium 235 than found in nature),[2] and bottled tritium (OHM 1998). Although no nuclear explosion occurred, the force of the explosion damaged the warhead, releasing some of its nuclear material with the smoke (OHM 1998). The warhead's radionuclides, such as plutonium, which readily adhere to dust and smoke particles, were released and carried aloft on the prevailing winds and dispersed to the south and southwest of the accident site (Earth Technology 1991). The tritium bottles were found intact and in good condition, with no signs of releases.

As part of the fire-fighting activity and to keep the fire from spreading to the other missile shelters in the complex, emergency response personnel sprayed the area with water from fire hoses for approximately 15 hours. As a result, radiologic-contaminated water flowed from

[2] Naturally-occurring uranium consists of three isotopes, all of which are radioactive: uranium 238, uranium 235, and uranium 234. Uranium 235 is the only naturally occurring nuclear-fission fuel, but is only 1 part in 140 of natural uranium, with the more stable uranium 238 isotope making up the remainder. Uranium 234 is a decay product of uranium 238.

Shelter 204 and into the drainage ditch leading outside the site boundary (Earth Technology 1991). An earthen dam was constructed across the ditch to contain the contaminated water. The drainage ditch runs southerly from Shelter 204, paralleling the site boundary fence for several hundred feet before entering an underground culvert and crossing underneath Ocean County I-Highway 539 (Figure 5). From this point, the culvert opens into a sandy ditch that eventually flattens into a wooded area that is part of the Fort Dix Range and Impact Area.

Monitoring and decontamination activities were initiated on June 8, 1960, with placement of air samplers downwind of the accident site. On June 10, additional monitoring equipment was installed. Several sections of the floor of Missile Shelter 204 and the road outside the shelter had radiation readings over 2 million counts per minute (Earth Technology 1991). Background radiation levels using an alpha detector are generally less than 5 to 10 counts per minute. The area was again washed down and allowed to dry. The inside and outside of the shelter and surrounding asphalt driveway/road in front of the shelter then were spray-painted in an attempt to immobilize the contamination.

Based on interviews with Air Force retirees, it was determined that the missile wreckage was taken to a hangar at McGuire AFB for reconstruction and later shipped to the Boeing Company in Seattle, Washington (USAF 1995a). The launcher from Shelter 204 was apparently cut into sections, removed, and brought to the Fort Dix scrap yard (later known as the Defense Reutilization and Marketing Office) prior to disposal at the Department of Energy's Idaho National Engineering and Environmental Laboratory (Case 2002). No definitive information exists on the disposal of the roof and door panels from the shelter. Personnel interviewed stated with certainty that no large debris from the accident, perhaps indicative of the roof and door panels, was buried within or near BOMARC (USAF 1995b).

What is plutonium?

Plutonium is a radioactive metal that occurs naturally in the environment and can be produced in nuclear reactors. Plutonium can be found in several forms called isotopes. The most common of these are plutonium 238 and plutonium 239. Because plutonium is a radioactive element, it changes or decays, releasing energy as alpha radiation and forms new products called progeny.

People are most likely to be exposed to plutonium by breathing it in. Once in the body it tends to remain in the lungs or move to the bones or liver. Evidence from human studies is inconclusive, but some information from animal studies suggests that plutonium can cause cancer and other adverse effects.

In an effort to further immobilize the radiological contamination outside the shelter, 4 inches of reinforced concrete were poured over the asphalt apron in front of Shelter 204. An additional 2 inches of concrete were added to the apron in front of the shelter in 1967. Two inches of asphalt also were placed along the bottom of the drainage ditch that leads from the shelter to the nearby stream in order to prevent erosion of contaminated soils. The pit inside Shelter 204 was filled with soil excavated from the rear of the shelter and then sealed with concrete. A 6-foot chain link fence topped with barbed wire was installed around the site to restrict access (OHM 1998).

Evaluation of Environmental Data

During the missile accident, the fire-fighting, and the subsequent decontamination activities, radionuclides were transported by water and by air (smoke) off the Air Force facility, although not necessarily off military property, since they would have been transported onto the Range and Impact Area of Fort Dix. Water from the fire-fighting effort and subsequent decontamination washings flowed westward down the asphalt apron outside Missile Shelter 204 and then entered the drainage ditch, carrying with it isotopes of radionuclides released during the accident. Radionuclides in water could have been carried to, or beyond, the ponding area on Fort Dix property located to the west of Highway 539. In addition, contaminants could have been transported through air by resuspension of contaminated, unstabilized soil.

The amount of nuclear material contained in the warhead is still considered classified information. Estimates of the amount of plutonium released at the site vary from 100 grams (g) to 300 g to 1,500 g (USAF 1997b, Earth Technology 1991). These estimates are based on the difference between the estimated amount of plutonium in the waste removed from the site after the accident and the assumed amount of weapons-grade plutonium within the weapons, and are subject to a considerable amount of uncertainty. In addition, estimates by the Los Alamos National Laboratory (LANL) suggest that as much as 300 g of uranium 238 and 300 g of uranium 235 were unaccounted for in the recovered material and remained on site.

The Air Force conducted surveys following the accident and later conducted sampling over the intervening year to characterize the level of contamination released during the accident and possibly present at the site. The results of these investigations and others are described below.

<u>Post-Accident Surveys/Monitoring</u>

No real-time measurements of releases during and immediately following the accident were taken. On June 8, 1960, one day after the accident, the Air Force initiated air monitoring, placing air samplers downwind of the accident site. They monitored the air again on June 10. Later on June 24 and 28, 1960, the Human Systems Center from Brooks AFB, Texas, surveyed the area using handheld alpha radiation detectors to determine the extent of radioactive contamination. The alpha detectors were used as surrogates for plutonium contamination. Information gathered from these initial screenings suggested that no contamination was present beyond the BOMARC site boundaries (USAF 1998b).

The Air Force conducted routine radiation surveys from 1960 to the present and the Army Environmental Hygiene Agency/Army Center for the Promotion of Preventive Medicine has monitored periodically since the 1970s (Army 2001). The results from two Army surveys conducted in 1982 and 1985 were available to ATSDR. During the 1982 survey, a team from the Army visited BOMARC and collected soil samples from the drainage ditch near the southwest side of the site fence. The samples were analyzed for plutonium. Samples were also collected along the west fence line and the north fence line. Of the 16 soil samples, only the sample collected at the drainage ditch (near the exit from the fence) contained plutonium (0.71 becquerels per gram [Bq/g] [3], or 19.3 picocuries per gram [pCi/g]) in excess of the current guideline established by the EPA for this location of 0.3 Bq/g (8 pCi/g). Ten other samples were at or below the detection limit for plutonium. The remaining five samples averaged less than 0.0185 Bq/g (or 0.5 pCi/g) of plutonium, well below the EPA current guideline. Although at the time the team observed badly weathered warning signs on the fence surrounding the site, they found no evidence of trespassing onto the BOMARC site (USAEHC 1982).

During their 1985 survey, the Army observed similar site conditions as in 1982. They again analyzed soil samples for plutonium. The findings of this sampling indicated that plutonium was not migrating off site. The Army, however, recommended additional soil analysis along the site perimeter if the site is disturbed in the future, such as during remediation activities.

<u>Environmental Monitoring (1975–1998)</u>

Between 1975 and 1998, the Air Force monitored environmental media to better define the extent of nuclear contamination released during or after the accident (Maher 1986; Hunter 1988; Montgomery 1994, 1995; USAF 1998a). The Air Force's 1998 remedial investigation is probably the most extensive of all the studies, in terms of the number of locations sampled and the depth of sampling (OHM 1998). Through their investigations, the Air Force collected groundwater, surface water, ambient air, concrete/asphalt core, soil, sediment, and wipe samples from the site and screened the samples for gross alpha and gross beta activity. Since the predominant radioactive materials in weapons-grade plutonium are, and were in the past, plutonium 239, plutonium 240, plutonium 241, and americium 241 (a decay product of plutonium 241; also called Am 241), the Air Force analyzed samples for these isotopes. The Air Force also analyzed selected samples for uranium 234, uranium 235, and uranium 238.

[3] The international system of units, the SI system, has replaced conventional units of radioactivity. In this system, the becquerels has replaced the curie. There are 37 billion becquerels in a curie.

Soil/Sediment

Surface or Near Surface Soil and Sediment Samples

Exclusion Zone: The exclusion zone is the fenced-off area on the BOMARC property that contains Missile Shelters 201 through 210 and a portion of the drainage ditch (see Figure 5). The primary radionuclide of concern detected at the site is plutonium 239/240.[4] The early studies found plutonium 239/240 at levels above EPA's risk-based level of 0.3 Bq/g, or 8 pCi/g, concentrated in the top layers of soil, with concentrations decreasing with depth (up to 10 inches below the surface at the time of the testing) (Maher 1986; Hunter 1988; Montgomery 1994, 1995). Investigations in 1998 expanded upon earlier work by collecting 227 soil samples to further delineate the area of contamination. Contours of plutonium measurements indicated that plutonium contamination followed the local drainage patterns from the front of Missile Shelter 204 to the drainage ditch. In fact, the highest concentrations of plutonium (between 74 Bq/g and 513 Bq/g [between 2,000 pCi/g and 13,864 pCi/g], compared with the EPA risk-based value of 0.3 Bq/g [8 pCi/g]) were confined to samples collected within 50 feet southwest of the missile shelter and up to 8 feet below ground surface. Much lower plutonium concentrations were detected between 8 and 24 feet below ground surface. The sampling also showed that the distribution of the plutonium across the site was not uniform and that there are localized areas, known as "hot spots," of plutonium contamination. Uranium 235 (0.0007 Bq/g or 0.02 pCi/g), uranium 238 (0.03 Bq/g or 0.78 pCi/g), and total uranium (0.28 Bq/g or 7.48 pCi/g) [5] were present at concentrations below the National Council on Radiation Protection and Measurements's (NCRP's) surface soil screening level for commercial property of 3.88 Bq/g, or 105 pCi/g, for uranium 238 (OHM 1998, NCRP 1999).

Drainage Ditch: The drainage ditch carried runoff from the concrete shelter at Missile Shelter 204 to a corrugated pipe near the concrete culvert (see Figure 5). Plutonium activity in ditch soil samples reached levels up to 136 Bq/g, or 3,676 pCi/g, with the highest concentrations detected at the head of the ditch (near Missile Shelter 204). From that location, concentrations appear to decrease with distance from the accident site. Much lower levels of uranium 235 (0.002 Bq/g or 0.05 pCi/g), uranium 238 (0.02 Bq/g or 0.48 pCi/g), and total uranium (0.17 Bq/g or 4.58 pCi/g) were detected. Plutonium activity at 6 to 12 inches below ground surface was generally higher than activity in samples from 0 to 6 inches below ground surface. It would appear that the plutonium contamination remaining in the ditch, before the asphalt covering was laid in 1967, had migrated several inches below the surface of the ditch. However, it was noted that about 6 inches of clean sand covered the plutonium-contaminated soil. It is believed that this clean sand was laid to reduce contamination and to improve the bed for the asphalt placement (Earth

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[4] Radiochemical techniques cannot differentiate between the isotopes plutonium 239 and plutonium 240.

[5] Total uranium amounts to the sum of uranium 234, uranium 235, and uranium 238.

Technology 1991). This layer of clean sand may explain why there are relatively low plutonium concentrations in the top layer of sediment.

Concrete Culvert: The 30-foot concrete culvert carries effluent from the corrugated pipe beneath Highway 539. During early sampling, plutonium 239/240 was detected at levels greater than 0.3 Bq/g, or 8 pCi/g; however, during the 1998 investigations, no plutonium or uranium were detected at levels greater than 0.07 Bq/g.

Core Samples

Core samples were collected from beneath Missle Shelter 204, the concrete apron, and the drainage ditch. Samples from these areas were analyzed to determine whether contamination had infiltrated the soil beneath these structures.

Missile Shelter 204 Area and Concrete Apron: The shelter housed the fire that caused the release of plutonium, and the concrete apron connects the paved driveway in front of the shelter with the drainage ditch. Data collected during the earlier studies found the highest plutonium activity at what would have been the ground surface at the time of the accident. At one sampling location (where water used to extinguish the fire first entered the soil) a high concentration of plutonium 239/240 (5,180 Bq/g or 140,000 pCi/g) was detected (OHM 1998). The highest plutonium levels (greater than 74 Bq/g or 2,000 pCi/g) were generally measured in samples collected less than 6 feet below ground surface in the general drainage pathway leading from the shelter. The total uranium concentration in one core sample taken at depth (9.4 Bq/g or 255 pCi/g) exceeded the NCRP screening value of 3.88 Bq/g, or 105 pCi/g, for surface soil. Concentrations of uranium 235 (0.5 Bq/g or 14 pCi/g) and uranium 238 (0.7 Bq/g or 21 pCi/g) in the sample were much lower than the NCRP value.

Another area of high plutonium concentrations was found at depths between 22 and 24 feet where, plutonium at levels greater than 0.3 Bq/g, or 8 pCi/g, was measured. There is, however, no obvious, clearly defined mechanism by which the plutonium could have migrated more than 2 feet below the surface, primarily because the concrete apron placed over the contaminated area after the accident, coupled with the designed drainage, should have prevented waterborne downward migration in subsequent years. One explanation for plutonium's migration from the top few inches is that it traveled by way of conduits, such as the electrical and communication bunkers that paralleled the shelters. The bottoms of the bunkers appear to be about 10 feet below the surface. Previous studies show that plutonium was carried into the bunkers by the fire-fighting water (Hunter 1988). Even if these bunkers were flooded several times over the years subsequent to the fire, though, it is unlikely that the plutonium would have moved approximately 80 feet from the location of the initial contamination from flooding alone. Only if there is a highly porous layer at about 14 feet below the surface with a good, continuous flow of water is it possible that the plutonium traveled 80 feet (at a rate of 2 feet per year). No such layer has been observed. Another possible explanation for the high levels of plutonium contamination with depth is poor sample handling.

In summary, the results of radiological investigations of soil and sediment at BOMARC indicated that:

- The soil and sediment contamination is not distributed uniformly across the site, but occurs in discrete "hot spots" in an area covering less than 5,000 square feet;
- The persistence of contamination has remained stable over the intervening years. There has been no significant migration of the contamination since the initial accident and fire fighting events;
- In general, the pouring of concrete and/or asphalt over the original ground surface at the time of the accident effectively fixed most of the plutonium contamination under the concrete and inhibited further migration of plutonium 239 (Earth Technology 1991; Mak 1998).

Other Media

Groundwater: Groundwater samples were collected and analyzed for gross alpha (as a substitute for plutonium) and gross beta activity. The sampling indicates that gross alpha and beta activity increase steadily toward the north and east of the site. Groundwater, however, does not appear to be contaminated by plutonium or related decay products from the missile accident (Earth Technology 1991). None of the samples from the monitoring wells showed plutonium above detection limits, so it seems that the elevated gross alpha and beta activity are not due to plutonium contamination or its decay products. The generally increasing activity levels in groundwater to the northeast may be related to groundwater recharge leaching naturally occurring alpha emitters, such as uranium or thorium, entering the groundwater through recharges (Earth Technology 1991).

Surface Water/Sediment: No surface water bodies are present under normal conditions at the BOMARC site. Water from the fire-fighting activities may have collected at the asphalt apron, drainage ditch, and concrete culvert, and rainwater may collect at the site today. The nearest surface water is the Elisha Branch, which flows along the southeastern boundary of the site. Patterns established through in situ surveys confirm that *plutonium has moved off site as a result of fire fighting activities that used water to contain the fire.* The highest off-site activity exists where the surface water drainage from the site crosses beneath Highway 539 onto Fort Dix's Range and Impact Area, and slightly beyond the ponding area that eventually leads to Elisha Branch (Earth Technology 1991). If reports from the eyewitnesses are correct, however, the water from the fire-fighting effort probably did *not* travel past the ponding area on Fort Dix property. *Contamination has not been detected in Elisha Branch.*

Much of the movement of contaminated materials off site probably took place during or shortly after the missile accident and prior to asphalting the drainage ditch. After asphalting, little movement of material, if any, would occur under the cap, but movement could continue from the unlined portions of the site (Earth Technology 1991). Additional movement to and out of the ponding area, but still on Fort Dix property, may have taken place during major storms since the ditch was asphalted (Earth Technology 1991).

Evaluation of Public Health Hazards

This section evaluates whether people could have come in contact with radiological contaminants released during the 1960 accident at BOMARC's Missile Shelter 204 and whether this contact would result in harmful effects. Even though contaminants were released into the environment, such releases do not always result in human exposure. People can only be exposed to a site contaminant if they breathe, ingest, or touch it. It is also important to remember that an exposed person would not necessarily experience adverse health effects.

ATSDR assessed the health effects that may result from exposures of individuals to site contaminants released from the BOMARC accident in 1960. Health effects, if any, resulting from the exposure are related to a number of factors, including contaminant concentration, exposure route, exposure frequency, exposure duration, and population exposed. ATSDR assessed potential effects resulting from three plausible exposure scenarios: (1) *past exposure of workers or response personnel to contaminants released during or shortly after the accident, and (2) current and future exposure of on-site personnel, and (3) current and potential future exposures of off-site residential populations to residual contamination.* These exposure scenarios and the public health implications associated with them will be discussed here and are summarized in Table 3. Note that ATSDR eliminated groundwater and surface water from further discussion in this section because radionuclide contamination occurs at levels below health concern or lacks viable pathways for human exposure.

The environmental monitoring did indicate the presence of uranium in the soil as would be expected if enriched uranium was present in the weapon. Surprisingly, however, the concentrations of uranium in surface soil are low (below the NCRP's value for commercial property of 3.88 Bq/g), and the potential hazards are insignificant in comparison to those of the plutonium concentrations detected at the site. Therefore, our evaluation of public health hazards focuses on plutonium and its decay products.

Past Exposure: Workers

Exposed Population

Workers near Missile Shelter 204 at the time of the accident, or shortly thereafter, would have had the greatest likelihood of coming into contact with radionuclides released from the accident. Prevailing winds would have transported the smoke from the accident site across BOMARC, predominately to the south-southwest, and off site. Workers downwind from the accident also could have been exposed.

The following describes personnel on site during or shortly after the 1960 accident, their location, if known, and whether they wore protective equipment.

- *Emergency response workers:* Emergency response personnel at BOMARC would have had the greatest likelihood of coming into contact with radionuclide contaminants carried in the smoke. Individuals responding to the accident included two Air Police personnel, four fire-fighters, several disaster control personnel from McGuire AFB, and explosive, ordnance, and demolition (EOD) teams from Fort Dix, Wright Patterson AFB, and Griffiss AFB. No information is available on where most of these people went or how much time they spent downwind of the accident site. Documentation suggests that the fire-fighters, disaster control, and EOD personnel wore protective equipment, which included respiratory protection equipment; information is not available for the other responders (USAF 1997b, USAF 1998b).

- *BOMARC workers:* BOMARC was active in 1960, so BOMARC personnel would have been working at the site at the time of the accident. ATSDR does not know whether BOMARC workers were evacuated during the accident or were wearing protective equipment during or following the accident. According to eyewitness accounts, personnel remained upwind of Missile Shelter 204 after the accident (USAF 1997b).

- *Remediation workers:* Workers involved in site cleanup include two Air Police officers, four fire-fighters, as well as an unknown number of disaster control personnel from McGuire AFB and EOD teams from Fort Dix, Wright Patterson AFB, and Griffiss AFB. No information is available for most of these individuals with regard to their location or the amount of time spent downwind of the accident site (USAF 1997b). Additional response teams are believed to have participated, but specific information was not available (AMC 2001).

Evaluating Exposure and Estimating Radiation Doses

How much radiation a worker was exposed to during or shortly after the accident is determined by the sum of their external and internal doses. External doses result from exposure to radioactive sources outside the body. These sources can penetrate through the human skin. Internal doses result from exposure to radioactive sources that have been taken into the body by inhaling radioactive particles or eating contaminated food. Whether an exposure contributed to a worker's external or internal dose depends primarily on the type of radiation— that is, alpha and beta particles or gamma rays—to which a worker was exposed. Plutonium is known as an alpha emitter because as it decays, it releases energy primarily as *alpha particles*. Any other radiation emitted by plutonium is of extremely low energy and significance. Plutonium forms decay products, or progeny, that are radioactive. Depending on the isotope of plutonium, these products continue to decay releasing small amounts of either alpha or beta particles and gamma rays (ATSDR 1990, 1999).

Alpha particles cannot travel far or pass through intact skin into the body. Therefore, exposures to alpha particles contribute only to a person *internal* dose if they inhale particles or ingest foods contaminated with alpha particles. *Beta particles* can be responsible for both *internal and external* doses, but they do not penetrate body tissue, nor contribute to external doses, as easily as gamma rays. *Gamma rays* can travel long distances and easily penetrate body tissues and are therefore the primary type of radiation that harm people exposed to a source outside the body.

Workers at BOMARC may have come in contact with radiological material or radiation by three different scenarios. These scenarios include: (1) external exposures from physical contact with the radioactive smoke cloud, (2) external exposures from gamma radiation released from the ground, and (3) internal exposures from inhaling plutonium. *Because plutonium releases primarily alpha radiation, internal exposure from breathing in plutonium is the primary exposure scenario of health concern.* External exposures from beta or gamma radiation are expected to pose a much lower hazard.

In assessing potential public health hazards to workers in the past, ATSDR evaluated radiation dose estimates derived by Air Force scientists (USAF 1997b). The Air Force estimated radiation doses for workers at the site during the accident and downwind of the accident using computer models coupled with best available data from Air Force records. A simple Gaussian plume model running HOTSPOT code was used. HOTSPOT assesses exposure related to accidents and is designed to assess short-term (less than 24 hours) releases. The model code has some limitations, but they would not be expected to alter the estimated doses.

To derive an individual's radiation dose as accurately as possible, one needs to understand the exact conditions of exposure. Unfortunately, the Air Force does not have complete information about conditions at the time of the accident. When possible, therefore, the Air Force used available information from original accident reports, eyewitness accounts of the accident, or data collected at the site. To account for the absence of certain data, the Air Force used conservative (or high-end, worst-case exposure level) assumptions or default values as the basis for determining likely doses and whether adverse health effects were possible. These estimated radiation exposure levels usually are much higher than the levels that people are really exposed to. For example, the Air Force assumed that the particle size distribution of the plutonium was 1 micrometer (μm), which is much smaller than the largely non-respirable size particles reported in the site documents. Additionally, the burning of high explosives produces a heavy smoke, which would further clump the particles together, thus reducing the amount of respirable particles (Sandoval 1993). Nonetheless, radiation dose estimates, derived using assumptions rather than actual information are expected to have some degree of uncertainty (USAF 1997b).

The Air Force evaluated exposure under three hypothetical exposure scenarios: 1) an approximate 40-foot (13-meter) high release, 2) an approximate 400-foot (123-meter) high release, and 3) a buoyant plume release. Radionuclides of concern possibly carried on the smoke particles are plutonium and uranium. Of these radionuclides, however, sufficient information for evaluating the hypothetical exposure scenarios was only available for plutonium (and its decay product americium). All three scenarios were evaluated twice, once assuming a release of 5 kilograms of plutonium and once assuming a 10-kilogram release. According to Air Force sources, these estimates are very high and overestimated the possible intakes and related equivalent radiation doses (AMC 2001).

ATSDR compared the derived radiation doses to guidance on radiological hazards provided by the International Commission on Radiological Protection (ICRP). ICRP's basic responsibility is to provide guidance in matters of radiation safety by preparing recommendations on the basic principles of radiation protection. For *occupational exposure*, ICRP recommends a maximum effective-dose limit of 5,000 millirem, or mrem (equivalent to 50 millisieverts, or 50 mSv[6]) above background in any one year, or 2,000 mrem (20 mSv) averaged over 5 years (ICRP 1991).

Table 4 lists the estimated radiation doses for workers near and downwind of the accident. The greatest estimated radiation dose occurs assuming a 40-foot high release. Under this scenario, workers within 300 feet of the accident could have been exposed to plutonium at levels up to 0.1 Sv, which is above the ICRP recommendation of 50 mSv a year. Under the remaining two scenarios, exposure to other personnel downwind of the accident was likely small and similar to or below background radiation (less than 3.6 mSv). Assuming a 400-foot release, the highest exposure of 1.62 mSv (from a 10-kilogram source) would occur at a quarter of a mile downwind of the accident site—on military property. Exposure estimates for the buoyant plume scenario were all below 0.2 mSv. If an emergency responder entered the accident area more than once, the

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[6] In the Systeme International (SI) system, the radiation dose quantity "rem" has been replaced with the sievert (Sv). One Sv equals 100 rem.

dose would be proportionally higher, depending on the time spent in the area as well as the time of the second entry into the fire-fighting area (USAF 1997b). In the case of remediation workers who entered the facility after the fire, the exposure pathway of concern is one of resuspension and inhalation of contaminated soils. In this case, the cumulative radiation dose possibly received is less than 25 Sv (USAF 1997b).

As noted, the exposure scenario assuming a 40-foot high release predicted doses (up to 100 mSv) that exceed ICRP's guideline for occupational exposures of 50 mSv per year. Radiation doses resulting from exposures to plutonium greater than the doses from the accident at BOMARC are suspected to cause measurable increases in cancers and leukemia, and damage to genetic material (ATSDR 1990). Any exposure to radiation, no matter how small, is likewise assumed to possibly cause adverse effects. At doses at even 100 mSv per year, however, the risks are generally still so small that the effects are not measurable in small populations and may be negligible. Because sufficient conservatism has been used in deriving the radiation dose estimates, the estimated radiation dose likely overestimates the exposure incurred by the workers. Therefore, the actual maximum radiation dose could be smaller than 100 mSv, and possibly at levels of little health concern for workers.

Current and Future On-Site Exposures

ATSDR's review of the current levels of plutonium in the soil at the site indicates that radiation doses to current or future remediation workers would be on the same order of magnitude as those for the past remediation workers at the site. Military personnel also may have intruded on the site inadvertently, but any potential doses to them are not expected to cause adverse health effects.

Public exposure to on-site contamination is remote. The BOMARC site is a secure site surrounded by a locked chain fence and signs are posted along the perimeter of the site prohibiting trespassing. The site is no longer used and no plans for future use of the site are indicated. Most plutonium contamination at and around Missile Shelter 204 and in the drainage ditch was covered with concrete and asphalt after fire-fighting efforts concluded in 1960. Furthermore, efforts are underway to remove contaminated structures, debris, and soil from the site. *Therefore, no current or potential future on-site pathways via inhalation of resuspended soil appear to exist.*

Past, Current, and Future Off-Site Exposures

Smoke released from the 1960 accident was carried south, southwest, or southeast off the BOMARC site—although not necessarily off military property, as it may have been transported onto the Range and Impact Area of Fort Dix. Areas within a 5-mile radius south and southwest of the BOMARC site are all on Fort Dix Military property. Southeastern areas within 5 miles of the BOMARC site are the Naval Air Engineering Station, Lakehurst, and the Colliers Mill Wildlife

Management Area. These areas are sparsely populated. An estimated 1995 sector census provided information on the current population living around the BOMARC site. The census found that the closest residents were 3 miles (4.8 kilometers) to the south-southeast (122 people) and southeast (52 people) from the site. The population increases to 1,031 individuals 5 miles south-southeast of the site and 1,258 individuals 5 miles southeast of the site (USAF 1997b). No census data are, however, available to describe the number of persons who lived near BOMARC at the time of the 1960 accident. In the absence of these data, ATSDR compared 1960 U.S. Census data that were available for the nearby communities of New Egypt (1,737 vs. 2,237), Lakehurst (2,780 vs. 3,078), and Wrightstown (4,846 vs. 3,843) against 1990 U.S. census data. In doing so, ATSDR noted that little difference exists between the total 1960 population for these three communities (9,363 people) when compared to the 1990 population (9,158 people). Using this information, ATSDR assumes that, likewise, there should be little difference in the local population around the BOMARC site over time and that the 1995 sector census should be reasonably representative of the number people living in the 3-mile and 5-mile buffer of the BOMARC site during the 1960s (U.S. Census 2002).

The Air Force used RESRAD to estimate the radiation doses for people hypothetically exposed to maximum concentrations of radionuclide contamination. RESRAD is a complex computer model designed to estimate radiation doses and risk from residual radioactive (RESidual RADioactive) materials in the environment. Even though such a scenario is unlikely, the estimates considered exposure of a farm family to the maximum contaminant concentrations detected on site (USAF 1992). The radiation doses considered three routes by which off-site populations could have been exposed during or shortly after the accident:

- external exposure from radioactivity released from the ground,
- internal radiation exposure from inhaled radioactive particles, and
- internal radiation exposure from ingestion of soil and crops.

In modeling exposure, the Air Force used available data for plutonium and americium. It should be noted that fallout from combustion of plutonium and americium tends to be in the form of oxides. Information about the oxides suggests that they do not easily dissolve in water and have a high affinity for soil particles. As a consequence, these radionuclides are not highly mobile in the environment and are not readily taken up by plants and animals. *Therefore, the most important current and potential future pathways of exposure are inhalation of resuspended dust and inadvertent ingestion of soil.*

As noted in Table 4, the estimated total dose rate for current or potential future exposure is 0.47 mSv per year. Internal dose accounted for about 99% of this total dose. Inhalation of resuspended dust accounted for about 76% of the dose (65% from plutonium and 11% from americium), with an additional 24% from ingestion of plutonium and americium (USAF 1992). External gamma radiation, largely from americium, contributed less than 1%. The estimated dose is small in comparison to the average annual background radiation dose, which is about 3.6 mSv per year. It is also less than 1 mSv per year above background limit recommended by the ICRP for public exposures to radioactive material and below the ATSDR minimal risk level for ionizing radiation (ATSDR 1999). Thus, any health effects associated with the derived doses are unlikely. *Therefore, exposure to radiological contaminants does not pose a current or future health threat to off-site populations.*

Concern: VOCs

Have VOCs contaminated the groundwater or surface water in areas used by the public? If so, has that contamination resulted, or will it result, in adverse human health effects?

Conclusions

After reviewing the available data, ATSDR has drawn the following conclusions:

- A TCE plume is migrating eastward from the BOMARC Missile Site toward the Colliers Mill Wildlife Management area.
- No public or private drinking water wells draw water from the vicinity of the TCE plume.
- The TCE plume from BOMARC discharges into the Success Branch at the Colliers Mill Wildlife Management Area. The stream, however, is not used as a source of drinking water, and people wading, fishing or hunting in or near the stream are not expected to come in contact with potentially harmful levels of TCE.

Discussion

In the late 1980s and early 1990s, the Air Force's investigations of BOMARC determined that the groundwater beneath the site was contaminated with VOCs, primarily with TCE. EPA investigations in 1993 further examined the groundwater and determined that a VOC-groundwater plume was

What are VOCs?

Volatile organic compounds (VOCs) are a group of organic chemicals having similar physical properties. Certain VOCs were detected in high concentrations in a plume moving eastward from the site boundary. VOCs easily evaporate when exposed to air.

Chemicals in this group include trichloroethylene (TCE) and its breakdown product 1,2-dichloroethylene (1,2-DCE). At BOMARC, TCE may have been used as a cleaning solvent for degreasing.

moving easterly from the BOMARC site toward the adjacent Colliers Mill Wildlife Management Area (see Figure 6). TCE use at BOMARC has not been documented, but it is a commonly used degreaser for cleaning metals parts (AFRL 2000).

The Colliers Mill Wildlife Management area is primarily a scrub pine forest dominated by older cedar trees and surrounded by a dense underbrush of deciduous trees. Other than several small dirt roads and transcontinental buried fiber optics line markers, there are no signs of development (Tetra Tech 1998). Spongy peat and small pools of standing water are common along the floor of the forest. The New Jersey Department of Natural Resources owns Colliers Mill, and the New Jersey Pinelands Commission manages the property. The Colliers Mill area is located in the northeast corner of the New Jersey Pinelands (or Pine Barrens), a large, level wooded area that spans 40 miles along the Coastal Plain area of New Jersey (Army 2001a). The Pinelands has restrictions on development and use, as it is protected as a natural preserve. Elisha Branch southeast of the BOMARC site flows easterly into the Success Branch in the Colliers Mill Wildlife Management Area (AFRL 2000)..

Evaluation of Environmental Data

<u>Groundwater</u>

Over 60 acres of land east of the BOMARC fence line have been investigated for possible VOC groundwater contamination. About one-third of the area is considered a buffer zone (between BOMARC site activities and adjacent lands) and the remaining two-thirds of the investigation area is within Colliers Mill Wildlife Management Area (Tetra Tech 1998). Studies conducted in the 1980s and again between 1995 and 1998 have collected samples from groundwater monitoring wells and hydropunch borings. Study results indicate that VOCs are present in the groundwater at concentrations above health-based screening values. Of the VOCs, TCE was detected most frequently and in the highest concentrations. The highest concentrations of TCE (420 parts per billion, or ppb) were measured in MW-10 at 42 feet below ground surface. So far, both the northern and southern boundaries of the plumes, which cover more than 60 acres, have been defined by 1 ppb TCE hydropunch borings. (These data must be confirmed by monitoring well sampling and analysis.) The eastern and western boundaries of the TCE plume have not yet been defined, but TCE has not been detected in groundwater samples collected from monitoring wells located by Highway 539 along the western boundary of the BOMARC site. The vertical extent of the plume is still being delineated (AFRL 2000).

With information provided by the early studies, the Air Force Research Laboratory (AFRL) and the U.S. Geological Survey (USGS) further studied the area to determine whether the plume was discharging into wetland or creek sediment and surface water and to gather information on natural degradation processes. These studies' results indicate that the TCE plume travels through a wetland area before reaching and discharging into the Success Branch in the Colliers Mill

Wildlife Management Area. Further sampling indicated that TCE was either not present or present at very low concentrations in groundwater samples collected from the eastern side of the creek (AFRL 2000).

1,1,-DCE and 1,2-DCE were detected sporadically in groundwater samples collected from the central region of the area under investigation (Tetra Tech 1998). The presence of DCE (a degradation byproduct of TCE) indicates that TCE concentrations are decreasing as a result of natural processes. Only low concentrations of DCE have been measured, however, suggesting that the wetland is not efficiently attenuating or destroying the TCE. The greatest amount of 1,1-DCE relative to TCE was found in a sediment sample collected 3 feet deep in the wetland where methane concentrations were also high. This finding suggests that natural attenuation was greatest under methanogenic conditions (AFRL 2000).

Because of concerns about the TCE plume overlapping with plutonium contamination, the Air Force took soil samples from two soil boring locations upgradient from Missile Shelter 204. With the exception of methylene chloride and acetone (two probable laboratory contaminants), no VOCs were detected in either boring. From these results, it appears that the plutonium contamination and the VOC groundwater plume have not overlapped.

Surface Water/Sediment

Investigations have shown that the TCE plume is "discharging into the wetland sediments," but they also show that the plume predominantly discharges into Success Branch, more than 2,000 feet from the site boundary. Some of the highest TCE concentrations (up to 35 ppb) were found along the western bank of Success Branch, where the consistency of the higher levels suggests that TCE is steadily discharged upward from the aquifer into this portion of the creek. TCE concentrations decrease to less than 1 ppb about 800 feet downstream from this point (AFRL 2000).

The AFRL and the USGS also installed piezometers (with screen depths less than 4 feet) to measure TCE in the wetland sediment and streambed sediment. TCE was detected at concentrations above 100 ppb in the stream bed sediment (between 1 and 4 feet below surface). The highest concentrations (130 to 150 ppb) were found in the sediment where groundwater discharges into Success Branch (at CM-13). No TCE, or TCE in very low concentrations, was found on the other, or eastern, side of the Success Branch.

Evaluation of Public Health Hazards

A VOC plume is moving east from the BOMARC site through a wetland buffer zone and toward the Colliers Mill Wildlife Management Area. No one has been or is currently exposed to harmful levels of VOCs in the plume because groundwater in the area of the plume has never been used as a source of drinking water. The nearest potable wells are located at the Naval Air Engineering Station, Lakehurst. Lakehurst maintains three potable water treatment systems that serve its work force and resident population. Lakehurst tests and treats its drinking water supply regularly for compliance with state and federal drinking water standards, including standards for VOCs and radionuclides (Lakehurst 2001).

The TCE plume is discharging into the Success Branch of the Colliers Mill Wildlife Management Area. No comparison values are available for surface water and sediment, so ATSDR compared contaminant concentrations to drinking water and surface soil comparison values. Even though contaminants reached levels greater than health-based comparison values, individuals who wade while fishing in the creek at the wildlife area are not at risk of developing health effects. For such people, contact with contaminants is likely intermittent and of short duration, and would not caused harmful effects. Only trace amounts of VOCs were detected further downstream, suggesting that surface water entering Toms River is not expected to be affected by VOC contamination from the BOMARC site. The Air Force, with NJDEP oversight, is continuing to evaluate the extent of the plume and its impact to the environment (AMC 2001).

COMMUNITY HEALTH CONCERNS

Through the public health assessment process, ATSDR has gathered information about health concerns voiced by members of the community. In gathering this information, ATSDR interviewed base public affairs personnel who address community questions and concerns about McGuire AFB, met with other base personnel (including the support group commander, civil engineers, the judge advocate, and the flight commanders of public and occupational health) who also meet with the public, reviewed the results of the base's own survey of community concerns, and reviewed concerns offered during the public health assessment process for the neighboring Fort Dix site.

McGuire AFB has a community relations plan that provides guidance for involving the community and other interested parties in the remediation decision-making process and for distributing information to these parties (USAF 1997b). As part of its community relations activities, McGuire AFB has formed a restoration advisory board (RAB). The RAB, which is largely made up of local community members, meets to periodically to review site documents and comment on actions and proposed actions taken by McGuire AFB.

Concern: *What measures are being taken to manage the radiological-contaminated media at BOMARC?*

The BOMARC site is located on Fort Dix property, however, the contamination at this site is the result of Air Force activities. As a result, it is the responsibility of the Air Force to address the contamination at this site. A record of decision (ROD) signed in 1992 outlined the preferred cleanup measures for the Missile Accident Site (RW-01). The preferred alternative calls for removal of contaminated soil and structural materials and off-site disposal at a licensed radioactive waste disposal facility (USAF 1992). Remediation of contaminated soil will help to ensure that contamination at this site will not continue to migrate off site. Although there is no expectation of the site becoming a residential area in the future, the Air Force intends to clean the site to "a condition that would allow people to establish residence in the middle of the site for 70 years and not be affected" (USAF 1992). The ROD for the Missile Accident Site states that the Air Force will excavate soil that contains more than 8 pCi plutonium per gram of soil. This level was developed in coordination with the U.S. Environmental Protection Agency and the New Jersey Department of Environmental Protection and is the lowest cleanup level for plutonium-containing soil at any Department of Defense or Department of Energy site nationwide. ATSDR reviewed the draft remediation work plan for remediation at BOMARC in 2000 and provided its comments to the Air Force.

As of Spring 2002, the Air Force began demolishing buildings and establishing plans for excavating contaminated soil and debris from BOMARC. The Air Force is employing numerous measures that include dust control and air monitoring to protect against off-site dispersion of material during the cleanup work. About 12,500 cubic yards of soil and 440 cubic yards of building debris, concrete, and asphalt will be removed. The two missile shelters on either side of the one destroyed by the 1960 accident will also be removed to aid the soil removal process. Cleanup will extend to areas off the BOMARC site, such as the area where the drainage ditch crosses Highway 539 and on the Fort Dix Range and Impact Area. The material will then be moved by truck through Fort Dix and the Naval Air Engineering Station, Lakehurst, then by rail for disposal at a Nuclear-Regulatory Commission-licensed facility in Utah. After the excavation is complete, the Air Force will verify that the site is clean through surveys and then backfill the excavated area with clean soil (McGuire AFB 2002).

Concern: *Has plutonium released during the accident been accounted for?*

Examination of the remnants of missile parts after the incident indicated a loss of up to 1.5 kilograms of weapons-grade plutonium. The historical data taken together are consistent with the estimate made by Los Alamos investigators of unaccounted-for plutonium in the recovered material.

Concern: *Could nearby drinking water supplies have been contaminated by materials injected into a BOMARC injection well?*

A report of the Office of the Project Manager for Chemical Demilitarization and Installation Restoration indicated that a 100-foot-deep injection well was located in the southwest portion of the BOMARC site, reportedly about 500 feet northeast and downgradient of the BOMARC water supply wells. The report gives no information on the type and quantity of material disposed of in the injection well (U.S. Army 1977). However, during a sampling effort at the site on April 6 and 7, 1981, no injection well was found. Rather, a rock-filled pit, apparently used for seepage disposal of liquids, was discovered at the suspected location of the injection well (U.S. Army 1981).

During that 1981 visit, the Army collected water samples from BOMARC site well No. 2 as well as from six other water supply sources (those identified in Table 2 plus a fire pond located one-third of a mile east at the Naval Air Engineering Station, Lakehurst.) The well water samples were tested for a variety of chemicals, including VOCs, metals, pesticides, nitrates/nitrites, sulfates, and an unsymmetrical dimethylhydrazine. Monitoring results indicated that the analytes were either not present or present at levels below ATSDR CVs and/or EPA's MCLs. The study results indicate that no contamination existed during this one-time sampling. The limited sampling cannot prove that the wells were never contaminated. Since the early 1980s, however, EPA has required public water suppliers to routinely test their water supply for compliance with federal standards for chemical constituents and radioactivity level. Lakehurst and other neighboring water suppliers regularly monitor their water for compliance and take steps to ensure that the drinking water distributed to consumers is safe to drink.

Concern: *Should I be concerned about exposure to radionuclides if I consume venison caught in the vicinity of the BOMARC site?*

Information about the levels of radionuclide contamination in deer or other game animals has not been collected in the area of BOMARC. Radionuclides fallout from the combustion of plutonium during the accident would have been in the form of oxides. Oxides do not readily dissolve in water nor do they have a high affinity for soil particles. As a result, plutonium is not readily taken up by plants possibly eaten by deer in the area. Some uptake by plants may occur through the leaves or other parts of the foliage, but according to Eisenbud and Gesell (1997), this range of uptake is still quite small and in the order of 0.01% to 1.4% of the levels in the soil.

Even if deer consumed plants containing plutonium oxides, little, if any, plutonium would be absorbed through the animal's gastrointestinal tract or stored in its muscle tissue. Plutonium is considered a bone seeker, so about 50% of the plutonium is deposited in the skeleton. Much of the remaining portion is taken up in the liver. Therefore, there is little chance for the plutonium to reside in muscle tissue and adversely affect someone who eats venison. Given the low amount of plutonium likely incorporated into plants and then possibly eaten and absorbed by deer, ATSDR considers venison to be a safe food to eat.

ATSDR CHILD HEALTH INITIATIVE

ATSDR's Child Health Initiative 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 kinds of exposures to hazardous substances emitted from waste sites and emergency events. In general, children are more likely to be exposed because they play outdoors and they often bring food into contaminated areas. They are shorter than adults, which means they breathe dust, soil, and heavy vapors 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.

Contaminants have been detected at the BOMARC site and the Colliers Mill Wildlife Management Area. ATSDR attempted to identify populations of children in the vicinity of the BOMARC site and any public health hazards threatening these children. ATSDR determined, however, that harmful exposures are unlikely to occur because children cannot access the BOMARC site or locations of contamination at BOMARC (and children probably never have visited the site) and no harmful exposures associated with the site are specific to children in the vicinity of the site. Although children may visit the Colliers Mill Wildlife Management Area adjacent to the BOMARC site, contaminants that have entered the surface water and sediment are relatively low and children are not expected to come in contact with levels that could cause health effects. Following a careful evaluation of the potential exposure pathways as they relate to children, ATSDR determined that no harmful exposures have occurred in the past, nor are they likely to occur either now or in the future. (These potential exposure pathways are discussed in the Evaluation of Contamination and Potential Exposure Pathways section of this public health assessment.)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions regarding potential past, current, and future exposures to various environmental media on and in the vicinity of the McGuire AFB BOMARC site are based on a thorough evaluation of remedial site investigation data; groundwater, soil, and surface water/sediment monitoring data; municipal drinking water supply data; and observations made during site visits. Conclusions regarding exposures are described below. (The public health hazard conclusion categories used below are described in the glossary.)

- No apparent public health hazards are associated with an explosion and fire at the BOMARC site in 1960, which released radionuclides to the environment via smoke, dust, and water runoff from fire-fighting efforts. Workers responding to the accident, downwind at the time of the accident, or involved in cleanup may have breathed in alpha radiation when then inhaled radionuclides, primarily plutonium, carried on smoke or attached to resuspended soil, or they could have been exposed to small amounts of external gamma radiation. Given the lack of information about the exposure conditions at the time of the accident, it is challenging to accurately assess workers' intake and doses. Conservative estimates, however, suggest that radiation doses received during or after the accident are not expected to cause harmful long-term effects or cancer. At the conservatively estimated radiation doses, the risks are generally so small that the effects are not measurable in small populations and may be negligible. Because sufficient conservatism has been used in deriving the radiation dose, the estimated dose likely overestimates the exposure incurred by the workers. Exposure levels would have been highest near the accident site, but would have decreased with distance to levels similar to background radiation levels. Due to the restricted nature of the site, the concrete and asphalt barriers, and remedial activities, on-site contamination is not expected to pose a current or future threat to public health.

- No public health hazards are associated with VOC-contaminated groundwater moving eastward from the BOMARC site: no wells draw water from the area of the VOC plume.

- No apparent public health hazards to off-site recreational users of the nearby streams (Elisha Branch or Success Branch) or the Colliers Mill Wildlife Management Area are associated with past or current exposures to contaminants in surface water and sediment. To prevent future exposures, the Air Force is evaluating remedies with oversight by NJDEP.

PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan (PHAP) for the BOMARC Missile site contains a description of actions taken by ATSDR, the Air Force, EPA, and NJDEP at and in the vicinity of the site. It also describes the actions the same entities plan to take after this public health assessment is completed. The purpose of the PHAP is to ensure that this public health assessment not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, being implemented, planned, or recommended are as follows:

Completed Actions

1. Following the explosion that occurred in 1960, paint was applied to the shelter and concrete was poured over the most heavily plutonium-contaminated portions of the asphalt apron and floor area of the shelter. An asphalt cover was placed in the drainage ditch that leads from the shelter to the nearby stream to impede erosion of contaminated soil. Access to the accident area is restricted by a 6-foot chain link fence topped with barbed wire.

2. The BOMARC site was deactivated in 1972 and all missiles were removed.

3. The Air Force conducted a series of radiological surveys at and near the site to characterize the radiological releases to soil, air, surface water/sediment, and groundwater in the aftermath of the 1960 explosion at the missile shelter. Several other investigations have been conducted at this site (RW-01) under the IRP program. The Air Force and EPA signed a ROD for the area in 1992 that earmarks an estimated 7,000 cubic yards of radiological-contaminated soil (containing plutonium 239 at levels above 8 pCi/g) and other material for removal and proper disposal at an approved waste disposal facility.

4. The Air Force identified five other IRP sites during base investigations. Interim remedial actions were conducted at three of these: OT-12, OT-16, and ST-15. PCB-contaminated soil was removed from OT-12 in 1993, launcher hydraulic fluid was removed from OT-16 in 1996, and petroleum-contaminated soil and underground storage tanks were removed from ST-15 in 1993.

5. Groundwater monitoring efforts of the Air Force, USGS, NJDEP, and EPA have helped to identify a roughly 60-acre TCE plume and delineate its northern and southern boundaries. The plume, which extends eastward from the site, discharges into Success Branch.

6. The Air Force proposed no further response actions for WP-05, OT-12, WP-17, and ST-15.

Ongoing/Planned Actions

1. The Air Force is gathering additional confirmation sampling to support a no further action decision and closure at OT-12, ST-15, and WP-05.

2. Further monitoring of groundwater and surface water quality is underway in the area of the TCE plume to further delineate the eastern, western, and northern boundary of the plume and to determine whether natural attenuation is effectively reducing the concentrations of TCE/DCE in the groundwater.

3. The Air Force has begun demolishing buildings and establishing plans for removal of soil and debris from the BOMARC site. The excavated material, including approximately 12,500 cubic yards soil and 440 cubic yards debris, will be transported by truck through Fort Dix and Naval Air Engineering Station Lakehurst, and then shipped by train to a Nuclear Regulatory Commission licensed disposal facility area in Utah. Once the site is determined to be clean through confirmatory surveys, the Air Force will backfill the excavated areas with clean soil.

4. Members of the community and the Air Force participate in regularly scheduled Restoration Advisory Board meetings. These meetings serve as a forum for communication of ongoing and planned activities at BOMARC to the community and for communication of community concerns to Air Force and McGuire AFB personnel.

Recommended Actions

1. If new information from site investigations identifies contaminants in site media above ATSDR's health-based comparison values, ATSDR will assess contaminant data and exposure situations to identify if any public health hazards exist. ATSDR will also re-evaluate the potential for public health hazards if changes in proposed land use, remedial

activities, or risk management actions (e.g., institutional controls) may lead to future exposures.

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TABLES

Table 1. Evaluation of IRP Sites at the BOMARC Site

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
Boeing Michigan Aeronautical Research Center (BOMARC) Missile Accident Site (Radioactive Waste Site [RW]-01)			
During the 1950s, rows of shelters were constructed to house missiles and their launchers. On June 7, 1960, a fire and non-nuclear explosion occurred in Missile Shelter 204. Weapons-grade plutonium and enriched uranium were released through airborne emissions and transported via surface water flow to a nearby drainage ditch by the fire-fighting efforts working to contain the fire.	**Groundwater:** The groundwater was monitored for radionuclides during remedial investigation (RI) field activities. No radionuclides were detected. **Soil:** Soil was analyzed for volatile organic compounds (VOCs) and radionuclides. The primary radionuclide of concern is plutonium 239/240. Plutonium 239/240 at levels above U.S. Environmental Protection Agency's (EPA's) risk-based level of 0.3 becquerels per gram (Bq/g) (or 8 picocuries per gram [pCi/g]) was found to be concentrated in the top layers of soil. At one sampling location (where water used to extinguish the fire first entered the soil) a high concentration of plutonium 239/240 (5,180 Bq/g, or 140,000 pCi/g) was detected. **Surface Water:** (same as groundwater) **Sediment:** Sediment from the nearby drainage ditch was analyzed for VOCs, semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and radionuclides. Of the radionuclides, plutonium 239/240 was detected most frequently. Other analytes, including metals, pesticides, SVOCs, and PCBs were detected. **Structures:** Contained alpha radiation greater than permissible levels.	Following the accident, containment measures were applied to the missile shelter and a nearby asphalt apron. The shelter was washed down and painted (both inside and outside) and 6 inches of reinforced concrete was poured in front of Missile Shelter 204 to fix the plutonium. Installation restoration program (IRP) activities were initiated in 1986 followed by a remedial investigation /feasibility study between 1989 and 1992. A record of decision (ROD) recommending excavation and off-site disposal of contaminated waste was signed on November 16, 1992. To address issues raised in the ROD, a site characterization report was completed in August 1995. Additional areas were addressed in a final study in February 1998.	**Past:** Response workers, remediation workers, and downwind populations may have been exposed to radionuclides released during or shortly after the 1960 accident. **Current and Future:** No harmful exposures are occurring, nor are they expected to occur. Access has been restricted since the facility was deactivated in 1972. Any off-site exposure to radiological contaminants in resuspended soil or foods is not expected to be at levels of health concern.

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
JP-X Discharge Pit (Waste Pit [WP]-05)			
The JP-X discharge pit was used from 1958 to 1972 for disposal of missile fuel residues generated from routine missile maintenance activities. The pit is located near Building No. 37, in the west-central portion of the support area at the BOMARC Missile Facility.	**Groundwater:** In 1991, groundwater samples collected from the JP-X discharge pit were analyzed for VOCs, SVOCs, pesticides, metals, and hydrazines. Trichloroethylene (TCE) was detected frequently at concentrations up to 67 ppb, which exceeds the Agency for Toxic Substances and Disease Registry's [ATSDR's] Cancer Risk Evaluation Guide [CREG] of 3 ppb in drinking water and EPA's maximum contaminant levels (MCL) of 5 ppb. Other analytes were also detected, but infrequently or at low concentrations. **Soil:** Samples were analyzed for VOCs, SVOCs, pesticides, PCBs, petroleum hydrocarbons, and metals; select samples were analyzed for hydrazines. Most analytes were either not detected or detected at levels below New Jersey's Department of Environmental Protection (NJDEP's) unrestricted use soil cleanup criteria. **Surface Water/Sediment:** Surface water was sampled for pesticides; 4,4-DDE, 4,4-DDE, and 4,4,-DDT were detected. Sediment was not sampled.	A no further response action planned (NFRAP) decision document (DD) was prepared by the Air Force and submitted to NJDEP in 1991. A RI is currently underway. The Air Force is in the process of collecting additional data to aid in the process of closing this site.	**Past:** Due to restricted access at the site, no harmful exposures were likely to have occurred in the past. **Current and Future:** No exposures are occurring, nor are they expected to occur. Access to the facility has been restricted since the facility was deactivated in 1972 and no one drinks water drawn from beneath this site.

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
Transformer Locations (Other [OT]-12)			
In 1958, electric power was distributed throughout the site by five power transformers mounted on concrete pads (T-11 through T-15) and by transformers on poles. PCBs and petroleum hydrocarbons were disposed of at these locations.	**Groundwater:** Not sampled. **Soil:** Soil samples were analyzed for VOCs, SVOCs, pesticides, PCBs, and petroleum hydrocarbons in 1993 and/or 1997. PCBs and petroleum hydrocarbons were detected at three of the transformer pads. VOCs, SVOCs, and pesticides were typically at levels below NJDEP's cleanup criteria. **Surface Water/Sediment:** Not sampled.	A contractor removed the transformer pads (T-12, T-13, and T-15) and excavated the surrounding contaminated soil (containing up to 16.6 parts per million [ppm] PCBs in a subsurface sample at T-15) in October 1993 to meet NJDEP's cleanup goal of 100 ppm in effect at the time. (PCB contamination around T-11 and T-14 did not exceed NJDEP's unrestricted use criteria.) After NJDEP lowered their PCB non-residential cleanup goal to 2 ppm, the Air Force excavated an additional 80 tons of PCB-contaminated soil in 1997. The Air Force may need to establish institutional controls before obtaining NJDEP's approval for no further action.	**Past:** Due to restricted access to the site, no harmful exposures were likely to have occurred in the past. **Current and Future:** No exposures are occurring, nor are they expected to occur. Access has been restricted since the facility was deactivated in 1972 and contaminated soil and material have been removed from the site.

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
MOGAS Storage Tank (Storage Tank [ST]-15)			
This 5,000 gallon-capacity gasoline tank was located on the west side of Auto Alley near the intersection of South BOMARC Drive at the BOMARC Missile Facility. It was used for fueling motor vehicles with MOGAS (automobile gasoline) from 1961 to 1972.	**Groundwater:** In 1991, groundwater samples were analyzed for VOCs, SVOCs, and metals, but only metals (antimony, chromium, lead, mercury, nickel) were detected. Samples collected in 1996 and 1997 (after soil and underground storage tank [UST] removal) were analyzed for VOCs, lead, methyl-tertiary butyl ether (MTBE), and tertiary butyl alcohol, but only lead was detected. With the exception of one hit (31.3 ppb), the levels of lead in the groundwater were below the EPA action levels (15 ppb). **Soil:** In 1987, surface and subsurface soil samples were analyzed for VOCs, SVOCs, lead, and petroleum hydrocarbons. Analytes were detected at levels below NJDEP's target cleanup criteria then in effect. Post-excavation surface and subsurface soil samples were analyzed for VOCs, SVOCs, petroleum hydrocarbons, and lead in 1993 and 1997. No VOCs were detected. Lead and petroleum hydrocarbons were detected but at levels below NJDEP's unrestricted use cleanup criteria. **Surface Water/Sediment:** Not sampled.	To eliminate petroleum-contaminated soil and to comply with UST regulations, the contaminated soil and UST were removed in 1993. An NFRAP DD was signed in 1994. The Air Force is collecting additional data as part of the process to support closing this site.	**Past:** Due to restricted access to the site, no harmful exposures were likely to have occurred in the past. **Current and Future:** No exposures are occurring, nor are they expected to occur. Access has been restricted since the facility was deactivated in 1972, the UST and associated contaminated soil have been removed from the site, and no one drinks water drawn from beneath this site.

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
Missile Launchers (OT-16)			
Eighty-four missile launch shelters were located in the northern half of the BOMARC Missile Facility. Each launcher had a 150-gallon reservoir of hydraulic fluid, although some have been drained. Some hydraulic units were reported to be leaking fluid. Maintenance shop waste solvents, including TCE and dichloroethylene (DCE), were disposed of in the launcher area.	**Groundwater:** During 1991 field investigations, samples were analyzed for VOCs, petroleum hydrocarbons, and radionuclides. Of the analytes, the VOCs TCE and DCE were detected most frequently and in the highest concentrations. Plutonium was also detected. As part of the 1997 TCE/DCE plume characterization, groundwater samples were analyzed for select VOCs. The study identified a TCE/DCE plume extending from this site beyond the eastern site boundary. Concentrations exceeded ATSDR CV and EPA's MCL of 5 ppb for TCE. The specific source of the TCE/DCE has not yet been identified. **Soil:** Not sampled. **Surface Water/Sediment:** In 1997, surface water samples from Elisha Creek were analyzed for select VOCs. TCE was detected but at low concentrations. Sediment was not sampled.	All missiles were removed in 1972, when the site was decommissioned. Through a 1996 Hydraulic Fluid Interim Remedial Action, hydraulic fluids in the launcher sump pit and in the hydraulic supply were drained. The area is being investigated through activities related to the TCE/DCE groundwater plume.	**Past:** Due to the restricted access to the site, no harmful exposures were likely to have occurred in the past. **Current and Future:** No exposures are occurring, nor are they expected to occur. Access has been restricted since the facility was deactivated in 1972. No operating drinking water supply wells have been identified in the vicinity of the TCE/DCE plume. Contact with contaminants reaching Elisha Branch or Success Branch at Colliers Mill Wildlife Management Area is not expected to pose harm to recreational users of the area.

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

Site Description and History	Investigation Results/Environmental Monitoring Results[1]	Corrective Activities and/or Current Status	Evaluation of Exposure
Acid Neutralization Pit (WP-17)			
The acid neutralization pit, an unlined crushed limestone filled below-grade concrete basin, was located near Building No. 26 in the west-central portion of the support area. The pit was used between 1958 and 1972 for disposal of fuel residues from routine missile maintenance operations. Acid spills and rinsates were flushed to an acid spill pit and then to the acid neutralization pit.	**Groundwater:** In 1991 and 1997, samples were analyzed for VOCs, SVOCs, and metals; 1991 samples were also analyzed for hydrazines, nitrate/nitrite, and plutonium. Only metals (chromium, lead, nickel, and mercury) and nitrite were detected. Nitrates were detected at concentrations up to 2.96 ppm, but at levels below EPA's MCL of 10 ppm. Chromium (up to 258 ppb) and lead (up to 22.7 ppb) were detected at levels above their respective EPA MCL (100 ppb) or EPA action level (15 ppb). **Soil:** In 1991 and 1997, samples were analyzed for VOCs, SVOCs, and metals; 1991samples were also analyzed for pesticides, PCBs, petroleum hydrocarbons, and hydrazines. No contamination was present. **Surface Water/Sediment:** Not sampled.	An NFRAP DD was submitted to NJDEP in September 1991. A RI is currently underway. The Air Force is collecting additional data as part of the process to support closing this site.	**Past:** Due to restricted access to the site, no harmful exposures were likely to have occurred in the past. **Current and Future:** No exposures are occurring, nor are they expected to occur. Access has been restricted since the facility was deactivated in 1972.

Sources: URS 1998a, 1998b, 1998c, 1998d; OHM 1996, 1998.

Key:

ATSDR	Agency for Toxic Substances and Disease Registry	DD	Decision Document
BOMARC	Boeing Michigan Aeronautical Research Center	EMEG	ATSDR's environmental media evaluation guide
Bq/g	Becquerels per gram	IRP	Installation Restoration Program
CREG	ATSDR's cancer risk evaluation guide	MCL	EPA's maximum contaminant level
DCE	dichloroethylene	MOGAS	automobile gasoline

Table 1. Evaluation of IRP sites at BOMARC Site (continued)

MTBE	methyl tertiary butyl ether	RW	radioactive waste site
NFRAP	no further response action planned	ST	storage tank
NJDEP	New Jersey Department of Environmental Protection	TCE	trichloroethylene
OT	other	EPA	U. S. Environmental Protection Agency
PCBs	polychlorinated biphenyls	UST	underground storage Tank
pCi/g	picocuries per gram	VOC	volatile organic compound
ppb	parts per billion	WP	waste pit
ppm	parts per million		
PQL	practical quantitation limit		
RI	remedial investigation		

[1] A formal background quality study has not been established for the BOMARC Missile Facility. In the absence of site–specific background concentrations, ATSDR presented groundwater/surface water analytes that exceed NJDEP's practical quantitation limits (PQLs) and soil/sediment analytes that exceed NJDEP clean-up criteria or EPA's risk based criteria. The PQL is the lowest concentration of a constituent that can currently be reliably detected during routine laboratory operations.

Table 2. Area Drinking Water Wells in 2.5 Mile Radius of the BOMARC

Description	Years of Operations	Location/Approximate Distance from BOMARC	Depth of Wells (feet)
On-Site Wells			
BOMARC Well 1	approximately 1958 - 1972	southwest corner of site	100
BOMARC Well 2	approximately 1958 - 1972	southwest corner of site	100
BOMARC Well	approximately 1958 - 1972	unknown	unknown
BOMARC Well	approximately 1958 - 1972	unknown	unknown
Off-Site Wells			
Ft. Dix, National Guard UTES (for BOMARC)	1979 - present	1.5 miles W	87
NAES, Lakehurst	1958 - present	0.88 miles N	50
NAES, Lakehurst	1958 - present	1.7 miles ESE	52
Army Corp of Engineers	1958	0.66 miles WNW	93
Ft. Dix, Bivouac Site 18	unknown	2.3 miles SSE	103
Ft. Dix, Bivouac Site 20	unknown	1.2 miles SSW	118
Ft. Dix, Bivouac Site 22a	unknown	0.9 miles WNW	125

Sources: U.S. Army 1981; URS 1998b.

Table 3. Exposure Pathways Evaluation Table

Exposure Pathway Elements						Comments
Source of Contamination	**Time Period of Exposure**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Potentially Exposed Population**	
Exposures Related to the 1960 Accident at Missile Shelter 204						
BOMARC Missile Facility Accident—On June 7, 1960, an explosion and a fire occurred at Missile Shelter 204.	***Past***—during and shortly after the accident in 1960	• Airborne weapons-grade plutonium exhausted from the building during and shortly after the June 7, 1960, accident. • External gamma radiation • Contaminated resuspended dust	On-site and, possibly, off-site downwind locations	•Inhalation of smoke and resuspended dust • External radiation exposure	McGuire AFB personnel assigned to the BOMARC site, McGuire AFB and Fort Dix personnel responding to the accident (fire-fighters, disaster control personnel, air police), and possibly Fort Dix personnel at the surrounding off-site downwind locations.	Personnel responding to the accident and in the immediate area (less than 0.5 miles from the accident site) were likely exposed to the highest levels of weapons-grade plutonium. On-site (and off-site) personnel downwind beyond 0.5 miles of the accident site were exposed, if at all, to radiation levels indistinguishable from background radiation levels.

Table. 3 Exposure Pathways Evaluation Table (continued)

Exposure Pathway Elements						Comments
Source of Contamination	**Time Period of Exposure**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Potentially Exposed Population**	
BOMARC Missile Facility Accident	***Current and Potential Future***	• External gamma radiation • Contaminated resuspended dust • Contaminated foods	Off-site downwind locations, including Fort Dix (to the south and southwest) and Naval Air and Engineering Station, Lakehurst. These areas are sparsely populated and cover a 5-mile radius from the BOMARC Missile Facility.	•Inhalation of resuspended dust • Ingestion of soil and foods • External radiation exposure	Personnel working and residents living in downwind locations	No releases of plutonium or other radioactive material have been reported after the 1960 accident, and the site has been deactivated since 1972. Any exposure of off-site populations to radiological contaminant in soil or foods is not of health concern.

Table. 3 Exposure Pathways Evaluation Table (continued)

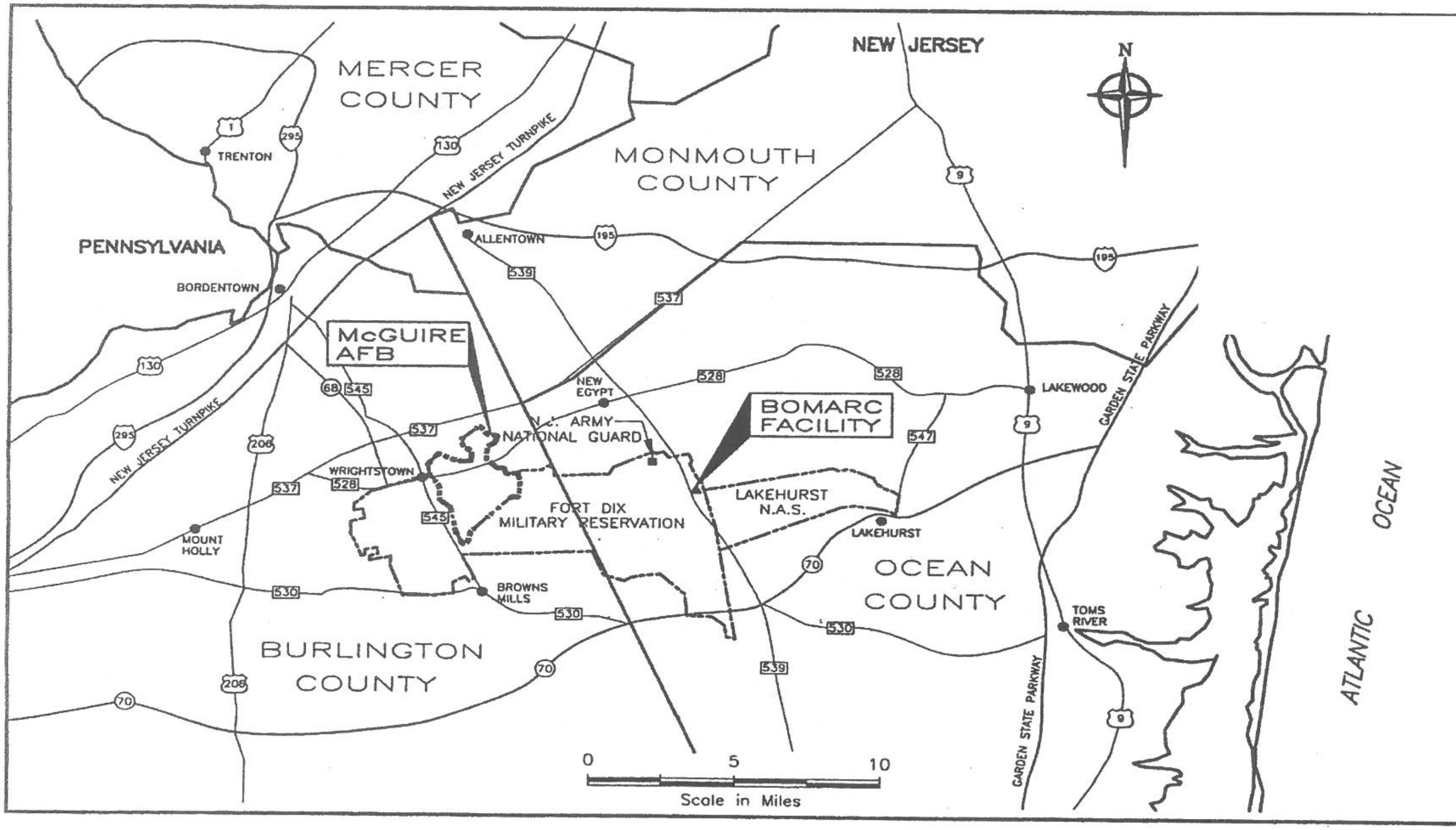
Exposure Pathway Elements						Comments
Source of Contamination	**Time Period of Exposure**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Potentially Exposed Population**	
Exposures Related to the VOC plume						
BOMARC Missile Facility. The specific source of VOCs at the site has not yet been identified.	***Past, Current, and Potential Future***	Groundwater	None	None	None	The former BOMARC drinking water supply wells were located upgradient and away from the VOC plume. No private or public drinking water wells draw water from the path of the plume.
		Surface water	Success Branch in Colliers Mill Wildlife Management Area	Dermal contact	Recreational users (e.g., anglers, hunter) of the wildlife area	VOCs have been detected in Success Branch. Limited contact with surface water associated with fishing or hunting is not expected to be of health concern.

Table 4. Maximum Estimated Annual Committed Effective Doses for Radiation Exposure Near BOMARC

Time Period	Route of Exposure	Maximum Estimated Annual Committed Effective Dose (mSv)	
Past	Radiation from smoke Radiation from ground Inhalation of particles	40-foot high release	about 0.1 Sv at less than 0.1 miles from the accident site
		400-foot high release	0.81 - 1.62 mSv at 0.25 mile from the accident site
		buoyant plume	up to 0.16 mSv at almost 1 mile from the accident site
Current/Potential Future	Radiation from ground Inhalation of particles Ingestion of food and soil	0.47 mSv	
Key: mSv = millisieverts			

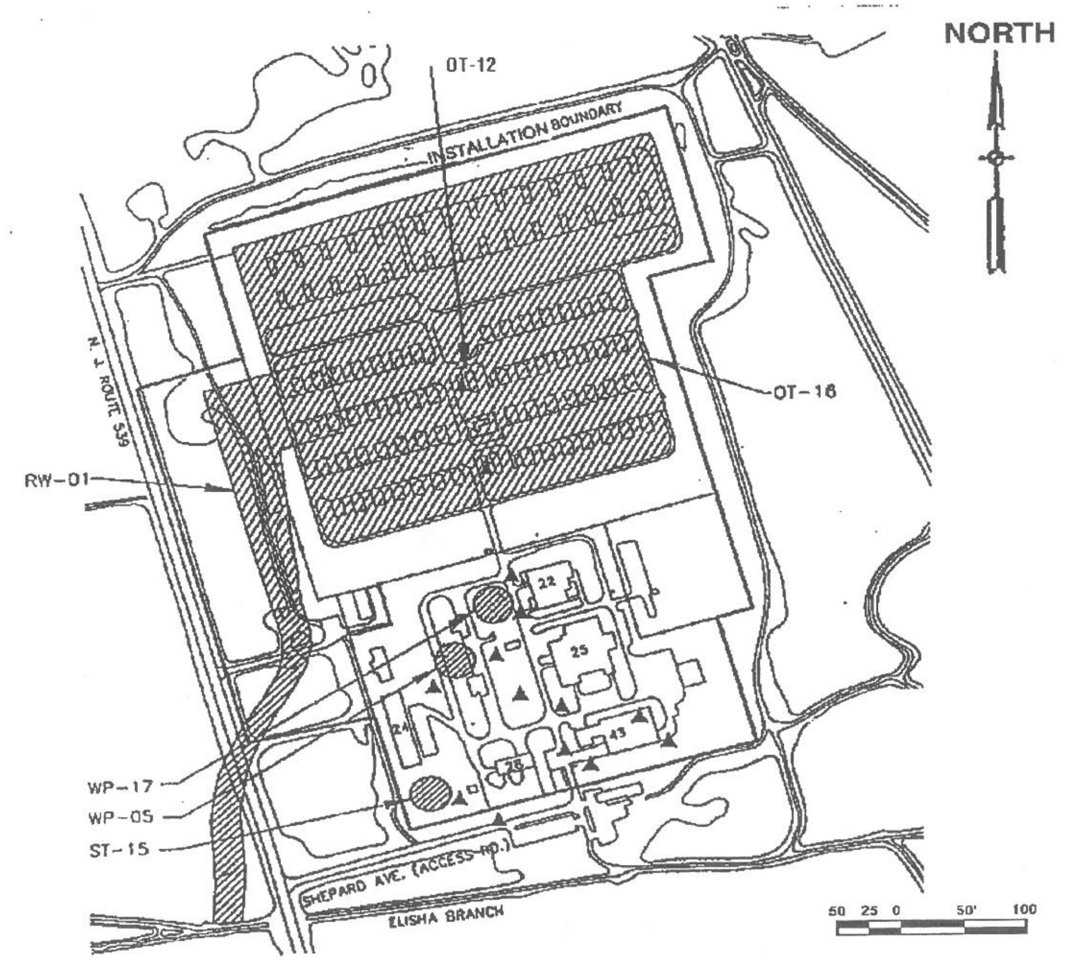
FIGURES

Figure 1. Location Map
BOMARC Missile Site



Source: URS 1998a.

Figure 2. Site Map
BOMARC Missile Site



SITE	DESCRIPTION
RW-01	BOMARC MISSILE SITE ACCIDENT AREA
WP-05	BOMARC MISSILE SITE JP-X DISCHARGE PIT
OT-12	BOMARC MISSILE SITE TRANSFORMERS
ST-15	BOMARC MISSILE SITE MOGAS STORAGE TANK
OT-16	BOMARC MISSILE LAUNCHERS
WP-17	BOMARC MISSILE ACID NEUTRALIZATION PIT

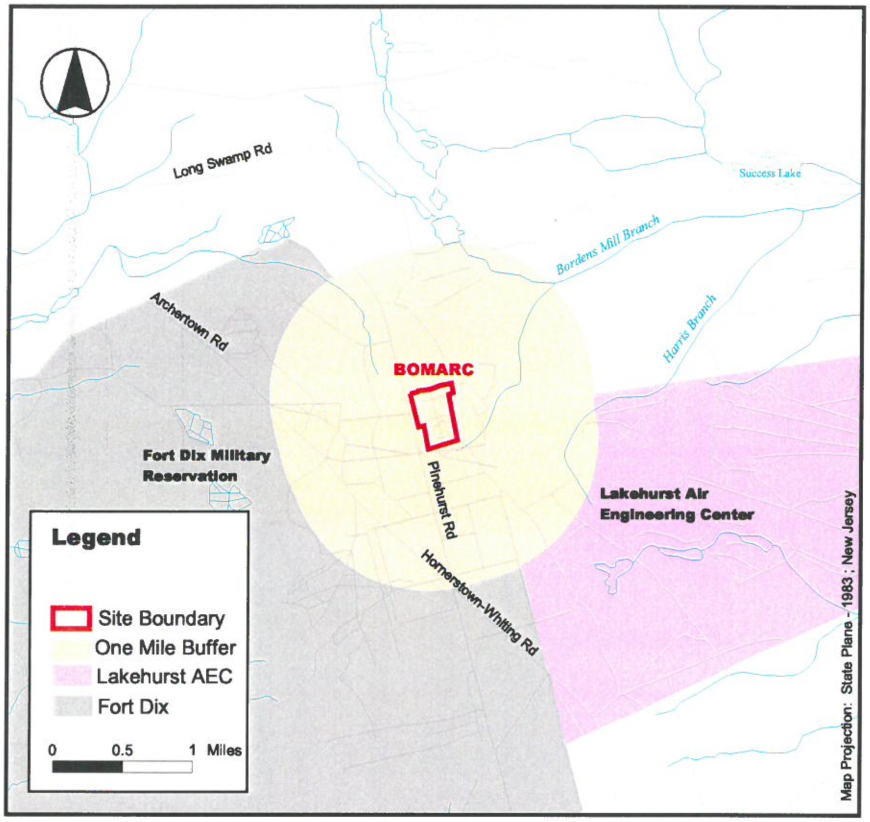
Source: URS 1998a.

BOMARC

New Egypt, New Jersey

EPA Facility ID NJ2570026268

INTRO MAP

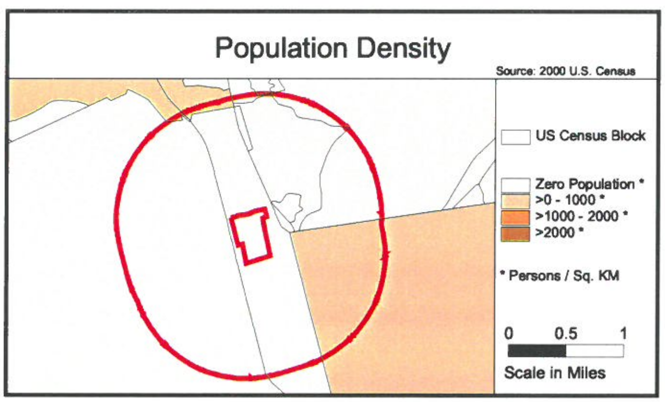


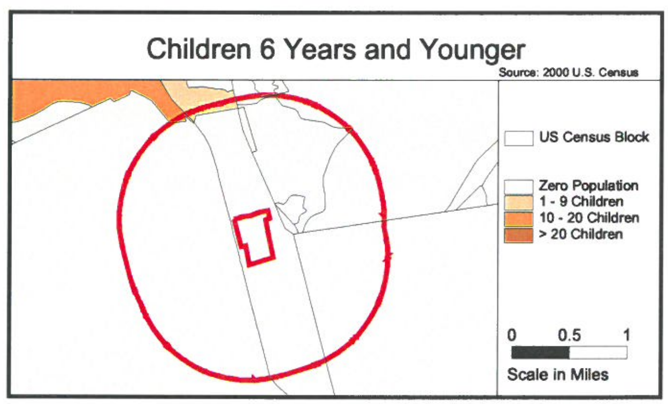
Base Map Source: 1995 TIGER/Line Files

Ocean County, New Jersey

Demographic Statistics Within Area of Concern*	
Total Population	4
White alone	4
Black alone	0
Am. Indian and Alaska Native alone	0
Asian alone	0
Native Hawaiian and Other Pacific Islander alone	0
Some other race alone	0
Two or More races	0
Hispanic or Latino	0
Children Aged 6 and Younger	0
Adults Aged 65 and Older	0
Females Aged 15 - 44	1
Total Housing Units	1

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





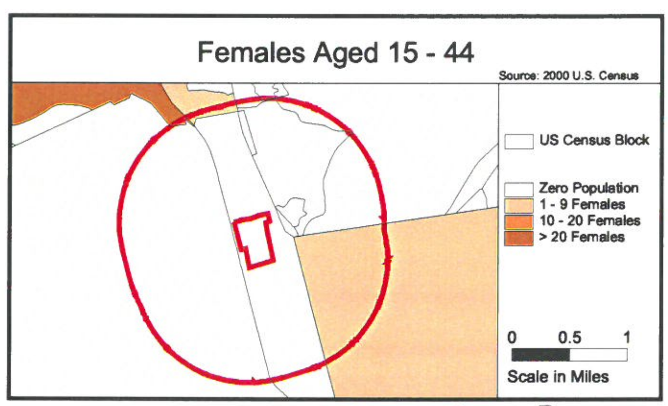


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Figure 3

Figure 4. ATSDR's Exposure Evaluation Process

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? → **Are People Exposed To Areas With Potentially Contaminated Media?** → **For Each Completed Exposure Pathway, Will the Contamination Affect Public 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:

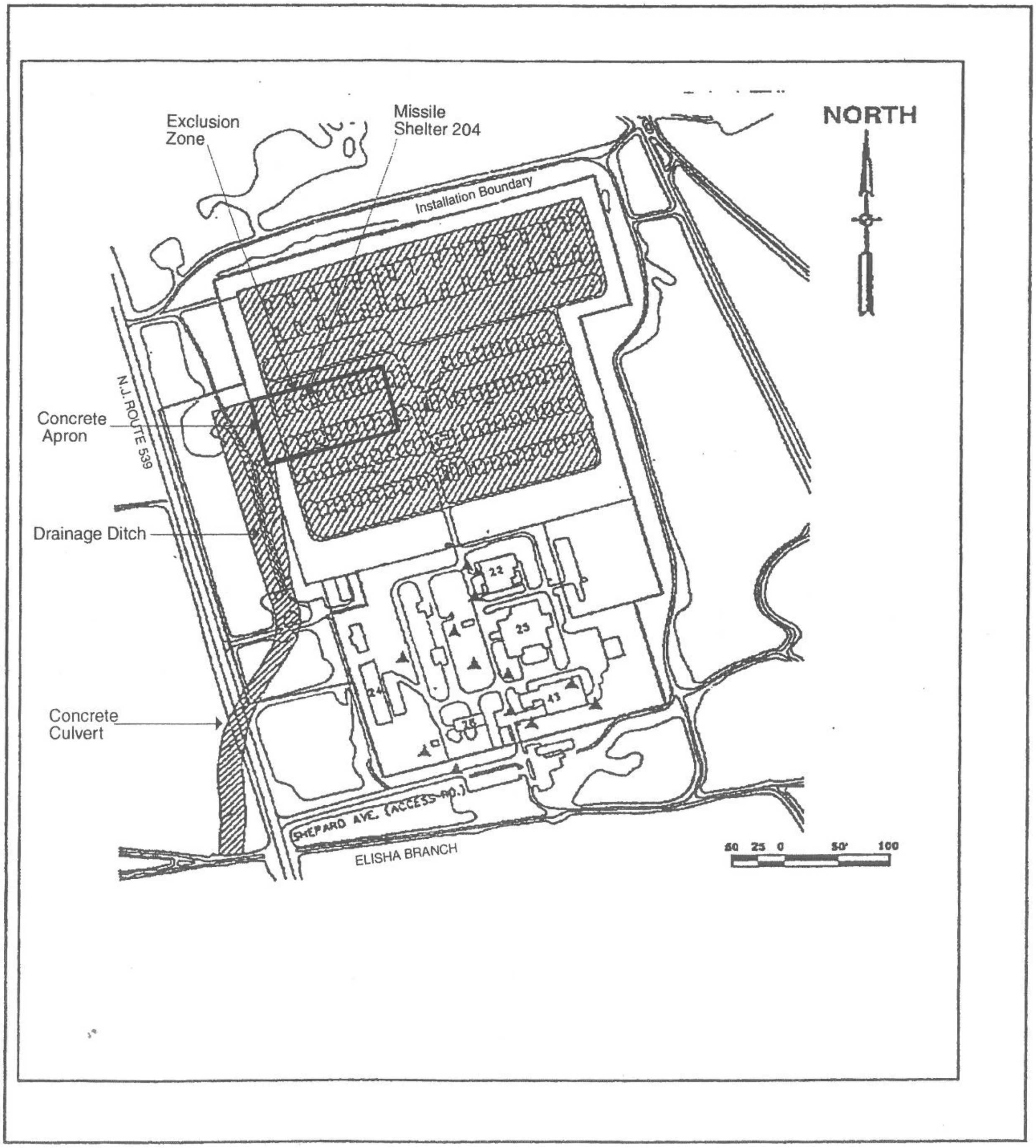
Inhalation
Ingestion
Dermal absorption

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

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

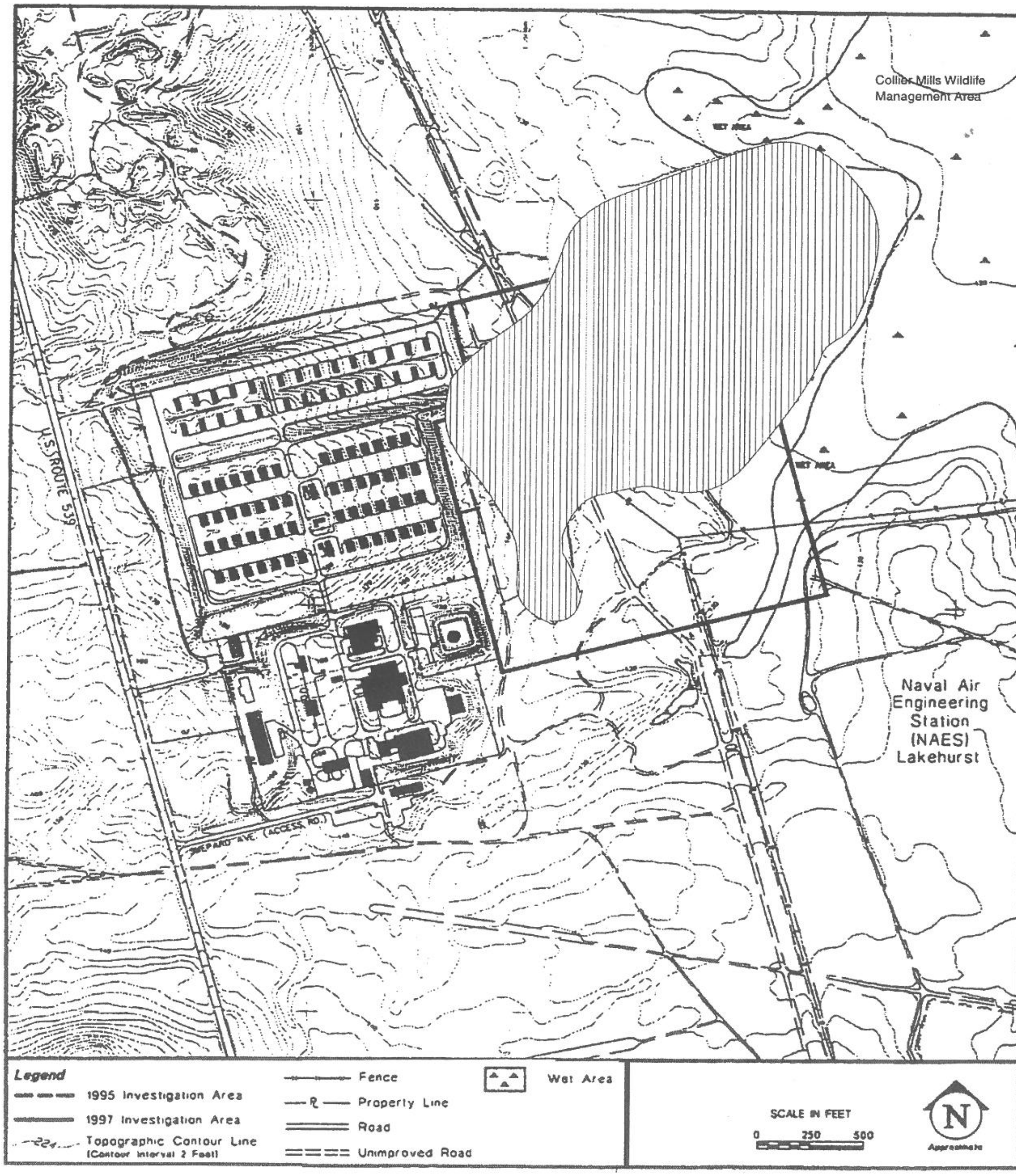
ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

Figure 5. BOMARC Missile Accident Site



Source: Adapted from USAF 1998a.

Figure 6. Area of the TCE Plume



Source: Adapted from Tetra Tech 1998.

APPENDIX A. RADIOLOGICAL DATA REVIEW

Varied Sampling and Laboratory Techniques

According to documentation reviewed by ATSDR, annual sampling did not always follow the same general sampling plan. Different laboratories and techniques were used, so the data quality, number of samples, and location of measurements vary. Nevertheless, the available monitoring results are in good agreement and they can be used to assess public health concerns and to assist in clean-up decisions.

Estimates of Plutonium Isotopes

Weapons-grade plutonium contains various amounts of plutonium isotopes, including plutonium 239, plutonium 240, and americium 241. The Air Force calculated plutonium concentrations based on the concentration of americium 241 detected, as determined mostly by gamma spectrometry. ATSDR identified data quality issues that need to be addressed because gamma spectrometry has two important sources of error.

- **The ratio of plutonium 239 to americium 241.** The likely ratio is 5.4:1. One must consider several things (having to do with inclusion of plutonium 240 and sample preparation) to apply this ratio correctly. Typical laboratory procedures cannot separate plutonium 239 from plutonium 240, because their radiation decay energies are essentially identical. Reported ratios for the data sets reviewed are 5.9, 2.8, and 3.83. Nonetheless, the magnitude of the possible error maintains the concentrations within a factor of two.

- **Small-scale distribution of debris.** According to the initial observations of the accident and early reports generated after the accident, the debris was initially distributed as particles, which are largely insoluble. This insolubility insures little migration of the contaminants except by physical movement. One result of this is that the material *remains heterogeneously distributed as* particulate matter in the environment. This heterogeneity is very important in the detection, fate, and transport analysis of contamination in the environment.

  Gamma radiation spectrometry assumes that the gamma emissions originate *homogeneously* throughout the volume of soil being analyzed. If, despite extensive laboratory sample preparation, the samples are not homogeneous—the plutonium and americium are not uniformly distributed throughout the soil—large errors can be introduced into the analysis, especially for detection of americium 241. Americium 241 has a very weak gamma ray energy that can be easily absorbed, reducing its detection efficiency. Therefore, heterogeneous distribution of particles of nuclear material in the soil would make the uncertainty of a single sample high. The error from the heterogeneity can be compensated for if multiple samples from the same source are analyzed, as is generally the case for the BOMARC site.

APPENDIX B. GLOSSARY

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific-environment.

Biota: Used in public health, things that humans would eat – including animals, fish and plants.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CERCLA: See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway**.

Comparison Value: (CVs) Concentrations or the amount of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Delayed Health Effect: A disease or injury that happens as a result of exposures that may have occurred far in the past.

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

- Source of Contamination,
- Environmental Media and Transport Mechanism,
- Point of Exposure,
- Route of Exposure, and
- Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

Malignancy: See **Cancer**.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Plume: A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds and streams).

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). For examples:

> the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:

- Urgent Public Health Hazard
- Public Health Hazard
- Indeterminate Public Health Hazard
- No Apparent Public Health Hazard
- No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The Superfund Amendments and Reauthorization Act in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or

	certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.
Superfund Site:	See **NPL**.
Survey:	A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.
Synergistic effect:	A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together are greater than the effects of the chemicals acting by themselves.
Toxic:	Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.
Toxicology:	The study of the harmful effects of chemicals on humans or animals.
Tumor:	Abnormal growth of tissue or cells that have formed a lump or mass.
Uncertainty Factor:	See **Safety Factor**.

APPENDIX C. COMPARISON VALUES

Comparison values represent media-specific contaminant concentrations that are used to select contaminants for further evaluation to determine the possibility of adverse public health effects. The conclusion that a contaminant exceeds the comparison value does not mean that it will cause adverse health effects.

Cancer Risk Evaluation Guides (CREGs)

CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over their lifetime. ATSDR's CREGs are calculated from EPA's cancer potency factors.

Environmental Media Evaluation Guides (EMEGs)

EMEGs are based on ATSDR minimal risk levels (MRLs). 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.

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 the free-flowing outlet. MCLs are considered protective of public health over a lifetime (70 years) for people consuming 2 liters of water per day.

Reference Media Evaluation Guides (RMEGs)

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

APPENDIX D. RADIATION AND RADIOLOGIC MATERIAL

What is radioactivity?

"Radioactive" is the word used to describe an unstable atomic nucleus that spontaneously emits radiation. Atoms are the smallest units of an element that have the same properties as the element. All matter is made up of atoms, and atoms are made up of protons and neutrons (found in the nucleus of the atom) and electrons. The number of protons in an atom of a particular element is always the same, but the number of neutrons may vary. Whether an atom is unstable is determined by the ratio of neutrons to protons. *Isotopes* are forms of the same element with different numbers of neutrons. The number of protons and neutrons in the atom are added to name the isotope. For example, an atom of cobalt that has 27 protons and 33 neutrons is called cobalt-60. Cobalt-60 is radioactive and is therefore called a radioisotope or a *radionuclide.*

What causes radioactivity?

All elements heavier than lead (which contains 83 protons) are naturally radioactive. Atoms can also become radioactive through natural processes in the environment. (Carbon 14 is an example of this.) Everyone is exposed to naturally occurring radiation from space and from radioactive materials in the ground. Humans can also create radioactive atoms of most elements. (For example, humans create radioactive atoms to use as tracers to help measure the flow of materials in the environment.) Radioactive material can travel through the air as particles or gases and can also enter soil, water, plants, and animals. Most radiation that people are exposed to is radon, an alpha emitter that results from decaying uranium 238, which is found in all air.

What is radiation?

Radiation is the emission of waves or particles from an unstable atom undergoing a transformation to stabilize the number of protons compared to the number of neutrons in its nucleus. This transformation changes the radioactive atom into a stable atom of a different element. For example, a proton in a cobalt-60 atom may change into a neutron and emit radiation, leading the atom to become a nickel-60 atom.

What are alpha particles, beta particles, and gamma radiation?

Alpha particles can be emitted by atoms that are more massive than lead, such as radium. Alpha particles are composed of two protons and two neutrons and have a large charge, which can pull electrons off neighboring atoms (or cause them to ionize). Alpha particles cannot penetrate the skin, but can be taken into the body by inhaling particles or ingesting foods contaminated with alpha particles. If they enter the human body, alpha particles can be absorbed in the blood, incorporated into molecules in the body, and deposited in living tissue. Plutonium is an alpha emitter.

Beta particles are high-energy electrons that result from a neutron changing into a proton or a proton changing into a neutron. Some beta particles have very little energy and cannot pass through the dead outer layer of a person's skin, but most can do so and expose the living tissue underneath the outer layer of skin to radiation. Beta particles cannot penetrate through the human body, however. Exposure to beta radiation can also result from internal exposure, such as through inhaling air or ingesting food or liquids containing beta particles.

Gamma rays result from the release of excess energy when an atom gives off an alpha or beta particle. Gamma rays consist of moving energy and have no mass or charge. They can travel long distances and move through the air, body tissue, or other materials. A gamma ray that passes through a body might hit nothing inside it, but it might hit atoms in its path. Gamma rays are the primary type of radiation that can harm people when they are exposed to a source outside the body (external gamma radiation). Americium emits gamma rays.

Source: Agency for Toxic Substances and Disease Registry. 1999. Toxicological profile for ionizing radiation. September 1999.

APPENDIX E. RESPONSE TO PUBLIC COMMENTS

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments/questions during the public comment period (June 10 to July 25, 2002) for the BOMARC Public Health Assessment (PHA). Comments were received from a total of three respondents from the U.S. Air Force and the Army. Most of the comments provided new or updated information, which ATSDR has incorporated into the PHA. ATSDR documents our reply to two comments below.

Comment: A commenter noted that ATSDR references the International Commission on Radiological Protection (ICRP) Publication 60 for guidance on radiological hazards. The commenter questioned whether the ICRP Publication 60 was relevant in the context of this PHA and U.S. Federal Radiation protection guidelines and suggested that ATSDR use ICRP Publication 26.

Response: ATSDR is keeping the text and references to ICRP 60 in the PHA as written. It is important to note that the ICRP 26 provides guidance on assessing worker exposures, while the ICRP 60 provides guidance for both worker and public exposures. As described in the PHA, some of the responders to the accident were *civilian* firefighting force. These responders would not have been considered radiation workers, but members of the public. ATSDR, therefore, uses the guidance for members of the public as provided in ICRP 60 publication to accurately assess exposure for these responders.

Comment: A commenter noted that the 2,000 millirem (mrem) (or 20 millisievert [mSv]) average for one year's exposure cited in the PHA has not been accepted in the United States.

Response: ATSDR acknowledges that the 2,000 mrem has not been accepted in the United States. As a non-regulatory agency, ATSDR is not restricted to any established evaluation criteria. Rather, ATSDR made decisions about public health based upon the best available information and guidance provided by reputable national or international organizations.