PUBLIC HEALTH ASSESSMENT

NAVAL AIR STATION FALLON
FALLON, CHURCHILL COUNTY, NEVADA
EPA FACILITY ID: NV9170022173
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agl	above ground level
AIRS	Aerometric Information Retrieval System
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
CVs	ATSDR's comparison values
EPA	U.S. Environmental Protection Agency
HC	Health Consultation
IRP	Installation Restoration Program
MCL	EPA's maximum contaminant level
MW	monitoring well
NAAS	Naval Air Auxiliary Station
NAAQS	National Ambient Air Quality Standards
NASF	Naval Air Station Fallon
NAC	Nevada Administrative Code
NPL	national priorities list
NSHD	Nevada State Health Division
PA/SI	preliminary assessment/site inspection
PHA	Public Health Assessment
PHAP	Public Health Action Plan
PCBs	polychlorinated biphenyls
PM10	particulate matter less than 10 microns
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	record of decision
SVOCs	semi-volatile organic compounds
SWMU	solid waste management unit
TCE	trichloroethylene
TPH	total petroleum hydrocarbons
TSP	total suspended particulates
VOCs	volatile organic compounds

SUMMARY

The Nevada State Health Division (NSHD) has been investigating a childhood leukemia cluster in the Fallon area since late summer 2000. To assist the investigation, NSHD requested technical assistance from the Agency for Toxic Substances and Disease Registry (ATSDR) to identify possible chemical releases, evaluate environmental data, and conduct an exposure pathway analysis. An exposure pathway is the way by which humans come in contact with materials in the environment. ATSDR prepared this public health assessment (PHA) to evaluate exposure pathways and to respond to community concerns about past, current, and potential future exposures to contaminants originating at the Naval Air Station in Fallon (NASF), Nevada.

This PHA evaluates the likelihood that any contaminants identified at NASF may be a public health concern. The ATSDR public health assessment process is exposure, or contact, driven. People may or may not be exposed to chemicals in the environment, through contact with soil, air or water. If people are exposed, it is important to determine whether the exposure is to amounts, and in a manner, that could result in adverse health effects. ATSDR uses environmental and toxicological evaluations to determine whether it is possible for such adverse health effects to occur. The process ATSDR uses in its evaluation is detailed in this document. ATSDR conducted a comprehensive evaluation of NASF, including evaluating chemicals that are not associated with leukemia.

NASF is an active station located in Churchill County, Nevada, approximately 6 miles southeast of the city of Fallon. The main station covers 7,982 acres and contains airfield, maintenance, public works, and housing facilities. An additional 14 parcels totaling 148,000 acres are used for flight training exercises and are located in the general vicinity of the main station. The main station is fenced and all entrances are gated.

Most of the hazardous wastes generated or disposed of at NASF are associated with jet fuel spills or leaks (JP-5 and JP-8) from aircraft fueling and refueling operations and fuel disposal activities. In addition to fuel-related contamination, solvents, oils, and other wastes associated with aircraft operations and maintenance activities at NASF have resulted in the release of substances into the soil, surface water and sediment, air, and groundwater.

NASF, in accordance with the Department of Defense's Installation Restoration Program, has conducted investigations to characterize the nature and extent of contamination at NASF. Most contamination at NASF has been detected in on-site groundwater and to a lesser extent in soil. NASF has conducted a remedial investigation and an intrinsic remediation assessment to identify the most appropriate methods of cleaning up contaminated soil and groundwater plumes at NASF.

ATSDR conducted site visits to NASF in April and August 2001. During these site visits, ATSDR met with NASF's Commanding Officer and other NASF personnel and was briefed on

specific concerns pertaining to environmental releases at NASF. ATSDR also met with representatives from NASF's environmental office and toured the base. During the course of these site visits, ATSDR collected relevant information about the day-to-day operations of NASF, noted any past environmental issues or concerns, and gathered data from reports and documents generated from prior investigations. Based on all the information gathered, ATSDR reached the following conclusions:

Groundwater: *As long as the groundwater is not used for drinking, exposure to on-site groundwater at NASF poses no past, current, or future public health hazard.* ATSDR reviewed available on-site groundwater data. Low levels of contaminants have been detected in groundwater on-site. However, the contaminant plume does not extend past NASF boundaries. Some chemicals were detected in on-site monitoring wells at levels above ATSDR's health-based comparison values (CVs). These chemicals include: total petroleum hydrocarbons (TPHs), volatile organic compounds (VOCs) (e.g., trichloroethylene, benzene, and cis1,2-dichloro-ethylene), and metals (e.g., boron and arsenic, which are often naturally occurring in groundwater). Although fuel and some solvents released to the environment have resulted in areas of groundwater contamination at NASF, groundwater beneath the station has never been used as a source of drinking water. According to NASF representatives, there are no current or future plans to use groundwater at NASF for drinking water or other domestic purposes (e.g., showering or cooking).

Drinking Water: *ATSDR concludes that the drinking water supply for NASF and the city of Fallon has not been impacted by site-related contaminants. Although high levels of naturally occurring arsenic is a health concern, a water treatment plant is being constructed to reduce levels of arsenic in the drinking water to meet EPA's safe drinking water standards.* Drinking water for NASF and most Fallon residents is obtained from off-site wells that get water from a deep aquifer. These wells have not been impacted by site-related chemicals because they are at least 2 miles northwest of any NASF source areas, are upgradient from NASF, and the depth to the basalt aquifer (the drinking water aquifer) is more than 500 feet below ground surface. All past monitoring results have met state and federal safe drinking water standards for VOCs, semi-volatile organic compounds, and pesticides. The only inorganic substance that has not met state and federal safe drinking water standards is arsenic. Arsenic, which is naturally occurring in the Fallon area, has been detected at levels that exceed EPA's maximum contaminant level.

Private Drinking Water Wells: *On the basis of currently available data, ATSDR concludes that exposure to site-related chemicals in private drinking water wells poses no past, current, or future public health hazards.* Groundwater investigations at NASF have indicated that contamination is confined to the shallow aquifer beneath NASF. Generally, private wells in the area surrounding NASF draw water from the intermediate aquifer and are not be impacted by contamination in the shallow aquifer. Since monitoring wells in all aquifers studied around NASF's boundary have not contained site-related chemicals at levels above ATSDR's CVs, it is not expected that private wells have been impacted by site-related chemicals.

Surface Water, Sediment and Drainage Canals: *ATSDR concludes that exposure to surface water and sediment at NASF or to chemicals in drainage canals flowing from the base to off-site locations poses no past, current, or future public health hazard.* Permanent surface water features at NASF are limited to irrigation ditches and drainage canals. Fuel-related chemicals and some metals have been detected at levels below health concern in drainage canals on site. The irrigation ditches and drainage canals have not been used for recreational purposes (e.g., swimming, fishing, boating) on site. In addition, any potential exposures to on-site surface water or sediment would be very infrequent, of short duration, and not of public health concern. Outside NASF, levels would be as low or lower as a result of dilution, so that individuals who may come in contact with drainage canal waters flowing from the base to off-site locations would not be exposed at levels that would be of public health concern.

Soil: *ATSDR concludes that exposure to soil contamination at NASF poses no past, current, or future public health hazard. ATSDR concludes that there is no off-site soil contamination from activities at NASF.* ATSDR reviewed available on-site soil data. TPHs and some VOCs were detected in surface soil above their CVs at some sites within NASF. Access to NASF, however, is restricted and there is no evidence that on-site personnel or their families living in family housing have been in contact with these areas. Since some of the installation restoration sites that contain contaminated soil are not fenced, ATSDR cannot rule out the possibility that some residents of the station and on-site personnel could be exposed. However, any exposures to soil contaminants would likely be infrequent and of short duration. Generally, these sites do not contain NASF-related contaminants in soil that exceed ATSDR's CVs. Therefore, soil contaminants from NASF are not expected to be transported off site at levels that would be of health concern.

Air: *ATSDR concludes that exposure to air contaminants from stationary sources at NASF pose no past, current, or future public health hazard.* ATSDR evaluated possible exposures to air contaminants from stationary sources such as boilers, generators, and painting operations at NASF. NASF's air quality analysis results showed that the predicted concentrations of EPA criteria pollutants (i.e., CO, NO_2, PM10, SO_2) from stationary sources at the station do not exceed corresponding national ambient air quality standards. Meteorological data shows that prevailing winds are from the west, from the direction of the city of Fallon toward NASF and therefore generally serve to blow any contaminants away from the town. Recent air monitoring data in the Fallon area from EPA's Aerometric Information Retrieval System database showed that PM10 concentrations were well below EPA's national ambient air quality standards.

Jet Fuel and Engine Emission Byproducts: *ATSDR concludes that exposure to air contaminants related to jet fuel and engine emission byproducts at NASF pose no past, current, or future public health hazard.* As mentioned above, meteorological data shows that prevailing winds are from the west, from the direction of the city of Fallon toward NASF and therefore would generally serve to blow any airborne contaminants away from the town. An extensive

literature search was conducted for information on the nature of military jet engine emissions. ATSDR researched the most current aircraft emissions data available from EPA, FAA, and the Navy. We used these data sets to develop realistic emissions estimates for the aircraft engines at NASF. Using this information, a screening model for dispersion of emissions was conducted. Using the most representative data available, we found that estimated ambient air concentrations for all pollutants considered were either below health-based comparison values or reasonably consistent with levels routinely measured in small communities and suburban locations across the United States. The sampling conducted by the Centers for Disease Control and Prevention (CDC) did not detect levels of chemicals that might be components of jet fuel or jet engine emission byproducts in either biological and environmental samples in case families or control families. ATSDR therefore can not link the potential exposure of members of the Fallon community to jet fuel and emission byproducts to non-cancer public health effects. Additionally, extensive literature search was conducted on existing toxicologic research on jet fuel and emission byproducts. Based on these data searches, a toxicological evaluation was conducted. The toxicological evaluation also supports the finding that aircraft emissions from NASF can not be linked with either the leukemia cases in the nearby community nor are exposures likely that would result in non-cancer public health effects.

Several members of the community in the vicinity of NASF have expressed concern over the possibility that fuel jettisoned from Naval aircraft might be a potential cause of illnesses in the community. According to U.S. Navy operations guidelines, fuel jettisoning typically only occurs when an emergency landing is required. The fuel is released in order to decrease the potential for an explosion or fire during an urgent or emergency landing. The community concern regarding the jettisoning of fuel by Navy aircraft is extensively discussed in the Community Health Concerns section. Based on information provided by NASF, *ATSDR concludes that jettisoning at NASF does not pose a past, current or future public health hazard.*

BACKGROUND

Site Description and History

Naval Air Station Fallon (NASF) is an active station located in Churchill County, Nevada, approximately 6 miles southeast of the city of Fallon (Figure 1). The main station covers 7,982 acres and contains airfield, maintenance, public works, and housing facilities. The main station is fenced and all entrances are gated, allowing only authorized personnel access. An additional 14 parcels used for flight training exercises totaling 148,000 acres are located in the general vicinity of the main station. The station is bounded on the west by U.S. Route 95 and on the north and east by U.S. Route 50. Carson Lake Pasture, which is a series of ditches and small marshes, is approximately 3 miles to the south of the station. There is very little developed land in between NASF and the Carson Lake Pasture (ORNL 1994).

NASF was originally established as a military facility in 1942 under the Civil Aviation Administration and Army Air Corps. Initially, four airfields were constructed as part of the Western Defense Program. In 1943, the Navy assumed control of the air fields and, in June 1944, Naval Air Auxiliary Station (NAAS) Fallon was commissioned (ORNL 1994). Over the years, the station has undergone several operational changes. NAAS Fallon originally provided training, servicing, and support to air groups sent to the station for combat training. From 1945 to 1975, the Air Force also used part of the station as part of an early warning radar network.

Training operations at NAAS Fallon peaked between April and September 1945. After a brief period of inactivity during the late 1940s and early 1950s, NAAS Fallon was reestablished in October 1953. In January 1972, NAAS Fallon expanded its operations and officially became known as NASF. NASF currently serves primarily as an aircraft weapons delivery and tactical air combat training facility (ORNL 1994).

In addition to the main station, nine other major parcels used by NASF include:

- Range B-16 (21,120 acres)
- Range B-17 (21,400 acres)
- Range B-19 (17,332 acres)
- Range B-20 (41,030 acres)
- Electric Warfare Range (34, 380 acres)
- Shoal Sites, which consists of two parcels (4,620 acres total)
- Army Electronics Command (AEC) Site (2,560 acres)
- Helicopter Training Range (5,760 acres)

Most of the hazardous wastes generated or disposed of at NASF were from: (1) jet fuel spills or leaks (JP-5 and JP-8) from aircraft fueling and refueling operations and fuel disposal activities; (2) the discharge and disposal of solvents, oils, jet fuels, antifreeze, and hydraulic fluid used in vehicle and air station maintenance activities and fire training exercises; and (3) the disposal of other wastes associated with activities at NASF, including pesticides and herbicides, detergents, paints, and industrial and municipal garbage (ORNL 1994). These practices have resulted in the release of contaminants into the soil, surface water and sediment, air, and groundwater.

Remedial and Regulatory History

In August 1986, the Nevada Department of Environmental Protection (NDEP) issued a *Finding of Alleged Violation* and an *Order to Comply* resulting from the discovery of jet fuel contamination in soils and in groundwater at NASF's New Fuel Farm (Site 2). These actions were issued in accordance with Nevada Revised Statutes (NRS) 445.221, which prohibit the unlawful discharge of pollutants without a permit. The *Order to Comply* required that NASF submit information on the extent of contamination and implement an approved plan to clean up the site (ORNL 1994). Other actions by NDEP included issuing a notice of violation in March 1989 due to a malfunction of the fuel farm oil/water separator and, in February 1990, an investigation concerning an alleged fuel spill during February 1988 (ORNL 1994). In addition to these incidents, NDEP's Bureau of Corrective Actions has generated a total of eight other case files documenting incidents (e.g., small fuel spills) resulting from NASF activities on site.

Based on initial information from historical records, aerial photographs, agency contacts, field inspection, and personnel interviews, a total of 27 potentially contaminated sites were identified at NASF (Dames & Moore 1988). In accordance with the Department of Defense's Installation Restoration Program (IRP) managed under the authority of the Navy, a preliminary assessment/site inspection (PA/SI) was conducted at NASF in September 1987. As a result of the PA/SI, 21 of the 27 potentially contaminated sites initially identified were found to warrant further investigation (Figure 2). The other six sites were not considered to be significant sources of contamination. Seventeen of these 21 sites were divided into four groups, while four of the sites remained alone. As of this writing, nine of the 27 potentially contaminated sites (5, 7, 8, 13, 15, 19, 25, 26, and 27) have been closed by NDEP and do not require any additional cleanup. The groups and the sites, including the six "no action" sites, are listed below and a description of each of the 21 "action" sites is provided in Table 1:

- ***Four Individual Sites*** located in different areas of the station:

  1) Crash Crew Training Area (Site 1);
  2) Hangar 300 Area (Site 3);
  3) Checkerboard Landfill (Site 20); and
  4) Road Oiling Area (Site 24).

- ***Group I Sites*** include two sites located in the northwest portion of the station:

  1) New Fuel Farm (Site 2); and
  2) Transportation Yard (Site 4).

- ***Group II Sites*** are clustered together on the east central portion of NASF, located within about 1,000 feet south of the lower diagonal No. 1 drain, which extends the horizontal length of the station:

  1) Defuel Disposal Area (Site 6);
  2) Napalm Burn Pit (Site 7);
  3) Receiver Site Landfill (Site 21); and
  4) Northeast Runway Landfill (Site 22).

- ***Group III Sites*** include two sites located in the southeast portion of the station:

  1) Wastewater Treatment Plant (Site 9); and
  2) Southeast Runway Landfill (Site 18).

- ***Group IV Sites*** include nine sites located in the southern portion of the station:

  1) Ground to Air Transmitting and Receiving (GATAR) Compound (Site 10);
  2) Paint Shop (Site 11);
  3) Pest Control Shop (Site 12);
  4) Boiler Plant Tanks (Site 13);
  5) Old Vehicle Maintenance Shop (Site 14);
  6) Old Fuel Farm (Site 16);
  7) Hangar 5 (Site 17);
  8) Post World War II Burial Site (Site 19); and
  9) Shipping and Receiving Disposal (Site 23).

- ***No Action Sites*** include six sites that were identified during the initial PA/SI but were not considered a significant source of contamination and did not warrant further investigation:

  1) Ordnance Area (Site 5);
  2) Bore Site Gunbutt (Site 8);
  3) Old Navy Exchange Gas Station (Site 15);
  4) New Runway Rubble Disposal Area (Site 25);
  5) Off-site Rubble Disposal Area (Site 26); and
  6) Diesel Fuel Spill Site (Site 27).

ATSDR Activities

The Nevada State Health Division (NSHD) has been investigating contributing factors that may be associated with a leukemia cluster in the Fallon area that has primarily affected young children. As part of this investigation, NSHD has requested technical assistance from ATSDR in order to identify possible contaminant releases, evaluate environmental data, and conduct appropriate pathway analyses that will help address community concerns related to any possible associations between environmental contaminants and leukemia.

ATSDR conducted a site visit to NASF on April 18, 2001. This site visit was part of a larger ATSDR effort to investigate whether potential exposures from environmental contaminants might be associated with a clustering of leukemia in children living in the Fallon, Nevada, area. During this site visit, ATSDR met with NASF's commander and other NASF personnel and was briefed on specific concerns pertaining to environmental releases at NASF. ATSDR also met with representatives from NASF's environmental office and received a tour of each of the IRP sites. During the course of the site visit, ATSDR collected information about the day to day operations of NASF, noted any past environmental issues or concerns, and gathered data from reports and documents generated from prior investigations.

In August 2001, ATSDR attended a briefing by the new commander at NASF and met with several members from NASF's environmental office. A tour of the station was provided for ATSDR staff who were visiting for the first time. The site visit to NASF was part of a larger effort by ATSDR and other state and federal agencies to gather information and conduct public availability sessions within the community.

ATSDR has been gathering information about environmental releases of contaminants occurring not only at NASF, but throughout all of Churchill County, Nevada. However, this public health assessment (PHA) addresses only those environmental releases that are a result of activities or operations at NASF. The focus of this PHA is to evaluate any contaminants identified at NASF that may pose a potential public health hazard, not just those that may be associated with leukemia. The scope of this evaluation only includes NASF activities that have resulted in contamination at the main station. If warranted, other Navy or Navy-related operations that take place off-site of the main station in the Fallon area are addressed within the community concerns section of this document.

Climate and Wind Patterns

The climate and prevailing wind patterns of a given location affect how contaminants move through the air. Annual climatological summaries for the Fallon area from 1997 to 2001, provided by the National Climatic Data Center (NCDC), indicate that the annual temperatures ranged from a low of 4 degrees Fahrenheit (°F) to 104°F. Annual mean minimums for 1997 to 2001 were 37-38°F. Annual mean highs were 68-70°F. Annual mean average temperature in the Fallon ranged from 53 to 54°F. For the same period, annual precipitation ranged from 3.5 to 6.7 inches.

Figure 3 is a wind rose generated from data collected at NASF's onsite meteorological station between 1991 and 1995. Prevailing wind patterns are clearly from west to east (i.e., the winds blow away from the community toward NASF). Winds rarely blew from NASF to the community; specifically, southeasterly winds were observed only 3% of the time.

Demographics

ATSDR examines demographic 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. Demographic information for the site and residential areas surrounding NASF is presented in this section.

According to the most recent statistics released by NASF in March 2001, a total of 3,077 people were employed at NASF; including 1,038 active duty military personnel, 1,250 contractors, 542 civil service personnel, and 247 other employees. According to NASF personnel, the average length of assignment of military staff at the station is approximately 36 months. An average of 40,000 total military personnel pass through the various training courses at NASF every year and

the average length of stay for these individuals is 14 days (NASF official website October 2001; NASF housing office, Personal Correspondence, May 11, 2001).

There are currently about 50 on-site housing units at NASF that are designated for families. These housing units are in the southern portion of NASF and are referred to as the Fairview Housing area. An additional 213 permanent housing units and 1,148 transient housing units are designated for single (i.e., not married) personnel. These housing units are located in several different parts of the station (NASF housing office, Personal Correspondence, May 11, 2001). There are also approximately 328 military personnel who live in off-site military housing (Desert Winds, Blue Sky, Mountain View, and Sagebrush housing areas) directly west of and adjacent to NASF. As of March 2001, there were 84 children under the age of 18 living on site and 307 children under the age of 18 living in off-site military housing. There is one daycare facility on navy property for use by NASF personnel. Located just west of the NASF Main Gate, the facility accommodates approximately 124 children under the age of 18 (NASF housing office, Personal Correspondence, May 11, 2001).

The city of Fallon is the largest population center in the area, with approximately 7,500 people. Approximately 23, 980 people live in the surrounding unincorporated parts of Churchill County (US Census Bureau 2000). The Fallon Shoshone-Paiute tribe, with approximately 1,300 members, maintains over 8,200 acres of land in the area. The population for both the city of Fallon and the county has been slowly increasing over the last several years (USGS 2001). A small number of residences are located within a one mile radius of NASF, however, the area immediately adjacent to NASF is mostly undeveloped or used for agriculture. During ATSDR's site visit, NASF representatives noted one residence directly east of the station's boundary. Additional information provided by the Navy confirms a total of five residences east of the NASF boundary (Cottle 2002).

Land Use and Natural Resources

NASF is located in the Lahontan Valley, which is part of the Carson Desert. The Lahontan Valley serves as a sink for surface water runoff from the surrounding mountains and the Carson River. The station is situated in an undeveloped area, midway between the city of Fallon to the northwest, Stillwater Point Reservoir to the northeast, and Carson Lake to the south (Ecology and Environment 1989).

The Carson Desert covers approximately 2,000 square miles and includes a large basin, which is approximately 4,000 feet above sea level, surrounded by mountains. The Stillwater Range and the Lahontan Mountains border the basin on the east; the West Humboldt Range on the north; the Hot Springs and Dead Camel Mountains on the west; and the Desert, White Throne, Blow Sand, Cocoon, and Bunejug Mountains on the south. The mountains range from 4,400 feet to 8,800 feet above sea level (Battelle 2001).

The soil beneath NASF is primarily fine-grained (e.g., clay or silty clay) with lesser amounts of coarser-grained materials (e.g., silty sands, sandy loam). Beneath the top soils are approximately 2,000 feet of sedimentary deposits of various origin. Basalts are present beneath the sedimentary deposits (Dames & Moore 1988). Most of the land surrounding NASF is either open brush or irrigated farmland. Alfalfa is the main irrigated crop in the Lahontan Valley. Non-irrigated land is sparsely vegetated with greasewood, rabbit brush, salt grass, and marsh grasses (USGS 2001). Much of the area immediately surrounding the station is irrigated, and there are several irrigation ditches used to deliver water and drainage canals to remove excess water (ORNL 1992).

Approximately half of all the land area at the main station is leased out for non-military uses. The safety buffer zone surrounding the airfield is leased out to ranchers as part of the Navy's Agricultural Outlease Program. There are 11 parcels of land leased out and some of the lessees grow alfalfa, rye, barley, and corn. Most of the leased land is used for irrigated pasture for cattle.

These agricultural parcels, totaling about 3,900 acres, are located in the northwest, northeast, and southeast corners of the station, and off the west end of runway # 7 (Dames & Moore 1988; Cottle 2002).

Surface water enters the Carson Desert from the west via Carson River and the Truckee Canal. Both of these surface water bodies flow into the Lahontan Reservoir (also referred to as Lake Lahontan), a man-made feature that was built as part of the Newlands Irrigation Project in the early 1900s to provide irrigation water to the Carson Desert (Battelle 2000). Water from the Lahontan Reservoir is channeled through a network of irrigation ditches and open drainage canals (drains) that flow toward Carson Sink and Carson Lake, which are the lowest points in the Carson Desert. Carson Sink is a flat salt-encrusted basin, located in the northeastern portion of the desert, that covers approximately 400 square miles. Carson Lake is located in the southeastern part of Carson Desert and occupies approximately 25,000 acres. Approximately 340 miles of man-made ditches provide irrigation water to an estimated 1,500 farm head gates. Approximately 350 miles of drainage ditches route irrigation return flow and shallow groundwater seepage to the Carson Lake and Stillwater Wildlife Management Area (Battelle 2000).

Four primary surface water distribution systems are located at NASF: 1) the L-Line Canal; 2) the Lower Diagonal No. 1 (LD # 1) Drain; 3) the Lower Diagonal (LD) Drain; and 4) the New River Drain north of Wildes Road. All four of these surface water systems converge approximately 2 miles from the station boundary and feed into the Stillwater Point Diversion Drain, eventually draining into the Stillwater National Wildlife Refuge and the Stillwater Reservoir (Ecology & Environment 1989; Cottle 2002).

Some fishing and hunting of waterfowl, game birds, rabbits, coyotes, and deer occurs off site in the Valley, however, fishing and hunting do not occur at NASF. The only on-site surface water features are the irrigation ditches and drainage canals, which become very shallow after the

irrigation season. The majority of fish species in the drains are not typically consumed and usually do not survive through the year because of fluctuating water levels.

Quality Assurance and Quality Control

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. Documents prepared for Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response and Liability Act (CERCLA) programs must meet specific standards for adequate quality assurance and quality control measures for chain-of-custody procedures, laboratory procedures, and data reporting. The environmental data presented in this PHA are largely from site characterization, remedial investigation, and groundwater monitoring reports prepared by the U.S. Navy under CERCLA's Installation Restoration Program. Additional reports and information have been provided by USGS and NDEP. The validity of the analyses and conclusions drawn in this document are dependent on the availability and reliability of the referenced information.

ATSDR reviews data from site-related reports and evaluates whether detection limits are set at levels that are protective of public health. ATSDR also notes any inconsistencies or problems with data collection or reporting and evaluates whether the information is adequate to be used for making public health decisions. Based on our evaluation, ATSDR determined that the quality of environmental data available from the site-related documents for NASF is adequate to make public health decisions.

EVALUATION OF ENVIRONMENTAL CONTAMINATION AND POTENTIAL EXPOSURE PATHWAYS

In this section, ATSDR evaluates whether community members have been (past), are (current), or will be (future) exposed to harmful levels of chemicals. Figure 5 describes the conservative exposure evaluation process used by ATSDR.

What is exposure?

ATSDR's public health assessments are exposure, or contact, driven. Chemical contaminants disposed 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 chemical if they come in contact with the chemical. Exposure may occur by breathing, eating, or drinking a substance containing the contaminant or by skin (dermal) contact with a substance containing the contaminant.

When do health effects occur?

Exposure does not always result in health effects. The type and severity of health effects that occur in an individual from contact with a contaminant depend on the properties of the chemical, 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, life style, 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.

If exposure was or is possible, ATSDR then considers whether chemicals were or are present at concentrations that might be harmful to people. ATSDR does this by screening the concentrations of contaminants in environmental media (e.g., groundwater or soil) against health-based comparison values (CVs) (Appendix A). CVs are chemical concentrations that health scientists have determined are not likely to cause adverse effects, even when assuming very conservative/worst case exposure scenarios. Because CVs are not thresholds of toxicity, environmental levels that exceed CVs would not necessarily produce adverse health effects. If a chemical is found in the environment at levels exceeding its corresponding CV, ATSDR examines potential exposure variables and the contaminant toxicology. *ATSDR emphasizes that a public health hazard exists only if contact with harmful levels of contaminated media occurs with sufficient frequency and duration for harmful effects to occur.*

Following the strategy outlined above, ATSDR examined whether human exposure to harmful levels of contaminants via these pathways existed in the past, exists now, or could potentially exist in the future. ATSDR summarizes its evaluation of these exposure pathways in Table 2 and describes it in more detail in the discussion that follows. To acquaint readers with terminology used in this report, a glossary is included in Appendix B.

ATSDR reviewed the environmental data generated from initial environmental assessments and remedial investigations (RIs) of the IRP sites at NASF to determine if there are any associated past, current, or future public health hazards. ATSDR also evaluated other environmental data such as drinking water monitoring data. ATSDR's exposure pathway evaluation will focus on groundwater, surface water and sediment, soil, and air contaminants (Table 2).

Evaluation of Groundwater Exposure Pathway

Conclusions

- *ATSDR concludes that exposures to on-site groundwater at NASF **pose no past, current, or future public health hazard**. Although fuel-related releases and some solvents have resulted in areas of groundwater contamination at NASF, groundwater beneath the station has never been used as a source of drinking water. According to NASF representatives, there are no current or future plans to use groundwater beneath NASF for drinking water or other domestic* (e.g., showering or cooking) *purposes.*

- *ATSDR concludes that exposures to off-site groundwater near NASF **pose no past, current, or future public health hazard**. The NASF drinking water wells, which are screened in the basalt aquifer, have not been impacted by site-related contaminants. Since the potable wells are at least two miles northwest of any NASF source areas, are upgradient from NASF, and the depth to the basalt aquifer is more than 500 feet below ground surface, they are not likely to be impacted by contaminated groundwater from NASF.*

  Groundwater from the shallow alluvial aquifer around NASF is not widely used as a source of potable water due to its high levels of naturally occurring dissolved solids and metals. There are some private wells to the east and south of the station boundary that are screened in the intermediate aquifer and a very small number of private wells to the

south of NASF that are screened in the shallow aquifer. These wells are primarily used for irrigation and for livestock. Groundwater samples collected from monitoring wells near the station boundary have not contained any site-related contaminants at levels of health concern.

Discussion

Hydrogeology

The Lahontan Valley is part of the Basin and Range geological province. It is a sink for surface water runoff from surrounding mountains and the Carson River. The area is arid and, on average, only receives about 5 inches of rain per year. In order to address the water needs for the Carson Desert area, the U.S. Department of the Interior funded the Newlands Irrigation Project. This project was designed to irrigate more than 400,000 acres of land in western Nevada using the combined waters of the Truckee and Carson Rivers. Water for the Newlands Irrigation Project is diverted from the Truckee River into the Truckee Canal for irrigation. The Carson River, augmented by the Truckee River, provides more than 95 percent of all the surface water received by the Carson Desert (ORNL 1992).

Groundwater

Groundwater in Lahontan Valley is primarily found in four principal aquifer systems: 1) a shallow alluvial aquifer; 2) an intermediate alluvial aquifer; 3) a deep alluvial aquifer; and 4) the Fallon basalt aquifer. The intermediate and deep alluvial aquifers are often considered one aquifer system and will be presented as such. A brief description of each of these aquifers is provided below.

Shallow Alluvial Aquifer: The shallow alluvial aquifer is an unconfined aquifer with the water table forming the upper surface. This aquifer extends approximately 50 feet below ground surface (bgs). Groundwater levels in the shallow alluvial aquifer beneath NASF range between 10 feet bgs in the northwestern portion of the station to 3 feet bgs in the

southeastern portion of the station. The groundwater flow in the shallow alluvial aquifer is southeastward in the NASF area. Recharge to the shallow aquifer is primarily from infiltration of irrigated water used on fields and leakage of unlined irrigation ditches (Dames & Moore 1988).

Intermediate and Deep Alluvial Aquifers: The intermediate and deep alluvial aquifers lie beneath the shallow alluvial aquifer. The intermediate alluvial aquifer begins around 50 feet bgs and the boundary separating the intermediate and deep aquifer is approximately 2,200 feet bgs. The strata within this aquifer consist of interbedded deposits of clay, silt, and sand, with occasional stringers of gravel. These deposits are found at depths greater than 50 feet bgs. Groundwater flow direction in the upper part of the aquifer is approximately east-southeasterly (Dames & Moore 1988).

Fallon Basalt Aquifer: The Fallon basalt aquifer consists of buried basalt deposited by volcanic activity from about 1 to 2.5 million years ago. The aquifer is an asymmetrical, mushroom-shaped body that is about 4 miles wide and about 10 miles long from southwest to northeast. The aquifer is surrounded by sediments of the shallow, intermediate, and deep aquifers and is confined over much of its extent, limiting the amount of recharge from the surrounding aquifers and surface water runoff. USGS studies of the basalt aquifer suggest that at depths greater than 1,000 feet bgs, the basalt aquifer narrows and becomes a very thin column. The basalt aquifer is surrounded by, and in contact with, all three alluvial aquifers (Dames & Moore 1988;USGS 2001).

Groundwater Use

Most of the potable drinking water for the Fallon area comes from the basalt aquifer. This aquifer is the sole source of drinking water for NASF and also provides potable water to the city of Fallon and the Fallon Paiute-Shoshone reservation, which is approximately 10 miles northeast of NASF. Some private residences within Churchill County rely on shallow and intermediate alluvial aquifer wells for drinking water. Most wells in the intermediate aquifer are completed at depths of 90 to 120 feet bgs. Water obtained from the shallow aquifer in much of the Lahontan Valley is not potable due to high levels of naturally occurring dissolved solids and metals (NASF 1994). Surface water is not used as a source of drinking water at NASF or for off-site residential areas (USGS 2001).

On-site Drinking Water Wells: There are no drinking water wells on NASF property and the groundwater underneath the station is not used for any other domestic (e.g., cooking or showering) purposes.

Off-site NASF Wells: NASF obtains its potable water from three drinking water supply wells located off site, approximately 2.5 miles north of NASF, near an area referred to as Rattlesnake Hill (Figure 4). The wells are approximately 540 feet deep and are completed in the basalt aquifer. Typically, the depth to the basalt aquifer is around 2,500 feet. However, the wells are in an area where the depth to the basalt aquifer is around 500 feet bgs. The three wells combined are capable of yielding between 1,000 and 2,100 gallons per minute. There is one storage tank with a capacity of 1.2 million gallons. The only water treatment is chlorination (Dames & Moore 1988; NASF 1994; Bud Ford, NASF Environmental Office, Personal Communication, October 22, 2001).

Off-site Public (Municipal) Wells: The city of Fallon maintains four wells that supply water to most of the residents. The groundwater is drawn from wells in the basalt aquifer that are approximately 600 feet deep. The municipal wells are located near the NASF supply wells. The city has two storage tanks with a combined capacity of 2.8 million gallons. Fallon does not currently have a water treatment plant and the only treatment currently required is chlorination for bacteria. In 1990, the city entered into a Compliance Schedule Agreement with the Nevada State Board of Health to design and implement a treatment system to remove arsenic from the drinking water (Larry White, City of Fallon Water Department, Personal Communication, October 30, 2001).

Off-site Private Wells: The outlying areas in the region are supplied by individual wells which usually tap the shallow or intermediate alluvial aquifers. The closest drinking water wells are approximately 0.2 mile to the east of Site 6 (Defuel Disposal Area), which are downgradient of the shallow aquifer plume. There are five dwellings that each have a private well that has been used for drinking water. In addition to the five private wells to the east of NASF, several domestic wells that draw from the shallow alluvial aquifer are located downgradient of NASF. The closest domestic well is approximately 0.5 mile southeast of the station. These wells are not used for drinking water because of high levels of naturally occurring dissolved solids and mineral content and are used primarily for irrigation and livestock watering (Dames & Moore 1988; Ecology & Environment 1989). Since contaminants have not been detected in samples collected from monitoring wells near the NASF boundary, it is unlikely that the domestic wells used for irrigation or livestock would contain site-related contaminants.

On-site Groundwater Contamination

Groundwater in the shallow alluvial aquifer beneath NASF has been impacted by releases of chemicals, resulting in several plumes. The main plumes are associated with six contaminated source areas (Figure 6). Groundwater monitoring is routinely conducted at these six primary source areas. Additional monitoring wells have also been installed on site in areas where leaking underground or above ground storage tanks (USTs or ASTs) have been identified or in other locations where groundwater contamination was suspected mostly as a result of small fuel spills. Previous groundwater investigations at NASF (e.g., assessment of intrinsic remediation) indicate that the intermediate aquifer is not impacted by shallow aquifer contamination because there is an upward hydraulic gradient from the intermediate aquifer to the shallow aquifer preventing the downward migration of contaminants (Battelle 2001). The nature and extent of contamination at these six primary areas are described below.

- *Crash Crew Training Area (Site 1)* — This area, located in the southern portion of NASF, has been contaminated as a result of fire training activities conducted at the site between the mid 1950s and April 1988. Waste products from the fuel farms and aircraft and vehicle maintenance areas were burned routinely in an earthen pit. The waste liquids were usually stored in two ASTs and transported to the pit via pipes beneath the ground (Battelle 2001). Groundwater at Site 1 is monitored with 28 wells and 9 piezometers. The primary contaminants in the groundwater at this site are volatile organic compounds (VOCs) and total petroleum hydrocarbons (TPHs). Trichloroethylene (TCE) (840 ppb) and benzene (800 ppb) were among the VOCs detected above ATSDR's CVs (Table 3).

  Free-phase product (primarily petroleum with low concentrations of solvents) accumulated on the surface of the water table about 200 feet to the southwest of the former fire training pit. Approximately 880 gallons of free product was removed from the site using a bioslurper system containing 30 extraction wells. The bioslurper system was installed in 1996 and is not currently active due to very low production rates. The wells continue to be monitored and if increased levels of free product are identified, the system may be reactivated (Battelle 2001; ORNL 2001; Brown 2002). Since the completion of the RI, cis-1,2-dichloroethylene (1,2-DCE) (2,500 ppb), a break down product of TCE, has been

detected above ATSDR's CV in samples collected from Site 1 (The Environmental Co., Inc. 2001).

- *New Fuel Farm (Site 2)* — Site 2 is located in the west-central portion of NASF. The New Fuel Farm was constructed in 1957 to replace the Old Fuel Farm, which was taken out of service in 1963. Site 2 is used to store jet fuel, diesel fuel, and gasoline. As a result of known spills and fuel handling practices (e.g., daily draining of fuel trucks and routine disposal of residual liquids at the bottom of storage tanks), free-phase petroleum has contaminated the soil and groundwater. This site contains a large number of monitoring wells (at least 40), product recovery wells, and piezometers. The first wells were installed in 1986 and wells have been installed as recently as 1995 for the purpose of delineating the extent of contamination and recovering free product.

  Groundwater is routinely analyzed for VOCs and TPHs. Other than benzene (290 ppb), which was detected above ATSDR's CV, and TPHs quantified as diesel (TPH-D), very few fuel constituents were detected in groundwater at the site. Several remedial actions have been implemented at this site to remove free-phase contamination from the subsurface, including: (1) installation of a bioslurper system installed in 1993 until its operation was discontinued in November 2001; (2) periodic removal of product from recovery wells installed in March 1992; and (3) operation of three recovery trenches installed in 1996 (Battelle 2001).

- *Hangar 300 Area (Site 3)* — Site 3 is located in the west-central portion of the station and includes several small former disposal areas in the vicinity of the Hangar 1 facility. The site includes two groundwater plumes: one area is located north of Hangar 1, referred to as the northern plume, and the other area is located south of Hangar 1, referred to as the southern plume. The southern plume is the primary area of focus since the northern plume does not contain significant contamination. Groundwater in the southern plume became contaminated as a result of discarding aircraft and vehicle maintenance wastes onto unpaved ground in three areas: (1) the south disposal area; (2) the ground-support equipment area; and (3) the wells air start area. These areas were used from the 1960s through the 1980s. Some of the wastes that were discarded include jet fuel, hydraulic fluids, lube oil, and solvents (e.g., carbon tetrachloride and TCE).

  A total of 15 monitoring wells have been installed to characterize the extent of contamination in the southern plume. The most recent samples were analyzed for VOCs and TPH. Samples collected from previous investigations were also analyzed for metals. In April 1999, as part of the intrinsic remediation assessment, TCE (22 ppb) and cis 1,2-DCE (28 ppb) were detected in groundwater above

ATSDR's CVs. TCE was detected in monitoring wells as high as 160 ppb in April 1991 (Table 3) (Battelle 2001).

- *Defuel Disposal Area (Site 6)* — Site 6 is located along the eastern boundary of the station, midway between the northern and southern station boundaries. The site was used to dispose fuel which did not meet military specifications and was removed from aircrafts during maintenance operations. Approximately 70,000 gallons of waste fuel are believed to have been disposed directly onto unpaved ground between 1966 and 1972. Twenty monitoring wells and 10 piezometers have been installed at Site 6. One of the wells was installed for the purposes of recovering free product. The most recent groundwater samples were analyzed for VOCs and TPH. Samples collected from previous investigations were also analyzed for metals.

  The RI for Site 6 did not recommend remedial action for groundwater. However, because of the proximity to the eastern station boundary, the Navy decided to include the site in the intrinsic remediation assessment (e.g., natural attenuation), which is designed to determine whether intrinsic remediation is suitable to address groundwater contamination (Battelle 2001).

- *Old Vehicle Maintenance Shop (Site 14)* — Two separate groundwater plumes have been identified at Site 14. The first plume, referred to as the "northern plume," is located north of E Street near the Old Vehicle Maintenance Shop. Groundwater contamination has resulted from leaks and spills, primarily from two lube pits and two USTs. The lube pits have been filled with soil and the USTs have been removed. A total of 25 monitoring wells and seven piezometers have been installed to characterize the southern plume. The groundwater is primarily contaminated with fuel-derived compounds (e.g., TPHs)(Table 3). Beginning in 1994, NASF began removing free product from two wells (MW-18 and MW-52) (Battelle 2001).

  The second plume, referred to as the "southern plume," is located south of E Street, near the Seabee Yard. Fuel-related constituents and some chlorinated solvents (e.g., 1,2-DCA and benzene) have been detected in the groundwater. The primary source of the fuel contamination is likely the Old Vehicle Maintenance Shop (Site 14) and possibly the Old Fuel Farm (Site 16). A total of 17 monitoring wells were installed to characterize the southern plume. There are no current sources of contamination in the area. Soil sampling conducted during the intrinsic remediation assessment did not identify elevated soil contaminants that would result in additional groundwater contamination (Battelle 2001).

- *Old Fuel Farm (Site 16)*— Site 16 is located in the southern portion of the station and served as the main fuel storage and dispensing area from 1943 to 1962. The area is contaminated with various fuels (e.g., jet fuel, diesel, and gasoline) that were used for operations at NASF. These fuels were stored in four large concrete USTs located at the northern end of the site. In 1992, the USTs were destroyed and partially removed. A total of 35 monitoring wells and 10 piezometers have been installed at Site 16. One of the wells primarily serves to recover free product. VOCs, including benzene (130 ppb), 1,2-dichloroethane (54 ppb), and TCE (42 ppb) were detected above ATSDR's CVs (Table 3).

Contamination close to the NASF boundary is primarily limited to low concentrations of TPHs. Although most boundary or near-boundary monitoring wells do not contain any contaminants above ATSDR's CVs, TPHs have been detected at two monitoring wells near the eastern and southern boundary of the station. The highest concentration of TPH (86 ppb) identified along the eastern boundary was detected in monitoring well (MW) 46 and the highest concentration of TPH (60 ppb) identified near the southern boundary was detected in MW 31. Recent analyses of selected monitoring wells have not detected VOCs or TPHs (JBR 2000; JBR 2001). Screening values are not available for TPHs, however, the individual components that make up TPHs (e.g., benzene, ethylbenzene, toluene, xylene) are routinely tested for at NASF. None of these contaminants exceeded ATSDR's CVs in the monitoring wells closest to the NASF boundary. Some metals, such as arsenic (3,500 ppb), boron (60,000 ppb), molybdenum (420 ppb), and vanadium (1,300 ppb), were detected above ATSDR's CVs in monitoring wells near the NASF boundary (ORNL 1994; NASF 2001). These metals are naturally occurring and the concentrations are consistent with levels that have been detected in drainage canals and in the shallow aquifer in the Fallon area (USGS 1994; USGS 1997).

Off-site Groundwater Contamination

There are three off-site wells that are used to supply drinking water to NASF. These wells are approximately one mile northwest of the NASF boundary and upgradient of all the contaminant plumes on site. The NASF drinking water wells, which are screened in the basalt aquifer, have

not been impacted by site-related contaminants. It is very unlikely that contaminants could impact these basalt aquifer wells because they are upgradient from NASF and the depth to the basalt aquifer is more than 500 feet (Dames & Moore 1988). Arsenic occurs naturally in the basalt aquifer and samples collected from the drinking water wells frequently exceed EPA's MCL. In January 2001, EPA established a new MCL (10 ppb) for arsenic in drinking water replacing the old standard of 50 ppb. Recent sampling conducted in January 2000 detected arsenic at 140 ppb from one of NASF's supply wells (NASF 2001). There are also four off-site wells used by the city of Fallon to supply water to most residents. These wells are located in close proximity to the NASF wells and are also screened in the basalt aquifer. Recent monitoring tests have not detected any site-related contaminants in these wells.

Evaluation of Potential Public Health Hazards

On-Site

Groundwater beneath NASF has never been used as a source of drinking water and no plans exist to use the groundwater in the future. The Navy is currently conducting a pilot study to evaluate different groundwater remediation methods. The study includes evaluation of: 1) enhanced in-situ anaerobic bioremediation for treating groundwater contaminated with dissolved chloroethenes (solvents); 2) enhanced in-situ aerobic bioremediation for treating groundwater contaminated with dissolved fuel hydrocarbons; 3) air sparging for removing dissolved chloroethenes and fuel hydrocarbons; and 4) aboveground treatment of pumped groundwater containing dissolved chloroethenes and/or fuel hydrocarbons using air stripping technology. The studies are being conducted at Sites 1, Crash Crew Training Area and Site 14, Old Vehicle Maintenance Shop (southern plume). Construction on the individual treatment systems is complete and studies are anticipated to continue through the end of the year. According to NASF representatives, a planned bioreactor (groundwater treatment facility) study has been

moved from the field (full scale) to the laboratory (bench scale). A report on the pilot study is due out late next year (Brown 2002).

Assuming that groundwater is not used in the future, ATSDR concludes that on-site groundwater contamination at NASF do not pose a past, current or future public health hazard.

Off-site

ATSDR concludes that off-site NASF and city of Fallon municipal wells have not been impacted by site-related contamination and do not pose a past, current of future public health hazard. NASF and the city of Fallon obtain their drinking water from supply wells that are screened in the basalt aquifer, which is located one mile northwest and upgradient of the station's northern boundary. These are deep wells that are at least 2 miles from any of the known sources of contamination. Groundwater at NASF flows towards the south and southeast, in the opposite direction of the drinking water supply wells.

Based on reviews of drinking water monitoring reports for NASF, containing information dating back to 1996, (March 2001) and the city of Fallon, containing information dating back to 1981, (February 2000), ATSDR did not identify any contaminants, other than naturally occurring arsenic, of potential public health concern. All monitoring results have met state and federal safe drinking water standards for VOCs, semi-volatile organic compounds (SVOCs), and pesticides. The only inorganic compound that has not met state and federal safe drinking water standards is arsenic. Arsenic, which is a naturally occurring contaminant in the Fallon area, has been detected at levels that exceed its CV. A treatment plant designed to remove arsenic is being constructed for the city of Fallon, NASF, and the Fallon Paiute-Shoshone Tribe. It is expected to be in operation by the beginning of 2004. The new treatment plant will sufficiently reduce the levels of arsenic in the drinking water to comply with the new EPA arsenic standard of 10 ppb.

Private drinking water wells — There are private wells to the east of the station boundary that are screened in the intermediate aquifer. Groundwater from the shallow alluvial aquifer is not generally used as a source of potable water due to high levels of naturally occurring dissolved solids and metals. Since groundwater flows southeast, towards the station's boundary near Site 6, it is possible that contaminants in groundwater could migrate off site in this area in the future. However, NASF has been routinely sampling monitoring wells that are located near the eastern and southern station boundary. So far, only very low levels of TPHs have been detected in the past in these monitoring wells and it does not appear that any site-related contaminants have migrated off site. On-site groundwater plumes on the eastern and southern portions of the station have the potential to migrate off site. However, monitoring wells near the station boundary have not contained any site-related contaminants above ATSDR's CVs. In addition, the on-site groundwater plumes are only in the shallow aquifer and private wells in the area are generally screened in the intermediate aquifer. Groundwater remediation activities are ongoing to reduce on-site contamination at NASF and contaminated groundwater from NASF plumes is not expected to migrate off site at levels that would result in harmful exposures. *ATSDR concludes that off-site private wells have not been impacted by site-related contamination at NASF and, therefore, do not pose a past, current or future public health hazard.*

Evaluation of Surface Water and Sediment Exposure Pathway

Conclusions

- *Other than the manmade irrigation ditches and drainage canals, there are no permanent surface water bodies at NASF. No VOCs, SVOCs, polychlorinated biphenyls (PCBs), or pesticides were detected above ATSDR's CVs in samples collected from the drainage canals. Since concentrations of TPHs and metals detected in surface water and sediment within the drainage canals were not at levels of health concern and the potential for human contact with the drainage canals is very limited,* ***ATSDR concludes that exposures to on-site surface water and sediment pose no past, current, or future public health hazard.***

Discussion

The irrigation ditches and drainage canals are the only permanent surface water features at NASF. The L-Line Canal supplies irrigation water to the agricultural fields that are leased by NASF. The two main drains running through NASF are the LD #1 and the LD Drain. The LD # 1 Drain is about 12 feet wide and 12 feet deep with an average water depth of about 1 foot during low flow in the winter. The LD Drain is about 25 feet wide and 12 feet deep with an average water depth of 2 feet during low flow. In addition to the two main drains, there are several small, unnamed lateral drains. The L-Line Canal, which supplies irrigation water to the station, has not been sampled by NASF because all the water is transported from off site locations. The two main drainage canals running through the station are potential pathways for migration of contaminated groundwater since both of the drainage canals can accumulate water from the shallow alluvial aquifer at certain times of the year. However, groundwater flow is generally to the southeast and the drain is located upgradient (north) of any NASF sites that have been identified.

According to NASF representatives, surface water samples from NASF are collected on an annual basis and submitted to a NDEP-certified laboratory (Krishnamoorthy 2002). During the RI investigation of water quality in the two drains, LD #1 Drain and LD Drain, investigators determined that groundwater in the vicinity of the contaminated groundwater plume alternately discharges to and is recharged by the surface water in the LD #1 Drain. In addition, a fuel spill in February 1991 caused extensive contamination in the LD #1 Drain. The spill was cleaned up in March 1991.

Nature and Extent of Contamination

On-Site Surface Water and Sediment Contamination

During the RI, surface water samples were collected from eight locations, four from each drain. The irrigation ditches were not sampled because the water from these ditches is being transported

from off site locations onto NASF property. These samples were collected every two weeks from early September through early October 1989. Sediment samples were collected in August 1989 near the center of flow from the drain bottom at each surface water sampling location. Water and sediment samples were analyzed for VOCs, SVOCs, PCBs, metals, pesticides, and TPHs. In addition to the samples collected during the RI, NASF has collected surface water samples annually from five sampling locations along the drainage canals. ATSDR has reviewed the annual surface water sampling data from 1993 through 2001.

The results of surface water analyses during the RI did not show detectable levels of VOCs or SVOCs in any of the samples. Arsenic (268 ppb), boron (7,470 ppb), selenium (60 ppb), and lead (30 ppb) were the only metals that exceeded ATSDR's CVs for drinking water (Table 4). Selenium was only detected in one of the samples and lead was detected in two of the eight surface water samples collected. TPHs were also identified in most of the surface water samples, ranging from 1 to 5 ppm. Specific jet fuel contaminants such as benzene, naphthalene, toluene, ethylene, and xylene were not evaluated during the RI sampling. The routine monitoring results reviewed from 1993 through 2001 showed that all TPHs were below the reported detection limits. The VOCs, bromoform (40 ppb), bromodichloromethane (8.9 ppb), and dibromochloromethane (30 ppb) were detected above ATSDR's CVs.

The results of sediment analyses did not show detectable levels of PCBs or pesticides in sediment. No VOCs or SVOCs were detected above ATSDR's CVs. One jet fuel contaminant, naphthalene (2.1 ppm), was detected at one sampling location, however, it is well below ATSDR's health-based CV. TPHs were detected in all the sediment samples, however, none exceeded NDEP's action level of 100 ppm. Some of the same metals that were elevated in the surface water were also elevated in sediment.

Off-Site Surface Water and Sediment Contamination

The water from the drainage canals eventually flows to either the Stillwater Reservoir and Wildlife Preserve to the northeast or Carson Lake and wetlands area to the south. No samples were collected during NASF investigations in irrigation ditches or drainage canals off site.

Evaluation of Potential Public Health Hazards

On-site

Surface water -- Permanent surface water features at NASF are limited to the irrigation ditches and drainage canals. According to NASF representatives, these ditches and canals have not been used for recreational purposes (e.g., swimming, fishing, boating) on site. Access to the drainage canals is restricted to on-site personnel. Any potential exposures to on-site surface water or sediments would have been very infrequent and of short duration. There are no current of future plans to use the drainage canals for recreational activities or to allow access to non-authorized personnel. Low levels of TPHs were identified in the water and sediment samples collected in the drainage canals during the 1994 RI. Since concentrations of TPHs detected in surface water and sediment were low and the potential for human contact with the drainage canals was very limited, *ATSDR concludes that exposures to on-site surface water and sediment do not pose a past, current or future public health hazard.*

Off-site

Surface water and sediment— Some low levels of fuel-related contaminants and metals have been detected in drainage canals on site. Off-site migration of site-related contaminants from the drainage canals in the future will depend, in part, on the successful completion of ongoing remedial activities to reduce groundwater contamination underneath NASF. There are no current plans by NASF to evaluate the potential for pesticides and other contaminants in surface water to migrate off site. In the unlikely event that an individual came in contact with surface water flowing off site, these levels would not be expected to pose a health concern. *ATSDR concludes that past, current, and future exposures to off-site surface water and sediment from the base do not pose a public health hazard.*

Evaluation of Soil Exposure Pathway

Conclusions

- *Soil contamination is limited to a small number of source areas on site. Some source areas are accessible (e.g., not fenced) to on-site personnel and are a relatively short distance from the family housing area. Therefore, potential exposure pathways cannot be ruled out. However, access to these and other working areas at NASF is restricted and any exposures to soil contaminants by visitors, workers, or on-site personnel would likely be infrequent and of short duration. During a site visit, ATSDR observed that security personnel diligently investigated unauthorized persons and did not allow access working areas without clearance. It is unlikely that children or other unauthorized persons would wander into working areas of NASF without being noticed.* ***As long as current installation access controls and restrictions exist, ATSDR concludes that exposure to soil contaminants at NASF poses no apparent public health hazard.***

Discussion

Surface or subsurface soil samples were collected at each of the IRP site areas. Soil contamination at most of the sites consists of petroleum-hydrocarbon-related compounds (e.g.,

TPHs) and to a lesser extent solvents. Samples were also analyzed for PCBs at Site 23 where transformers were formerly stored. The nature and extent of soil contamination detected at each of the IRP sites and any corrective measures taken by NASF are summarized in the discussion that follows.

Nature and Extent of Contamination

On-site Soil Contamination

Below is a review of surface soil contamination detected at NASF sites. Refer to Table 1 for a description of each of the IRP site areas.

- Four individual sites
  - *Crash Crew Training Area (Site 1):* The most significant surface soil contamination at this site occurs at the fire pit, which was used to burn flammable liquids. The concentrations of TPH (5,300 ppm) in soil samples collected from the fire pit has exceeded the NDEP action level of 100 ppm in soils. VOCs and SVOCs were detected at concentrations below ATSDR's CVs. The only other soil contamination discovered outside the fire pit area is associated with the contaminated groundwater plume associated with Site 1.

    The primary soil remediation effort at Site 1 consists of the "biopile." NASF has selected to reduce the levels of TPH and VOC contamination within this biopile through a process of biodegradation remediation. NASF adopted this method shortly after the Navy's contractor tested the effectiveness of the technology. In July 1999, contaminated soil from the fire training pit was collected and placed in a designated area within Site 1. The average TPH and total chlorinated solvent concentrations at the time the "biopile" was formed were approximately 3,200 ppm and 25 ppm respectively. For the first 4 months, samples were collected on a monthly basis. However, since contaminant concentrations have not decreased very rapidly, the sample collection period has been reduced to every 6 months.

    The most recent samples (at the time this document was generated) were collected in November 2001 and TPH levels were approximately 600 ppm. This level continues to be above the regulatory goal of 100 ppm set by NDEP. Most of the chlorinated solvents were removed from the pile during the first few months of

operation, and were not detected in the October 1999 sampling event. In July 2002, a fence was placed around the biopile and a contract has been approved to remove, treat, and dispose of the contaminated soil at an off site regulated disposal facility (Brown 2002; Chuck Deverin, NASF Environmental Office, Personal Correspondence, January 25, 2002).

- *Hangar 300 Area (Site 3):* Soil contamination at this site is mainly confined to small areas and consists of petroleum-hydrocarbon-related compounds and low concentrations of solvents, which were below ATSDR's CVs. None of the soil samples collected contained TPH levels exceeding the NDEP action level of 100 ppm.

- *Checkerboard Landfill (Site 20):* No site-related contaminants were detected in soil above ATSDR's CVs.

- *Road Oiling Area (Site 24):* No site-related contaminants were detected in soil above ATSDR's CVs.

- Group I sites

  - *New Fuel Farm (Site 2):* Most of the soil samples have been collected in the northern portion of Site 2. Low levels of TPH contamination were identified and only one soil sample exceeded NDEP's action level of 100 ppm. This was a sample from the weed control area near the fence line that separates Site 1 and Site 2. Low concentrations of pesticides below ATSDR's CVs were also detected in this area.

  - *Transportation Yard (Site 4):* Soil samples were mostly collected around Building 378, which contained a floor drain where vehicle fluids, coolants, and paint wastes were flushed into subsoils beneath the building. TPHs were not detected in these soil samples and no other contaminants were detected above ATSDR's CVs.

- Group II sites (includes the Defuel Disposal Area [Site 6]; Napalm Burn Pit [Site 7]; Receiver Site Landfill [Site 21]; and the Northeast Runway Landfill [Site 22])

No site-related contamination was detected in soil samples collected from the Group II Sites. The Phase II RI could not confirm the presence of the Napalm Burn Pit, which was reportedly located within the Receiver Site Landfill (Site 21). This site was recommended for "no further action" after the RI was completed.

- Group III sites (includes the Wastewater Treatment Plant [Site 9] and Southeast Runway Landfill [Site 18])

  TPH was detected in one soil sample above NDEP's action level of 100 ppm. Other than this one sample, no site-related contaminants were detected in soil. This site was recommended for "no further action" after the RI was completed.

- Group IV sites

  - *Gator Compound (Site 10):* No site-related soil contamination was detected during the RI.

  - *Paint Shop (Site 11):* No site-related soil contamination was detected during the RI.

  - *Pest Control Shop (Site 12):* Low levels of DDT (0.82 ppm), DDE (0.14 ppm), and DDD (0.13 ppm) were detected in some soil samples. The levels of DDT, DDE, and DDD in all of the soil samples collected were below ATSDR's health-based CVs. One sample was analyzed for petroleum hydrocarbons, but none were detected.

  - *Boiler Plant Tanks (Site 13):* Soil contamination was identified at Site 13 during the removal of the boiler plant USTs. TPHs detected in soil exceeded NDEP's action level of 100 ppm.

  - *Old Vehicle Maintenance Shop (Site 14):* One sample collected during the installation of a monitoring well (MW 18) contained TPHs and VOCs. Benzene (41 ppm) was detected above its CV.

  - *Old Fuel Farm (Site 16):* Some of the soil samples collected from boreholes around the USTs contained petroleum hydrocarbons that exceeded NDEP's action level of 100 ppm. Additional samples collected from excavation pits during the removal of USTs contained TPHs as high as 4,500 ppm. All samples with detectable contamination were collected from subsurface soil. VOCs, SVOCs, and metals were not detected above ATSDR's CVs.

  - *Hangar 5 (Site 17):* No site-related soil contamination was detected at Site 17 above ATSDR's CVs.

- *Post-World War II Burial Site (Site 19):* Very low levels of petroleum hydrocarbons were detected in one of the soil samples near MW 29. No other site-related contaminants were detected at this site.

- *Shipping and Receiving Disposal (Site 23):* Although transformers were formerly stored at this location, PCBs were not detected in any of the soil samples. Very low concentrations of DDT (0.10 ppm), DDD (0.02 ppm), and DDE (0.09 ppm) were detected, however, they were below ATSDR's CVs.

Off-site Soil Contamination

NASF has not collected soil samples in any off site locations.

Evaluation of Potential Public Health Hazards

On-site

Soil contamination —NASF is fenced and public access to the station has always been restricted. Generally, source areas (i.e., contaminated soil or disposal areas) contain very low levels of contamination that do not exceed ATSDR's CVs. Most of the soil contamination at NASF comes from jet fuel related spills or leaks from USTs and ASTs. Most source areas are not in close proximity to base residential areas. An exception is the biopile located within Site 1, that contains TPHs and VOCs. However, the biopile was fenced off in July 2002 and is not a public health concern. Any past contact with the biopile or any other source areas and soil contaminants by unauthorized personnel would likely be of short duration. *For these reasons, ATSDR concludes that exposure to contaminated soil does not pose a past, current or future public health hazard.*

Off-site

NASF has not collected any soil samples off site. Most IRP areas on site do not contain site-related contaminants that exceed ATSDR's conservative health-based CVs. Therefore, site-

related soil contaminants are not expected to be transported off site at levels that would be of health concern. *ATSDR concludes that exposure to soil contamination at NASF poses no past, current, or future public health hazard. ATSDR concludes that there is no off-site soil contamination from activities at NASF.*

Evaluation of Air Exposure Pathway - Stationary Sources

Conclusions

- ATSDR evaluated specific air quality issues related to stationary sources at NASF. We started by accessing meteorological data to identify the directions in which emissions most frequently blow. Figure 3 shows the prevailing wind directions measured over a 5-year period at NASF. The figure indicates that winds in this area blow most commonly out of the west, the north, and the south. It is important to note that winds rarely blew from the southeast to the northwest; therefore, emissions from NASF only infrequently blow directly toward the community.

- ATSDR evaluated potential sources of air emissions from stationary sources (e.g., boilers, generators, and painting operations) at NASF. In December 2000, NASF conducted an air quality analysis to evaluate the impacts of most EPA criteria pollutants in the vicinity of the station (i.e., nitrogen oxides [NO_x], carbon monoxide [CO], particulate matter [PM]10, and sulfur dioxide [SO_2]). The results of NASF's analysis indicated that the criteria pollutants listed above do not exceed national ambient air quality standards (NAAQS). Therefore, ***ATSDR concludes that exposure to air contaminants from stationary sources at NASF poses no public health hazard.***

Discussion

Some of the stationary emission sources operated by NASF require permitting under Nevada Administrative Code (NAC) regulations. Sources of regulated air pollutants at NASF include boilers, generators, and painting operations. In order to comply with the NAC regulations, NASF is required to complete an environmental evaluation, which includes providing maximum concentration estimates of EPA's criteria pollutants. In order to comply with this requirement, NASF conducted a dispersion modeling analysis for NASF's stationary emission sources (URS

2000). There are no stationary emission sources (e.g., incinerators or open burning/open detonation activities) that result in significant heavy metal or other toxic releases at NASF. Most emissions sources at NASF are non-stationary (e.g., aircraft and military vehicles).

Nature and Extent of Air Contamination

On-site Air Monitoring

According to NASF representatives, ambient or point source air monitoring has not been conducted at NASF in the past and there are no plans to institute a monitoring program in the future. NASF conducted air dispersion modeling to evaluate the impacts of most EPA criteria pollutants (i.e., NO_2, CO, PM10, and SO_2) released in the NASF area. The modeling was conducted using the U.S. EPA Industrial Source Complex Short Term model, standard EPA methodologies, and a modeling protocol that was reviewed by NDEP's Bureau of Air Quality. NASF's analysis was limited to estimating emissions from on-site stationary sources (e.g., boilers, heaters, generators, painting operations). The dispersion model also included the contribution from ambient background concentrations (URS 2000). The results of the dispersion modeling analysis estimated that none of the EPA criteria pollutants evaluated exceeded the NAAQS.

What are TSPs?

Total suspended particulates (TSP) refers to a wide range of solid particles and liquid droplets found in ambient air. TSPs typically have diameters less than 40 microns. EPA's health-based National Ambient Air Quality Standards (NAAQS) regulated ambient air concentrations of TSP until 1987. The standard required that 24-hour average TSP concentrations are below 260 $\mu g/m^3$. EPA stopped regulating airborne levels of TSP in 1987 because research demonstrated that PM10 represented those particulates that were most likely to penetrate into sensitive regions of the respiratory tract.

What is PM10?

Particulate matter smaller than 10 microns (PM10) refers to the subset of TSP that includes particles smaller than 10 microns in diameter. EPA regulates levels of PM10 and requires 24-hour average concentrations to be less than 150 $\mu g/m^3$.

Off-site Air Monitoring

ATSDR reviewed air monitoring data from EPA's Aerometric Information Retrieval System (AIRS). ATSDR identified limited ambient air monitoring for the Fallon area between 1972 and 2001. Data were available for two air monitoring stations in Fallon, Nevada. One station, located at South Main Street, operated from 1972 through 1987 and collected data for 24-hour average total suspended particulates (TSP). The other station, located at South Russell Street, operated for 5 months in 1998. Sampling data were collected for 24-hour average PM10 concentrations.

From 1972 through 1987, 24-hour average concentrations of TSP exceeded EPA's NAAQS (260 $\mu g/m^3$) on four occasions. A total of 743 samples were collected over this period and the maximum TSP concentration was 385 $\mu g/m^3$ measured in May 1975. During the short time period that PM10 monitoring occurred, none of the samples exceeded EPA's NAAQS. There were a total of 25 samples collected and analyzed for PM10 with the maximum detected value of 71 $\mu g/m^3$.

Evaluation of Potential Public Health Hazards

On-site and off-site

NASF's air quality analysis results showed that the predicted concentrations of criteria pollutants (i.e., CO, NO_2, PM10, SO_2) from stationary sources at NASF do not exceed the NAAQS. The model combines both emissions from NASF as well as background concentrations and compares the total with NAAQS. Since the emissions from stationary sources at NASF have not changed significantly since the station began operation, it is very unlikely that air contaminants from these sources would have exceeded EPA's NAAQS in the past. There are no other significant sources of air contaminants at NASF. TSP concentrations exceeded the NAAQS on four occasions during the 15-year monitoring period (1982-1987), however, the TSP concentrations for most of

the monitoring period were below EPA's standard. Limited air monitoring data in the Fallon area from EPA's AIRS database showed that PM10 concentrations were well below EPA's regulatory standard.

According to NASF representatives, site-related activities at NASF are not expected to change in the future. There are no plans to construct any facilities on site that would significantly increase the levels of air contaminants emitted from stationary sources. Based on the available information, *ATSDR concludes that exposure to air contaminants from stationary sources at NASF do not pose a past, current or future public health hazard.*

Evaluation of Air Exposure Pathway - Jet Fuel and Emission Byproducts

Conclusions

- ATSDR evaluated the potential for adverse public health effects from exposure to jet fuel and jet engine emission byproducts. As a part of this evaluation, ATSDR examined specific air quality issues related to jet fuel and jet engine emission by-products at NASF. We started by accessing meteorological data to identify the directions in which emissions would most frequently blow. Figure 3 shows the prevailing wind directions measured over a 5-year period at NASF. The figure indicates that winds in this area blow most commonly out of the west, the north, and the south. It is important to note that winds rarely blew from the southeast to the northwest; therefore, emissions from NASF only infrequently blow directly toward the community.

- Screening model analyses of emissions from NASF aircraft found that estimated ambient air concentrations for all pollutants considered were either below health-based comparison values or reasonably consistent with levels routinely measured in small communities and suburban locations across the United States.

- CDC collected biological samples from families of ALL victims and from control families in Fallon. Environmental samples were also collected from the houses of ALL victims and control families in Fallon. Analysis of these samples did not detect levels of volatile organic compounds or semivolatile organic compounds, including jet fuel and emission byproducts components at levels that could represent a public health hazard.

- A toxicological evaluation of jet fuel and emissions byproducts, also suggests that exposure to emissions from airplanes (commercial and military) in the Fallon, NV area is not likely to be responsible for the leukemia reported in the community. The potential exposure of members of the Fallon community to jet fuel and emission byproducts is not expected to be sufficient to result in non-cancer public health effects.

Discussion

Jet fuels are one of the primary fuels for turbine engines worldwide and are the most widely available aviation fuels. Commercial illuminating kerosene was the fuel chosen for early jet engines because of its availability compared to gasoline during wartime. As a result, the development of commercial jet aircraft following WWII centered primarily on the use of kerosene-type fuels. Thus, many commercial jet fuels today have basically the same composition as kerosene, but are under more stringent specifications than those for kerosene (Irwin 1997). Jet Propulsion Fuel 8 (JP-8) is basically the same as jet fuel used by the commercial airline industry (i.e. Jet A), except for performance enhancing additives. JP-8 has been used by the militaries of some North Atlantic Treaty Organization (NATO) countries since 1972 and since 1992-1996 by the US Air Force, the US Army and the Japanese Self-Defense Forces.

Approximately 60 billion gallons of JP-8 (F-34 international designation) and the commercial jet equivalents Jet A (domestic flights) and Jet A-1 (international flights) are used internationally on an annual basis, with approximately half being used in the US (Ritchie et al. 2001a).

Jet fuel (e.g., JP-8 and Jet A) is mixture of many chemicals, with the primary component being kerosene (>98%). Most petroleum products are made from crude oil. Crude oil contains primarily hydrocarbon compounds linked in chains of different carbon lengths. Gasoline is a blend of compounds with shorter carbon chains. Kerosene is a blend of the middle distillate or medium carbon chain compounds. Diesel fuel and home heating fuel contain longer carbon chain compounds. Gasoline typically contains more benzene and benzene-containing compounds than kerosene and diesel fuel. Kerosene normally has a boiling range well above the boiling-point of benzene; accordingly, the benzene content of JP-8 is usually below 0.02%. In the United States, gasoline typically contains less than 1% benzene by volume, but in other countries the benzene concentration may be as high as 5% (ATSDR 2000).

Nature and Extent of Contamination

Exposure Considerations - Jet Engine Emissions

A critical first step in this evaluation is to determine the likelihood that exposures are or can occur to sufficient amounts of the contaminants to present a possible public health hazard. In this case, airborne contaminants must be reaching the community of Fallon for a possible hazard to exist. Figure 3 is a wind rose generated from data collected at NASF's onsite meteorological station between 1991 and 1995. Prevailing wind patterns are clearly from west to east (i.e., the winds blow away from the community toward NASF). Winds rarely blew from NASF to the community; specifically, southeasterly winds were observed only 3% of the time. Based on this information, it is apparent that airborne contaminants would only seldom be able to reach the community.

The second step in ATSDR's evaluation was to conduct a screening model to in order to understand the possible extent of emissions for aircraft at NASF, ATSDR conducted a screening analysis of inhalation exposures to contaminants in aircraft emissions from NASF. The analysis

was based on modeling of emissions and dispersion. The analysis was also based largely on data from aircraft engine testing conducted by the Navy's Aircraft Environmental Support Office. These data were found to be generally consistent with emission factors adopted by the Federal Aviation Administration (FAA) and used in ATSDR's previous evaluation of aircraft emissions from Kelly Air Force Base.

In cases such as this where actual data do not exist, models are the only tools available to evaluate the nature and extent of contamination. ATSDR emphasizes that models are only capable of *estimating* exposure concentrations, based on a scientific understanding of how chemicals move in the environment. All models, however, have assumptions and uncertainties and may or may not accurately represent actual conditions.

Aircraft emissions from an airport or military base are determined by many factors, such as the amount of aircraft operations, the aircraft engine types, the fuel burned, and the durations that aircraft operate in different engine modes. Multiple approaches have been used to estimate aircraft emissions for different scenarios. These approaches all focus on characterizing the aircraft emissions that occur while aircraft operate on the ground and during takeoff and landing; they do not characterize emissions while aircraft operate aloft. Appendix C provides a brief summary of the approaches used.

Aircraft activity and the resulting ground level emissions are defined by the landing and takeoff cycle (LTO). The LTO cycle operation modes are defined by standard power settings for aircraft. An LTO cycle is comprised of five components: approach, taxi/idle-in, taxi/idle-out, takeoff, and climb out (EPA, 1999). Generally, volatile organic compound emissions rates are highest when engines are operating at low power, such as when idling or taxiing. Taxi/idle time depends on airport specific operational procedures, and would generally be less at a military airbase.

In a U.S. Navy report (2000), hazardous pollutants from aircraft engine test cells were estimated. It was reported that approximately 94% of the total hazardous air pollutants emitted during a typical LTO were formed during engine idle modes, which represented approximately 10% of the total fuel used during the engine test, but this mode accounted for most of the time in the LTO cycle.

Because aircraft emissions are highly dependent on the number of aircraft operations, types of aircrafts, and fuels used, ATSDR reviewed available information on aircraft activity at NASF. (Rogers, 2001). The number of sorties at NASF ranged from 38,500 in 1998 to 41,200 in 2001. The number of aircraft operations for the same time period ranged from 202,000 to 244,000. NASF considers the following different activities as individual "operations": landing, takeoff, and entering into restricted air space. A "sortie," on the other hand, is essentially every time an aircraft leaves and returns to the base. Therefore, a plane that takes off from NASF, enters restricted air spaces three separate times, and lands at NASF is considered a single sortie, with five operations. Emissions estimates are based on the number of sorties, which best reflect the activities that contribute to overall emissions.[1] Specifically, emissions are calculated assuming 41,200 sorties occur per year—the highest aircraft activity rate from the available data. According to base personnel, data on the number of sorties from years prior to 1998 are not available (Rogers, 2001).

Base personnel also communicated the percentage of aircraft types found at NASF (Rogers, 2001). The number of sorties per aircraft type was estimated by multiplying the percent of total aircraft by the total number of sorties per year. According to this approach, the estimated numbers of sorties per aircraft type shows that the largest number were by F/A18, with 18,450 sorties, followed F-14s, with 6,180 sorties and F-5s with 4,120. Appendix C provides detailed

[1] This approach essentially assumes that "touch-and-go" operations do not contribute to the overall emissions. ATSDR has no data on how many of these operations occur during a year. However, the idle mode of aircraft engines is associated with the largest portion of aircraft emissions. Since "touch-and-go" operations presumably do not involve idle engine modes, neglecting these operations is expected to have only marginal impacts on the estimated emission rates.

information on the number of sorties by aircraft type as well as a detailed explanation of the modeling procedures used.

Table 5 presents the estimates of the highest annual average air concentrations that result from aircraft emissions at NASF. Estimates were made for the 11 hazardous air pollutants most frequently detected in aircraft emissions, and are based entirely on emissions data for F/A-18 aircraft operating on JP-8 fuel. This aircraft type accounts for the largest number of aircraft at the base. Multiple data analyses show that the aircraft emissions are dominated by contributions from aircraft idling.

A crucial step in the assessment methodology is evaluating the public health implications of exposure to any contaminants identified as requiring further evaluation. For these contaminants, ATSDR puts the public health implications of exposure into perspective by considering site-specific exposure conditions and interpreting toxicologic and epidemiologic studies published in the scientific literature. Thus, this step is a state-of-the-science review of what the exposure levels mean in a public health context.

Of the 11 chemicals considered, only acrolein, benzene, and formaldehyde had estimated air concentrations higher than health-based comparison values, but by relatively small margins (a factor of 5 or less). It is important to note that ambient (i.e., nationwide air concentrations of these three chemicals are consistently higher than the most conservative health-based comparison values at locations throughout the United States, and the predicted levels for NASF fall within the range, or below the range, of levels routinely measured in small communities around the country. Two studies were conducted a commercial airports that provide a perspective on the levels of emissions and the potential public health effects for these emissions.

Comparison of aircraft activity (landing and take off cycle (LTO/year)) at three airports in the United States.

Fallon Naval Air Station	Reno/Tahoe International Airport	Chicago O'Hare International Airport*
41,200 LTO/year**	>130,000 LTO/year	>800,000 LTO/year

*Chicago O'Hare International Airport is one of the busiest airports in the world.
**This does not include "touch and go" operations.

A 1993 EPA study of the cancer risks attributed to air pollution in Southwest Chicago reported that Chicago's Midway Airport (approximately 800,000 LTO/year) was in the top five pollutant source contributors. Road vehicle emissions were the number one contributor, with emissions from Chicago's Midway Airport ranking number five. In general, this means that in combination, cars, trucks, buses and trains are the major contributors of carcinogens in Southwest Chicago (approximately 25% of the estimated cancer risk). Chicago's Midway Airport represented approximately 10% of the estimated cancer risk with road vehicles representing 25% (EPA, 1993).

The Illinois EPA (IEPA, 2002) recently reported that emissions from Chicago O'Hare International Airport (one of the world's busiest airports) have an impact on air quality in adjacent communities, but that the impact did not result in levels higher than those found in a typical urban environment (IEPA, 2002).

Most of the published hypothetical cancer risks associated with airports have been based on extrapolated probabilities for exposure to known carcinogens emitted (measured or estimated) from airplanes. Two studies investigated the cancer incidence of communities near airports. The Illinois Department of Pubic Health (2001) examined actual cancer incidence observed in communities near Chicago's O'Hare and Midway airports, and the Washington State Department of Health (1999) similarly investigated Seattle's SeaTac airport. Both studies found no evidence to substantiate a clear and observable elevation of cancer cases among communities residing close to airports.

One would expect air concentrations of airplane and vehicle emissions to be greater near these airports as compared to the Fallon, NV area. The results of these epidemiologic studies suggest that leukemia and other cancer rates associated with airplane emissions would not be elevated in the areas adjacent to the NASF.

CDC Biological and Environmental Sampling Analyses

According to information forwarded to ATSDR from CDC's National Center for Environmental Health, environmental samples were collected from the homes of both the families of the leukemia victims and from control families living in the Fallon area. Environmental media sampled included; indoor air, indoor dust, water from taps, and outdoor surface soil. CDC also collected blood samples from the families of leukemia victims and the control families. According to the preliminary results made available by CDC, these samples did not detect levels of VOCs or SVOCs that would indicate the presence of jet fuel constituents or emission byproducts at levels that would pose a public health hazard (CDC 2002a, 2002b). These results provide further evidence that jet fuel and jet engine emissions are not the likely cause of the leukemia cluster.

Toxicological Evaluation Considerations - Jet Fuel

The general population can be exposed to jet fuel (JP-8 and Jet A) vapors and emissions in the air. EPA has conducted air quality studies near several commercial airports and in certain cities. The EPA (1993) reported that aircraft engines are major source contributors for several volatile organic compounds (1,3-butadiene, formaldehyde, and benzene) and polycyclic organic compounds/particulate matter.

People living near airports or military air bases may also be exposed to higher levels of jet fuel vapors than the general population. People are exposed to many of the same jet fuel chemicals at

gasoline stations, in their garage, while using lawn mowers and other gasoline-powered tools, and near areas with vehicle traffic. Additionally, some people use kerosene heaters during cold weather seasons, which would also result in exposure to the same chemicals present in jet fuel chemicals. People working in military and commercial jet fuel industries, where jet fuels are used, may be exposed to higher levels than the general population.

A chemical comparison of jet fuels and gasoline indicates that gasoline has a much higher benzene content (see Table 1 of Appendix D). Additionally, the difference between military and commercial jet fuel is in the performance enhancing additives. Some of the additives are formulated with hydrocarbons found in fuel (e.g., ethylbenzene and xylene), but none of the additives are considered leukemogenic (i.e., capable of causing leukemia). In general, it appears that as a source of air pollution in urban areas, motor vehicle emissions contribute more volatile organic compounds (including benzene, 1,3-butadiene and formaldehyde) than jet engine emissions. Exposure to benzene occurs during vehicle refueling. However, the exposure level can vary greatly depending on the environmental conditions and filling procedure. Exposure concentrations for benzene during vehicle refueling have been reported to range from approximately 1.5 ppb to 1.3 ppm (Smith, 1999).

Ambient concentrations of benzene in air in the United States range from 2 to 19 ug/m3, with higher levels in urban areas (Wallace, 1996). Because approximately 85% of atmospheric benzene is from mobile sources, such as motor vehicles or airplanes, higher concentrations are often detected inside motor vehicles and adjacent to major roadways (Egeghy, 2000). Egeghy et al. (2000) indicated that benzene concentrations can be 3-8 times higher inside vehicles than in ambient air and that the mean concentration of benzene in breath before refueling was 8.6 ug/m3. The mean level of benzene in breath immediately after refueling was 160 ug/m3. Interestingly, the reported background levels of benzene in breath of nonsmokers ranged from 0.8 to 5.3 ug/m3. Based on the screening model used for this evaluation, ATSDR is estimating a level, for

the nearest offsite receptor, of benzene of 0.222 ug/m3. This level is not excessive when compared with the levels noted above.

Emissions from vehicles and airplanes contain volatile organic compounds, including 1,3-butadiene and formaldehyde. The DHHS has determined that 1,3-butadiene is a human carcinogen and formaldehyde is a probable human carcinogen. Studies in animals, as low as 6.25 ppm, have shown that 1,3-butadiene is carcinogenic in mice and rats at multiple organ sites (EPA 1998). Human epidemiologic studies have reported an association between 1,3-butadiene exposure and lymphatic leukemia in styrene-butadiene rubber workers. It's important to note that there is a lack of quantitative exposure data in the monomer plant workers and the polymer plant workers exposure data is limited but suggest that concentrations greater than 1 ppm for years are necessary to increase the risk of cancer in workers. Ambient air levels of 1,3-butadiene in urban and suburban locations ranged from 0.10 to 0.46 ppb while levels in smoke-filled bars ranged from 1.2 to 8.4 ppb (EPA 1998). The modeled annual average air concentration for 1,3-butadiene from aircraft emissions at Naval Air Station Fallon was estimated to be 0.3 ppb (see Table 5 of Appendix C). Formaldehyde has been shown to cause nasal cancer in animals. Excess mortality from leukemia and brain cancer was generally not seen among industrial workers, which suggests that the excess for these cancers among workers is due to something other than formaldehyde.

Evaluation of Potential Public Health Hazards

A principal part of the environmental pathways evaluation for jet fuel and engine emission byproducts involves a determination of how likely it would be for these contaminants to migrate via air from NASF to the community. Meteorological data for NASF indicates that predominant wind direction is from west to east, from the community toward NASF. Screening models predict that the levels of contamination generated are not sufficient to present a public health hazard, even if wind patterns were to allow contaminants to migrate from NASF to the

community. CDC analysis of environmental and biological samples collected from the community do not indicate the presence of sufficient levels of jet fuel constituents or emission byproducts to present a likely public health hazard.

Finally the results of the toxicological evaluation do not suggest that jet fuel or emission byproducts are likely to present a public health hazard in Fallon. The majority of leukemia cases (15 of 16 cases) in Fallon, NV are the acute lymphocytic leukemia (ALL) type. Since benzene-related leukemia is predominantly of the AML type, this would suggest that these leukemias resulted from something other than exposure to benzene. The most common leukemia associated with benzene exposure is AML rather than ALL. Modeled concentrations of benzene and 1,3-butadiene from NASF in the Fallon area are below levels that increase the risk of cancer, including ALL. A review of the chemical composition of jet fuel (JP-8 and Jet A) found no other compounds, including additives, that have been shown to cause leukemia.

Based on our review, it appears that exposure to emissions from airplanes (commercial and military) in the Fallon, NV area is not likely responsible for the leukemia reported in the community. The potential exposure by members of the Fallon community to jet fuel and emission byproducts is not expected to be sufficient to result in non-cancer public health effects.

COMMUNITY HEALTH CONCERNS

ATSDR has communicated with community members who live near NASF and has documented specific health concerns related to the activities at NASF. A Community Information Fair was held on August 21 and 22, 2001, at the Fallon Convention and Tourism Authority, in Fallon, Nevada, to provide an opportunity for community members to discuss health and site-related concerns with ATSDR staff as well as other state and federal agencies involved with the Fallon childhood leukemia investigation. ATSDR identified the following community concerns regarding contamination and health effects associated with NASF from the site visits, the Community Information Fair, and other site-related activities.

- *Concern about the possible contamination of drinking water supplies.*

ATSDR has identified the primary sources of drinking water for NASF, the city of Fallon, and the Fallon Paiute-Shoshone Tribe. Groundwater beneath NASF is not used as a source of drinking water. The NASF drinking water wells and the city of Fallon municipal wells are screened in the basalt aquifer which has not been impacted by site-related contaminants. These drinking water wells are upgradient from NASF and the depth to the basalt aquifer is more than 500 feet below ground surface. Arsenic, which is naturally occurring in the Fallon area, continues to be detected above EPA's safe drinking water standard. The city of Fallon, NASF, and the Fallon Paiute-Shoshone Tribe are addressing this issue by constructing a water treatment plant designed to remove arsenic. The plant is expected to be in operation by the beginning of 2004. There are some private drinking water wells to the east of the station boundary. However, monitoring wells near the station boundary have not contained any site-related contaminants that have exceeded ATSDR's CVs.

- *Concern about air contamination from fuel jettisoning.*

Several members of the community in the vicinity of NASF have expressed the concern that fuel jettisoned from Naval aircraft might be a potential cause of illnesses in the community. There is a perception that fuel is routinely jettisoned by aircraft prior to landing. According to U.S. Navy operations guidelines, this is not the case. Jettisoning typically occurs when an emergency landing is required. The fuel is released in order to decrease the potential for an explosion or fire during an urgent or emergency landing.

The U.S. Navy Operational and Training Manual for General Aircraft Operations (OPNAV Instruction 3710, January 1997) states that: "Whenever practicable, fuel shall not be jettisoned (dumped) below an altitude of 6,000 feet above the terrain. Should weather or emergency conditions dictate jettisoning at a lower altitude, every effort shall be made to avoid populated areas. When under positive control, the pilot in command should advise the air traffic control facility that fuel will be jettisoned."

As mentioned above, jettisoning is not a common occurrence at NASF or other military air bases. Even during urgent or emergency circumstances, to the extent allowed by the situation, procedures must be followed to minimize exposure to the greatest extent possible given the circumstances. Additionally, jettisoning of fuel close to the ground can produce turbulent conditions that could cause the aircraft to become difficult to control and increase the likelihood of a crash. For these reasons, standard procedures do not recommend jettisoning of fuel close to the ground.

Table 6 lists the actual jettisoning events that have occurred at NASF between 1986 and 2001 (Rybold, 2001). The jettisoning incidents occurred when mechanical or electronic problems created dangerous operating conditions increasing the potential for an accident upon landing. The amount of fuel jettisoned were, in all cases, relatively small and occurred over undeveloped and unpopulated areas, specifically Salt Wells Flat and bombing ranges B-17 and B-20, located from 10 to 30 miles from the city of Fallon. These locations are depicted in Figure 6. It should be noted that these locations are not upwind from the city of Fallon, making it unlikely that ground fall would move toward the city.

U.S. Air Force research on ground fall of jettisoned fuel (i.e., JP-8) found much of the jettisoned fuel evaporates and remains in the atmosphere long enough to be dissipated. This research also found that ground temperature is an important factor in determining the amount of fuel that will reach the ground. At ground temperatures above 30 degrees Celsius(30º C) (86º (F)) less than one percent of JP-8 jettisoned at 3000 feet above ground level (agl) will reach the ground. At 0º C (32º F) approximately 25 percent of the fuel will reach the ground (AFESC, 1981). The balance of the jettisoned fuel becomes entrained in the atmosphere for an indefinite period of time. Without specific knowledge of the speed of the aircraft, the flight path and meteorological information such as wind speed and direction, and humidity, it is not possible to determine precisely how much fuel would have reached the ground during specific jettisoning events. However, the jettisoning occurred over areas down wind and removed from the city of Fallon and did not occur over residential areas. It is unlikely that people were exposed to the limited amount of jettisoned fuel that would reach the ground in these areas.

At NASF, whenever fuel jettisoning occurs, an on-site inspection is conducted of the area. This inspection includes soil sampling if fumes or other fuel-related products are observed, is conducted by explosive ordnance personnel. To date, no evidence of fuel contamination has been discovered. Additionally, the base routinely tests the shallow water aquifer (218 monitoring wells

are located at NASF and periodically tested) and conducts quarterly testing of the three drinking water wells. To date, no fuel related chemicals have ever been discovered in off-base property or in the drinking water supply (Naughton, 2001).

Members of the Fallon community have expressed concern that jettisoning occurred more frequently and at lower altitudes than reported in Table 6. ATSDR can not determine what was actually observed, there are several phenomena that might be mistaken for jettisoning.

Figure 8 depicts an aircraft actually venting fuel. The venting is believed to be the result of an accidental overfill during refueling. However, the visual effect is the same as jettisoning (personal communication, Jeff Kellam, from Jet Safety, July 7, 2002) . The visual effect is similar to that of a vapor trail except that a vapor trail can extend for a considerable distance, even horizon-to-horizon, whereas a jettisoning event lasts for a few seconds and will likely leave a much shorter visible trail.

When viewed from a distance, other types of emissions may be mistaken for fuel jettisoning. Figures 9 - 12 are photographs of military aircraft, collected from various military websites. While these were not taken from aircraft at NASF, each depicts phenomena that might be mistaken for fuel being jettisoned. These phenomena include; exhaust plumes, vapor trails, heat plumes, and the firing of flares. Exhaust plumes are the smoke fumes that are similar to those that are emitted by any internal combustion engine. Vapor trails are streams of water vapor that are condensed from the air by the increased air pressure created by the aircraft moving through the atmosphere. These are the contrails that are commonly seen trailing many aircraft such as commercial airliners. A heat plume is created by the variation of density of the heated emissions of an aircraft engine. The difference in density between the heated exhaust and the cooler air creates the wavy pattern behind the aircraft. These wavy patterns are similar to the 'heat waves' seen above paved roads during hot weather. The firing of flares may be mistaken for jettisoning if observed from a distance, but would only be seen over the training ranges. These flares are defensive measures taken by military aircraft in combat and are used to 'confuse' antiaircraft weapons that target the heat of the aircraft engine.

Because fuel jettisoning is a very rare event and does not typically occur over populated areas, ATSDR has determined that fuel jettisoning at NASF does not present a public health hazard.

- *Concern about leaks in the Fallon jet fuel pipeline that provides JP-8 fuel to NASF.*

ATSDR has prepared a separate public health consultation (HC) that addresses the issue of whether jet fuel releases are likely to have occurred along the Fallon jet fuel pipeline that delivers JP-8 fuel to NASF (ATSDR 2002). The HC provides a description of the history, operation, maintenance, and monitoring of the pipeline, and evaluates any potential pathways for human exposure. Based on this evaluation, ATSDR concluded that the Fallon jet fuel pipeline does not

pose a past, current, or likely future public health hazard. The Fallon Jet Fuel Pipeline HC was released for public comment and is on-line at ATSDR's web-site: http://www.atsdr.cdc.gov/HAC/PHA/fallonpipe/fallon_toc.html

- *Concern about any potential exposures from chaff materials that are used by the Navy.*

Community members have voiced concern about possible public health risks associated with the Navy's use of chaff at NASF. Chaff is a metallic material consisting of aluminum-coated glass fibers. Chaff fibers typically are 25 microns (µm) thick and between 1 and 2 centimeters long (Naval Research Laboratory 1999). The primary elements in chaff are aluminum and silicon—two of the most abundant naturally occurring elements in the earth's crust. It is used by the military to confuse radar signals, which allows aircraft to operate without easily being detected.

Part of NASF's mission is to conduct training operations that accurately simulate wartime conditions. Air crews at NASF complete chaff deployment training missions and other training exercises which result in the release of approximately 50,000 chaff canisters or bundles per year. At NASF, most of the chaff is released at 15,000 to 20,000 feet above ground level over an area covering approximately 10,000 square miles. Each canister of chaff contains approximately 2.1 million fibers and weighs about 1.5 ounces. This is equivalent to approximately 2 ½ tons of chaff fibers released annually. Once released into the atmosphere, the dispersion of chaff and its ground concentrations depend on such conditions as temperature, humidity, wind directions and speed, release altitude, aircraft speed, and topographic features (Tetra Tech, Inc. 1998; Naval Research Laboratory 1999) In general, chaff is released at high altitudes, drifts over very large areas, and is greatly dispersed before falling to the Earth's surface.

Based on the site-specific information presented above, 2 ½ tons of chaff fibers released each year over 10,000 square miles would result in an annual average PM_{10} or $PM_{2.5}$ concentration of 0.018 µg/m^3. This is far below the NAAQS of 50 µg/m^3 for PM_{10} and 15 µg/m^3 for $PM_{2.5}$. To provide some perspective, annual average background PM_{10} concentrations range from 6.4 µg/m^3 in northern California and Western Nevada to 20 µg/m^3 along the east coast. The lowest background $PM_{2.5}$ concentrations, which are typically found in Nevada, Utah, Wyoming, and northern Arizona, are around 3 µg/m^3. The PM_{10} or $PM_{2.5}$ concentrations that would result from chaff at NASF would be much lower than average background concentrations found across the U.S.

A Chaff Survey was conducted by the Navy between December 1994 and January 1995. The survey area covered approximately 107 acres at the Electronic Warfare Range, which is approximately 25 miles east-southeast of NASF. The survey did not find any observable effects of chaff debris in vegetation, wildlife, soils, or water within the survey area (Tetra Tech 1998). Although the Navy survey did not evaluate human health impacts associated with the inhalation

of chaff fibers, a recent report issued by the U.S. Air Force did not identify any studies that found chaff to contribute significantly to particulate matter or any EPA criteria pollutants in the atmosphere (USAF 1997). In addition, a panel of independent experts from academic and research institutes concluded that chaff fibers are too large to be inhaled into the lungs and are, therefore, not of health concern for inhalation exposure (Naval Research Laboratory 1999). Based on a review of the scientific literature and recent evaluations at other sites, ATSDR concludes that the usage of chaff at NASF does not pose a public health hazard.

- *Concern about any potential exposures from depleted uranium that may have been used by the Navy.*

Navy records report that ordnance containing depleted uranium has not be used at NASF. According to NASF information, some of the aircraft used in training at NASF could be equipped to fire the types of ordnance that contain depleted uranium. Training with DU must be specifically authorized on designated DOD targets. There are no authorized targets within the Fallon Range Training Complex and DU does not appear on the list of approved ordnance for the Fallon ranges. No record exists of DU ever being authorized or used in the Fallon Range Training Complex or of expended DU ever being encountered during range clean up. (Electronic communication, Captain B.T. Goetsch, Commanding Officer NASF, February 26, 2002).

- *Concern about elevated tungsten detected in biological sampling conducted by NSHD and CDC.*

Elevated levels of tungsten were found in the biological sampling of case and control families in the Fallon area. At present there is no established causal link between tungsten and leukemia. The NSHD, CDC and ATSDR are continuing to evaluate tungsten in the environment in the Fallon area.

ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children may be more sensitive than adults to environmental exposure in communities faced with contamination of their water, soil, air, or food. This sensitivity is a result of the following factors: (1) children are more likely to be exposed to certain media like soil when they play outdoors; (2) children are shorter and therefore may be more likely to breathe dust, soil, and vapors close to the ground; and (3) children are smaller than adults and therefore may receive a higher dose of chemical exposure relative to their body weight. Children also can sustain permanent damage if exposed to toxic substances during critical growth stages. ATSDR is committed to evaluating children's special interests at sites such as NASF as part of its Child Health Initiative.

ATSDR evaluated the likelihood that children living at or near NASF may have been or may be exposed to contaminants at levels of health concern. Based on the most recent NASF estimates, there are 84 children under the age of 18 years living in NASF housing on site. There are no schools or daycare facilities on site. The on-site family housing area (i.e., Fairview Housing) does not border any of the IRP sites. Although most of the IRP sites are not in close proximity to the family housing, Site 1 is approximately 2,500 feet from the Fairview Housing area. As a conservative safety measure, ATSDR recommended that a fence be installed around the "biopile" located within Site 1 to minimize any potential for exposure. In July 2002, a fence was placed around the "biopile" at Site 1. In addition, a contract has been approved to remove, treat, and dispose of the contaminated soil at an off-site approved disposal facility (Brown 2002). Based on available data, information from NASF personnel, and the site visit to NASF, ATSDR did not identify any situations where children were likely to be exposed to contaminants at levels which pose a health concern.

CONCLUSIONS

After evaluating available environmental data and available toxicologic and medical information, ATSDR has reached the following conclusions regarding media- and site-specific exposure pathways. ATSDR concludes that there are no past, current or future public health hazards presented by exposures to NASF-related contaminants in the environment.

- *As long as the groundwater is not used for drinking, exposure to on-site groundwater at NASF poses no past, current, or future public health hazard.* Although fuel and some solvents released to the environment have resulted in areas of groundwater contamination at NASF, groundwater beneath the station has never been used as a source of drinking water. Moreover, according to NASF representatives, there are no current or future plans to use groundwater at NASF for drinking water or other domestic purposes (e.g., showering or cooking).

- *On the basis of currently available data, ATSDR concludes that exposure to site-related chemicals in public water supplies or private drinking water wells poses no past, current, or future public health hazards.* The only inorganic substance that has not met state and federal safe drinking water standards is arsenic. Arsenic, which is naturally occurring in the Fallon area, has been detected at levels that exceed EPA's maximum contaminant level, which is currently 10 ppb. A treatment plant designed to remove arsenic is being constructed for the city of Fallon, NASF, and the Fallon Paiute-Shoshone Tribe and is expected to be in operation by the beginning of 2004. NASF, most Fallon residents, and members of the Fallon Paiute-Shoshone Tribe obtain their drinking water from off-site wells which draw water from the basalt aquifer. These wells have not been impacted by site-related contamination because they are at least 2 miles northwest of any NASF source areas, the wells are upgradient from NASF, and the depth to the basalt aquifer is more than 500 feet below ground surface. All past monitoring tests have met state and federal safe drinking water standards for VOCs, semi-volatile organic compounds (SVOCs), and pesticides.

  Groundwater investigations at NASF have indicated that contamination is confined to the shallow aquifer beneath NASF. Most private wells in the Lahontan Valley are screened in the intermediate aquifer and would not be impacted by NASF contamination of the shallow aquifer. There are a small number of private residences to the south and east of NASF that use shallow aquifer wells. Monitoring wells near the station boundary have not contained any site-related contaminants that have exceeded ATSDR's CVs. Since, boundary wells have not contained contaminants at levels above ATSDR's CVs, it is not expected that private wells have been impacted by site-related contaminants.

- *Exposure to surface water and sediment at NASF poses no past, current, or future public health hazard.* Site-related contaminants have not been detected at levels that could present a public health concern. Permanent surface water features at NASF are limited to the irrigation ditches and drainage canals. These have not being used for recreational purposes (e.g., swimming, fishing, boating) on site. Therefore, any potential exposures to on-site surface water or sediment would be very infrequent, of short duration, and not of public health concern.

- *Exposure to off-site surface water and sediment poses no past, current, or future public health hazard.* Low levels of fuel-related contaminants and metals have been detected in drainage canals on site. These contaminants are not present at levels of health concern and any exposure to off-site residents or other individuals would likely be of short duration.

- *Exposure to soil contamination at NASF poses no past, current, or future public health hazard.* NASF is gated and access is restricted to all but authorized personnel. Soil contamination is limited to a small number of source areas on site. Some of the IRP sites that contain contaminated soil are not fenced. However, security procedures effectively limit access. Therefore, any exposures to soil contaminants would likely be infrequent and of short duration.

- *Exposure to air contamination at NASF from stationary sources did not pose a past public health hazard and does not pose a current or future public health hazard.* NASF's air quality impact analysis results showed that the predicted concentrations of EPA criteria pollutants (i.e., CO, NO_x, PM10, SO_2) from stationary sources at NASF do not exceed the national ambient air quality standards. Meteorological data shows that prevailing winds are from the west, from the direction of the city of Fallon toward NASF and therefore generally serve to blow any contaminants away from the town. In addition, recent air monitoring data for the Fallon area from EPA's AIRS database showed that PM10 concentrations for the Fallon area were well below EPA's national ambient air quality standards.

- *The potential exposure by members of the Fallon community to jet fuel and emission byproducts is not expected to be sufficient to result in cancer or non-cancer public health effects.* As described above, meteorological data shows that prevailing winds are from the west, from the direction of the city of Fallon toward NASF and would therefore generally serve to blow any contaminants away from the town. A toxicological evaluation of jet fuel and emission byproducts, and the screening model for dispersion of emissions suggest that exposure to emissions from airplanes (commercial and military) in the Fallon, NV area is not likely to be responsible for the leukemia reported in the community. The potential exposure by members of the Fallon community to jet fuel and emission byproducts is also not expected to be sufficient to result in non-cancer public

health effects. Screening model analyses of emissions from NASF aircraft found that estimated ambient air concentrations for all pollutants considered were either below health-based comparison values or reasonably consistent with levels routinely measured in small communities and suburban locations across the United States.

RECOMMENDATIONS

Based on the conclusions about potential exposure pathways at NASF, ATSDR makes the following recommendations.

1. As a conservative safety measure, ATSDR recommended that NASF fence off the area that contains the "biopile" at Site 1 (Crash Crew Training Area) until a permanent plan is in place to remove the contaminated soil and transport it to a long-term storage facility. Although it is unlikely that children or station personnel are coming into direct contact with soil contaminants at levels of concern from the biopile, fencing would eliminate any possibility of exposure. The Navy informed ATSDR that a fence was installed around the biopile in July 2002 and a plan is in place to remove the contaminated soil at an off site disposal facility.

2. ATSDR recommends that NASF continue to conduct routine annual testing of boundary monitoring wells in the vicinity of the plumes on the east and south to ensure that site-related contaminants are not migrating off site.

3. If site-related contaminants are detected off site to the east or south of the station, ATSDR recommends that NASF determine whether any of the private wells in the vicinity of NASF are used for drinking water and test those wells as appropriate.

4. As a conservative safety measure, ATSDR recommends that NASF continue to routinely sample the drainage canals at the point where they exit the base, and analyze for specific petroleum and jet fuel constituents (e.g., benzene, toluene, xylenes) to verify that fuel constituents are not migrating into these canals and off-site.

PUBLIC HEALTH ACTION PLAN

The public health action plan (PHAP) for NASF contains a description of actions to be taken by ATSDR and other government agencies at and in the vicinity of the site upon completion of this PHA. The PHAP is designed to ensure that this PHA not only identifies public health hazards, but provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The plan includes a commitment on the part of ATSDR to follow up and ensure that the plan is implemented. The public health actions completed and to be implemented are as follows:

Completed Actions

1. A bioslurper system for the removal of free product (i.e., petroleum hydrocarbons) was installed at Site 1 in 1996 and has removed approximately 900 gallons of free product. The system is not currently operating because of very low production rates.

2. A bioslurper system for the removal of free product at Site 2 was installed in 1993.

3. ATSDR has prepared a public health consultation which evaluates the potential exposure to fuel from the Kinder-Morgan pipeline supplying fuel to NASF.

4. The U.S. Geological Survey has collected and analyzed water samples from the faucets from the homes of both the leukemia families and the control families which were evaluated in the NSHD and CDC studies. Analyses included (but were not limited to) those necessary to detect arsenic and tungsten.

5. The city of Fallon has conducted analyses of drinking water from the public water facility. Analyses included (but were not limited to) those necessary to detect arsenic and tungsten.

6. A contract for the remediation of Site 1 contaminated soils was issued in 1998. NASF was using an experimental form of remediation which involves collecting contaminated soil and forming a large pile. The contaminated pile of soil, referred to as a “biopile”, is injected with bacteria that are designed to breakdown the organic contaminants. According to NASF officials, the technology did not reduce

the concentrations of VOCs and other organics as much as expected, and NASF plans on removing the contaminated soil from Site 1.

7. A research project headed by the U.S. Air Force has been completed at Site 1 to evaluate the anaerobic dechlorination of chlorinated compounds in the groundwater.

Ongoing and Planned Actions

1. Groundwater contamination identified during previous investigations at Site 2 is expected to be assessed as part of the intrinsic remediation assessment for IRP sites at NASF.

2. Free product removal is ongoing, as necessary, at Sites 2, 6, 14, and 16.

3. Groundwater monitoring at the six primary sites where groundwater plumes have been identified continues to be conducted by NASF under the intrinsic remediation assessment.

4. NASF has initiated a pilot study that would include the installation of more than 100 injection and/or extraction wells at Sites 1 and 14. The current study includes: 1) the evaluation of anaerobic bioremediation for treating groundwater contaminated with dissolved solvents; 2) aerobic bioremediation for treating groundwater contaminated with dissolved fuel hydrocarbons; 3) air sparging for removing dissolved solvents and fuel hydrocarbons; and 4) above ground treatment of pumped groundwater containing dissolved solvents and/or fuel hydrocarbons using air stripping technology.

5. A treatment plant designed to remove arsenic is being constructed for the city of Fallon, NASF, and the Fallon Paiute-Shoshone Tribe and is expected to be in operation by the beginning of 2004. This facility is intended to supply water for domestic purposes to NASF for the foreseeable future. Water from the facility will be sampled and analyzed under requirements of the Safe Water Drinking Act.

6. NASF continues to work closely with the community and the state in coordinating the exchange of information about activities that may be related to the leukemia cluster in Fallon.

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REFERENCES

AFESC, 1981. The Effect of Fuel Composition on Groundfall from Aircraft Fuel Jettisoning, Air Force Engineering and Services Center Tyndall AFB FL Engineering and Services Lab. March 01, 1981.

ATSDR: Case Studies in Environmental Medicine - Benzene Toxicity. April 2000. ATSDR Publication Number: ATSDR-HE-CS-2001-0003.

ATSDR. 2002. Public Health Consultation, Evaluation of Potential Exposures from the Fallon JP-8 Fuel Pipeline, Fallon, Churchill County, Nevada. May 2002.

Battelle. 2001. Assessment of Intrinsic Remediation at Installation Restoration Sites at Naval Air Station Fallon. March 2001.

Brown J. 2002. Comments regarding NASF Public Health Assessment (Data Validation Draft) Jim Brown, Engineering Field Activity Northwest (EFANW). November 7, 2002.

Centers for Disease Control and Prevention (CDC). 2002a. National Center for Environmental Health, Centers for Disease Control. Concentrations with Associated Comparison Values for Fallon. February 26, 2002.

CDC. 2002b. National Center for Environmental Health, Centers for Disease Control. Concentrations with Associated Comparison Values for Fallon. May 21, 2002.

City of Fallon. 2000. Drinking Water Analysis Results. February 2000.

Cottle G. 2002. Comments on Data Validation Draft NASF PHA. October 2002.

Dames & Moore. 1988. Preliminary Assessment/ Site Inspection Naval Air Station, Fallon, Nevada. April 1988.

Ecology and Environment, Inc. 1989. Federal Facility Preliminary Assessment/Site Inspection Review. July 1989.

Egeghy PP, Tornero-Velez R, and Rappaport SM. 2000. Environmental and biological monitoring of benzene during self-service automobile refueling. Environ Health Perspectives. 108(12):1195-1202.

EPA. 1993. Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southwest Chicago. Final Summary Report. Submitted to: U.S.EPA Region 5 Air and Radiation Division by ViGYAN. EPA Contract No. 68-D0-0018. April 1993.

EPA. 1999. Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft. EPA420-R-99-013. April 1999.

Illinois Department of Public Health. 2001. Cancer Incidence in Populations Living Near Chicago O'Hare and Midway Airports, Illinois 1987-1997. November 2001.

IEPA. 2002. Final Report: Chicago O'Hare Airport Air Toxic Monitoring Program June-December, 2000. Illinois Environmental Protection Agency, Bureau of Air. May 2002.

Irwin RJ, VanMouwerik M, Stevens L, Seese MD, and Basham W. 1997. Environmental Contaminants Encyclopedia: Jet Fuel 8. National Park Service, Water Resources Division, Fort Collins, Colorado.

JBR Environmental Consultants (JBR). 2000. NAS Fallon Groundwater Monitoring Report 1999. January 2000.

JBR. 2001. NAS Fallon Groundwater Monitoring Report 2001. July 2001.

Jet Safety, 1999. http://www.jetsafety.com/images/photo2/f16tanker2.JPG.

Krishnamoorthy R. 2002. Comments on Data Validation Draft NASF PHA. October 2002.

Naughton, R.J. 2001. Correspondence to The Honorable Harry Reid.19 June 2001. Author: R.K. Naughton, Commander, Naval Strike and Air Warfare Center.

Naval Air Station-Fallon (NASF). 1994. Installation Restoration Program Community Relations Plan. September 1994.

NASF. 2001. Monitoring Well Concentrations (ppb) Database. Developed by the NASF Environmental Division. May 2001.

NASF. 2001. Laboratory Analysis Report NASF Drinking Water Supply Wells. January 2000.

NASF official Website, http://fallon.navy.mil. October 2001.

Naval Research Laboratory. 1999. Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security. August 31, 1999.

Oak Ridge National Lab (ORNL). 1992. Preliminary Site Characterization Summary Installation Restoration Program, NASF. January 1992.

ORNL. 1994. Final Remedial Investigation Report Naval Air Station Fallon, Nevada. September1994.

ORNL 1992. Preliminary Site Characterization Summary Naval Air Station Fallon. January 1992.

ORNL. 2001. Comparison of Groundwater Alternatives Report Naval Air Station Fallon, Nevada. March 2001.

OPNAV, 1997, The U.S. Navy Operational and Training Manual for General Aircraft Operations, Instruction 3710, January 1997.

Ritchie GD, Bekkedal MY, Bobb AJ, and Still KR. 2001a. Biological and Health Effects of JP-8 Exposure. Report No. TOXDET 01-01. Naval Health Research Center Detachment (Toxicology), Wright-Patterson Air Force Base, Ohio.

Rybold, E.K. 2001. Memorandum, 6 August 2001. Information for ATSDR Author: E.K. Rybold, Executive Officer NASF.

Smith RG. 1999. A study on benzene exposure during vehicle refueling. Maxxam Report#: 9900387 for the Health Protection Branch, Health Canada. Contract #: CCME#: 989-040. April 1999.

Tetra Tech, Inc. 1998. Final Chaff and Flare Survey, Naval Air Station Fallon, Nevada. April 3, 1998.

The Environmental Company, Inc. 2001. Sampling and Analysis Plan Fall 2001 Groundwater Monitoring Naval Air Station Fallon, NV (Internal Draft). October 2001.

URS Group, Inc. (URS). 2000. Air Quality Impact Analysis in Support of an Environmental Evaluation for Naval Air Station Fallon, Fallon Nevada. December 2000.

U.S. Air Force Air Combat Command (USAF). 1998. Environmental Effects of Self Protection Chaff and Flares, Final Report. August 1997.

U.S. Census Bureau. 2000. Census 2000 Redistricting Data (Public Law 94-171) Summary File, Matrices PL1 and PL2. 2000.

USGS. 1994. Ground-Water Quality and Geochemistry, Carson Desert, Western Nevada. Open-file Report 94-31. 1994.

USGS. 1997. Concentrations, Loads, and Yields of potentially Toxic Constituents in Irrigation-Drain Systems, Newlands Project Area, Carson Desert, Nevada, November 1994-October 1995. Water-Resources Investigations Report 97-4034. 1997.

USGS. 2001 Hydrogeology and Geochemistry of the Fallon Basalt and Adjacent Aquifers, and Potential Sources of Basalt Recharge, in Churchill County, Nevada. Water-Resources Investigations Report 01-4130. 2001.

U.S. Navy. 2000. Hazardous Air Pollutants from Department of Defense Aircraft Engine Test Cells: Best Estimates. Aircraft Environmental Support Office, Naval Aviation Depot-North Island, San Diego, CA. AESO Report No. 2001-7. December 2000.

Washington State Department of Health. 1999. Progress Report: Cancer Cluster Investigation, SeaTac International Airport. Updated February 1999, Updated December 1999, Updated March 2000. <http://www.metrokc.gov/health/phnr/eapd/reports/cancer/> (as of 6/26/02).

Other Citations

Goetsch, B.T. 2002. Electronic mail correspondence between Captain B.T. Goetsch (Commanding Officer NASF) and Jeff Kellam (ATSDR). February 26, 2002.

TABLES

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Crash Crew Training Area (Site 1)	The Crash Crew Training Area is in the southern part of Naval Air Station Fallon (NASF). The area consisted of an unlined, earth-bermed pit and two aboveground storage tanks (ASTs). The pit is roughly 25 feet in diameter and 3 feet deep. The storage tanks, located about 180 feet west of the pit, were removed in 1994 along with the underground piping that feeds into the pit. The two storage tanks had a capacity of approximately 1,000 and 5,000 gallons respectively. The pit was used to conduct firefighter training activities for NASF personnel beginning in the mid-1950s and ending in April 1988. Altogether, an estimated 1.1 million gallons of flammable liquids were burned in the pit.	**Soil:** Four surface soil samples were collected during the remedial investigation (RI). Samples were analyzed for low boiling point petroleum hydrocarbons (LBPHCs), high boiling point petroleum hydrocarbons (HBPHCs), polychlorinated biphenyls (PCBs), pesticides, semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), and metals. In April 1999, 66 additional soil samples were collected and analyzed for VOCs and total petroleum hydrocarbons (TPH) as part of the intrinsic remediation assessment. Arsenic (8 parts per million [ppm]) was the only contaminant that exceeded ATSDR's CV. HBPHCs were detected at a maximum concentration of 2,100 ppm and LBPHCs were detected at a maximum concentration of 2,200 ppm.	The RI recommended removal actions for the soil in the former burn pit area and the recovery of free-product in the groundwater. Upon removal of free product from the groundwater, the RI recommended an assessment of residual product in the soil at and above the capillary fringe. In the summer of 1999, a significant portion of the contaminated soils in the former burn pit and the former AST area were excavated.	This site does not pose a public health hazard because most of the contaminants in soil were not detected at levels of health concern and the area is monitored by NASF security and only authorized personnel are permitted in the area. Although short term exposure would not likely cause harm, as a precautionary measure, ATSDR recommended placing a fence around the "biopile" in the unlikely event that children from the family housing area are able to briefly access the area. In July 2002, the Navy installed a fence and has arranged to remove, treat, and dispose contaminated "biopile" soil at an off-site disposal facility.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Crash Crew Training Area (Site 1) (continued)	The flammable liquids burned in the pit were waste products, including off-specification fuel (90 percent of the wastes burned), napalm, oil (9 percent of the wastes burned), and solvents (1 percent) of the wastes burned. These materials were obtained from the old (site 16) and new (site 2) fuel farms, the aircraft maintenance shop (not a site of concern), and the vehicle maintenance shop (not a site of concern). Napalm, off-specification fuel, oil, and solvents (e.g., carbon tetrachloride, trichloroethylene [TCE], and methyl ethyl ketone) were burned from the mid-1950s to 1982, but only off-specification JP-5 jet fuel from the new fuel farm was burned from 1982 to April 1988.	**Groundwater:** Twenty-five groundwater samples were collected during the RI and analyzed for LBPHCs, HBPHCs, PCBs, SVOCs, VOCs, and metals. Additional data have also been collected as routine monitoring of the groundwater continues at this site. *VOCs and SVOCs:* Benzene (800 parts per billion [ppb], toluene (490 ppb), di(2-ethyl hexyl)- phthalate (9 ppb), 4-methylphenol (910 ppb), 1,1-dichloro-ethene (28 ppb), 4-methyl -2-pentanone (2,200 ppb), methylene chloride (37 ppb), vinyl chloride (3 ppb), *cis*-1,2-dichloro- ethene (2,500 ppb), tetrachloro-ethylene (PCE) (680 ppb), and TCE (840 ppb) were detected above ATSDR's CVs. *Metals:* Arsenic (892 ppb), boron (60,400 ppb), manganese (1,980 ppb), molybdenum (1,730 ppb), and vanadium (351 ppb) were detected above ATSDR's CVs.	NASF has been involved with an experimental method of remediation for soils contaminated with TPHs and VOCs at Site 1. In July 1999, contaminated soil from the fire training pit was collected and placed in a designated area, referred to as the biopile, within Site 1. In July 2002, a fence was installed around the biopile and NASF has approved a plan to remove, treat, and dispose contaminated soil from the biopile at an off site regulated disposal facility.	Groundwater is not used for drinking or any other purpose and monitoring wells near the site boundary have not detected site-related contaminants.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
New Fuel Farm (Site 2)	The New Fuel Farm is in the northwestern part of NASF. It is used to store an estimated 3.3 million gallons of jet fuel (JP-8), 8,000 gallons of diesel fuel, and 12,000 gallons of motor vehicle gasoline fuel. The site has served as the main fuel storage and distribution terminal for NASF since 1957. The JP-8 fuel is received from an underground pipeline originating in Sparks, Nevada, and is currently stored in three three ASTs. Aircraft are fueled and de-fueled at the site, and various fuels that are stored here are tested periodically. It is estimated that 2,500 gallons of fuels have spilled in the vehicle parking area at this site. Site 2 also includes a tank bottom disposal area, an oil/water separator leach field, and a weed control area. Up to 60,000 gallons of tank bottom liquids were disposed at the site between 1957 and 1981. The tank bottom disposal area may have received an additional 5,000 gallons of JP-4 or JP-5 jet fuel from a leaking fuel tank during the early 1960s.	**Soil:** Two surface soil samples were collected during the 1988 Phase 1 Preliminary Assessment/Site Investigation (PA/SI) of the Installation Restoration (IR) Program and analyzed for TPHs. Two additional surface soil samples were collected during the Nevada Department of Environmental Protection's (DEP's) investigation of a spill and analyzed for TPHs. During the RI, four surface soil samples were collected and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, PCBs, pesticides, and metals. Arsenic (40 ppm) exceeded ATSDR's CV. TPHs were detected at a maximum concentration of 7,690 ppm.	Two underground gas storage tanks (USTs) with a total capacity of 100,000 gallons were removed in June 1992. A third UST was also recently removed. Following tank removal, a product-recovery sump was constructed in the excavation pit and a monitoring and recovery well was installed. A new 1.26 million gallon AST along with the other two existing ASTs currently store approximately 3.2 million gallons of fuel.	This site does not pose a public health hazard because most contaminants in soil were not detected at levels of health concern and the area is only accessible to authorized personnel. Groundwater is not used for drinking or any other purpose and monitoring wells near the western boundary have not detected site-related contaminants other than low levels of TPHs. These monitoring wells are more than 1,000 feet from the NASF boundary. It is unlikely that TPH contamination has migrated off site since groundwater flows in the opposite direction.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
New Fuel Farm (Site 2) (continued)	The oil/water separator, installed in 1981, collects surface runoff and spills from the tank and loading rack area. In 1985, about 2,000 gallons of JP-5 fuel spilled in this area and, between 1957 and 1981, as much as 18,000 gallons of fuel were spilled from daily draining of fuel trucks. About 500 gallons of waste fuel were applied to unpaved ground in the weed control area between 1957 and 1981.	**Groundwater:** Samples from eight monitoring wells were collected during a 1988 site investigation and analyzed for TPHs and VOCs. During the RI, 48 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, and metals. *VOCs:* Benzene (290 ppb), bromoform (21 ppb), and dichlorobromomethane (4 ppb) exceeded ATSDR's CVs. *Metals:* Arsenic (69 ppb), antimony (38 ppb), boron (91,700 ppb), manganese (2,050 ppb), molybdenum (1,310 ppb), and vanadium (1,230 ppb) exceeded ATSDR's CVs. *Total petroleum hydrocarbons*: TPHs were detected at a maximum concentration of 24,000 ppm.	The RI recommended removal of four areas of free petroleum product from the groundwater at Site 2.	

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Hangar 300 Area (Site 3)	Site 3 is in the west-central part of NASF and consists of the north and south disposal areas, bowser (a military vehicle) disposal area, oil/water separator area, ground-support equipment area, and the wells air start building area. A drainage ditch runs northeast through Site 3 and connects with a series of ditches that intersect the lower diagonal (LD) drain on the eastern boundary of NASF. The bowser area is located north of the apron (the paved strip near the hangar) and east of the drainage ditch and oil/water separator area. Between 1960 and 1984, approximately 12,500 gallons of waste aircraft fluid—including JP-5 jet fuel, hydraulic fluids, lube oil, carbon tetrachloride, TCE, and PD-680 (a stoddard solvent)—was disposed of in this area. The north and south disposal areas are unpaved surfaces. Between 1960 and 1981, waste aircraft fluid was occasionally dumped on the ground surface in these areas. An estimated 4,000 gallons of waste aircraft fluid were dumped in each of these areas.	**Soil:** Three surface soil samples were collected during the Phase 1 PA/SI of the IR Program and analyzed for VOCs and TPH. During the RI, eight surface soil samples were collected and analyzed for HBPHCs, LBPHCs, SVOCs, and VOCs. Arsenic (26 ppm) exceeded ATSDR's CV. TPH was detected at a maximum concentration of 15,000 ppm.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because most of the contaminants in soil were not detected at levels of health concern and the area is only accessible to authorized personnel. Groundwater is contaminated with VOCs, metals, and petroleum hydrocarbons. However, no one drinks the groundwater underneath the station and groundwater flow is towards the southeast, away from station and municipal drinking water sources. Since the groundwater plume at Site 3 is near the central portion of NASF, it is contained on site.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Hangar 300 Area (Site 3) (continued)	Between 1960 and 1986, the oil/water separator area received about 3,000 gallons of aircraft maintenance wastes and cleaning solvents that originated from the Hangar 300 floor drain. These wastes occasionally bypassed the oil/water separator due to equipment malfunctions and, as a result, flowed directly into the drainage ditch. The ground-support equipment area is partially unpaved and is located west of building 374. Between 1960 and 1987, this area received approximately 1,350 gallons of waste fluids from spills and leaks that occurred at an adjacent storage area. These wastes were similar to those disposed at the north and south disposal areas. The wells air start building area is located between building 374 and building 432. Between 1978 and 1987, this area received compressor blowdown, which contained lube oil. This material probably ponded or drained slightly to the west. Approximately 750 gallons of lube oil reached an unpaved area nearby.	**Groundwater:** Twelve groundwater samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, and VOCs. *VOCs:* TCE (160 ppb), benzene (2 ppb), and 1,1-dichloroethene (2 ppb) were detected above ATSDR's CVs. *Metals:* Arsenic (4,430 ppb), boron (126,000 ppb), molybdenum (3,440 ppb), antimony (47 ppb), and vanadium (581 ppb) were detected above ATSDR's CVs. TPH-E and TPH—Purgeable (TPH-P) were detected at a maximum concentration of 1,000 ppb and 250 ppb, respectively.		

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Transportation Yard (Site 4)	The Transportation Yard, located directly south of Site 2, consists of Building 371 and Building 378, which was used for vehicle maintenance, storage, and painting. From 1976 to 1981, Building 378 was used for painting and light overhaul operations. An estimated 50 gallons of wastes, including radiator coolants, vehicle fluids, and paint wastes, were flushed into subsoils beneath the building, and an additional 400 gallons of waste fluids were spilled in the adjacent yard during vehicle repair.	**Soil:** During the RI, three surface soil samples were collected and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, and metals. No SVOCs or VOCs exceeded ATSDR's CVs. **Groundwater:** During the RI, 48 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, and metals. *VOCs:* Bromoform (21 ppb) and dichlorobromomethane (4 ppb) exceeded ATSDR's CVs. *Metals:* Antimony (38 ppb), boron (91,700 ppb), manganese (2,050 ppb), molybdenum (1,310 ppb), and vanadium (1,230 ppb) exceeded ATSDR's CVs.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because contaminants in soil were not detected at levels of health concern and the area is only accessible to authorized personnel.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Defuel Disposal Area (Site 6)	The site currently consists of two regions of relatively level, unpaved surface soils where once two unlined pits existed. Each disposal pit is estimated to have been 500 feet by 500 feet in size. One of these disposal areas is within Site 21, the Receiver Site Landfill. Site 6 is in the northeastern part of NASF. Between 1966 and 1972, a total of 70,000 gallons of off-specification JP-4 and JP-5 jet fuel were removed from aircraft fuel tanks and disposed on the ground surface in the Defuel Disposal Area.	**Soil:** Subsurface soil samples were collected and analyzed for petroleum hydrocarbons during the RI. Twenty-three soil samples were collected in April 1999 to further characterize contamination in the suspected source area, which is the Southern Disposal Area. All the samples were analyzed for TPH-D (Diesel) and two of the samples were analyzed for VOCs. No surface soil samples were collected during any of the investigations. Low concentrations of VOCs were detected in the two soil samples. TPH-D was detected in soil at 14, 089 ppm. **Groundwater:** During the RI, 20 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Di(2-ethylhexyl)phthalate (4 ppb), tetrachloroethene (17 ppb), and 1,2,4-trimethylbenzene (31 ppb) exceeded ATSDR's CVs.	The RI recommended a removal action to recover free-product in the groundwater at Site 6. The RI recommended no further action for soil because the area with contaminated soil was small and access was restricted.	This site does not pose a public health hazard because the area does not contain harmful levels of contaminants in soil and is only accessible to authorized personnel. Groundwater underneath NASF is not used for drinking or any other purpose. The Site 6 groundwater plume is close to the northeastern boundary of the station and groundwater flow could allow contaminants to migrate off site. A sample from one monitoring well near the station boundary contains very low concentrations of fuel-related contaminants (TPH). However, there are no off-site drinking water wells in close proximity to the site boundary.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Defuel Disposal Area (Site 6) (Continued)		*Metals:* Arsenic (7,300 ppb), antimony (38 ppb), boron (240,000 ppb), cadmium (6 ppb), mercury (2 ppb), molybdenum (2,200 ppb), vanadium (2,600 ppb), and lead (110 ppb) exceeded ATSDR's CVs. TPH-E was detected at a maximum concentration of 41,000 ppb. TPH-P was detected at a maximum concentration of 86 ppb.		
Napalm Burn Pit (Site 7)	Site 7 is purportedly in the northeastern part of NASF within Site 21, west of Site 6. From the early 1960s to 1983, up to 240,000 gallons of excess napalm were burned at Site 7 using diesel fuel; however, the PA/SI team could not locate the site and the NASF Fire Chief testified in 1991 that napalm was not burned here and was instead burned at Site 1.	**Soil:** No surface soil samples were collected during the RI. **Groundwater:** During the RI, 20 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Di(2-ethylhexyl)phthalate (4 ppb) and tetrachloroethene (17 ppb) were detected above ATSDR's CVs. *Metals:* Antimony (38 ppb), cadmium (6 ppb), and mercury (2 ppb) met or exceeded ATSDR's CVs.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because the area does not contain harmful levels of contaminants in soil and is only accessible to authorized personnel. Groundwater is not used for drinking or any other purpose and is not a health concern.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Wastewater Treatment Plant (Site 9)	The Wastewater Treatment Plant, in the southwestern part of NASF, is the primary treatment facility and since 1943, has received sewer wastes from all base operations. The plant consists of treatment basins, settling ponds, and sludge and grit disposal areas. As a result of sludge and grit disposal, a leaking underground diesel tank and insufficiently treated water, diesel fuel, metals, oils, paint wastes, photographic chemicals, and tank sludge may have contaminated the site.	**Soil:** Seven surface soil samples were collected during the RI and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, pesticides, PCBs, and metals. Arsenic (14 ppm) exceeded ATSDR's CV. TPHs were detected at a maximum concentration of 296 ppb. **Groundwater:** Two groundwater samples were collected during the RI and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. Arsenic (1,650 ppb), boron (66,900 ppb), molybdenum (2,070 ppb), and vanadium (800 ppb) exceeded ATSDR's CVs.	A 500-gallon underground diesel tank, located north of Building 130, was removed in 1985.	This site does not pose a public health hazard because the area does not contain harmful levels of contaminants in soil and is only accessible to authorized personnel. Groundwater is not used for drinking or any other purpose and is, therefore not a health concern.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Ground to Air Transmitting and Receiving (GATAR) Compound (Site 10)	The GATAR Compound consists of a graveled and fenced area in the southern part of NASF. It has been used for interim storage of hazardous wastes since 1986. Wastes temporarily stored at the site in aboveground containers (primarily 55-gallon drums) include oil filters, aircraft debris, waste oil containing PCBs, paints, solvents, waste oils, and hydraulic fluids. Several 1-gallon containers of waste oil containing PCBs were reported buried at the site in 1984, but the exact burial location is unknown.	**Soil:** Five surface soil samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. Arsenic (36 ppm) was the only contaminant that exceeded ATSDR's CVs. **Groundwater:** No groundwater samples were collected at Site 10 during the RI.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because the area does not contain harmful levels of contaminants.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Paint Shop (Site 11)	The Paint Shop, in the southern part of NASF, received paint wastes from the early 1960s to 1986. Waste paints and thinners were either disposed of or spilled on unpaved ground north of the shop.	**Soil:** Only two subsurface soil samples were collected during the RI and they showed very low concentrations of VOCs. No surface soil samples were collected at Site 11 during the RI. **Groundwater:** Eight groundwater samples were collected during the RI and analyzed for LBPHCs, HBPHCs, SVOCs, and VOCs. *VOCs:* Benzene (330 ppb), di(2-ethylhexyl)phthalate (8 ppb), pentachlorophenol (11 ppb), chloroform (3 ppb), and TCE (12 ppb) were detected at or above ATSDR's CVs. LBPHCs (gasoline) were detected at a maximum concentration of 680 ppb. HBPHCs (diesel) were detected at a maximum concentration of 310 ppb.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. Access to this site is restricted and groundwater is not used for drinking or any other purpose.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Pest Control Shop (Site 12)	The Pest Control Shop, in the southern part of NASF, has handled pesticides from the early 1960s to the present. DDT was handled at the site prior to 1974. After 1974, malathion, pyrethrin, diazinon, parathion, and 2,4-dichlorophenoxyacetic acid were handled and stored at the site. A leachfield south of the site once received runoff from the rinsing of pest control vehicles, but today is no longer operational. A northern leachfield received rinsewater from the mixing and rinsing of empty containers.	**Soil:** Seven soil borings were drilled at Site 12. Low levels of pesticides were detected, but they did not exceed ATSDR's CVs. **Groundwater:** Three groundwater samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Benzene (47 ppb)and di (2-ethylhexyl)phthalate (4 ppb) were detected above ATSDR's CVs. *Pesticides:*Alpha-BHC (0.16 ppb), gamma-BHC (0.14 ppb), and 2,4-dichlorophenol (220 ppb) were detected above ATSDR's CVs. *Metals:* Arsenic (561 ppb), boron (66,100 ppb), molybdenum (2,850 ppb), and vanadium (209 ppb) were detected above ATSDR's CVs. HBPHCs (diesel) were detected at a maximum concentration of 5,000 ppb. LBPHCs (gasoline) were detected at a maximum concentration of 170 ppb.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because soil does not contain contaminants at harmful levels and access to the area is restricted. Groundwater is not used for drinking or any other purpose.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Boiler Plant Tanks (Site 13)	Site 13, in the southern part of NASF, formerly consisted of two 26,000-gallon USTs , located southeast of Site 12. From 1943 to 1981, the tanks were used to store fuel for the boiler plant. From 1981 to 1992, the tanks were used for occasional storage of other fuels and oils. About 350 gallons of waste spills, possibly of No. 6 fuel oil, waste lubrication oil, hydraulic fluid, JP-5 jet fuel, or diesel fuel, occurred around inlets to the tanks during filling operations.	**Soil:** Subsurface soil samples were collected during the RI. No contaminants were detected above ATSDR's CVs. No surface soil samples were collected at Site 13 during the RI. **Groundwater:** Ten groundwater samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. VOCs: Benzene (1 ppb), di(2-ethylhexyl)phthalate (5 ppb), TCE (52 ppb), chloroform (18 ppb), and methylene chloride (11 ppb)were detected above ATSDR's CVs. *Metals:* Antimony (60 ppb), arsenic (1,210 ppb), boron (136,000 ppb), cadmium (9 ppb), lead (2,390 ppb), manganese (1,120 ppb), molybdenum (4,250 ppb), and vanadium (261 ppb) were detected above ATSDR's CVs. HBPHCs (diesel) were detected at a maximum concentration of 240 ppb. LBPHCs (gasoline) were detected at a maximum concentration of 580 ppb.	The two 26,000-gallon USTs were removed during the summer of 1992. The RI recommended that the site be backfilled with soil following removal of the two USTs.	This site does not pose a public health hazard because access to the area is restricted and people are not exposed to harmful levels of contaminants. Groundwater underneath the site is not used for drinking or any other purpose. Although groundwater flow could allow contaminants to migrate off site, people do not use groundwater for drinking in the area south of NASF because of the high salinity content of the shallow aquifer.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Old Vehicle Maintenance Shop (Site 14)	The Old Vehicle Maintenance Shop, in the southern part of NASF, was used from 1943 to 1946 and 1951 to 1971 to service and fuel public works transportation and other vehicles. From 1971 to 1973, the site was used as an auto hobby shop. USTs at the site stored leaded gasoline and diesel fuel. These tanks were found to be leaking in 1989. The site currently consists of concrete slabs that served as foundations for a mechanic bay, fueling station, and support building. Two lube pits from the site are now filled with soil. An estimated 150 gallons of lube oil, hydraulic fluid, and radiator coolant leaked into the pits.	**Soil:** Soil samples were collected during the installation of monitoring wells during the RI. Only one soil sample collected in conjunction with monitoring well 18 contained fuel-related contaminants (e.g., benzene, ethylene, toluene, xylenes, and petroleum hydrocarbons). Benzene (20 ppm) was the only contaminant that was detected above its CV. **Groundwater:** Ten groundwater samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Benzene (14,000 ppb), carbon tetrachloride (10 ppb), 1,2-dichloroethane (2,300 ppb), 1,2,4-trimethylbenzene (1,000 ppb), 1,3,5-trimethylbenzene (260 ppb), toluene (26,000 ppb), xylene (16,000 ppb), ethylbenzene (2,800 ppb), di(2-ethylhexyl)phthalate (3 ppb), 2,4-dimethylphenol (3,600 ppb), 4-methylphenol (330 ppb), naphthalene (7,900 ppb), and pentachlorophenol (2 ppb) were detected above ATSDR's CVs.	Two USTs were removed in 1989. The RI recommended removal of free product in areas where it was accumulating excessively on the groundwater table. Residual product in soils at and above the capillary fringe should be assessed after the removal of free product.	This site does not pose a public health hazard because access to the area is restricted and people are not exposed to harmful levels of contaminants. Groundwater underneath the site is not used for drinking or any other purpose. Although groundwater flow could allow contaminants to migrate off site, people do not use groundwater for drinking in the area south of NASF because of the high salinity content of the shallow aquifer.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Old Vehicle Maintenance Shop (Site 14) (continued)		*Metals:* Antimony (60 ppb), arsenic (1,210 ppb), boron (136,000 ppb), cadmium (9 ppb), lead (2,390 ppb), manganese (1,120 ppb), molybdenum (4,250 ppb), and vanadium (261 ppb) were detected above ATSDR's CVs. HBPHCs (JP-5 jet fuel) were detected at a maximum concentration of 14,000 ppb. LBPHCs (gasoline) were detected at a maximum concentration of 850,000 ppm. TPH-P was detected at a maximum concentration of 110 ppm. In addition, 2-methylnaphthalene (no comparison value) was detected at a maximum concentration of 6,000 ppb.		

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Old Fuel Farm (Site 16)	The Old Fuel Farm, in the southern part of NASF, served as the main fuel storage and dispensing facility from 1943 to 1962. The Old Fuel Farm consisted of four 50,000-gallon concrete USTs. From 1963 to 1985, the tanks were used for dead storage of various fuels. Fuels stored at the Old Fuel Farm include aviation gas, JP-4 and JP-5 jet fuel, diesel fuel, gasoline, and No. 6 fuel oil. Leaks and spills have likely occurred at the site. The former location of a 5,500-gallon UST is also included in Site 16. As much as 9,000 gallons of fuel may have leaked or spilled at this site.	**Soil:** Soil samples were collected from eight boreholes and six monitoring well borings. Additional soil samples were collected during the UST removal program. Petroleum hydrocarbons were detected in subsurface soil at levels above NDEP's action level of 100 mg/kg. No surface soil samples were collected at Site 16 during the RI. **Groundwater:** Twenty-three groundwater samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Benzene (320 ppb), 1,2-dichloroethane (54 ppb), TCE (42 ppb), ethylbenzene (1,200 ppb), di(2-ethylhexyl)phthalate (6 ppb), pentachlorophenol (36 ppb), and 2,4,6-trichlorophenol (14 ppb) were detected above ATSDR's CVs. *Metals:* Antimony (35 ppb), arsenic (1,320 ppb), boron (80,800 ppb), cadmium (7 ppb), manganese (2,190 ppb), molybdenum (2,660 ppb), and vanadium (818 ppb) exceeded ATSDR's CVs. TPH-E was detected at a maximum concentration of 26,000 ppb.	The four USTs and associated piping were demolished and partially removed in the summer of 1992. The RI recommended the soil be removed in the location of the former storage tank near Building 409. The RI also recommended that free product be removed from groundwater at the site.	This site does not pose a public health hazard because access to the area is restricted and people are not exposed to harmful levels of contaminants. Groundwater underneath the site is not used for drinking or any other purpose. Although groundwater flow could allow contaminants to migrate off site, people do not use groundwater for drinking in the area south of NASF because of the high salinity content of the shallow aquifer.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Hangar 5 (Site 17)	Located in the southern part of NASF, the unpaved surfaces near Hangar 5 (formerly known as Hangar 4) received a total of 4,500 gallons of runoff from aircraft washing activities and aircraft fluid spills between 1943 and 1946 and 1951 and 1987. Runoff may have included cleaning solvents (Turco), lubrication oil, hydraulic fluid, grease, aviation gas, JP-4 and JP-5 jet fuel, methyl ethyl ketone, isopropyl alcohol, and PD-680 (a Stoddard solvent).	**Soil:** Five surface soil samples were collected during the RI and analyzed for HBPHCs, LBPHCs, SVOCs, VOCs, and metals. Di(2-ethylhexyl)phthalate (290 ppm), arsenic (22.4 ppm), and iron (28,200 ppm) exceeded ATSDR's CVs. TPHs were detected at a maximum concentration of 350 ppb. **Groundwater:** No groundwater samples were collected during the RI for Site 17.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because soil does not contain contaminants at harmful levels and access to the area is restricted.
Southeast Runway Landfill (Site 18)	The Southeast Runway Landfill, in the southern part of NASF and in the southeastern corner of Site 9, received up to 18,000 tons of waste between 1943 and 1946. No details of the exact landfill location or disposal activities are available, although it is suspected that municipal refuse, concrete rubble, building debris, paints, metals, and petroleum hydrocarbons were buried at this site in trenches no deeper than the area water table.	**Soil:** No surface soil samples were collected at Site 18 during the RI. **Groundwater:** Two groundwater samples were collected during the RI and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *Metals:* Arsenic (1,650 ppb), boron (66,900 ppb), molybdenum (2,070 ppb), and vanadium (800 ppb) exceeded ATSDR's CVs.	No corrective actions were recommended for this site.	This site does not pose a public health hazard because soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Post-World War II Burial Site (Site 19)	The Post-World War II Burial site is in the southern part of NASF. The area received 2,200 cubic yards of trash and other wastes generated during facility decommissioning activities between 1946 and 1949. Wastes, including vehicles and vehicle maintenance waste, wood, paints, thinners, and solvents, were buried in trenches that were no deeper than 8 feet.	**Soil:** No surface soil samples were collected during the RI for Site 19. **Groundwater:** No groundwater samples were collected during the RI for Site 19.	No corrective actions were recommended for this site.	Since contamination was not observed during site investigations, Site 19 does not pose a public health hazard.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Checkerboard Landfill (Site 20)	The Checkerboard Landfill, which is on a nearly level area of open ground, is in the southwestern corner and near the boundary of NASF. Between 1951 and 1965, approximately 85,000 tons of wet garbage, trash, and rubble were disposed of at the landfill. Some of the waste may have been deposited at depths below the water table. Additional waste buried at the site includes sludge from the wastewater treatment plant and an estimated 1,400 gallons of waste liquids (primarily petroleum hydrocarbons). These waste liquids, which may have been burned at the site, were probably from the old vehicle maintenance shop and aircraft maintenance shop.	**Soil:** No surface soil samples were collected at this site during the RI. **Groundwater:** Forty-two groundwater samples were collected during the RI and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *Metals:* Arsenic (1,740 ppb), boron (51,200 ppb), manganese (3,140 ppb), molybdenum (1,980 ppb), and vanadium (190 ppb) exceeded ATSDR's CVs. HBPHCs (diesel) was detected at a maximum concentration of 72 ppb.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. The soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Receiver Site Landfill (Site 21)	The Receiver Site Landfill consists of nearly level, unpaved ground and is in the northeastern corner of NASF. Between 1965 and 1980, the landfill received solid waste (wet garbage, trash, and rubble) and about 1,000 gallons of liquid waste (JP-5 jet fuel, gasoline, diesel fuel, waste oils, and hydraulic fluids). Wastes were buried in trenches, and some of the liquid wastes, including hydrocarbons, were burned. No hydrocarbon waste was disposed at the landfill from 1975 to 1980, and only dry trash and rubble were disposed at the landfill from 1979 to 1980.	**Soil:** During the RI, six soil samples were collected in conjunction with drilling boreholes for groundwater monitoring wells. No contaminants were detected above ATSDR's CVs. No surface soil samples were collected during the RI. **Groundwater:** During the RI, 20 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Di(2-ethylhexyl)phthalate (4 ppb) and tetrachloroethene (17 ppb) were detected above ATSDR's CVs. *Metals:* Antimony (38 ppb), cadmium (6 ppb), and mercury (2 ppb) were detected at or above ATSDR's CVs.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. The soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Northeast Runway Landfill (Site 22)	The Northeast Runway Landfill is an unpaved area south of Site 21. It received an estimated 60,000 tons of waste between 1980 and 1987. The landfill received dry trash, rubble, paint waste, and metals. In general, Site 22 received fewer hazardous materials than Site 21. Wastes were buried in excavated trenches. Site 22 is located in the northeastern part of NASF.	**Soil:** No surface soil samples were collected during the RI. **Groundwater:** During the RI, 20 groundwater samples were collected and analyzed for LBPHCs, HBPHCs, PCBs, pesticides, SVOCs, VOCs, and metals. *VOCs and SVOCs:* Di(2-ethylhexyl)phthalate (4 ppb) and tetrachloroethene (17 ppb) were detected above ATSDR's CVs. *Metals:* Antimony (38 ppb), cadmium (6 ppb), and mercury (2 ppb) were detected above ATSDR's CVs.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. The soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Shipping and Receiving Disposal (Site 23)	Located in the southern part of NASF, Site 23 includes the shipping and receiving disposal area, an aircraft burial area, and an area where 9 cubic yards of asbestos and metallic debris from building and pipe insulation was reportedly buried. In addition to the disposal areas, transformers containing PCB fluids may have been stored at the site. About 1,300 cubic yards of waste in the shipping and disposal area were buried in four trenches and included junk, debris, metal, rubble, paints, thinners, petroleum liquids, oils, and lubricants.	**Soil:** Four surface soil samples were collected during the RI and analyzed for HBPHCs, LBPHCs, PCBs, and pesticides. No contaminants exceeded ATSDR's CVs. **Groundwater:** No groundwater samples were collected during the RI for Site 23.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. The soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Road Oiling Area (Site 24)	The Road Oiling Area, along the north, east, and southeast borders of NASF, consists of perimeter roads that were oiled with approximately 37,000 gallons of waste oils, fuels, and solvents for dust control. Dust control occurred between 1943 to 1946 and again from 1951 to 1981. Wastes used for dust control included hydraulic fluids, antifreeze, leaded gasoline, carbon tetrachloride, motor vehicle gasoline, JP-4 and JP-5 jet fuel, TCE, and trichloroethane. Although some parts of the north perimeter roads are currently paved, before 1981, all of the roads were unpaved.	**Soil:** During the RI, five soil samples were collected and analyzed for LBPHCs, HBPHCs, SVOCs, VOCs, and metals. Arsenic (12 ppm) was the only contaminant that exceeded ATSDR's CVs. **Groundwater:** No groundwater samples were collected during the RI for Site 24.	No corrective actions were recommended for this site.	This site does not pose a public health hazard. The soil does not contain contaminants at harmful levels and access to the area is restricted.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sites	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities	ATSDR's Evaluation of Public Health Hazards
Non-specific site sampling				
LD Drain and LD #1 Drain	The LD Drain and the LD #1 Drain are the two main drains running through NASF. The drains carry water southeastward to Carson Lake and northeastward to Harmon and Stillwater Point Reservoirs. The LD Drain is approximately 25 feet wide and 12 feet deep, while the LD #1 Drain is approximately 12 feet wide and 12 feet deep.	**Surface Water:** Surface water samples were collected during an 8 week period (August through September) in 1989 from eight locations, four in each drain. Arsenic (268 ppb), lead (30 ppb), and selenium (60 ppb) exceeded ATSDR's CVs. TPHs were detected at a maximum concentration of 5,000 ppb. **Sediment:** Sediment samples were collected in August 1989 from the same eight locations surface water was collected from. No contaminants exceeded ATSDR's CVs. TPHs were detected at a maximum concentration of 43 ppm.	There have been no corrective activities associated with the drainage canals.	This site does not pose a public health hazard. The surface water and sediment from the drains do not contain contaminants at harmful levels.

TABLE 1: Evaluation of Potential Public Health Hazards Associated with the 21 IRP Sites at NASF (Continued)

Sources:

Ecology and Environment. 1989. Federal Facility Preliminary Assessment/Site Inspection Review. July 31, 1989.

Oak Ridge National Laboratory (ORNL). 1994. Final Remedial Investigation Report. Naval Air Station Fallon. September 1994.

Naval Air Station Fallon. 1994. Installation Restoration Program Community Relations Plan. September 1994.

Battelle. 2001. Assessment of Intrinsic Remediation at Installation Restoration Sites at Naval Air Station Fallon. March 2001.

Table 2. Summary of Potential Exposure Pathways at NASF

Pathway Name	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Comments
Completed and Potential Exposure Pathways						
Off-site private drinking water	Fuel spills and waste disposal activities at NASF	Groundwater	Off-site private drinking water wells	Ingestion, dermal contact, and inhalation	Residents living near the NASF boundary east of Site 6 (Defuel Disposal Area) and south of NASF	**Past Exposure:** Only very low concentrations of total petroleum hydrocarbons (TPHs) have been detected in monitoring wells in the past near the NASF boundary. Based on previous sampling results, it is unlikely that site-related contaminants are impacting private drinking water wells. ATSDR concludes that past exposures to drinking water from private wells posed no public health hazard. **Current and Future Exposures:** TPHs and other site-related contaminants have not been detected above ATSDR's CVs in recent sampling of monitoring wells near the NASF boundary. Although it is unlikely that contaminants would migrate off site at levels that would be harmful, it is possible that private wells that are screened in the shallow aquifer and are down gradient of Site 6 could be impacted by contaminants migrating off site. Therefore, ATSDR concludes that future exposures to off-site private drinking water wells pose no apparent public health hazard.

Table 2. Summary of Potential Exposure Pathways at NASF

Pathway Name	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Comments
Completed and Potential Exposure Pathways						
Off-site NASF and city of Fallon drinking water wells	Fuel spills and waste disposal activities at NASF	Groundwater	NASF distribution system and Fallon residences that are connected to municipal supply	Ingestion, dermal contact, and inhalation	NASF personnel, station residents, and Fallon residents who are connected to the municipal water supply	**Past, Current , and Future Exposure:** NASF and city of Fallon drinking water supply wells have not been and are not expected to be impacted by site-related contamination because they are at least 2 miles northwest of any NASF source areas, the wells are upgradient from NASF, and the depth to the basalt aquifer is more than 500 feet below ground surface. There is no completed exposure pathway and these wells do not pose a public health hazard.
On-site ground-water	Fuel spills and waste disposal activities at NASF	Groundwater	None	Ingestion, dermal contact, and inhalation	NASF personnel and station residents	**Past, Current , and Future Exposure:** Groundwater beneath NASF has not been used and is not expected to be used as a source of drinking water or for any other domestic (e.g, cooking, showering) purposes. There is no completed exposure pathway and groundwater beneath NASF does not pose a public health hazard.

Table 2. Summary of Potential Exposure Pathways at NASF

Pathway Name	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Comments
Completed and Potential Exposure Pathways						
Surface water and sediment	Fuel spills and waste disposal activities at NASF	Surface water and sediment	On-site irrigation ditches and drainage canals	Ingestion, dermal contact, and inhalation	NASF personnel and station residents	**Past, Current , and Future Exposure:** Low levels of TPHs have been detected in surface water and sediment in drainage canals on site. Since TPHs were not at levels that are considered harmful and only authorized NASF personnel would have occasional access to these canals, ATSDR concludes that exposure to surface water and sediment at NASF poses no public health hazard.
Surface soil	Fuel spills and waste disposal activities at NASF	Soil	Installation restoration program (IRP) contaminated sites at NASF	Ingestion and dermal contact	NASF personnel and station residents	**Past, Current , and Future Exposure:** Soil contamination is limited to a small number of source areas on site. Some of the IRP sites that contain contaminated soil (e.g., the biopile) are not fenced and access may not be restricted. ATSDR cannot rule out the possibility that some exposure to residents of the station and on-site personnel could occur. However, any exposures to soil contaminants would likely be infrequent and of short duration. ATSDR concludes that on-site exposures to soil pose no apparent public health hazard.

Table 2. Summary of Potential Exposure Pathways at NASF

Pathway Name	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Comments
Completed and Potential Exposure Pathways						
Air	Emissions from stationary sources (e.g., boilers and generators)	Air	Non-point source	Inhalation	NASF personnel and station residents and off-site residents who are in close proximity to NASF	**Past, Current, and Future Exposure:** The results of NASF's air quality analysis showed that the predicted concentrations of EPA criteria pollutants (i.e., CO, NO_2, PM10, SO_2) from stationary sources at NASF do not exceed the national ambient air quality standards. Recent air monitoring data in the Fallon area from EPA's AIRS database showed that PM10 concentrations were well below EPA's national ambient air quality standards. Therefore, ATSDR concludes that emissions from stationary sources at NASF do not pose a public health hazard.

Table 2. Summary of Potential Exposure Pathways at NASF

Pathway Name	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Comments
Completed and Potential Exposure Pathways						
	Jet engine emissions	Air	Jet aircraft operating from NASF	Inhalation	People at or nearby to NASF	**Past, Current and Future Exposure:** A toxicological evaluation and the screening model for dispersion of emissions indicate that exposure to emissions from airplanes (commercial and military) in the Fallon, NV area is not a likely contributing factor to the leukemia cases reported in the community. The potential exposure by members of the Fallon community to jet fuel and emission byproducts is not expected to be sufficient to result in non-cancer public health effects. Screening model analyses of emissions from NASF aircraft found that estimated ambient air concentrations for all pollutants considered were either below health-based comparison values or reasonably consistent with levels routinely measured in small communities and suburban locations across the United States. Therefore, engine emission byproducts at NASF pose no past, current, or future public health hazard.

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
SOUTHERN PLUME - ***Site 1 (Crash Crew Training Area)***					
Metals					
Arsenic	892	NA	NA	0.02 50	CREG MCL
Boron	60,400	NA	NA	4,000	RMEG
Molybdenum	1,730	NA	NA	200	RMEG
Vanadium	351	NA	NA	100	EMEG
Organics					
Benzene	800 42.0	December 1991 November 1999	MW 51U MW-51U	5 0.6	MCL CREG
1,1-DCE	28 14	December 1991 September 1997	MW-50U MW-14	7 0.06	MCL CREG
1,2-DCE (cis)	2,500 1,600	March 1998 November 1999	MW-51U MW-51U	70	MCL
Methylene chloride	37	April 1992	MW-51U	5	MCL
4-Methylphenol	910	April 1992	MW-51U	180	RBC
PCE	680 30	October 1993 November 1999	MW 51U MW 51U	5	MCL

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
TCE	840 13	December 1991 November 1999	MW 51U MW 51U	5	MCL
Vinyl chloride	3	April 1992	MW-51U	0.03 2.0	CREG MCL
TPH-E	110,000	November 1999	MW 51U	-	-
SOUTHERN PLUME - ***Site 14 (Old Vehicle Maintenance)***					
Metals					
Antimony	60	NA	NA	6	MCL
Arsenic	1,210	NA	NA	0.02 50	CREG MCL
Boron	136,000	NA	NA	4,000	RMEG
Cadmium	6	NA	NA	5	MCL
Lead	2,390	NA	NA	15	EPA
Organics					
Benzene	14,000 13,000	April 1991 November 1999	MW-18U MW-18U	5 0.6	MCL CREG
Carbon tetrachloride	10	November 1999	MW-22	5 0.3	MCL CREG

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
1,2-DCA	2,300	November 1999	MW-18U	5 0.4	MCL CREG
2,4-Dimethylphenol	3,600	April 1991	MW-18U	700	RMEG
Ethylbenzene	2,800	December 1991	MW-52	700	MCL
4-Methylphenol	330	April 1991	MW-18U	180	RBC
Naphthalene	7,900	April 1991	MW-51	700	RMEG
Pentachlorophenyl	2	April 1991	MW-19	0.2 1.0	CREG MCL
Toluene	26,000	April 1991	MW-18U	1,000	MCL
1,2,4-Trimethylbenzene	1,000	March 1998	GTI14-2	?	RBC[2]
1,3,5-Trimethylbenzene	260	March 1998	GTI14-2	?	RBC[2]
Xylene	16,000	December 1991	MW-52	7,000 10,000	I-EMEG MCL
TPH-P	110,000	November 1999	MW-18U	-	-

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
SOUTHERN PLUME - ***Site 16 (Old Fuel Farm)***					
Metals					
Arsenic	1,320	1991-1992	NA	0.02 50	CREG MCL
Boron	80,800	1991-1992	NA	4,000	RMEG
Cadmium	7	1991-1992	NA	5	MCL
Manganese	2,190	1991-1992	NA	2,000	RMEG
Molybdenum	2,660	1991-1992	NA	200	RMEG
Vanadium	818	1991-1992	NA	100	EMEG
Organics					
Benzene	130	September 1997	MW-63	5 0.6	MCL CREG
1,2-DCA	54	September 1997	MW-65	5 0.4	MCL CREG
TCE	42	March 1998	MW-65	5	MCL
TPH-E	26,000 11,400	September 1996 November 1999	MW 77 MW-77	- -	- -

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
NORTHERN PLUME (Site 2 - New Fuel Farm)					
Organics					
Benzene	290	April 1988	MW-20	0.6	CREG
Bromoform	21	June 1990	MW-FB00	4	CREG
TPH	24,000 ppm	April 1988	MW-20	-	-
NORTHERN PLUME (Site 3 - Hangar 300 Area)					
Metals					
Antimony	47	1991	NA	6	MCL
Arsenic	4,430	1991	NA	0.02 50	CREG MCL
Boron	126,000	1991	NA	4,000	RMEG
Molybdenum	3,440	1991	NA	200	RMEG
Vanadium	581	1991	NA	100	EMEG
Organics					
Benzene	2	October 1993	MW 41U	0.6	CREG
1,1-Dichloroethylene	2	April 1991	MW-41U	0.06 7	CREG MCL

Table 3.
Summary of Contaminants Detected Above ATSDR's CVs in Groundwater Monitoring Wells at NASF[1]

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
TCE	160	April 1991	MW 41U	5	MCL
TPH-E	1,000	September 1995	MW 41U	-	-
NORTHERN PLUME (Site 6 -Fuel Disposal Area)					
Metals					
Arsenic	7,300	September 1996	MW-58	50 0.02	MCL CREG
Boron	240,000	September 1999	MW-57	400	IEMEG
Lead	110	September 1996	MW-58	15	EPA
Molybdenum	2,200	September 1996	MW-58	200	RMEG
Vanadium	2,600	September 1996	MW-58	100	IEMEG
Organics					
Tetrachloro-ethylene	17	April 1991	MW-48	5	MCL
1,2,4-Trimethyl-benzene	31	Sample date not provided	GT16-1A	12	EPA's RBC
TPH-E*	41,000	November 1999	MW-57	-	-

Source: Ecology and Environment 1988; ORNL 1994; Battelle 2001

[1] Comparison Values (CVs) for total petroleum hydrocarbons (TPHs) in groundwater are not available.
[2] RBC = Risk Based Concentration (RBCs) are chemical concentrations that correspond to a fixed level of risk for water, air, fish tissue, and soil. They are used as a screening tool and are not used for purposes of regulation.

CREG = Cancer Risk Evaluation Guide
IEMEG = Intermediate Environmental Media Evaluation Guide
MCL = Maximum Contaminant Level
NA = Information was not available
RMEG = Reference Dose Media Evaluation Guide
TPH-E = Total Petroleum Hydrocarbons Extractable
TPH - P = Total Petroleum Hydrocarbons Purgeable

Note: In some cases two values are provided for a contaminant. This was done for purposes of comparison where recent data were available and the values exceeded ATSDR's CVs.

Table 4.
Summary of Contaminants Detected in Surface Water and Sediment Above ATSDR's CV's:
Collected from 8 Locations In the Lower Diagonal (LD) Drain and the LD No. 1 Drain

Contaminant	Maximum Concentration (ppb)	Date Maximum Concentration Detected	Location of Maximum Concentration	Comparison Value	
				Value (ppb)	Source
Surface Water Samples					
Arsenic	268	Sept/Oct 1989	SW-06 (LD-Drain)	5 0.02	MCL CREG
Bromoform	40	April 2000	LD Sewer	80 4	MCL CREG
Bromodichloromethane	9	April 2000	LD Sewer	80 0.6	MCL CREG
Dibromochloromethane	30	April 2000	LD Sewer	0.13	RBC
Lead	30	Sept/Oct 1989	SW-04 (LD #1-Drain)	15	EPA
Selenium	60	Sept/Oct 1989	SW-07 (LD-Drain)	50	MCL
TPHs	5,000	Sept/Oct 1989	SW-01 (LD-Drain) SW-02 (LD #1-Drain)	----	----
Sediment Samples					
TPHs	43,000	August 1989	SW-03 (LD #1-Drain)	----	----

ND = Not Detected
NA = Not Applicable
RBC = EPA's Risk Based Concentrations
TPHs = Total Petroleum Hydrocarbons ----- = No comparison value exists for TPHs in water

Table 5
Estimated Emission Rates and Annual Average Ambient Air Concentrations

Contaminant	Estimated Emission Rate (g/s)	Estimated Annual Average Air Concentration		Lowest Health-Based Comparison Value		Type of Comparison Value
		µg/m^3	ppb	µg/m^3	ppb	
Acetaldehyde	0.0198	0.024	0.013	0.07	0.04	CREG
Acrolein	0.0626	0.076	0.033	0.02	0.009	EMEG-intermediate
Benzene	0.183	0.222	0.070	0.1	0.03	CREG
1,3-Butadiene	0.545	0.660	0.300	0.004	0.002	CREG
Ethylbenzene	0.0264	0.032	0.007	4,350	1,000	EMEG-intermediate
Formaldehyde	0.347	0.421	0.343	0.08	0.07	CREG
Methyl ethyl ketone	0.00171	0.002	0.001	1,000	340	RfC
Naphthalene	0.0511	0.062	0.012	3	0.6	RfC
Styrene	0.0265	0.032	0.008	260	60	EMEG-chronic
Toluene	0.092	0.112	0.030	300	80	EMEG-chronic
m,p-Xylene	0.0579	0.070	0.016	440	100	EMEG-chronic
o-Xylene	0.0282	0.034	0.076	440	100	EMEG-chronic

Notes:Estimated annual average air concentration is based on multiplying the SCREEN3 output (highest 1-hour average concentration) by a factor of 0.1 (EPA-recommended value for estimating annual average impacts from a screening evaluation).

The table addresses the hazardous air pollutants that were most frequently detected in the engine testing (AESO 1998). This study did not report emission factors for 1,3-butadiene; the 1,3-butadiene data in the table were generated from an aircraft emissions study based on JP-5.

The source document reported methyl ethyl ketone and isobutyraldehyde as a single contaminant, presumably because the analytical equipment could not distinguish the two chemicals. This analysis assumes that the entire amount detected was methyl ethyl ketone—the chemical with more readily available toxicity information.

The following abbreviations are used for health-based comparison values: Cancer Risk Evaluation Guide (CREG), Environmental Media Evaluation Guide (EMEG), and reference concentration (RfC). The lowest comparison value for all xylene isomers was applied to the last two rows.

Table 6 - Jettisoning Events at NAS Fallon 1986 - 2001				
Date	Aircraft Type	Circumstance	Volume	Location
12 Jun 01	F-14	Landing Gear Emergency	500 gallons	B-20 8k Agl
5 Jun 01	F-14	Landing Gear Emergency	500 gallons	Salt Wells Flat 6k Agl
5 Oct 00	F-14	Landing Gear Emergency	600 gallons	B-20 8k agl
12 May 00	FA-18	Single Engine Emergency	300 gallons	B-17 10k Agl
20 Jul 99	EA-6B	Single Engine Emergency	500 gallons	B-20 10K Agl
18 Oct 98	F-14	Landing Gear Emergency	600 gallons	B-17 8k Agl
16 Apr 98	F-18	Flight Control System Failure	300 gallons	B-20 6k Agl
17 Nov 97	F-14	Single Engine Emergency	500 gallons	B-17 10 Agl
6 Mar 97	FA-18	Landing Gear Emergency	300 gallons	B-20 10k Agl
8 Jan 97	EA-6B	Single Engine Emergency	500 gallons	B-17 9k Agl
20 Dec 96	F-14	Hydraulic Failure	400 gallons	Salt Wells Flat 8k Agl
16 Mar 96	FA-18	Landing Gear Emergency	300 gallons	B-17 10k Agl
22 Oct 95	F-14	Single Engine Emergency	400 gallons	B-20 10 k Agl
20 May 95	EA-6B	Single Engine Emergency	300 gallons	B-17 8k Agl
23 Sep 94	F-14	Hydraulic Failure	500 gallons	B-20 10k Agl
30 Jun 94	F-14	Single Engine Failure	300 gallons	B-17 8k Agl
15 Apr 94	F-14	Single Engine Failure on Take-off	600 gallons	Salt Wells Flat 3k Agl
16 Nov 93	FA–18	Flight Control System Failure	300 gallons	B-17 8k Agl
20 Jul 93	FA-18	Single Engine Failure	400 gallons	B-17 10k Agl
18 Apr 93	F-14	Single Engine Failure	400 gallons	B-20 10 k Agl
10 Nov 92	A-6	Hydraulic Failure	300 gallons	B-17 10k Agl
12 Aug 92	F-14	Hydraulic Failure	500 gallons	B-20 10k Agl
22 Apr 92	A-6	Single Engine Failure	300 gallons	B-20 10k Agl
10 Dec 91	A-6	Single Engine Failure	400 gallons	B-17 10k Agl
6 Jun 91	FA-18	Flight Control System Failure	300 gallons	B-17 8k Agl
15 Sep 90	A-6	Hydraulic Failure	500 gallons	B-20 10k Agl
15 Sep 89	FA-18	Single Engine Failure	500 gallons	B-20 8k Agl
10 Jun 89	F-14	Landing Gear Emergency	500 gallons	B-20 10k Agl
22 Apr 89	F-14	Landing Gear Emergency	300 gallons	B-17 12k Agl
15 Sep 88	A-6	Hydraulic Failure	500 gallons	B-20 15k Agl
24 Jun 88	A-6	Landing Gear Emergency	400 gallons	B-20 10k Agl
20 Apr 88	F-14	Single Engine Failure	300 gallons	B-17 8k Agl
15 Nov 87	FA-18	Flight Control System Failure	400 gallons	B-17 8k Agl
26 Sep 87	FA-18	Single Engine Failure	300 gallons	B-20 10k Agl
10 Jun 87	A-6	Landing Gear Emergency	300 gallons	B-20 12k Agl
17 Apr 87	F-14	Single Engine Failure	500 gallons	B-20 10k Agl
10 Sep 86	A-6	Landing Gear Emergency	300 gallons	Salt Wells Flat 8k Agl
15 Jun 86	F-14	Single Engine Failure	500 gallons	B-20 8k Agl

k = 1000 feet
Agl = above ground level

FIGURES

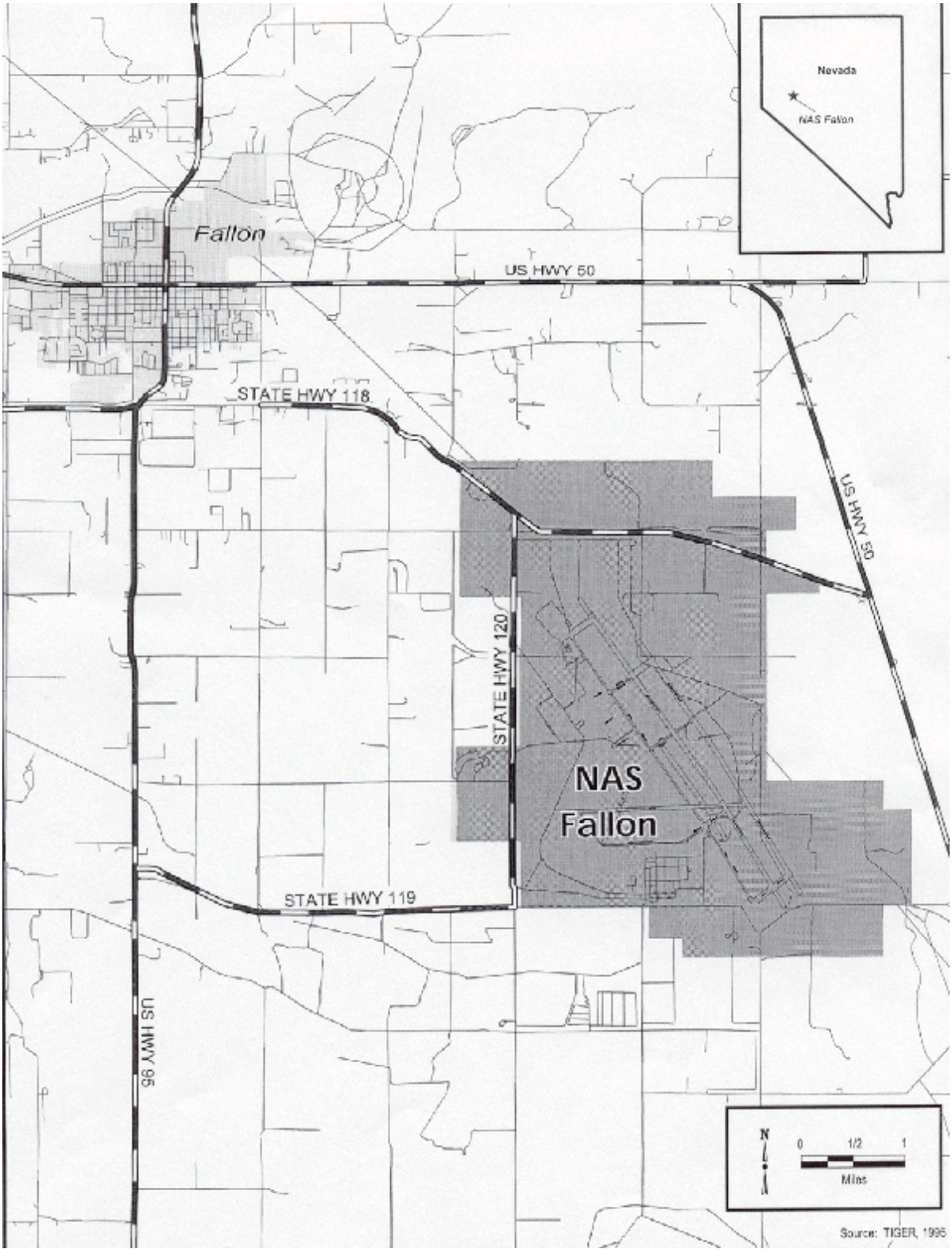


Figure 1: NAS Fallon Location Map

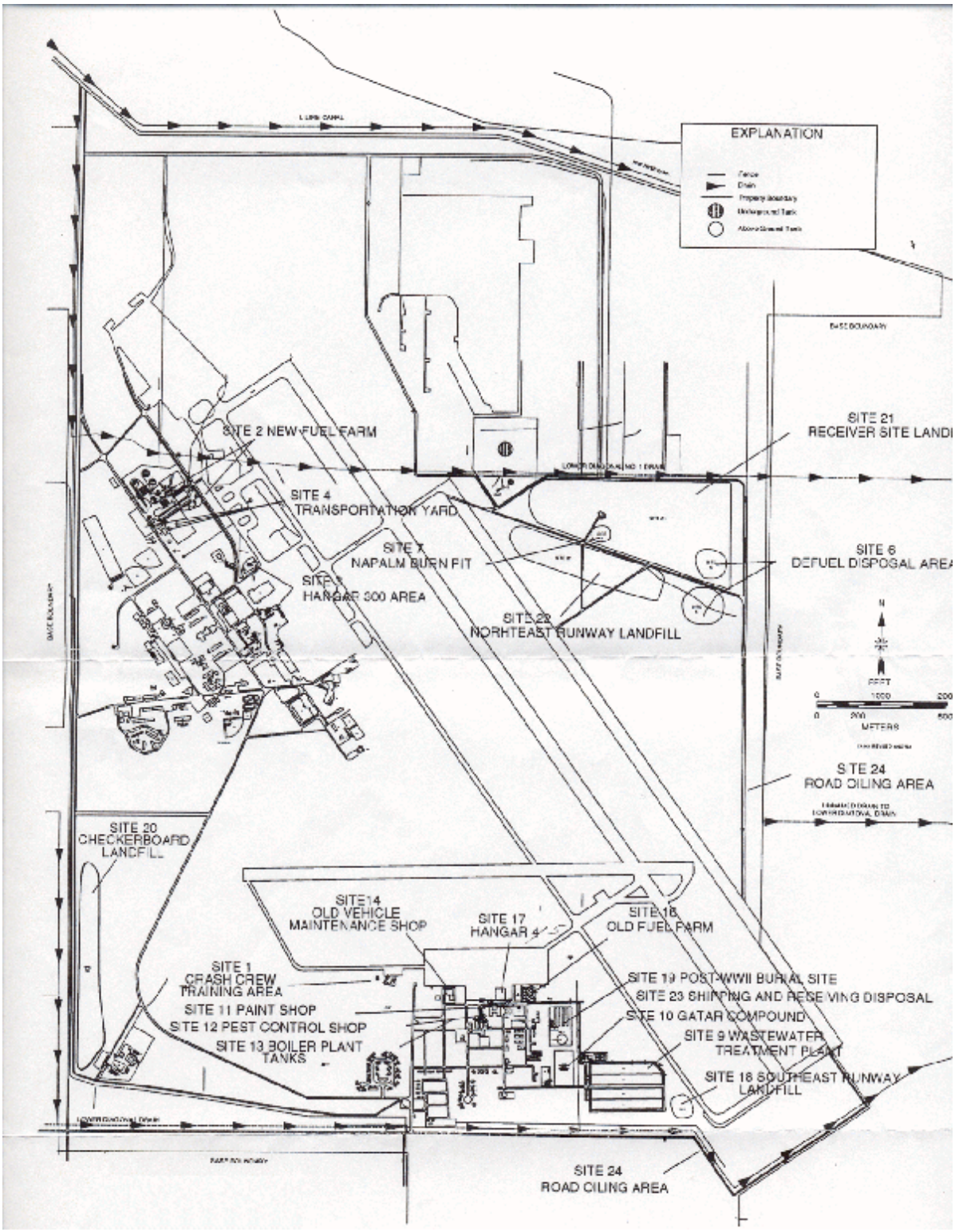
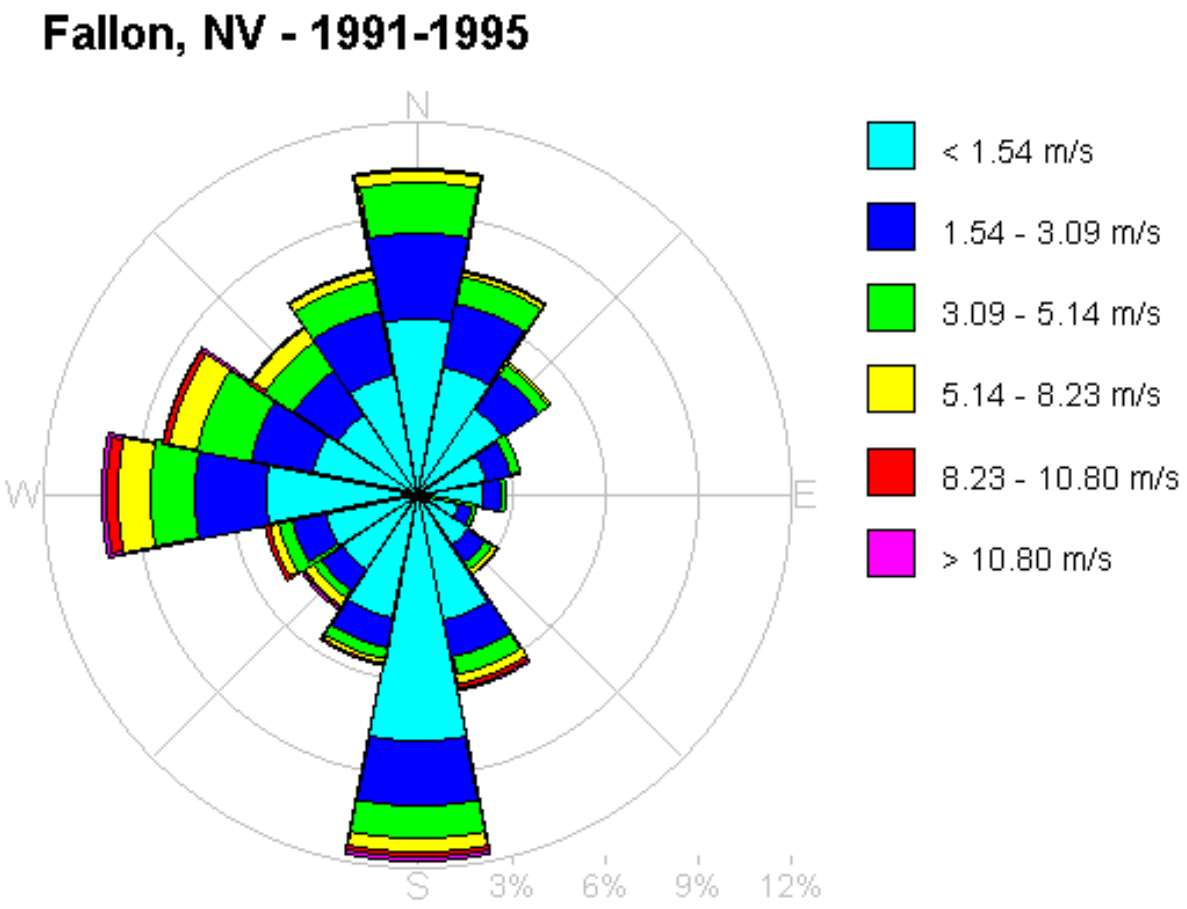


Figure 2: NAS Fallon Site Map

Figure 3: Fallon Area Wind Rose

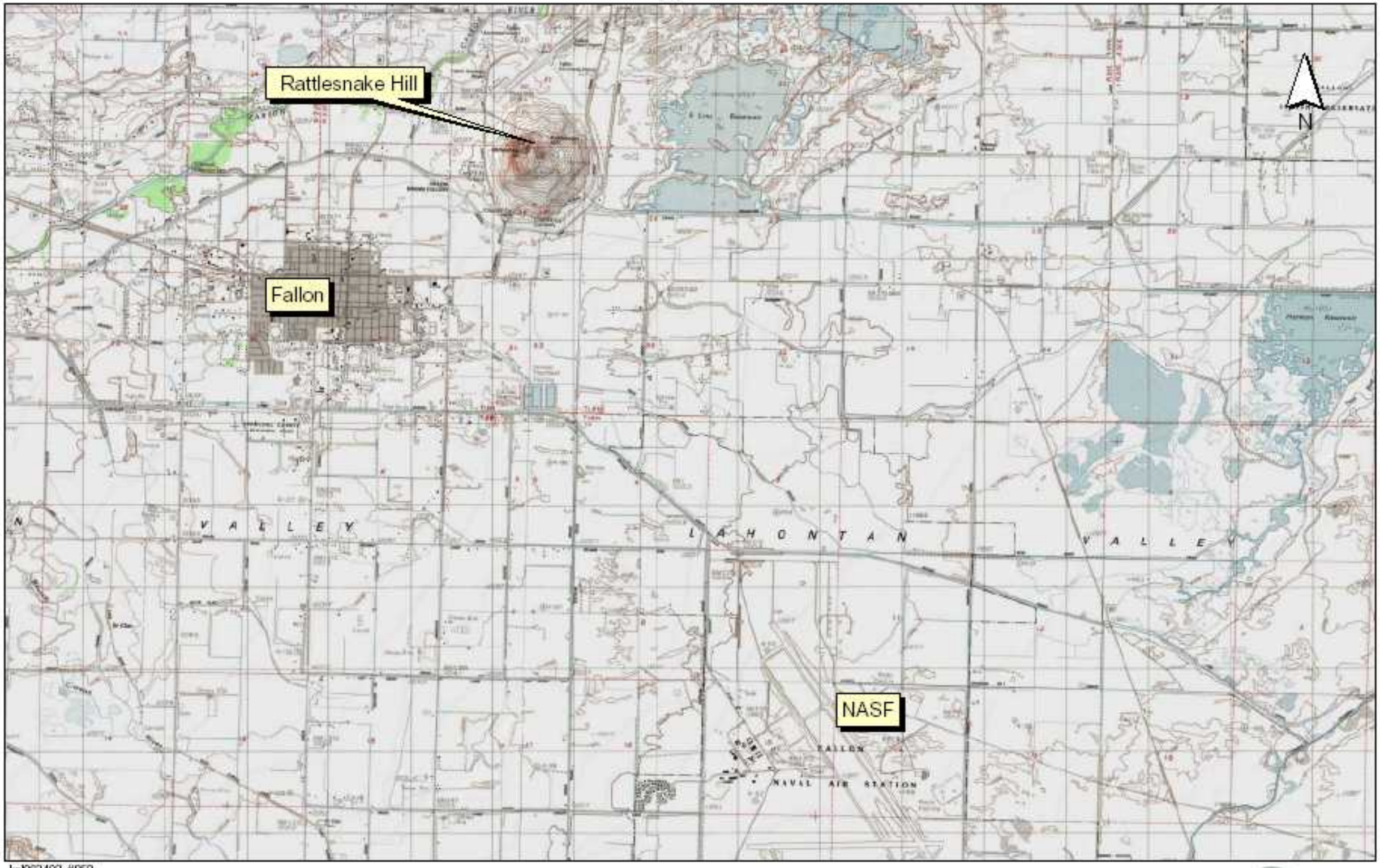
[1]



[1] m/s = meters per second

Location of NASF Drinking Water Supply Wells

Figure 4



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ATSDR CHS SAIDS

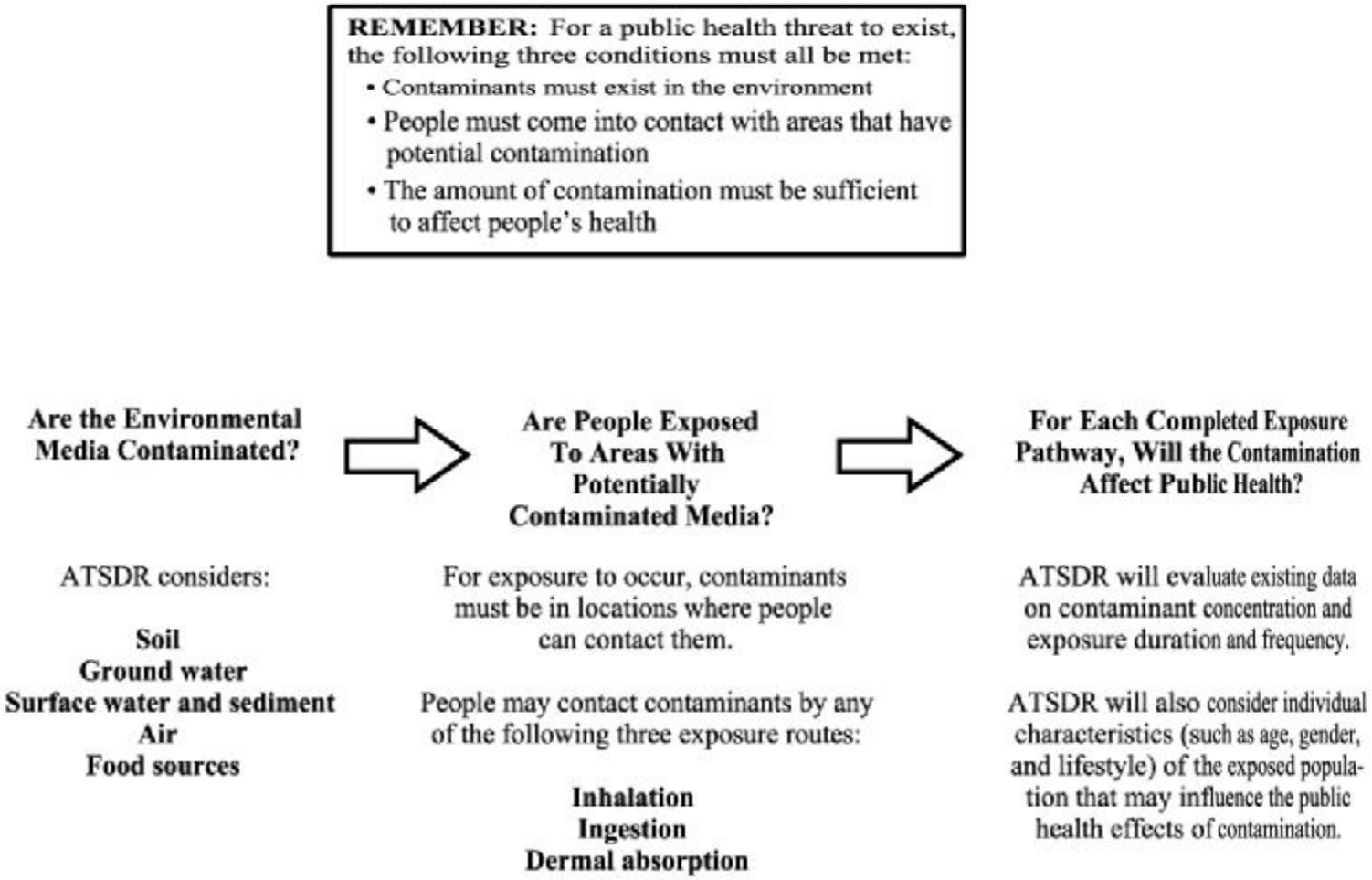

FIGURE 5. ATSDR's Exposure Evaluation Process

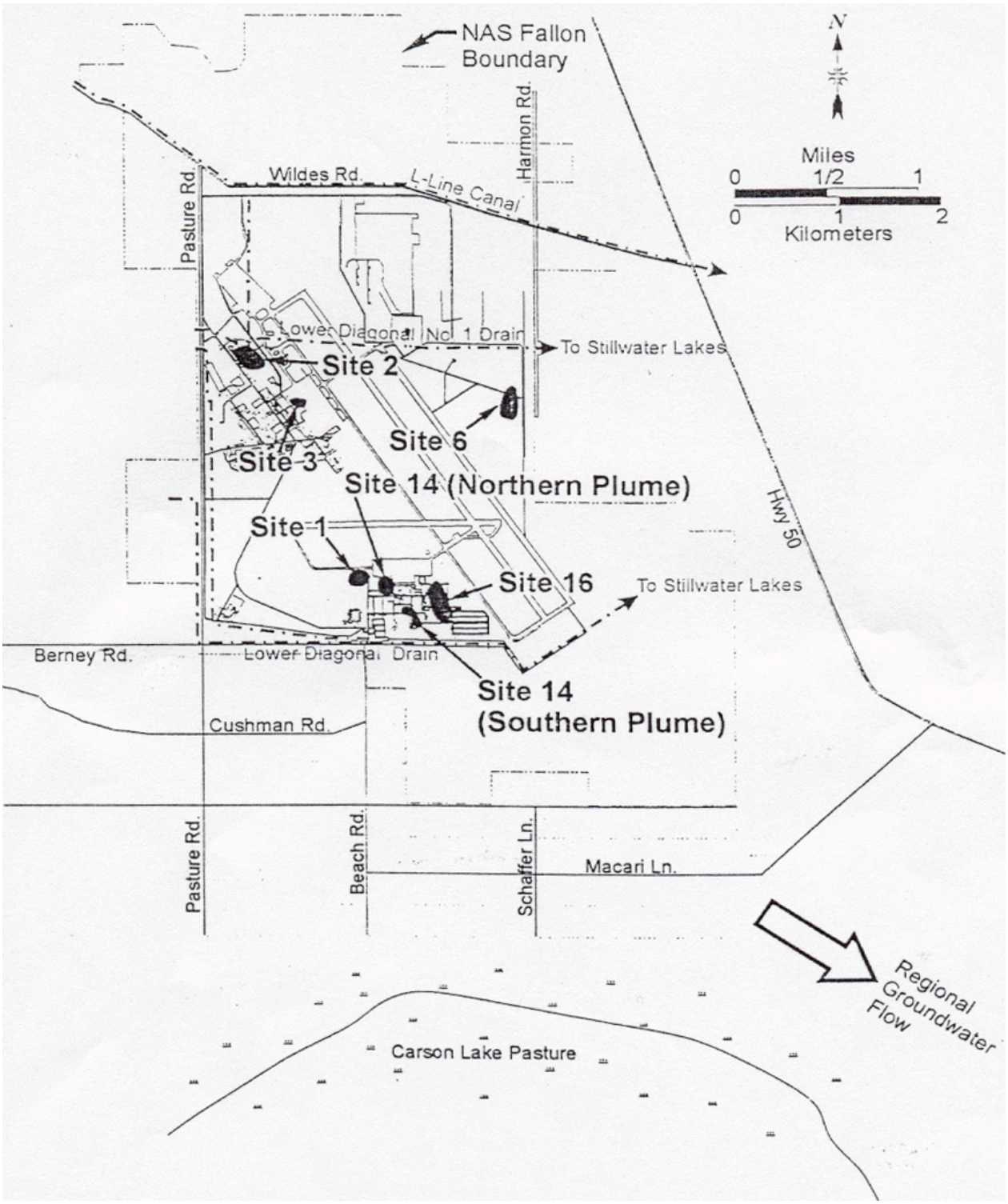

Figure 6: Location of On-site Groundwater Plumes

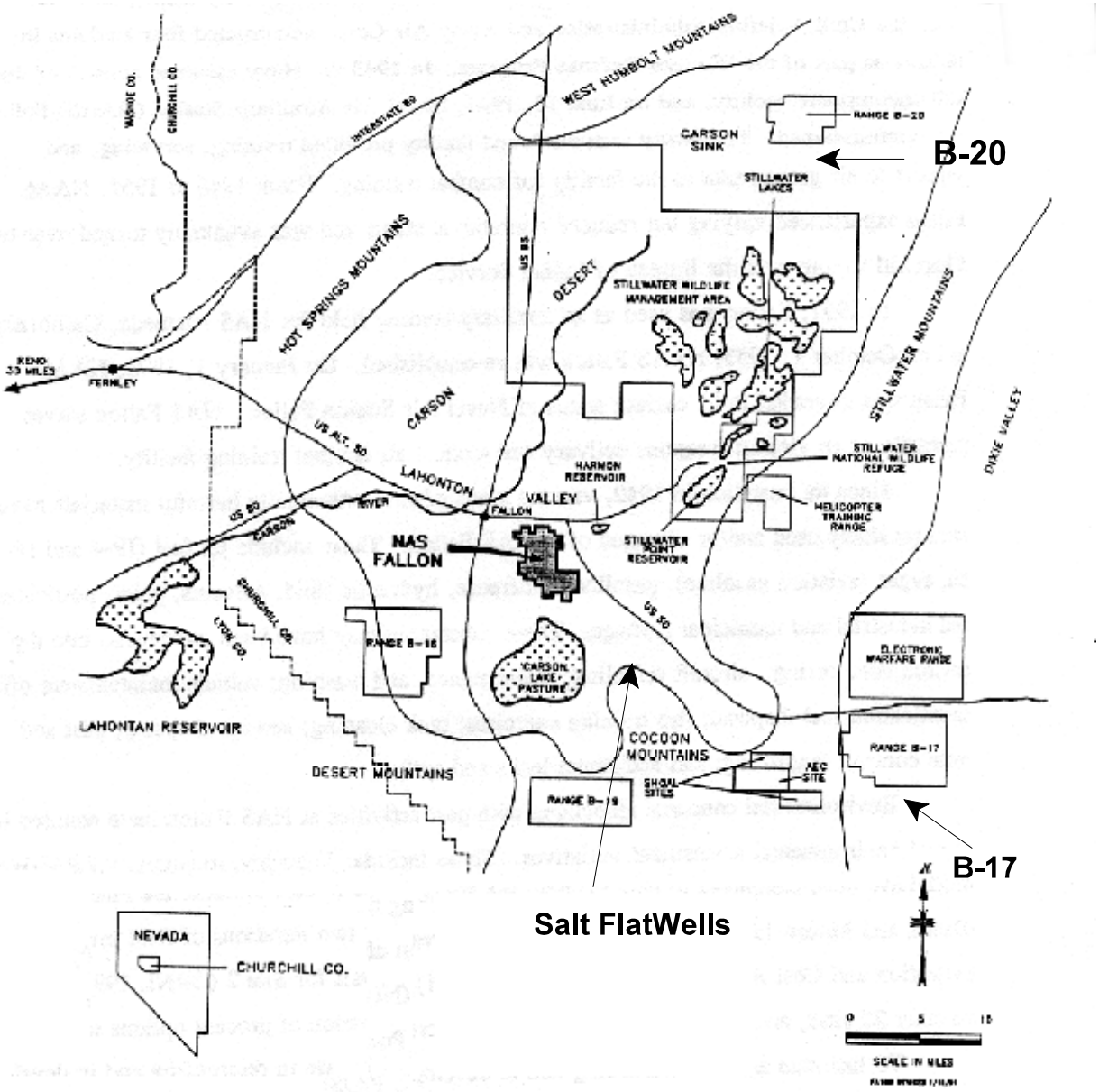

Figure 7: Locations of Areas where Jettisoning Occurred - 1986 - 2001.
Source: Oakridge National Lab 1992. Preliminary Site Characterization Summary Naval Air Station Fallon. January 1992.

Source: http://www.jetsafety.com

Figure 8: F-16 venting fuel during refueling activity. This venting is believed to be a result of overfilling during refueling. Although this is not 'jettisoning' as such, it does provide a visual reference for the appearance of fuel coming out of an aircraft during flight.
NOTE: This is NOT an NASF aircraft.

Source: http://www.globalsecurity.org/military/systems/aircraft/images/f-14-FALLONland.jpg
Figure 9: F-14 exhaust plume

Source: http://www.chinfo.navy.mil/navpalib/aircraft/ea6b/prowl-vapor.jpg
Figure 10: EA-6 vapor trail

Source: http://www.globalsecurity.org/military/systems/aircraft/images/f-14-071.jpg
Figure 11: F-14 emitting heat plume

Source: http://www.chinfo.navy.mil/navpalib/ships/carriers/stennis/tom-flare.jpg
Figure 12: F-14 dropping flares

APPENDICES

APPENDIX A. List of 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 (CPFs).

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 individuals consuming 2 liters of water per day.

Environmental Media Evaluation Guides (EMEGs)

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

Reference Media Evaluation 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 B: Glossary

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

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

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

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

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

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

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

Aerobic
Requiring oxygen [compare with **anaerobic**].

Ambient
Surrounding (for example, *ambient* air).

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

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

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

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

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

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

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

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

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

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

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

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

CAP
See **Community Assistance Panel**.

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

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

Carcinogen
A substance that causes cancer.

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

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

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

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

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

Chronic
Occurring over a long time (more than 1 year) [compare with **acute**].

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

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

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

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

Completed exposure pathway [see **exposure pathway**].

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

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

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

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

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

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

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

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

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

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

DOD
United States Department of Defense.

DOE
United States Department of Energy.

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

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

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

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

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

EPA
United States Environmental Protection Agency.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Metabolite
Any product of **metabolism**.

mg/kg
Milligram per kilogram.

mg/cm^2
Milligram per square centimeter (of a surface).

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

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

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

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

Mutagen
A substance that causes **mutations** (genetic damage).

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

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

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

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

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

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

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

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

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

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

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

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

ppb
Parts per billion.

ppm
Parts per million.

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

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

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

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

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

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

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

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

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

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

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

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

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

Radionuclide
Any radioactive isotope (form) of any element.

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

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

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

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

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

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

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

RfD
See **reference dose**.

Risk
The probability that something will cause injury or harm.

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

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

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

Safety factor [see **uncertainty factor]**

SARA [see **Superfund Amendments and Reauthorization Act**]

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

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

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

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

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

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

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

Substance
A chemical.

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

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

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

Surveillance [see **epidemiologic surveillance**]

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

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

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

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

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

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

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

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

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

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

Other glossaries and dictionaries:

Environmental Protection Agency http://www.epa.gov/OCEPAterms/

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

National Library of Medicine http://www.nlm.nih.gov/medlineplus/dictionaries.html

APPENDIX C: Evaluation of Aircraft Emissions from Naval Air Station Fallon

The following describes the ATSDR analysis of inhalation exposures to contaminants in aircraft emissions from Naval Air Station Fallon (NASF). This analysis was completed in multiple steps, which are described below. The analysis is based largely on aircraft engine testing data conducted by the Navy's Aircraft Environmental Support Office. These data were found to be generally consistent with emission factors adopted by the Federal Aviation Administration (FAA) and used in ATSDR's previous evaluation of aircraft emissions from Kelly Air Force Base.

The analysis of emissions from NASF estimated that ambient air concentrations for all pollutants considered were either below health-based comparison values or reasonably consistent with levels routinely measured in small communities and suburban locations across the United States. This analysis is based entirely on emissions and dispersion modeling and may understate or overstate actual ambient air concentrations.

Published approaches for characterizing aircraft emissions. Aircraft emissions from an airport or military base are determined by many factors, such as the amount of aircraft operations, the aircraft engine types, the fuel burned, and the durations that aircraft operate in different engine modes. Multiple approaches have been used to estimate aircraft emissions for different scenarios. These approaches all focus on characterizing the aircraft emissions that occur while aircraft operate on the ground and during takeoff and landing; they do not characterize emissions while aircraft operate aloft. Following is a brief summary of the candidate approaches identified to date:

- *FAA approach.* FAA developed the Emissions and Dispersion Modeling System (EDMS) to characterize aircraft emissions from commercial airports and military bases. FAA released Version 4.0 of the EDMS software last year (CSSI 2001). EPA has designated EDMS as a "preferred air quality model" for assessing impacts of aircraft emissions (EPA 1996). EPA specifically noted that EDMS's intended use is for predicting the changes in ambient air concentrations that might result from changes in aircraft operations.

- *Navy data.* Several studies conducted by the Navy on aircraft emissions (AESO 1998, 1999a, 1999b, 2000a, 2000b) were utilized. The individual studies document measured air emission rates for different combinations of aircraft engines, engine modes, and fuel types. Many of the aircraft engines considered in these tests are used by aircraft at NASF.

- *ATSDR calculations.* ATSDR utilized several spreadsheets for other military installations, particularly Kelly Air Force Base (Kaplan 2002) indicating how aircraft emissions have been estimated . The analyses in these spreadsheets draw from multiple data sources, including the Navy and documents in the open literature.

- *EPA approach.* EPA quantified aircraft emissions when developing its National Toxics Inventory, a nationwide emissions inventory of hazardous air pollutants. Emissions from commercial aircraft were considered in the final inventory, but emissions from military aircraft were excluded due to the "limited availability of emission factor and speciation data and appropriate activity data" (ERG 2000).

Based on this initial review, ATSDR considered the first three approaches documented above when characterizing aircraft emissions at NASF.

Activity data for NASF. Because aircraft emissions are highly dependent on the number of aircraft operations, types of aircrafts, and fuels used, ATSDR obtained information on aircraft activity at NASF. Base personnel provided the following data on the number of aircraft "sorties" and "operations" per year (Rogers 2001):

Year	Number of Sorties	Number of Operations
1998	38,500	202,000
1999	39,600	230,000
2000	41,200	244,000

NASF considers the following different activities as individual "operations": landing, takeoff, and entering into restricted air space. A "sortie," on the other hand, is essentially every time an aircraft leaves and returns to the base. Therefore, a plane that takes off from NASF, enters restricted air spaces three separate times, and lands at NASF is considered a single sortie, with five operations. Emissions estimates are based on the number of sorties, which best reflect the activities that contribute to overall emissions.[2] Specifically, emissions are calculated assuming 41,200 sorties occur per year—the highest aircraft activity rate from the available data. According to base personnel, data on the number of sorties from years prior to 1998 are not available (Rogers 2001).

Base personnel also communicated the percentage of aircraft types found at NASF (Rogers 2001). The number of sorties per aircraft type was estimated by multiplying the percent of total aircraft by the total number of sorties per year. According to this approach, the estimated numbers of sorties per aircraft type follow:

[2] This approach essentially assumes that "touch-and-go" operations do not contribute to the overall emissions. ATSDR has no data on how many of these operations occur during a year. However, the idle mode of aircraft engines is associated with the largest portion of aircraft emissions. Since "touch-and-go" operations presumably do not involve idle engine modes, neglecting these operations is expected to have only marginal impacts on the estimated emission rates.

Aircraft Type	Percent of Total Aircraft	Estimated Number of Sorties
F/A-18	45%	18,540
F-14	15%	6,180
F-5	10%	4,120
EA6	5%	2,060
E2C	5%	2,060
Helicopters	5%	2,060
Other tactical	5%	2,060
Cargo planes	10%	4,120

Finally, all aircraft at NASF operated on JP-5 jet fuel until October, 1993, when the base switched entirely to JP-8 fuel. Emissions estimates in this evaluation are based on current conditions at NASF, that is, use of JP-8 fuel.

Emissions estimates. Multiple approaches were used for characterizing aircraft emissions at NASF, based on the activity data documented in the previous section. First ATSDR compared emissions estimates for total hydrocarbons calculated using different approaches, and then estimated emissions for specific contaminants using what was judged to be the most representative approach. The following paragraphs describe our evaluations:

- *Step 1: Compare hydrocarbon emissions estimates for different approaches.* Initial analyses focused on comparing results from four different emissions approaches. This was done to determine whether the approaches involved considerable differences and also to understand what aircraft engine modes account for the greatest portion of estimated emissions. For this initial evaluation, the following scenario was used: 41,200 landing-takeoff (LTO) cycles involving only F/A-18 aircraft operating on JP-5 or JP-8 fuel. This scenario was selected because four different approaches are available for estimating emissions of total hydrocarbons (HC), which allows for direct comparisons between approaches published by different parties.

  Table C-1 compares the emissions estimation for total hydrocarbons for four different approaches. Footnotes to the table describe the model inputs that were used to estimate annual emission rates for the scenario. Two important observations are apparent from this initial evaluation. First, the emissions estimates across the four approaches are reasonably consistent, all falling approximately within a factor of two of each other. This consistency is important, because it gives confidence that none of the approaches grossly understates or overstates emission rates. Second, all four approaches predict that engine idle time accounts for the greatest proportion of hydrocarbon (HC) emissions. Therefore, estimated emission rates for any airport or military base will be very sensitive to the input for the average time that jet engines idle, which is determined primarily by start-up time and taxi time.

According to every emissions estimation approach examined, aircraft emissions during idling engine modes account for the overwhelming majority (>95%) of total emissions available for downwind transport. Consequently, site-specific emission rates are highly dependent on the average amount of time that aircraft idle. The aircraft idling time used in this evaluation are default parameters based on emissions tests conducted at Edwards Air Force Base (AESO 1998), which are assumed in this model to be similar to conditions at NASF. Also, some of the emissions estimation approaches reviewed include emissions data for "in-frame, maintenance testing" of aircraft engines. These approaches estimate that typical emissions associated with maintenance activities for a single aircraft are approximately equal to the emissions that the same aircraft releases during 30 landing-takeoff cycles (AESO 2000b). If the maintenance-related air emissions occurs at NASF, the actual emissions would increase.

- *Step 2: Estimate emissions of individual contaminants for the NASF evaluation.* As noted previously, we compiled the data in Table C-1 to compare different emissions estimation approaches, which we found to have comparable predictions. To characterize air quality impacts at NASF, we used what we considered to be the most representative approach: emission factors and aircraft engine mode data published by the Navy's Aircraft Environmental Support Office (AESO 1998), or data presented in the final two columns in Table C-1. The final emissions estimates for aircraft at NASF were based on emission factors and aircraft engine mode data published by the Navy's Aircraft Environmental Support Office (AESO 1998). This approach was selected because it is the only data set received that presents emission factors for the aircraft type and fuel most commonly used at NASF: other references presented emissions factors for other aircraft engines not in use at NASF and for JP-5 fuel. As Table C-1 shows, the HC emissions predicted by this approach are consistent with those predicted by other similar approaches.

  The emission rates calculated are based on chemical-specific emission factors reported for different engine modes (AESO 1998), combined with data compiled in another reference on typical times that aircraft operate in specific engine modes (AESO 2000b, as shown in Table C-1). The evaluation is based exclusively on F/A-18 aircraft using JP-8 fuel during 41,200 sorties, or landing-takeoff (LTO) cycles.[3] Specifically, for each chemical, the time in each mode was multiplied by a chemical's emission rate in that mode and then multiplied by the total LTO cycles. The resulting emission rate in tons per year was converted to units of grams per second for purposes of the dispersion modeling. Table C-2 lists the emission rates that ATSDR calculated for every chemical. Eleven

[3] To a first approximation, representing all aircraft at NASF appears to overstate emissions. EDMS model predictions, for example, indicate the following HC emissions for a single LTO: F/A-18, 49.34 pounds; F-14, 29.00 pounds; F-5, 13.40 pounds; E2C, 1.07 pounds; and EA6, 30.74 pounds. Therefore, assuming all aircraft sorties were conducted by F/A-18s does not appear to underestimate air quality impacts.

chemicals were identified as being hazardous air pollutants, combustion by-products, and most often detected in aircraft engine exhaust (AESO 1998).

The emissions estimates that we calculated are not equivalent to exposure. Rather, emissions will move through the air and gradually disperse as they move downwind. A dispersion model is needed to predict what ambient air concentrations would result from the estimated emission rates. In other words, emissions data in Table D-1 were used as an input to our dispersion modeling analysis, which is described below.

Dispersion modeling. Aircraft emissions from NASF, like those at virtually all commercial airports and military installations, are not continuous or stationary sources. Rather, aircraft emissions occur periodically during the year, and the release point is a mobile source. Modeling such emissions sources is a challenging task, given that the majority of regulatory air dispersion models have been developed for continuous, stationary sources.

The initial evaluation of the aircraft emissions used the SCREEN3 dispersion model. The SCREEN3 model is a screening tool that was designed to assess worst-case air quality impacts from three general types of continuous emissions sources (point, area, and volume) (EPA 1995). Aircraft emissions at NASF were modeled as occurring from a volume source. This approach assumes that contaminants are continuously released from a fixed volume of air. Though this approach does not perfectly represent conditions at NASF, it allows for an initial evaluation of potential air quality impacts associated with the aircraft emissions.

Model inputs for the volume source were as follows: emission rate, 1.0 gram per second; source height, 3.0 meters; initial lateral dimension, 525.0 meters; initial vertical height, 30.0 meters; and rural dispersion coefficients were assumed. Unit emission rates were used to calculate a normalized air concentration, which could then be applied to all contaminants. The height of the volume source was assumed to be the approximate height of aircraft engines. The dimensions of the volume source were assumed to be the approximate dimensions of an aircraft runway, or 5,000 meters by 1,000 meters. Per direction of the SCREEN3 user's guide, these values were divided by 4.3 to calculate the initial lateral and vertical dimensions that are required to be input to the model. Based on these inputs, SCREEN3 predicted the highest 1-hour average normalized concentration to be 12.14 $(\mu g/m^3)/(g/s)$ at the receptor of concern, which was located 5 kilometers (approximately 3 miles) downwind from the source. This is the distance that separates the residential areas in Fallon from the end of the runway at NASF. To translate this normalized concentration to an annual average time frame, the maximum 1-hour average value was multiplied by a factor of 0.1—consistent with procedures EPA published for screening analyses (EPA 1992). Therefore, the normalized annual average concentrations was 1.214 $(\mu g/m^3)/(g/s)$.

The annual average concentrations of specific chemicals was estimated by multiplying the emission rates and the normalized concentration. Table C-2 lists the estimated annual average concentrations and their corresponding health-based comparison values. Of the 11 chemicals

considered, only three—acrolein, benzene, and formaldehyde—had estimated ambient air levels higher than corresponding health-based comparison values. None of the estimated concentrations exceeded the comparison values by more than a factor of five. Closer examination of the data reveals that the estimated ambient air concentrations are lower than levels, or fall within the range of levels, typically measured in rural, suburban, and urban areas throughout the United States. Specifically, EPA's Urban Air Toxics Monitoring Program (UATMP) has recently reported the following ranges of average concentrations at 12 monitoring stations across the country[4]: average acrolein levels in the 1997 UATMP ranged from 0.02 to 0.08 ppb; average benzene levels ranged from 0.21 to 1.56 ppb; and average formaldehyde levels ranged from 1.83 to 8.68 ppb (ERG 1999). This observation suggests that other sources of air pollution found throughout the United States (e.g., mobile sources) also contribute to ambient air concentrations of these three pollutants.

Regarding model sensitivity, it is noted that the screening analysis for this source varies with essentially three input parameters: the lateral dimension of the volume source, the vertical dimension of the volume source, and the emission rate. The sensitivity to the volume source dimensions was examined by running the SCREEN3 model with different source configurations, but the modeling outputs were not highly sensitive to the volume source dimensions. Specifically, decreasing the initial lateral dimension by a factor of two caused the predicted concentrations to increase by 46%, and decreasing the initial vertical dimension by a factor of two caused the predicted concentrations to increase by only 10%. It is likely that the overall modeling evaluation is far more sensitive to the estimated emission rates, as determined largely by the idling time.

Conclusion. Table C-2 presents estimated highest annual average air concentrations that result from aircraft emissions at NASF. Estimates were made for the 11 hazardous air pollutants most frequently detected in aircraft emissions, and are based entirely on emissions data for F/A-18 aircraft operating on JP-8 fuel. This aircraft type accounts for the largest number of aircraft at the base. Multiple data analyses show that the aircraft emissions are dominated by contributions from aircraft idling.

Of the 11 chemicals considered, only acrolein, benzene, and formaldehyde had estimated air concentrations higher than health-based comparison values, but by relatively small margins (a factor of 5 or less). It is important to note that ambient air concentrations of these three chemicals are consistently higher than the most conservative health-based comparison values at locations throughout the United States, and the predicted levels for NASF fall within the range, or below the range, of levels routinely measured in small communities around the country.

[4] Though the name of EPA's monitoring program implies that sampling occurred only in urban environments, the monitoring locations included rural, suburban, and urban areas, including: five locations in Vermont, a remote location in Arkansas, industrial locations in Louisiana, and urban areas in New Jersey and Texas.

References.

AESO 1998. Aircraft Engine and Auxiliary Power Unit Emissions Testing Report. Prepared by Environmental Quality Management, Inc.; prepared for the United States Air Force. November 30, 1998.

AESO 1999a. Aircraft Emission Estimates: F-5 Landing and Takeoff Cycle and In-Frame, Maintenance Testing Using JP-5. Aircraft Environmental Support Office. AESO Memorandum Report No. 9923. February 1999.

AESO 1999b. Toxic Organic Contaminants in the Exhaust of Gas Turbine Engines for JP-5 and JP-8 Fuel. Aircraft Environmental Support Office. AESO Report No. 12-90, Revision B. February 1999.

AESO 2000a. Aircraft Emission Estimates: F-14 Landing and Takeoff Cycle and In-Frame, Maintenance Testing Using JP-5. Aircraft Environmental Support Office. AESO Memorandum Report No. 9813, Revision F. April 2000.

AESO 2000b. Aircraft Emission Estimates: F/A-18 Landing and Takeoff Cycle and In-Frame, Maintenance Testing Using JP-5. Aircraft Environmental Support Office. AESO Memorandum Report No. 9815, Revision D. May 2000.

CSSI 2001. Emissions and Dispersion Modeling System (EDMS) Reference Manual. Prepared by CSSI, Inc.; prepared for the U.S. Department of Transportation, Federal Aviation Administration. Document number FAA-AEE-01-01. May 2001.

EPA 1992. Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised. U.S. Environmental Protection Agency. Document number EPA-454/R-92-019. October 1992.

EPA 1995. SCREEN3 Model User's Guide. U.S. Environmental Protection Agency. Document number EPA-454/B-95-004. September 1995.

EPA 1996. Guideline on Air Quality Models. 40 CFR 51, Appendix W. U.S. Environmental Protection Agency. August 12, 1996.

ERG 1999. 1997 Urban Air Toxics Monitoring Program (UATMP). Prepared by Eastern Research Group; prepared for the U.S. Environmental Protection Agency. January 1999.

ERG 2000. Documentation for the 1996 Base Year National Toxics Inventory for Aircraft Sources. Prepared by Eastern Research Group; prepared for U.S. Environmental Protection Agency. June 2, 2000.

Kaplan 2002. Electronic mail correspondence between Brian Kaplan (ATSDR) and John Wilhelmi (ERG). July 3, 2002.

Rogers 2001. Electronic mail correspondence between Captain Roy Rogers (NASF) and Mary Ann Simmons (Navy Environmental Health Center). August 5, 2002.

Table C-1
Assumed Duration of Engine Modes and Total Hydrocarbon Emissions: Based on 41,200 Landing-Takeoff Cycles for F/A-18 Aircraft Using JP-5 or JP-8

Engine Mode (Power setting)	Data for Different Emissions Estimation Approaches							
	EDMS Evaluation (JP-5)		ATSDR Evaluation (JP-5)		AESO Data (JP-5)		AESO Data (JP-8)	
	Time in Mode	HC Emissions	Time in Mode	HC Emissions	Time in Mode	HC Emissions	Time in Mode	HC Emissions
Idle/Taxi	40.4 minutes	1008.41 tons	21.8 minutes	543.45 tons	44 minutes	1,096.9 tons	44 minutes	777 tons
Unstick (75%)	NA	NA	0.3 minutes	5.83 tons	0.6 minutes	11.74 tons	NA	NA
Run-up (80%)	NA	NA	NA	NA	0.5 minutes	1.71 tons	NA	NA
Approach (85%)	3.22 minutes	5.07 tons	NA	NA	3.0 minutes	2.88 tons	4.1 minutes	0.073 tons
Climb-out (95%)	0.31 minutes	0.54 tons	1.1 minutes	1.57 tons	1.0 minutes	1.42 tons	1.0 minutes	0.024 tons
Take-off (100%)	0.94 minutes	2.39 tons	0.8 minutes	2.03 tons	0.5 minutes	1.28 tons	0.5 minutes	4.61 tons
Totals	*44.8 minutes*	*1016.4 tons*	*24.0 minutes*	*552.9 tons*	*49.6 minutes*	*1,115.9 tons*	*49.5 minutes*	*782 tons*
Percent from Idle	90%	99%	91%	98%	89%	98%	89%	99%

Notes: References: EDMS Evaluation (CSSI 2001); ATSDR Evaluation (Kaplan 2002); AESO JP-5 Data (AESO 2000b); AESO JP-8 Data (AESO 1998).
The various idle engine modes correspond to the time that the aircraft starts, warms up, and taxis on runways.
NA indicates that an engine mode was not part of the description from this reference.
The JP-8 study (AESO 1998) did not include times for the engine modes; instead, the other AESO report's data were used.
For these evaluations, a 100% engine mode for take-off indicates that emissions were measured while engine afterburners were engaged.
Regarding the EDMS evaluation, an idle time of 40.36 minutes was selected to be consistent with the AESO data, even though the EDMS default idle time for F/A-18 aircraft in this software is 0.36 minutes. All other times per engine mode are EDMS defaults.
Regarding the AESO data evaluation, the time in mode entries are taken from 1998 interviews with maintenance personnel.
Data from the ATSDR evaluation are based on times in mode and emission factors tabulated in a spreadsheet used to evaluate aircraft emissions at Kelly Air Force Base. The time in mode originate in a publication titled "Aircraft Engine Emissions Estimator."

Table C-2
Estimated Emission Rates and Annual Average Ambient Air Concentrations

Contaminant	Estimated Emission Rate (g/s)	Estimated Annual Average Air Concentration		Lowest Health-Based Comparison Value		Type of Comparison Value
		µg/m³	ppb	µg/m³	ppb	
Acetaldehyde	0.0198	0.024	0.013	0.07	0.04	CREG
Acrolein	0.0626	0.076	0.033	0.02	0.009	EMEG-intermediate
Benzene	0.183	0.222	0.070	0.1	0.03	CREG
1,3-Butadiene	0.545	0.660	0.300	0.004	0.002	CREG
Ethylbenzene	0.0264	0.032	0.007	4,350	1,000	EMEG-intermediate
Formaldehyde	0.347	0.421	0.343	0.08	0.07	CREG
Methyl ethyl ketone	0.00171	0.002	0.001	1,000	340	RfC
Naphthalene	0.0511	0.062	0.012	3	0.6	RfC
Styrene	0.0265	0.032	0.008	260	60	EMEG-chronic
Toluene	0.092	0.112	0.030	300	80	EMEG-chronic
m,p-Xylene	0.0579	0.070	0.016	440	100	EMEG-chronic
o-Xylene	0.0282	0.034	0.076	440	100	EMEG-chronic

Notes: Estimated annual average air concentration is based on multiplying the SCREEN3 output (highest 1-hour average concentration) by a factor of 0.1 (EPA-recommended value for estimating annual average impacts from a screening evaluation).

The table addresses the hazardous air pollutants that were most frequently detected in the engine testing (AESO 1998).

The source document reported methyl ethyl ketone and isobutyraldehyde as a single contaminant, presumably because the analytical equipment could not distinguish the two chemicals. This analysis assumes that the entire amount detected was methyl ethyl ketone—the chemical with more readily available toxicity information.

The following abbreviations are used for health-based comparison values: Cancer Risk Evaluation Guide (CREG), Environmental Media Evaluation Guide (EMEG), and reference concentration (RfC). The lowest comparison value for all xylene isomers was applied to the last two rows.

APPENDIX D: Kerosene-based Jet Fuel: Jet Propulsion Fuel-8 (JP-8) and Commercial Jet Fuel (Jet A)

Background:

Jet fuels are one of the primary fuels for turbine engines worldwide and are the most widely available aviation fuels. Commercial illuminating kerosene was the fuel chosen for early jet engines because of its availability compared to gasoline during wartime. As a result, the development of commercial jet aircraft following WWII centered primarily on the use of kerosene-type fuels. Thus, many commercial jet fuels today have basically the same composition as kerosene, but are under more stringent specifications than those for kerosene (Irwin 1997). Jet Propulsion Fuel (JP-8) is basically the same as jet fuel used by the commercial airline industry (i.e. Jet A), except for performance enhancing additives. JP-8 has been used by the militaries of some North Atlantic Treaty Organization (NATO) countries since 1972 and since 1992-1996 by the US Air Force, the US Army and the Japanese Self-Defense Forces.

Approximately 60 billion gallons of JP-8 (F-34 international designation) and the commercial jet equivalents Jet A (domestic flights) and Jet A-1 (international flights) are used internationally on an annual basis, with approximately half being used in the US (Ritchie et al. 2001a).

Jet fuel (JP-8 and Jet A) is mixture of many chemicals, with the primary component being kerosene (>98%). Most petroleum products are made from crude oil. Crude oil contains primarily hydrocarbon compounds linked in chains of different carbon lengths. Gasoline is a blend of compounds with shorter carbon chains. Kerosene is a blend of the middle distillate or medium carbon chain compounds. Diesel fuel and home heating fuel contain longer carbon chain compounds. Gasoline typically contains more benzene and benzene-containing compounds than kerosene and diesel fuel.

Kerosene normally has a boiling range well above the boiling-point of benzene; accordingly, the benzene content of JP-8 is usually below 0.02%. In the United States, gasoline typically contains less than 1% benzene by volume, but in other countries the benzene concentration may be as high as 5% (ATSDR 2000).

Human Health Considerations:

This section of the document describes the health effects, both non-cancer and cancer, in animals and humans (where available) following exposure to raw fuel and emission via different routes of exposure.

Non-cancer:

The main acute health hazard associated with JP-8 is aspiration in to the lungs, of liquid JP-8, such as might occur if the fuel is accidentally swallowed. This can occur by directly inhaling liquid droplets or indirectly as a result of inhaling vomit containing JP-8. can be aspirated in to the lungs (directly or indirectly via vomiting).

JP-8 can cause irritation, redness, skin rash, and the perception of skin heat or burning when in contact with the skin, usually as a result of prolonged contact. Due to the physical and chemical characteristics of JP-8, it does not easily wash off the skin. Repeated and/or long-term skin exposure can result in defatting of the skin and dermatitis. Ullrich (1999) reported that dermal exposure (uncovered multiple or single large dose) to JP-8 in female mice resulted in immune suppression. The immunosuppressive effects occurred 24-48 hours post-exposure. Immunosupressive effects have not been reported in military personnel working acutely/chronically with JP-8. Wolfe et al. (1997) reported on the health effects associated with short-term exposure to JP-8 in animals. In rabbits, 4 hour dermal exposure resulted in slight erythema. In rats, inhalation exposure to concentrations greater than 3,000 mg/m3 resulted in eye and upper respiratory irritation.

There are two reported human neurotoxicity studies regarding chronic effects of repeated exposure to JP-4/JP-8. Smith et al. (1997) reported that military workers exposed to JP-4/JP-8 for nine months exhibited significantly increased postural sway patterns, but only under the most difficult testing condition. McInturf et al. (2001) reported that USAF personnel exposed to JP-8 for at least 4 months, showed a significant deficit in two parameters of eye blink response. There are multiple animal studies regarding the neurotoxicity of JP-8. Ritchie et al. (2001b) provides a review of the neurotoxicity of selected hydrocarbon fuels.

Several animal studies have reported immunosupression following dermal exposure to raw JP-8 or by inhalation to JP-8 aerosol (Harris et al. 1997a,b and 2000; Ullrich, 1999; and Ullrich and Lyons 2000). The animals were exposed to JP-8 at concentrations and via routes that would represent exposures seen in military personnel working directly with JP-8. Based on modeling results and distance from the potential source, offsite residents are not expected to have JP-8 exposure at levels resulting in immunosuppression. We do not know if JP-8 jet fuel is immunosuppressive in humans, but it appears that the mouse is more sensitive.

It should be noted that, in general, military personnel working with jet fuel are exposed to higher concentrations on a more frequent basis than the general population with reports of limited health effects. Pleil et al. (2000) reported that military fuel system maintenance personnel had the highest overall exposure to JP-8 compounds. Whereas, military personnel exposed to aircraft exhaust in typical outdoor settings have measurable exposure at least 10 times less than the fuel system maintenance workers. Also, there was a slight measurable elevation in JP-8 compounds in personnel at air force bases without direct aircraft or jet fuel contact as compared to the general public. The mean level of benzene in breath of nonsmoking personnel was 1.92 ug/m3 for controls and 5.43 ug/m3 for the exposed workers, with smoking providing an additional 400% incremental mean body burden of benzene. Additionally, air modeling indicates that off-

site concentrations of benzene (0.222 ug/m3) are below levels of health concern for acute and chronic effects (see Table 5 of Appendix C). Therefore, it is not expected that lower levels of exposure to jet fuel vapors and emissions typically seen in the general population would result in adverse health effects.

Cancer:

Human or other animal cancer studies regarding JP-8 exposure could not be located. The International Agency for Research on Cancer (IARC) has concluded that there is insufficient information available to determine if jet fuels cause cancer.

There are limited epidemiological data regarding cancer in humans following chronic inhalation exposure to kerosene. Studies have shown that no association, between the use of kerosene stoves for cooking and bronchial cancer, was found among nonsmoking females (ATSDR 1996).

Long term exposure to levels of benzene much higher than that modeled for Fallon (see Table 5 of Appendix C) or expected from exposure to gasoline, jet fuel, and/or jet exhaust emissions has been shown to cause cancer in humans and animals (see leukemia discussion in next section). The Department of Health and Human Services (DHHS) and IARC have determined that benzene is a human carcinogen.

Emissions from vehicles and airplanes contain volatile organic compounds, including 1,3-butadiene and formaldehyde. The DHHS has determined that 1,3-butadiene is a human carcinogen and formaldehyde is a probable human carcinogen. Studies in animals, as low as 6.25 ppm, have shown that 1,3-butadiene is carcinogenic in mice and rats at multiple organ sites (EPA 1998). Human epidemiologic studies have reported an association between 1,3-butadiene exposure and lymphatic leukemia in styrene-butadiene rubber workers. It's important to note that there is a lack of quantitative exposure data in the monomer plant workers and the polymer plant workers exposure data is limited but suggest that concentrations greater than 1 ppm for years are necessary to increase the risk of cancer in workers. Ambient air levels of 1,3-butadiene in urban and suburban locations ranged from 0.10 to 0.46 ppb while levels in smoke-filled bars ranged from 1.2 to 8.4 ppb (EPA 1998). The modeled annual average air concentration for 1,3-butadiene from aircraft emissions at Naval Air Station Fallon was estimated to be 0.3 ppb (see Table 5 of Appendix C). Formaldehyde has been shown to cause nasal cancer in animals. Excess mortality from leukemia and brain cancer was generally not seen among industrial workers, which suggests that the excess for these cancers among workers is due to something other than formaldehyde.

JP-8, gasoline and emissions from airplanes and vehicles contain polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs. The addition of performance additives to vehicle fuel can increase PAH emissions (Mi et al. 1998). The DHHS and IARC have determined that certain PAHs are probable human carcinogens.

Leukemia:

There are several types of leukemia. They are grouped two ways: (1) by how quickly the disease develops and (2) by the type of blood cell affected. Leukemia is either acute or chronic. Leukemia can appear in either of two major types of white blood cells – lymphoid cells or myeloid cells.

Acute Non-Lymphocytic Leukemia (ANLL), also called acute myelogenous leukemia (AML), is the most common tumor associated with benzene exposure. Some scientists believe the evidence demonstrates that benzene-induced leukemia is only of the AML type (Snyder and Kalf 1994; Crump 1994; and Irons and Stillman 1996). Crump (1994) reported that the dose response between benzene exposure and leukemia mortality in the Pliofilm cohort was due to AMLs and consideration of other types of leukemia diluted the dose response. Epidemiologic data have suggested that a threshold of at least 200 ppm-years of benzene exposure in air is necessary to increase the risk of AML (Raabe and Wong, 1996; Crump, 1994).

EPA (1997) states that the primary type of lymphohematopoietic cancer induced by chemicals and radiation in humans is myeloid leukemia, that administration of human leukemia-inducing agents in mice results in more lymphohematopoietic tumors, and that mice are more responsive than rats to the induction of lymphohematopoietic neoplasia following administration of human leukemogens. Additionally, the origin of the resulting neoplasms in mice and rats are primarily lymphoid.

Acute lymphocytic leukemia (ALL) is the most common type (approximately 75%) of leukemia in young children. It can also affect adults, especially those age 65 and older. Malignancies in this disease can arise from either T-cell or B-cell lymphocytes. The majority (~80%) of ALL cases arise from the B-cell lymphocytes. The causes of ALL are not known, but experts believe that a combination of genetic and environmental factors are instrumental.

The ALL incidence rate peaks in children between the ages of two and three. Caucasian children are more likely to get ALL than African American children. Several genetic mutations associated with ALL have been identified. The majority of leukemias have genetic rearrangements, called translocations. A translocation occurs when some genetic material (genes) on a chromosome is altered, or moved, between a pair of chromosomes. The most common translocation in ALL is t(12;21), which represents a genetic shift between chromosome 12 and 21. It (t(12;21)) occurs in approximately 20-25% of ALL patients. Approximately 20% of adults and 5% of children with ALL have a genetic shift called Philadelphia (Ph) chromosome (t(9;22)).

Certain inherited diseases can increase the risk for leukemia. Children with Down's syndrome have a 20-fold increased risk of developing acute leukemia versus the general population.

Scientists are studying viruses and other infectious agents that may cause leukemia. For example, Kinlen and Balkwill (2001) compared childhood leukemia mortality in wartime and

postwar cohorts of Orkney and Shetland children. In Orkney and Shetland (the UK's northernmost islands), during World War II, local people were outnumbered by servicemen stationed there in case of a northern invasion. Childhood leukemia increased 3.6-fold, (p=0.001) in the wartime, but not in the postwar, cohort compared with national Scottish rates. Ross et al. (1999) investigated seasonal variations in the diagnosis of childhood cancer in the US. Overall there was not a significant seasonal variation for all childhood cancers combined. However for diagnosis-specific malignancies, there was a significant seasonal variation for ALL (peak in summer), rhabdomyosarcoma (peak in spring/summer), and hepatoblastoma (peak in summer). Additionally, when cancer cases were evaluated for latitudes greater than 40 degrees north, seasonal patterns were apparent only for ALL and hepatoblastoma. Reno, NV and Fallon, NV are between 39 and 40 degrees north.

Some viruses called retroviruses cause leukemia in animals. One virus associated with human leukemia is human T-cell lymphtrophic virus type-1 (HTLV-1), which may cause some cases of adult acute T-cell leukemia. A virus causing ALL has not been found.

Exposure Considerations:

The general population can be exposed to jet fuel (JP-8 and Jet A) vapors and emissions in the air. EPA has conducted air quality studies near several commercial airports and in certain cities. The EPA (1993) reported that aircraft engines are major source contributors for several volatile organic compounds (1,3-butadiene, formaldehyde, and benzene) and polycyclic organic compounds/particulate matter.

People living near airports or military air bases may also be exposed to higher levels of jet fuel vapors than the general population. People are exposed to many of the same jet fuel chemicals at gasoline stations, in their garage, while using lawn mowers and other gasoline-powered tools, and near areas with vehicle traffic. Additionally, some people use kerosene heaters during cold weather seasons, which would also result in exposure to jet fuel chemicals (JP-8 and Jet A are >98% kerosene). People working in military and commercial jet fuel industries, where jet fuels are used, may be exposed to higher levels than the general population.

A chemical comparison of jet fuels and gasoline indicates that gasoline has a much higher benzene content (see C-1). Additionally, the difference between military and commercial jet fuel is in the performance enhancing additives. Some of the additives are formulated with hydrocarbons found in fuel (e.g., ethylbenzene and xylene), but none of the additives are considered leukemogenic. In general, it appears that as a source of air pollution in urban areas, motor vehicle emissions contribute more volatile organic compounds (including benzene, 1,3-butadiene and formaldehyde) than jet engine emissions.

Table D-1: General Chemical Comparison between JP-8, Jet A and Unleaded Gasoline.			
Chemicals	**JP-8**	**Jet A**	**Unleaded Gasoline**
Benzene	**> 0.02%**	**>0.02%**	**> 1.0%**
Primary constituents	**>98% kerosene (C7 through C18 range)**	**>98% kerosene (C7 through C18 range)**	**>98% refined hydrocarbons (C4 through C12 range)**
Additives (combined typically <0.2% by volume)	**antioxidants, metal deactivators, static dissipator, corrosion inhibitors, fuel system icing inhibitors, octane enhancers, ignition controllers, detergents & dispersants**	**antioxidants, metal deactivators, static dissipator, corrosion inhibitors, fuel system icing inhibitors, octane enhancers, ignition controllers, detergents & dispersants**	**antioxidants, metal deactivators, static dissipator, corrosion inhibitors, fuel system icing inhibitors, octane enhancers, ignition controllers, detergents & dispersants**

Exposure to benzene occurs during vehicle refueling. However, the exposure level can vary greatly depending on the environmental conditions and filling procedure. Exposure concentrations for benzene during vehicle refueling ranged from approximately 1.5 ppb to 1.3 ppm (Smith, 1999).

Ambient concentrations of benzene range from 2-19 ug/m3, with higher levels in urban areas (Wallace, 1996). Because approximately 85% of atmospheric benzene is from mobile sources (motor vehicles, airplanes,...), higher concentrations are often detected inside motor vehicles and adjacent to major roadways (Egeghy, 2000). Egeghy et al. (2000) indicated that benzene concentrations can be 3-8 times higher inside vehicles than in ambient air and that the mean concentration of benzene in breath before refueling was 8.6 ug/m3. The mean level of benzene in breath immediately after refueling was 160 ug/m3. Interestingly, the reported background levels of benzene in breath of nonsmokers ranged from 0.8 to 5.3 ug/m3.

Aircraft activity considerations:

Aircraft activity and the resulting ground level emissions are defined by the landing and takeoff cycle (LTO). The LTO cycle operation modes are defined by standard power settings for aircraft. An LTO cycle is comprised of five components: approach, taxi/idle-in, taxi/idle-out, takeoff, and climbout (EPA, 1999). Generally, volatile organic compound emissions rates are highest when engines are operating at low power, such as when idling or taxiing. Taxi/idle time depends on airport specific operational procedures, and would generally be less at a military airbase.

In a U.S. Navy report (2000), hazardous pollutants from aircraft engine test cells were estimated. It was reported that approximately 94% of the total hazardous air pollutants emitted were formed during the idle mode. Interestingly, the idle mode only represented approximately 10% of the total fuel used during the engine test.

Table D-2: Comparison of aircraft activity (landing and take off cycle (LTO/year)) at three airports in the United States.

Fallon Naval Air Station	Reno/Tahoe International Airport	Chicago Midway Airport	Chicago O'Hare International Airport*
<50,000 LTO/year**	**>130,000 LTO/year**	**>300,000 LTO/year**	**>800,000 LTO/year**

*Chicago O'Hare International Airport the one of the busiest airports in the world.
**This does not include "touch and go" operations.

A 1993 EPA study of the cancer risks attributed to air pollution in Southwest Chicago reported that Chicago's Midway Airport (approximately 300,000 LTO/year) was in the top five pollutant source contributors. Road vehicle emissions were the number one contributor, with emissions from Chicago's Midway Airport ranking number five. In general this means that cars, trucks, buses and trains are the major contributors of carcinogens in Southwest Chicago (approximately 25% of the estimated cancer risk). Chicago's Midway Airport represented approximately 10% of the estimated cancer risk with road vehicles representing 25% (EPA, 1993). Table D-2 provides a comparison of the relative volume of traffic at Chicago O'Hare, NASF and Reno/Tahoe International Airport.

The Illinois EPA (IEPA) recently reported that emissions from Chicago O'Hare International Airport (one of the world's busiest airports) have an impact on air quality in adjacent communities, but that the impact did not result in levels higher than those found in a typical urban environment (IEPA, 2002).

Cancer Incidence near airports:

Most of the published hypothetical cancer risks associated with airports have been based on extrapolated probabilities to known carcinogens emitted (measured or estimated) from airplanes. Two studies investigated the cancer incidence of communities near airports. The Illinois Department of Pubic Health (2001) examined actual cancer incidence observed in communities near Chicago's O'Hare and Midway airports and the Washington State Department of Health (1999) similarly investigated Seattle's SeaTac airport. Both studies found no evidence to substantiate a clear and observable elevation of cancer cases among communities residing close to airports.

One would expect air concentrations of airplane and vehicle emissions to be greater near these airports as compared to the Fallon, NV area. The results of these epidemiologic studies suggest that cancer and leukemia rates associated with airplane emissions would not be elevated in the areas adjacent to the Fallon Naval Training Station.

Exposure to Chemical Mixtures:

ATSDR considered interactive effects (cumulative, additive, synergistic, and antagonistic) of chemicals following exposure to multiple chemicals to the extent of the scientific knowledge in this area. ATSDR has reviewed the scientific literature surrounding chemical interactions and noted that if the estimated exposure doses for individual contaminants detected at the site are below doses shown to cause adverse effects, then ATSDR considers that the combined effect of multiple chemicals is not expected to result in adverse health effects. Several animal and human studies (Berman et al. 1992; Caprino et al. 1983; Drott et al. 1993; Harris et al. 1984) have reported thresholds for interactions. Studies have shown that exposure to a mixture of chemicals is unlikely to produce adverse health effects as long as components of that mixture are detected at levels below the NOAEL for individual compounds (Seed et al. 1995; Feron et al. 1995). Additionally the absence of interactions at doses 10-fold or more below effect thresholds have been demonstrated by Jonker et al. (1990) and Groten et al. (1991). Specifically, in two separate subacute toxicity studies in rats (Groten et al. 1997; Jonker et al. 1993), adverse effects disappeared altogether as the dose was decreased to below the threshold level. Specific to fuel related exposures, ATSDR's review of physiologically based pharmacokinetic model predictions indicate that toluene, ethylbenzene, and xylene are not expected to influence (no interaction) the hematotoxic and carcinogenic effects of benzene at exposure concentrations below approximately 20 ppm of each component (ATSDR, 2002). For carcinogens, the interactions are more difficult to quantify at environmental doses because at the lower doses observed from environmental exposure a large study group (humans or animals) is needed for statistical significance. In an animal study, Takayama et al. (1989) reported that 40 substances tested in combination at 1/50 of their cancer effect level (CEL) resulted in an increase in cancer. However, Hasegawa et al. (1994) reported no increase in cancer when dosing animals at 1/100 of the CEL for 10 compounds. It should be noted that typical environmental exposures to chemicals (non-carcinogens and carcinogens) are greater than 1000 times below laboratory-induced health effect thresholds.. In a review of a recently released 1970s study on binary mixtures of carcinogens in rats, Gough (2002) reported that testing chemicals in pairwise combinations produced no convincing evidence for synergistic carcinogenic interactions and by contrast, the same tests produced several examples of antagonism.

Summary:

The majority of leukemia cases (15/16) in Fallon, NV are the acute lymphocytic leukemia (ALL) type. This would suggest that these leukemias resulted from something other than exposure to benzene, since benzene related leukemia is predominantly of the AML type. A review of the chemical composition of jet fuel (JP-8 and Jet A) found no other compounds, including

additives, that are considered to cause leukemia. Incomplete combustion of a variety of fuels, including wood, gasoline, tobacco, gasoline, diesel fuel and jet fuel produces 1,3-butadiene. An association between 1,3-butadiene and lymphatic leukemia has been reported in styrene-butadiene workers at levels higher than that found in ambient air adjacent to an airport. Based on several air toxic compound investigations surrounding airports, more benzene, 1,3-butadiene, and formaldehyde are produced from vehicles than airplanes. Based on ATSDR's review, it appears that exposure to emissions from airplanes (commercial and military) in the Fallon, NV area is not responsible for the ALL reported in the community.

References:

ATSDR: Case Studies in Environmental Medicine - Benzene Toxicity. April 2000. ATSDR Publication Number: ATSDR-HE-CS-2001-0003.

ATSDR: Interaction Profile for: benzene, toluene, ethylbenzene, and xylenes (BTEX). Atlanta, GA: US Department of Health and Human Services; DRAFT for Public Comment, May 2002.

ATSDR: Toxicological Profile for Jet Fuels (JP-5 and JP-8). Atlanta, GA: US Department of Health and Human Services; August 1996.

Berman E, House DE, Allis JW, et al. 1992. Hepatotoxic interactions of ethanol with allyl alcohol or carbon tetrachloride in rats. J Toxicol Environ Health 37(1): 161-176.

Caprino L, Borrelli F, Anonetti, et al. 1983. Sex-related toxicity of somatostatin and its interaction with pentobarbital and strychnine. Toxicol Lett 17:145-149.

Childers JW, Witherspoon CL, Smith LB, and Pleil JD. 2000. Real-time and integrated measurement of potential exposure to particle-bound polycyclic aromatic hydrocarbons (PAHs) from aircraft exhaust. Environ Health Perspect. 108(9):853-862.

Crump KS. 1994. Risk of benzene-induced leukemia: a sensitivity analysis of the piloform cohort with additional follow-up and new exposure estimates. J Toxicol Environ Health 42:219-242.

Drott P, Meurling S, Gebre-Medhin M. 1993. Interactions of vitamins A and E and retinol-binding protein to healthy Swedish children---evidence of thresholds of essentiality and toxicity. Scand J Clin Lab Invest 53:275-280.

Egeghy PP, Tornero-Velez R, and Rappaport SM. 2000. Environmental and biological monitoring of benzene during self-service automobile refueling. Environ Health Perspect. 108(12):1195-1202.

EPA. 1993. Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southwest Chicago. Final Summary Report. Submitted to: U.S.EPA Region 5 Air and Radiation Division by ViGYAN. EPA Contract No. 68-D0-0018. April 1993.

EPA. 1997. Chemical and Radiation Leukemogenesis in Humans and Rodents and the Value of Rodent Models for Assessing Risks of Lymphohematopoietic Cancers. National Center for Environmental Assessment-Washington Office. Office of Research and Development. EPA/600/R-97/090. May 1997.

EPA. 1998. Health risk assessment of 1,3-butadiene. National Center for Environmental Assessment. Office of Research and Development. NCEA-W-0267. January 1998.

EPA. 1999. Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft. EPA420-R-99-013. April 1999.

Feron VJ, Groten JP, van Zorge JA, Cassee FR, Jonker D, van Bladeren PJ. (1995). Toxicity studies in rats of simple mixtures of chemicals with the same or different target organs. Toxicol Lett, 82-83, 505-512.

Gough M. 2002. Antagonism-no synergism-in pairwise tests of carcinogens in rats. Regulatory Toxicology and Pharmacology, 35, 383-392.

Groten JP, Schoen ED, van Bladeren PJ, Kuper CF, van Zorge JA, Feron VJ. (1997). Subacute toxicity of a mixture of nine chemicals in rats: detecting interactive effects with a fractionated two-level factorial design. Fundam Appl Toxicol, 36(1), 15-29.

Groten JP, Sinkeldam EJ, Muys T, Luten JB, van Bladeren PJ. (1991). Interaction of dietary Ca, P, Mg, Mn, Cu, Fe, Zn and Se with the accumulation and oral toxicity of cadmium in rats. Food Chem Toxicol, 29(4), 249-258.

Harper CC, Faroon O, and Mehlman MA. 1993. Carcinogenic effects of benzene as a major component of gasoline and jet fuels. In E.J. Calabrese and P.T. Kostecki, eds., Hydrocarbon Contaminated Soils: Volume III. Lewis Publishers. 215-241.

Harris LW, Lennox WJ, Talbot BG, et al. 1984. Toxicity of anticholinesterases: Interactions of pyridostigmine and physostigmine with soman. Drug Chem Toxicol 7:507-526.

Harris DT, Sakiestewa D, Robledo RF, and Witten M. 1997a. Immunological effects of JP-8 jet fuel exposure. Toxicol Ind Health. 13(1): 43-55.

Harris DT, Sakiestewa D, Robledo RF, and Witten M. 1997b. Short-term exposure to JP-8 jet fuel results in long-term immunotoxicity. Toxicol Ind Health. 13(5): 559-570.

Harris DT, Sakiestewa D, Robledo RF, Young RS, and Witten M. 2000. Effects of short-term JP-8 jet fuel exposure on cell-mediated immunity. Toxicol Ind Health. 16(2): 78-84.

Hasegawa R, Miyata E, Futakuchi M, Hagiwara A, Nagao M, Sugimura T, et al. (1994). Synergistic enhancement of hepatic foci development by combined treatment of rats with 10 heterocyclic amines at low doses. Carcinogenesis, 15(5), 1037-1041.

IEPA. 2002. Final Report: Chicago O'Hare Airport Air Toxic Monitoring Program June-December, 2000. Illinois Environmental Protection Agency, Bureau of Air. May 2002.

Illinois Department of Public Health. 2001. Cancer Incidence in Populations Living Near Chicago O'Hare and Midway Airports, Illinois 1987-1997. November 2001. <http://www.idph.state.il.us/about/epi/iscrrpt.htm> (As of 6/24/2002).

Irwin RJ, VanMouwerik M, Stevens L, Seese MD, and Basham W. 1997. Environmental Contaminants Encyclopedia: Jet Fuel 8. National Park Service, Water Resources Division, Fort Collins, Colorado.

Jonker D, Woutersen RA, van Bladeren PJ, Til HP, Feron VJ. (1993). Subacute (4-wk) oral toxicity of a combination of four nephrotoxins in rats: comparison with the toxicity of the individual compounds. Food Chem Toxicol, 31(2), 125-136.

Jonker D, Woutersen RA, van Bladeren PJ, Til HP, Feron VJ. (1990). 4-week oral toxicity study of a combination of eight chemicals in rats: comparison with the toxicity of the individual compounds. Food Chem Toxicol, 28(9), 623-631.

Kinlen LJ, Balkwill A. 2001. Infective cause of childhood leukaemia and wartime population mixing in Orkney and Shetland, UK. The Lancet: Volume 357: 858.

McInturf SM, Bekkedal MY, Ritchie GD, Nordholm AF and Rossi J. 2001. Effects of repeated JP-8 jet fuel exposure on eyeblink conditioning in humans. Abstract. The Toxicologist. 60(1): 555.

Mi HH, Lee WJ, Chen SJ, Lin TC, Wu TL, and Hu JC. 1998. Effect of gasoline additives on PAH emission. Chemosphere. 36(9): 2031-2041.

Pleil JD, Smith LB, Zelnick SD. 2000. Personal exposure to JP-8 jet fuel vapors and exhaust at air force bases. Environ Health Perspect. 108(3):183-192.

Raabe GK, and Wong O. 1996. Leukemia mortality by cell type in petroleum workers with potential exposure to benzene. Environ Health Perspect 104(6):1381-1392.

Ritchie GD, Bekkedal MY, Bobb AJ, and Still KR. 2001a. Biological and Health Effects of JP-8 Exposure. Report No. TOXDET 01-01. Naval Health Research Center Detachment (Toxicology), Wright-Patterson Air Force Base, Ohio.

Ritchie GD, Still KR, Alexander WK, Nordholm AF, Rossi J, and Mattie DR. 2001b. A review of the neurotoxicity risk of selected hydrocarbon fuels. J Toxicol Environ Health, B 4: 101-191.

Rogers, D. 2001. Electronic mail correspondence between Captain Roy Rogers (NASF) and Mary Ann Simmons (Navy Environmental Health Center). August 5, 2002.

Seed J, Brown RP, Olin SS, and Foran JA. (1995). Chemical mixtures: Current risk assessment methodologies and future directions. Regul. Toxicol. Pharmacol, 22, 76-94.

Smith RG. 1999. A study on benzene exposure during vehicle refueling. Maxxam Report#: 9900387 for the Health Protection Branch, Health Canada. Contract #: CCME#: 989-040. April 1999.

Smith LB, Bhattacharya A, Lemasters G, Succop P, Puhala E, Medvedovic M, and Joyce J. 1997. Effect of low-level exposure to jet fuel on postural balance of US Air Force personnel. J Occup Environ Med. Jul;39(7): 623-632.

Takayama S, Hasegawa H, Ohgaki H. (1989). Combination effects of forty carcinogens administered at low doses to male rats. Jpn J Cancer Res, 80(8), 732-736.

Ullrich SE. 1999. Dermal application of JP-8 jet fuel induces immune suppression. Toxicol Sci. 52(1): 61-67.

Ullrich SE and Lyons HJ. 2000. Mechanisms involved in the immunotoxicity induced by dermal application of JP-8 jet fuel. Toxicol Sci. 58(2): 290-298.

U.S. Navy. 2000. Hazardous Air Pollutants from Department of Defense Aircraft Engine Test Cells: Best Estimates. Aircraft Environmental Support Office, Naval Aviation Depot-North Island, San Diego, CA. AESO Report No. 2001-7. December 2000.

Wallace L. 1996. Environmental exposure to benzene: An update. Environ Health Perspect 104(Suppl 6):1129-1136.

Washington State Department of Health. 1999. Progress Report: Cancer Cluster Investigation, SeaTac International Airport. Updated February 1999, Updated December 1999, Updated March 2000. <http://www.metrokc.gov/health/phnr/eapd/reports/cancer/> (as of 6/26/02).

Wolfe RE, Kinead ER, Feldmann ML, Leahy HF, and Jederberg WW. 1997. Acute toxicity evaluation of JP-8 jet fuel and JP-8 jet fuel containing additives. Govt. Reports Announcements & Index (GRA&I), Issue 09.