Health Consultation

CONTAMINANT ACCUMULATION POTENTIAL
IN PLANTS AND ANIMALS
USED BY THE
AROOSTOOK BAND OF MICMAC INDIANS
AT THE
FORMER LORING AIR FORCE BASE

LIMESTONE, AROOSTOOK COUNTY, MAINE

EPA FACILITY ID: ME9570024522

SEPTEMBER 30, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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BACKGROUND

Purpose and Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) developed this health consultation to address concerns expressed by the Aroostook Band of Micmac Indians (referred to as the Micmac Tribe) about the safety of using plant and animal resources from the Loring Air Force Base (LAFB) lands recently transferred to the Tribe or to adjacent properties that the Tribe may use for traditional practices. With input from representatives from the Micmac Tribe, ATSDR has prepared this health consultation. This evaluation is based on a review of the scientific literature specifically pertaining to the accumulation potential of contaminants in plants, fish, and wildlife. It is important to note that ATSDR did not conduct an exhaustive review of all the scientific literature. The objective was to provide perspective about whether the contaminants of concern identified during environmental monitoring efforts at LAFB are likely to accumulate in the plant and animal resources traditionally used by the tribe.

In March 1999, ATSDR released a public health assessment (PHA) for LAFB. In the PHA, ATSDR evaluated ways in which people could come in contact with contaminants released from LAFB and whether that contact was likely to result in adverse health effects. As part of the PHA process, ATSDR compiled and addressed community concerns related to the site. After release of the PHA, representatives of the Micmac Tribe expressed concerns about the potential of certain plant or animal species to accumulate contaminants in soil, surface water, and sediment previously released during LAFB-related activities (ATSDR 1999a).

The Micmac Tribe in the vicinity of LAFB currently lists more than 16,000 registered Micmac members, but their actual membership in both Canada and the United States is much higher, perhaps as many as 25,000. Canada has 28 separate groups of Micmac. But only one Micmac tribe is currently recognized in the United States. The 500-member Aroostook Band of Micmac in northern Maine received state recognition in 1973 and federal status in 1991 (Figure 1).

Loring Air Force Base History

LAFB, originally named Limestone Air Force Base, was activated in February 1953 as a Strategic Air Command base and manned by the 42nd Bombardment Wing. LAFB closed on September 30, 1994, pursuant to the Defense Base Realignment and Closure Act of 1990, following recommendations from the Defense Base Realignment and Closure (BRAC) Commission.

The closed base is located in Aroostook County at the northeastern tip of Maine, about two miles northwest of the town of Limestone, eight miles northeast of Caribou, and five miles west of the border of New Brunswick, Canada. The site covers an area of approximately 9,400 acres (14.6 square miles) in the lower Aroostook River Basin and is bounded on the north and northwest by the townships of Caswell and Connor, respectively. The site is in a rural area with an approximate population of 1,500 within a one–mile radius.

The property that was previously LAFB was designated the Loring Commerce Centre (LCC) and divided into parcels for transfer to other government and commercial organizations under guidelines set forth by BRAC legislation. The Air Force Real Property Agency (AFRPA) has transferred all property; 58 percent of the property has been transferred to other federal agencies and 42 percent of the property going to public organizations and non-federal (state and local) government agencies. AFRPA, in concert with the United States Environmental Protection Agency (USEPA) and the Maine Department of Environmental Protection, is coordinating remedial investigations and actions to comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and state solid waste and underground storage tank requirements. These requirements are to ensure no hazards remain that could adversely affect persons or the environment during subsequent use of the property (AFBCA 1996).

Before the currently established environmental regulations, previously accepted hazardous material handling and disposal practices resulted in environmental contamination at various areas on base. Hazardous wastes generated on the base included waste oils, fuels cleaned from aircraft and vehicles, spent solvents, polychlorinated biphenyls (PCBs), and pesticides. Historically, wastes have been burned or buried in landfills. As a result, LAFB was included on the USEPA's National Priorities List in February of 1990. The Air Force conducted an initial assessment of potentially contaminated areas beginning in 1983 and identified a number of Installation Restoration Program (IRP) Sites. There were over 50 IRP sites on the LAFB property, divided among 15 Operable Units (OUs). Installation-wide investigations and site restorations continue under this program, although most clean up actions have been completed.

Previous ATSDR Evaluations

ATSDR personnel conducted site-visit evaluations at LAFB during the periods September 17-20, 1991, July 26-28, 1994, and May 13-15, 1997. ATSDR released four health consultations that addressed specific contamination and public health issues. The 1991 health consultation evaluated groundwater concerns and recommended continued monitoring and hydrologic characterization of the site to ensure that drinking water wells off base did not become contaminated from on-base releases. In 1994, ATSDR released two health consultations to address radiological and chemical contamination related to the on-base power plant. The fourth health consultation in 1997 addressed the presence of volatile organic compound (VOC) contaminants in sediments and surface water at the Flight Line Drainage Ditch (FLDD) and the Power Plant Drainage Pipe (PPDP) and determined that air-quality in the on-base residential areas was not adversely impacted.

In 1999, ATSDR released a public health assessment that evaluated the environmental information at IRP sites within the various OUs and assessed the potential for human exposure in each case. Additionally, ATSDR evaluated six specific exposure situations 1) catching fish from area waters, 2) drinking water from area water wells, 3) wading and swimming in on-site waterways, 4) future land use by new occupants, 5) contact with water at Limestone Stream, and 6) volatile contaminants in the air. ATSDR determined that contamination released from LAFB did not present a public health hazard based on the assumptions made about exposure frequency, duration, and contacted media given the fish advisory and groundwater well restrictions in place. ATSDR's public health assessment for Loring Air Force Base can be found at http://www.atsdr.cdc.gov/HAC/PHA/loring/laf_p1.html

REUSE OF FORMER LAFB PROPERTY

Reuse Issues

LAFB property transfer has been completed. The former LAFB property was partitioned into sections A-F with numerical subsets noting non-contiguous areas (Figure 2). Clean up continues on a few parcels that remain in Air Force control. Additionally, institutional controls are in place at some parcels where complete clean up was not possible due the nature of the contamination or financial constraints. This health consultation addresses the contaminants that may remain in soil, sediment, or surface water at very low levels, but which may be of concern for animals and humans high up the food chain. On the basis of information gathered during our investigations and concerns expressed by Tribal representatives, ATSDR has reviewed the most current environmental sampling data for parcels of interest at LAFB, compiled information from the scientific literature related to specific factors that increase or reduce the potential for the selected contaminants of concern to accumulate in plant and animal species.

Areas of Concern

Parcel D (including D-1 and subsets) contains approximately 608 acres that has been transferred to the Bureau of Indian Affairs, with subsequent transfer planned to the Micmac Tribe. Parcel E (including E-1 and subsets) contains 4,112 acres that have been transferred to the Department of the Interior, U.S. Fish and Wildlife Service. Both areas may be used by the Micmac Tribal members. Some areas within these parcels have be designated as having use restriction zones (URZ) due to soil contaminant issues and groundwater management zones (GMZ) where groundwater use is restricted. Figure 2 shows the parcels and the current institutional controls. Institutional controls within Parcel D include the Industrial Area GMZ 1, Fuel Tank Farm GMZ 2, and URZ, and the Fly Ash Disposal Site URZ.

As part of the Air Force environmental investigations (CERCLA, SARA, and IRP), base-wide surface water, sediment, and associated biological sampling at the former LAFB was designated as OU 13. OU 13 overlaps large portions of Parcels D and D-1. Operable Unit 13 includes brooks, streams, ditches, lakes, ponds, and wetlands across approximately 30 square miles of watershed. Because of the size of the area and the number of drainage systems involved, Operable Unit 13 was subdivided into three primary study areas. The study areas are the three major watersheds that comprise the geographic area in and around the LAFB and include: Wolverton Brook/Brandy Brook Greenlaw Brook, and Butterfield Brook/Limestone Stream (ABBES 1997a).

These brooks receive runoff from the western portion of LAFB as well as off-base areas west of the base, and flow south-westerly into Little Madawaska River. The Little Madawaska River is a relatively broad, but shallow, river located approximately 1.5 miles west of the base boundary. The Little Madawaska River flows south approximately 7 miles and merges with the Aroostook River. The Butterfield Brook also flows east of the base to Aroostook River (MWH Americas 2005).

Sediment, surface water, and some fish data are available to evaluate risks that might be posed by contamination in brooks, streams, and ponds at LAFB. Much of this information is contained in the Base-wide Surface Water/Sediment Operable Unit (OU13) Remedial Investigation Report. The Air Force calculated acceptable risks and corresponding soil and sediment cleanup levels based on future land-use scenarios (residential, recreational, industrial/commercial) as defined in the Record of Decision for Disposal of LAFB, Maine(AFBCA 1996). Using environmental sampling data as a guide, AFRPA contractors performed removal actions to comply with state and federal clean-up standards. In the 1999 public health assessment, ATSDR concurred with the recommendation for people to comply with the established fishing advisories and restrictions for groundwater use and determined that wading and swimming did not pose a health hazard to adults or children (ABBES 1997a, 1997b).

Wolverton Brook and Brandy Brook are southwestwardly flowing tributaries of the Little Madawaska River, which itself flows south toward its confluence with the Aroostook River southeast of the town of Caribou. Wolverton Brook and Brandy Brook are located along the western side of LAFB and is approximately 4,600 acres in size; with about 700 acres within LAFB boundaries (ABBES 1997a).

The flightline drainage ditch is located in the south-central part of the base, west of the flight line area and south of the nose-dock area. The flightline drainage ditch is an unlined, drainage channel that is 20 to 25 feet wide and approximately 2,500 feet long. The flightline drainage ditch extends from a triple-culvert headwall and drains the flight line area. It passes through the Spill Containment Facility continues through the flightline drainage ditch wetland, and flows into the East Branch of Greenlaw Brook, which joins the West Branch of Greenlaw Brook before the confluence of Greenlaw Brook with the Little Madawaska River. The spill containment facility is an oil-water separator located on the western bank of the lower end of the flightline drainage ditch and upstream of the flightline drainage ditch wetland. Spill Containment Facility sediment "hot-spots" were excavated and properly disposed of during OU13 remediation (ABBES 1997b).

The January 8, 1997, ATSDR Health Consultation for LAFB recommended that wading in the flightline drainage ditch be prohibited due to an increased exposure risk attributable to levels of PCBs found in water sampled from the flightline drainage ditch and wetland area. A remedial action was undertaken in the summer of 1997 to excavate areas of the flightline drainage ditch wetland, and East Branch of Greenlaw Brook to remove PCBs and other contaminants. Work was completed on the flightline drainage ditch and flightline drainage ditch wetland during 1997. Post remediation sampling of sediment and water by AFRPA contractors confirmed that current PCB levels were at or below the acceptable concentrations of 1 ppm PCBs in stream sediment and 5 ppm in flood-plain sediment. The remediation plan is outlined in the Record of Decision for OU13. All remaining excavation work was completed by the end of 1998 and long-term monitoring has been in place to assess the effectiveness of the remediation process (ABBES 1997b).

East Branch of Greenlaw Brook begins in a wetland south of the Fuels Tank Farm, flowing west for about 2,500 feet to its confluence with the flightline drainage ditch wetland drainage. The East Branch of Greenlaw Brook combines with the West Branch of Greenlaw Brook and then eventually merges with the Little Madawaska River. A total of 29 IRP sites are located near the East Branch of Greenlaw Brook, and several are known to have contributed contaminants, including the Fuels Tank Farm, Base Laundry, Refueling Maintenance Shop Area, and Coal Storage Pile/Fly Ash Area. The East Branch of Greenlaw Brook has also been impacted by contaminants flowing downstream from the flight line area via the flightline drainage ditch and wetland. Primary contaminants in the East Branch of Greenlaw Brook include polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), chlorinated pesticides (including DDT metabolites and chlordane), PCBs, and lead, among other inorganics/metals (ABBES 1997a).

The West Branch of Greenlaw Brook begins in a wetland north of the flight line area, about 750 feet west of the base boundary. The West Branch of Greenlaw Brook flows south onto base property, passes west of the Quarry and Nose Dock area, and forms Malabeam Lake. Upon leaving the lake the watercourse forms and then exits Chapman Pit Pond. About 3.4 miles from its source the West Branch of Greenlaw Brook merges with the East Branch of Greenlaw Brook. The West Branch of Greenlaw Brook Study Area contains five IRP sites, including the Quarry, the Nose Dock Area, the Base Exchange Service Station, Landfill 1, and the Chapman Pit Disposal Area. Green Pond, beaver ponds, and several drainage ditches and wetlands are also within this study area. The primary contaminants detected in the West Branch of Greenlaw Brook Study Area were PAHs, TPHs, and metals such as cadmium, lead, manganese, silver, barium, and zinc (ABBES 1997a).

Little Madawaska River flows south from the dam forming the Madawaska Reservoir and follows a course about 1.5 miles west of the LAFB boundary. Its tributaries include Wolverton, Brandy, and Greenlaw Brooks. The Little Madawaska River joins the Aroostook River a few miles south and east of the city of Caribou. Greenlaw Brook is the primary pathway carrying base-related contaminants toward the Little Madawaska River. However, chemical analysis of pre-design and OU13 Remedial Investigation samples of Greenlaw Brook sediments west of the culvert plunge pool under Sawyer Road showed concentrations of PCBs to be below the remediation goals of 1 ppm for stream sediments and 5 ppm for sediments or soil in the floodplain (ABBES 1997a).

Butterfield Brook flows south onto the eastern side of LAFB and into East Loring Lake, a 40-acre impoundment surrounded by the Weapons Storage Area. Willard Brook joins Butterfield Brook as the latter flows from East Loring Lake to Durepo Reservoir, an 80-acre, man-made water body just south of the base boundary. The flow from the reservoir is joined by Durepo Stream from the east to form Limestone Stream. Limestone Stream enters the Aroostook River 10 miles further south. There are a number of IRP sites within the Butterfield Brook/Limestone Stream Study Area that might contribute contaminants to surface water, including the Railroad Maintenance Site, Fire Training Area, Underground Transformer Site, and the 9,000 Debris Area. The Underground Transformer Site Wetland required excavation to achieve clean-up goals that meet state and federal standards (ABBES 1997a, 1997b).

Contaminants Identified at LAFB

On the basis of discussions with representatives of the Micmac Tribe, ATSDR has included discussion of the following contaminants: metals or inorganics — barium, cadmium, lead, mercury, silver, and zinc; pesticides — chlordane and DDT (DDD, and DDE); PCBs, PAHs, and petroleum compounds. Long-term monitoring of contaminants at OU 13 was initiated in 2001. Recent environmental sampling reported in the 2001 and 2003 long-term monitoring reports are presented in Tables 1 (surface water) and 2 (sediments) below. The primary contaminants in the

East Branch of Greenlaw Brook sediments include PAHs, benzo(a) pyrene; PCBs (PCBs may be reported as Arochlor 1260, which is a common trade name); pesticides, diesel range organics (DRO), and lead. PCBs and low levels of pesticides have also been detected in fish tissue samples collected in the East Branch of Greenlaw Brook. The primary contaminants in the West Branch of Greenlaw Brook include PAHs, lead, and zinc (ABBES 1997a).

Table 1: Surface Water Sampling Within Operable Unit 13 at LAFB

	Contaminant	Historical Max. Conc (ppb)	Recent Sampling (2001) (ppb)	Screening Value (ppb)
Flight Line Drainage Ditch (FLDD)	Lead	5	2.8	15[1]
East Branch of Greenlaw Brook (EBGB)	Tetrachloroethylene (PCE) Benzo(a)pyrene Lead	2J ND 3J	0.1 0.04 3.7	5[2] 0.2[3] 15[1]

Source: Woodlot Alternatives, Inc 2002

1 This screening value represents EPA's action level for lead in drinking water
2 This screening level represents EPA's maximum contaminant level (MCL) for PCE in drinking water
3 This screening value represents EPA's MCL for benzo(a)pyrene in drinking water

J = Estimated value
ND = Below method detection limit
Conc = concentration
Max = maximum
ppb = parts per billion

Table 2: Sediment Sampling Within Operable Unit 13 at LAFB						
	Contaminant	Historical Maximum Conc. (ppm)	Recent Sampling 2001 (ppm)	Recent Sampling 2003 (ppm)	Screening Value	Source of Screening Value
Flight Line Drainage Ditch (FLDD)	PAH -Benzo(a)pyrene	13 (floodplain)	0.2	NA	0.1	CREG
	PCBs (Aroclor 1260)	6.4 (stream)	0.46*	NA	0.32	RBC
	Chlordane (Total)	0.64 (stream)	0.005	NA	2	CREG
	4,4'- DDT/DDD/DDE	0.49 (floodplain)	0.01	NA	2	CREG
	DRO	NA	0.34	NA	100	ME NL
	Lead	474 (floodplain)	133	NA	400	EPA
East Branch of Greenlaw Brook (EBGB)	PAH -Benzo(a)pyrene	NA	0.04	NA	0.1	CREG
	PCBs (Aroclor 1260)	10 (stream)	0.54	0.17	0.32	RBC
	Chlordane (Total)	0.1 (stream)	ND	0.01	2	CREG
	4,4'- DDT/DDD/DDE	0.37 (stream)	0.01	0.04	2	CREG
	DRO	NA	50	NA	100	ME NL
	Lead	126 (stream)	15.1	NA	400	EPA
West Branch Greenlaw Brook (WBGB)	PAH -Benzo(a)pyrene	NA	NA	NA	0.1	CREG
	PCBs (Aroclor 1260)	NA	ND	NA	0.32	RBC
	Chlordane (Total)	NA	ND	NA	2	CREG
	4,4'- DDT/DDD/DDE	NA	ND	NA	2	CREG
	DRO	NA	10	NA	100	ME NL
	Lead	427	13.1	NA	400	EPA
	Zinc	952	96.1	NA	200,000	EMEGc
Butterfield Brook	PAH -Benzo(a)pyrene				0.1	CREG
	PCBs (Aroclor 1260)	1	ND	NA	0.32	RBC
	Chlordane (Total)	1.3	ND	NA	2	CREG
	4,4'- DDT/DDD/DDE	0.18	ND	NA	2	CREG
	DRO	NA	4.6	NA	100	ME NL
	Lead	302	8*	NA	400	EPA
	Zinc	201	106	NA	200,000	EMEGc
	Zinc	201	106	NA	200,000	EMEGc

Source: Woodlot Alternatives, Inc 2002; 2004

* = estimated value
ND = Below method detection limit
NA = Not Available;
CREG = ATSDR's cancer risk evaluation guide
RBC = EPA's Region III risk based concentration
EMEGc = ATSDR's chronic Environmental Media Evaluation Guide
DRO = Diesel range organics (METHOD Corrected)
ME NL = State of Maine notification level

Note: Cadmium, barium, silver, and mercury were not analyzed for in sediment at any sampling locations
Zinc was only analyzed at the West Branch of Greenlaw Brook and Butterfield Brook

Screening Values used here as perspective. They are considered to be "overly protected" and assume a daily exposure (ingestion) for 30 or 70 years without deleterious health effects.

Under environmental programs, the Air Force sampled surface water, sediment, soil, groundwater, and fish for contaminants with concurrences by Maine Department of Environmental Protection and USEPA. The Air Force has completed or is in process of cleaning up sites that have contamination at levels considered to pose unacceptable risk to adults or children by way of direct contact. Where cleanup is ongoing or contaminants remain, land use restrictions have been established.

Unrestricted areas do not contain contaminants that would pose a health hazard to adults or children. However, concern has been expressed about low levels of residual contaminants that could be accumulated by plants and animals, concentrating up the food chain, and eventually used for food or for other purposes by people. Sampling for contaminants present in all the natural resources available to Tribal members would present a monumental task. Based on the current information and available sampling results, there is no evidence that chemicals are present at levels of health concern. Sampling to date has been conducted for surface water, groundwater, soil, and sediment; with limited sampling of plants and animals that may be utilized by locals.

In the sections that follow, ATSDR provides information compiled from various scientific sources to help individuals determine which plants and animals, and which specific parts of those resources, are known to accumulate contaminants. In this way, individuals can make informed decisions about their natural resource use and their health.

RESOURCE OF INTEREST: PLANTS

General Information

Native populations use plant materials for a wide variety of purposes. Subsistence use of such plant products as roots and tubers, stalks, leaves, berries, and nuts provide essential nutrients to native people. The use of plants for medicinal purposes is widespread, as is the use of tobacco. Tobacco, sweet grass, cedar, and sage have important religious and ceremonial significance. The use of grasses and other plant resources for basket, box, and tool making, textiles, matting, dyes, paints, and soaps also can be observed in the cultures of numerous Native American groups (DOI-BLM 2005).

The wide use of plant materials by the MicMac Tribe presents numerous exposure possibilities if plant resources are gathered from contaminated lands. Plants have the potential to accumulate contaminants from soils, surface waters and sediments. Contaminants may also be deposited on the surface of plants from pollutants that are circulated in the air. In addition, people who harvest plant resources may be exposed to contaminants through frequent contact with contaminated soils and sediments.

In general, plants do not bioaccumulate (the term bioaccumulation represents the process that takes place when chemicals accumulate in tissues at higher levels than are found in the environmental media they are exposed to) most contaminants as efficiently as animals since plants are at the bottom of the food chain. Contaminants accumulate in terrestrial vegetation by either 1) direct uptake (i.e., absorption) of contaminants from soil to the roots, 2) dry deposition on aerial parts (particle-bound or gaseous), or 3) wet deposition on aerial parts (particle-bound or solute). Aquatic plants accumulate most contaminants either in the root systems from sediments or from the surrounding water, with wet deposition and adherence to plant parts being more important than dry deposition.

Plant tissues may accumulate and store contaminants, especially certain metals (e.g., selenium and zinc) that provide nutrients to the plant. Under normal circumstances (e.g., non-contaminated soils), organic (e.g., pesticides, PCBs, and other chlorinated compounds) and inorganic (i.e., metals) contaminants are rarely found at concentrations in plant tissues that would pose a human health hazard (ATSDR 2003a; 2003b; ERG 2001). Heavy metals (i.e., metals with high molecular weights) such as lead, cadmium, and mercury may be present in trace amounts in plant tissues. However, these metals are usually not accumulated to edible portions of the plant at levels that would be of human health concern (ERG 2001).

A review of the scientific literature indicates that most plants do not contain chemical concentrations in their tissues that are higher than the contaminant levels in the soils that they grow on. In fact, when soils contain adequate plant nutrients and pH-balanced (i.e., not too acidic), metals and other contaminants are generally not absorbed much at all in plant tissues beyond the roots. There are, however, exceptions to this general statement regarding plant accumulation of contaminants. The information presented below is important to consider before deciding whether to harvest and use plant materials for foods, medicines, or other culturally important activities. Washing plants significantly reduces the amount of contaminants present on the outer plant tissues.

Factors that Influence the Accumulation of Contaminants

The availability of soil contaminants to plants is controlled by many factors. Soil pH is considered one of the most important factors controlling the plant's ability to bioaccumulate certain metals (e.g., cadmium, lead, and zinc). Soil pH is a measure of the acidity or alkalinity in the soil. Many heavy metals become more water soluble under acidic conditions. A soil pH is considered acidic if it is below 7.0 (7.0 is neutral). Any soil pH below 6.0 is considered strongly acidic (USDA 1998). Strongly acidic soil allows metals to be absorbed into the root system and distributed more readily throughout the plant (Dudka and Miller 1999). Soils at Loring are considered acidic and tend to take up metals more easily. Other important factors that influence the potential for plants to accumulate contaminants and contribute to human exposures include:

- The portion of the plant that is harvested — fruits and berries are less likely to accumulate contaminants from the soil because of physiological processes which prevent metals and some other contaminants from being distributed to the tops of plants. Contaminants can be deposited onto plant surfaces, but exposure can be minimized by washing and/or peeling the edible portions of the plant (ERG 2001);

- Phytoavailability — the extent that metals are available to be absorbed and taken up by plants. Some metals are used by the plant as nutrients and can be distributed throughout the shoots and leaves. Heavy metals are toxic to most plants, but those plants with higher tolerances for heavy metals tend to store them in the root cells and not in above ground portions of the plant (ERG 2001);

- Phytotoxicity —this occurs when the concentrations of contaminants in the edible plant harm or kill the plant. In most situations, plant growth is retarded and the phytotoxic effects are evident before the levels become harmful to humans. Plants exhibiting phytotoxicity have visible signs including yellowing of leaves; necrosis of leaf tips, stunting, low yields of fruits or vegetables, and eventual plant death. Common metals that exhibit phytotoxicity at levels below human health concern include zinc, copper, nickel, cobalt, and manganese (ERG 2001); and

- The bioavailability of metals — the extent to which plants store contaminants in a form that can be absorbed and metabolized by people.

Site Specific Information

Table 3 provides common plants used by the Micmac Tribe near LAFB.

Table 3. Common Native Plants Used by the Micmac Tribe		
Black Ash, White Ash	Wild raspberries	Sweet grass
Alders	Gooseberry / Currant	Goldthread root
White Spruce	Blueberry	Cattail
Poplar and Willow	Chokecherries	Sweet flag rhizome
Hazelnut	Fiddlehead ferns	Burdock roots and shoots
Note: Information for this table was provided by Fred Cory (Environmental Director for the Micmac Tribe) and Barbara Harper (Draft Provisional Exposure Factors for LAFB). The plant species listed in this table represent some of the more important species utilized by the Tribe and are found near LAFB. This is not meant to represent the only plant species that are utilized by the Micmac Tribe, only the most common ones.		

Potential for Contaminant Accumulation

Metals

When evaluating the potential for human exposure to metals from plant materials, it is important to make the distinction between the metals that are known to readily accumulate in plants and are essential for plant growth (e.g., zinc and magnesium) and those that are not readily taken up and are harmful to plants (e.g., lead and cadmium).

An important principle in plant physiology that influences the potential for human exposure from consuming edible plants is the soil-plant barrier. This barrier involves processes that typically prevent the accumulation of potentially toxic heavy metals. These metals are often toxic to plants at levels below which they are toxic to animals and humans. There are exceptions that reduce the effectiveness of the soil-plant barrier. One of the most important exceptions occurs under conditions where plants are deficient in phosphate. Without phosphates plants can readily accumulate certain metals (e.g., cadmium, selenium) into their tissues (ERG 2001).

A few species of metal accumulating plants commonly referred to as hyperaccumulators can tolerate high levels of certain metals. For example, alpine pennycress (Thlaspi caerulescens), common in the western part of the U.S., can concentrate cadmium in its leaves up to 1,500 ppm and zinc up to 30,000 ppm. These levels are between 100 and 1,000 times higher than typical concentrations observed in non-hyperaccumulator plants (Agricultural Research 2000). Willow commonly grows along streams or on river bottomlands where ground water is generally at shallow depth and readily available. Cadmium may concentrate in willow leaves and leaf buds to as much as 100 times the levels found in soil (Erdman et. al., 2003)

Under ideal circumstances, all plant materials could be sampled and the levels of contaminants in different portions of the plants measured. However, this type of sampling effort is time consuming, expensive, and generally not feasible. Researchers have developed alternative methods for estimating contaminant levels in plant tissues. Bioconcentration factors (BCFs) may be used to predict the accumulation of specific chemicals in plant or animal tissues based on the concentration of the chemicals in the surrounding environment. The BCF is defined as the concentration of the chemical in the plant/animal tissue at equilibrium divided by the concentration of the chemical in the medium being measured (e.g., soil, water).

The following metals were identified as contaminants of concern (COCs) during environmental sampling at LAFB. The metals are listed in order of highest potential to contribute to human exposure under various traditional exposure scenarios. When available, BCFs are presented for selected crops.

Cadmium — Many aquatic plants have the ability to accumulate cadmium, primarily in the roots, but also to some extent in the stem and leaves. An important factor affecting plant accumulation of cadmium is soil pH. The application of phosphate fertilizer and highly acidic soils are factors that contribute to the accumulation of cadmium from soil into plant tissues.

Some studies have shown that higher concentrations of lead in soil also increase the amount of cadmium taken up by some plant species. The highest concentrations of cadmium are typically found in leafy vegetables such as spinach and lettuce as well as tobacco, mushrooms, and some root vegetables.

Most research on cadmium accumulation in food crops indicates that the highest risk for cadmium exposure in the food chain is when there are insufficient levels of zinc in the soil. A deficiency in zinc in soil results in additional accumulation of available cadmium from soil (ERG 2001). Table 4a presents cadmium BCFs for selected crops. There are two plant species that are known to accumulate cadmium at much higher concentrations than other plants. Such plants are often referred to as "hyperaccumulators." The two known species of cadmium hyperaccumulators include penny cress (*Thlaspi caerulescen*s) and Brassicaceae cress (*Arabidopsis halleri).* These two plant species are able to accumulate greater than 100 ppm of cadmium in the leaves.

Table 4a:Cadmium Bioconcentration Factors for Selected Crops

Item	Sample Size	pH Range (Alkaline to acidic[1])	Range	Geometric Mean
Grains and cereals	14	8.0—4.4	0.002 —0.346	0.36
Potato	14	8.0—4.7	0.002 — 0.076	0.008
Leafy Vegetables	71	8.4—4.6	0.002 — 14.12	0.364
Legumes	14	7.7—5.1	0.002 — 0.054	0.004
Root Vegetables	25	8.0—4.6	0.002 — 1.188	0.064
Garden Fruits	19	7.1— 4.6	0.002 — 1.272	0.09
Sweet Corn	12	7.1—5.1	0.02 — 0.666	0.118
General (i.e. Unspecified)	(17 Studies) 155 Observations	NA	0.0107— 22.88	1.7 (AM)

Source: EPA 1996; USDOE 1998[general/unspecified]; USDA 1998

Note: The higher the BCF, the greater the accumulation in living tissue is likely to be.
AM=Arithmetic Mean
NA=Not Available

[1] Extremely acid 3.5 – 4.4; Very strongly acid 4.5 – 5.0; Strongly acid 5.1 – 5.5; Moderately acid 5.6 – 6.0
Slightly acid 6.1 – 6.5; Neutral 6.6 – 7.3; Slightly alkaline 7.4 – 7.8; Moderately alkaline 7.9 – 8.4

What studies have found: In plants grown in gardens that had been contaminated with silver mine waste material, the cadmium concentration was highest in the leaves (0.6-11.9 ppm), intermediate in the roots and tubers (0.5-3.6 ppm), and lowest in the fruit (<0.5-2.7 ppm). Soil contaminant levels ranged from 9.2 to 808 ppm (lead), from 0.2 to 14.2 ppm (cadmium), and from 8.4 to 484 ppm (zinc) (Boon and Soltanpour 1992). Additionally, studies that have measured cadmium in washed and unwashed lettuce leaves have demonstrated that washing lettuce leaves removed over 50 percent of the cadmium (Thornton 1992).

Lead — The soil-plant barrier is usually effective in limiting the amount of lead accumulated by plants. Small amounts of lead may be transferred from the soil into the roots of plants, but lead is not typically accumulated in high concentrations in the edible aboveground portion of the plant. This is generally due to the low solubility (ability for a substance to dissolve in water) of lead in the soil, which influence the mobility of lead within the plant. However, cessation of growth in late summer and fall may be accompanied by increased mobilization of lead from roots into the plant tops. Some of the important variations in plant accumulation of lead are due to plant age and species, organic matter content, soil phosphorus level, pH, soil texture, climate, topography, pollution, and geological history of the soil. The amount of lead accumulated into the plant tissues decreases as pH, cation-exchange capacity (a measure of the soils ability to retain essential nutrients), and available phosphorus of the soil increases.

Lead on leafy parts of plants generally result from deposition from air. Under normal conditions, even when plants are grown in soil containing substantial amounts of lead, only a very small percentage of total soil lead is accumulated by the plant. This is assuming that all lead particulates are thoroughly washed from the plant surface before being analyzed. In general, soil contamination on the plant (e.g., small particles of soil that are on the surface of the plant) may be the most significant source of exposure for people (ERG 2001). Table 4b presents range and arithmetic mean lead BCFs for sampled crops.

Table 4b:Lead Bioconcentration Factor			
Item	Sample Size	Range	Arithmetic Mean
General (i.e. Unspecified)	(19 Studies) 133 Observations	0.0001— 10.6	0.34
Source: USDOE 1998 Note: The higher the BCF, the greater the accumulation in living tissue is likely to be. Information regarding pH was not available.			

<u>What studies have found</u>: Studies conducted on contaminated sites or in areas known to contain high concentrations of lead in soil, sediment, and surface waters have demonstrated that under certain conditions plants can accumulate high levels of lead. Occasionally, the concentrations are high enough to pose a human health concern. For example, aquatic plants from the Chesapeake Bay region contained 2.2-18.9 ppm lead (dry weight). Aquatic bryophytes (i.e., non-flowering plants comprising mosses, liverworts, and hornworts) contained 34-49,400 ppm lead (dry weight), which correlated well with the concentration of dissolved lead in the streams (National Park Service 1997a).

Pasture vegetation growing in an abandoned lead mining area (soil pH 4 and soil lead levels 3,600 ppm) accumulated up to 74 ppm lead (dry weight basis) in their leaves. Corn plants accumulated lead up to 38 ppm from lead-contaminated soil, but the kernels from the plants grown in lead-contaminated soil did not contain significantly more lead than the kernels from the plants grown in non-contaminated soil (0.3-0.5 ppm). Lettuce and radishes also accumulated lead from soil. Studies have also shown that both tree lichens and mosses are capable of accumulating lead (National Park Service 1997a).

The hyperaccumulation of lead is rare due to the limited amount of “free lead” (Pb 2) available in soil for absorption. Since lead bonds strongly with soil minerals and organic matter, it is difficult for plants to extract it from the soil and into its roots. Once lead is absorbed by the plant, it complexes with plants nutrients limiting its ability to be translocated to the harvestable shoots (Fiegl J.L. et al.). The following plant species were identified as having the greatest potential to hyperaccumulate lead.

Scientific Name	**Common Name**
Armeria maritime	Seapink thrift
Ambrosia artemisiifolia	Ragweed
Brassica juncea	Indian mustard
Brassica napus	Rape, Rutabaga, Turnip
Brassica oleracea	Flowering/ornamental kale & cabbage, Broccoli
Festuca ovina	Blue/sheep fescue
Helianthus annuus	Sunflower
Thlaspi rotundifolium	Pennycress
Triticum aestivum	Wheat (scout)
Zea mays	Corn
Source: Fiegl J.L. et al (Date unknown) http://www.civil.northwestern.edu/ehe/html_kag/kimweb/MEOP/	

Zinc — Levels of zinc found in most common plants are rarely at levels of human health concern. At high enough concentrations, zinc will be toxic to the plant well before it reaches a level that is known to be harmful to people. A few plant species (primarily Thlaspi – member of the broccoli and cabbage family) that hyperaccumulate zinc grows in Europe. However, these plants are not common in the eastern United States (ERG 2001). The concentration of zinc in plants depends on the plant species, soil pH, and the composition of the soil. Plant species do not concentrate zinc above the levels present in soil (ATSDR 2003b). Among food crops, the spinach/beet family and lettuce are known to accumulate zinc more readily than other crops. However, there is no evidence in the scientific literature that the levels of zinc that can accumulate in these food crops pose a risk to consumers. Table 4c presents zinc BCFs for selected crops.

Table 4c:Zinc Bioconcentration Factors for Selected Crops

Item	Sample Size	pH Range (Alkaline to acidic[1])	Range	Geometric Mean
Grains and cereals	13	8.0—5.3	0.016 — 0.37	0.1
Potato	14	8.0—4.7	0.01 — 0.12	0.024
Leafy Vegetables	47	8.0—4.6	0.012 — 4.49	0.25
Legumes	10	7.7—5.1	0.002 — 0.11	0.036
Root Vegetables	20	8.0—4.6	0.002 — 0.41	0.044
Garden Fruits	21	7.3—4.6	0.002 — 0.39	0.046
Sweet Corn	8	6.5—5.1	0.02 — 0.19	0.02
General (i.e. Unspecified)	(20 Studies) 164 Observations	NA	0.0086— 34.29	1.26 (AM)

Source: EPA 1996; USDOE 1998[general/unspecified]; USDA 1998

Note: The higher the BCF, the greater the accumulation in living tissue is likely to be.
AM=Arithmetic Mean; NA=Not Available

[1] Extremely acid 3.5 – 4.4; Very strongly acid 4.5 – 5.0; Strongly acid 5.1 – 5.5; Moderately acid 5.6 – 6.0
Slightly acid 6.1 – 6.5; Neutral 6.6 – 7.3; Slightly alkaline 7.4 – 7.8; Moderately alkaline 7.9 – 8.4

<u>What studies have found</u>: A typical plant may accumulate about 100 ppm zinc. Thlaspi can accumulate up to 30,000 ppm zinc (USDA 2000). Vegetation may accumulate high levels of zinc if grown on contaminated soils. Corn seedlings grown in a highly contaminated soil (1,425 ppm) had zinc concentration in shoots and roots of 484 and 1,330 ppm (dry weight), respectively. In contrast, seedlings grown in uncontaminated soil (67 ppm) had zinc

concentrations in shoots and roots of 25 and 21 ppm (dry weight), respectively (ATSDR 2003b). Another study found concentrations of zinc were highest in grass samples collected immediately adjacent to a municipal waste incinerator (136 ppm dry weight) compared to grass samples collected upwind or a distance from the incinerator (17.8–73.8 ppm dry weight). Grasses collected from the Milltown Reservoir Superfund Site in Montana contained zinc at concentrations of 154 and 882 ppm for above- and below-ground samples, respectively. In contrast, samples grown in uncontaminated areas contained zinc at concentrations of 72 and 36 ppm for above- and below-ground samples, respectively. Other studies have not shown significant correlations between zinc concentrations in soils and vegetation (ATSDR 2003b).

Mercury — When mercury is released onto soil, it is strongly bound in the clays and other particles, usually resulting in a low potential for transfer to plants. There is a also a tendency for mercury accumulation to be mostly limited to the roots, indicating that the roots serve as a barrier to accumulation, especially with respect to the movement of mercury from plant roots to plant tops. Thus, large increases in soil mercury levels produce only modest increases in plant mercury levels by direct accumulation from soil. Factors affecting plant accumulation include soil or sediment organic content, carbon exchange capacity, and oxide and carbonate content.

Mercury is found in the environment in different forms. The most common forms of mercury are metallic (i.e., elemental mercury), inorganic, and organic (usually methylmercury). Most mercury present in water, soil, sediment or plants and animals is in the inorganic or organic form (e.g., methylmercury) (University of Texas 2001). The form that the metal takes is important to determining how easily it will be accumulated by plants and animals. Although some wetland plants do accumulate mercury, these plants typically store them in a form that is not readily bioavailable (i.e., more easily absorbed and metabolized) in humans. Mercury concentration in above ground parts of plants appears to largely depend on accumulation of mercury volatilized from the soil. The deposition of the volatilized mercury onto the leaves and shoots of plants poses greater exposure potential to humans than the accumulation of mercury from soil. Table 4d presents mercury BCFs in selected crops.

Table 4d:Mercury Bioconcentration Factors for Selected Crops				
Item	Sample Size	pH Range (Alkaline to acidic[1])	Range	Geometric Mean
Grains and cereals	1	7.1—5.3	0.086 — 0.0854	0.085
Potato	1	7.1—5.3	0.002 — 0.002	0.002
Leafy Vegetables	9	7.1—5.3	0.002 — 0.092	0.008
Legumes	3	7.1—5.3	0.002 — 0.002	0.002
Root Vegetables	6	7.1—5.3	0.002 — 0.086	0.014
Garden Fruits	7	7.1—5.3	0.002 — 0.086	0.01
Sweet Corn	NA	NA	0.02 — 0.002	0.002
General (i.e. Unspecified)	(12 studies) 142 observations	NA	0.0015—12.23	1.51 (AM)

Source: EPA 1996; USDOE 1998[general/unspecified]
Note: The higher the BCF, the greater the accumulation in living tissue is likely to be.
AM=Arithmetic Mean
NA=Not Available

[1] Extremely acid 3.5 – 4.4; Very strongly acid 4.5 – 5.0; Strongly acid 5.1 – 5.5; Moderately acid 5.6 – 6.0
Slightly acid 6.1 – 6.5; Neutral 6.6 – 7.3; Slightly alkaline 7.4 – 7.8; Moderately alkaline 7.9 – 8.4 (USDA 1998).

What studies have found: Most studies show that very little mercury is accumulated from the soil into the shoots of plants, although mercury concentrations in the roots may be significantly elevated and reflect the mercury concentrations of the surrounding soil. For example, a study that measured mercury concentrations in municipal solid waste sludge from the Metropolitan Water Reclamation District of Greater Chicago were found to range from 1.1 to 8.5 ppm, with a mean concentration of 3.3 ppm. About 80–100 percent of the mercury applied to the soils in sewage sludge since 1971 still resided in the top 15 centimeters (5.9 inches) of soil. The contaminated sewage sludge did not increase plant tissue mercury concentrations in corn or wheat grown on the contaminated land. Grasses sampled downwind of a municipal waste incinerator contained up to 0.20 ppm of mercury, with concentrations decreasing with increasing distance from the facility. Background mercury levels in vegetation were usually below 0.1ppm dry weight (ATSDR 1999b).

Mercury in the roots of five species of freshwater vascular plants in the polluted Ottawa River was 10–40 percent higher than in the shoots. Concentration of mercury in the plant tissues exposed to 46, 230, and 460 ppm of inorganic mercury compounds in sediment ranged from 1.7 to 4, 4.8–6, and 6.6–10 ppm, respectively. In contrast, the concentrations of mercury in plant tissues exposed to 46, 230, and 460 ppm of the organic mercury compounds in the sediment ranged from 2.4 to 7.2 ppm, 36–85 ppm, and 115–243 ppm, respectively. The control plants (i.e., no mercury compounds added to the sediments) contained no more than 0.3ppm mercury (ATSDR 1999b).

Most plants contain very little mercury. Mushrooms grown in mercury-contaminated soil may contain levels of mercury that could pose some risk to health, if large amounts were consumed. A survey of raw foods in Germany in 1986 found that grains, potatoes, vegetables, and fruits contained average mercury concentrations of 0.005 to 0.05 ppm fresh weight; however, wild mushrooms contained up to 8.8 ppm of mercury (ATSDR 1999b).

Barium — In general, barium does not accumulate in common plants in sufficient quantities to be toxic to people. Relative to the amount of barium found in soils, only a small portion is typically accumulated by plants. For example, a BCF of 0.4 has been estimated for plants in a Virginia floodplain with a barium soil concentration of 104 ppm. However, barium has been found to bioconcentrate (i.e., accumulate in greater concentrations in the plant or animal tissue than in the medium it is exposed to) in some marine plants by a factor of 400 to 4,000 times the level present in the surrounding water. Some terrestrial plants, such as legumes, forage plants, Brazil nuts, and mushrooms are known to accumulate barium as well. BCFs from 2 to 20 have also been reported for tomatoes and soybeans (ATSDR 2005b). Table 4e presents barium BCFs in sampled crops.

Table 4e:Barium Bioconcentration Factor			
Item	Sample Size	Range	Arithmetic Mean
Tomatoes and soybeans	NA	2 — 20	NA
General (i.e. Unspecified)	28 Observations	0.357— 0.915	0.213
Source: USDOE 1998[general/unspecified]; Robinson et al. 1950; ATSDR 2005b Note: The higher the BCF, the greater the accumulation in living tissue is likely to be. Information regarding pH was not available. NA = Not Available			

<u>What studies have found</u>: The barium content in corn samples from Georgia, Missouri, and Wisconsin collected during a number of field studies ranged from 5 to 150 ppm with mean concentrations ranging from 15 to 54 ppm. Barium was detected in the leaves of corn plants at a mean concentration of 3 ppm. Barium has been found to accumulate in dry tobacco leaves up to 293 ppm. Brazil nuts have notably high concentrations of barium (3,000–4,000 ppm). The barium content in other cultivated plants (e.g., lima beans, cabbage, soybeans, and tomatoes) from Georgia, Missouri, and Wisconsin ranged from 7 to 1,500 ppm with mean concentrations in various plants ranging between 38 and 450 ppm. The highest levels occurred in cabbage from Georgia and soybeans from Missouri and the lowest levels occurring in Georgia tomatoes (ATSDR 2005b).

Barium has also been found in grain stalks, forage plants, red ash leaves, as well as black walnut and hickory trees. In general, those parts of the plants that accumulate barium are seldom used for food (Robinson et al., 1950). In general, reported concentrations of barium in vegetables are relatively low. The highest concentrations have been detected in beets and sweet potatoes (WHO-IPCS 1990).

Silver — Aquatic plants can concentrate silver from their environments. In general, accumulation of silver by terrestrial plants from soils is low. Even if the soil is contaminated with silver or the plants are grown on tailings from silver mines, silver accumulates mostly in the root systems. Table 4f presents silver BCFs in unspecified plant tissues.

Table 4f: Silver Bioconcentration Factor			
Item	Sample Size	Range	Arithmetic Mean
General (i.e. Unspecified)	10 Observations	0.003— 0.04	0.164
Source: USDOE 1998 Note: The higher the BCF, the greater the accumulation in living tissue is likely to be. Information regarding pH was not available.			

<u>What studies have found</u>: In terrestrial plants, silver concentrations are usually less than 0.1ppm dry weight and are higher in trees, shrubs, and other plants near regions of silver mining. Seeds, nuts, and fruits may contain higher concentrations of silver than other portions of the plant. In non-contaminated soils considered as background, trees and other plants contained between 0.1 and 1.4 ppm of silver (National Park Service 1997b; WHO 2002; ATSDR 1990).

<u>Persistent Organic Pollutants (POPs)</u>

Organic compounds such as PCBs or pesticides are more likely to be deposited and adsorbed (i.e., adhering or binding) onto plant surfaces rather than being taken up into the root system. For example, when PCBs are released into the environment in industrialized areas they typically volatilize in the air and are transported through the atmosphere and ocean. PCBs may eventually be deposited on terrestrial or aquatic vegetation a large distance from the original source. In most cases, deposition onto vegetation does not represent a significant human exposure pathway. However, direct and repeated applications of pesticides and other organic compounds may result in greater exposures that could pose a human health concern. The following organic chemicals were detected in soil and/or surface water at LAFB at levels of health concern.

Chlordane— Chlordane can be transported from contaminated soil into plants. The amount taken up varies with plant species and stage of plant development.

<u>What studies have found</u>: A bioconcentration factor of 1.06 was reported in a plant species that grows in water, Hydrilla weed (*Hydrillu verticillatu)*. Chlordane also bioconcentrates in the roots from contaminated sediment and can be transported into the shoots, usually at very low concentrations (ATSDR 1994). Chlordane may accumulate in the roots of some plants at relatively high concentrations.

DDT/DDE/DDD— Although DDT is strongly bound to soil, at least a portion of the compound, and the common breakdown products DDE, and DDD, are available to plants. However, most studies indicate that the major source of DDT contamination in plants is due to volatilized residues from treated soil adhering to the surface of vegetation (ATSDR 2002).

What studies have found: Studies conducted on oats and peas showed that accumulation of DDT into roots was low and there was little or no evidence of transport to other portions of the plant. Grain, corn, and rice plants can accumulate DDT adsorbed to soil. However, most of the residues were found in the roots of the plant, and the lowest concentration of DDT residues was found in the shoots, indicating low potential for transport to other portions of the plant (ATSDR 2002).

Polychlorinated Biphenyls (PCBs) — PCB ingestion from plants used for foods or other traditional purposes generally represents a very small proportion of the total dietary PCB intake (ATSDR 2000). Terrestrial vegetation typically accumulate PCBs by vapor-to-plant transfer (PCBs that are volatilized and in a gaseous state in the air). Portions of the plant that are above ground (i.e., aerial) and not coming in contact with the soil (e.g., tomato plant leaves) adsorb more highly chlorinated congeners primarily by vapor-to-plant transfer, while the lower chlorinated congeners are both adsorbed on and absorbed in the above ground portions of the plant. Strong binding of PCBs to soil organic matter and clay inhibits the accumualtion of PCBs in plants through the roots. As a result, root crops, such as potatoes often accumulate the lowest levels of total PCBs. This is quite different from the accumulation of metals in root crops, which typically is expected to be greater than most other portions of the plant. However, higher accumulation of PCBs from soil can occur in certain root crops (e.g., carrots) by attracting the fat-soluble chemicals into the epidermal layer (skin), which typically contains the highest fat content of the plant (ATSDR 2000). Table 5 presents the reported plant BAFs for PCBs in soil.

Table 5: PCB Bioaccumulation Factors for Selected Crops

Item	Range
Carrot	< 0.16 (Aroclor 1254) —1.5 (PCB 52)
Corn Aroclor 1254 and 1260	< 1 (Aroclor 1254 and 1260)
Lettuce PCB 52 and 153)	0.74 (PCB 153) — 6.0 (PCB 52)
Potato (PCB 52; 101)	0.01 (PCB 101) — 0.29 (PCB 52)
Radish (Aroclor 1254; 1224)	0.005 (Aroclor 1254) — 0.02 (Aroclor 1224)
Soybean sprouts (Aroclor 1242)	0.002
Sugarbeat (Aroclor 1254)	0.01 (leaves) — 0.5 (whole plant)
Tomato	0.01 — 0.64

Source: ATSDR 2000

Note: The higher the BAF, the greater the accumulation in living tissue is likely to be.

What studies have found: Concentrations ranging from less than 10 to 812 parts per billion (ppb) (mean about 20-30 ppb) were detected in plant leaves collected from 15 nations (including USA) during 1984-1985.

Other Contaminants of Concern at LAFB

PAHs— The accumulation of PAHs from soil to plants is generally quite low. Some terrestrial plants can accumulate PAHs from soil via the roots or from air via the foliage. Mosses and lichens have been used to monitor atmospheric deposition of PAHs. Most studies indicate that atmospheric deposition on leaves largely exceeds accumulation from soil by roots as a route of PAH accumulation (ATSDR 1995).

What studies have found: Ratios of PAH concentrations in vegetation to those in soil have been reported to range from 0.001 to 0.18 for total PAHs and from 0.002 to 0.33 for benzo[a]pyrene. This corresponded to concentrations in the plant material of between 0.1 to 150 ppb (dry weight) for benzo(a)pyrene.

In a study of PAH accumulation from cropland soils conducted in the United Kingdom, elevated concentrations of PAHs in soils were not correlated with concentrations in plant tissues. The PAH concentrations in aboveground plant parts were not strongly related to soil PAH levels but were probably the result of atmospheric deposition. The presence of PAHs in root crop tissues was probably due to soil adhering to the root surfaces. Transfer of PAHs from the root peel to the core appeared to be minimal. This again suggests that simple adsorption onto the peel maybe an important process (ATSDR 1995).

In long-term field studies (20-30 yrs), no evidence was found of elevated PAH concentrations in the above-ground portions of several crop species grown in PAH-contaminated soils. Air-borne sources of PAHs were regarded as the main origin of plant contamination in contaminated and non-contaminated soils. The transfer of PAHs from soil was minimal for root crops, and essentially zero for above-ground crops (NRC 1996).

Ways to Minimize Exposure

- Avoid vegetation that appears to be stressed (e.g., wilting, brown or burnt leaves, premature coloration, or leaf drop): Avoid harvesting fruits, vegetables, or any plant materials that will be used as food or for medicinal purposes if plants do not appear healthy. This could be an indicator of contamination.

- As a rule, the higher off the ground the fruit, vegetable, or portion of the plant to be harvested is, the less likely it will be impacted by contamination from the soil.

- Always wash all fruits and vegetables and any portions of the plant that will be ingested. This is by far the most efficient way of being exposed to contaminants that are in the soil or sediments, either by soil adhering root crops like tubers or from soil spray that results in contaminant deposition onto above ground portion of plants.

- Peeling away the skin or top surface layer of the fruit or vegetable

- Smoking or ingesting tobacco products produces the greatest potential for above-average exposure to cadmium. It has been estimated that tobacco smokers are exposed to 1.7 micrograms (µg) of cadmium per cigarette. The amount of cadmium absorbed from smoking one pack of cigarettes per day is about l-3 µg/day, roughly the same as from a typical diet (ATSDR 1999c).

Considerations for sampling plants with highest potential for contamination

- Measure Soil pH— Determine the pH of the soil in popular harvest locations. This is a relatively easy and inexpensive test and can provide very useful information about the potential for vegetation in the area to accumulate metals.

- Sample the root and near surface portions of the plant since they would be likely to be most impacted by direct accumulation of metals from soil.

- Try to measure contamination in both washed and unwashed samples when possible. Contamination will often be deposited on the surface of the plants rather than taken up by the plant's vascular system. In most cases, thoroughly washing or peeling off the outer layer of the sample will remove most of the contamination.

- The levels of mercury and other metals in the reeds of plants commonly used for basket weaving could represent a potential for human health risk. Consideration for analysis of the mercury level in these plants is recommended.

RESOURCE OF INTEREST: FISH AND WILDLIFE

General Information

The Micmac Tribe utilizes a wide variety of fish and wildlife resources for food, clothing, and ceremonial activities. In a similar fashion to plants, animals will accumulate contaminants that are in soil, sediments, and water. However, unlike most plants chemical concentrations in species high on the food chain can be many times greater than their levels in the soil and water. Algae and plants, which form the base of the food chain, can take up small amounts of these contaminants directly from the water and sediment. Animals, especially herbivores, can subsequently ingest large quantities of these plant materials as well as contaminated soil and sediments in the process. Contaminant concentrations typically increase with each step of the food chain because they accumulate in tissues faster than they can be metabolized and removed from the body (Extoxnet 1993).

A review of the scientific literature indicates that the accumulation of contaminants in animals depends largely on the diet of the animal (i.e., carnivore, herbivore, or omnivore) and the type of contaminant the animal is exposed to (e.g., PCBs, pesticides, or metals). For example, deer, moose and caribou are primarily herbivores and are most likely to accumulate and store metals in their kidney, liver, and bones. Other organic compounds may also be stored in the organs and fat tissues of these animals. However, concentrations of PCBs and organic pesticides are not typically found at high concentrations in herbivores because they do not eat the animals that readily accumulate these compounds in their fatty tissues (e.g., fish, ducks, and seals) (NCP 2003).

Many contaminants (e.g., metals and chlorinated compounds) bind to proteins or lipids and accumulate over time in animals. Contaminants tend to be stored most readily, and in the highest concentrations, in fatty tissues or filter organs such as the liver or kidney. Most metals accumulate in kidneys and liver, whereas organic compounds tend to accumulate at the highest concentrations in fatty tissues. Lead is a very toxic heavy metal that accumulates most readily in bone, and to a lesser extent in the kidney, liver, and muscle tissue of animals (Burger et. al., 2002).

It is estimated that about 25 percent (approximately 1 pound per day) of the total caloric intake for a typical adult member of the Micmac Tribe may comprise wild game (Harper 2006). Although the specific use of different portions of game animals (e.g., liver, kidney, skin) has not been quantified, many native cultures consume portions of game animals as part of a traditional subsistence diet (Arnold et. al., 2005). Since these traditional foods are not a common part of the U.S. diet, this may present unique exposure scenarios. The information presented below can be used to guide individual or tribal decisions about what types of animal resources are likely to contain the lowest contaminant levels and are most suitable to harvest for foods or other culturally important activities. Information is also presented to assist the Tribe in making decisions about where to target and prioritize environmental sampling given the limited availability of resources.

Factors that Influence the Accumulation of Contaminants

As previously stated, contaminant levels in wildlife are largely related to the animals feeding habits. In general, animals at the bottom of the food chain (e.g., insects, rodents, and small fish) are less likely to accumulate contaminants at sufficient levels to cause harm to people than those at the top. The term trophic level is used to describe feeding position in a food chain such as primary producers, herbivore, primary carnivore, etc. Green plants form the first trophic level, the producers. Herbivores form the second trophic level, while carnivores form the third and even the fourth trophic levels. Herbivores (e.g., deer, moose, and rabbits) are less likely to accumulate harmful levels of chlorinated compounds and most metals then carnivores. This is especially true for those animals that do not typically ingest much soil in their diet (see below). Other important factors that influence the potential for animals to accumulate contaminants and contribute to human exposures include:

- *Size and age of animal* — Larger and older animals usually contain the highest contaminant concentrations. This is especially true with respect to chlorinated compounds that accumulate over time in fatty tissues. However, metals will also accumulate in the liver and kidneys and these concentrations are often correlated with the age of the animal as well

- *Availability* — Contaminants vary in their availability to be absorbed and distributed in animal tissues. Some contaminants bind to soil or sediments and are not readily available to be taken up by fish and aquatic and terrestrial wildlife.

- *Soil ingestion* — soil ingested both intentionally and incidentally by many species of wildlife can be a significant exposure pathway for some contaminants (EPA 1993; Beyer et al. 1994). Grazing animals such as sheep, goats, and elk feed on grasses and are more likely to ingest soil and sediments that could potentially contain contaminants. Browsers, such as deer and moose often forage on shrubs, twigs, and other woody vegetation, typically ingesting less soil than grazers. Aquatic organisms, especially bottom feeders, may ingest large amounts of sediment resulting in higher contaminant body burdens (Beyer et al. 1994).

- *Home range* — home range size can be used to determine the proportion of time that an individual animal is expected to come in contact with contaminants from a specific location. Home range refers to the geographic area encompassed by an animal's activities, except migration, over a specified period of time. Animals that roam large areas feeding from different locations are less likely to accumulate contaminants from a specific source area. Animals that have very small home ranges are more likely to have body burdens that reflect the contaminants found in their immediate surroundings (EPA 1993). Migratory species of birds and fish will exhibit varying patterns of contaminant uptake, but generally will have lower body burdens than animals that have smaller home ranges near sources of contamination.

- *Contaminant composition* — Chlorinated compounds accumulate in organisms because of their attraction to lipids and the stability (i.e., biological inactivity) of the parent chemical or metabolites. When chlorinated compounds accumulate in fatty tissue they typically remain there for a long time and are not rapidly metabolized. Predicting the rates of accumulation of compounds such as PCBs, dioxins and furans in animals is complicated because they comprise a large number of congeners. The term congener refers to one of many variants or configurations of a common chemical structure. The more highly chlorinated congeners of PCBs, dioxins, and furans are not easily metabolized by most animals and remain in the body for longer periods of time. The congeners that contain less chlorine are more readily metabolized and are removed from the body. The capability to metabolize certain chlorinated compounds also varies, to some extent, by animal species (Norstrom 1992).

The accumulation of metals in animals will vary according to the specific form of an element (i.e., speciation) as well as the metabolic rate of the organism. Different forms of an element may be mobilized differently in the environment and may exhibit different rates of bioavailability (NCP 2003). Studies indicate that most aquatic and terrestrial species accumulate free metal ions (metal hydroxides) from solution (i.e., water) more efficiently than from direct particulate matter ingestion that may occur from exposure to soil or sediments.

Site Specific Information

Table 6 provides common fish and wildlife resources harvested by the Micmac Tribe near LAFB. This list was compiled on the basis of discussions with representatives of the Micmac Tribe. Although it represents the most common fish and wildlife species utilized by the tribe, it is not exhaustive and other species may be considered to be important to the tribe as new information about fish and wildlife resources and common harvesting practices are obtained.

Table 6. Common Indigenous Fish and Wildlife Harvested by the Micmac Tribe

Fish and Wetland Species	Birds and Water Fowl	Land Species
Brook Trout	Grouse	Moose
Cat Fish	Woodcock	Bear
Crayfish	Mallard and Black Ducks	Fisher
White Suckers	Geese	Rabbit
Turtles		Raccoon and Red Squirrel
Mink and Otter		Dear and Snowshoe Hare
Beaver and Muskrat		Porcupine

Note: Information for this table was provided by Fred Cory (Environmental Director for the Micmac Tribe) and Barbara Harper (Draft Provisional Exposure Factors for LAFB). The wildlife species listed in this table represent some of the more important species utilized by the Tribe and are found near LAFB. This is not meant to represent the only fish and wildlife species that are utilized by the Micmac Tribe, only the most common ones.

A fish advisory was issued by the Maine Department of Human Services in May 1996 warning against the consumption of fish from certain water bodies within and around the former LAFB. The areas covered by the advisory include Chapman Pit, Green Pond, Greenlaw Brook, and the Little Madawaska River and its tributaries. As part of the long-term monitoring (LTM) program initiated by the Air Force in 2001, fish tissue samples were collected during 2001 and again in 2003 from these impacted surface water bodies and analyzed for specific COCs identified at LAFB (MWH Americas 2005; Woodlot Alternatives, Inc 2002, 2004). Table 7 presents the results of these analyses. No other biological resources of interest were sampled as part of the LTM program.

Table 7. Contaminants Detected in Fish Samples Collected at LAFB

Fish Species: Brook Trout	Contaminant	Historical Maximum Conc. (ppb)	Recent Sampling Max. (2001) (ppb)	Most Recent Sampling Max. (2003) (ppb)	Screening Value (ppb)[1]
EBGB (LT-10)	Heptachlor epoxide	NA	17J	4.4	0.35
	4,4'-DDE	44	180J	56	93
	4,4'-DDD	76	33J	27	13
	4,4'-DDT	140	86J	36	93
	Alpha (cis) chlordane	42	7.2J	9.2	9
	PCB 1260	2,100	2,500J	560	1.6
WBGB/ Chapman Pit (LT-05)	Heptachlor epoxide	NA	ND	4.7	0.35
	4,4'-DDE	44	330J	100	93
	4,4'-DDD	76	120	37	13
	4,4'-DDT	140	ND	22	93
	Alpha (cis) chlordane	42	ND	2.4	9
	PCB 1260	2,100	1,200	490	1.6
Little Madawaska River (LT-02)	Heptachlor epoxide	NA	ND	ND	0.35
	4,4'-DDE	44	ND	150	93
	4,4'-DDD	76	ND	12	13
	4,4'-DDT	140	ND	49	93
	Alpha (cis) chlordane	42	ND	1.3	9
	PCB 1260	2,100	ND	21J	1.6
Willard Brook (Reference) (LT-12)	Heptachlor epoxide	NA	ND	ND	0.35
	4,4'-DDE	44	110J	32J	93
	4,4'-DDD	76	12J	3.4	13
	4,4'-DDT	140	ND	5.6	93
	Alpha (cis) chlordane	42	ND	ND	9
	PCB 1260	2,100	77	18J	1.6
Caribou Stream (Reference) (CS-01)	Heptachlor epoxide	NA	NA	NA	0.35
	4,4"-DDE	44	ND	44	93
	4,4"-DDD	76	ND	4	13
	4,4"-DDT	140	ND	4.9	93
	Alpha (cis) chlordane	NA	NA	NA	9
	PCB 1260	2,100	ND	1.9	1.6
Prestile Brook (Reference) (PB-01)	Heptachlor epoxide	NA	NA	NA	0.35
	4,4"-DDE	44	ND	180	93
	4,4"-DDD	76	ND	13	13
	4,4"-DDT	140	ND	43	93
	Alpha (cis) chlordane	NA	NA	NA	9
	PCB 1260	2,100	ND	3	1.6

Source: Woodlot Alternatives, Inc 2002; 2004

[1] EPA Region III Risk-based Concentration Table (Fish tissue)

EBGB = East Branch of Greenlaw Brook
WBGB = West Branch of Greenlaw Brook
ND = Not detected; NA = Not available

Note: 2003 sampling effort analyzed fillets whereas earlier analyses only referred to samples as "fish tissue" and did not specify fillet or whole body.

Potential for Contaminant Accumulation

Metals

Metals contamination in soil, water, and sediments is a concern since they persist in the environment for a long period of time and can be taken up by plants and animals. Metals contained in air particulates can also travel large distances before settling onto surface soil, vegetation, or in water. Consequently, even remote areas that are a distance from industrial sources can contain metals that exceed natural background levels. Plants grown on soils containing elevated levels of metals can be consumed by animals. Even low levels of certain metals in plants can eventually become harmful to animals and humans as they concentrate in some organs of animals that are at the top of the food chain. The highest concentrations of metals are typically found in organs such as the liver and kidney and sometimes the bones of animals.

The following metals were identified as COCs during environmental sampling at LAFB. The metals are listed in order of highest potential to accumulate in animals and potentially cause health effects in humans.

Cadmium — Cadmium can be found in almost all soils, surface waters and plants, and it is readily distributed by industrial activities such as mining. As a result, cadmium is a potential health threat to wildlife species (Larison et. al., 2000). Cadmium accumulates with increasing age of the animal and most studies find the highest levels of cadmium in the kidneys and then the liver. Although the available data on the levels of cadmium contamination in wildlife are not extensive, cadmium concentrations in some common wildlife species have been reported in the scientific literature.

In places where traditional foods continue to comprise all or a significant portion of the total human diet, cadmium analysis has been conducted in deer, caribou, and moose. Elevated cadmium levels in deer and moose livers have prompted several states to issue consumption advisories. Cadmium concentrations have been reported to range from 0.002 to 23 ppm (dry weight) for deer livers from Connecticut, New Jersey, Illinois, and Maine, with mean concentrations of 1.7, 4, 0.4, and 1.3 ppm, respectively (Musante et al. 1993). The State of Maine has a deer and moose liver and kidney consumption advisory due to elevated concentrations of cadmium detected in these organ meats.

Cadmium levels in other wildlife species have also been reported in the literature. Table 8a presents cadmium concentrations that have been detected in several fish and wildlife species. Levels of cadmium are generally not elevated in the muscle and fatty tissues of fish. For example, concentrations of cadmium in brook trout samples collected from the Mere Brook in Brunswick Maine were well below levels of health concern. The levels of cadmium in the liver of carp contained the highest concentration in the fish sampled identified in the literature.

Table 8a. Cadmium concentrations detected in different wildlife species

Species	Tissue	Range ppm*	Average ppm*	Location	Source
Beaver	Kidney	NA	1.4	Canada (Ontario)	Wren 1984
	Liver	NA	0.2		
	Muscle	NA	ND		
Bird Species				Japan[1]	Mochizuki et al. 2002
Duck (Mallards)	Kidney	4.7—38.1	15.4		
Seabirds	Kidney	ND—67.4	12.9		
Wild Birds	Kidney	0.45—174.4	42	Japan[2]	
Caribou	Kidney	9.7—33.9[3]	NA	Canada (Northwest Territory)	Elkin and Bethke 1995
	Liver	2.0—4.4[3]	NA		
Deer	Liver	0.002—23	1.3	CT, Il, ME, and NJ,	Musante et al. 1993
	Kidney	0.03—9.7[w]	2.2[w]	Poland	Falandysz et al. 2005
	Liver	ND—0.87[w]	0.2[w]		
	Muscle	ND—0.85[w]	0.1[w]		
Fish Species					
Brook Trout	Whole	0.02—0.05	0.03 [w]	Maine (Mere Brook)	USFWS 1997
Carp	Liver	4.9—26.3[4]	NA	OK, MO	Brumbough et al. 2005
	Carcass	0.1—0.7[4]	NA		
Catfish	Carcass	< 0.03–0.1[4]	NA		
LM Bass	Carcass	<0.03[4]	NA		
Crayfish	Whole	NA	3.4	WA (Seattle)	Stinson & Eaton 1983
Mink	Kidney	NA	0.2[w]	Canada (Yukon)	Gamberg et al. 2005a
	Kidney	NA	3.6	Canada (Kootenay River)	Harding et al. 1998
	Kidney	0.2—0.9[w]	NA	Canada (Ontario)	Wren et al. 1988
	Liver	0.1—0.2[w]	NA		
Moose	Kidney	NA	28.1[w]	Canada (Yukon)	Gamberg et al. 2005b
	Liver	NA	4.9[w]		
	Muscle	NA	0.03[w]		
	Kidney	1.7—22.8[w]	NA	Alaska[5]	Arnold et al. 2005
	Liver	0.5—2.5[w]	NA		
Muskrat	Kidney	ND–1.1	0.3[w]	Idaho	Blus et al. 1987
Otter	Kidney	NA	0.1	Canada (Ontario)	Wren 1984
	Liver	NA	ND		
	Muscle	NA	ND		
	Liver	NA	0.68	Canada (Kootenay River)	Harding et al.1998
	Kidney	0.4—1.5[w]	NA	Canada (Ontario)	Wren et al. 1988
	Liver	0.1—0.2[w]	NA		
Raccoon	Kidney	NA	1.2	Canada (Ontario)	Wren 1984
	Liver	NA	0.2		
	Muscle	NA	ND		
	Kidney	NA	2.2[w]	SC (Savanna River) On Site	Burger et al. 2002
	Liver	NA	0.5[w]		
	Kidney	NA	2.2[w]	SC (Savanna River) Off Site	
	Liver	NA	0.5[w]		

*Concentrations are reported as dry weight unless a [w] follows the value, in which case the concentrations are reported as wet weight
[1] Samples collected from non-contaminated areas
[2] Samples collected from contaminated areas
[3] Values represent the range of average (i.e., mean) concentrations detected in caribou from 5 sampling locations (kidney) and 4 sampling locations (liver) in the Northwest Territories of Canada
[4] Values represent the range of average (i.e., mean) concentrations from 10 different sampling locations
[5] Values represent the range of the average (i.e. mean) concentration detected in moose from 4 sampling locations in Alaska

LM Bass = Large mouth bass; NA = Not applicable; ND = Not detected
Note: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure.

Mercury — Methyl mercury accumulates in living organisms because it has a strong attraction for certain protein structures, referred to as sulfhydryl groups, in the body. The target site for mercury is usually muscle tissue, although high concentrations of inorganic mercury may also accumulate in the kidney. As organisms at the bottom of the food chain are eaten by higher-order organisms, the mercury concentration is increased along the food chain, often many times higher than the levels found in the environment (e.g., sediments, water, or air) (Davis 2003). The BCF of methylmercury in fish has been reported to be as high as three million (ATSDR 1999b).

The potential for bioaccumulation in terrestrial food chains has been observed in a variety of plants and animals. However, people are primarily exposed to methyl mercury (i.e., organic mercury), which is readily accumulated by organisms, through consuming large fish or marine mammals. Most terrestrial animals do not appear to be an important dietary source of methyl mercury for people (Renzoni et al. 1998). However, wild game, such as wild birds and mammals (e.g., bear) that eat large amounts of contaminated fish may accumulate mercury at higher levels than most other terrestrial animals. Fish appear to accumulate methyl mercury from both food sources and water. However, some studies have demonstrated that food is the predominant source of mercury uptake in fish (ATSDR 1999b).

Table 8b presents mercury concentrations that have been detected in several wildlife species. Among a variety of fish species sampled, large mouth bass contained the highest levels of mercury, both in samples collected in the northeast and across the U.S. Brook trout, which are commonly consumed by the Micmacs, and brown bullhead contained the lowest levels of mercury in fish sampled across the Northeast (NESCAUM 1998). Raccoons (kidney and liver), mink, and otter also contained somewhat elevated levels of mercury.

Lead — Lead is a heavy metal which can accumulate in the food chain. The availability of lead to organisms in the environment is limited by its adherence to soil and sediment. Some soil lead is taken up by plants and passed to animals, but a major fraction is accumulated at the surface of root cells. In most terrestrial animals most of the accumulated lead is stored in bone. It is also stored to a much lesser extent in the liver and kidney of animals. Fish accumulate lead mostly in the gill, liver, kidney, and bone (WHO-IPCS 1989). Higher blood lead levels are usually indicative of recent lead exposures. It is rare for lead to accumulate significantly in muscle or adipose tissue, and therefore, meat from game animals contributes very little to an individual's lifetime lead body burden.

Most studies that have measured levels of lead in the bone and other organs of different wildlife species find similar relationships regarding the target area for greatest lead accumulation. Table 8c presents lead concentrations that have been detected in several wildlife species. Some of the highest lead concentrations were detected in otters (kidney, liver, and bones) (Anderson-Bledsoe 1983) and carp (liver and carcass) (Brumbough et al. 2005). However, the results were reported as dry weight values and other studies that report results as wet weight values are not directly comparable. In general, dry weight values are higher than wet weight values, but the percentage difference will vary based on the water content of the sample. A review of the literature indicates that deer, moose, and caribou generally have low concentrations of lead in edible tissues (Falandysz et al. 2005; Gamberg et al. 2005b; Elkin and Bethke 1995).

Table 8b. Mercury concentrations detected in different wildlife species

Species	Tissue	Range (ppm)*	Average (ppm)*	Location	Source
Beaver	Kidney Liver Muscle	NA NA NA	0.03 0.03 0.03	Canada (Ontario)	Wren 1984
Caribou	Kidney Liver	0.5—2.9[1] 0.2—0.9[1]	NA NA	Canada (Northwest Territory)	Elkin and Bethke 1995
Fish Species					
LM Bass	NS	0—8.9	0.5	Northeast, U.S (Includes ME, VT, NH, MA, RI, CT, NY, and NJ)[2]	NESCAUM 1998
Yel. Perch	NS	0—3.2	0.4		
Lake Trout	NS	0—2.7	0.3		
Brook Trout	NS	0—0.1	0.3		
Crayfish	Whole	0.03—0.2[3]	NA	WA (Seattle)	Stinson and Eaton 1983
Mink	Liver	0.1—4.1	NA	Idaho and WA	Blus et al. 1987
	Kidney Liver Brain	NA NA NA	0.7 0.9 0.2	Canada (Yukon)	Gamberg et al. 2005a
	Kidney	NA	3.4[4]	Canada (Kootenay River)	Harding et al.1998
	Brain Liver Fur	0.1—2.6 0.2—8.0 1.8—68.5	0.4 1.2 17.5	Maine	Yates et al. 2005
Moose	Kidney	NA	0.02	Canada (Yukon)	Gamberg et al. 2005b
Muskrat	Liver	ND—0.22	NA	Idaho and WA	Blus et al. 1987
Otter	Kidney Liver Muscle	NA NA NA	1.4 3.0 0.9	Canada (Ontario)	Wren 1984
	Brain Liver Fur	0.2—3.3 0.5—8.7 2.8—73.7	0.5 1.8 20.7	Maine	Yates et al. 2004
Raccoon	Kidney Liver	NA NA	1.2 1.5.	SC (Savanna River) On Site	Burger et al. 2002
	Kidney Liver	NA NA	0.5 0.7	SC (Savanna River) Off Site	
	Kidney Liver Muscle	NA NA NA	4.5 1.1 0.3	Canada (Ontario)	Wren 1984

*Unless otherwise noted all concentrations are reported as wet weight

[1] Values represent the range of the average (i.e., mean) concentration detected in caribou from 5 sampling locations (kidney) and 4 sampling locations (liver) in the Northwest Territories of Canada
[2] Some of the data were obtained using different methodologies, quality assurance and quality control methods, and laboratory analyses. In some cases, whole fish were analyzed and, in other cases, only fillets or muscle tissue were analyzed.
[3] Values represent dry weight concentrations
[4] Values are reported as dry weight

NA = Not applicable; ND = Not detected; NS = Not specified; LM Bass = Large mouth Bass; Yel Perch = Yellow Perch

Note: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure.

Table 8c. Lead concentrations detected in different wildlife species

Species	Tissue	Range (ppm)*	Average (ppm)*	Location	Source
Caribou	Kidney Liver	0.1—0.5[1] 0.3—3.4[1]	NA NA	Canada (Northwest Territory)	Elkin and Bethke 1995
Deer	Kidney Liver Muscle	0.08—1.3 0.05—1.0 0.01—1.5	0.3 0.3 0.2	Poland	Falandysz et al. 2005
Fish Species Carp	Liver Carcass	0.2—3.3[2] 0.8—12.8[2]	NA NA	OK, MO	Brumbough et al. 2005
Crayfish	Muscle	0.05—0.3[3]	NA	Northern Louisiana	Madigosky et al. 1991
Mink	Liver Bone	0.1—0.4 1.0—3.0	NA NA	Canada (Ontario)	Wren et al. 1988
	Liver	0.1—4.1[4]	NA	Idaho and WA	Blus et al. 1987
	Kidney	NA NA	1.1[5] 0.6[6]	Canada (BC) Canada (BC)	Harding et al. 1998
Moose	Kidney Liver Muscle	NA NA NA	0.09 0.1 0.03	Canada (Yukon)	Gamberg et al. 2005b
Muskrat	Liver	0.27—0.96	0.5	Idaho and WA	Blus et al. 1987
Otter	Liver Bone	0.1—0.5 0.7—3.9	NA NA	Canada (Ontario)	Wren et al. 1988
	Liver[7] Kidney[7] Bone[7]	0.4—55.9 0.4—6.0 0.4—35.2	1.4 0.8 1.4	Virginia	Anderson-Bledsoe 1983
	Kidney Liver	NA NA	0.3 0.3	SC (Savanna River) On Site	Burger et al. 2002
	Kidney Liver	NA NA	0.4 0.5	SC (Savanna River) Off Site	
Raccoon	Kidney Liver	NA NA	0.3 0.3.	SC (Savanna River) On Site	Burger et al. 2002
	Kidney Liver	NA NA	0.4 0.5	SC (Savanna River) Off Site	

*Unless otherwise noted all concentrations are reported as wet weight

1 The highest average dry weight concentration detected in caribou from 5 sampling locations (kidney) and 4 sampling locations (liver) in the Northwest Territories of Canada
2 Values represent the range of dry weight average (i.e., mean) concentrations reported from 10 different sampling locations
3 Values represent the range of dry weight average (i.e., mean) concentrations reported from 10 different sampling locations
4 Values represent the range of average (i.e., mean) concentrations from 3 sampling locations
5 Samples were collected on a dry weight basis from the Kootenay River (a tributary of the Columbia River)
6 Samples were collected on a dry weight basis from the Fraser River
7 Results are reported as dry weight
BC = British Columbia
NA = Not applicable

Note: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure.

A recent study reported lead (and other metals) concentrations in stream sediments collected from different game management zones in the Yukon Territory of Canada where moose samples were obtained. The average lead concentration in stream sediment reported in this study was 56.2 ppm. For purposes of comparison, lead concentrations were reported to be as high as 15.1 ppm in sediment samples collected in 2001 from the East Branch of Greenlaw Brook at LAFB. Lead and cadmium showed statistically significant relationships between levels detected in the moose kidney and sediment concentrations from different home ranges. Lead levels in animals were not at levels known to be harmful. The authors hypothesized that the most likely mode of transfer of these elements from sediment to moose is through vegetation, which is consumed by the animals (Gamberg et al. 2005b).

Barium — Although the data are limited, barium does not appear to accumulate at harmful levels in fish and aquatic wildlife species. No adverse effects have been reported in ecological assessments of terrestrial wildlife (WHO 2001).

Silver — Most people are exposed to very low levels of silver mainly in food and drinking water, and less in air. The silver in these sources is at least partially due to naturally occurring silver in water and soil. In its pure metal form or in ores, silver does not dissolve and is not likely to accumulate extensively in fish and wildlife. Consumption of fish and wildlife does not contribute significantly to an individual's lifetime body burden (ATSDR 1990).

A review of the scientific literature did not identify many studies that measured levels of silver in fish and wildlife. One of the few studies that measured silver in terrestrial wildlife found that levels of silver were below detection limits in most or all liver samples collected from raccoons from the Department of Energy's Savannah River Site in South Carolina (Burger et al. 2002). Silver was also not detected in kidney samples collected from caribou across the Yukon Territory in Canada (Gamberg 2002).

Zinc — Zinc is an essential element for animals, including humans. At high enough levels, zinc can result in several toxic effects to a wide variety of animal life. Zinc can interact with numerous chemicals. The pattern of accumulation, metabolism, and toxicity from these interactions sometimes differs greatly from those produced by zinc alone. It is, however, rare for zinc to accumulate in terrestrial animals, either in bone, muscle tissue, or fat, at levels that would cause adverse health effects (Eisler 1993).

Background concentrations of zinc seldom exceed 40 ppb in water and 200 ppm in soils and sediment. Zinc concentrations in field collections of plants and animals are extremely variable and difficult to interpret. The maximum historical concentration of zinc in sediments collected from the West Branch of Greenlaw Brook at LAFB was 952 ppm. More recent sampling at the West Branch of Greenlaw Brook found levels of zinc at much lower concentrations (96 ppm) in sediments, similar to typical background levels (Woodlot Alternatives, Inc 2002).

Elevated concentrations have been found in some species of oysters, scallops, red and brown algae, and terrestrial arthropods. However concentrations rarely exceed 700 ppm in fish tissue and 200 ppm in birds, and terrestrial animals (Eisler 1993). Zinc has been measured in fish and wildlife in some studies identified in the scientific literature search. Zinc in the kidney of caribou from the Yukon Territory in Canada ranged from 75.5—181 ppm with an average concentration of 155 ppm. These concentrations are similar to those found in caribou from the Northwest Territory of Canada (97—123.5 ppm dry weight). According to the authors, concentrations of zinc found in caribou from the Yukon Territory should be considered normal background levels (Gamberg 2002).

Persistent Organic Pollutants (POPs)

POPs can be released into marine and freshwater ecosystems through atmospheric deposition, runoff, and other means. POPs contaminate local areas close to where they are released into the environment from industry and agriculture. POPs also contaminate regions remote from their source because they can be transported for thousands of miles through the atmosphere. These compounds bond strongly to particulate matter in aquatic sediments. When bound to these sediments these compounds have a minimal impact on marine and terrestrial wildlife. If disturbed, however, they can be reintroduced into the environment and food chain, potentially becoming a source of local, regional, or global, contamination. The primary target sites for POPs in animals are fat and tissues, organs, or body fluids that contain a high proportion of fat (e.g., skin, liver, and breast milk). Organic contaminants such as chlordane, DDT and its breakdown products (DDE and DDD), and PCBs, are typically not of health concern in large terrestrial herbivores such as deer, caribou, and moose (Elkin and Bethke 1995; NCP 2003).

PCBs — PCBs have been routinely monitored in fish and numerous wildlife species since their use was discontinued in the late 1970s. Most studies that have measured levels of PCBs in fish over time have shown a decrease in the average total PCB concentrations since the mid1970s. For example, the average concentrations of PCBs in lake trout from Lake Huron declined from 8.1 ppm in 1976 to 0.5 ppm in 1994. Among trout from Lake Ontario, PCB concentrations have decreased by as much as 80 percent between 1977 (9.1 ppm) and 1993 (1.7 ppm) (ATSDR 2000).

Table 8d presents PCB concentrations detected in different fish and wildlife species across the U.S and some parts of Canada. Fish that inhabit remote areas of the world often contain measurable levels of PCBs. From 1993 to 1994, PCB residues were evaluated in lake trout from the Sierra Nevada ecosystem. Analysis of fish muscle revealed that the concentration of total PCBs ranged from 0.02 to 0.43 ppm (20 to 430 ppb) wet weight for lake trout (ATSDR 2000). These levels are considerably lower than those recently measured (2001 and 2003) in brook trout collected from the east and west branches of the Greenlaw Brook at LAFB, which ranged from 490 to 2,500 ppb (See Table 7).

Waterfowl may be an important source of PCB for people who consume this resource, especially for native populations that rely on traditional diets. Tissues of fish- and shellfish-eating waterfowl (i.e., goldeneye and mergansers) typically contain higher PCB concentrations than tissues of dabbling ducks (i.e., black ducks and mallards). Grazers (e.g., Canadian Geese) usually contain the lowest concentrations of PCBs. Their diet readily consists of aquatic vegetation, upland grass, and grain (ATSDR 2000).

PCB concentrations in the tissues of edible turtles have been measured near contaminated sites. Mean concentrations (wet weight) of PCBs measured in the muscle tissue of snapping turtles from 16 sites in southern Ontario, Canada ranged from less than 0.2 to 0.7 ppm. PCBs were measured in fat, liver, and muscle tissue from snapping turtles collected near Akwesasne, along the U.S. Canadian border, where turtles are a source of food for a Native American community of nearly 10,000 people. Concentrations of total PCBs (wet weight) ranged from 36.1 to 1,347 ppm in fat, 2.9–94.8 ppm in liver tissue, and not detected to 3 ppm in muscle tissue of snapping turtles (ATSDR 2000).

Frogs may also accumulate PCBs in their body, although usually to a lesser extent than turtles. During a 1993-1994 sampling effort, PCB levels in northern leopard frog tissues from the Fox River and other nearby locations around Greenbay, Wisconsin ranged from 0.002 to 0.2 ppm wet weight (ATSDR 2000). Mean residues of Aroclors 1254 and 1260 in tissues of frogs, collected along the Canadian shores of Lakes Erie and Ontario, and the St. Lawrence River, ranged from 0.3 to 1.7 ppm lipid weight in green frogs and 0.3–1.6 ppm lipid for leopard frogs. Based on frog tissue content and sediment PCB content, biota-sediment accumulation factors of 33.3–1.1 and 23–0.42 were calculated for leopard frogs and green frogs, respectively (Gillan et al. 1998).

PCB concentrations were analyzed in fat, liver, and muscle tissue of red and grey squirrels, beaver, muskrat, snowshoe hares, cottontail rabbits, and white-tailed deer. PCBs were typically found only in fatty tissues and occasionally in liver tissues, but were not detected in muscle tissue. Only two liver-tissue samples from muskrats contained detectable concentrations of PCBs (refer to Table 8d) (ATSDR 2000).

DDT/DDE/DDD — Even though DDT has not been used in this country since 1972, soil may still contain some DDT that may be taken up by plants and ingested by wildlife. DDT from contaminated water and sediment may continue to be taken up by fish for many years. Some aquatic organisms bioaccumulate DDT and its metabolites at concentrations from 1,000 to 1,000,000 times that measured in surrounding soil, water, and sediments (EPA 1989, 2002).

DDT levels have noticeably decreased in fish, shellfish, and aquatic mammals since its use was discontinued in the early 1970s (ATSDR 2002). Levels of DDT in fish were determined at 112 locations across the United States by the U.S. Fish and Wildlife Service's (USFWS) National Contaminant Biomonitoring Program (NCBP)[1] in 1976 and 1984. The mean concentrations of total DDT decreased from 370 ppb in 1976 to 260 ppb in 1984. Individually, DDT, DDE, DDD decreased from 50, 260, 80 ppb, respectively, in 1976 to 30, 190, 60 ppb, respectively, in 1984 (Schmitt et al. 1990).

DDE concentrations in brook trout from four remote lakes in Maine ranged from 11 to 34 ppb (Schmitt et al. 1990). DDE ranged from 0.2 to 382 ppb in whole fish collected from a sample of lakes in Maine (DiFranco et al. 1995). These levels are similar to those recently

[1] The NCBP tracks temporal and geographic trends in contaminant concentrations in composite samples of whole fish collected from 112 sites throughout the United States.

measured (2001 and 2003) in brook trout collected from the East Branch of Greenlaw Brook and West Branch of Greenlaw Brook at LAFB, which ranged from 56 to 330 ppb (See Table 7).

In 1998 and 2001, beaver and muskrat tissue samples were collected from the Mackenzie River watershed of the Northwest Territory in Canada. Overall, DDT levels were low and below available guideline levels (Gamberg et al. 2005c). As noted previously, the highest concentrations of DDT and its breakdown products are typically found in fish and marine mammals. There were few recent studies identified that measured levels of most DDT in terrestrial wildlife (e.g., bear, deer, or moose).

Chlordane —Chlordane bioaccumulates in aquatic organisms and levels can become quite elevated, especially in larger predator fish. BCFs have been reported to be as high as 18,500 in rainbow trout (ATSDR 1994). Chlordane may also accumulate in marine mammals and, to a lesser extent, in terrestrial wildlife. The wildlife species with the greatest potential to accumulate chlordane include water fowl (e.g. ducks and geese), certain species of turtles, otters, seals, and minks. Chlordane monitoring data are not widely available for most of these species. Chlordane was measured in the fat tissue of caribou from the Northwest Territory of Canada. The highest chlordane concentration measured in caribou was 5 ppb. The highest levels in animals are typically found in the fat and it is likely that muscle tissue concentrations were very low or below the method detection limits.

In an EPA nationwide study of chemical residues in fish (EPA 1992), the average total chlordane tissue (fillet) concentration in brown trout was 7.3 ppb. In the Surface Water Ambient Toxic Monitoring Program of Maine, three brook trout fillet samples contained a mean chlordane concentrations of 1.5 ppb (Sowles et al. 1996). The mean total chlordane concentrations in brook trout collected from the Mere Brook, adjacent to landfills associated with Naval Air Station Brunswick, were 193 ppb for adults and 32 ppb for juveniles (USFWS 1997). Chlordane (cis) was measured in recent samples (2001 and 2003) of brook trout collected from the East Branch of Greenlaw Brook and West Branch of Greenlaw Brook. Concentrations measured in fish tissue samples ranged from ND to 9.2 ppb (Woodlot Alternatives, Inc 2002; 2004).

Other Contaminants of Concern at LAFB

PAHs —Although PAHs are accumulated in terrestrial and aquatic plants, fish, and invertebrates, many animals are able to metabolize and eliminate these compounds. The ability of fish to metabolize PAHs may explain why these compounds are not detected or found only at very low levels in fish from environments where PAH contamination is known to exist. BCFs, for fish and crustaceans are frequently reported to range between 10 and10,000. Fish and other aquatic wildlife do not appear to significantly bioaccumulate PAHs and, unlike POPs, the concentrations of these compounds typically are lower in wildlife species at the top of the food chain compared to those at the bottom. In some areas of the United States, however, fish consumption advisories have been issued based on elevated concentrations of PAHs found in locally caught fish or shellfish (ATSDR 1995).

Few studies have focused on measuring PAHs in fish and wildlife. However, some additional perspective can be provided from the findings reported from environmental investigations of Prince Williams Sound in Alaska following the Exxon Valdez accident, which spilled more than 10 million gallons of crude oil into the sound. PAHs in various fish and shellfish species from Prince William Sound were not detected in 18 percent (72/402) of the samples collected; trace levels were found in 78 percent (312/402) of the samples; and individual PAH concentrations ranging from 5 to 12 ppb (wet or dry weight not specified) were found in 4 percent (18/402) of the samples. There was no apparent difference between PAH concentrations in salmon collected from impacted areas and those collected from reference locations. In samples collected in 1990, PAHs were detected in all samples (n=41) and 13 percent (6 samples) had individual PAH concentrations that exceeded 5 ppb (ATSDR 1995).

Wildlife that forage in areas that have high PAH levels in soils and sediments are likely to have the highest tissue concentrations, especially if the animals ingest large quantities of soil during feeding. PAH levels in fish and wildlife are not widely reported in the scientific literature.

Table 8d. PCB concentrations detected in different fish and wildlife species

Species	Tissue	Range (ppb)	Average (ppb)	Location	Source
Caribou	Fat	6.2—31.7[1]	NA	Canada (Northwest Territory)[2]	Elkin and Bethke 1995
Duck (Mallard)	Unspecified	NA	80	New York State	Foley 1992
	Unspecified	ND—21	NA	Wisconsin	Botero et al. 1996
Duck (Black)	Unspecified	NA	70	New York State	Foley 1992
Fish Species					
Brook Trout	Unspecified	4.9—8.1	NA	CA (Kaweah River)	Datta et al. 1998
SM Bass	Unspecified	NA	115	St Lawrence Seaway	Chan et al. 1999
Mink	Liver	154—219[3]	NA	Georgia, SC, NC	Osowski et al. 1995
	Liver	7—73	NA	Canada (NW Territory)	Poole et al. 1998
Muskrat	Liver Muscle Whole	ND—700 ND ND—800	NA ND	NY (Akwesasne Tribe)	Skinner 1992
Sea Otter	Unspecified	8—31	NA	AK, CA	Bacon et al. 1999
Turtles (Snapping)	Fat Liver Muscle	**36—1,347**[4] **2.9—94.8**[4] **ND—3**[4]	NA	NY (Akwesasne Tribe)	Skinner 1992
	Muscle	200—655[5]	NA	Canada (Ontario)	Hebert et al. 1993

Values are reported as wet weight concentrations unless otherwise noted

[1] PCB equals the sum of 43 individual congeners
[2] Values represent the range of the average (i.e., mean) concentration detected in caribou from 5 sampling locations in the Northwest Territories of Canada
[3] Values represent the range of the average (i.e., mean) concentration detected in mink across the three sampling locations (i.e., Georgia, SC, and NC)
[4] Concentrations in bold type are reported as parts per million (ppm)
[5] Values represent the mean (i.e., average) concentrations (wet weight) of PCBs from 16 sites in southern Ontario

NA = Not available; SM Bass = Small Mouth Bass
ND = Not detected
Note: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure.

Table 8e. Other POPs concentrations detected in different fish and wildlife species					
Species	**Contaminant**	**Range (ppb)**	**Average (ppb)**	**Location**	**Source**
Caribou	Chlordane[1]	0.8—5.0	NA	Canada (Northwest Territory)[3]	Elkin and Bethke 1995
	DDT[2]	0.5—2.6	NA		
Ducks	Chlordane	NA	190	MD (Chesapeake Bay)	White et al. 1979
Fish Species					
Brook Trout Adult[5]	Chlordane[4] DDE DDD DDT Total DDT	100—353 60—130 43—120 120—290 223—540	200 92 77 177 346	Maine (Mere Brook, Brunswick). Adjacent to three former landfills at the U.S. Naval Air Station in Brunswick, Maine (NASB).[6]	USFWS 1997
Juvenile[5]	Chlordane[4] DDE DDD DDT Total DDT	30—34 88—96 39—46 57—78 184—220	32 91 41 66 198		
Mink	DDT[2]	NA	9.5	Canada (Northwest Territory)	Poole et al. 1998
Turtles	Chlordane	ND—9,330	3,900	NJ and MD	Albers et al. 1986

[1] Chlordane equals the sum of oxy-, cis-, and trans-chlordane, cis-and trans-nonachlor, and heptachlor epoxide
[2] DDT equals the sum of p,p'-DDT, p,p'-DDE, and p,p'-DDD
[3] Values represent the range of the average (i.e., mean) concentration detected in caribou from 5 sampling locations in the Northwest Territories of Canada
[4] Chlordane equals the sum of cis-, and trans-chlordane
[5] Two size classes of brook trout were collected: adults (average length = 15 centimeters or 6 inches) and juveniles (average length = 7 centimeters or 2.75 inches)
[6] POPs concentrations were considerably higher in fish collected adjacent to the former NASB landfills than in selected reference locations.

Note: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure.

Ways to Minimize Exposure

- ATSDR recommends that people select younger, smaller fish; remove the skin and fatty tissue in the belly and along the sides; and avoid eating the liver and other internal organs of the fish.

- Certain methods of preparing fish and other game may help minimize an individual's exposure to certain chemicals. Frying fish traps chemicals in the fat of the fish or the oil that is used. Baking or broiling the fish and throwing away the fatty juices and drippings can reduce exposure to PCBs and other compounds that accumulate in fat.

- With few exceptions, metals do not concentrate in the muscle tissues of animals at levels that would be considered harmful. Organs such as the kidney and liver, however, may concentrate metals and other contaminants and, if consumed in high enough frequency, could be harmful. There is no way of knowing for sure if game animals that are harvested for food are contaminated unless samples of organs from the animals are collected and analyzed. If there is any reason to suspect that harvested animals have been feeding in contaminated areas it is prudent to limit the consumption of organs such as the kidney and liver.

- As mentioned previously (ways to minimize exposure to contaminants in plants), smoking or ingesting tobacco products produces the greatest potential for above-average exposure to cadmium.

- The removal of fat and skin prior to cooking may substantially reduce exposure to contaminants for people who consume waterfowl. A study conducted with common goldeneye from the Niagara River demonstrated that much of the contaminant burden in these birds was associated with adipose tissue. This study resulted in further modifications of human health advisories for the consumption of waterfowl (NYDEC 2003).

POTENTIAL FOR HUMAN EXPOSURE

ATSDR considered what native plants and animal resources the Micmac Tribe uses for traditional practices and how such activities may translate into exposures. On the basis of a review of the scientific literature, the following observations about the potential for exposure to contaminants from certain common traditional practices or daily activities are provided below.

- The highest potential of risk at sites contaminated with heavy metals (e.g., lead, arsenic) is from soil ingestion. Eliminating carryover soil from plant materials as well as from clothing and hands is an important step in preventing exposure to these contaminants. Raccoons may be good indicators of cadmium environmental contamination because they are omnivorous, depend upon both aquatic and terrestrial resources, are non-migratory, and they occur over a large area of North America, allowing for large-scale comparisons of contaminants (Burger et al. 2002). Cadmium was not included in recent sediment and surface water sampling efforts at LAFB. This heavy metal may accumulate in certain plants and may accumulate at levels of concern in the kidney and other organs of some animals.

- Workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants workers may be exposed at levels that could be harmful.

- Some medicinal plant materials are used by native populations, either daily or on a regular basis, to promote health. However, the potential for exposure to metals or other contaminants could present concerns similar to those connected with consuming plants for subsistence purposes. For example, members of the Micmac Tribe use poplar and willow trees as infusions (bark and roots), decoctions, and poultices; and are used for a wide variety of purposes, including as an analgesic, anti-diarrheal, eye medicine, headache reliever, and dermatological treatments (Fred Cory, Environmental Director, Micmac Tribe. Personal Communication. February 21, 2006).

- If dyes or paints, especially cosmetics or face paints, are made from the roots of plants, this use of the plant may be a potential exposure scenario. This is not likely to contribute significantly to overall exposure. However, cumulative sources of exposure may be sufficient to pose a health concern.

- Contaminants from plant materials (e.g., sage) used in sweat lodges, which typically contain red hot lava rocks to heat the room, may volatilize into the air (e.g., mercury, PCBs).

- From an exposure standpoint, it is important to consider which parts of the plants are used. Root crops (e.g., potatoes) and low lying plants (e.g., strawberries) are more likely to be harmful when grown in contaminated soils than are parts of the plants that are higher from the ground. In general, the use of fruits and berries that grow higher from the ground will not be a significant source of exposure to metals or other contaminants from the soil. In most cases these plant materials will not present an exposure pathway unless there is evidence of significant aerial deposition.

- A review of the literature suggests that animal skins and furs may contain high levels of mercury. Other contaminants were not measured in these studies. If members of the Micmac Tribe are known to routinely trap and skin animals for their furs and coats this should be considered as a potential exposure pathway. This would most likely be a dermal exposure concern, which is probably not a significant pathway, but one that could contribute a small amount to overall cumulative exposures from different activities and traditional practices.

- Fish are an important and healthy part of the traditional diet. Fish provide rich sources of omega-3 fatty acids which are associated with lower rates of heart disease. Fats in fish are generally unsaturated fats that are better for heart health than saturated fats found in many other foods.

Considerations for sampling fish and wildlife with highest potential to contribute to human exposures (See Table 9).

Table 9 provides a compilation of the plant and animal resources that are utilized by the Micmac Tribe and presents important information that can be used to evaluate the potential that each resource has for contributing to an individual's cumulative exposure. The levels of concern for the consumer and for the harvester, hunter, or worker, represent qualitative evaluations that are based on a review of the literature, available site-specific data, and any anecdotal information regarding how members of the Micmac Tribe may utilize specific resources. The table is not meant to be used as a tool for developing quantitative risk assessments, but rather as a resource that will assist the tribe and other groups to help prioritize potential environmental concerns and more efficiently allocate resources.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Plant Resources						
Blueberry Gooseberry Chokecherries Raspberries	Fruit/Berries	Metals: Low POPs: Low	Metals: Low Organics: Low	Very little sampling data are available in the scientific literature for some of the specific berries that are used. However, in general, fruits and berries that grow high off the ground do not contain high levels of contaminants.	No	No-Sampling of these plant resources should not be a high priority since it is unlikely that the upper portions of plants will contain harmful contaminants.
Cattails	Root	Metals: Medium POPs: Low	Metals: Medium Organics: Low	Cattails have the potential to bioaccumulate metals and some species are purposely used in the bioremediation of polluted wetlands and the treatment of industrial wastewater. Low soil pH will increase the potential for metals accumulation in the cattails.	No–Sediment samples have been collected at some locations (e.g., EBGB and WBGB)	**Yes**–Cattails can accumulate metals and collecting samples at locations where contaminated sediments were found would help confirm that biota is safe and that none of the cattail species are hyper-accumulating metals.
Fiddlehead Ferns	Stem and fronds	Metals: Low POPs: Low	Metals: Low/medium Organics: Low	A small number of studies have collected and analyzed fiddlehead ferns.	No–Sediment samples have been collected at some locations (e.g., EBGB and WBGB)	No–Fiddleheads should not receive high priority for sampling. Fiddlehead ferns do not typically accumulate metals or POPs at levels of health concern. If resources are available, it may be worthwhile to collect samples at locations with the highest lead and PCB sediment concentrations to confirm that these plants are not accumulating contaminants.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Goldthread Root	Root	Metals: Medium POPs: Low	Metals: Low/medium Organics: Low	No studies were found in the scientific literature that presented data on accumulation of contaminants in goldthread root.	No	No–Sampling for this root should not receive highest priority.
Black/White Ash Alders Burdock Hazelnut Poplar White Spruce	Bark Wood Leaves	Metals: Low/medium POPs: Low Metals: Low/medium POPs: Low Metals: Low POPs: Low	Metals: Low Organics: Low	Some trees have the capacity to accumulate lead from highly contaminated soil; for example, the tips of larch, pine, and fir contained 100 ppm lead when grown in lead mining areas with lead concentrations in soil greater than 80,000 ppm.	No	**Yes–**The most likely species to accumulate metals is the poplar. Other plant resources in this category should receive much lower priority for sampling. Poplar is a common plant consumed by herbivores and omnivores. Therefore, the poplar could serve as a useful indicator species to assess the potential for metals to accumulate in the organs of herbivores. It may also be more cost-effective to sample soil before biota sampling is considered. If soil samples do not show elevated levels of contamination, it is unlikely that harvesting these plant resources will pose a health concern.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Sweet Grass	All parts of the plant	Metals: Low POPs: Low	Metals: Medium Organics: Low/medium	Very little sampling data are available in the scientific literature.	No–Sediment samples have been collected at some locations (e.g., EBGB and WBGB)	**Yes–**Sampling of this resource should not be given highest priority. However, given its wide range of traditional uses (e.g., baskets, crafts, medicinal, other ceremonial uses) it is possible that people who routinely harvest and work with these plants could be exposed to contaminants. Sampling of sweet grass should be collected from areas where metals were frequently detected in sediments.
Sweet Flag Rhizome	Rhizomes Leaves Root	Metals: Low POPs: Low Metals: Low POPs: Low Metals: Medium POPs: Low	Metals: Low Organics: Low Metals: Low Organics: Low Metals: Medium Organics: Low	Sufficient information was not identified in the scientific literature to provide evidence that this resource may be a potential health concern or to rule it out as a concern.	No	No–Sampling of sweet flag rhizome is not likely to be a concern if other plant resources are not accumulating contaminants. The highest priority would be the plants that are known to accumulate metals (i.e., poplar, willow, and cattails).

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants						
Name	**Portion of the plant/animal frequently used**	**Exposure Concern Consumer[1]**	**Exposure Concern Harvester, hunter, and/or worker[2]**	**Supporting Evidence/Scientific Literature**	**Sampled at LAFB[3] (Yes/No)**	**Recommend Sampling (Yes/No)**
Willow	Leaf Wood Roots	Metals: Low/Medium POPs: Low Metals: Low POPs: Low Metals: Low/Medium POPs: Low	Metals: Medium Organics: Low Metals: Medium Organics: Low Metals: Medium Organics: Low	Willows are capable of concentrating cadmium in their plant tissues at levels many times higher than in the soil they are growing in. Research has shown that cadmium can accumulate at high concentrations in the leaves and stems of the plant as well as in the roots.	No	**Yes–**The primary exposure concern is for people who routinely harvest and work with these plants. Portions of the Willow and poplar are also commonly consumed by many species of herbivores and omnivores. If these plants do not contain elevated levels of metals such as cadmium and zinc, then it is unlikely that wildlife feeding on these plants will accumulate these elements at levels high enough to be of health concern. It may also be more cost-effective to sample soil before biota sampling is considered. If soil samples do not show elevated levels of contamination, it is unlikely that harvesting these plant resources will pose a health concern.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants						
Name	**Portion of the plant/animal frequently used**	**Exposure Concern Consumer[1]**	**Exposure Concern Harvester, hunter, and/or worker[2]**	**Supporting Evidence/Scientific Literature**	**Sampled at LAFB[3] (Yes/No)**	**Recommend Sampling (Yes/No)**
Wildlife Resources						
Bear	Meat (including organs) and Skin Fat, Oil	Metals: Low/medium POPs: Low/medium for meat. Medium/High for fat and oils	Low	Sufficient information was not identified in the scientific literature to provide evidence that this resource may be a potential health concern or to rule it out as a concern.	No	Sufficient information is not available at this time to provide a sampling recommendation. However, use of Black bear fat and oils in lotions and medicines, if consumed at high levels, could be of concern. Therefore, it may be prudent to sample bear fat if the resource is used extensively by the MicMac Tribe.
Cray fish	Meat	Metals: Low/medium POPs: Low/medium	Low	Levels of metals in Cray fish were generally low. However, cadmium did accumulate in the hepatopancreata and to a lesser extent in other tissues.	No	No–Cray fish are not likely consumed with high enough frequencies to warrant sampling.
Deer	Meat and organs	Metals: Low/medium POPs: Very Low	Medium	In general, levels of contaminants in deer meat have not been shown to be elevated. Organs have shown elevated levels, hence the statewide consumption advisory for liver.	No	In general, deer do not accumulate contaminants at high enough concentrations to prioritize for sampling. There is a consumption advisory for deer liver. If it is determined that people are consuming deer liver, it should be considered for sampling.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Grouse	Meat, including organs and skin	Metals: Medium/High POPs: Medium	Low	Animals that forage on willow growing in cadmium-rich soils are most susceptible. Avoid consuming the liver or kidneys of grouse or other animals.	No	No–Recommend sampling willows. If leaves contain high levels of cadmium, may want to sample animals that eat willow leaves. Grouse may be a good candidate if the willows are contaminated, since they feed on willow.
Fish (Brook trout, cat fish, white suckers)	Whole fish	Medium/High	Low/medium	The Air Force has sampled brook trout as part of its long-term monitoring obligations. Levels of PCBs continue to be elevated in the recent fish sampling efforts. The investigation conducted by the USFWS at Mere Brook in Brunswick Maine, did not detect any PCBs in the fish samples collected.	Yes Brook trout have been sampled from several locations at LAFB (see Table 7)	Yes–continued sampling of brook trout as well as other bottom feeding species
Mink	Meat and hide	Metals:	Low/medium (Trappers?)	The literature shows that contaminants (Metals and organics) accumulate in mink, primarily in the kidney. Other parts of the animal do not appear to accumulate high levels of contaminants.	No	No–not a priority Need additional information about the fur/coat

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants						
Name	**Portion of the plant/animal frequently used**	**Exposure Concern Consumer**[1]	**Exposure Concern Harvester, hunter, and/or worker**[2]	**Supporting Evidence/Scientific Literature**	**Sampled at LAFB**[3] **(Yes/No)**	**Recommend Sampling (Yes/No)**
Moose	Meat and organs	Metals: Medium/High POPs: Low	Low	Moose feed on primarily aquatic vegetation and willows in the summer; woody plants, aquatic vegetation, and barks during the winter. Moose can accumulate cadmium in their kidney and to a lesser extent in the liver.	No	No–Collecting samples of moose may not be the best use of limited resources. We know that cadmium accumulates in the organs of these animals. Advisories have already been established for the consumption of moose. However, sampling would serve to confirm whether moose near LAFB have elevated levels of cadmium and other metals in their organs. If it is determined that people are consuming moose liver, it should be considered for sampling.
Muskrats	Meat, hide, often used whole	Metals: Low/medium POPs: Low	Medium	Muskrats specifically feed on plants such as cattails, arrowhead, bulrush and occasionally animal matter such as clams, carp, crayfish, turtles, and snails	No	Consumption of the whole muskrat would increase exposure. There is not sufficient information in the literature to make a sampling recommendation. If people are consuming a significant number of muskrat, it should be considered for sampling.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Otters	Skin and fur Meat	Metals: Low/medium POPs: Medium	Metals: Low/Medium POPs: Low	Otters are primary carnivores near the top of the aquatic food chain. These animals would be more likely to accumulate chlorinated compounds and some metals, especially if feeding from areas with highly contaminated fish. Otters (especially males) are not likely to accumulate high levels of contaminants from one source area because they typically feed from a large geographic area (Anderson-Bledsoe and Scanlon 1983). One noteworthy observation is that mercury appeared to accumulate at high concentrations in the fur of otters.	No	No–not a priority Additional data would be useful regarding contaminant levels in the furs of the otters.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Rabbits (Snowshoe hare and cottontail)	Meat	Metals: Low POPs: Low	Low	In general, levels of contaminants detected in rabbit meat have not been shown to be elevated. Some studies showed a tendency for higher levels of contaminants to accumulate in the organs and fat tissues rabbits. However, not at levels of health concern.	No	No–not a priority
Raccoons	Meat Fats and Oils	Meat (including organs) and Skin Fat, Oil	Metals: Low/medium POPs: Low/medium for meat. Medium/High for fat and oils	Raccoons have been shown to accumulate high concentrations of POPs and metals mainly because they are omnivores and eat a wide variety of plants and animals including aquatic species.	No	Yes, Raccoons make a good indicator species for higher food chain consumers due to their diet. Meat and fat should be sampled. Rendering the animals fat into oils could concentrate fat-soluble contaminants.
Turtles and frogs	Meat	Metals: Medium POPs: Medium/High (highest concern in turtles)	Low/medium	Turtles can accumulate very high concentrations of POPs because of their habitats and diet. Frogs may accumulate contaminants, but not to the same extent that turtles do.	No	Yes–Turtles may be a good indicator species for aquatic and/or terrestrial wildlife, depending on the species. If older freshwater turtles do not contain elevated levels of POPs or metals then it is unlikely that other aquatic species will contain high enough levels of contaminants to be of health concern.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)
Water fowl (Ducks, geese)	Meat and organs Other parts of the animal may be used as well.	Metals: Medium POPs: Medium/High	Low/medium	Studies have measured high levels of POPs and some metals in water fowl. The potential for these animals to accumulate contaminants in fat tissue and organs varies by species. Bottom feeders, especially those that consume fish and shellfish, accumulate more contaminants than grazers (e.g., Canadian geese).	No	**Yes**–Mergansers or goldeneye ducks would receive highest sampling priority. However, they were not among the species listed as common wildlife resources. Mallards or black ducks would also be good species to sample.
Other Wildlife - Porcupine - Fisher -Red squirrels	Meat	Metals: Low POPs: Low	Low	Sufficient information was not identified in the scientific literature to provide evidence that this resource may be a potential health concern or to rule it out as a concern.	No	No–there is very little information regarding the extent to which these other wildlife species accumulate contaminants in their tissues and organs. However, unless these species are consumed frequently, it is unlikely that they contain contaminants at high enough concentrations to pose a health hazard.

Table 9: Common Plant and Animal Resources near LAFB: Potential for Human Exposure to Contaminants

Name	Portion of the plant/animal frequently used	Exposure Concern Consumer[1]	Exposure Concern Harvester, hunter, and/or worker[2]	Supporting Evidence/Scientific Literature	Sampled at LAFB[3] (Yes/No)	Recommend Sampling (Yes/No)

[1]The consumer exposure concern classification (i.e., low, medium, and high) are based on the assumption that soil and/or sediment and surface water concentrations in the area where the plants are growing or wildlife harvested exceed human health-based screening values for the contaminant of concern. Under most circumstances if contaminant-specific concentrations in the media (i.e., soil, water, sediments) where the plants or wildlife are harvested do not exceed human health-based screening values than the plant materials or wildlife should not pose an exposure concern. For migratory fish and other wildlife species that forage over large areas this general rule may not always hold true.

[2] This includes people who harvest the plants and make products (e.g., baskets, pottery, and clothing) from plant materials. The exposure categories (e.g., low, medium, and high) are assigned assuming that workers are harvesting in areas that may contain levels of contamination that could pose a health concern or hazard. If workers are harvesting from uncontaminated areas or areas where contamination is not of health concern then exposure is not a concern.

[3] Have environmental sampling efforts at LAFB directly or indirectly helped to assess contaminant levels in the specified resource? In most cases plant and terrestrial wildlife samples have not been collected. However, this column can be updated as additional sampling efforts are undertaken by the Air Force, Tribe, or other state or local entities.

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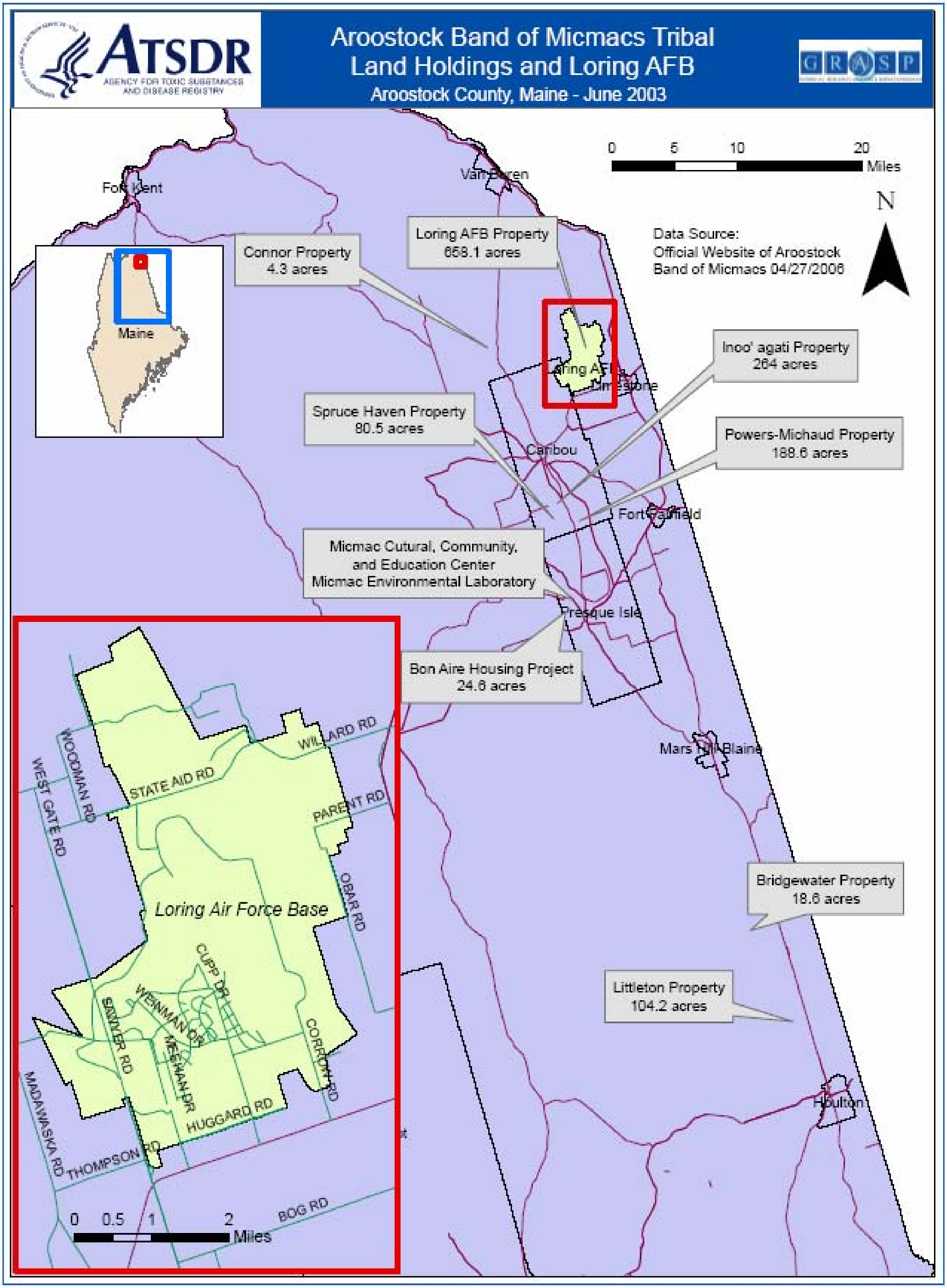

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY
Aroostock Band of Micmacs Tribal
Land Holdings and Loring AFB
Aroostock County, Maine - June 2003
GRASP
0 5 10 20 Miles
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Data Source:
Official Website of Aroostock
Band of Micmacs 04/27/2006
Fort Kent
Van Buren
Maine
Connor Property
4.3 acres
Loring AFB Property
658.1 acres
Inoo' agati Property
264 acres
Spruce Haven Property
80.5 acres
Powers-Michaud Property
188.6 acres
Loring AFB
Limestone
Caribou
Fort Fairfield
Micmac Cutural, Community,
and Education Center
Micmac Environmental Laboratory
Presque Isle
Bon Aire Housing Project
24.6 acres
Mars Hill
Blaine
Bridgewater Property
18.6 acres
Littleton Property
104.2 acres
Houlton
Loring Air Force Base
WILLARD RD
STATE AID RD
WOODMAN RD
WEST GATE RD
PARENT RD
OBAR RD
CUPP DR
WEINMAN DR
SAWYER RD
WESMAN DR
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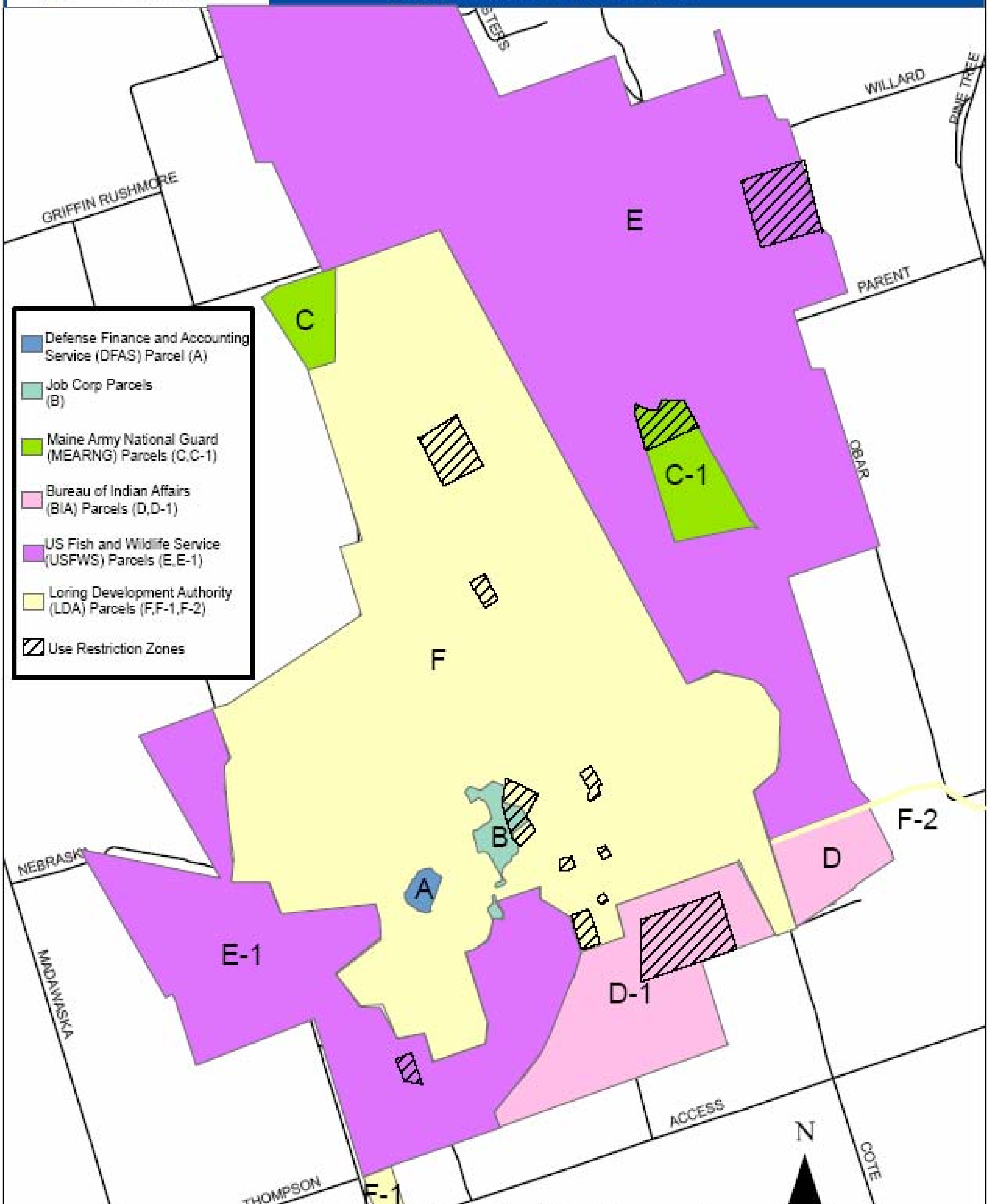
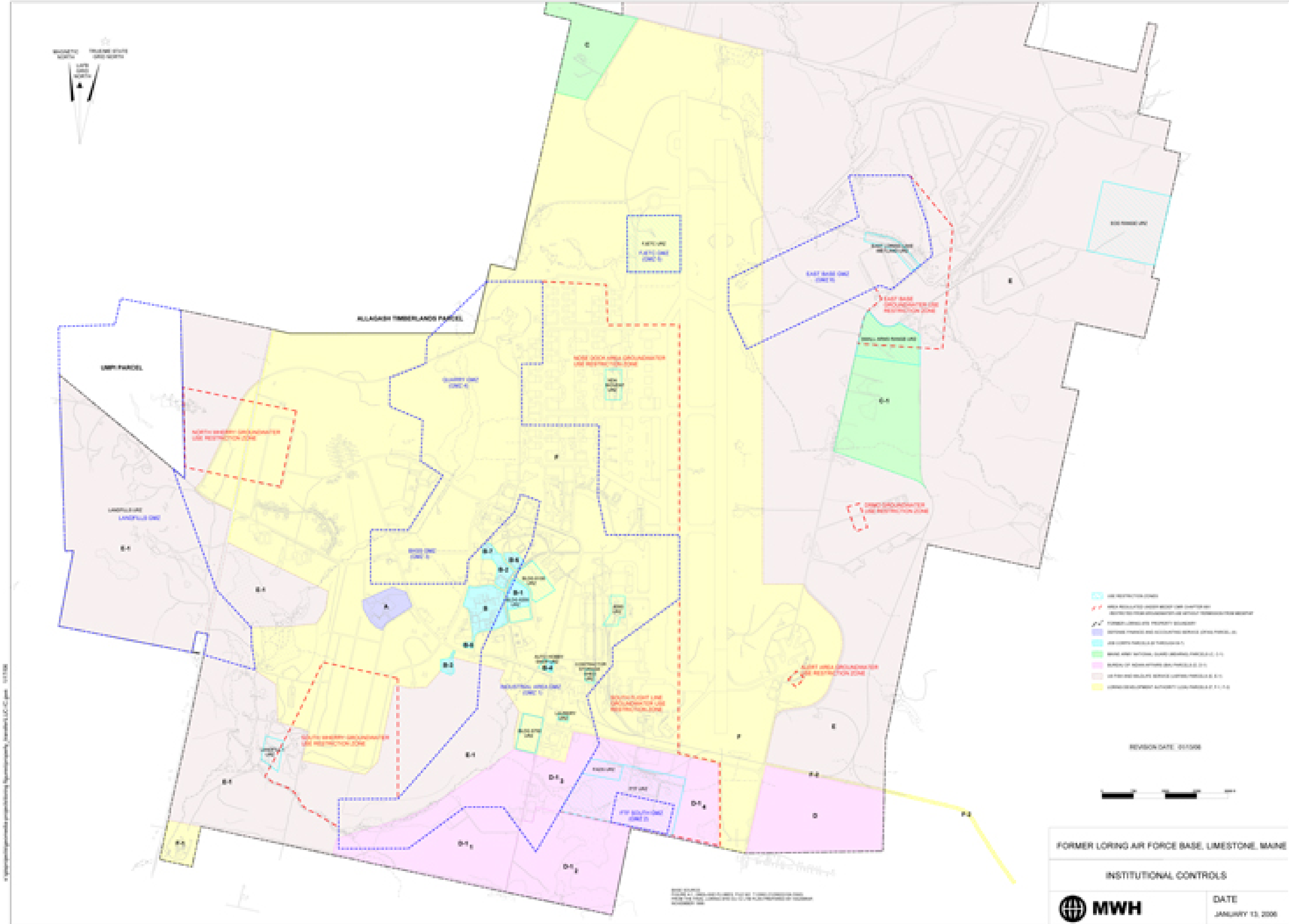
Loring AFB, Maine
Disposal Parcelization and Institutional Controls





ALLAGASH TIMBERLANDS PARCEL
UMPI PARCEL
NORTH SHERRY GROUNDWATER USE RESTRICTION ZONE
NOSE DOCK AREA GROUNDWATER USE RESTRICTION ZONE
QUARRY OMZ (OMZ 4)
LANDFILLS OMZ
EAST BASE GROUNDWATER USE RESTRICTION ZONE
SMALL ARMS RANGE URZ
DRMO GROUNDWATER USE RESTRICTION ZONE
ALERT AREA GROUNDWATER USE RESTRICTION ZONE
SOUTH FLIGHT LINE GROUNDWATER USE RESTRICTION ZONE
SOUTH SHERRY GROUNDWATER USE RESTRICTION ZONE
INDUSTRIAL AREA OMZ (OMZ 1)
FTP SOUTH OMZ (OMZ 2)
C
C-1
E
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REVISION DATE: 01/13/06
FORMER LORING AIR FORCE BASE, LIMESTONE, MAINE
INSTITUTIONAL CONTROLS
MWH
DATE
JANUARY 13, 2006