REPORT OF FINDINGS

CONTAMINANT STUDY OF THE ENVIRONMENT SURROUNDING THE CAPE ROMANZOF LONG RANGE RADAR SITE

Prepared for:

Ron Perry, Refuge Manager
U.S. Fish and Wildlife Service
Yukon Delta National Wildlife Refuge
Bethel, Alaska

By:

Wayne M. Crayton
Environmental Contaminants Specialist

Approved by:

David McGillivary, Field Supervisor
U.S. Fish and Wildlife Service
Ecological Services Anchorage
605 West 4th Avenue Room 62
Anchorage, Alaska 99516

JANUARY 1991

EXECUTIVE SUMMARY

The Cape Romanzof Long Range Radar Site (Cape Romanzof) contains many petroleum-related spills and hazardous substances. Therefore, in 1987 and 1988 a field study was conducted by the U.S. Fish and Wildlife Service (Service) to determine if contaminants from station activities had entered the Yukon Delta National Wildlife Refuge's (Refuge) environment and/or trust resources.

Analytical results indicate that elevated levels of some polycyclic aromatic hydrocarbons (PAHs), organochlorines and trace elements - most likely originating from Cape Romanzof - are accumulating in wildlife tissue. Most notable were organochlorine compounds in vole, fox and fish samples. Detected were: 1) p,p' DDE in all but one sample (0.06 - .15 ppm) and p,p' DDD in vole and fish samples (0.01 - 0.06 ppm), and 2) total PCBs in all samples (voles, 0.95 - 1.14 ppm; fox adipose fat, 0.58 ppm; fish muscle, 0.16 - 1.22 ppm). Pathways of uptake include contact, ingestion, or inhalation of contaminated soil, sediment, water, waste or food (e.g. fish, small mammals, birds).

Sediment samples collected by the Service and water and sediment samples collected by Woodward-Clyde Consultants indicate that the Old Landfill is a primary contributor of PAHs, PCBs, chlordane, lead and cadmium contamination.

Most of the Service's concerns about Cape Romanzof's contaminant problems are being adequately addressed under the U.S. Air Force's Installation Restoration Program. However, the source(s) of PCBs and other organochlorine compounds should be identified and eliminated to prevent their continuing migration into wildlife and other natural resources. Therefore, we recommend that:

1. a letter from either the Regional Director or Yukon Delta National Wildlife Refuge be sent to the U.S. Air Force informing them of our findings and recommending that appropriate remediation actions be quickly initiated in consultation with the Service, the Environmental Protection Agency and Alaska Department of Environmental Conservation;

2. the State of Alaska's Department of Environmental Conservation interim standard of 100 mg/kg (ppm) for Total Petroleum Hydrocarbons in soil be adopted by the U.S. Air Force as a cleanup level for the Cape Romanzof Long Range Radar Site;

3. the Environmental Protection Agency's "Polychlorinated Biphenyls Spill Cleanup Policy" (52 FR 10688. April 2, 1987) be used as a guide to remediate affected sites;

4. the Refuge conduct additional and more extensive monitoring every two years, at a minimum, and be adjusted as results and known inputs of contaminants dictate. Analytes should include organchlorines, cadmium, mercury, lead and total petroleum hydrocarbons.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Cape Romanzof Long Range Radar Site (Cape Romanzof), shown in Figure 1, is located within the Yukon Delta National Wildlife Refuge (Refuge). Spills of petroleum-related products have occurred; electrical transformers are/were stored on-site, and may have leaked polychlorinated biphenyls (PCBs). Extensive leaching of these chemicals into the surrounding environment could pose a threat to Refuge resources.

The U.S. Fish and Wildlife Service (Service) needs to determine the presence or absence of contaminants at Cape Romanzof because: 1) contaminants may be transferred through the food chain to Service trust resources (migratory birds, anadromous fish); and 2) existing contaminant problems may become the Service's responsibility if land management authorities are acquired.

Included in this report is a summary of field activities, and an interpretation of analytical data. Contaminated sites requiring remediation are identified and recommendations are made to assist the Refuge Manager.

STUDY AREA

Background

Cape Romanzof consists of 4900 acres within the Refuge and is located 540 miles west of Anchorage on a small peninsula that extends into the Bering Sea. The facility contains a Lower and Upper Camp which is connected by a gravel road and tramway (Figure 1). The Upper Camp is located on Towak Mountain at an elevation of 2250 feet while the Lower Camp lies in a glacially formed cirque at an elevation of 1550 feet. Radar equipment is located at the Upper Camp while support facilities (i.e. housing, power plant, fuel storage) are located at the Lower Camp (Figures 2 and 3). Cape Romanzof is accessible only by air and sea.

Cape Romanzof was constructed in 1952 and began operation as an aircraft control and warning site in 1953. In 1958 the White Alice Communication System (WACS) replaced the high frequency radio communication system. In 1979 a commercial system (Alascom) replaced the WACS operation. The facility is currently being operated by General Electric Government Services. Military positions at the facility were eliminated in 1983 and staff levels continue to drop with technological advances.

The U.S. Air Force began to address contaminant issues at Cape Romanzof in 1985 by contracting with Engineering Science to perform a Phase I Records Search, under the auspices of the Installation Restoration Program (Program) (Engineering Science,

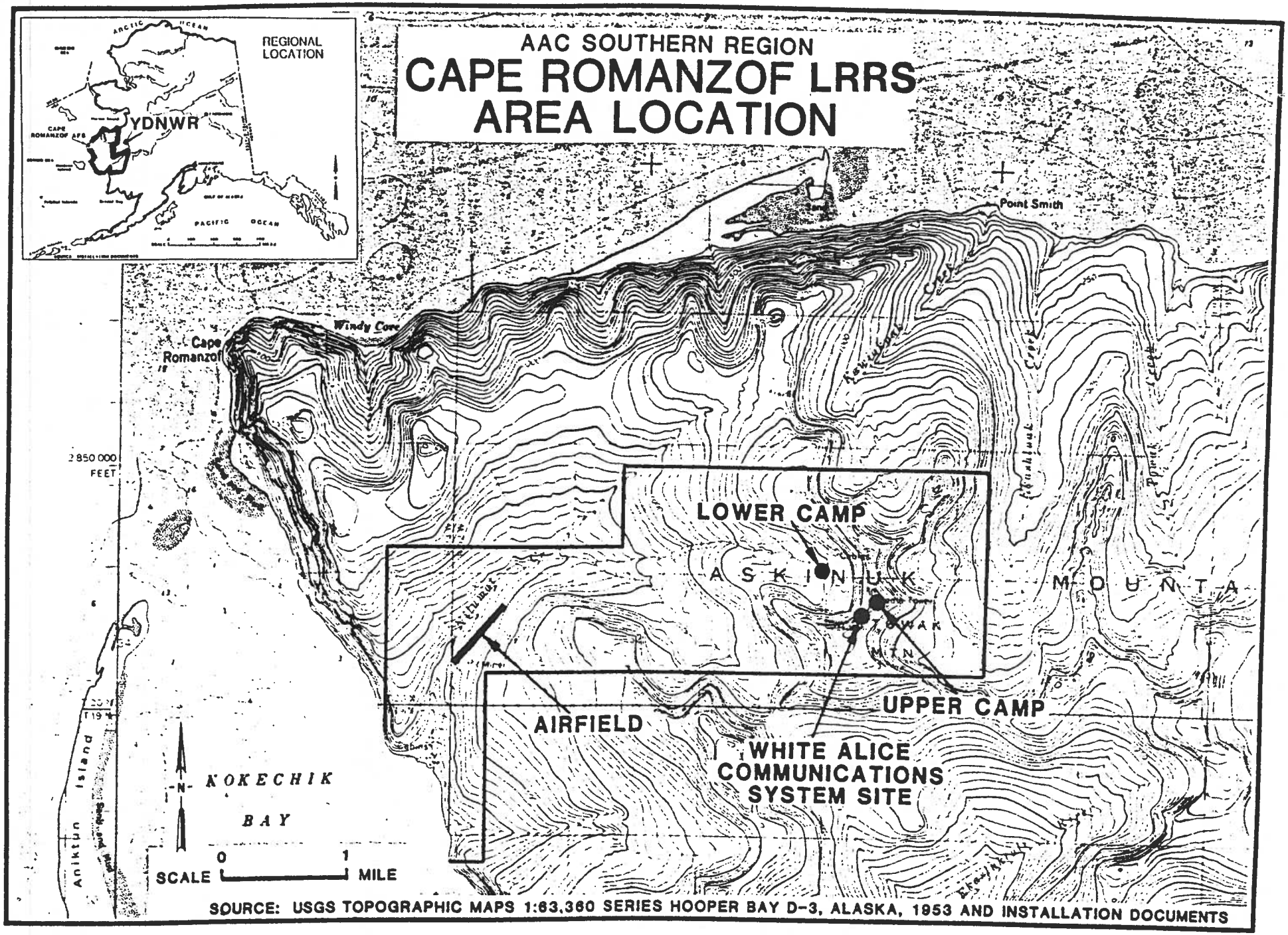

Figure 1. Cape Romanzof Long Range Radar Site (LRRS), Yukon Delta National Wildlife Refuge.

1985). [Note: The Program parallels and conforms to the U.S. Environmental Protection Agency's Superfund Program and is designed to identify, evaluate, and remediate hazardous waste sites on active military bases]. The Phase I Record Search identified sites possibly contaminated by past generation, accumulation and disposal of hazardous wastes. For example, wastes were applied to roads for dust control and thousands of gallons of diesel fuel were spilled since the 1950's. In total, eleven sites were assigned the highest hazard potential and were recommended for further Program action.

A new composite facility, providing living quarters at the Lower Camp, became operational in 1986, and in 1987 old Lower Camp structures (some containing asbestos) were demolished and disposed on-site. In 1987 Woodward-Clyde Consultants (WCC) began assessing for the U.S. Air Force, past hazardous material disposal and spills and developing remedial recommendations for those areas which pose a threat to human health and welfare or to the environment. As a result, nine sites were investigated in 1989 for petroleum hydrocarbons, PCBs, volatile and semi-volatile organics and metals contamination (WCC, 1990). WCC concluded that the only soil contamination problem at the facility is total petroleum hydrocarbons (TPHs). Results of surface water analyses indicate that water near an old landfill is contaminated with TPHs and PCBs. Groundwater results indicate the presence of TPHs and alpha benzenehexachloride (BHC), a pesticide, in selected wells. A qualitative risk assessment concluded that three sites required no further action, but remedial action should be considered for six sites (WCC, 1990). Remedial alternatives are currently being considered by the U.S. Air Force.

Refuge Resources

Cape Romanzof is located within Fowler (Nilumat) Creek's (Creek) drainage (Figure 4). The Creek (Figure 5) and the other small streams in the area are all classified by the State of Alaska as having high water quality. All creeks at Cape Romanzof flow into Kokechik Bay, which supports cackling Canada geese, emperor geese, white-fronted geese, northern pintail, swan and a variety of other waterfowl and shorebirds. Rock ptarmigan occur throughout the area. Dolly Varden inhabit, and pink salmon spawn in the Creek. Peregrine falcon nest within 10 miles of the facility and have been observed using the area.

Because overburden at the Upper Camp is virtually nonexistent, vegetation, where found, is of the alpine tundra/barren ground community. Pockets of vegetation are dominated by mountain-avens, lichens, low-growing herbs and grasses (Figure 5).

Mammal populations are largely unknown; however, red fox and voles commonly occur in the area and mink and wolverine are less common. Beaver ponds have been constructed in Fowler Creek.

METHODS

Sample Sites and Field Procedures

In 1987 fourteen sediment samples (i.e. replicate samples at seven sites) were collected in the Fowler Creek drainage (Figure 6). Sediment was chosen for analyses because it would be expected to accumulate contaminants originating from surface-runoff. Creek samples were collected from Hudson Dam's impoundment (Site 1), 1000 feet below Hudson Dam (Site 2), 2400 feet below Hudson Dam (Site 3) and immediately below the confluence of the Creek and a small tributary (Site 4), originating from an old landfill (Figure 6). Sediment samples were also collected around (Site 5), next to (Site 6) and below (Site 7) the previously mentioned old, (1.5-acre) landfill, see Figure 6, because emanating streams - which drain into Fowler Creek - contain debris and unusually-colored sediment (Figures 7 and 8). [Note: This site corresponds to Woodward-Clyde Consultant's ROM-8 site and will be discussed in greater detail later in this report.]

Each sediment sample was a composite of several grab samples collected from the top inch of sediment with acetone-rinsed, stainless steel spoons. Sediment samples collected for inorganic analyses were stored in acid-cleaned polyethylene jars and frozen; samples collected for organic analyses were stored in acid-cleaned glass jars and frozen.

In 1988 the Service collected biological samples from four general areas, see Figure 6, to determine if contaminants had entered the food chain. Dolly Varden were caught using minnow traps and fishing tackle; voles were caught using pitfall and snap traps; and the red fox were collected using a .22-rimfire rifle and snare.

The biological sample sites and the specimens collected are described below:

Site 8: New Composite Facility - 3 red fox (Vulpes fulva) inhabiting the rocky slopes behind the Facility.

Site 9: Open Area - 5 voles (Microtus sp.) from an area between New Composite Facility and Fowler Creek.

Site 10: Open Area - 4 voles from an area between the southern end of runway and Fowler Creek.

Site 11: Fowler Creek - 10 Dolly Varden (Salvelinus malma) caught between the mouth of Fowler Creek and the confluence of Fowler Creek and a tributary located north of the runway.

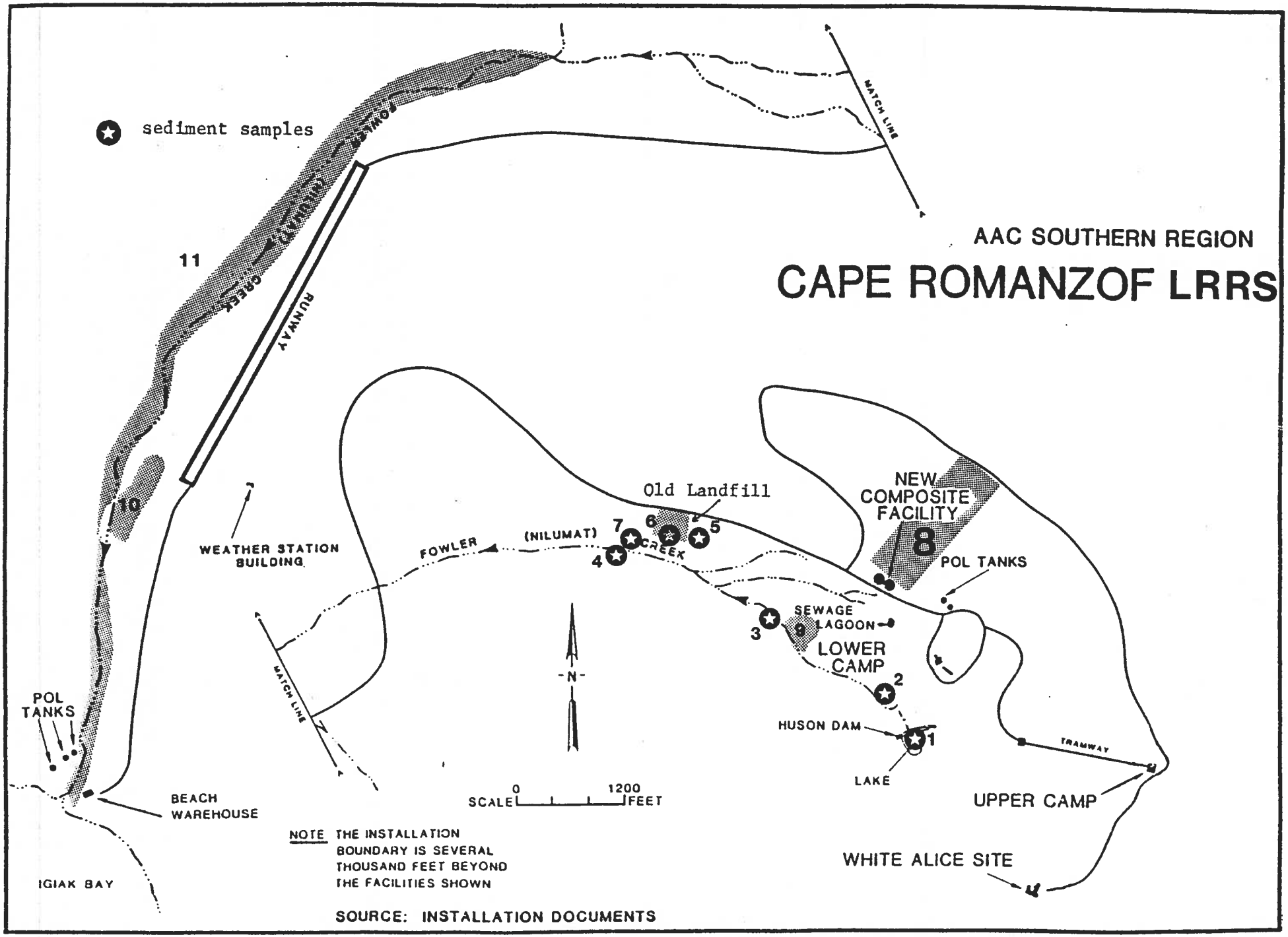

Figure 6. Cape Romanzof Long Range Radar Site sample sites (1987 -1988).

Analytical Procedures

Standard techniques were utilized by Research Triangle Institute in 1988 and Versar, Inc. in 1987 to determine the concentrations of selected metals: atomic absorption spectrometry (arsenic, selenium), cold vapor (mercury), inductively coupled plasma (ICP) methodologies (antimony, cadmium, chromium, copper, iron, lead, manganese, nickel, thallium, zinc). Other analytes coincidently determined by ICP include: aluminum, barium, beryllium, boron, cobalt, magnesium, molybdenum, silver, strontium, tin and vanadium. ICP-preconcentration techniques were used to analyze tissues. Texas A & M Research Foundation's organic analyses were performed by capillary gas chromatography (CGS) with a flame ionization detector for aliphatic hydrocarbons, CGS with electron capture detector for pesticides and PCBs, and a mass spectrometer detector for polycyclic aromatic hydrocarbons (PAHs). All dissections, including vole skinning, were performed by laboratory personnel.

Table 1 lists chemical compounds and inorganics determined in this investigation. All PAHs and organochlorine concentrations are expressed in parts per million (ppm) and were determined on a wet weight basis. Inorganic values are also expressed in ppm, but were determined on a dry weight basis, unless otherwise indicated. The lower levels of detection for the organochlorine analytes is 0.5 ppm for PCBs and 0.02 ppm for the balance. The detection limit for PAHs is 0.01 ppm. Detection levels for inorganics varied for each sample and element.
Untabulated data and Quality Control/Quality Assurance reports are available upon request.

The following matrix summarizes analyses:

	PAHs	Organochlorines	Inorganics
9 Voles			
3 individuals, whole body			X
3 composites, whole body (2 individuals/composite)	X	X	
3 Red fox			
3 liver			X
3 adipose fat	X	X	
10 Dolly Varden			
5 liver			X
5 fillets	X	X	
14 Sediment			
7 composites			X
7 composites	X	X	

Table 1. Analytes for the Cape Romanzof LRRS contaminants study, Yukon Delta National Wildlife Refuge.

INORGANICS	POLYNUCLEAR AROMATIC HYDROCARBONS	ORGANOCHLORINES
antimony (Sb)	naphthalene	oxychlordane
arsenic (As)	1-methylnaphthalene	cis-nonachlor
cadmium (Cd)	2-methylnaphthalene	alpha chlordane
chromium (Cr)	2,6 dimethylnaphthalene	gamma chlordane
copper (Cu)	2,3,4-trimethylnaphthalene	transnonachlor
iron (Fe)	1-methylphenanthrene	heptachlor
manganese (Mn)	acenaphthylene	heptachlorepoxide
mercury (Hg)	acenaphthene	o,p'-DDE
nickel (Ni)	fluorene	p,p'-DDE
lead (Pb)	phenanthrene	o,p'-DDD
selenium (Se)	anthracene	p,p'-DDD
thallium (Tl)	fluoranthene	o,p'-DDT
zinc (Zn)	pyrene	p,p'-DDT
	benzo(a)anthracene	total DDT
incidentals:	chrysene	mirex
aluminum (Al)	benzo(b)fluoranthene	dieldrin
barium (Ba)	benzo(k)fluoranthene	aldrin
beryllium (Be)	benzo(e)pyrene	alpha BHC
boron (B)	benzo(a)pyrene	hexachlorobenzene
cobalt (Co)	perylene	beta BHC
iron (Fe)	indeno(1,2,3-c,d)pyrene	lindane
magnesium (Mg)	dibenzo(a,h)anthracene	delta BHC
molybdenum (Mo)	benzo(g,h,i)perylene	total Cl-2 (PCB)
silver (Ag)	biphenyl	total Cl-3 (PCB)
strontium (Sr)		total Cl-4 (PCB)
vanadium (V)		total Cl-5 (PCB)
		total Cl-6 (PCB)
		total Cl-7 (PCB)
		total Cl-8 (PCB)
		total Cl-9 (PCB)
		total PCBs
		toxaphene

RESULTS

Concentrations of selected analytes in sediment samples and wildlife tissues are tabulated in Appendix A.

Sediment Samples

Fowler Creek: Organochlorines were not detected in any samples.

Total aromatic hydrocarbons contamination ranged from 0.86 to 2.18 ppm. Compounds with the highest concentrations were naphthalene-based. Site 1 and 4 samples contained the highest PAH concentrations, and the former sample site also had the most detected PAH compounds (14).

Antimony, cadmium, mercury and thallium concentrations occurred very close to their respective detection limits. Chromium, copper, nickel and zinc concentrations progressively decreased downstream, but no such pattern was noted for arsenic, selenium or lead.

Old Landfill: Organochlorines were not detected in any samples.

This area had the highest number of aromatic hydrocarbon compounds detected (20), and total aromatic hydrocarbons concentrations (0.60 to 2.45 ppm). Like samples from Fowler Creek, the highest concentrations reported were naphthalene-based.

This area also had some of the highest reported trace element concentrations. Elevated zinc and lead concentrations were detected in sites 5 and 6. Mercury, selenium and thallium were not detected in samples. Antimony was detected in only one sample, and unlike those samples from Fowler Creek, cadmium was detected in all samples. The remaining four trace elements occurred at intermediate levels, and at all sites.

Wildlife Samples

Red Fox: Only two organochlorines were detected, total PCBs in one specimen and p,p'-DDE in two specimens.

All 24 aromatic hydrocarbon compounds were detected in two of three specimens. Twelve aromatic hydrocarbons were detected in the third fox sample. Total aromatics in the three fox specimens ranged between 0.90 and 2.94.

Antimony, arsenic and selenium were not detected. Copper, iron and zinc concentrations were highest reported. The non-essential elements mercury, cadmium and lead were detected in all specimens. The remaining trace elements were detected in all samples.

Dolly Varden: Similar organochlorine compounds were detected in four of five fish specimens. Most notable were the GC/MS-confirmed high concentrations of DDT-related compounds and total PCBs in all samples. Chlordane-related compounds, total BHC and dieldrin were commonly detected, but at low levels.

Only one specimen contained elevated aromatic hydrocarbon concentrations, as twenty-three of 24 aromatics were detected between 0.03 and 0.30 ppm. In contrast, only six aromatics were detected ($\leq$ 0.02 ppm) in the remaining specimens. Fluoranthene and pyrene were detected in all specimens.

Antimony was the only element not detected. Similar to red fox specimens, iron, zinc and manganese had the highest concentrations. Lead and mercury levels were low (ND - 1.3 ppm). Cadmium concentrations varied considerably. Intermediate concentrations of chromium, copper and selenium were detected in all specimens.

Voles: Organochlorines were detected in all three vole samples. Twenty-one compounds were detected in one sample collected near the runway. A second sample, also collected near the runway, contained 10 organochlorines and the remaining sample (consisting of one vole collected near New Composite Facility and two voles from near the runway) contained only seven compounds. Most notable were the detection (and confirmation using GC/MS) of chlordane-related and DDT-related compounds, dieldrin and total PCBs in all samples. Low total BHCs concentrations occurred in two samples.

Collectively, eight aromatic hydrocarbons were detected in the three samples and concentrations were low.

Antimony, arsenic, lead and selenium were not detected in any vole specimens. Low mercury concentrations were detected in all three samples. When detected, cadmium, chromium, and nickel were also low. The highest concentrations were iron, zinc and manganese. The remaining elements had intermediate concentrations.

DISCUSSION

Data Interpretation

The process of interpreting chemical analyses is aimed at addressing the question "Do the sample data indicate a problem exists?" In its simplest form this act would appear to consist of comparing each sample datum with a list of action levels or threshold levels (= criteria), above which a problem - albeit undefined - exists. Indeed, this would be ideal. However, a variety of problems impede this approach.

In the cases of water and soil/sediment, the total amount of a chemical reported for a sample is not synonymous with the amount that is (biologically) available. The latter is strongly influenced by a complex suite of physical, chemical and biological factors (e.g. pH, Eh, hardness, alkalinity, salinity, concentration of organic matter, texture). One never has all relevant information for each sample that would allow adjustment of calculated values prior to comparison with a list of criteria (Long and Morgan, 1990; Shea, 1988).

In the case of tissue samples, a different criterion may exist for each species, as well as the particular tissue within that species (e.g. liver vs. kidney vs. muscle vs. whole body homogenate). A sublethal criterion (e.g. avoidance, impaired growth, impaired reproductive success) is much lower than a criterion for safe consumption levels or acute mortality. Moreover, several reviews have warned that using tissue levels of metals as indicators of pollution is not justifiable (Jenkins, 1980; Mance, 1987; Phillips, 1977; Stokes, 1979). Phillips (1980) emphasized this point by stating: "...no study has yet been reported in which an indisputable correlation between levels of metals in the fish and those in the environment was demonstrated." These and other problems with developing a single set of rigid criteria are thoroughly discussed in Long and Morgan (1990) and Soholt, et al. (1981).

Notwithstanding all the above problems, a partial set of criteria has been subjectively constructed by amalgamating a variety of information including: Environmental Protection Agency's water quality criteria; review papers/series that offer lists of "action levels;" U.S. Food and Drug Administration's action levels for poisonous or deleterious substances in human food; World Health Organization's list of water quality criteria; and sundry literature dealing with a biological effect of one, a few, or a group of individual chemicals. As many of the above sources as time allowed were reviewed prior to finalizing the criteria (Appendix B). Our review of information is an ongoing process; thus, the criteria are subject to change.

The approach to interpretation consists of a 4-step process, essentially comparing each laboratory-reported value to a series of screens:

(1) Background or control samples taken from the study area;
(2) The subjective set of criteria (Appendix B);
(3) Literature values listing averages and ranges for Alaska (Gough, et al., 1988); and
(4) Literature values listing averages and ranges on a worldwide basis (Fortescue, 1980).

In general, **we did not consider a sample value problematical (i.e., requiring corrective action) unless it exceeded one order of magnitude of the appropriate screen(s)**. This is a common strategy designed to provide a buffer for a variety of sources of inherent variance, principally site specificity and laboratory methodology. However, any sample which exceeds the appropriate screen (by less than one order of magnitude) requires some attention, as it may be indicative of a developing problem - albeit undefined.

Findings

Analytical results indicate that fish, wildlife and aquatic resources surrounding Cape Romanzof have been contaminated (to varying degrees) with organic compounds and trace elements. Thirty-nine contaminants of potential concern have been detected (Table 2). These contaminants are of concern because: 1) their concentrations exceed Service criteria; 2) their concentrations are potentially toxic (i.e., carcinogenic, mutagenic) to humans and the environment; or 3) their mere presence may be indicative of a more extensive problem. Profiles of the contaminants of potential concern are presented in Appendix C. WCC identified TPHs in soil and surface water, and PCBs in surface water as contaminants of concern at Cape Romanzof (WCC, 1990).

Fowler Creek sediment: Five contaminants of potential concern were identified in Fowler Creek sediment - four are PAHs and the fifth is an organochlorine (Table 2). Naphthalene-based compounds exceeded our criteria by an order of magnitude at two sites (Nos. 1 and 4). The carcinogen benzo(a)pyrene is listed despite its low concentration. Organochlorines were not detected in Service samples; however, one of interest (PCBs) was detected in WCC samples. Thus it was placed on the list of contaminants of concern. No inorganic element exceeded the Service's criteria.

The sources of PAH contamination in Fowler Creek are obvious. During the Service's investigation, many empty and partially-full barrels of antifreeze, lube oil, and unknown Dow Chemical Company products were found in the creek's channel. Furthermore, WCC (1990) identified six sites as possible sources of contamination to Fowler Creek (Figure 9):

> ROM-1S Large Fuel Spill - Soil samples contained TPHs concentrations ranging from 1,500 to 17,000 ppm with the highest concentrations occurring along a tributary to Fowler Creek.
>
> ROM-3 Former Shop Area - Four soil samples contained TPHs ranging from 2,400 to 35,000 ppm. PCBs occurred in sediment at 0.39 parts per billion (ppb).

Table 2. List of contaminants of potential concern detected at Cape Romanzof LRRS, Yukon Delta National Wildlife Refuge.

	VOLES			RED FOX			DOLLY VARDEN					SEDIMENT: FOWLER CREEK				SEDIMENT: OLD LANDFILL		
	1	2	3	1	2	3	1	2	3	4	5	1	2	3	4	5	6	7
POLYCYCLIC AROMATIC HYDROCARBONS																		
naphthalene (naph.)				+	+	+		+										
1-methylnaph.				+		+		+								+		
2-methylnaph.				+		+		+								+		
2,6 dimethylnaph.				+	+	+		+				!	+	+	!	!	!	+
2,3,4-trimethylnaph.				+		+						!	+	+	!	!	!	+
1-methylphenanthrene				+	+	+												
acenaphthylene				+	+	+		+										
acenaphthene												+			+	+	+	
fluorene																+		
phenanthrene				+		+	+									+		
anthracene							+											
fluoranthene				+		+	+									+		
pyrene				+		+	+									+		
benzo(a)anthracene					+		+											
chrysene				+		+	+									+		
benzo(b)fluoranthene				+		+	+											
benzo(k)fluoranthene				+		+	+											
benzo(e)pyrene				+	+	+	+											
benzo(a)pyrene				+	+	+	+								*	*		
perylene				+			+											
indeno(1,2,3-c,d)pyrene				+		+	+											
dibenzo(a,h)anthracene				+		+												
benzo(g,h,i)perylene				+		+	+											
biphenyl				+		+	+											
ORGANOCHLORINES																		
technical chlordane	+	+	+				+		+	+	+							
p,p'-DDE	+	+	+	*		*	*	*	*	*	*							
p,p'-DDD	+	*	*				*		*	*	*							
dieldrin	*	*	*				*		*	*	*							
total BHCs	*		*				*		*	*	*							
total PCBs	!	!	!			*	*	*	*	*	*				*	*		
TRACE ELEMENTS & HEAVY METALS																		
cadmium					+	+										*		
chromium	+	+	+			+												
copper	+	+	+	!	!	!												
iron	!	!	!	!	!	!	!	!	!	!	!							
lead																+		
manganese	!	!	!	!	!	!												
mercury				+		+												
nickel						+												
zinc	!	!	!	!	!	!	!	!	!	!	!							

\+ - exceeded criteria.
! - exceeded criteria by one order of magnitude or greater.
* - presence is of concern regardless of concentration found or in the case of sediments, contaminant is present in surrounding environment, as documented by Woodward-Clyde Consultants (1990).

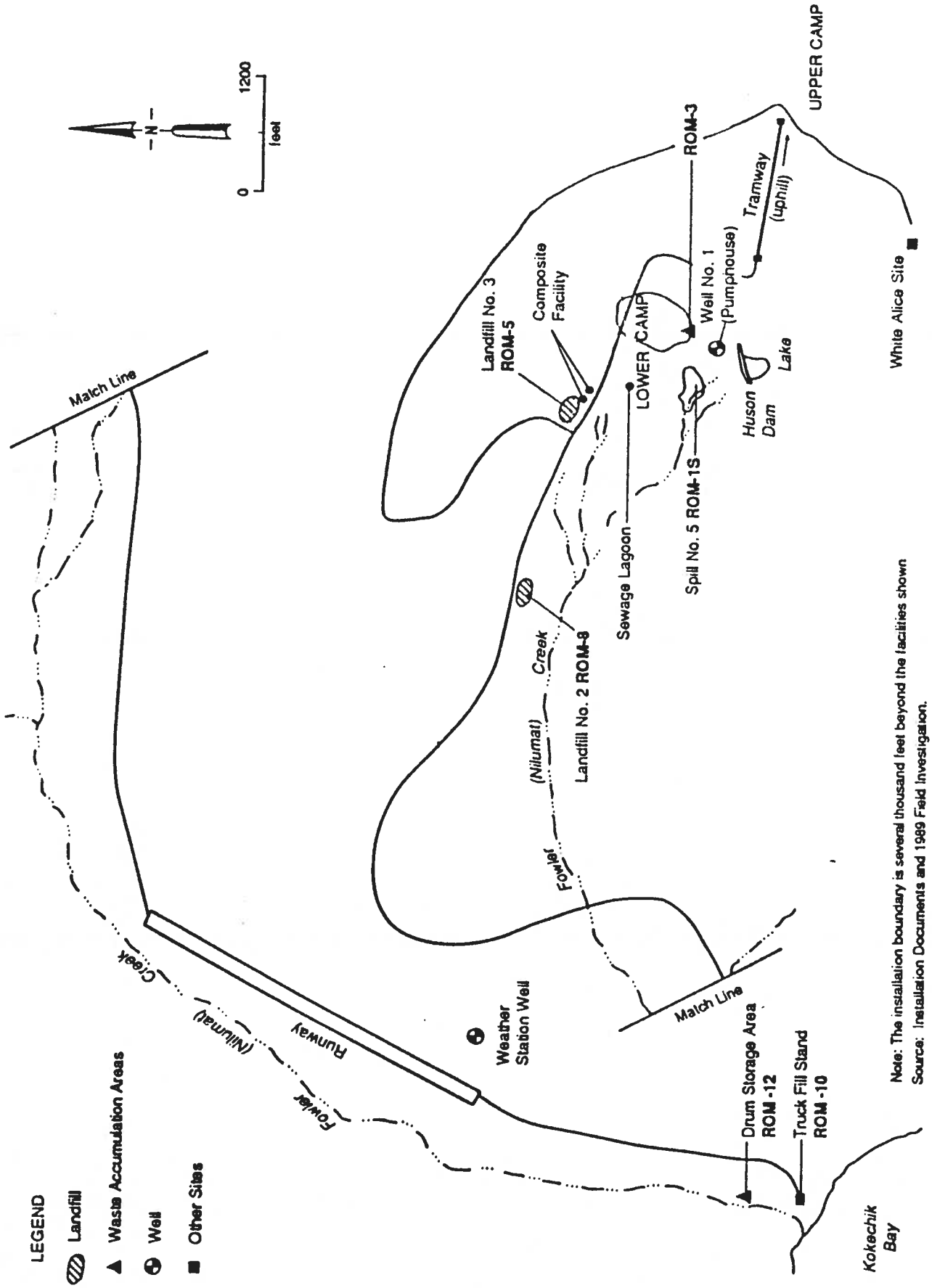

Figure 9. Contaminant sources potentially affecting Fowler Creek (from WCC, 1990).

ROM-5 New Landfill - TPHs occurred at a concentration of 100 ppm.

ROM-8 Abandoned Landfill - Soil samples had TPHs levels ranging from 40 to 100,000 ppm and 7.0 ppm cadmium. Surface water contained 0.009 ppm cadmium. Lead levels as high as 430 ppm lead were detected in soil. Several organic compounds were detected in surface water samples: 2,4-methyl phenol (220 ppb), 1,4 dichlorobenzene (4.6 ppb), PCBs (2.7 ppb), 1,1,1-trichloroethane (1.1 ppb), xylenes (4.0 ppb). Ground water samples contained organic chemicals also.

ROM-10 Former Truck Fill Stand - TPHs occurred at a concentration of 4900 ppm. WCC stated that because of the proximity of this contamination to Fowler Creek and Kokechik Bay, the site represents a potentially significant environmental risk. Note: Beaver constructed several ponds near this site.

ROM-12 Former Drum Storage Area - One soil sample contained 0.21 ppm PCBs; two soil samples contained TPHs values of 100,000 and 200,000 ppm. Sediment contained 50 ppm TPHs. The site's TPH contamination and proximity to Fowler Creek may pose a significant environmental risk. Note: Beaver constructed several ponds near this site.

Old Landfill sediment: Fourteen contaminants of concern were detected at this site: 11 PAHs, 1 organochlorine (PCBs), 2 heavy metals (cadmium and lead). Naphthalene-based compounds exceeded our criteria by an order of magnitude at the two sites closest to the landfill (Nos. 5 and 6). The carcinogen benzo(a)pyrene is listed despite its low concentration. Organochlorines were not detected in Service samples; however, PCBs were detected in WCC water samples.

Lead was the only trace element exceeding Service criteria.

WCC reported cadmium and PCBs exceeded the Environmental Protection Agency's ambient water quality criterion - to protect against chronic effects - by 3 and 40 times, respectively. Thus they were added to the Services's list of contaminants of concern.

The Old Landfill is a serious environmental hazard because the listed contaminants will eventually migrate into the surrounding environment; Moreover, analyses for additional hazardous materials will probably indicate their presence. Sources of contamination may include hazardous waste and/or materials buried within the landfill. The area is also littered with empty

barrels, an electrical transformer and assorted metal debris. Water seeping through, over and around the landfill is the likely contaminant transport mechanism.

The Service's results support the following WCC statements:

> The duration and/or frequency of exposure of aquatic life to cadmium and PCBs, could be adequate to potentially cause adverse effects if cadmium and PCBs in the surface water at ROM-8 (i.e., the Old Landfill) entered Fowler Creek.
>
> The exposure frequency/duration of aquatic organisms to PCBs and TPH (is) ... adequate to potentially cause toxic effects.

Wildlife Samples: Of primary concern is the number and concentration of organochlorines found in **all** sample types and the number of PAHs detected in red fox.

Vole samples contained six organochlorine contaminants of concern. PCBs levels exceeded Service criteria by an order of magnitude in all samples, and may pose a threat to the food chain. Technical chlordane and DDT-related compounds also exceeded Service criteria, and may warrant biological concern. The presence of dieldrin and BHCs is a lesser concern because of their low levels.

Dolly Varden specimens also contained six organochlorine contaminants of concern. DDT-related compounds and PCBs were found in all samples; however, only technical chlordane exceeded Service criteria. DDT-compounds, dieldrin, BHCs and PCBs are of concern, despite low concentrations, because they are inherently toxic to fish.

The only two organochlorines (p,p'-DDE and PCBs) detected in red fox occurred at concentrations below Service criteria. However, their presence indicates that organochlorine contamination has migrated into higher trophic levels.

Red fox samples contained 24 PAH-contaminants of concern. PAH-exposure probably occurred through dermal contact, incidental soil ingestion, contaminated dust inhalation and/or prey. Eight PAHs were detected in vole samples. Dolly Varden samples were relatively free of PAHs except for one individual. This result is surprising given the high probability of petroleum wastes being swept into the Fowler Creek drainage and the ability of fish to metabolize PAHs quickly.

Presence of PAHs in any specimen is of concern because in general, PAHs show little tendency to biomagnify in food chains, despite their high lipid solubility (Eisler, 1987). Their

occurrence indicates that gross petroleum contamination exists at Cape Romanzof in accessible areas. The PAHs detected are extremely variable in toxicity and have various effects on different species and individuals of the same species (Lee and Grant, 1981). Thus, we can not presently conclude that the PAH concentrations detected are biological dangerous.

Many trace elements exceeded Service criteria; however, only mercury and cadmium (found only in red fox tissue) are of concern because of their documented adverse impacts on wildlife. Other elements exceeded criteria in some cases by an order of magnitude; however, their potential impacts are uncertain because of the inherent problems of relating specific residual concentrations of biologically-essential elements with known adverse biological impacts.

CONCLUSIONS AND RECOMMENDATIONS

Analytical laboratory results indicate that organochlorines, polycyclic aromatic hydrocarbons and selected trace elements - most likely originating from the Cape Romanzof Long Range Radar Site - have entered the aquatic environment and accumulated in the food chain. Although the levels found are not sufficient to cause acute mortality, they may be sufficient to cause either reproductive, physiological or morphological damage. Major pathways of transfer are dermal contact with contaminated soil, sediment, water, or waste; inhalation of contaminated particles; and ingestion of contaminated soil, water, waste and/or prey.

Sediment samples collected by the Service, and water and sediment samples collected by WCC indicate that the Old Landfill (WCC's Site ROM-8) is a primary contributor of PAHs, PCBs, chlordane, lead and cadmium contamination. Like WCC (1990), we believe contaminant sources include: hazardous waste; gasoline and diesel fuel spills; and, leaks from drums in landfills and/or petroleum, oil and lubricant tanks and pipes.

Results of this effort are in accord with WCC's qualitative risk assessment and conclusions: three sites require no further action, but the following six sites have contaminant concentrations requiring remedial action (WCC, 1990):

ROM-1 Waste Accumulation Area
ROM-1S (Soil) Large Fuel Spill
ROM-3 Former Shop Area
ROM-8 Old Landfill
ROM-10 Former Truck Fill Stand
ROM-12 Former Drum Storage Area

Rainfall and snowmelt runoff appears adequate to move chemical contaminants from the above sites to Fowler Creek and into Kokechik Bay.

Most of the Service's concerns about Cape Romanzof's contaminant problems are being adequately addressed under the U.S. Air Force's Installation Restoration Program. However, the source(s) of PCBs and other organochlorine compounds should be identified and eliminated to prevent their continuing migration into wildlife and other natural resources. Therefore, we recommend that:

1. a letter from either the Regional Director or Yukon Delta National Wildlife Refuge be sent to the U.S. Air Force informing them of our findings and recommending that appropriate remediation actions be quickly initiated in consultation with the Service, the Environmental Protection Agency and Alaska Department of Environmental Conservation;

2. the State of Alaska's Department of Environmental Conservation interim standard of 100 mg/kg (ppm) for Total Petroleum Hydrocarbons in soil be adopted by the U.S. Air Force as a cleanup level for the Cape Romanzof Long Range Radar Site;

3. the Environmental Protection Agency's "Polychlorinated Biphenyls Spill Cleanup Policy" (52 FR 10688. April 2, 1987) be used as a guide to remediate affected sites;

4. the Refuge conduct additional and more extensive monitoring every two years, at a minimum, and be adjusted as results and known inputs of contaminants dictate. Analytes should include organchlorines, cadmium, mercury, lead, total petroleum hydrocarbons.

CITED LITERATURE

Eisler, R. 1987
. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11). Patuxent Wildlife Research Center, Laurel, Maryland. 81 pp.

Engineering-Science. 1985. Installation Restoration Program Phase I: Records Search. AAC-Southern Region, King Salmon AFS, Cape Newenham AFS, Cape Romanzof AFS, Cold Bay AFS, Sparrevohn AFS and Tatalina AFS. Prepared for USAF, Tyndall AFB, Florida and Elmendorf AFB, Alaska.

Fortescue, J. A. C. 1980. Environmental Geochemistry: A Holistic Approach. Springer - Verlag, New york. 347 pp.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element Concentrations in Soils and Other Surficial Materials of Alaska. U.S. Geol. Survey Prof.Paper 1458. 53 pp.

Jenkins, D. W. 1980. Biological Monitoring of Toxic Trace Metals. Volume I, Biological Monitoring and Surveillance. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-089, NTIS PB81-103475. September. 215 pp.

Lee, S.D. and L. Grant (eds.). 1981. Health and ecological assessment of polynuclear aromatic hydrocarbons. Pathotex Publ., Park Forest South, Illinois. 364 pp.

Long, Edward R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Tech. Mem. NOS OMA 52. 175 pp.

Mance, Geoffery. 1987. Pollution Threat of Heavy Metals in Aquatic Environments. Elsevier Applied Science, London. 363 pp.

Phillips, D. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments - a review. Environ. Pollut. 13: 281-317.

Shea, D. 1988. Developing national sediment quality criteria. Environ. Sci. Technol. 22(11): 1256 - 1261.

Soholt, L. F., Vocke, R. W., Beskid, N. J., Derickson, W. K., Knight, M. J., Ness, D. D., Siskin, B. and W. S. White. 1981. Coal Combustion Waste Manual: Evaluating Impacts to Fish and Wildlife. U.S. Fish and Wildlife Service, Biological Services Program, National Power Plant Team, FWS/OBS-81/05. 150 pp.

Stokes, P. 1979. Copper Accumulations in Freshwater Biota. Chap. 12 in J. Nriagu (Ed.) Copper in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

Woodward-Clyde Consultants (WCC). 1990. Installation Restoration Program Remedial Investigation/Feasibility Study, Stage 1, Cape Romanzof LRRS, Alaska. Prepared for Alaskan Air Command, Elmendorf Air Force Base, Alaska and Human Systems Division, Brooks Air Force Base, Texas.

APPENDIX A

TABULATED ANALYTICAL RESULTS

CAPE ROMANZOF LONG RANGE RADAR SITE (LRRS)

YUKON DELTA NATIONAL WILDLIFE REFUGE

Table 1. Organochlorine concentrations (ppm, wet weight) in sediment samples from the Cape Romanzof Range Radar Site, Yukon Delta National Wildlife Refuge.

	Fowler Creek				Old Landfill		
	1	2	3	4	5	6	7
Analytes							
oxychlordane							
cis-nonachlor							
alpha chlordane							
gamma chlordane							
transnonachlor							
heptachlor							
heptachlor epoxide							
mirex							
dieldrin							
aldrin							
alpha BHC							
hexachlorobenzene							
beta BHC							
lindane (gamma BHC)	**NO ORGANOCHLORINES WERE DETECTED IN ANY SAMPLES FROM ANY SITES**						
delta BHC							
o,p'-DDE							
p,p'-DDE							
o,p'-DDD							
p,p'-DDD							
o,p'-DDT							
p,p'-DDT							
total DDTs							
total Cl-2 (PCB)							
total Cl-3 (PCB)							
total Cl-4 (PCB)							
total Cl-5 (PCB)							
total Cl-6 (PCB)							
total Cl-7 (PCB)							
total Cl-8 (PCB)							
total Cl-9 (PCB)							
total PCBs							
toxaphene							

Detection limits: toxaphene and PCBs (0.50 ppm), balance of the organochlorines (0.02 ppm).

Table 2. Petroleum hydrocarbon concentrations (ppm, wet weight) in sediment samples from the Cape Romanzof Range Radar Site, Yukon Delta National Wildlife Refuge.

	Fowler Creek				Old Landfill		
	1	2	3	4	5	6	7
Analytes							
naphthalene	-	-	-	-	.05	.01	-
1-methylnaphthalene	-	-	-	-	.06	.01	-
2-methylnaphthalene	.02	-	-	.01	.09	.03	-
2,6, dimet.naph.	.68	.41	.41	.91	.64	.79	.30
2,3,4-trimet.naph.	.63	.38	.35	.94	.63	.78	.27
1-met.phenanthrene	-	-	-	-	.02	-	-
acenaphthylene	-	-	-	-	-	-	-
acenaphthene	.08	.04	.04	.11	.16	.09	.03
fluorene	.02	.01	.01	.04	.12	.02	-
phenanthrene	.01	.01	-	.02	.22	.02	-
anthracene	-	-	-	-	-	-	-
fluoranthene	-	.01	-	-	.10	-	-
pyrene	-	-	-	.01	.13	.02	-
benzo(a)anthracene	-	-	-	.02	.03	-	-
chrysene	-	-	-	.02	.06	-	-
benzo(b)fluoranthene	-	-	-	-	.04	-	-
benzo(k)fluoranthene	-	-	-	-	.02	-	-
benzo(e)pyrene	-	-	-	.02	-	-	-
benzo(a)pyrene	-	-	-	.03	.03	-	-
perylene	-	-	-	.01	-	-	-
indeno(1,2,3-c,d)pyr.	-	-	-	.02	.01	-	-
dibenzo(a,h)anthrac.	-	-	-	.02	-	-	-
benzo(g,h,i)perylene	-	-	-	-	.01	-	-
biphenly	-	-	-	-	.02	-	-
TOTAL AROMATICS	1.44	.86	.81	2.18	2.45	1.77	.60
TOTAL ALIPHATICS	1.43	1.43	1.96	.22	.76	.94	.59
TOTAL UCM*	3.0	3.0	4.0	4.0	7.0	11.0	8.0

- = below detection limit of 0.01 ppm
* = unresolved complex mixture

Table 3. Heavy metal and trace element concentrations (ppm, dry weight) in sediment samples from the Cape Romanzof Long Range Radar Site, Yukon Delta National Wildlife Refuge.

	Fowler Creek				Old Landfill		
	1	2	3	4	5	6	7
Analytes							
antimony	-	-	-	-	.6	-	-
arsenic	10	9	8	13	9	10	5
cadmium	-	-	-	.1	1.9	.3	.1
chromium	22	17	19	14	16	20	18
copper	17	13	11	7	13	15	10
iron	no analyses performed						
lead	7	12	5	5	54	44	8
manganese	no analyses performed						
mercury	-	-	-	-	-	-	-
nickel	13	10	9	6	13	11	10
selenium	2	-	1	-	-	-	-
thallium	-	-	-	-	-	-	-
zinc	43	37	31	23	183	57	49

- = below detection limit, ppm: (antimony 0.5; arsenic .005; cadmium, 0.1; chromium, 0.5; copper, 0.6; mercury, 0.1; nickel, 0.1; lead, 0.2; selenium, 0.5; thallium 0.4; zinc, 0.2)

Table 4. Organochlorine concentrations (ppm, wet weight) in Cape Romanzof Long Range Radar Site's fish and wildlife resources, Yukon Delta National Wildlife Refuge.

	VOLES[a]			RED FOX[b]			DOLLY VARDEN[c]				
	1	2	3	1	2	3	1	2	3	4	5
Analytes											
oxychlordane	-	-	-	-	-	-	-	-	-	-	-
cis-nonachlor	.01	.01	.01	-	-	-	.01	-	-	.02	.01
alpha chlordane	.06	.05	.03	-	-	-	.04	-	.02	.05	.03
gamma chlordane	.04	-	.02	-	-	-	.01	-	.01	.03	.02
transnonachlor	.05	.03	.03	-	-	-	.03	-	.02	.06	.03
heptachlor	.01	-	-	-	-	-	-	-	-	-	-
heptachlor epoxide	.01	-	-	-	-	-	-	-	-	-	-
o,p'-DDE	.01	-	-	-	-	-	-	-	-	-	-
p,p'-DDE	.13	.12	.15	.06	-	.07	.07	.03	.08	.17	.13
o,p'-DDD	.01	-	-	-	-	-	-	-	-	-	-
p,p'-DDD	.05	.01	.03	-	-	-	.02	-	.02	.06	.03
o,p'-DDT	.02	-	-	-	-	-	-	-	-	-	-
p,p'-DDT	.02	-	-	-	-	-	-	-	-	-	-
mirex	.01	-	-	-	-	-	-	-	-	-	-
dieldrin	.02	.02	.01	-	-	-	.02	-	.01	.02	.01
aldrin	.01	-	-	-	-	-	-	-	-	-	-
endrin	-	-	-	-	-	-	-	-	-	-	-
alpha BHC	.01	-	-	-	-	-	-	-	-	-	-
hexachlorobenzene	-	-	-	-	-	-	-	-	-	-	-
beta BHC	.01	-	-	-	-	-	-	-	-	-	-
lindane (gamma BHC)	.01	-	-	-	-	-	-	-	-	-	-
delta BHC	.01	-	.01	-	-	-	.03	-	.02	.03	.01
total BHCs	.04	-	.01*	-	-	-	.03	-	.02	.04*	.01
total PCBs	.95	.73	1.14*	-	-	.58	.67	.16	.47	1.22*	.79
toxaphene	-	-	-	-	-	-	-	-	-	-	-

a = each of the three vole samples consist of two, whole-body individuals.

b = fox adipose fat

c = fish muscle tissue

* = confirmed by GC/MS

- = below detection limit: toxaphene and PCBs (0.10 ppm for vole and fish tissue, 0.50 ppm for fox tissue); balance of organochlorines (0.05 ppm for fox tissue, 0.01 ppm for vole and fish tissue).

Table 5. Petroleum hydrocarbon concentrations (ppm, wet weight) in Cape Romanzof Long Range Radar Site's fish and wildlife resources, Yukon Delta National Wildlife Refuge.

	VOLES[a]			RED FOX[b]			DOLLY VARDEN[c]				
	1	2	3	1	2	3	1	2	3	4	5
Analytes											
naphthalene	.02	-	-	.14	.06	.13	-	.10	-	-	-
1-methylnaphthalene	.01	-	-	.12	-	.22	-	.06	-	-	.02
2-methylnaphthalene	.01	-	-	.14	-	.12	-	.11	-	-	-
2,6, dimet.naph.	-	-	-	.09	.09	.09	-	.06	-	-	-
2,3,4-trimet.naph.	-	-	-	.07	-	.04	-	.03	-	-	-
1-met.phenanthrene	-	-	-	.06	.17	.08	-	-	-	-	-
acenaphthylene	-	-	-	.06	.12	.06	-	.06	-	-	-
acenaphthene	-	-	-	.05	.05	.04	-	.03	-	-	-
fluorene	-	-	-	.05	.04	.05	-	.04	-	-	-
phenanthrene	-	-	-	.13	-	.12	-	.10	-	-	-
anthracene	-	-	-	.05	-	.05	-	.07	-	-	-
fluoranthene	-	.01	-	.21	.03	.24	.02	.23	.01	.02	.01
pyrene	-	.02	.01	.23	-	.25	.02	.30	.02	.02	.01
benzo(a)anthracene	-	-	-	.01	.10	.02	-	.09	-	-	-
chrysene	-	-	-	.07	-	.06	-	.10	-	-	-
benzo(b)fluoranthene	-	-	-	.36	.01	.16	-	.10	-	-	-
benzo(k)fluoranthene	-	-	-	.23	-	.17	-	.09	.01	-	-
benzo(e)pyrene	-	-	-	.09	.16	.08	-	.11	-	-	-
benzo(a)pyrene	-	-	-	.08	.06	.08	-	.09	-	-	-
perylene	-	.02	-	.10	-	.03	.01	.26	.02	-	-
indeno(1,2,3-c,d)pyr.	.02	-	-	.09	-	.08	.01	.11	-	-	-
dibenzo(a,h)anthrac.	.02	-	-	.07	-	.06	-	.05	-	-	-
benzo(g,h,i)perylene	-	-	-	.08	-	.08	-	.11	-	-	-
biphenly	-	-	-	.36	.01	.16	-	.10	-	-	-
TOTAL AROMATICS	.08	.05	.01	2.94	.90	2.47	.06	2.40	.06	.04	.04

- = below detection limit of 0.01 ppm

a = each of the three vole samples consist of two, whole-body individuals.

b = fox adipose fat

c = fish muscle tissue

Table 6. Heavy metal and trace element concentrations (ppm, dry weight) in Cape Romanzof Long Range Radar Site's fish and wildlife resources, Yukon Delta National Wildlife Refuge.

	VOLES[a]			RED FOX[b]			DOLLY VARDEN[c]				
Analytes	1	2	3	1	2	3	1	2	3	4	5
antimony	-	-	-	-	-	-	-	-	-	-	-
arsenic	-	-	-	-	-	-	.2	-	.2	-	-
cadmium	.3	.3	-	.8	2.2	1.7	.3	-	-	.3	2.5
chromium	2.0	1.8	3.9	1.0	1.3	1.7	2.8	1.5	3.1	1.4	1.5
copper	12	11	9	25	97	44	4	4	2	4	4
iron	416	385	308	866	485	361	841	332	189	209	424
manganese	30	41	76	15	16	23	12	14	4	13	5
mercury	.05	.04	.08	.10	.09	.42	.04	-	.03	.27	.03
nickel	.9	.9	-	-	1.2	3.9	.7	-	1.1	-	-
lead	-	-	-	2.8	3.9	5.2	1.3	-	-	-	-
selenium	-	-	-	-	-	-	4.0	3.9	2.8	3.1	3.5
thallium	no analyses performed										
zinc	89	120	100	131	168	177	113	97	136	112	115

a = whole body

b = fox liver

c = fish liver

- = below detection limit, ppm: (antimony 4.5; arsenic 0.2; cadmium, 0.15; chromium, 0.3; copper, 0.5; iron, 5.0; manganese, 0.15; mercury, 0.02; nickel, 0.7; lead, 1.2; selenium, 0.3; zinc, 3.0)

APPENDIX B

U.S. FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES ANCHORAGE

WATER, SOIL, SEDIMENT, FLORA AND FAUNA CRITERIA

Table 1. Organochlorines criteria - water (fresh and marine).

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	
chlordane & isomers oxychlordane cis-nonachlor alpha chlordane gamma chlordane transnonachlor	FW: 0.0 ppt (EPA WQC, Protection of Aquatic Organisms and Drinking Water). SW: 0.0040 ppb as a 24 hour mean, NTE 0.09 ppb at anytime (EPA Ambient WQC).
heptachlor & its metabolite heptachlor epoxide	FW: 3.8 ppt as a 24 hour mean, NTE .52 ppt at anytime (EPA Ambient WQC). SW: 3.6 ppt as a 24 hour mean, NTE .053 ppt at anytime (EPA Ambient WQC).
total DDT & each isomer o,p'-DDT p,p'-DDT o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE	FW: 0.0 ppb (EPA WQC, Protection of Aquatic Organisms and Drinking Water). SW: 0.0 ppb as a 24 hour mean, NTE 0.13 ppb at anytime (EPA Ambient WQC).
hexachlorobenzene	FW: 0.0 ppt (EPA WQC, Protection of Aquatic Organisms and Drinking Water).
mirex	FW & SW: 1.0 ppt (Literature review)
dieldrin	FW: 0.0019 ppb as a 24 hour mean, NTE 2.5 ppb at anytime (EPA Ambient WQC). SW: 0.0019 ppb as a 24 hour mean, NTE 0.71 ppb at anytime (EPA Ambient WQC).
aldrin	FW: NTE 3.0 ppb, SW NTE 1.3 ppb (EPA Ambient WQ Criteria)
hexachlorocyclohexane (benzene hexachloride) & related compounds alpha BHC beta BHC lindane delta BHC	FW: .0002 ppm (literature review)
total PCBs total Cl-2 total Cl-3 total Cl-4 total Cl-5 total Cl-6 total Cl-7 total Cl-8 total Cl-9	FW & SW: 14 ppt (EPA Ambient WQ Criteria and Literature Review)
toxaphene	FW: 13 ppt as a 24 hour mean, NTE 1.6 ppb (EPA WQC, Protection of Aquatic Organisms). SW: NTE 0.07 ppb at anytime (EPA WQC, Protection of Aquatic Organisms).

Table 2. Organochlorines criteria - soil/sediment.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	
chlordane & each isomer	
oxychlordane	
cis-nonachlor	
alpha chlordane	
gamma chlordane	
transnonachlor	
heptachlor & its metabolite heptachlor epoxide	
total DDT & each isomer	
o,p'-DDT	
p,p'-DDT	
o,p'-DDD	
p,p'-DDD	
o,p'-DDE	
p,p'-DDE	
hexachlorobenzene	
mirex	
dieldrin	
aldrin	
hexachlorocyclohexane (benzene hexachloride) & related compounds	
alpha BHC	
beta BHC	
lindane	
delta BHC	
toxaphene	
total PCBs	10 ppm urban areas; 25 ppm isolated areas.
total Cl-2	
total Cl-3	
total Cl-4	
total Cl-5	
total Cl-6	
total Cl-7	
total Cl-8	
total Cl-9	

Table 3. Organochlorines criteria - fish (page 1 of 2).

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	Freshwater	Marine
chlordane & each isomer oxychlordane cis-nonachlor alpha chlordane gamma chlordane transnonachlor	0.10 ppm (ww) whole body[1/] 0.30 ppm (ww) edible portion[3/]	0.05 ppm (ww) whole body[2/] 0.30 ppm (ww) edible portion[3/]
heptachlor & its metabolite heptachlor epoxide	0.10 ppm (ww) whole body[1/] 0.30 ppm (ww) edible portion[3/]	0.05 ppm (ww) whole body[2/] 0.30 ppm (ww) edible portion[3/]
total DDT isomers o,p'-DDT p,p'-DDT o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE	0.10 ppm (ww) whole body[1/] 5.0 ppm (ww) edible portion[3/]	0.05 ppm (ww) whole body[2/] 5.0 ppm (ww) edible portion[3/]
hexachlorobenzene	0.10 ppm (ww) whole body[1/] 0.20 ppm (ww) fat[4/]	0.05 ppm (ww) whole body[2/]
mirex	0.10 ppm (ww) edible portion[3/]	0.05 ppm (ww) whole body[2/] 0.10 ppm (ww) edible portion[3/]
dieldrin	0.10 ppm (ww) whole body[1/] 0.3 ppm (ww) edible portion[3/]	0.005 ppm (ww) whole body[2/] 0.3 ppm (ww) edible portion[3/]
aldrin	0.10 ppm (ww) whole body[1/] 0.3 ppm (ww) edible portion[3/]	0.005 ppm (ww) whole body[2/] 0.3 ppm (ww) edible portion[3/]
hexachlorocyclohexane (benzene hexachloride) & related compounds alpha BHC beta BHC lindane delta BHC	0.10 ppm (ww) whole body[1/]	0.05 ppm (ww) whole body[2/]
total PCBs total Cl-2 total Cl-3 total Cl-4 total Cl-5 total Cl-6 total Cl-7 total Cl-8 total Cl-9	0.50 ppm (ww) whole body[1/] 2.0 ppm (ww) edible portion[3/]	0.50 ppm (ww) whole body[2/] 2.0 ppm (ww) edible portion[3/]

1/ National Academy of Sciences, 1974. Predator Protection Levels, Aquatic Wildlife.
2/ National Academy of Sciences, 1974. Predator Protection Levels, Marine Wildlife (homogenate of at least 25 fish of appropriate size and species).
3/ U.S. Food and Drug Administration Action Levels.
4/ Literature review.

Table 3. Continued. Organochlorines criteria - fish (page 2 of 2).

Criterion for all compounds unless indicated otherwise: Any organochlorine is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	Freshwater	Marine
toxaphene	0.10 ppm (ww) whole body[1/] 5.0 ppm (ww) edible portion[3/]	0.50 ppm (ww) whole body[2/] 5.0 ppm (ww) edible portion[3/]

1/ National Academy of Sciences, 1974. Predator Protection Levels, Aquatic Wildlife.

2/ National Academy of Sciences, 1974. Predator Protection Levels, Marine Wildlife (homogenate of at least 25 fish of appropriate size and species).

3/ U.S. Food and Drug Administration Action Levels.

4/ Literature review.

Table 4. Organochlorines criteria - shellfish.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	Criteria
chlordane & each isomer oxychlordane cis-nonachlor alpha chlordane gamma chlordane transnonachlor	0.03 ppm (ww)[1/]
heptachlor & its metabolite heptachlor epoxide	0.20 ppm (ww)[1/]
total DDT isomers o,p'-DDT p,p'-DDT o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE	1.5 ppm (ww)[1/]
hexachlorobenzene	
mirex	0.10 ppm (ww)[2/]
dieldrin	0.20 ppm (ww)[1/]
aldrin	0.20 ppm (ww)[1/]
hexachlorocyclohexane (benzene hexachloride) & related compounds alpha BHC beta BHC lindane delta BHC	0.20 ppm (ww)[1/]
total PCBs total Cl-2 total Cl-3 total Cl-4 total Cl-5 total Cl-6 total Cl-7 total Cl-8 total Cl-9	
toxaphene	5.0 ppm (ww)[2/]

Sum of aldrin, dieldrin, endrin, heptachlor and heptachlor epoxide:
1. "Alert" level if sum exceeds 0.20 ppm (ww).
2. Close shellfish bed if sum exceeds 0.25 ppm (ww)

1/ National Shellfish Sanitation Program.

2/ U.S. Food and Drug Administration Action Levels

Table 5. Organochlorines criteria - avifauna.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	
chlordane & each isomer oxychlordane cis-nonachlor alpha chlordane gamma chlordane transnonachlor	
heptachlor & its metabolite heptachlor epoxide	
total DDT isomers o,p'-DDT p,p'-DDT o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE	10.0 ppm (ww) minimum level in brain indicative of lethal exposure. (Stickel, Stickel & Coon, 1970).
hexachlorobenzene	
mirex	210 ppm (ww) brain (Literature review).
dieldrin	
aldrin	0.3 ppm (ww) muscle (WHO residue tolerance level & literature review).
hexachlorocyclohexane (benzene hexachloride) & related compounds alpha BHC beta BHC lindane delta BHC	
total PCBs total Cl-2 total Cl-3 total Cl-4 total Cl-5 total Cl-6 total Cl-7 total Cl-8 total Cl-9	280 ppm (ww) brain (Literature review).
toxaphene	

Table 6. Organochlorines criteria - mammals.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds	
chlordane & each isomer	
oxychlordane	
cis-nonachlor	
alpha chlordane	
gamma chlordane	
transnonachlor	
heptachlor & its metabolite heptachlor epoxide	
total DDT isomers	
o,p'-DDT	
p,p'-DDT	
o,p'-DDD	
p,p'-DDD	
o,p'-DDE	
p,p'-DDE	
hexachlorobenzene	0.50 ppm (ww) fat
mirex	
dieldrin	
aldrin	
hexachlorocyclohexane (benzene hexachloride) & related compounds	
alpha BHC	
beta BHC	
lindane	
delta BHC	
total PCBs	
total Cl-2	
total Cl-3	
total Cl-4	
total Cl-5	
total Cl-6	
total Cl-7	
total Cl-8	
total Cl-9	
toxaphene	

Table 7. Polycyclic aromatic hydrocarbons criteria - all water types.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds
naphthalene
1-methylnaphthalene
2-methylnaphthalene
2,6 dimethylnaphthalene
2,3,4-trimethylnaphthalene
1-methylphenanthrene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(a)pyrene
benzo(e)pyrene
perylene
indeno(1,2,3-c,d)pyrene
dibenzo(a,h)anthracene
benzo(g,h,i)perylene
biphenyl
Total PAHs

Table 8. Polycyclic aromatic hydrocarbons criteria - soil/sediment.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds

naphthalene
- 1-methylnaphthalene
- 2-methylnaphthalene
- 2,6 dimethylnaphthalene
- 2,3,4-trimethylnaphthalene

1-methylphenanthrene

acenaphthylene

acenaphthene

fluorene

phenanthrene

anthracene

fluoranthene

pyrene

benzo(a)anthracene

chrysene

benzo(b)fluoranthene

benzo(k)fluoranthene

benzo(e)pyrene

benzo(a)pyrene

perylene

indeno(1,2,3-c,d)pyrene

dibenzo(a,h)anthracene

benzo(g,h,i)perylene

biphenyl

Total PAHs

TPH (total petroleum hydrocarbons: aromatics and aliphatics): 100 ppm (non-gasoline product); 10 ppm (gasoline product) (Alaska Department of Environmental Conservation **DRAFT** Interim Guidance for Soil Cleanup Levels, March 1, 1990). NOTE: Final State cleanup levels are determined by the Regional Supervisor or his designee based on site-specific conditions.

Table 9. Polycyclic aromatic hydrocarbons criteria - fauna.

Criterion for all compounds unless indicated otherwise: Any compound is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

Compounds
naphthalene
1-methylnaphthalene
2-methylnaphthalene
2,6 dimethylnaphthalene
2,3,4-trimethylnaphthalene
1-methylphenanthrene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(e)pyrene
benzo(a)pyrene
perylene
indeno(1,2,3-c,d)pyrene
dibenzo(a,h)anthracene
benzo(g,h,i)perylene
biphenyl
Total PAHs

Table 10. Polycyclic aromatic hydrocarbons criteria - flora.

Criterion for all compounds unless indicated otherwise: Any compound in any plant part is not to exceed 200 ppb.

Compounds
naphthalene
1-methylnaphthalene
2-methylnaphthalene
2,6 dimethylnaphthalene
2,3,4-trimethylnaphthalene
1-methylphenanthrene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(e)pyrene
benzo(a)pyrene
perylene
indeno(1,2,3-c,d)pyrene
dibenzo(a,h)anthracene
benzo(g,h,i)perylene
biphenyl
Total PAHs

Table 11. Heavy metals and trace elements - water, soil/sediment.

Criterion for all elements unless indicated otherwise: Any element is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

ELEMENT	CRITERIA[a]	
	Water[b]	Soil/Sediment[b]
Aluminum	400.0 (F);10.(M)	81000 (F)
Antimony	0.6 (F)	9.0
Arsenic	0.1 (F); 0.02 (M)	64.0
Barium		430
Beryllium	50.0 (F)	15.0
Boron	12.0 (F)	100
Cadmium	0.003 (F); 0.009 (M)	6.0 (F); 9.0 (M)
Chromium	0.03 (F); 1.2 (M)	37.0 (F); 128 (M)
Copper	0.01 (F); 0.005 (M)	310
Iron	0.3 (F)	
Lead	0.02 (F); 0.01 (M)	50.0 (F); 104 (M)
Manganese	7.0 (F); 2.0 (M)	1000
Mercury	0.002 (F); 0.0003 (M)	20.0 (F); 1.0 (M)
Molybdenum	50.0 (F)	100
Nickel	0.3 (F); 2.0 (M)	100
Selenium	0.3 (F); 0.4 (M)	10.0
Silver	0.001 (F); 0.01 (M)	2.1
Tin (inorganic)	0.05 (F); 0.3 (M)	200
(tributyl)	0.00001 (F)	
Vanadium	1.0 (F); 1.0 (M)	150
Zinc	20.0 (F); 5.0 (M)	200 (F); 267 (M)

Limnological Parameters:

alkalinity	> 400 mg/l $CaCO_3$
dissolved oxygen	< 5.0 mg/l
hardness	no criterion
pH	A range of 6.5 - 9.0, with no change > 0.5 units outside the natural seasonal maximum or minimum, is protective of freshwater life and is considered harmless to fish.
conductivity	no criterion
turbidity	Water Supply: NTE 5 NTU above natural conditions when natural turbidity is ≤ 50 NTU. Growth and Propagation of Fish and other aquatic life: NTE 25 NTU above natural condition.

[a] All water concentrations are in ppm, soil/sediment is ppm and believed to be dry weight.

[b] (F) = freshwater; (M) = marine

Table 12. Water Quality Criteria (recoverable metals mg/l = ppm).

Element	Safe Drinking Water Act	Environmental Protection Agency[a] Acute Toxicity Freshwater / Marine	Environmental Protection Agency[a] Chronic Toxicity Freshwater / Marine	State of Alaska Drinking Water Standards[b] Maximum Concentration Primary	Secondary
Aluminum		-- / --	-- / --	---- not listed ----	
Antimony		9* / --	1.6* / --	---- not listed ----	
Arsenic	0.05	-- / --	-- / --	0.05	
As+5		.85 / 2.3	.048 /.013		
As+3		.36 / .069	.190 /.036		
Barium	1.0	-- / --	-- / --	1.0	
Beryllium		.13* / --	.0053* / --	---- not listed ----	
Cadmium	0.01	.0039+ / 43+	.0011 / .0093	0.01	
Chromium		-- / --	-- / --	0.05	
Cr+6	0.05	.016 / 1.1	.011 / .05		
Cr+3	0.05	1.7+ / 10.3*	.210+ / --		
Copper		.018+ /.0029	.012+ / .0029		1.0
Iron		-- / --	1.0 / --	0.30	0.30
Lead	0.05	.082+ / .14	.0032+ / .0056	0.05	
Manganese		-- / --	-- / --		0.05
Mercury	0.002	.0024 / .0021	.000012 / .000025	.002	
Nickel		1.40+ / .075	.160+ / .0083	---- not listed ----	
Selenium	0.01	.260 / .41	.035 / .054	0.01	
Silver	0.05	.0041+ / .0023	.00012 / --	0.05	
Thallium		1.4* / 2.13*	.04* / --	---- not listed ----	
Tin		-- / --	-- / --	---- not listed ----	
Zinc		.12+ / .096	.11+ / .086	5.0	
pH				6.5 - 8.5	

a - Quality Criteria fro Water (EPA 440/5-86-001) and updates.
b - Alaska Drinking Water Standards (18 ACC 80.010, 18 ACC 80.070).
-- - information base not sufficient to establish/suggest criteria.
+ - hardness-dependent criteria used. (Hardness @ 100 mg/L).
* - value presented is the lowest observed effect level.

Table 13. Heavy metals and trace elements - fish.

Criterion for all elements unless indicated otherwise: Any element is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

ELEMENT	CRITERIA[a]			
	Muscle	Whole Body	Liver	Kidney
Aluminum				
Antimony				
Arsenic	50.0			
Barium				
Beryllium				
Boron				
Cadmium	0.5	2 to 5	10	10
Chromium	4.0	4.0	4.0	4.0
Copper	2.5			
Iron	7.0		15	12
Lead	2.0		>2.0	>2.0
Manganese	1.0			
Mercury	1.0	5.0	3.0	2.0
Molybdenum				
Nickel	1.0			
Selenium	4.0			
Silver				
Tin				
Vanadium				
Zinc	10		>10	>10

[a] All concentrations are in ppm and believed to be dry weight.

Table 14. Heavy metals and trace elements - mammals.

Criterion for all elements unless indicated otherwise: Any element is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

ELEMENT	CRITERIA			
	Muscle	Whole Body	Liver	Kidney
Aluminum				
Antimony				
Arsenic				
Barium				
Beryllium				
Boron				
Cadmium				
Chromium				
Copper				
Iron				
Lead				
Manganese				
Mercury				
Molybdenum				
Nickel				
Selenium				
Silver				
Tin				
Vanadium				
Zinc				

Table 15. Heavy metals and trace elements - avifauna.

Criterion for all elements unless indicated otherwise: Any element is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

ELEMENT	CRITERIA			
	Muscle	Whole Body	Liver	Kidney
Aluminum				
Antimony				
Arsenic				
Barium				
Beryllium				
Boron				
Cadmium				
Chromium				
Copper				
Iron				
Lead				
Manganese				
Mercury				
Molybdenum				
Nickel				
Selenium				
Silver				
Tin				
Vanadium				
Zinc				

Table 16. Heavy metals and trace elements - flora.

Criterion for all elements unless indicated otherwise: Any element is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

ELEMENT	CRITERIA			
	Muscle	Whole Body	Liver	Kidney
Aluminum				
Antimony				
Arsenic				
Barium				
Beryllium				
Boron				
Cadmium				
Chromium				
Copper				
Iron				
Lead				
Manganese				
Mercury				
Molybdenum				
Nickel				
Selenium				
Silver				
Tin				
Vanadium				
Zinc				

Table 17. List of references used to develop criteria.

American Fisheries Society. 1979. A review of the EPA Red Book: Quality criteria for water. American Fisheries Society, Water Quality Section, Bethesda,. MD. 313 pp.

Cleland, J. G. and G. L. Kingsburg. 1977. Multimedia Environmental Goals for Environmental Assessment. Vol II. MEG Charts and Background Information. EPA 600/7-77-1366. U.S. Environmental Protection Agency, Washington, D.C.

Day, John W., Jr., Hall, C. A., Kemp, W. M. and A. Yanez-Arancibia. 1989. Estuarine Ecology. John Wiley and Sons, New York. 543 pp.

Edwards, N. T. 1983. Polycyclic aromatic hydrocarbons (PAH's) in the terrestrial environment - a review. Journal of Environmental Quality. 12(4):427-441.

Eisler, R. 1989a. Molybdenum Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.19). Patuxent Wildlife Research Center, Laurel, Maryland. 61 pp.

Eisler, R. 1989b. Tin Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.15). Patuxent Wildlife Research Center, Laurel, Maryland. 83 pp.

Eisler, R. 1988. Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.12). Patuxent Wildlife Research Center, Laurel, Maryland. 92 pp.

Eisler, R. 1987a. Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.14). Patuxent Wildlife Research Center, Laurel, Maryland. 134 pp.

Eisler, R. 1987b. Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.10). Patuxent Wildlife Research Center, Laurel, Maryland. 90 pp.

Eisler, R. 1987c. Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.11). Patuxent Wildlife Research Center, Laurel, Maryland. 81 pp.

Eisler, R. 1986a. Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.6). Patuxent Wildlife Research Center, Laurel, Maryland. 60 pp.

Eisler, R. 1986b. Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.7). Patuxent Wildlife Research Center, Laurel, Maryland. 72 pp.

Eisler, R. 1985a. Cadmium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.2). Patuxent Wildlife Research Center, Laurel, Maryland. 46 pp.

Eisler, R. 1985b. Mirex Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.1). Patuxent Wildlife Research Center, Laurel, Maryland. 42 pp.

Eisler, R. 1985c. Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.5). Patuxent Wildlife Research Center, Laurel, Maryland. 57 pp.

Eisler, R. 1985d. Toxaphene Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.4). Patuxent Wildlife Research Center, Laurel, Maryland. 26 pp.

Farm Chemicals 1989. Farm Chemical Handbook. Meister Publishing Company, Willoughby, Ohio. 375 pp.

Fortescue, J. A. C. 1980. Environmental Geochemistry: A Holistic Approach. Springer - Verlag, New york. 347 pp.

Furness, R. W., and P. S. Rainbow (Eds.). 1990. Heavy Metals in the Marine Environment. CRC Press, Inc. Boca Raton, Florida.
256 pp.

Goldschmidt, V. M. 1954. Geochemistry. Clarendon Press, Oxford. 234 pp.

Table 17. Continued.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element Concentrations in Soils and Other Surficial Materials of Alaska. U.S. Geol. Survey Prof.Paper 1458. 53 pp.

Gough, Larry P., H. T. Shacklette, and A. A. Case. 1979. Element concentrations toxic to plants, animals, and man. Geol. Survey Bull. 1466. U.S. Govt. Printing Office. 80 pp.

Hem, J. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey Water-Supply Paper 2254. Alexandria, VA. 263 pp.

Jenkins, D. W. 1980a. Biological Monitoring of Toxic Trace Metals. Volume I, Biological Monitoring and Surveillance. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-089, NTIS PB81-103475. September. 215 pp.

Jenkins, D. W. 1980b. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part I. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-090, NTIS PB81-103483. September. 503 pp.

Jenkins, D. W. 1980c. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part II. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-091, NTIS PB81-103491. September. 478 pp.

Jenkins, D. W. 1980d. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part III. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-092, NTIS PB81-103509. September. 290 pp.

Johnson, W., and M. Finley. 1980. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates. U.S, Fish and Wildlife Service, National Fisheries Research Laboratory, Columbia, Missouri. Resource Pub. 137. 98 pp.

Jones, K., Stratford, J., Waterhouse, K. and N. Vogt. 1989.
Organic contaminants in Welsh Soil: Polynuclear Aromatic Hydrocarbons. Environ. Sci. Technol. 23:540-550.

Komarovskiy, F. and L. Polishchuk. 1982. Mercury and other heavy metals in the water: migration, accumulation, and toxicity to aquatic organisms (a review). Hydrobiological Journal 5:51-62.

Lindsay, W. 1979. Chemical equilibra in soils. John Wiley and sons, New York. 449 pp.

Long, Edward R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Tech. Mem. NOS OMA 52. 175 pp.

Malins, D. (editor) 1977. Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Volume II. Biological Effects. Academic Press, Inc. New York, NY. 477 pp.

Mance, Geoffery. 1987. Pollution Threat of Heavy Metals in Aquatic Environments. Elsevier Applied Science, London. 363 pp.

McErlean, A. and T. Duke. 1981. On the use of indices in aquatic toxicological hazard assessment. Regulatory Toxicological and Pharmacological. 1:344-354.

McKee, J.E. and H.M. Wolf. 1963. (1976 reprint). Water quality criteria. State Water REsources Control Board, State of California. Pub. No. 3-A. 548 pp.

Mearns, A., Matta, M., Simecek-Beatty, D., Buchman, M., Shigenaka, G. and W. Wert. 1988. PCB and Chlorinated Pesticide Contamination in U.S. Fish and Shellfish: A Historical Assessment Report. NOAA Technical Memorandum NOS OMA 39. Seattle, WA. February. 140 pp.

Menzie, C. 1980. Metabolism of Pesticides, Update III. U.S. Fish and Wildlife Service, Special Scientific Report - Wildlife No. 232. Washington, D.C. 709 pp.

National Academy of Sciences. 1973. Water Quality Criteria 1972. EPA Ecol. Res. Series EPA-R3-73-033. U.S. Environmental Protection Agency, Washington, D.C. 594 pp.

Table 17. Continued.

National Academy of Sciences and National Academy of Engineering. 1972. Water quality and criteria. A report of the Committee on Water Quality Criteria, Environmental Studies Board. EPA R3-73-003. March, 1973. PB 236-199/68A.

Nriagu, J. O. (Ed.). 1980. Cadmium in the Environment. Part I: Ecological Cycling. John Wiley & Sons. 682 pp.

National Research Council of Canada. 1983. Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Formation, Sources, Fate and Effects on Aquatic Biota. Panel on Polycyclic Aromatic Hydrocarbons Subcommittee on Water. Pub. No. NRCC 18981 of the Environmental Secretariat. Ottawa, Canada. 209 pp.

Nriagu, J. O. (Ed.). 1980. Cadmium in the Environment. Part I: Ecological Cycling. John Wiley & Sons. 682 pp.

Olsen L. and K. Adams. 1984. Effects of Contaminated Sediment on Fish and Wildlife: Review and Annotated Bibliography. U.S. Fish and Wildlife Service. Washington, D.C. FWS/OBS-82/66 April
103 pp.

Pavlou, Spyros P. 1987. The use of the equilibrium partitioning approach in determining safe levels of contaminants in marine sediments. Chap. 25 in Dickson, K. L., Maki, A. W. and W. A. Brungs (Eds.), Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems. Pergamon Press, New York. 447 pp.

Phillips, D. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments - a review. Environ. Pollut. 13: 281-317.

Phillips, D. 1980. Toxicity and Accumulation of Cadmium in Marine and Estuarine Biota. Chap. 12 in J. Nriagu (Ed.) Cadmium in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

Santodonato, J., Howard, P. and D. Basu. 1981. Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons. Center for Chemical Hazard Assessment. Pathotox. Pub., Park Forest South, Illinois 364 pp.

Sax, N. 1987. Hazardous Chemicals Information Annual, No. 2. (Editor) Van Nostrand Reinhold Co., New York. 707 pp.

Sax, N. 1986. Hazardous Chemicals Information Annual, No. 1. (Editor) Van Nostrand Reinhold Co., New York. 766 pp.

Sax, N. and R. Lewis. 1987. Hazardous Chemicals Desk Reference. Van Nostrand Reinhold Co., New York. 1084 pp.

Shea, D. 1988. Developing national sediment quality criteria. Environ. Sci. Technol. 22(11): 1256 - 1261.

Smith, J., Harte, P. and M. Hardy. 1989. Trace-metal and organochlorine residues in sediment of the upper Rockaway River, New Jersey. Bull. Environ. Contam. Toxicol. 39:465-473.

Soholt, L., Harris, V., Knight, M., Siskind, B. and D. Wyman. 1981. Coal Combustion Waste Manual: Evaluating Impacts to Fish and Wildlife. U.S. Fish and Wildlife Service, Biological Services Program, National Power Plant Team, FWS/OBS-81/05. 150 pp.

Stickel, W. H., Stickel, L. F. and F. B. Coon. 1970. DDE and DDD residues correlated with mortality of experimental birds. In Pesticides Symposia, ed. by W. B. Deichmann, p. 287-94. Miami, Florida, Halos and Assoc.

Stokes, P. 1979. Copper Accumulations in Freshwater Biota. Chap. 12 in J. Nriagu (Ed.) Copper in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

U.S. Environmental Protection Agency. 1986a. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-86/060 October. 175 pp.

U.S. Environmental Protection Agency. 1986b. Hazardous Waste Land Treatment. Municipal Environmental Research Laboratory. Office of Research and Development. Cincinnati, Ohio. Pub. SW-874. April. 671 pp.

Table 17. Continued.

U.S. Environmental Protection Agency. 1980a. Ambient Water Quality Criteria for Acenaphthene. Office of Water Regulations and Standards. EPA 440/5-80-015, NTIS PB81-117269. October. 38 pp.

U.S. Environmental Protection Agency. 1980b. Ambient Water Quality Criteria for Aldrin/Dieldrin. Office of Water Regulations and Standards. EPA 440/5-80-019, NTIS PB81-117301. October. 145 pp.

U.S. Environmental Protection Agency. 1980c. Ambient Water Quality Criteria for Chlordane. Office of Water Regulations and Standards. EPA 440/5-80-027, NTIS PB81-117384. October. 59 pp.

U.S. Environmental Protection Agency. 1980d. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards. EPA 440/5-80-038, NTIS PB81-117491. October. 163 pp.

U.S. Environmental Protection Agency. 1980e. Ambient Water Quality Criteria for Heptachlor. Office of Water Regulations and Standards. EPA 440/5-80-052, NTIS PB81-117632. October. 106 pp.

U.S. Environmental Protection Agency. 1980f. Ambient Water Quality Criteria for Fluoranthene. Office of Water Regulations and Standards. EPA 440/5-80-049, NTIS PB81-117608. October. 76 pp.

U.S. Environmental Protection Agency. 1980g. Ambient Water Quality Criteria for Naphthalene. Office of Water Regulations and Standards. EPA 440/5-80-059, NTIS PB81-117707. October. 67 pp.

U.S. Environmental Protection Agency. 1980h. Ambient Water Quality Criteria for Polychlorinated Biphenyls. Office of Water Regulations and Standards. EPA 440/5-80-068, NTIS PB81-117798. October. 190 pp.

U.S. Environmental Protection Agency. 1980i. Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons. Office of Water Regulations and Standards. EPA 440/5-80-069, NTIS PB81-117806. October. 191 pp.

U.S. Environmental Protection Agency. 1980j. Ambient Water Quality Criteria for Toxaphene. Office of Water Regulations and Standards. EPA 440/5-80-076, NTIS PB81-117863. October. 190 pp.

U.S. Environmental Protection Agency. 1979a. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. Introduction and Technical Background, Metals and Inorganics, Pesticides and PCBs. Office of Water Planning and Standards, Office of Water and Waste Management. Washington D.C. EPA-440/4-79-029a. NTIS PB80-204373. December. 400 pp.

U.S. Environmental Protection Agency. 1979b. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. Halogenated Aliphatic Hydrocarbons, Halogenated Ethers, Monocyclic Aromatics, Phthalate Esters, Polycyclic Aromatic Hydrocarbons, Nitrosamines, and Miscellaneous Compounds. Office of Water Planning and Standards, Washington D.C. EPA-440/4-79-029b. December.

U.S. Environmental Protection Agency. 1979c. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. Halogenated Aliphatic Hydrocarbons, Halogenated Ethers, Monocyclic Aromatics, Phthalate Esters, Polycyclic Aromatic Hydrocarbons, Nitrosamines, and Miscellaneous Compounds. Office of Water Planning and Standards, Office of Water and Waste Management. Washington D.C. EPA-440/4-79-029b. NTIS PB80-204381. December. 500 pp.

U. S. Environmental Protection Agency. 1976. Quality Criteria for Water. EPA 440/9-76-023.

U.S. Department of Health and Human Services. 1989. Fifth Annual Report on Carcinogens, Summary. National Toxicology Program. National Institute of Environmental Health Sciences. Research Triangle Park, North Carolina. NTP 89-239. 340 pp.

U.S. Food and Drug Administration. 1980. Action Levels for Poisonous or Deleterious Substances in Human food and Animal Feed. Washington, D.C. 35 pp.

Verschueren, K. 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York. 1310 pp.

APPENDIX C

PROFILES: CONTAMINANTS OF POTENTIAL CONCERN

CAPE ROMANZOF LONG RANGE RADAR SITE, ALASKA

YUKON DELTA NATIONAL WILDLIFE REFUGE

Appendix C: Profiles: Contaminants of potential concern, Cape Romanzof LRRS, Yukon Delta National Wildlife Refuge.

POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are a widely-distributed group of environmental contaminants, many of which are known to be mutagenic and some carcinogenic. Besides being produced by anthropogenic sources (i.e., petroleum products, combustion of fossil fuels), PAHs are also synthesized by microorganisms, algae, and macrophytes.

Concern about PAHs in the environment is due to their persistence and to the fact that some are known to be potent mammalian carcinogens. PAHs can be taken into the mammalian body by inhalation, skin contact, or ingestion. In water, PAHs may either evaporate, disperse into the water column, concentrate in aquatic biota (aquatic invertebrates), experience chemical oxidation and biodegradation, or become incorporated into bottom sediments. The ultimate fate of those PAHs that accumulate in sediments is believed to be biotransformation and biodegradation by benthic organisms. Fish do not appear to contain grossly elevated PAH residues; this may be related to their efficient PAH degradation system. PAHs in the soil may be assimilated by plants before entering the food chain, degraded by soil microorganisms, or accumulate to relatively high levels in the soil. There is very little information on contemporary normal (or typical) levels of PAHs in soils. The typical endogenous concentrations of PAHs in soil range from 0.001 to 0.01 ppm.

In view of the carcinogenic characteristics of many PAH compounds and their increasing concentrations in the environment, it appears prudent to reduce or eliminate them wherever possible, pending acquisition of more definitive ecotoxicological data.

naphthalene-based compounds (naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnaphthalene, 2,3,4-trimethylnaphthalene): naphthalene is used as an intermediate in the production of dye compounds and the formulation of solvents, lubricants, and motor fuels. Naphthalene vapor and dust can form explosive mixtures with air. Poisoning can occur by ingestion, inhalation or skin absorption. Acute and chronic toxicity to freshwater aquatic life (fish) occur at concentrations as low as 2.3 ppm and .620 ppm, respectively, and possibly at lower concentrations. It is not carcinogenic. Naphthalene is probably the most easily biodegraded PAH.

1-methylphenanthrene: found in wood preservative sludge, crude oil, gasoline (3.18 ppm) and in exhaust condensate of gasoline engines.

acenaphthylene: in soots generated by the combustion of aromatic hydrocarbon fuel doped with pyridine. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it quite persistent and may accumulate to high concentrations. It can be absorbed from ingestion, inhalation and skin contact. The present data base is inadequate to support the derivation of drinking water criteria for this compound.

acenaphthene: product of petroleum refining, shale oil processing, coal tar distilling. Used in plastics mfg; insecticide and fungicide mfg. Constituent in asphalt and in soots generated by combustion of aromatic fuels. Known to be mutagenic. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations. It is not very water soluble. Resists photochemical degradation in soil. Its ultimate fate in the aquatic system is accumulation in sediment and biodegraded and biotransformed by benthic organisms. Levels on the order of 0.5 to 2 ppm are acutely toxic to aquatic animals and algae. Levels above 0.7 ppm may present a chronic toxicity hazard to fish.

fluorene: Little information exists about the fate of fluorene in the aquatic environment; its aquatic fate, therefore, if inferred for the most part from data summarized for polycyclic aromatic hydrocarbons. Fluorene's aquatic solubility is 1.9 mg/l and it is strongly sorbed onto suspended particulates and in biota. It is not known to be carcinogenic. No data about the bioaccumulation of fluorene were available. Biodegradation and biotransformation may be the dominant fate process in the aquatic environment for fluorene. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations.

phenanthrene: used in dyestuffs, explosives, synthesis of drugs. Found in crude oil, gasoline at 15.7 mg/l, and in exhaust condensate of gasoline engines. Not carcinogenic. Moderately toxic by ingestion. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations. It is not very water soluble. No acute hazard levels identified or recommended for drinking water.

anthracene: A skin irritant, allergen, and experimental carcinogen. Known to be a mutagen. Combustible when exposed to heat or flames. Found in gasoline at 1.55 mg/l, in exhaust condensate of gasoline engine (0.53 - 0.64 mg/l). No effect on trout exposed to 5 mg/l anthracene, for 24 hours. Sorbed onto suspended particles and inorganic sediment and in biota. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms. Food chain magnification

anthracene (cont.): of this chemical is not likely to be significant, as it is readily metabolized.

fluoranthene: found in crude oil, wood preservative sludge, gasoline, lubricating motor oils, motor oils and exhaust condensate from gasoline engines (1.06 - 1.66 mg/l). Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms. Moderately toxic by ingestion and skin contact. An experimental tumorigen. Photochemical oxidation appears to be an important process in the destruction of oil slicks which contain fluoranthene.

pyrene: found in gasoline, crude oil, motor oil, exhaust condensate of gasoline engines and is emitted from hot asphalt. Carcinogenic to man. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

benzo(a)anthracene: found in gasoline (0.232 mg/l), crude oil, exhaust condensate of gasoline engines (0.5 -0.08 mg/l) and wood preservative sludge. It is carcinogenic and mutagenic. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Crustaceans are most sensitive and fish are more resistant.

chrysene: found in gasoline (0.052 mg/l - 2.96 mg/l), motor oil, crude oil, and tail gases and condensate of gasoline engines. A weak carcinogen and mutagen. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Crustaceans are most sensitive and fish are more resistant. No recommended drinking water limit has been established, as the available data base in inadequate.

benzo(b)fluoranthene: found in crude oil, gasoline (0.16 - 1.34 mg/l), motor oil and in tail gases and exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Not carcinogenic.

benzo(k)fluoranthene: found in crude oil, gasoline (.009 mg/l), and in tail gases and exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

benzo(e)pyrene: found in gasoline (0.18 mg/l -1.82 mg/l), lubricating motor oils (0.07 - 0.49 mg/l), used motor oil (92.2 mg/l - 278.4 mg/l) and crude oil. Known to be a weak experimental carcinogen.

benzo(a)pyrene: a poison via subcutaneous route. An experimental carcinogen. Manufactured sources include petroleum refining, kerosene processing and heat and power generating sources. Man caused sources include combustion of fuels, present in run off containing greases, oils, etc.; potential road bed and asphalt leachate. In gasoline (0.135 mg/l - 0.143 mg/l); fresh motor oil (0.02 mg/l - 0.10 mg/l); used motor oil (5.8 mg/l - 242.4 mg/l). Found in exhaust condensate of gasoline engines. A known strong carcinogen and mutagen. Less bioavailable when complexed to colloidal organic materials or adsorbed to organic or inorganic particulates than when in solution or in fine dispersion in water. Usually filter-feeding bivalve mollusks contain lower concentrations than the algae and plankton they feed upon. Demersel fish species do not contain notably higher concentrations than do pelagic species.

perylene: Manmade sources include crude oil, gasoline (0.018 mg/l - 0.16 mg/l), lubricating motor oils (0.01 mg/l - 0.09 mg/l), fresh motor oil (0.03 mg/l), used motor oil (14.3 mg/kg - 57.4 mg/kg).

indeno-(1,2,3-c,d)pyrene: No commercial uses. Manmade sources include gasoline (0.059 mg/l), fresh motor oil (0.03 mg/kg), and used motor oil (34.0 mg/kg to 83.3 mg/kg). Found in tail gases and exhaust condensate of gasoline engines. Less subject to photochemical or biological oxidation, especially if the sediment is anoxic. Therefore, it is quite persistent and may accumulate to high concentrations. An experimental carcinogen. Can be absorbed from inhalation, ingestion and skin contact. In most cases, crustaceans are more sensitive than fish.

dibenzo(a,h)anthracene: Man-made sources include wood preservative sludge. Poison by intravenous route. An experimental carcinogen. When heated to decomposition it emits acrid smoke and irritating fumes.

benzo(g,h,i)perylene: Manmade sources include fresh motor oil (0.12 mg/kg), used motor oil (108.8 mg/kg - 289.4 mg/kg), crude oil and gasoline (0.32 mg/kg - 1.24 mg/kg). Also found in exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

biphenyl: powerful, irritating poison by inhalation. Moderately toxic by ingestion. Found in coal tar, wood preservatives and petroleum products. An experimental tumorigen and carcinogen.

ORGANOCHLORINES

Organochlorines are commonly associated with pesticides (i.e., insecticides, herbicides, as well as defoliants and growth regulators) and PCBs. All are toxic to some degree to invertebrates, fish, birds, mammals, and humans. Some are carcinogenic (cancer promoting). Although they have been released into the environment for decades, PCBs and most of the chlorinated pesticides have either been banned or severely limited in use during the past 15 years. Nevertheless, they continue to persist the environment. By virtue of their toxicity, carcinogenicity, and continued occurrence, PCBs, and pesticides such as DDT, chlordane, and toxaphene, are prominent and pivotal factors in decisions concerning the cleanup of contaminated sites.

technical chlordane and related isomers (e.g. oxychlordane, cis-nonachlor, alpha chlordane): a mixture of chlorinated hydrocarbons that has been used as an insecticide since its introduction in 1947. Wildlife and humans are easily poisoned by ingestion and inhalation. When heated to decomposition, it emits toxic fumes. Highly toxic to fish. Residues in fish muscle sometimes exceed FDA action level of 0.3 mg/kg fresh weight. Animals poisoned by these compounds show marked loss of appetite and neurological symptoms; concentrations are highest in fat and liver, especially predatory species. In soils, chlordane can persist for 3 to 14 years because of low water solubility. Food chain biomagnification is usually low. Water concentrations between 0.2 and 3.0 ppb adversely affect many aquatic species.

DDT compounds: Sufficient evidence of carcinogenity. Poison by ingestion, skin contact, subcutaneous; effects central nervous system. Stored primarily in fat. Thus, this storage effect leads to concentration of DDT at higher levels of the food chain. Major fate process in aquatic environment are bioaccumulation and sorption to sediment and biota. Observed persistence of DDE may

DDT compounds (cont.):be due to the fact that DDE is mainly formed from DDT under biological conditions. DDE is much less susceptible to biotransformation process than DDT or DDD.

dieldrin: A prohibited insecticide in the U.S. that poisons by inhalation, ingestion, and absorption through the skin. It is more toxic than DDT by ingestion and skin contact and may accumulate in the body from chronic low dosages. There is sufficient evidence of carcinogenicity in animals. It, like chlordane, emits highly toxic fumes of chlorides and is highly toxic to fish.

PCBs and congeners: PCBs are persistent compounds which accumulate in food chains and the environment. They are toxic to aquatic organisms, wildlife and man. The skin, liver, gastrointestinal tract, and nervous system are sites of biological effects. Laboratory experiments, along with epidemiological studies of humans, have shown that the contaminant is carcinogenic. Humans and wildlife can be directly exposed to PCBs through ingestion of contaminated water or food, inhalation of PCB-contaminated particles or vapors, and absorption through the skin. In addition, off site migration of PCB-contaminated material (via surface water runoff and leachate presents a potential hazard to both man and wildlife).

BHCs: Moderately toxic by ingestion. A suspected human carcinogen. When heated to decomposition, it emits toxic fumes of Cl^-. Although sorption to suspended sediment and biota is not extensive, sorption is an important process for ultimately transporting BHCs to anaerobic sediments where transformation occurs (on the order of several days to more than a year when introduced into biologically rich, aquatic environments).

INORGANICS

Inorganics refer to compounds that do not contain carbon as the primary element; usually used as reference to metals and trace elements. Trace elements are essential and non-essential elements that typically occur in concentrations less than 1.0 ppm. For instance, cobalt, copper and zinc are believed essential to a healthy body, whereas forms of arsenic and lead are known to be extremely toxic. Heavy metals is a term generally used to define those metal and metalloid elements with a specific gravity greater than five (e.g., arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, zinc). They do not break down, although their chemical form will vary. They also are very persistent in the environment. Once absorbed, heavy metals stay in the body until excreted. Heavy metals are very dangerous contaminants, since they poison aquatic organisms even when present in comparatively low concentrations. Two

INORGANICS (cont.) metals have been identified as having no positive role in biological functioning: mercury, lead. In addition to their direct toxic effect, heavy metals produce dangerous, generation-skipping biological effects (mutagenic, embryotoxic). Heavy metals accumulate in different parts of the food web which ultimately disturbs biotic cycles and destabilizes aquatic systems.

cadmium: There is no evidence that cadmium, a relatively rare heavy metal, is biologically essential or beneficial; on the contrary, cadmium is a known teratogen and carcinogen, a probable mutagen, and has been implicated as the cause of severe deleterious effects on fish and wildlife. The freshwater biota is the most sensitive group; concentrations of 0.8 to 9.9 ppb in water were lethal to several species of aquatic insects, crustaceans and teleosts. Mammals and birds are comparatively resistant to the biocidal properties of cadmium. Cadmium residues in vertebrate kidney or liver that exceed 10 ppm wet weight or 2 ppm whole body wet weight should be viewed as evidence of probable cadmium contamination; residues of 200 ppm wet weight kidney, or more than 5 ppm whole body wet weight, are probably life-threatening to the organisms.

chromium: An experimental carcinogen and tumorigen. An essential nutrient (in humans and some other species) that is bioaccumulated by aquatic organisms and passed through the food chain at levels much higher than in ambient water. Hexavalent form is quite soluble in water. Found in concentrations of about 10-100 ppm in crust. Biological and environmental interactions are obscure and poorly characterized. Phytoplankton concentrates the element to a greater extent than other organisms, with the lowest levels being found in bottom-feeding fish.

copper: Strongly bioaccumulated and is an essential trace element; however, high concentrations of Cu(II) ion are toxic to aquatic organisms. Biological activity plays and important part in determining the aquatic fate of copper. Fish liver and gill tissues most accurately reflected copper exposure. Widely used as an algicide and herbicide. Biomagnification does not occur.

iron: The second most abundant metallic element. The element is essential in animal and plant metabolism. Biological and environmental interactions are obscure and poorly characterized.

lead: A biological nonbeneficial, non-essential element with the potential for high toxicity. Severe lead poisoning causes an array of effects on the central nervous system, the gastrointestinal system, the reproductive system and the kidneys. Bioaccumulation of lead has been demonstrated for a variety of organisms, but it is not biomagnified. Benthic microbes can

lead (cont.): methylate lead to form compounds which are volatile and more toxic than inorganic lead. Based on available information, fish accumulate very little lead in edible tissues.

manganese: An abundant metallic element. Known to be an experimental carcinogen, but is essential for both plant and animal life. Human toxicity caused by inhalation of dust or fumes.

mercury: a biological nonbeneficial, non-essential element with the potential for high toxicity. Mercury and its compounds each have different toxicological modes of action, depending on the molecular structure, stability in the organism, and routes of biotransformation and excretion. Organic mercury compounds (i.e., methylmercury) are more toxic than the inorganic forms. This is because the organic compounds dissolve readily in lipids and bond easily with proteins, thereby entering cells easily. Mercury is primarily removed from aquatic systems by adsorption onto the surfaces of particulates and subsequent settling to the bed sediment. There it is methylated by bacteria. Turbulence and/or the activity of benthic organisms then suspends this biologically available form into the water column. The average Hg concentration in soil is 0.03 ppm. Mineral soils in the United States usually contain between 0.01 - 0.3 ppm Hg. Usually Hg levels in soils or sediments are considered significantly elevated if their concentration is >20 ppm; such concentrations are usually due to anthropogenic sources. Uncontaminated sediments are usually <1.0 ppm.

nickel: An experimental carcinogen. Appears to be a mobile, heavy metal but in general, is not accumulated in significant amounts by aquatic organisms. Average concentration in the earth's crust is 80 ppm. In bottom sediments, nickel concentrations are correlated with iron and manganese. Suspended organic matter may be a good adsorbent.

zinc: A human skin irritant. An essential trace element in nutrition and is bioaccumulated in all organisms. Average concentration in earth's crust is 123 ppm. Precipitation of zinc compounds reduces zinc water pollution. There is an inverse correlation between zinc concentration and sediment grain size. Readily accumulated by both marine and freshwater fish from both food and water, but internal organs and bones accumulate much higher zinc levels than edible muscle tissue. Biota appear to represent a relatively minor sink when compared to sediment.

NOTE: References used to the prepare the profiles are the same used to develop the Service's criteria in Appendix B.