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Fort Richardson

Anchorage, Alaska
CERCLIS #AK6214522157

Site Exposure Potential

Eagle River Flats is the primary site of concern at Fort Richardson in Anchorage, Alaska. This 870-hectare estuarine marsh forms the mouth of the Eagle River in Upper Cook Inlet (Knik Arm) (Figures 1 and 2). Although artillery activities ceased in 1989, the U.S. Army used the salt marsh as an artillery range for about 50 years, contaminating sediments with white phosphorus particles. No estimates of the total amount of white phosphorus discharged to the marsh have been available. Since 1981, however, more than one thousand waterfowl deaths each year have been attributed to white phosphorus poisoning. Waterfowl use the area primarily as a migratory stop for several weeks in the spring and fall (U.S. Army 1994a).

Eagle River Flats is composed of numerous ponds, mudflats, and channel tributaries of the Eagle River. Tidal fluctuations, among the highest in the world (up to 11 m), periodically flood the entire marsh during the highest tides. White phosphorus has been found throughout the marsh, but particularly high concentrations have been found in ponded areas in central portions of the flat east of Eagle River. Investigations have divided the Eagle River Flats into ten general areas described in Table 1 and Figure 2.

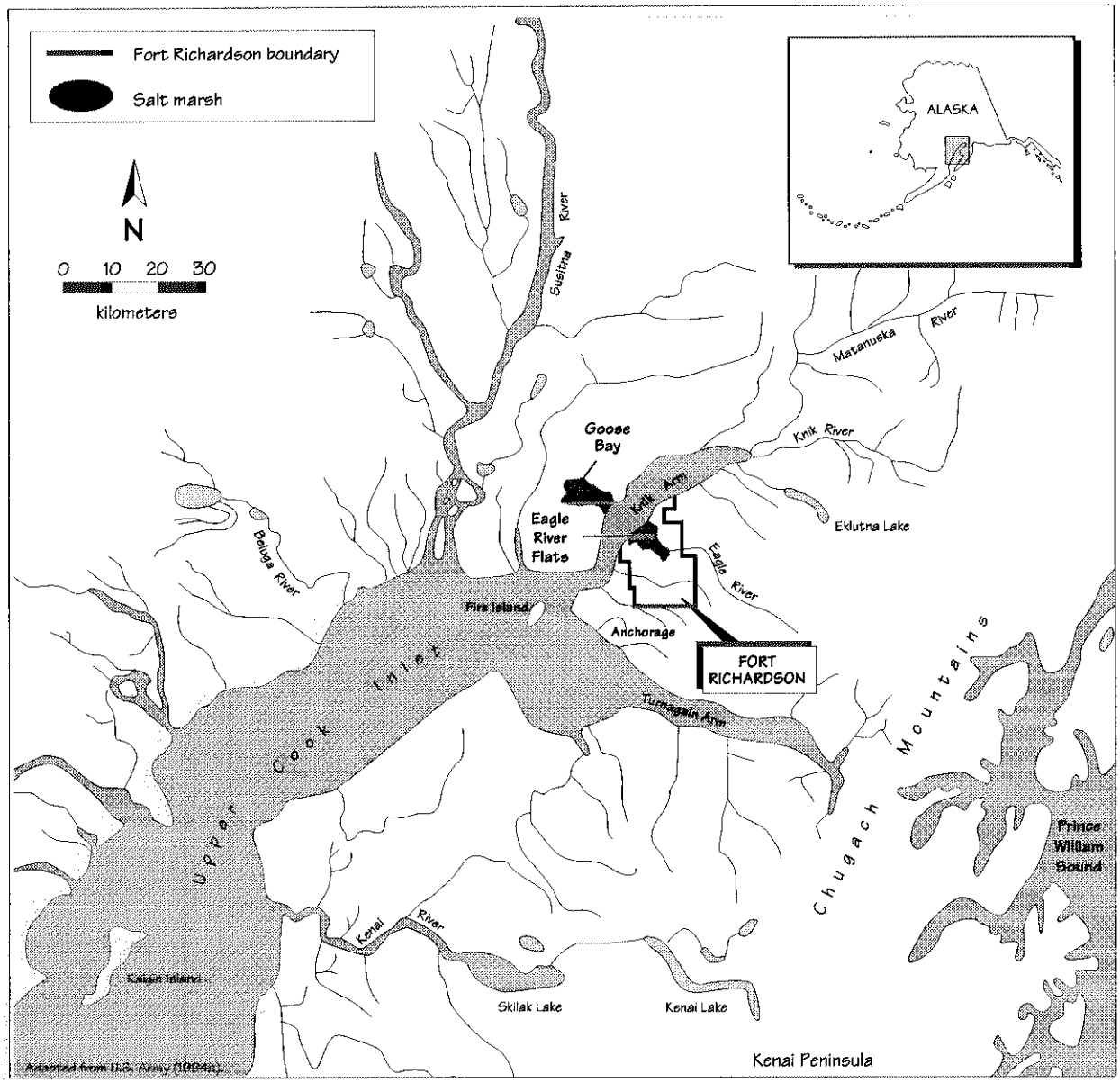

Figure 1. Fort Richardson and the Eagle River Flats site on Knik Arm, Upper Cook Inlet, near Anchorage, Alaska.

Currents produced by tides transport white phosphorus throughout the marsh and mudflats. Neither the extent of contamination in the main channel of the Eagle River nor its potential migration to Knik Arm is known. Plumes of white phosphorus within the sediments are not readily observed because the original distribution of white phosphorus was caused by directed artillery impact, and because of the physical behavior of white phosphorus. White phosphorus occurs mainly as a soft, waxy particulate that is

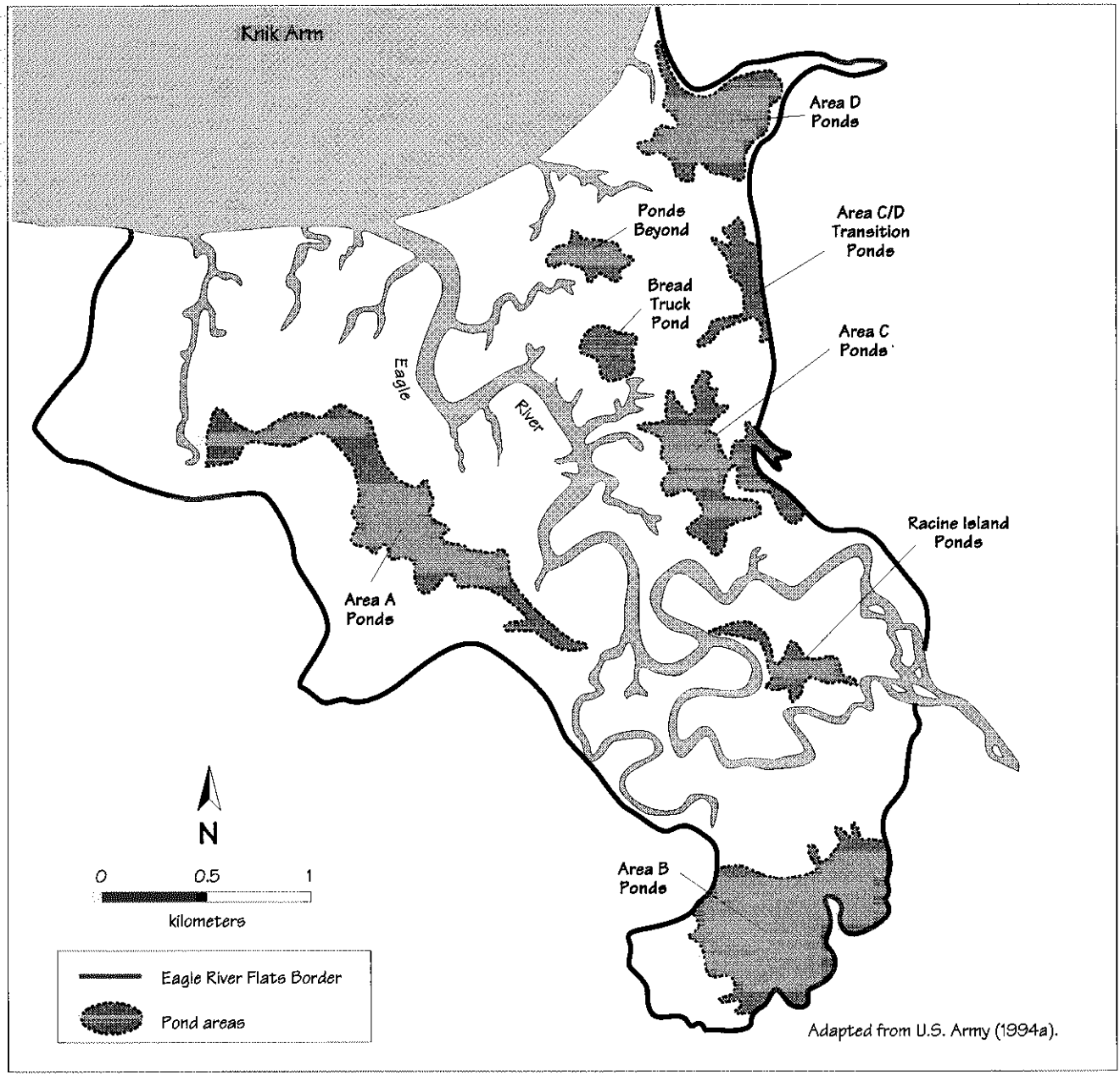

Figure 2. The Eagle River Flats site and ponded areas sampled for white phosphorus.

insoluble in water. The concentration is determined by the number and size of particles in sediment. Therefore, migration is a complex function of sediment erosion and/or bioturbation, subsequent particle suspension, and suspended-sediment transport in the water column (U.S. Army 1994a).

Except for the Eagle River Flats area, investigations of potential contamination at Fort

Table 1. Investigations at the Eagle River Flats (U.S. Army 1994a).

Area on Site	Location of Investigation
Area A Ponds	Western side of the Eagle River.
Area B Ponds	Southern end of Eagle River Flats.
Area C Ponds	Single large pond and a series of small ponds along the eastern edge of the flat.
Area D Ponds	Single, large permanent pond and a series of smaller ponds in an embayment on the northeast corner of the flat.
Area C/D Transition Ponds	Transition zone halfway between Areas C and D. Complex of deeper narrow ponds along the east side of the flat.
Bread Truck Pond	6.5-hectare, semi-permanent pond located near the Eagle River and approximately 500 m west of Area C/D.
Ponds Beyond	Small area of shallow ponds less than 200 m northeast of Bread Truck Pond.
Racine Island Ponds	Small ponds within a mudflat island formed by two channels of the Eagle River.
Mudflats	Mudflats are site-wide and are composed of areas that are not river channel, tributaries, and ponds. These areas are inundated only during the highest tides.
Channel Tributaries	Channel tributaries draining ponds and mudflats site-wide, draining to the Eagle River.

Richardson have not yet started. Only one other potential source has been identified: a building located near Ship Creek that was used to store PCB-contaminated soils. Sampling is planned to identify potential migration routes from this site to Ship Creek (Wilkening personal communication 1994).

NOAA Trust Habitats and Species

Habitats of concern to NOAA are surface water, associated bottom substrates, estuarine emergent wetlands, and intertidal mudflats associated with the Eagle River and the Knik Arm of Cook Inlet. Numerous anadromous trust species (Pacific salmon, Dolly Varden trout, and steelhead trout) seasonally migrate from the Knik Arm into the Eagle River. Knik Arm, a glacial estuary extending approximately 40 km north from upper portions of Cook Inlet, is a highly turbid estuarine system, with tidal currents exceeding 3.4 m/sec. Salinities, driven by the tide stage, range from 6 to 20 ppt. Massive quantities of sediment are continually loaded to the estuary via major glacial river discharge and erosion of coastal bluffs.

The Eagle River Flats is a dynamic, estuarine salt marsh actively undergoing progressive and significant changes due to high sedimentation rates and the cold climate. The primary source of sediment in the area is attributed to high tidal inundation from either Knik Arm or the Eagle River, or both. Vegetative cover associated with the mudflats near the mouth of the river varies from bare sediment, to sparse cover provided by

annual plants and alkali grass (*Puccinellia hultenii*), to well-vegetated stands of arrowgrass (*Triglochin maritima*), beach rye (*Elymus arenarius*), and/or goose tongue (*Plantago maritima*). Ramenski's sedge (*Carex ramenskii*), bullrush (*Scirpus paludosus* and *S. validus*), and Lyngbyaei's sedge (*Carex lyngbyaei*) predominate upstream from the mudflats (U.S. Army 1994a).

Salmonids, the most abundant trust species present in the Eagle River, use riparian habitats primarily as juvenile rearing habitat, adult forage area, and migratory corridor to reach spawning areas farther upstream (Table 2). Upstream from the site, the South Fork of the Eagle River serves as spawning ground and nursery habitat for chinook, chum, coho, and pink salmon; Dolly Varden; and steelhead trout (Gossweiler personal communication 1994; Hoffmann personal communication 1994). The Eagle River provides habitat to the threespine stickleback and slimy sculpin (Rothe et al. 1983; CH2M Hill 1992).

The Eagle River historically provided habitat to significant populations of Pacific salmon, steelhead trout, and Arctic grayling. Populations currently inhabiting the river have dramatically dropped in recent years. The natural chinook salmon population has been reduced to approximately 300 annually returning adults. The Alaska Department of Fish and Game has stocked approximately 100,000 chinook fingerlings into the Eagle River annually since 1990 to help increase the population. Chinook salmon smolt after one year in freshwater and typically spend four to five years in the ocean before maturing and returning to freshwater to spawn. Although some returns have already been observed in the Eagle River, the first "full return" is expected to begin in 1995 (Hoffmann personal communication 1994).

Pacific salmon in the Anchorage area spawn from the late summer to early fall. The salmon eggs are deposited in redds (nests) where they develop during the winter and subsequently hatch in the spring. Alevins, or sac-fry, remain within the redd until the yolk sac is absorbed, then emerge as fry. Depending on the species, alevins may emerge from the redd within a few weeks or a few months after hatching. The fry develop into fingerlings during the summer, and then into smolts before they leave the freshwater creeks to enter the ocean. The smolt stage represents a physiological change that occurs in preparation for life in salt water. Pink and chum salmon in the Upper Cook Inlet region "smolt" soon after the fry emerge from the redds. Chinook salmon smolt after one year in fresh water, coho after two years, and sockeye after one to three years. Depending on the species, Pacific salmon spend one to four years in the ocean before maturing and returning to fresh water to spawn (Hoffmann personal communication 1994).

Knik Arm provides adult forage habitat and a migratory corridor for Dolly Varden trout and steelhead trout (Hoffmann personal communication 1994). Dolly Varden spawn in the fall and eggs hatch the following spring. The fry and fingerling stages occur in spring and summer. Dolly Varden remain in fresh water and mature

Table 2. NOAA trust resources in the Eagle River near the Fort Richardson site, Fort Richardson, Alaska.

Species		Habitat Use				Fisheries	
Common Name	Scientific Name	Spawning Ground	Nursery Ground	Adult Forage	Migratory corridor	Comm.	Recr.
SALMONID SPECIES							
Pink salmon	*Oncorhynchus gorbuscha*		♦	♦	♦		
Chum salmon	*Oncorhynchus keta*		♦	♦	♦		
Coho salmon	*Oncorhynchus kisutch*		♦	♦	♦		
Sockeye salmon	*Oncorhynchus nerka*		♦	♦	♦		
Chinook salmon	*Oncorhynchus tshawytscha*		♦	♦	♦		
Steelhead trout	*Oncorhynchus mykiss*		♦	♦	♦		
Whitefish	*Prosopium spp.*		♦	♦	♦		♦
Dolly Varden	*Salvelinus malma*		♦	♦	♦		♦
Artic grayling	*Thymallus articus*		♦	♦	♦		♦
MARINE / ESTUARINE SPECIES							
Bering cisco [1]	*Coregonus laurettae*		♦	♦			
Slimy sculpin	*Cottus cognatus*	♦	♦	♦			
Saffron cod [1]	*Eleginus gracilis*		♦	♦			
Threespine stickleback	*Gasterosteus aculeatus*			♦			
Ringtail snailfish [1]	*Liparis rutteri*		♦	♦			
Ninespine stickleback	*Punigitius pungitius*	♦	♦	♦			
Eulachon [1]	*Thaleichthys pacificus*			♦			

1: While it is known that adults of these species are found in Knik Arm, there is insufficient information to determine whether these species are using the area for spawning habitat.

four to five years before outmigration to the ocean. Adult Dolly Varden spawn for several consecutive years. Both immature and mature Dolly Varden compete with salmon and trout for food and are predatory on salmon eggs and young salmon. Steelhead trout spawn from April through June. Fry emerge from the redd in the summer and juvenile trout remain in fresh water two or three years before outmigration to the ocean (Hoffmann personal communication 1994).

Other NOAA trust species—threespine stickleback, eulachon, and Bering cisco—migrate through the Knik Arm to spawning grounds in area streams including the Eagle River. Except for the stickleback, it is not known whether these species reside in the estuary year-round. The life span of sticklebacks is approximately one to three years. They spawn in June and July in a nest made of twigs and plant debris constructed by the male. Sticklebacks represent an important component of the forage base for steelhead and rainbow trout in those lakes and streams where they occur together.

The ecology of saffron cod, which inhabits the Knik Arm as an adult, suggests that it might also spawn in the lower portions of the Eagle River,

but this behavior has not been documented (Rothe et al. 1983; CH2M Hill 1992). Little is known about the life history of the slimy sculpin in Alaska, except that they spawn in the spring. Their main food source is benthic invertebrates, particularly aquatic insect larvae (Rothe et al. 1983; CH2M Hill 1992).

Cook Inlet is one of only eight recognized wintering areas in the world for beluga whales (*Delphinapterus leucas*). The small Cook Inlet population is resident year-round (Morris 1988). Beluga whales are known to concentrate at the mouth of the Eagle River annually from mid-May through September (Smith personal communication 1993). In recent years, beluga whales have been observed migrating as far as 2 km up the Eagle River from spring through late fall to feed on salmon (Gossweiler personal communication 1994).

Arctic grayling, whitefish, and Dolly Varden support a small recreational fishery near the site. In 1991, approximately 600 salmon were harvested from the river and over 80,000 salmonids were harvested from the Knik Arm (Table 3; Karcz personal communication 1993). There is commercial fishing in Knik Arm, but not in Eagle River; in 1993, 49,600 salmon were commercially harvested from Knik Arm (Table 4; Fox personal communication 1994).

Table 3. Numbers of salmon caught recreationally in surface water near Fort Richardson during 1991 (Karcz personal communication 1993).

Catch Area	Chinook	Coho	Pink	Sockeye	Chum	Rainbow Trout	Artic Grayling	Whitefish	Dolly Varden	Total Catch
Eagle River	6	0	0	0	0	0	30	7	584	627
Knik Arm	2,277	22,186	926	4,968	1,099	39,636	2,846	900	9,138	83,976

Table 4. Numbers of salmon caught commercially in Knik Arm (Fox personal communication 1994).

Year	Chinook	Coho	Pink	Chum	Sockeye	Total Catch
1987	0	2,043	264	403	24,090	26,800
1988	9	11,604	591	2,733	38,251	53,188
1989	4	6,075	545	4,979	47,925	59,528
1990	4	5,708	696	5,308	23,450	35,162
1991	0	1,630	21	961	10,459	13,071
1992	0	1,817	573	1,289	10,748	14,427
1993	0	831	29	990	47,751	49,601

Site-Related Contamination

White phosphorus is the primary contaminant that poses a threat to NOAA trust resources. Site investigations at Eagle River Flats between 1990 and 1993 collected sediment from over 600 surficial samples in ponds, 58 cores (multiple samples per core), 87 tributary channel samples, and 104 mudflat samples (Table 5). White phosphorus-contaminated sediments were widespread across Eagle River Flats, but were particularly associated with visible craters made by artillery fire near ponded areas. Of the 658 surface sediment and core samples collected in the ponded areas, 34 percent had measurable concentrations of white phosphorus. Lower concentrations and frequencies were observed on the mudflats and tributary channels (U.S. Army 1994a).

White phosphorus was most widespread in ponds of Area C, Racine Island, and Bread Truck Pond where 40 to 50 percent of the samples collected were contaminated. Maximum concentrations were over 3,000 mg/kg. Lower concentrations of white phosphorus were observed in 11 percent of the samples collected in Area A Ponds and were not observed in Areas B and D (Table 5; Figure 2; U.S. Army 1994a).

Measurable concentrations of white phosphorus were observed in approximately ten percent of the sediment samples collected in the mudflats.

Table 5. Distribution and concentration of white phosphorus in sediments of Eagle River Flats (U.S. Army 1994a).

Site Area	No. of samples [1]	Frequency of Detection	Percentage of Detection	Maximum concentration (mg/kg)
Ponded Areas				
A	189	21	11	0.053
B	38	0	0	ND
C	476	236	50	219
D	43	0	0	ND
C/D	35	2	6	0.012
Bread Truck	130	56	43	57.6
Pond Beyond	14	1	7	0.02
Racine Island	27	12	44	3071.3
Mudflats	104	10	10	0.15
Tributaries	87	3	3	0.049

1: For the ponded areas, the number of sediment samples included individual surface samples and multiple samples collected from cores.
ND: Not detected. The detection limit was not reported.

White phosphorus was observed in flats near Pond Areas A and C, and Bread Truck Pond, with a maximum concentration of 0.15 mg/kg observed near Bread Truck Pond. White phosphorus was not detected in three samples collected from craters in Knik Arm. Measurable concentrations of white phosphorus were observed in only three percent of the sediment samples collected within gullies and tributary channels flowing to the Eagle River (maximum concentrations of 0.049 mg/kg; U.S. Army 1994a).

In 1993, five surface water stations were sampled near Area C Ponds. Undisturbed samples (filtered and unfiltered) had measurable concentrations of white phosphorus ranging from 0.005 to 2.2 µg/l. Disturbed samples (0.1-liter sample shaken for five minutes with 10 ml of isooctane) had measurable concentrations two orders of magnitude higher, ranging from 1.2 to 290 µg/l. For undisturbed and disturbed samples, the highest concentrations were observed in confined areas with little flow or dilution (U.S. Army 1994a).

A benthic community study and sediment bioassays using the amphipod *Hyalella azteca* and the midge larva *Chironomus riparius* were performed in 1993. The benthic investigation found that infaunal populations were limited in the numbers of species present; the mean number of species found at any station was six. The study also found that the average species diversity and number of species were greatest in sediments most highly contaminated with white phosphorus. However, the total number of organisms was lower—only 20 percent of that observed at stations where white phosphorus was undetected. These data were therefore inconclusive (U.S. Army 1994a).

Sediment toxicity studies showed effects. All organisms in both the amphipod and midge larva tests died when exposed to contaminated sediments. However, the water concentrations of white phosphorus in the test chambers were several orders of magnitude higher than those found in surface waters of Eagle River Flats. The high concentrations probably resulted from white phosphorus suspended (in particulate form) in the water, which may increase the availability, and hence, toxicity of the substance. Water concentrations decreased by an order of magnitude from the start to the end of the 30-day test, indicating a gradual redeposition of white phosphorus particulates. Nonetheless, white phosphorus concentrations were still up to three orders of magnitude higher than those found in the field over equally contaminated sediments (U.S. Army 1994a).

These results suggest that any disturbance of contaminated sediments could resuspend white phosphorus particulates and be very toxic. This is supported by findings that disturbed surface water samples had higher white phosphorus concentrations than undisturbed samples. The data also suggest that white phosphorus particulates sequestered in the sediments may be less

bioavailable and therefore less toxic. Sediment disturbance and its effect on the bioavailability and toxicity of white phosphorus has not been investigated (U.S. Army 1994a) although there is a workplan to investigate sediment resuspension by waterfowl and tidal exchange (U.S. Army 1994b).

Bioaccumulation studies were also conducted at Eagle River Flats; 30 macroinvertebrate and 31 fish samples were analyzed for white phosphorus. Measurable concentrations of white phosphorus were observed in only one fish sample, indicating that white phosphorus is not readily accumulated in tissues of these organisms.

Concentrations of white phosphorus in the sediments are potentially toxic to aquatic resources of concern to NOAA. Bioassessment studies have shown acutely toxic effects. However, data suggest that toxicity is most severe when sediments are disturbed, suspending white phosphorus particles in the overlying water. White phosphorus may thus be less toxic when undisturbed in the sediments. The level of sediment resuspension and subsequent release and toxicity of white phosphorus under natural conditions have not been assessed. Eagle River Flats is subject to some of the largest known tidal ranges, which daily inundate the site and then recede, creating the potential for substantial sediment disturbance and subsequent adverse effects to aquatic resources of concern.

Summary

Eagle River Flats is contaminated with white phosphorus as a result of 40 to 50 years of artillery bombardment from Fort Richardson. This substance is widespread throughout the flats, with particularly high concentrations in ponded areas. White phosphorus is not very soluble and is present largely in particulate form within the sediments of the flats. Resuspension and ingestion of white phosphorus have caused annual die-offs of waterfowl, but potential effects to aquatic resources are not completely known.

References

CH2M Hill. 1992. Elmendorf Air Force Base, Alaska. Ecological Survey. Anchorage: U.S. Air Force and Battelle EMO.

Fox, J., fisheries biologist, Soldotna Fish and Game Office, Soldotna, Alaska, personal communication, May 3, 1994.

Gossweiler, W.A., Department of Public Works, U.S. Army Garrison, Fort Richardson, Alaska, personal communication, June 16, 1994.

Hoffmann, A., fisheries biologist, Division of Habitat Restoration, Alaska Department of Fish and Game, Anchorage, Alaska, personal communication, May 31, 1994.

Karcz, G., Alaska Department of Fish and Game, Division of Sport Fisheries, Anchorage, Alaska, personal communication, May 11, 1994.

Morris, B.F. 1988. *Cook Inlet beluga whales.* Anchorage: National Marine Fisheries Service.

Rothe, T.C., S.H. Lanigan, P.A. Martin, and G.F. Tande. 1983. *Natural Resource Inventory of Elmendorf Air Force Base, Alaska, Part I.* Anchorage: U.S. Fish and Wildlife Service.

Smith, B., fisheries biologist, National Marine Fisheries Service, Anchorage, Alaska, personal communication, May 7, 1993.

U.S. Army. 1994a. *Interagency expanded site investigation. Evaluation of white phosphorus contamination and potential treatability at Eagle River Flats, Alaska.* Hanover, New Hampshire: U.S. Army Cold Regions Research and Engineering Laboratory.

U.S. Army. 1994b. *Evaluation of White Phosphorus Effects on the Aquatic Ecosystem, Eagle River Flats, Fort Richardson, AK. Scope of Work for 1994 Studies.* Aberdeen Proving Ground, Maryland: U.S. Army Environmental Hygiene Agency, Water Quality Engineering Division.

U.S. Geological Survey (USGS). 1980. *Water Resource Data for Alaska.* U.S. Geological Survey Water-Data Report AK-80-1. Washington, D.C.: U.S. Government Printing Office.

Wilkening, M., U.S. Environmental Protection Agency Region 10, personal communication, December 2, 1994.